NONRESIDENT TRAINING COURSE

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UTILITIESMAN BASIC

NAVEDTRA 14265A

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Chapter 1

Plans, Specifications, and Color Coding

Topics

To hear audio, click on the box.

Overview

In your day-to-day work as a Utilitiesman (UT), you will be installing, assembling, inspecting, and troubleshooting many types of utility systems. To do these jobs properly, you must read and interpret plans and drawings. You may also have to read specifications that contain additional information on the details of construction and installation. Plans and specifications help you do the job correctly and safely.

After studying this chapter, you should be able to read and interpret simple drawings and sketches as well as use specifications to help you with more complex plans. Additionally, you should be able to draw simple shop drawings and specify the hazards associated with each color code for piping and compressed gas containers.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the different types of plans.
2. Describe the process of isometric drawing.
3. Describe the different types of blueprints
4. Describe the different types of specifications.
5. Identify the different colors associated with safety.

Prerequisites

None

This course map shows all of the chapters in Utilitiesman Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Utilities Equipment and Maintenance		
Air Conditioning		
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Fundamentals of Water Distribution		
Basic Math, Electrical, and Plumbing Operations		
Plans, Specifications, and Color Coding		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for

review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 BLUEPRINTS

1.1.0 Terms and Definitions

Blueprints (prints) are copies of mechanical or other types of technical drawings. The term “blueprint reading” means interpreting ideas expressed by others on drawings, whether or not the drawings are actually blueprints. Drawing or sketching is the universal language used by engineers, architects, technicians, and skilled craftsmen. Drawings need to convey all the necessary information to the person who will make or assemble the object in the drawing.

1.2.0 Parts of a Blueprint

This section deals specifically with NAVFAC and MIL-STD prints and terminology.

ASME Y14.24 (Types of Engineering Drawings) specifies the size, format, location, and type of information to include in military blueprints. These include the information blocks, finish marks, notes, specifications, legends, and symbols.

1.2.1 Information Blocks

The draftsman uses information blocks to give the user additional information about materials, specifications, and so forth that are not shown in the blueprint or that may need additional explanation. The draftsman may leave some blocks blank if the information in those blocks is not needed.

1.2.1.1 Title Block

The title block is located in the lower-right corner of all blueprints and drawings prepared according to MIL-STDs. It contains the drawing number, name of the part or assembly that it represents, and all information required to identify the part or assembly. See *Figure 1-1*.

Figure 1-1 — Title block.

A space within the title block with a diagonal or slant line drawn across it shows that the information is not required or is given elsewhere on the drawing.

The Naval Facility Engineering Command (NAVFACENGCOM) requires the following further information in title blocks: the name and location of the activity; the specifications and contract numbers (if any); the preparing activity, including the architect-engineer (A-

E) firm, if applicable; and the surnames of the personnel concerned in the preparation of the drawings. The code identification number 80091 is to appear in the title block of all NAVFACENGCOM drawings as well as a sheet designation letter (I - Index, C - Civil, A - Architectural, S - Structural, M - Mechanical, P - Plumbing, E - Electrical, and W - Waterfront).

1.2.1.2 Drawing Number

Blueprints are identified by a drawing number that appears in a block in the lower right-hand comer of the title block. The drawing number is especially important, both for filing the blueprint and for locating it if it is specified on another blueprint.

1.2.1.3 Revision Block

The revision block is usually located in the upper right-hand comer of the blueprint and used for recording changes (revisions) to the print. All revisions are noted in this block and are dated and identified by a letter and a brief description of the revision (*Figure 1-2*).

Figure 1-2 — Revision block.

1.2.1.4 Reference Number

Reference numbers that appear in the title block refer to numbers of other blueprints. A dash and a number show that more than one detail is shown on a drawing. When two parts are shown in one detail drawing, the print will have the drawing number plus a dash and an individual number. An example is the number 811709-1 in the lower right corner of title block.

In addition to appearing in the title block, the dash and number may appear on the face of the drawings near the parts they identify. Some commercial prints use a leader line to show the drawing and dash number of the part. Others use a circle 3/8 inch in diameter around the dash number, and carry a leader line to the part.

1.2.1.5 Zone Number

Zone numbers serve the same purpose as the numbers and letters printed on borders of maps to help you locate a particular point or part. To find a point or part, mentally draw horizontal and vertical lines from these letters and numerals. These lines will intersect at the point or part you are looking for.

You will use practically the same system to help you locate parts, sections, and views on large blueprinted objects. Parts numbered in the title block are found by looking up the numbers in squares along the lower border. Read zone numbers from right to left.

1.2.1.6 Bill of Material

On a blueprint, the bill of material block contains a list of the parts and material, identified by stock number or other appropriate number, used on or required by the print concerned. The block also lists the quantity of those parts or materials used or required.

The bill of material often contains a list of standard parts, known as a parts list or schedule. Many commonly used items, such as machine bolts, screws, fittings, and valves, have been standardized by the military. *Table 1-1 shows* a bill of material for an electrical plan.

Table 1-1 — Sample of Bill of Material.

BILL OF MATERIAL			
ITEM	**DESCRIPTION**	**UNIT**	**QTY**
(1)	PIPE PVC DMW SCH 40 3N PL-END	FT	16
(2)	PIPE STL GLV STD WT 3/4N	FT	20
3	CLPG PP MI BI 3/4 NPT	EA	1
(4)	STRAP PLMB GLV PERF 3/4N X 10FT	EA	1
5	SCREW MCH 0.25N-20 X IN UNC FILH BRS	EA	6
6	WASHER FL 0.29N ID X 0.64N OD DIA RND COP	HD	1
7	NUT 0.25N-20 UNC WING COP	EA	6
(8)	LUMBER 4 X 4 X 8 S4S STD & BETTER	EA	1
(9)	WIRE FABRIC STL 4FT 9IN LG X 3FT 4IN W	EA	1
(10)	DRUM 55 GAL 16GA EMPTY	EA	1
(11)	SCREEN, LATRINE, COTTON DUCK 55FT X 5.25FT	EA	1

1.3.0 Line Standards and Symbols

Figure 1-3 shows the types of lines a UT must be able to read and understand. These lines are shown as they may appear on a drawing.

Figure 1-3 — Construction drawing lines.

Trim line: a light, continuous line along which the tracing is trimmed to square the sheet.

Border line: a heavy, continuous line that outlines or borders the drawing. The drawing is complete within this lined border.

Main object line: a heavy, unbroken line used to show visible outlines or edges that would be seen by people looking at the article, house, or building. The main object line is one of the most important lines because it outlines the main wall lines on plans and sections. It shows clearly the important parts of the construction and emphasizes the outline of the elevations.

Dimension line: a light line drawing outside the structure or detail to show the distance between two points. This thin line is drawn between extension lines with an arrowhead terminating each end. Between the arrowheads, the distance will be given either at a break in the line or just above the line. On some drawings, the scale and the distance between the two points may not agree; in such cases, the distance will be given in a dimension line.

Extension line: a line that touches and is used with dimension lines. This line extends out from the edge or the point at which the dimension is to be determined.

Equipment line: a light, continuous, unbroken line used to show the location of equipment, such as transformers, panels, and galley equipment. This line is used to allow the electrician to install the necessary conduit in the proper location during rough-in work.

Broken line: a line with wavy breaks in it at intervals. It is used to indicate those parts that have been left out or to indicate that the full length of some part has not been drawn. The broken line is used in detail drawings where only a section of the object is to be shown.

Hidden (Invisible) line: a line that is made up of medium lines with short evenly spaced dashes. It is used to indicate an edge or edges hidden under some other part of the structure or concealed edges.

Center line: a line that is made up of thin lines made up of alternating long and short dashes and is used to indicate the center of an object and symmetry about an axis.

Section line: a solid line that has arrowheads at each end that point in the direction in which the section is to be built. This line tells just where the section line has been cut through the wall or building. The sections are indicated, in most cases, by the letters *AA, B-B,* and so forth, although numbers are sometimes used. Do not overlook these section lines on a plan. To obtain a clear picture of the construction at the particular point indicated, always refer to the section detail called for by the letter or number.

Stair indicator line: a solid line with an arrowhead indicating the direction of the run.

Break line: a thin solid-ruled line with freehand zigzags used to reduce the size of a drawing required to delineate an object and reduce detail.

1.3.1 Piping Systems

Piping is indicated on construction plans with lines. Lines are drawn differently depending on what will flow through them. Shown below are the types of lines representing common piping systems installed by UTs. See *Figure 1-4*.

Figure1-4 — Piping symbols.

1.3.2 Fixtures

Plumbing fixtures are indicated by symbols. Fixtures include items such as tubs, showers, water closets (toilets), kitchen sinks, and bathroom lavatories.

1.3.3 Fittings

Fittings are primarily used to join sections of pipe. They can also be used to branch off of a pipe in multiple directions or to change sizes of pipe at joint connections in the piping systems. Fittings may also include valves. Valves are installed in a piping system to control the flow of liquids and gases. Listed below are just a few of the valves and fittings available.

1.3.3.1 3.1 Common Water Fittings

Common water fittings include elbows, tees, and unions. There are numerous other fittings available. Shown below are the most common fittings UTs use during the installation of water distribution systems.

1.3.3.1.1 Elbows

Used to make 32.5 degree, 45 degree and 90 degree turns in a piping system, sizes include 1/8, 1/4, and 1/2. Elbows are available for all types of piping. Refer to *Figure 1-5*.

1.3.3.1.2 Tees

Used to branch off of a pipe at a 90-degree angle, tees are available for all types of piping. Refer to *Figure 1-5*.

1.3.3.1.3 Unions

Unions are installed in a pipe to allow removal and replacement of an installed plumbing component or piping section without cutting the pipe. Unions are used in galvanized steel or black iron piping systems. These types of pipe are generally screwed together. Refer to *Figure 1-5*

Figure 1-5 — Pipe fittings with associated symbols.

Valves are installed in piping to control the flow of water or other substances through the plumbing system. Many valves are available for this purpose. Shown below are just a sample of valves used in plumbing and their corresponding symbols.

1.3.3.1.4 Gate Valve

A gate valve is a linear motion valve used to start or stop fluid flow; it does not regulate or throttle flow. The gate valve may have a wedge-shaped movable plug or a (single or double) round disk that fits tightly against the seat when the valve is closed. (*Figure 1-6*) When the gate is open, it provides unrestricted flow, allowing fluid to flow through in a straight line with little resistance, friction, or pressure drop, provided the valve gate or disk is kept fully open.

Figure 1-6 — Gate valve.

1.3.3.1.5 Globe Valve

The globe valve (*Figure 1-7*), regulates the flow of liquids, gases, and vapor by means of throttling (adjusting rate of flow). They are well suited for services requiring regulated flow and/or frequent valve settings (throttling).

These valves are normally installed underneath a fixture such as a bathroom lavatory (commonly referred to as angle stop). The valve is used to shut off water to a single fixture during repair or maintenance without having to turn off water to the entire building.

Figure 1-7 — Globe valve.

1.3.3.2 Common Waste Fittings

Waste fittings change direction, reduce or increase pipe sizes at a joint, or permit the plumber to branch off a pipe in another direction in the same manner as fittings in water distribution systems. Common waste fittings include bends, sanitary tees, the combination wye, and the 1/8 bend. Bends serve the same function as elbows, they change piping direction. Unlike elbows, bends are described in terms of fractions. For example, a 90 degree elbow provides a right turn in water piping and a 1/4 bend provides a right turn in waste piping. Sanitary tees serves the same function as a tee, it allows you to branch off a pipe in a new direction. The sanitary tee is different because it has a sloping branch to guide wastewater that is flowing by gravity from the branch line into the primary wastewater piping. Sanitary tees are installed to carry wastewater from horizontal piping to vertical piping. A combination wye and 1/8 bend looks similar to a sanitary tee except that it has a longer sloping branch. This fitting is designed to carry waste from a vertical pipe to a horizontal piping system.

1.3.3.2.1 Bend

Bends are available in cast iron and plastic. 1/4 and 1/8th bends are frequently used in waste piping. Refer to *Figure 1-8*.

1.3.3.2.2 Sanitary Tee

Sanitary tees are available in cast iron and plastic. These fittings are commonly installed in vertical wastewater piping. Refer to *Figure 1-8*.

1.3.3.2.3 Combination Wye and 1/8 Bend

A combination wye and 1/8 bend is installed in horizontal wastewater piping to receive waste from vertical piping. The long sweeping branch reduces the chance of obstructions as the water makes the turn in the piping system. Refer to *Figure 1-8*.

Figure 1-8 — Common waste fittings.

1.3.4 Joints

Fittings and pipe must be joined together to transport liquids or gases. There are numerous types of joints made between pipe and fittings. Types of joints include screwed joints, soldered joints, no hub connections, and mechanical joints. These types of joints are indicated on construction plans with symbols. Shown below are examples of pipe joints and their corresponding symbols.

1.3.4.1 Screwed Joints

A single line shown at the connection between the fitting and pipe indicates a screwed joint. The pipe and fitting are threaded like a nut and bolt. This joint is commonly used with galvanized steel and black iron piping. Refer to *Figure 1-9 View A*.

1.3.4.2 Soldered Joints

A circle shown at the intersection between pipe and fitting indicates a soldered joint. The pipe and fitting are heated with a torch and then metal “solder” is drawn into the joint to form a watertight seal. Soldered joints are made on copper piping. Refer to *Figure 1-9 View B.*

1.3.4.3 No Hub Coupling

A line perpendicular to the piping with bars on either end indicates a no hub coupling joint. The no hub coupling consists of a rubber seal surrounded by a stainless steel band which is held in place with two hose clamps. This connection is used in wastewater piping. Refer to *Figure 1-9 View C*.

Figure 1-9 — Types of joints.

1.3.4.4 Mechanical Joints

Two parallel lines of equal length indicate a mechanical joint. The joint will consist of two metal plates bolted together with a rubber seal separating the metal plates. This type of joint is commonly used in large cast iron water piping systems. Refer to *Figure 1-9 View D*.

1.4.0 Types of Scales

An architect cannot make drawings full size. For convenience, they reduce all dimensions to some scale. The architect selects some smaller dimension to represent a foot and reduces all dimensions to this unit. A floor plan or an elevation is often drawn at l/48 the size of the real building. A drawing 1/48th size would be drawn at a scale of 1/4" = 1'0". Each l/4 inch on the drawing equals 1 foot on the actual building. Different scales are used to show different areas of the drawings. While floor plans and elevations are commonly drawn l/4" = 1'0", detail drawings are drawn at a larger scale, usually 1" = 1’0”.

Scaled drawings are made using an architect’s scale (*Figure 1-10.* An architect’s scale has 11 scales (*Table 1-2*). The numbers at each end of the architect’s scale designate the scale. *Figure 1-11* shows an enlarged view of part of an l/4-inch scale. Each division on the scale equals 1 foot on the actual building. The small divisions to the right equal 1 inch on the building, thereby allowing more accurate measurement. This scale is read from right to left. Architects and drafters use an architectural scale to draw blueprints. *Figure 1-12* shows how to use the scale to check a measurement on a blueprint.

Figure 1-10 — Architect’s scale.

Table 1-2 — Architect’s scales.

Scale	Relation of Scale to Object
16	1” = 1’
1/4	3” = 1’
1/8	1’ 1/2” = 1’
1/12	1” = 1’
1/16	3/4” = 1’
1/24	1/2" = 1’
1/32	3/8” = 1’
1/48	1/4" = 1’
1/64	1/16” = 1’
1/96	1/8” = 1’
1/128	3/23” = 1’

Figure 1-11 — Enlarged view of a 1/4 inch scale.

Figure 1-12 — Using a scale to check a measurement on a blueprint.

2.0.0 PLANS

You will be working with several types of plans and drawings. These may range from simple shop drawings and sketches, made perhaps by your immediate supervisor, to construction blueprints created by engineers. For the most part, you will be working with plans created by architects and engineers. In Seabee construction, a complete set of plans for a project consists of civil, architectural, structural, electrical and mechanical plans, or drawings. You will be spending the majority of your time with mechanical drawings, but you will need all of these plans together to obtain a full picture of your part of that project and how to accomplish it.

2.1.0 Site Plan

The site plan shown in *Figure 1-13* shows the ***contours***, boundaries, roads, utilities, trees, structures, and any other significant physical features on or near the construction site. It shows the locations of proposed structures in outline. This plan also shows corner locations relative to reference lines, shown on the plot, which can be located at the site. By showing both existing and finished contours, the site plan furnishes essential data for the ***graders***.

Figure 1-13 — Site plan.

2.2.0 Architectural Plans

Architectural plans show the architectural design and composition of a building. They include floor plans, exterior elevation plans, and door and window schedules.

2.2.1 Plot Plans

The plot plan is the starting point for any building 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, it shows such information, as well as the location of existing water, wastewater, and gas piping systems (*Figure 1-14*).

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

Figure 1-14 — Plot plan.

2.2.2 Foundation Plan

The foundation plan shows the location of the proposed structure and where the water and gas lines should enter the proposed building. The foundation plan also shows access points and openings in foundation walls for utilities inspection and maintenance, and building exit locations for waste lines. See *Figure 1-15*.

Figure 1-15 — Foundation plan.

2.2.3 Floor Plan

A floor plan provides a bird’s eye view of the structure. The plan appears as if some one has lifted the roof from the structure and you’re looking in from above. This type of construction plan shows the location of fixtures and interior walls and enables a plumber to install plumbing to the desired locations within the structure.

Figure 1-16 is a floor plan showing the lengths, thicknesses, and character of the outside walls and partitions at the particular floor level. It also shows the number, dimensions, and arrangement of the rooms, the widths and locations of doors and windows, and the locations and character of bathroom, kitchen, and other utility features.

Figure 1-16 — Floor plan.

2.2.4 Elevation Plan

This type of plan shows front, side, and rear views of the structure to indicate the height of items such as doors, windows, ceilings and roof, and other external characteristics of the structure. This information is helpful in determining the amount of pipe necessary for vertical piping systems. See *Figure 1-17*.

Figure 1-17 — Elevation plan.

2.2.5 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 used.

Detail drawings show a particular item on a scale larger than the general drawing's scale. A detail drawing may include additional features not viewable from the perspective of the general drawing or items too small to appear on a general drawing. They may also be in a view other than the general drawing's; for example, the detail may be in an isometric view to provide a three dimensional perspective for additional information. (*Figure 1-18*)

Figure 1-18 — Typical detail drawing.

2.3.0 Electrical Plans

Electrical plan information and layout are usually superimposed on the plot plan and the building plan, providing common reference points for all the respective trades.

This section will address electrical plans pertaining to the electrical (power) distribution system (outside power lines and equipment for multi-building installations) and the interior electrical wiring system.

You are not required to design the electrical wiring system, but you must be familiar with symbols, nomenclature, basic functions of components, and installation methods, as well as the transmission, distribution, and circuit hookups associated with the electrical systems.

2.3.1 Electrical Symbols

There are a myriad of electrical symbols used in schematic drawings, electronics, avionics, shipboard lighting, and so on. The ones you will use as an UT will be limited to those typical of the construction industry. An electrical plan's symbols indicate general layout, units, related equipment, fixtures and fittings, and the routing and interconnection of various electrical wiring. *Figure 1-19* shows the most common types of symbols used in electrical drawings for construction.

Figure 1-19 — Common electrical symbols for construction.

2.3.2 Types of Electrical Drawings

2.3.2.1 Interior Electrical Layout (Plan)

The interior electrical layout for a small building is usually drawn into a print of the floor plan. On larger projects, additional separate drawing sheets are necessary to accommodate detailed information needed to meet construction requirements.

Figure 1-20 shows an interior electrical layout of a typical public works shop. Note again that the electrical wiring diagram is superimposed on an architectural floor plan.

Figure 1-20 — Typical interior electrical plan.

2.4.0 Mechanical Plans

In the Navy, mechanical systems vary greatly depending on whether they are aboard ship or shore-based. As a UT, your concern will be with shore-based systems ranging from permanent installations with the most modern fixtures and equipment, to temporary installations at advanced bases that normally use the most economical materials that serve the purpose.

In this section, a mechanical plan refers to drawings, layouts, diagrams, and notes that relate to water distribution and sanitary drainage systems only. Heating and air conditioning, refrigeration, and other like systems are not included.

2.4.1 Water Supply and Distribution Diagram

Normally, a structure's water supply system starts at the water main. A self-tapping tool (*Figure 1-21*) drills and taps into this source (the source is still under pressure) and a corporation stop is installed during the same process (See *Figure 1-22*).

Water then enters the building through a cold-water service line that usually runs through a gate valve-meter-gate valve configuration.

As a UT, you may be called upon to develop field sketches and drawings from larger sets of plans or, in reverse, to do "as-built" drawings and sketches. You may at some point need to do drawings of existing conditions so planners involved in a remodel or rehabilitation project can design retrofit potential possibilities. The following three isometric diagrams demonstrate typical layout drawings that apply to mechanical systems for plumbing, that is, for water distribution and soil and waste removal.

Figure 1-21 — Water main self tapping tool.

Figure 1-22 — Typical service line.

Figure 1-23 shows typical hot- and cold-water service lines for a single-story residential building and how the lines connect to the fixtures.

This layout is a riser diagram in isometric as a method of visualizing or showing a three dimensional picture of the pipes in one drawing.

2.4.2 Waste and Soil Drainage Diagram

Figure 1-24 shows the waste and soil pipe fittings and the symbols associated with the hot- and cold-water riser's diagram.

The arrow represents the direction of flow; all pipes are sloping towards the building drain.

Figure 1-23 — Typical hot water and cold water risers' diagram.

Figure 1-25 shows the basic layout of a simple but typical drainage system. Refer to it as the chapter presents the function of each element.

Fixture drain - pipe extending from the trap of a fixture to a junction with any other drainpipe

Branch - horizontal drainpipe connecting fixtures to the stack

Soil and waste fixture branch - pipe that feeds into a vertical pipe, referred to as a stack

Soil stack - stack that is used to transport solid wastes/fecal matter

Waste stack - stack that carries liquid waste not to include fecal matter

Figure 1-24 — Typical waste and soil risers diagram.

Floor drain – used to drain overflow water from floor spaces, commonly located in heads near heating and units subject to overflow or leakage

Cleanout - fitting with a removable cap or plug that provides access for maintenance and inspection of Drain Waste Vent (DWV) systems

Building drain (house drain) - the lowest piping of the drainage system receiving discharge from all other drainage pipes inside a facility and conveys that waste to the building sewer

Building sewer - the horizontal piping extending from the end of the building drain to the public, private or individual disposal system/sewer

Figure 1-25 — Basic drainage system layout and terminology.

2.4.3 Plumbing Layout

In construction drafting, a mechanical (or utility) plan normally includes both water distribution and sanitary drainage systems combined, especially on smaller buildings or houses. The plumbing layout is usually drawn into a copy of the floor plan for proper orientation with existing plumbing fixtures, walls and partition outlines, and other utility features. *Figure 1-26* shows a typical plumbing layout.

Figure 1-26 — Typical plumbing layout plan.

Test your Knowledge (Select the Correct Response)

1. Which of the following plans show proposed entry points for water and gas lines?

   A. Foundation
   B. Plot
   C. Mechanical
   D. Floor

3.0.0 SPECIFICATIONS

Each project will have specific specifications. Each project will have similarities, but may require different procedures and installation requirements; specifications will provide specific guidance on the installation of specific plumbing systems and fixtures for specific projects.

Although the plans you will be working from usually have sufficient detail, you will need additional information regarding materials and methods of installation. This information is located in the appropriate specifications. Plans and specifications go together to provide visual and written information about a project that you, as the constructor, installer, or maintainer, require to produce the best quality product.

There are several types of specifications (SPECS), but you will work primarily with project guide, federal, military, and Naval Facilities (NAVFAC) specifications.

Project guide specifications usually begin with Division 1, the GENERAL REQUIREMENTS for the structure. They state the type of foundation, the character of load-bearing members (wood frame, steel frame, and concrete), the type or types of doors and windows, the types of mechanical and electrical installations, and the principal function of the building. Next comes the SPECIFIC CONDITIONS that are carried out by the constructors. The conditions are grouped in divisions under headings applying to each major phase of construction. We will focus on the mechanical portion classified as Division 15.

3.1.0 Mechanical Specifications

Division 15 pertains to plumbing. Take notice of the terminology used in the below sections. Specifications are the rules for your specific project.

3.1.1 General Requirements

The work consists of a complete plumbing system, including the sanitary soil, waste, and vent piping; cold- and hot water supply piping, water meter (if required), plumbing fixtures, hot-water heater, and other appurtenances. The system must be inspected, tested, and approved by local governing plumbing codes before burying, concealing, or covering the various piping systems. Each system must be complete and ready for operation except as specified or indicated otherwise.

3.1.2 Sanitary Sewer, Below Ground

Must be of extra-heavy cast-iron soil piping and fittings of the bell-and-spigot type, extending 3 to 5 feet beyond the foundation wall and graded not less than 1/8 inch per foot. All horizontal soil connections to the system must be accomplished by Y-fittings or combination Y and 1/8 bends. All changes in direction greater than a 1/8 bend must be of the long sweep pattern. Lines should be well-supported to eliminate sagging. Backfilling will be well-tamped in (1-inch layers).

3.1.3 Sanitary Sewer, Above Ground

Must be as specified for the below ground level, except waste lines and vent piping above the ground must be of zinc-coated, standard weight, screwed-end steel pipe and cast iron, recessed, long radius, screwed drainage fittings, and graded not less than 1/8 inch per foot. The sanitary sewer vent will extend full size through the roof for a distance of not less than 12 inches, where it must be flashed with suitable corrosion-resistant metal before the roofing is installed. A 4-inch cleanout will be provided slightly above the ground elevation at the base of the soil stack. All male screw ends will be coated with a good grade pipe joint compound before entering into fittings. The bathtub trap must be provided with a 3/4-inch brass, screw dram plug; all lines must be properly supported from the floor joists with suitable hangers. A closet-bowl floor connection must have a cast-iron closet-bowl floor flange with provisions for anchoring the brass closet bowl bolts and an approved type of horn gasket. The finished joint must be absolutely leak proof, and the bowl will sit squarely on the finished floor.

3.1.4 Water piping Buried in the Ground

Must be joint-less, type "K," soft copper tubing. No kinking of the tube will be allowed.

3.1.5 Water piping Aboveground

Must be type "L," hard copper tubing with solder-type fittings, except that vertical lines may be of type "L," soft copper tubing. All tubing lines will be properly anchored to the floor joists to eliminate pipe sag and vibration and pitched to the main shutoff valve for draining, when necessary. A hose bib will be provided at the rear of the building with a stop and waste valve located inside the foundation wall for winter cutoff and waste and arranged for complete drainage of the line from the hose bib. Slip-joint connections will not be permitted below the finished floor.

4.0.0 ISOMETRIC SKETCHING

You may not be able to sketch or draw objects exactly as they should look or as a two-dimensional ***orthographic*** picture. However, with the aid of some basic rules and practice, you can learn to draw an isometric sketch that can contain more detail and fit a three dimensional space.

4.1.1 Purpose of the Isometric Drawing

The purpose of an isometric drawing is to show a three-dimensional picture in one drawing. It resembles a picture without the artistic details. Many UTs have difficulty visualizing a piping system installation clearly when they are converting a floor plan to an elevation drawing and back. The isometric drawing combines the floor plan and the elevation. Its purpose is to show the details and the relationship of the pipes in the piping system.

Normally, isometric drawings are NOT drawn to scale on blueprints; however, when you sketch out an isometric drawing, you have the option of drawing it to scale.

The isometric drawing follows certain rules or conventions to show three dimensions on a flat surface. These rules are as follows:

1. Vertical lines in an orthographic elevation remain vertical in an isometric sketch.
2. Horizontal lines in an orthographic elevation are projected at an angle of 30 degrees and 60 degrees in an isometric drawing.

4.2.0 Comparison of Isometric and Orthographic Drawings

Compare the simple rectangular block shown in the orthographic representation in *Figure 1-27*, *View A* and the three-dimensional-view isometric representation in *View B*. Notice that the vertical lines of the orthographic drawing and isometric drawing (*Views A* and *B*) remain vertical. The horizontal lines of the orthographic drawing are NOT horizontal in the isometric drawing but are projected at 30 degree and 60 degree angles, and the length of the lines remains the same in the isometric as they were in the orthographic.

Once you understand the drawing in *Figure 1-27*, the same idea can be applied to the drawing of the shape of a room, as shown in *Figures 1-28* and *1-29*.

Figure 1-27 — Orthographic and isometric drawings.

Figure 1-28 — Isometric drawing of a room.

Figure 1-29 — Isometric drawing of a room and drainage pipe.

4.3.0 Drawing an Isometric View

To determine the pipe layout, you can draw the dimensions of a room in several ways. Some Engineering Aids suggest that the lines of the room be drawn with fine, light lines, and the pipe diagram with heavy, dark lines to give the effect of a transparent room you can see into, as shown in *Figure 1-30*. Sketching the room and fixtures is an advanced technique that can be honed with time and practice.

Figure 1-30 — Isometric layout.

Another means of visualizing the layout is to "section" or remove from the drawing those parts in front of what is important to show. The usual section in an electrical wiring layout leaves the ceiling and two walls out of the drawing, as shown in View C of *Figure 1-30*.

A third method is simpler; it shows the room only in a partial floor plan view, as shown in View D, *Figure 1-30*. The walls are omitted from the drawing entirely. The walls are understood to be there, but they are left out of the drawing so that it shows the piping diagram without unnecessary details.

To lay out a 45 degree angle in an isometric drawing, draw a square and lay out the 45 degree angle, as shown in View A, *Figure 1-31*. Now look at View B and you will see a block with a 45 degree ***chamfer***. The chamfer is located by measuring equal distances from the corner that would ordinarily be there.

A piping diagram with a 45 degree angle, as shown in View C, is very similar to the lines for part of the block, as shown in View B. To draw a 45 degree angle in an isometric drawing, begin with a 90 degree angle. Measure an equal distance from the intersection of the two legs connecting these points; then establish two sides of a square. By connecting these points,

Figure 1-31 — Isometric 45 degree squares, chamfers, and diagonals.

you have established the diagonal, which is a 45 degree angle. In View C, point A would be the intersection of the two legs of a 90 degree angle, measured an equal distance along each leg; three fourths of an inch is used here. Now, locate points B and C. Connect points B and C, and you have established the 45 degree offset.

4.4.0 Dimensioning an Isometric Drawing

An isometric drawing, or sketch, is dimensioned with extension and dimension lines nearly like a two dimensional drawing. The extension lines extend from the drawing, so the dimension lines are parallel to the object line and of equal length to it.

The isometric drawing is more difficult to dimension because there is only a single view, and less room is available than on three separate views. *Figure 1-32* shows a dimensioned isometric drawing for part of a pipe hanger. In making the isometric pipe diagram, refer to the architect's plans for accurate information.

Figure 1-32 — Isometric drawing of a pipe hanger.

Since pipe diagrams are measured from the center of one fitting to the center of the next fitting, it is possible to omit the extension and dimension lines by use of a notation, such as 13 inch c to c (center to center).

Pipe sizes must be added to the pipe diagram. The size of pipe is shown by a number near the line indicating the pipe, as shown in *Figure 1-33*.

4.5.0 Placing Dimensions on an Isometric Drawing

The purpose of an isometric pipe layout is best served by a simplified dimensioning system. *Figure 1-33* is an example of an isometric pipe layout.

Figure 1-33 — Pipe layout.

4.6.0 Sketching Practice

So far, this chapter has discussed the principles of reading prints and drawing sketches. To practice these rules, look at the three isometric drawings in *Figure 1-34* and sketch three 3-view drawings. Now, make three isometric sketches.

Figure 1-34 — Three isometric views to be drawn orthographically.

Test your Knowledge (Select the Correct Response)

2. An isometric drawing is designed to show what type of picture?

   A. Two dimensional
   B. Three dimensional
   C. Four dimensional
   D. Freehand sketch

5.0.0 COLOR CODING for SAFETY

Color warnings provide for marking physical hazards, for indicating the location of safety equipment, and for identifying fire and other protective equipment. As a UT, you may often be concerned with uniform colors used for marking pipelines carrying hazardous materials, compressed gas cylinders, and fire- protection equipment.

5.1.0 Classes of Materials and Their Color Codes

Five classes of materials have been selected to represent the general hazards for all dangerous materials, while a sixth class has been reserved for fire protection materials. A standard color represents each of these classes, as shown in *Table 1-3*.

In some instances, piping systems that do not require warning colors may be painted to match surroundings; in other instances, such systems may be painted aluminum or black or remain unpainted.

Table 1-3 — Warning colors.

Class	Standard Color	Class of Material
A	Yellow	**FLAMMABLE MATERIALS**. All materials known ordinarily as flammables or combustibles. Of the chromatic colors, yellow has the highest coefficient of reflection under white light and can be recognized under the poorest conditions of illumination.
B	Brown	**TOXIC AND POISONOUS MATERIALS**. All materials extremely hazardous to life or health under normal conditions as toxics or poisons.
C	Blue	**ANESTHETICS AND HARMFUL MATERIALS**. All materials productive of anesthetic vapors and all liquid chemicals and compounds hazardous to life and property but not normally productive of dangerous quantities of fumes or vapors.
D	Green	**OXIDIZING MATERIALS**. All materials which readily furnish oxygen for combustion and fire producers which react explosively or with the evolution of heat in contact with many other materials.
E	Gray	**PHYSICALLY DANGEROUS MATERIALS**. All materials not dangerous in themselves, which are asphyxiating in confined areas or which are generally handled in a dangerous physical state of pressure or temperature.
F	Red	**FIRE PROTECTION MATERIALS**. Materials provided in piping systems or in compressed-gas cylinders for use in fire protection.

5.2.0 Marking Piping Systems

In addition to color warnings, use **WRITTEN TITLES** to identify hazardous or dangerous materials conveyed in piping systems.

Titles should be stenciled or lettered on pipe (or covering) where the view is unobstructed, such as on the lower quarters. Lettering in this position is unlikely to be obscured by dust collection or mechanical damage. Titles should be in black or white ONLY and be clearly visible from operating positions, especially those next to control valves.

Use stencils with standard-size letters, as shown in *Table 1-4*. For pipelines smaller than three quarters of an inch in diameter, use securely fastened metal tags with lettering etched or filled in with enamel. Apply titles with uppercase letters and Arabic numerals whenever applicable. For further information refer to MIL-STD-101B (Color Code for Pipelines and for Compressed Gas Cylinders).

Table 1-4 — Size of Stencil Letters.

Outside diameter of pipe or covering	Size of Stencil Letters
Inches	**Inches**
Under 1 1/2	1/2
1 1/2 to 3 1/2	3/4
3 1/2 to 6	1 1/4
6 to 9	2
9 to 13	3
Over 13	3 1/2

PRIMARY COLOR WARNINGS should be a single color, applied as a BAND (or BANDS), that completely encircle(s) the piping system. They are located on the piping system immediately next to all operating accessories, such as valves, regulators, strainers, and vents. Paint the bands throughout the system at convenient intervals where branch lines join the system, where the system passes underground or through walls, and at any other conspicuous place where warnings are required. All piping and covering of an entire system, excluding straps, hangers, and supports, may be painted with the primary color warning. When you do this, DO NOT paint color bands of any kind on the system.

Use a colored ARROW next to each primary color warning applied to a piping system to indicate the normal direction of flow of the material in the system. Use a double-headed arrow on lines subject to reverse flow. The color of arrows can be the same as the primary warning when bands are used, black or white. (Refer to *Figure 1-36* for identification of piping systems.)

A secondary color warning alerts you to the secondary hazard of a material. The second hazard differs from the primary hazard. These colors appear as arrows (or triangles) on piping systems and as main body, top, or band colors on compressed gas cylinders.

Two ***decalcomanias*** may be applied on the shoulder of each cylinder diametrically opposite at right angles to the titles. They should indicate the name of the gas, precautions for handling, and use. Use a background color corresponding to the primary color warning of the content.

Stencil a shatterproof cylinder with the phrase "Non-Shat" longitudinally at 90 degrees from the title. Letters must be black or white and approximately 1 inch in size.

On cylinders owned by or procured for the Department of Defense (DOD), the bottom and the lower portion of the cylinder body opposite the valve end may be used for service ownership titles.

The appearance on the body, top, or as a band of any of the six colors listed in *Table 1-3* warns of danger from the hazards in handling the type of material contained in the cylinder.

Figure 1-37 shows compressed gas cylinders and Table 1-5 shows cylinder colors most commonly found in a Naval Mobile Construction Battalion (NMCB) or in a Public Works Department (PWD) where Seabee personnel will be working.

Figure 1-36 — Identification of piping system.

Figure 1-37 — Compressed gas cylinders commonly used by UTs.

Table 1-5 — Cylinder Color Chart.

Type Cylinders	Top Color	Band Color	Main Body Color
Chlorine	-	-	Brown
Ammonia	Brown	Yellow	Orange
Acetylene	-	-	Yellow
F-12 Dichlorodifluoromethane	-	-	Orange
Oxygen	-	-	Green
Butane	Yellow	Orange	Yellow
Methyl Chlorine	Yellow	Brown	Orange

Test your Knowledge (Select the Correct Response)

3. If a pipe is 10 inches in diameter, what size should the stencil lettering be?

   A. 1/2 inch
   B. 2 inches
   C. 3 inches
   D. 3 1/2 inches

Summary

Your use of blueprints and plans is an integral part of each day on a construction project. You need solid blueprint, floorplan, and plot plan reading skills on the job, whether you're laying sewer lines, installing bathroom fixtures, or digging a trench in preparation of water lines. All above skills are critical for any construction crewmember.

Mechanical specifications dealing with water piping above and below ground or sewerage lines above or below ground are an important factor in the accomplishment of your job as an UT. As a UT, there will be times when it will be necessary to utilize the different color schemes associated with piping and gas cylinders. Knowledge of safe installation and operational requirements are essential for not only your safety, but the safety of your crewmembers. As a UT, you will be looked upon to complete the task or project on time and safely.

Review Questions (Select the Correct Response)

1. **(True or False)** Utilitiesmen use different types of plans and drawings. These plans and drawings are developed by immediate supervisors, architects, and engineers.

   A. True
   B. False

2. Which of the following plans illustrates both existing and finished contours, an essential data for grader operations?

   A. Plot
   B. Site
   C. Foundation
   D. Floor

3. Which of the following plans show the location of existing wastewater and gas piping systems?

   A. Civil
   B. Foundation
   C. Plot
   D. Floor

4. Location of proposed entry points for water and gas lines can be found on which of the following plans?

   A. Plot
   B. Civil
   C. Floor
   D. Foundation

5. As a UT, you need to be aware of the locations of interior walls and fixtures. Which of the following plans will provide this information?

   A. Plot
   B. Civil
   C. Floor
   D. Foundation

6. Which set of plans is useful in helping you in determining the amount of pipe necessary for vertical piping systems?

   A. Electrical
   B. Floor
   C. Foundation
   D. Elevation

7. Electrical plan information and layout are usually superimposed on which of the following plans if any?

   A. Civil
   B. Plot
   C. Foundation
   D. None of the above

8. **(True or False)** The interior electrical layout for a small building is usually drawn into a print of the floor plan.

   A. True
   B. False

9. The electrical wiring diagram is superimposed over what type of plan?

   A. Foundation
   B. Plot
   C. Floor
   D. Electrical

10. Through which type of water line does water enter the structure from the main distribution line?

   A. Cold water distribution line
   B. Hot water service line
   C. Hot/Cold water service line
   D. Cold water service line

11. Which of the following fittings extends from the P-trap of a fixture to a junction with any other drainage fixture?

   A. Soil stack
   B. Fixture drain
   C. Cleanout
   D. Fixture branch

12. What is used to connect horizontal drainage to the stack?

   A. Fixture drain
   B. Soil waste branch
   C. Fixture branch
   D. Floor drain

13. Which of the following fittings feeds into a vertical pipe?

   A. Cleanout
   B. Floor drain
   C. Waste stack
   D. Soil and waste fixture branch

14. Which of the following fittings will include human waste?

   A. Waste stack
   B. Soil and waste fixture branch
   C. Fixture branch
   D. Soil stack

15. Which of the following stacks carries waste but not human waste?

   A. Soil stack
   B. Waste stack
   C. Sewer stack

16. Which fixture usually located near heating and laundry areas is installed to receive floor water drainage?

   A. Fixture drain
   B. Floor trap
   C. Fixture trap
   D. Floor drain

17. What piece of equipment extends from the building drain to the community sewer line?

   A. Floor drain
   B. Building drain
   C. Building sewer
   D. Soil stack

18. The isometric drawing is a combination of which of the following plans?

   A. Floor and elevation
   B. Floor, elevation, and plot
   C. Plot and elevation
   D. Floor and plot

19. Horizontal lines in an orthographic elevation are projected at what angles in an isometric drawing?

   A. 15, 30,and 45 degrees
   B. 30 and 60 degrees
   C. 60 and 90 degrees
   D. 30, 60, 90, and 120 degrees

20. Blueprints are copies of what type of drawing?

   A. Isometric
   B. Orthographic
   C. Plot
   D. Mechanical

21. Which of the following Mil Standard specifies the size, format, location, and type of information that should be included in military blueprints?

A. MIL-STD-100A
B. MIL-STD-200A
C. MIL-STD-300A
D. MIL-STD-400A

22. The title block of a military blueprint can be located where?

A. Upper left corner
B. Lower right corner
C. Upper right corner
D. Lower left corner

23. A space within the title block with a diagonal or slant line drawn across it indicates what to the reader?

A. No further entries required
B. Information not required
C. Blueprint is outdated
D. Information is continued on next sheet

24. A letter designation of “S” on an NAVFACENGCOM drawing indicates what type of information?

A. Safety
B. Sewer
C. Structural
D. Seaborne

25. Where does the drawing number appear on a set of blueprints?

A. Upper right hand corner
B. Lower right hand corner
C. Lower left hand corner
D. Upper left hand corner

26. Revision number is located where on a set of blueprints?

A. Upper right hand corner
B. Upper left hand corner
C. Lower right hand corner
D. Lower left hand corner

27. What is utilized to find a specific part on a blueprint?

A. Zone number
B. Drawing number
C. Location number
D. Revision number

28. Which part of the blueprint will provide the number of specific parts needed for job?

A. TOA
B. Bill of Material
C. Parts required list
D. Supply block

29. Which of the following construction lines is a light and continuous along which the tracing is trimmed?

A. Border
B. Extension
C. Trim
D. Dimension

30. Which type of line is drawn outside the structure or detail to show distance?

A. Border
B. Dimension
C. Equipment
D. Section

31. Which line is used in conjunction with the dimension line?

A. Center
B. Break
C. Extension
D. Hidden

32. Which line contains wavy breaks at specified intervals?

A. Break
B. Hidden
C. Broken
D. Section

33. Which line is made of alternating long and short dashes to indicate the center of an object?

A. Hidden
B. Stair indicator
C. Broken
D. Center

34. Which of the following is NOT considered a plumbing fixture?

A. Sink
B. Water closet
C. Shower
D. Gas trap

35. Common water fittings include all of the below except which of the following?

A. Elbow
B. Bend
C. Tees
D. Unions

36. Which piece of equipment is utilized to make turns in a piping system?

A. Elbow
B. Bend
C. Joint
D. Union

37. Tees are used to achieve how much of a angle to be branched off a line?

A. 30 degrees
B. 90 degrees
C. 60 degrees
D. 45 degrees

38. Unions are used in which type of piping systems?

A. Cast iron
B. plastic
C. Black iron
D. Copper

39. What type of valve is commonly used to start and stop water flow?

A. Globe
B. Check
C. Relief
D. Gate

40. What type of valve is utilized to regulate the flow of gases by throttling?

A. Gate
B. Globe
C. Check
D. Vent

41. Which valve is used to shut off water to a single fixture?

A. Vent
B. Check
C. Globe
D. Gate

42. Which of the following is NOT part of common waste fittings?

A. Bends
B. Sanitary tees
C. Combination wye
D. 1/4 bend

43. Which waste fittings are used in vertical wastewater piping?

A. Sanitary tees
B. Bends
C. Combination wyes
D. 1/8 bends

44. What is the reason for the long sweeping branch in combination wye fittings?

A. Increase flow speed
B. Only allows wastewater through
C. Reduces obstructions
D. Decreases flow speed

45. Which joint is used with galvanized steel piping?

A. Soldered joints
B. Mechanical joints
C. Screwed joints
D. No hub coupling

46. What are soldered joints manufactured of?

A. Soft iron
B. Galvanized steel
C. Copper
D. Black iron

47. While reviewing a blueprint, you notice a line perpendicular to the piping with bars on either end. This indicates which type of joint to be used?

A. Mechanical
B. Soldered
C. Screwed
D. No hub coupling

48. Two parallel lines of equal length on a blueprint indicate which of the following?

A. Soldered joint
B. Mechanical joint
C. No hub coupling
D. Screwed joint

49. Mechanical joints are commonly used in which type of piping system?

A. Small cast iron water piping system
B. Black iron wastewater piping system
C. Large cast iron water piping system
D. Copper waste piping system

50. What is the division number associated with mechanical aspects of a project on a set of specifications?

A. Division 16 Part A
B. Division 15 Part B
C. Division 15
D. Division 15 Part A

51. What type of piping material is used when dealing with a sanitary sewer, below ground installation?

A. Steel
B. Hard copper
C. Extra heavy cast iron
D. Soft copper

52. In a sanitary sewer, above ground system, the sanitary sewer vent will extend full size through the roof for a distance of not less than how many inches?

A. 12 inches
B. 18 inches
C. 24 inches
D. 36 inches

53. Water piping buried in the ground will be manufactured out of what type of material?

A. Type L, hard copper
B. Type K, soft copper
C. Type L, soft copper
D. Type K, hard copper

54. Vertical lines used in the installation of water piping aboveground will be manufactured out of what type of material?

A. Type L, hard copper
B. Type K, soft copper
C. Type L, soft copper
D. Type K, hard copper

55. Which type of connections are not permitted below the finished floor?

A. Routers
B. Bib
C. Tee
D. Slip-joint

56. How many classes are associated with general hazards?

A. 4
B. 5
C. 6
D. 7

57. What color does yellow represent with respect to general hazards categories?

A. Toxic materials
B. Flammable materials
C. Oxidizing materials
D. Fire protection materials

58. Anesthetics and harmful materials is depicted by what color?

A. Blue
B. Red
C. Gray
D. Brown

59. All materials which readily furnish oxygen for combustion is identified by which color?

A. Brown
B. Blue
C. Gray
D. Green

60. Gray represents which of the following classes of material?

A. Fire protection
B. Physically dangerous
C. Flammable
D. Toxic

61. When using shatterproof cylinders how big and what color should the stenciling be?

A. 1 inch with red lettering
B. 2 inches with white lettering
C. 1 inch with black lettering
D. 1/2 inch with black lettering

62. What color should the cylinder be that contains chlorine gas?

A. Green
B. Orange
C. Yellow
D. Brown

63. Supply has just dropped off a yellow colored cylinder, which of the following gases is contained inside?

A. Ammonia
B. Methyl Chlorine
C. Butane
D. Acetylene

64. What color is the cylinder containing oxygen?

A. Yellow
B. Green
C. White
D. Black

65. Which of the following cylinders contains methyl chlorine?

A. Brown, yellow, and orange markings
B. Yellow, orange, and yellow markings
C. Yellow, brown, and orange markings
D. Orange, green, and brown markings

Trade Terms Introduced in this Chapter

Contours	The outline of a figure or body; the edge or line that defines or bounds a shape or object
Graders	A machine for grading
Orthographic	Representation of two dimensional views of an object, showing a plan, vertical elevation and/or section
Chamfer	A cut that is made in wood or some other material, usually at a 45° angle to the adjacent principal faces
Decalcomanias	The art or process of transferring pictures or designs from specially prepared paper to wood, metal, glass, etc.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Basic Machines, NAVEDTRA 12199, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

OSHA Regulations (Standards – 29 CFR)

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Naval Construction Force Manual, *NAVFAC P-315,* Naval Facilities Engineering Command, Washington, D.C., 1985.

McPortland, J.E, and Brian J. McPortland, *National Electrical Code® Handbook,* 22d Ed, McGraw-Hill, NY, 2008.

Engineering Aid Basic, NAVEDTRA 10696-A, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Fluid Power, NAVEDTRA 12964, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

National Standard Plumbing Code-Illustrated, National Association of Plumbing-Heating-Cooling Contractors, Washington, DC, 2006.

Plumbing Manual, Volume II, NTTC Course 140-B, NAVFAC P-376, NAVFAC Technical Training Center, Navy Public Works Center, Norfolk, VA, 1965.

Safety and Health Requirements Manual, EM-385-1-1, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

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Chapter 2

Basic Math, Electrical, and Plumbing Operations

Topics

To hear audio, click on the box.

Overview

The origin of the modern technical and electronic Navy goes back to the beginning of naval history, when the first navies were no more than small fleets of wooden ships using wind and oars. As time passed, the advent of the steam engine and electrical power sources signaled the rise of more practical energy sources. With this technological advancement, the need for competent technicians increased. Today there is scarcely anyone in the United States Navy who does not use electrical, electronic, or mechanical equipment. This equipment is needed in systems of lighting, power, heating, and plumbing. As an Utilitiesman, your understanding and knowledge of basic electrical and mechanical theory will enable you to conduct the Navy's and Seabee's missions.

Utilitiesmen use basic mathematical skills every day. A sound understanding of these basics prepares you for the more complex math skills you're likely to use on construction projects. These skills range from whole numbers, fractions, decimals, ratios, proportions, percentages, and square roots to measurements and calculations using geometric shapes.

Safety can be impacted by calculations you make for your project. For example, water main and branch line locations require precise calculations to prevent equipment damage and personnel injury or death.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the rules and principles of basic mathematics.
2. Describe the fundamentals of electricity.
3. Describe the different types and components of electrical circuits.
4. Describe the troubleshooting methods for electrical circuits.
5. Describe pipe measurement procedures.

6. Describe excavation procedures.
7. Describe the purpose and operational constraints of backfilling procedures.

Prerequisites

None.

This course map shows all of the chapters in Utilitiesman Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Utilities Equipment and Maintenance	↑	
Air Conditioning		
Refrigeration		
Heating Systems		U
Steam Distribution Systems		T
Boilers		
Sewage Disposal, Field Sanitation, and Water Treatment		B
Prime Movers, Pumps, and Compressors		A
Plumbing Fixtures		S
Piping System Layout and Plumbing Accessories		I
Structural Openings and Pipe Material		C
Fundamentals of Water Distribution		
Basic Math, Electrical, and Plumbing Operations		
Plans, Specifications, and Color Coding		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.
- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 RULES and PRINCIPLES

Utilitiesmen must be able to perform various mathematical tasks to effectively install plumbing systems. In this section, we will address some basic math skills. Necessary math skills include the knowledge of the order in which mathematical equations must be solved, decimal rules, how to round off numbers, and the rules for working with fractions.

1.1.1 Basic Math Rules

In order to perform mathematical calculations that involve more than one type of function (parenthesis, exponents, multiplication, division, addition, subtraction) you must perform the calculations in a specific order. Equations must be completed in the order indicated below:

1. Parenthesis
2. Exponents
3. Multiplication
4. Division
5. Addition
6. Subtraction

1.2.0 Decimal Rules

1.2.1 Parts of a Whole Number

Whole numbers are made up of ***digits***, which can be any numerical symbol from 0 to 9. Each digit of a whole number represents a ***place value***, as shown in *Figure 2-1*. The number in this example is read as one million two hundred thirty-four thousand five hundred sixty-seven.

1	2	3	4	5	6	7
Millions	Hundred Thousands	Ten Thousands	Thousands	Hundreds	Tens	Units

Figure 2-1 — Place values in whole numbers.

Every digit has a value that depends on its place, or location, in the whole number. In the example above, the place value of the 1 is one million; the place value of the 5 is five hundred.

Numbers can be positive or negative. ***Positive numbers*** are larger than zero and don't usually have a positive sign (+) before them. ***Negative numbers*** are smaller than zero and always have a negative sign (-) before them. Zero is not positive or negative; it never has a positive or negative sign before it. Any whole number that doesn't have a negative sign in front of it is a positive number.

Decimals are numbers in the base 10 system, using any numerical symbol from 0 to 9. The place values in decimal numbers are similar to the place values in whole numbers, except that decimal numbers appear to the right of a decimal point and do not use comma separators. Place values in decimal numbers are shown in *Figure 2-2*.

.	1	2	3	4	5	6
Decimal Point	Tenths	Hundredths	Thousandths	Ten Thousandths	Hundred Thousandths	Millionths

Figure 2-2 — Place values in decimal numbers.

Like whole numbers, decimal numbers have values that depend on their place in the number. In the example above, the place value of the 1 is one tenth, the place value of the 3 is three thousandths.

Operations with decimals are very similar to operations with whole numbers. The only difference is that you have to keep track of the decimal point.

1.2.1.1 Adding Decimals

When you add numbers containing decimals, you need to make sure you keep the decimal points lined up. For example, if you add 12.34 to 5.678, they should look like this when you add them:

$$\begin{array}{r} 12.34 \\ \underline{+\ 5.678} \end{array}$$

Make sure that you add each column of numbers, starting with the numbers that are farthest right. In this case, the first number has no digit in the thousandths position, so it can be treated as a zero:

$$\begin{array}{r} 12.340 \\ \underline{+5.678} \\ 8 \end{array}$$

As you move left adding the columns, make sure to carry any numbers greater than 10. When you add 4 and 7 in the hundredths column, the sum is 11. Record a 1 in the hundredths column and carry a 1 to the tenths column as shown below:

$$\begin{array}{r} {\scriptstyle 1} \\ 12.340 \\ \underline{+5.678} \\ 18 \end{array}$$

When you add the tenths column, you have to add 3 and 6 and the 1 you carried from the sum in the hundredths column. This will give you a sum of 10, so record the 0 in the tenths column and carry a 1 to the units' column as shown below:

$$\begin{array}{r} {\scriptstyle 1} \\ 12.340 \\ \underline{+5.678} \\ .018 \end{array}$$

Add the remaining numbers as you would any whole number. Remember to place the decimal point between the units' column and the tenths column, as shown below:

12.340
+5.678
18.018

1.2.1.2 Subtracting Decimals

Subtracting decimals is very similar to adding decimals. You need to line up the decimal points as in addition. Subtracting 5.678 from 12.34 looks like this:

12.37
- 1.248

Since there are only 2 decimal points after the whole number in 12.34, we need to add a zero at the end so we can subtract the three decimal points in 5.678.

12.370
- 1.248

You subtract columns the same way as you add them, starting with the farthest right column. In this case, you can't subtract 8 from 0, so you need to borrow from the hundredths column to be able to subtract from 10, as shown below:

6
12.3~~7~~10
- 1.24 8
2

You now have 6 to subtract 4 from, since you borrowed 1 from 7. The rest of the numbers subtract normally, as shown below:

6
12.3~~7~~10
- 1.24 8
11.122

1.2.1.3 Multiplying Decimals

Multiplying numbers with decimals is a two step process. First multiply the numbers as if they were whole numbers. Then place the decimal point in the correct location. The example below shows the product of 1.2 and 3.4, before the decimal is placed.

1.2
x 3.4
408

To get the correct location for the decimal point, count the number of decimal places in each number and add the number of decimal places. In this case, each number has one decimal place, so the product will have two decimal places. The product of the equation is 4.08.

1.2.1.4 Dividing Decimals

Dividing numbers with decimals is a four step process.

1. Convert the divisor to a whole number. A divisor of .1 becomes 1.
2. Convert the dividend by the same number of decimal places as the divisor. In this case, 2.40 becomes 24.0.
3. Divide the two numbers as shown below.

$$\begin{array}{r} 12.0 \\ 2\overline{)24.0} \end{array}$$

4. Place the decimal according to the number of decimal places in the dividend.

1.3.0 Rounding Rules

You are expected to produce quality products and services as UT's. However, extremely precise measurements are not normally required during the installation or repair of water, wastewater, or gas piping systems. For that reason, it is normally acceptable to round off decimal values to the nearest hundredth. When working with decimals, if the number indicated in the thousandth place (third place to the right of the decimal) is *5 or higher*, *round up* to the nearest hundredth. For example, **18.756** would be rounded up to **18.76**. If the number in the thousandth place is *less than 5, eliminate it and everything to the right of that digit* (**9.83312** would be rounded to **9.83**).

1.4.0 Fraction Rules

A fraction is a part of a whole. Fractions are usually written as two numbers separated by a slash, such as 1/2. The slash means the same thing as the division sign (÷), so 1/2 = 1 ÷ 2. *Figure 2-3* shows a whole triangle shaded blue and a triangle with one half (1/2) shaded blue.

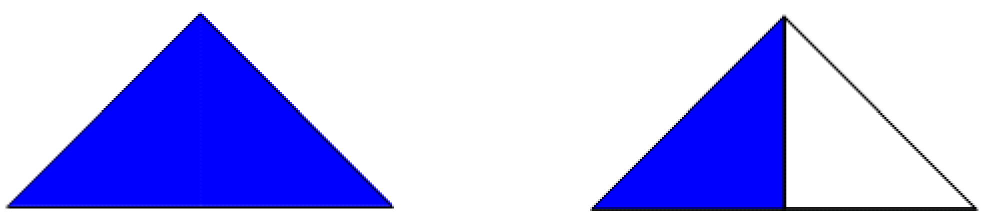

Figure 2-3 — Whole and half triangles.

The bottom number of a fraction is called the ***denominator*** and tells how many parts the whole is being divided into. The top number of a fraction is called the ***numerator*** and tells how many of the parts are being used. In the example of 1/2, 2 is the denominator and 1 is the numerator. The denominator and numerator are also known as the terms of the fraction.

Equivalent fractions are different fractions which mean the same amount. For example, 1/2 is an equivalent fraction to 2/4, 10/20, and 25/50.

1.4.1 ducing Fractions to Their Lowest Terms

Fractions shown with different numbers can have the same value. Fractions are easier to work with when they are at the lowest terms possible. For example, it is easier to work with the fraction 1/2 than it is to work with the equivalent fraction 17/34. To reduce a fraction to its lowest terms, there are three steps.

1. Determine what the largest number is that will divide evenly into both the numerator and the denominator. If the only number that will divide evenly into both numbers is 1, the fraction is at its lowest terms.
2. Divide both the numerator and denominator by the number you determined in Step 1.
3. For the fraction 8/32, the largest number that evenly divides both the numerator 8 and the denominator 32 is 8. Reducing the fraction to its lowest terms looks like this:

   8/32 ÷ 8/8 = 1/4

1.4.2 omparing Fractions and Finding the Lowest Common Denominator

Comparing fractions is simple if the two fractions have the same denominator. In this case, the fraction with the larger numerator is larger than the fraction with the smaller numerator.

Most fractions that you need to compare won't have the same denominator. You need to convert them to the same denominator to compare them. The simplest way to convert fractions to the same denominator is to multiply their denominators to get a ***common denominator***, and then convert each fraction to the resulting denominator. For example, if you are comparing 3/4 to 5/7, you would convert and compare them as shown below

1. Find the common denominator.

   4 x 7 = 28

2. Convert each fraction to the common denominator.

   3/4 x 7/7 = 21/28

   5/7 x 4/4 = 20/28

3. Compare the fractions. You find that 3/4 is larger than 5/7.

Just as you can find the lowest terms for single fractions, you can find the ***lowest common denominator*** for multiple fractions.

1. Reduce both fractions to their lowest terms.
2. Determine the lowest common multiple for the denominators. You may find that one denominator is a multiple of the other. For example, if you are comparing 1/4 and 3/8, the denominator 8 is a multiple of the denominator 4.
3. Convert the fractions to equivalent fractions with the common denominator.

   1/4 x 2/2 = 2/8

   3/8 x 1/1 = 3/8

4. Compare the fractions. You find that 1/4 is smaller than 3/8.

1.4.3 Adding Fractions

Sometimes you calculate a number where the numerator is larger than the denominator. This is called an ***improper fraction.*** You can convert an improper fraction to a whole number and a fraction, which is known as a ***mixed number.*** Start by adding the fractions as you would normally. To add 5/7 to 3/4:

1. Find the common denominator.

7 x 4 = 28

2. Convert each fraction to the common denominator.

   5/7 x 4/4 = 20/28

   3/4 x 7/7 = 21/28

3. Add the numerators of the fractions, and place the sum over the common denominator. Do NOT add the denominators.

   20/28 + 21/28 = 41/28

4. Convert the improper fraction to a mixed number.

   41 ÷ 28 = 1 with a remainder of 13 or 1 13/28

   The remainder becomes the numerator for the fraction portion of the mixed number. The resulting mixed number is 1 13/28.

1.4.4 Subtracting Fractions

When you need to subtract measurements that include fractions on plumbing projects, it is very similar to adding fractions. If the denominators of the fractions are the same, subtract the numerators, place the result over the denominator, and reduce the resulting fraction to its lowest terms. If the denominators are not the same, follow these steps.

1. Write out the equation.

   3/4 – 1/8 = X

2. Determine the common denominator for the fractions you need to subtract. For the fractions 3/4 and 1/8, the common denominator is

   4 x 8 = 32

3. Convert the fractions to equivalent fractions with the common denominator.

   3/4 x 8/8 = 24/32

   1/8 x 4/4 = 4/32

4. Subtract the numerators of the fractions, and place the result over the common denominator. Do NOT subtract the denominators.

   24/32 – 4/32 = 20/32

5. Reduce the resulting fraction to its lowest terms.

   20/32 ÷ 4/4 = 5/8

Sometimes you need to subtract a fraction from a whole number. To do this you need to convert the whole number to an equivalent fraction, and then make your subtraction. In this example we'll subtract 5/8 from 1.

1. Write out the equation.

   - 5/8 = X

2. Convert the whole number to an equivalent fraction.

   1 x 8/8 = 8/8

3. Subtract the numerators of the fractions, and place the result over the common denominator. Do NOT subtract the denominators.

   8/8 – 5/8 = 3/8

4. Reduce the resulting fraction to its lowest terms. In this case the result is already in its lowest terms.

1.4.5 ultiplying Fractions

Multiplying fractions is fairly simple, since you don't need to worry about finding a common denominator. When you read or hear that you need to find a part of a number, such as 3/8 of 5/6, it means you need to multiply the numbers using the steps below.

1. Write out the equation.

   3/8 x 5/6 = X

2. Multiply the numerators.

   3 x 5 = 15

3. Multiply the denominators.

   8 x 6 = 48

4. Reduce the resulting fraction to its lowest terms.

   15/48 ÷ 3/3 = 5/16

In this case, 3 is the largest number that can be evenly divided into both the numerator and the denominator. You may find it easier to work with the fractions if you reduce them to their lowest terms before you multiply them.

1.4.6 viding Fractions

Dividing fractions is very similar to multiplying fractions, except that you invert or flip the fraction you are dividing by. Use the following steps to divide 7/8 by 1/4.

1. Write out the equation.

   7/8 ÷ 1/4 = X

2. Invert the fraction you are dividing by.

   1/4 becomes 4/1

3. Convert the division sign (÷) to a multiplication sign (x) and write the new equation.

   7/8 ÷ 1/4 becomes 7/8 x 4/1

4. Multiply the numerators.

   7 x 4 = 28

5. Multiply the denominators.

   8 x 1 = 8

6. Reduce the resulting fraction to its lowest terms.

   28/8 ÷ 4/4 = 7/2

7. Convert the improper fraction to a mixed number.

   3 1/2

1.4.7 Conversions – Fractions and Decimals

There will be times when you need to convert numbers so that all of the numbers you are working with are in the same format. The most common conversions you will work with are from fractions to decimals and from decimals to fractions.

1.4.7.1 Converting Fractions to Decimals

To convert a number from a fraction to a decimal, divide the numerator by the denominator.

$$.10 \div 2 = .05$$

1.4.7.2 Converting Decimals to Fractions

There are three steps to convert a decimal to a fraction. The decimal .125 can be converted to a fraction as follows:

1. Place the number to the right of the decimal point in the numerator.

   125/

2. Count the number of decimal places in the number. Place this number of zeros following a 1 in the denominator.

   125/1000

3. Reduce the fraction to its lowest terms.

   $125/1000 \div 125/125 = 1/8$

1.4.7.3 Converting Inches to Decimals Equivalents in Feet

Sometimes you will need to convert measurements in inches to decimal equivalents in feet. You can calculate what the decimal equivalent in feet would be for 6 inches with the following steps.

1. Show the measurement as a fraction of a foot, using 12 as the denominator.

   6/12

2. Reduce the fraction to its lowest terms.

   $6/12 \div 6/6 = 1/2$

3. Convert the fraction to a decimal. Divide the numerator by the denominator.

1.5.0 Volume of Shapes

The volume of any solid, liquid or gas is how much three-dimensional space it occupies. Volumes of straight edged and circular shapes are calculated using arithmetic formulae, based on length, width, and height. Volume is measured in cubic units, as shown in *Table 2-1*.

Table 2-1 – Cubic Measurements.

Cubic Measure	Full Expression	Abbreviation
Cubic inch	1 inch x 1 inch x 1 inch	$inch^3$
Cubic foot	1 foot x 1 foot x 1 foot	$foot^3$
Cubic yard	1 yard x 1 yard x 1 yard	$yard^3$
Cubic centimeter	1 centimeter x 1 centimeter x 1 centimeter	$centimeter^3$
Cubic meter	1 meter x 1 meter x 1 meter	$meter^3$

1.5.1 Volume of a Rectangular or Cube Tank

The volume of a rectangular or cube shape is the length times the width times the depth. Refer to *Figure 2-4* for example of rectangular shape.

Formula: $V = L \times W \times H$

V = volume

L = length

H = height

W = width

To find the volume in liters:

Measure the tank in centimeters and divide by 1000.

or

Measure the tank in meters and multiply by 1000.

To find the volume in gallons:

Measure the tank in inches and divide by 231.

or

Measure the tank in feet and multiply by 7.48.

Figure 2-4 — Rectangular shape.

1.5.2 Volume of a Cylindrical Tank

The volume of a cylinder, which is based on a circle, is π times the radius² times the length of the cylinder. Another way to think of this is the area of the circle times the length of the cylinder. Refer to *Figure 2-5* for example of shape tank.

Formula: $V = D \times D \times 0.7854 \times L$ or $V = \pi R^2 H$

V = volume

D = diameter

R = radius

H = height

Figure 2-5 — Cylindrical shape.

To find the volume in liters:

Measure the tank in centimeters and divide by 1000.

Or

Measure the tank in meters and multiply by 1000.

To find the volume in gallons:

Measure the tank in inches and divide by 231.

Or

Measure the tank in feet and multiply by 7.48.

1.5.3 Volume of an Elliptical Tank

Refer to *Figure 2-6* for an example of a elliptical shape.

Formula: $V = H \times W \times 0.7854 \times L$

V = volume

L = length

W = width

H = height

To find the volume in liters:

Measure the tank in centimeters and divide by 1000.

Or

Measure the tank in meters and multiply by 1000.

Figure 2-6 — Elliptical shape.

To find the volume in gallons:

Measure the tank in inches and divide by 231.

Or

Measure the tank in feet and multiply by 7.48.

1.5.4 Volume of Spherical Tank

Refer to *Figure 2-7* for an example of a spherical shape.

Formula: $V = D^3 \times 0.5236$

V = volume

D^3 = distance cubed

To find the volume in liters:

Measure the tank in centimeters and divide by 1000.

Or

Figure 2-7 — Spherical shape.

Measure tank in meters and multiply by 1000.

To find volume in gallons:

Measure tank in inches and divide by 231.

Or

Measure tank in feet and multiply by 7.48.

1.5.5 Volume of a Frustum Tank

A frustum may be formed from a cone with a circular base by cutting off the tip of the cone with a cut perpendicular to the height, forming a lower base and an upper base that are circular and parallel. Refer to *Figure 2-8* for an example of frustum shape.

Formula: V = $\frac{\pi h}{3}(R^2 + Rr + r^2)$

V = volume

h = height

R = radius of lower base

r = radius of upper base

$\pi =$ 3.14

Figure 2-8 — Frustum shape.

To find the volume in liters:

Measure the tank in centimeters and divide by 1000.

Or

Measure tank in meters and multiply by 1000.

To find volume in gallons:

Measure tank in inches and divide by 231.

Or

Measure tank in feet and multiply by 7.48.

1.6.0 Area Formulas

The following is a list of area formulas which you may encounter as a UT.

Area of a square or rectangle: A= L x W

Area of a parallelogram: A = B x pH

Area of a triangle: 1/2B x pH

Area of a circle: A = π^2 x 0.7854 or D^2 x 0.7854

Area of an ellipse: A = L x W x 0.7854

Area of pipe wall: 0.7854 x [(o.d. x o.d.) – (i.d. x i.d.)]

Legend:

A = Area

L = Length

W = Width

B = Base

pH = Perpendicular Height

π = 3.14 squared

D^2 = Distance squared

o.d. = Outside Diameter of pipe

i.d. = Inside Diameter of pipe

1.7.0 Other Useful Formulas

The approximate weight of a piece of pipe may be determined by the flowing formulas:

Cast iron pipe: $W = (A^2 - B^2) \times L \times 0.2042$

Steel pipe: $W = (A^2 - B^2) \times L \times 0.2199$

Copper pipe: $W = (A^2 - B^2) \times L \times 0.2537$

Legend:

W = Weight

A = outside diameter of pipe in inches

B = inside diameter of pipe in inches

L = Length

1.7.1 Calculation of Pipe Offsets

To calculate a pipe offset, use *Figure 2-9* as a guide.

γ = fitting nominal angle

$\alpha = 180 - \gamma$

Travel = Offset/sin γ

Travel = Advance/cos γ

Advance = Offset/tan γ

Offset = Advance x tan γ

Figure 2-9 — Piping offsets figures.

1.7.1.1 45° Offsets

sin 45° = cos 45° = 1/1.4142 = 0.7071

tan 45° = 1

Advance = Offset

Travel = Offset x 1.4142

Travel = Advance x 1.4142

1.7.1.2 11 1/4° Offsets

Refer to *Figure 2-10*.

sin 11 1/4° = 0.1951 = 1/5.1258

cos 11 1/4° = 0.9808 = 1/1.0196

tan 11 1/4° = 0.1989 = 1/5.0277

Advance = Offset x 5.0277

Offset = Advance x 0.1989

Travel = Offset x 5.1258

Travel = Advance x 1.0196

Figure 2-10 11 1/4° Pipe offset.

1.7.1.3 22 1/2° Offsets

Refer to *Figure 2-11*.

sin 22 1/2° = 0.3827 = ½.6131

cos 22 1/2° = 0.9239 = 1/1.0824

tan 22 1/2° = 0.4142 = 1/2.4142

Advance = Offset x 2.4142

Offset = Advance x 0.4142

Travel = Offset x 2.6131

Travel = Advance x 1.0824

Figure 2-11 — 22 1/2° Pipe offset.

1.7.1.4 60° Offsets

Refer to *Figure 2-12*.

sin 60° = 0.866 = 1/1.1547

cos 60° = 0.5 = 1/2

tan 60° = 1.7321 = 1/0.5774

Advance = Offset x 0.5774

Offset = Advance x 1.7321

Travel = Offset x 1.1547

Travel = Advance x 2

Figure 2-12 — 60° Pipe offset.

1.7.2 Parallel Offsets

When running offsets parallel to one another, it is important to shift the offsets in order to keep the distance between the pipelines equal throughout the offset. The distance between the pipelines is referred to as Spread. The amount of offset moved is known as the Spread Allowance.

Spread Calculate allowance for any type of offsets using the formula:

$$SA = S \sin \frac{\gamma}{2}$$

Where γ is the angle that is used to name the fitting (for 45° elbow use 45, not 35, the actual angle of a 45° elbow).

SA is Spread Allowance

S is Spread

Refer to *Figure 2-13* for parallel offset calculation.

$\alpha = \gamma/2$

$\beta = (180 - \gamma)/2$

γ = fitting nominal angle

A = Advance

O = Offset

T = Travel

S = Spread

SA = Spread Allowance

Figure 2-13 — Parallel pipe offsets.

1.7.2.1 45° Parallel Offset

SA = S x sin (45°/2) = S sin 22.5°

SA = s x 0.383

Pipe 1b = pipe 1a – SA

Pipe 2b = pipe 2a + SA

1.7.2.2 11 1/4° Parallel Offset

Refer to Figure 2-14.

γ = 11 1/4°

SA = S x sin (11 1/4°/2) = S sin 5 5/8°

SA = S x 0.098

Figure 2-14 — 11 1/4° Parallel offset.

1.7.2.3 22 1/2° Parallel Offset

Refer to *Figure 2-15.*

γ = 22 1/2°

SA = S x sin (22 1/2°/2) = S sin 11 1/4°

SA = S x 0.1951

1.7.2.4 60° Parallel Offset

Refer to *Figure 2-16*.

γ = 60°

SA = S x sin (60°/2) = S sin 30°

SA = S x 0.5

Figure 2-15 — 22 1/2° Parallel pipe offset.

Figure 2-16 — 60° Parallel pipe offset.

1.7.3 Rolled Offsets

A rolled offset may be described as an offset that has a vertical rise and horizontal spread which determines the amount of roll.

Refer to *Figure 2-17*.

γ = fitting nominal angle

α = 90 - γ

X = $\sqrt{V^2 + H^2}$

$$\frac{X}{T} = \cos\alpha = \cos(90 - \gamma)$$

$$T = X / \cos\alpha = X / \cos(90 - \gamma)$$

$$A = \sqrt{T^2 - X^2} = T \ x \sin\alpha = T \ x \sin(90 - \gamma)$$

Figure 2-17 — Rolled offsets.

Test your Knowledge (Select the Correct Response)

1. Which of the following formulas is utilized to determine the volume of a rectangular tank?

   A. V = H x W x 0.7854 x L

   B. V = $\frac{4}{3}\pi r^3 = \frac{1}{6}\pi d^3$

   C. V = $\frac{\pi h}{3}(R^2 + Rr + r^2)$

   D. V = L x W x H

2.0.0 FUNDAMENTALS of ELECTRICITY

In this section we're going to be looking at some important aspects of electrical fundamentals pertaining to safety which as we all know is a never ending job. We'll also be discussing electrical principles to see and understand how electricity behaves in a predictable manner as well as some of the methods of producing and controlling it.

2.1.1 Safety

What is safety? Safety means a great many things to many people. Regardless of your particular definition or some textbook definition, safety is the **first** priority with every job. This includes safety on the job site as well as at home. Safety can take on many meanings, but the one we prefer is this: Safety is nothing more than common sense prevailing. Common sense is that inner self that always demands that you think things through before you act.

Some things you should routinely do when working with electricity is remove any rings, watches, necklaces or anything that could conduct electricity. Wearing of these items could potentially cost you your life when you are working on an electrical component or circuit. Try to remember the phrase "WATCHES, RINGS AND SHINY THINGS**".** Other things that should be of concern to us are the appropriate wearing of clothing. This of course concerns the inappropriate choice of clothing for the job being done to include loosely worn items. Imagine a sleeve or jacket caught in a pulley being driven by a 50 horse power motor! As you can see, the wearing of loose clothing could be as deadly as the lack of respect for electricity itself.

Some other electrical safety precautions to be aware of are listed below:

- Proper lighting is essential. Fully illuminate the area in which you working.
- Insulate all workers from the ground with rubber mats or other suitable nonconducting materials.
- Remove all jewelry and/or related items.
- There must be absolutely no other distractions or horseplay.
- Use the proper tool for the job being performed.
- Work on deenergized circuits whenever possible.
- Use a lock out/ tagout program.
- Report all hazards or suspected hazards immediately.

2.2.0 Electrical Values

2.2.1 Current

Current is the actual movement of electrons through the conductor, just as in a water hose, current is the water running through the hose. In order for current to flow, there must be a complete path. If there are opens in the circuit, then no current will flow.

2.2.1.1 Effects

Any time electrical current is made to flow through a conductor (wire) four effects are created in and around the conductor: heat, magnetic field, chemical change, and physical shock.

2.2.1.1.1 Heat

As the electrons in a conductor travel from a negative to a positive place, they generate heat. Heat is a result of friction caused by the atom’s reluctance to give up its electron as well as the collisions caused by the movement of these electrons. Heat increases as the intensity (strength) of the current increases and that heat must be controlled. Increasing the size of the conductor to meet the intensity of the current normally controls the amount of heat produced. While it is easy to see that heat is something that must be overcome, there are also many ways to use this effect to our benefit such as heaters and defrosters. You will be introduced to different ways that heat can be generated by current flow and some of the benefits that heat can provide us.

2.2.1.1.2 Magnetic Field

As current flows, it produces a magnetic field. This effect is similar to heat in that as the intensity of the current grows so does the strength of the magnetic field. This effect is known as electromagnetism and will be discussed in detail later in this section. You will also discover in this section that you can use electromagnetism to operate switches, valves, motors, and many other devices.

2.2.1.1.3 Chemical Change

When a battery is being charged, the chemicals within the battery recombine to make the battery "like new". The process of charging a battery is done by “re-ionizing” the terminals so that the negative terminal will have an abundance of electrons, and the positive terminal will have an electron deficiency. You will run into this effect more often in the form of corrosion that forms on the metal parts of a circuit. When current flows through a substance it becomes polarized which allows the oxygen in the air to combine with it. This combination causes oxidation (rust). If oxidation builds up over time in a conductor, it will begin to impede the flow of current, interfering with the normal operation of electrical devices.

2.2.1.1.4 Physical Shock

This is the unpleasant and sometimes dangerous sensation you experience when you complete an electrical circuit with a part of your body. Voltage is often mistakenly believed to be the sole source of electrical shock. As a matter of fact, voltage is producing the shock but it is the *current flow* through your body that causes most of the damage. The pain and muscular contractions are the result of the nerves carrying many times more current than they are accustomed to.

2.2.1.2 Uses

There are two types of electrical current:

- Direct current (DC)
- Alternating current (AC)

2.2.1.2.1 Direct Current

Current flowing through a conductor in one continuous direction. It always flows from a negative potential to a positive potential in a conductor. Batteries and thermocouples produce direct current. Refer to *Figure 2-18*.

2.2.1.2.2 Alternating Current

Alternating current is current that continually changes in amplitude (volume) and periodically changes in direction (negative to positive). It is important to remember that while the current is constantly changing direction, the flow remains uniform and travels in only one direction at any given time. Refer to *Figure 2-19*.

Figure 2-18 — DC circuit and waveform.

Figure 2-19 — AC circuit and waveform.

2.2.2 Voltage

Voltage is described as the pushing force behind electricity. Voltage may also be referred to as Difference of Potential, Electromotive Force (EMF), or Electrical Pressure. Think of electricity as water running through a hose. The pressure (voltage) is what causes the water (current) to flow out of the end of the hose. The unit of measurement for voltage is the volt, and the letter for voltage is "V" except when used in formulas to calculate voltage. In this case the letter “E” is used to denote Electromotive Force.

2.2.2.1 Measurement

Measurement is performed with a voltmeter. It is important to remember, however, that while the voltmeter is giving you the answer in volts, it is actually comparing the difference in electrical potential between the two points where you have placed the leads of your voltmeter. The proper use of a voltmeter will be discussed in detail in a later section.

2.2.2.2 Source

Now that you have been introduced to voltage and the reason we need it, let's find out where it comes from. There are several ways to get controllable usable voltage:

- Chemical action (DC battery)
- Heat (Thermocouple, measured in millivolts DC)
- Mechanical action (AC generator)
- Solar

2.2.2.2.1 Chemical

A battery uses the principle of chemical action to create its output voltage. The output voltage of a battery is the difference of potential between its two terminals. A battery is made up of one or more cells. Each cell creates a certain voltage, and more cells can be added in series to create larger voltages. When those cells are wired in parallel, the battery can obtain higher amperage`. An automobile battery is a lead-acid battery made up of six cells. Each cell creates approximately two volts, so its total output voltage is twelve volts.

The active materials in a lead-acid battery are lead peroxide (the positive terminal) and sponge lead (the negative terminal). The final material is an acid/water solution called an electrolyte. The negative and positive plates are porous, like a sponge. The porous plates fill with the electrolyte in which they are immersed. Refer to *Figure 2-20*.

Electrical energy comes from a cell when the plates react with the electrolytes. As the battery discharges, the acid in contact with the plates separates from the electrolyte. As a molecule of sulfuric acid separates, part of it with excess electrons combines with the sponge lead plate giving it a negative charge. The remainder of the sulfuric acid, lacking electrons, has a positive charge. It takes electrons from the sponge lead plate (lead peroxide) leaving it positive, and the recombination neutralizes the positive ions forming ordinary water.

Figure 2-20 — Current flow in a battery.

2.2.2.2.2 Thermal

When a strip of metal such as copper is heated at one end, electrons tend to move away from the hot end toward the cooler end. This is true of most metals; however, ferrous metals such as iron react to heat in the opposite way. When iron is heated, the electrons move toward the heat. These reactions are illustrated in *Figure 2-21*.

Figure 2-21 — Thermocouple.

The electrons (negative charges) are moving away from the heat in the copper while they move toward the heat in the iron. They cross from the iron to the copper at the hot junction, giving the cooler end of the iron a positive charge, while the cool end of the copper builds a negative charge. The coolest end of both metals is called the cold junction. If a conductor is placed across the ends of the cold junction, electrons will flow from the copper to the iron. This device is called a thermocouple that typically produces 25 to 30 millivolts. One millivolt equals 0.001 volts (one one-thousandth of a volt).

2.2.2.2.3 Mechanical

A generator is a machine that converts mechanical energy to electrical energy by magnetic induction. There are three things needed to produce voltage in this manner.

- *Conductors* contain the flow of electrons and provide a path for current to flow.
- A *magnetic field* exerts a positive force on the free electrons in the conductor.
- *Relative motion* induces the direction of current flow.

The conductor must be moved to cut across the magnetic lines of force, or the field must be moved so that the lines of force are cut by the conductor. In accordance with these conditions, when a conductor or conductors move across a magnetic field to cut the lines of force, electrons within the conductor are propelled in one direction or another. Thus, an electric force, or voltage, is created. A simplified diagram of an AC generator is shown in *Figure 2-22*. In this illustration, there is a loop of wire rotating within a magnetic field.

Figure 2-22 — AC generator.

The conductors are moving parallel to the field; no voltage is produced. When the conductors are cutting across the field and the galvanometer indicates the direction of current by the needle pointing to the right. When conductor is parallel again, the meter shows zero. When the conductors move perpendicular again, the conductors are again cutting the field, and the meter shows maximum but in the opposite direction. What happened? The black side of the loop is moving up through the field. Now the black slip ring is negative. Current is directed from the white slip ring to the meter and back. The direction of current reversed itself, and the same is true in the external circuit to the meter.

The two ends of the loop are connected to slip rings that have two brushes riding on them. Rotating the loop generates a current. The current passes through the brushes to the external circuit. You now have an elementary AC generator.

2.2.2.3 Uses

Voltage is used in electrical and electronic equipment as the force, or pressure, to cause current to flow in a circuit.

2.2.3 Resistance

Resistance is defined as the opposition to current flow. Some materials offer more resistance than others. Rubber, for example, has more resistance than copper because of the difference in their molecular construction. Materials with little resistance are known as conductors because current can flow through them easily.

The unit of measurement for resistance is the ohm, and the symbol for resistance is "Ω". There are two kinds of resistance found in most electrical circuits, unavoidable and intentional resistance.

2.2.3.1 Unavoidable Resistance

Unavoidable resistance is resistance inherent to the conductor. Even the best conductive materials have some resistance.

2.2.3.2 Intentional Resistance

Intentional resistances are represented by those resistors designed and placed in circuits for a specific purpose, i.e., to divide voltage, to divide current, to limit current, etc.

2.2.3.3 Area of Conductor

The diameter or cross-sectional area of the conductor, as looked at from the end, is another factor in determining the resistance of that conductor.

The greater the cross-sectional area of the conductor, the less the resistance to current flow. For example a piece of copper wire with a cross-sectional area (diameter) of 0.1 cm^2 has a resistance of 6 ohms. Doubling the diameter area to 0.2 cm^2 decreases the resistance to 3 ohms or one-half its original value. Thus, the resistance of a conductor goes down as the diameter gets larger. Think of a two-lane road versus an eight-lane highway. Which of them could handle more traffic (or current flow) at any given time? It is obviously the highway, and the same is true for conductors.

2.2.3.4 Length of Conductor

The next factor affecting the resistance of a conductor is its length. The further current must travel through a conductor, the greater the resistance. A shorter length has less resistance. For example, if a piece of copper wire 1,000 feet long with a resistance of 6 ohms were increased to 2,000 feet, the resistance would increase to 12 ohms.

2.2.3.5 Temperature of Conductor

The final factor affecting the resistance of a conductor is its temperature. As any material's temperature increases its molecular motion increases. With increased molecular motion, friction will increase, resulting in more resistance. As the temperature of the conductor increases, the resistance goes up; as the temperature of the conductor decreases, the resistance goes down.

2.2.4 Electrical Safety

In the performance of your duties as an Utilitiesmen servicing Heating, Ventilation, and Air-Conditioning/Refrigeration (HVAC/R) equipment, you will install, maintain, and repair electrical and electronic equipment. This kind of work is often done in confined and restrictive spaces. Without adequate safety practices, hazards such as electrical shock, electrical fires, harmful gases, and injuries can occur. The development of safe and intelligent work habits is just as important as your knowledge of the electrical equipment on which you will be working.

2.2.4.1 Electrical Shock

People are electrocuted each year because they don't understand what causes electrical shock.

In actuality, all of the electrical phenomena encountered (capacitance, impedance, inductance, resistance, and voltage) can contribute to electrical shock, but **current** is the "killer."

Movement of free electrons through the human body affects the nervous system and muscles. Nerves normally carry tiny electrical impulses from the brain that cause the muscles to react in certain predictable ways. When an additional current flows through the nerves, the muscles respond causing involuntary and uncontrollable contortions. When the current flow becomes excessive, the affected muscles become paralyzed. This can cause the heart and lungs to stop working and electrocution can result.

Resistance and impedance oppose the flow of current. Certain factors affect the amount of resistance the human body has to the flow of current. Dry skin offers a high resistance; it acts to protect a person from low voltage shocks. Damp or wet skin offers less resistance because water is a good conductor of electricity. Some people carry less water (internally) than others, which affects the body's resistance to current flow. Electrical shock may cause instant death, unconsciousness, cessation of breathing, or burns of all degrees. Two factors determine the severity of the electrical shock:

1. The part of your body the current flows through.
2. The duration of the current flow.

If the current flows through your head or chest, the vital organs of your body like the brain, the heart, or the lungs will be affected, and the shock can be fatal. A shock of short duration will do less damage than a shock of a longer duration.

When repair work is required on electrical or electronic equipment, there is always the possibility for injury, fire, or equipment damage. It is especially true if an unsupervised novice or completely unqualified service technician is on the scene. However, carelessness or overconfidence is usually the root cause of most electrical injuries.

Most people are inclined to think in terms of high voltages as being painful or deadly, but low voltages can be just as dangerous under the right conditions.

The human skin through its resistance acts as a protector against electrical shock. This resistance to electrical current varies between 100,000 and 600,000 ohms for dry skin, and as low as 1,000 ohms for wet skin. The resistance of the internal body, hand to foot, is approximately between 400 and 600 ohms.

Assume that 120 volts comes into contact with the perspiring skin of a worker who is standing on a good electrical ground. If the worker has a total resistance of 1500 ohms, the current through him will be about 0.08 ampere, or 80 milliamperes. This amount of current is not always fatal, but it is painful. It causes severe muscular contractions and makes breathing difficult. If the current is between 100 and 200 milliamperes, it will produce a heart condition where the heart's muscle fibers work independently and without rhythm, causing instant death.

2.2.4.2 Ground Circuit

Because current will always take the path of least resistance, most portable tools are equipped with a ground wire and a standard ground plug. The ground wire must be connected to an approved ground, and must have a maximum resistance of *less than one ohm*. This will protect the operator if the power tool has an internal short circuit, by allowing current to flow to the ground circuit instead of through the operator. For this reason take extreme care to ensure proper grounding. If mechanical equipment were mistakenly grounded to a power source, a dangerous voltage would be present on the metal housing, which could fatally shock the operator.

2.2.4.3 Capacitors

Capacitors are devices that have the ability to store electricity. This characteristic allows them to produce an electrical shock even after being disconnected from their power source. Always take extreme care when handling capacitors for this reason. Most start capacitors today have bleed resistors to alleviate this problem, but for personal safety, always discharge capacitors in one of two ways. This can be done by simply connecting a 20,000-ohm (2-5 watt) resistor across the leads of the capacitor if one wasn’t already installed. Afterwards, use a pair of insulated pliers and again short across the leads insuring the bleed resistor hadn’t developed an open. It would now be safe to troubleshoot it.

2.2.4.4 Batteries

Acid burns are a hazard you may experience while working with batteries. This hazard can be avoided by using full-face shields or protective chemical goggles, rubber gloves, rubber aprons, and acid-resistant safety shoes or rubber knee length (safety-cap) boots. Batteries can explode if the hydrogen gas given off during charging is ignited. Open flames and smoking should not be permitted in a battery charging room or next to any lead acid battery and the room should be adequately ventilated.

2.2.4.5 Electrical Fires

The damage from electrical fires can be held to a minimum by keeping the work area clean. Electrical or electronic equipment that is clean and free of oil, grease, and carbon dust will not readily ignite from electrical arcing.

The proper fire extinguisher should be readily available and functional at all times while anyone is in the work area. For combating electrical fires, a dry chemical agent (CO2) extinguisher is recommended. Never use water on an electrical fire. Water is an excellent conductor of electricity and can cause more shorting, or provide a path for current flow from the circuit to you. If possible, first remove the electrical power from whatever is burning.

2.2.4.6 Working on Electrical Circuits

When any electrical equipment is to be *overhauled* or *repaired*, place the main power disconnects in the off positions. If work causes you to lose visual contact with the disconnect box, use proper lockout/tagout procedures to notify all personnel that the circuit is under repair.

2.2.4.7 Troubleshooting Electrical Circuits

Occasionally circuit troubleshooting must be done with the power applied. When working on circuits with power applied, insulate yourself from ground, and use enough lighting to ensure more than adequate visibility. Use the buddy system by working in teams and stationing a helper near the main power switch. In the event of an accident, the person at the switch can turn off the power, which will greatly reduce the risk of a fatal shock. Rendering first aid and CPR for shock victims are skills that you will find handy if there is an electrical accident. Once the fault is identified, remove power before beginning repairs.

Warning signs and suitable guards should be posted to prevent personnel from coming into accidental contact with high voltages. Provide yourself with the best possible insulation. Do not wear flammable clothing, metal badges, zippers, buttons, fasteners, and metal jewelry. They are all dangerous; avoid them when working on electrical circuits.

Test your Knowledge (Select the Correct Response)

2. As the temperature of the conductor increases, what does the resistance of the conductor do?

   A. Remain unchanged
   B. Increase
   C. Decrease

3.0.0 ELECTRICAL CIRCUITS

In this section we will be looking at some of the essential components that typically make up electrical circuits. We will also differentiate among the various types of circuits, particularly series and parallel, and lastly we'll conclude this objective by discussing the properties of Ohm's law as it applies to Direct Current circuits and introduce a variation to Ohm's law, the power formula. Since electricity cannot be seen, you can only study what it does. Electrical circuits are designed to do certain things. To correctly diagnose a circuit you must be aware of its proper operation before you can determine if there is a fault. That means you will have to know what electrical components are in the circuit and how they are supposed to work.

3.1.1 Circuit Components

A circuit must contain a minimum of three components to be considered an electrical circuit. These components are as follows:

- Source of power

- Load device
- Conductors

3.1.1 Power Source

All electrical circuits must include a source of electrical power. This may be a battery (for DC), or a wall outlet (for AC). The circuits we will discuss will show either the symbol for a battery, or an AC power source.

3.1.2 Load

Electrical current is used to do various types of work. That work is the load, also referred to as a unit of resistance. Some examples of loads are resistors, motors, lights, transformers and coils. Resistors convert electrical energy to heat energy, motors convert electrical energy to mechanical energy, and coils convert electrical energy to magnetism.

3.1.3 onductor Standards

Conductors, normally referred to as wires, are the components used to deliver current generated at the power source to the load and return it back to the power source. It is important to note that for current to flow in a circuit there must be a path of flow back to the source of power. Conductors are subjected to environmental factors such as extreme heat and cold and must meet certain requirements in order to provide a safe and secure path of current flow.

Conductor standards must meet specific requirements. In the last section we discussed the effects of current flow. The heat generated by the flow of current is the main concern in properly sizing conductors. There are four areas of concern that will determine how much current a conductor will be able to carry safely, (1) the material used, (2) the size of wire, (3) the type of insulation and (4) the location in which the conductor is to be used. Each of these effects must be considered when working with electrical devices.

3.1.3.1 Material

Today, wires are made from several materials or combinations of materials. The most common metals used are copper, copper alloy, aluminum, and copper-clad aluminum. Regardless of material used, its ability to handle heat is directly related to the size of the conductor. Copper, although not the least expensive, is still considered the best alternative of the most commonly used metals.

3.1.3.2 Wire Size

To work with different size wires, you must know something about the system used in wire numbering. Instead of referring to wires by their diameter or area, numbers have been assigned to represent sizes. The numbers used for electrical wires are called the American Wire Gauge (AWG) numbers. The range of the AWG is from No. 40, the smallest, to No. 4/0 (meaning 0000), the largest. The number is based on the diameter of the wire. The size of wire is measured by using the American Standard Wire Gauge.

Each wire size has the ability to carry a limited amount of current. *Table 2-1* below shows the maximum current flow for different wire sizes at lengths up to 50 feet.

Table 2-1 — Maximum current flow vs. wire size.

Wire Size	Copper Wire	Aluminum Wire
#14	15 amps	N/A
#12	20 amps	15 amps
#10	30 amps	25 amps
#8	40 amps	30 amps

The wire size listed is the minimum gauge for the amperage listed. Lengths greater than 50 feet require going up *one* wire size.

3.1.4 Insulation

The type of insulation needed for a conductor is based primarily on the external conditions to which it will be subjected and where it is going to be used. For example, you would not use a rubber or plastic-insulated wire in a place where it would be subjected to very high temperatures. Manufacturers of wire and cables are required to properly identify their product. They must show the size of wire, the type of insulation, the maximum working voltage, and the manufacturer's name or trademark. This information is placed on the outer surface of the insulation. You can learn a great deal about the wire or cable by just reading the markings. Some of the common letters used to indicate a type of insulation or a characteristic are as follows (See *Table 2-2*):

Table 2-2 — Insulation symbol table.

SYMBOL	DEFINITION
A	Asbestos
RH	Heat resistant rubber
R	Rubber
T	Thermoplastic
V	Varnished cambric
W	Moisture resistant
TW	Moisture-resistant thermoplastic
RHW	Heat and Moisture resistant rubber

3.1.5 Location

As mentioned before, the location where the conductor is to be installed also has an effect on its current-carrying capacity. A conductor used in free air (not inside a conduit) will safely carry more current than the same conductor installed along with other conductors inside conduit or cable. This is because the conductor in free air is able to dissipate heat more readily; caused by faster moving current flowing much faster than if it was inside any type of metal or plastic casing. The number of conductors installed in conduit also has an effect on the current-carrying capacity. The more conductors there are, the lower the safe current-carrying capacity. To determine the amount of current a specific size and type of conductor used in a certain location can carry, consult with a Construction Electrician (CE).

3.1.6 Wiring Standard

The requirements in the National Electrical Code (NEC) are used to help standardize electrical wiring. These standards help in the identifying and troubleshooting processes. For further assistance and clarification, consult a CE.

3.1.7 olor Codes

All replacement wire used on electrical equipment should be the same type, size and color as the original. Installers of line voltage wiring (above 50 volts AC) have generally accepted that green or bare conductors are used for ground wires, white to represent grounded neutral wires (often referred to as common), and other colors to represent the "hot" wires. The three most common colors for the "hot" wires are black, red, and blue.

3.1.8 Connections/Splices

Repairing wiring and equipment requires the ability to make various types of splices and connections. A great many of the wires used for circuits in a piece of equipment will have to be spliced. These splices are needed to connect wires together to form complete circuits. Splices are also used to connect and add ground wires, so that all metal units in electrical circuits can be joined together and grounded as a means of reducing electrical shock hazards. The splices you make most of the time are quite simple. The main thing to remember when making a splice is that it must be both mechanically and electrically secure. That is, the splice must be as strong as a continuous piece of wire and conduct electricity as well as if it were one piece of wire. In order to make any type of wire connection, first remove the insulation from the conductors. On small conductors, No. 10 AWG and smaller, use a wire stripper. When you use a wire stripper, take care to use the proper cutting notch, one that matches the wire size, to keep from nicking the wire. A nicked wire will break when it is bent. Cut through the insulation about 1 to 1 1/4 inches from the wire's end and then use side pressure to slip the cut insulation off the wire.

3.2.0 Circuit Types

3.2.1 Series Circuit

A series circuit is an electrical circuit having one or more load devices with only one path for current to flow. *Figure 2-23* is an example of a series circuit. The series circuit gets its name from the fact that the power source and all the loads are in series with each another. With this type of circuit, the current must flow through all the components in the circuit before returning to the power source. If one of the lamps were to burn out, current would stop flowing throughout the circuit, and all the lamps would go out. In *Figure 2-30*, the battery, Load 1, Load 2, and Load 3 are in series with one another.

3.2.2 Parallel Circuit

Figure 2-23 — Series circuit.

A parallel circuit is an electrical circuit having two or more paths for current flow, and each path must have at least one load in it (*Figure 2-24*). Each path will receive the total applied voltage to the circuit. If a break in one of the individual paths of current flow causes that load to stop working, the load(s) in the remaining paths continue to work because there is still a complete path for current to flow through them.

Figure 2-24 — Parallel circuit.

3.2.3 Series-Parallel Circuit

Another type of circuit you may encounter in the field is the series/parallel. It is a circuit containing at least three load devices with fewer paths for current flow than load devices. This circuit contains the characteristics of both the series and the parallel circuits, hence the name series/parallel. The application of Ohm's law to these circuits is the same as for the others; however, it is a bit more involved. The key is to apply the voltage, current, or resistance rule to the portion of the circuit with which you are dealing. We will not be discussing this circuit in depth; however, the technician must be aware of the fact that it does exist.

The following illustration (*Figure 2-25*) shows an example of a series/parallel circuit and gives values for the various portions of the circuit.

Figure 2-25 — Series-parallel circuit.

3.3.0 Ohm's Law

In the early 1800's, Professor George Ohm published the results of his research on electricity. Using instruments he designed and built, Professor Ohm formulated the mathematical relationship of current, voltage, and resistance in electrical circuits. Ohm's electrical relationship theories were mathematically proven, so they became "Ohm's Law". In narrative, Ohm's law states, "For any circuit or part of a circuit, the current in amperes is equal to the Electro Magnetic Force (EMF) in volts divided by the resistance in ohms". Ohm's law will only apply to purely resistive AC and DC circuits.

Since Ohm's Law is expressed as a mathematical equation, it can be used to find an unknown as long any two values are given.

3.3.1 Circuit Characteristics

As stated earlier there are two common types of electric current: DC and AC.

In this section we will discuss how Ohm's Law applies to series, parallel, and series-parallel circuits that operate using DC. It is important to remember that ohm's law will remain constant in each of these circuits. There will, however, be a change in the characteristics between different types of circuits.

3.3.2 Series Circuit

Remember that a series circuit is a circuit having one or more load devices with only one path for current flow. With this type of circuit, current must flow through all the components in the circuit before returning to the power source.

Characteristics of a series circuit are as state the follows:

1. Voltage (**E**) – The sum of the voltage measured across each load device ($\mathbf{E_{R1}}$, $\mathbf{E_{R2}}$) in a series circuit will equal the total applied voltage ($\mathbf{E_T}$) in the circuit.

$$\mathbf{E_T = E_{R1} + E_{R2}}$$

2. Current (**I**) – The flow of current (**I_T**) will remain the same throughout a series circuit.

$$I_T = I_{R1} = I_{R3}$$

3. Resistance (**R**) – The sum of the resistance measured at each load device will equal the total resistance (**R_T**) of a series circuit.

$$R_T = R_1 + R_2 = R_3$$

3.3.3 Parallel Circuit

As stated earlier, a parallel circuit is an electrical circuit having two or more paths for current flow, each path having at least one load device. If there a break in one path causes the load device to stop working, the load devices in the remaining paths will continue to work. That is because there is still a complete path for current flow from the power source and back to the source.

Characteristics of a parallel circuit are as state the follows:

1. The voltage to each load device will be the SAME as the total applied voltage.

$$E_T = E_{R1} = E_{R}2 = E_{R3}$$

2. The total amount of current in the circuit represents the SUM of the current flow to each load device.

$$I_T = I_{R1} + I_{R2} + I_{R3}$$

3. The resistance of the circuit is always LESS than any individual resistance; this is expressed mathematically by using the reciprocal method.

$$RT = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}}$$

Test your Knowledge (Select the Correct Response)

3. Which of the following colors is NOT associated with a "Hot" wire?

A. Black
B. Red
C. White
D. Blue

4.0.0 TROUBLESHOOT CIRCUITS

The key element to effective troubleshooting is knowledge of multimeter use. The multimeter is one of the most used tools in troubleshooting electrical components. For this reason, it is imperative that the technician be well trained in its use. In this section, we will look at the meters themselves, how to identify circuit faults with them, and safety issues regarding their use. The information in this section will deal with both the analog and digital types of multimeters.

4.1.0 Meters

The multimeter is made up of three different meters: the voltmeter, the ammeter, and the ohmmeter. The function used will depend on the situation at hand. For instance, never connect an ohmmeter into an energized circuit. On the other hand, using a voltmeter on a deenergized circuit would be useless for troubleshooting purposes.

4.1.1 Voltmeter

The voltmeter is used on an energized circuit to locate open switches, bad fuses, and various other opens throughout the circuit. Basically, the voltmeter will indicate whether a particular portion of the circuit is closed or open. In order to use the voltmeter, keep a

Figure 2-26 — Typical meters (Analog types A and B and Digital types C and D.

few things in mind. First, always select the correct voltage. Voltmeters have a function selector switch that must be placed on either AC or DC. This is a very important step because selecting the incorrect voltage could result in meter damage and, more importantly, personal injury. The next thing is range selection. Many meters, such as the Fluke digital meter, have the ability to select their own range automatically when applied into the circuit, while others require manual selection of the range on the meter itself. The third item to remember is that voltmeters are to be connected in parallel with the portion of the circuit that is being checked. See *Figure 2-26* for examples of meters.

Another area that has to be discussed is what the expected values should be in different circumstances. A voltmeter registers a *difference in potential*; therefore, there must be a difference or the meter will read zero. In other words, if there is an open, the meter will read voltage, if there is not an open, the meter will read zero. Following is a list of applications and expected readings:

The voltmeter gives a reading of voltage:

1. Open switch
2. Blown fuse
3. Broken wire
4. Across an energized coil
5. Across an energized motor or load device

The voltmeter gives a reading of zero:

1. Closed switch
2. Good fuse
3. Complete circuit
4. Across a deenergized load device
5. No power

The voltage read at an energized load device should be the total applied voltage, while the voltage read across an open may or may not be. Just remember, across a closed switch - zero, across an open switch - volts.

4.1.2 Ammeter

The ammeter is used on an energized electrical circuit to measure the amount of current draw at any given point in the circuit. Again, it is important to select the correct range and place the meter into the circuit correctly. Refer to *Figure 2-27.*

Probably the best approach is to select the highest range, and then move down the scale until the current reading is close to the middle of the scale. This will give the most accurate measurements and also protect the meter from damage. The meter must be connected in series to the circuit being measured. In some cases, the meter has to be used with the same meter leads as the voltmeter; however, the most common and preferred application is the clamp-on type.

Figure 2-27 — Ammeter.

4.1.3 Ohmmeter

NEVER use the ohmmeter on an energized circuit. It must be connected in series to the deenergized portion of the circuit being tested. Again, sometimes you must make range selections.

This mainly applies to the analog type ohmmeters, which will have different selections such Rx1, Rx100, and Rx10,000. Remember, the closer to the middle of the scale on an analog meter the reading is, the more accurate it will be, generally speaking. The reading on this meter will be either an ohmatic value that corresponds to that portion of the circuit, or it will be infinity, indicating an open. In many cases, such as across a closed, non-load portion of the circuit, the reading will be zero. This applies to both types except that a digital meter will indicate Over Limit (OL) as opposed to infinity. Following is a list of applications and expected readings:

The ohmmeter indicates a value of zero (analog or digital)

1. Across a closed switch
2. Across a good fuse
3. Across a closed portion of the circuit

The ohmmeter indicates a value of resistance (analog or digital)

1. Across motor windings
2. Across a coil, relay, contactor, or line starter

The ohmmeter indicates a value of infinity or OL

1. Across an open switch or wire
2. Across a blown fuse
3. Across an open motor winding
4. Across an open coil

4.1.4 Meter Safety

Probably the most commonly used tool in electrical troubleshooting is the multimeter. For that reason it is imperative that you be well rehearsed in its proper application and use. No matter how effective you are at troubleshooting, safety is the paramount concern. When using a meter, it is very important to connect it into the circuit properly. If you do not, the result could be damage to the meter, equipment, or the technician. Following is a list of multimeter uses and connections:

1. Voltmeter – connected in parallel
2. Ammeter – connected in series
3. Ohmmeter – Connected in series with the component being tested

4.2.0 Circuit Faults

Four basic faults can occur within an electrical circuit. They are: opens, shorts, grounds, and low power (voltage) situations.

4.2.1 Open

An open is a break in an electrical circuit, either intentional or unintentional. During troubleshooting, a voltmeter reads applied voltage across the open, or if an ohmmeter is used, it indicates infinity. Refer to *Figure 2-28* for example of an open circuit.

Figure 2-28 — Open circuit.

4.2.2 Shorts

Shorts can be broken down into three categories: direct short, cross short, and floating short. The first, direct short, is an accidental path of little or no resistance, which allows current to by-pass the load. In many cases a short can be identified by a burned area at the location of the malfunction. To troubleshoot a direct short, use an ohmmeter. The meter will indicate zero ohms. Refer to *Figure 2-29* for an example of a direct short.

Figure 2-29 — Direct short.

The next type is the cross short. This is the ungrounded (hot) conductor of one segment of a parallel circuit contacting an ungrounded (hot) conductor of another segment of that circuit. This problem can be observed by the ability of one switch to operate two load devices. In troubleshooting with a voltmeter, indication of a cross short would be zero volts; with an ohmmeter the indication would be zero ohms. Refer to *Figure 2-30* for an example of a cross short.

Figure 2-30 — Cross short.

The third type is the floating short (See *Figure 2-31*). This short is sporadic electrical contact by-passing the load. In many cases, this is the hardest fault to troubleshoot because the problem is intermittent. Indications of this situation could be an occasional open circuit protective device. Meter readings will be the same as they were for a direct short or a ground.

Figure 2-31 — Floating short.

4.2.3 Grounds

The next type of circuit fault we will look at is the ground. It is an accidental path for current to flow to metal conduit or ground, by-passing the load and neutral wires. As you can see, this is very much like a direct short. This type of fault can be dangerous because metal parts of the component casing could be "hot". If a ground fault is present, an ohmmeter will indicate zero ohms between the hot conductor and the equipment casing. Refer to *Figure 2-32*.

Figure 2-32 — Short to ground.

4.2.4 Low Power (Voltage)

Low power situations can arise from several causes, such as a weak transformer or an overloaded electrical service. Indications of this situation could be overheating conductors or equipment and incorrect operation of equipment, such as relay chatter and slow running motors.

In troubleshooting, the technician will find lower than rated voltages with a voltmeter and higher than rated current with an ammeter. As a rule of thumb, apply voltage to the load device that is within 10% of the rating on the data plate. The current draw should be within 5% of the rating on the data plate. There are special applications with much tighter tolerances; for these applications refer to the manufacturer data.

4.3.0 Troubleshooting Sequence

Following a logical sequence when troubleshooting will not only reduce the time it takes to troubleshoot a system but also help reduce the frustration. Take the following steps to help increase your effectiveness as a troubleshooter.

4.3.1 Diagnosis

Observe how the system or equipment operates. Are there signs of fire, arcing, or smoke? Is the piece of equipment vibrating abnormally? Do meters or gauges indicate any out of specification readings? Perform a operational check if available.

4.3.2 Sectionalization

Isolate the problem area to a section of the system or equipment. Problems can be associated with power supply, controls, or loads attached to system or equipment.

4.3.3 Localization

Reduce the problem to a single circuit, component, or location.

4.3.4 Isolation

Gradually reduce the area that you are troubleshooting until you isolate the faulty component. Connectors, wires, terminals, and modules are examples of the smallest component.

4.3.5 Repair

- Replaced burned wires with the same AWG.
- Replace worn contacts.
- Repair loose connections (with power Off).
- Clean debris from moving parts to allow proper operation.
- Repair/replace burned out motors or components.

4.3.6 Operation

- Determine if the equipment is operating in the proper operation.
- Ensure voltage and amperage is correct using data plates and meters.
- Ensure motors are rotating in the proper direction.

Test your Knowledge (Select the Correct Response)

4. When taking resistance readings the meter must be connected in what condition?

   A. Series
   B. Parallel
   C. Perpendicular
   D. No requirement needed

5.0.0 PIPE MEASUREMENT

Mathematical principles must be applied in order to effectively measure, cut and install piping in a plumbing system. Numerous measurements, such as pipe and fitting dimensions, can be significant during these calculations. Before making any pipe or fitting measurements or performing any mathematical calculations, first learn to read a tape measure.

5.1.0 Reading a Tape Measure

Tape measures are used to measure lengths of construction materials and to perform other linear measurements associated with construction activities. Lengths of objects are determined by comparing the reference lines on the tape to

Figure 2-33 — Measuring tape.

the length of the object being measured. Reference lines used to indicate length on the tape are perpendicular to its length. See *Figure 2-33.*

Each individual reference mark on the tape shown indicates a 1/16" of length. See *Figure 2-34.*

Figure 2-34 — Scales of measuring tape.

5.2.0 Pipe Characteristics

5.2.1 Galvanized Steel and Black Iron

Galvanized steel and black iron piping are most often assembled using threaded joints. Galvanized steel pipe is used to distribute water and black iron pipe is used to distribute natural gas. Since the pipe and fittings are threaded together, a portion of the pipe length is threaded into the fitting (thread engagement) during assembly. For this reason, measurements and pipe calculations must take into account the length of the thread engagement.

5.2.2 opper Piping

Copper piping and fittings are generally soldered together. Solder joints are made by heating the copper pipe and fitting with a torch while melting a metal alloy that is drawn into the space between the pipe and fitting to form a water tight seal. A portion of the copper pipe is inserted into the fitting before soldering, which takes away from the length of the overall assembly. The length of pipe that is lost in the assembly is called pipe engagement**.** Pipe engagement must be included in the mathematical calculations associated with copper pipe assembly.

5.2.3 Plastic

Plastic piping is commonly solvent cemented (glued) together using a liquid

Figure 2-35 — Fitting terminology.

primer and solvent cement that glues the pipe and fittings together. When connecting fittings in plastic piping systems, a portion of the pipe is inserted in the fitting, which takes away from the overall length of the assembly. Again, pipe engagement between pipe and fittings must be included in the mathematical calculations associated with plastic pipe assembly.

5.2.4 Fitting Terminology

To make piping system measurements and calculations, you must be familiar with some fitting terminology. “Center” means where lines of flow intersect. “Run” is the opening that is in line with the fitting. “Branches” are openings that are at an angle to the run of the fitting. “Face” refers to the outer most edge of a run or branch opening. See *Figure 2-35*.

In performing calculations with threaded fittings, the length of pipe that threads into the fitting (thread engagement) is important. Thread engagement contributes to the overall length of the assembled piping system. See *Figure 2-36*.

5.2.5 Pipe Terminology

To measure, mark, and cut pipe for assembly in a plumbing system, UTs must determine the length of pipe required to make joints with fittings that achieve the desired face to face distance between fittings. This length is referred to as an end to end measurement**.** There are other types of measurements performed during plumbing system assembly, yet eventually, end to end pipe measurements must be determined in order to cut the pipe to proper length. See *Figure 2-37*.

Figure 2-36 — Thread engagement.

Figure 2-37 — End to end measurement.

5.3.0 Common Pipe Measurement Methods

Seven methods are used in measuring pipe or tubing. They are: (1) end to end, (2) center to center, (3) end to center, (4) end to back, (5) center to back, (6) back to back, and (7) face to face. These measurements are also used in measuring threaded galvanized or black iron pipe.

The measurements are generally made with a ruler. Each of the seven methods mentioned above is explained below, and each is shown in *Figure 2-38*.

5.3.1 End to End

End to end indicates a pipe threaded on both ends. The measurement is from one end of the pipe to the other end, including both threads.

5.3.2 Center to Center

Center to center means there is a fitting on each end of the pipe. The measurement is made from the center of the fitting on one end to the center of the fitting on the other end.

5.3.3 End to Center

End to center method applies to pipe having a fitting on one end. The measurement is made from the end of the pipe to the center of the fitting.

5.3.4 End to Back

End to back also refers to pipe with a fitting on one end. The measurement is from the back of the fitting to the other end of the pipe.

5.3.5 Center to Back

Center to back indicates a pipe with a fitting on each end. The measurement is taken from the center of one fitting to the back of the other fitting.

5.3.6 Back to Back

Back to back measurement refers to pipe with a fitting on each end. Here the measurement is from the back of one fitting to the back of the other fitting.

Figure 2-38 — Methods of measuring pipe and tubing.

5.3.7 Face to Face

Face to face measurement refers to a pipe with a fitting on each end that has an opening directly across from the pipe it is connected to on both ends. Measure from the face of the opening to the face of the other fitting.

5.4.0 Calculating Threaded Pipe Lengths

When measuring for the installation of threaded pipe and fittings, allow for the thread engagement of the components. Measuring the distance between the fittings and then adding the thread engagement for each joint is necessary to determine the correct end to end measurement of the pipe. See *Figure 2-39* and *Table 2-3.*

Figure 2-39 — Calculating threaded pipe length.

Table 2-3 — Thread Lengths.

Pipe Size (in inches)	**Length of Threaded Portion** (in inches)
1/2	3/4
3/4	3/4
1	7/8
1 1/4	1
1 1/2	1
2	1
2 1/2	1 1/2
3	1 1/2
4	1 5/8

5.5.0 Calculating Soldered/Solvent Cemented Pipe Lengths

When measuring for the installation of copper or plastic pipe and fittings, allow for the pipe engagement of the components. Measuring the distance between the fittings and then adding the pipe engagement for each joint is required to determine the end to end measurement of the pipe. See *Figure 2-40*.

5.6.0 Calculating Slope for Waste Piping

5.6.1 Sloped Pipe for Gravity Flow

Wastewater piping receives water discharged through plumbing fixtures such as water closets, urinals, lavatories, showers and sinks and then transports the collected wastewater to a treatment plant. The horizontal piping in a waste system is installed at a slight slope so that the wastewater will flow due to the force of gravity.

5.6.2 Buried Pipe

As a UT, you will install waste piping in structures and in exterior waste water collection systems. Much of the horizontal piping that you install will be below ground in a trench. You will have to grade (slope) the bottom of the trench by manipulating the dirt or gravel in the floor of the excavation. After sloping the trench, install the piping. While laying the pipe, continuously check the grade to ensure you have not altered the desired slope.

Figure 2-40 — Calculating soldered/solvent cemented pipe lengths.

5.6.3 Slope Trench and Install Pipe Below Frost Line

You will have to perform some mathematical calculations to achieve this grade during the installation. For example, let’s say you have been tasked with installing 100 feet of pipe at a slope of 1/4 inch per foot. Before installing the pipe, dig a trench and slope the floor of the excavation to the desired grade. One end of the trench must be deeper than the other. The depth of the shallowest end of the trench will be determined by the frost line (max. depth to which the soil freezes). The depth of the deepest end of the trench is relative to the desired slope or grade, the frost line, and the length of the trench.

The depth of the frost line varies with geographic location. Piping is buried deeper in Alaska than in Texas.

Formula: L x DS = AD

L = Length (in feet)

DS = Desired slope (in fractions of an inch)

AD = Additional depth at deep end

For example, let's take the figures from above and calculate the depth of the deep end of 100 foot trench with a 1/4 inch slope.

AD = L x DS

AD = 100 feet x1/4 inch

AD = 25 feet

Now add the AD value to the shallow end depth to obtain the depth of the deep end when sloping is completed.

Formula: DDE = DSE + AD

DDE = Depth of deep end

DSE = Depth of shallow end

AD = Additional depth

DDE = DSE + AD

DDE = 2 feet (24 inches) + 25 inches

DDE = 49 inches (4 feet 1 inch)

On construction plans, the desired grade of waste pipe may be represented in degrees instead of inches per foot. If this is the case, here are the conversions to assist you in your calculations.

.5° = 1/16" per foot

1.0° = 1/8" per foot

2.0° = 1/4" per foot

Test your Knowledge (Select the Correct Response)

5. How many measuring methods are associated with piping?

   A. 3
   B. 7
   C. 5
   D. 9

6.0.0 EXCAVATION

Most of the piping systems in use today are underground. Therefore, many of your tasks will require you to excavate in various types of soil. You may think digging a trench simply means using a pick and shovel, but that is not the case. There are specific procedures that you must follow. During this section, we will address excavations as they pertain to the installation of buried pipe, with an emphasis on safety considerations.

6.1.0 Digging Procedures

6.1.1 Permission to Excavate

Installation and repair of buried pipe is a common task in the utilities career field. Before digging, it is very important to know if there are other underground utilities in the vicinity. Utility services such as water, gas, or electrical lines in the area of the proposed excavation must be uncovered carefully. The results of accidentally cutting buried utilities (such as gas, electrical, or communication lines) could cost thousands of dollars and may result in injury or death. Therefore, before any excavation work can begin, you must obtain permission to excavate from the local approving authority (the local approving authority at a military installation will be the Resident Officer In Charge of Construction (ROICC). A digging permit obtained through the approving authority at your military installation will identify existing utilities at the proposed excavation site and identify safety hazards.

NOTE

Never excavate until the digging permit is completed and signed by the appropriate authorities.

6.1.2 Procedures

Use earth moving equipment (such as backhoes and front end loaders) to dig large trenches for pipe installation. For smaller excavations, use picks and shovels. Common sense will be the guide when deciding whether to create trenches with hand tools or with heavy equipment. Regardless of the tools or equipment used, always place the material removed from the excavation (soil) at least 24 inches away from the edge of the open trench. Moving soil 24 inches away from the trench ensures that dirt, rock, and debris do not fall back into the trench during excavation. Separate all loose boulders, stumps, and other debris from the soil removed from the trench and haul it away from the work site.

Whichever method you use, dig the trench wide enough (2 feet minimum) to allow ample working room to join pipe sections. The bottom of the trench must also be sloped in the direction of flow, so sewage traveling through the pipeline laid in the trench is not restricted. On most jobs, an Engineering Aid (EA) is on hand to check elevations to ensure that the slope of the trench is close to the slope where the pipe is to be laid. On most jobs, EAs establish a system of batter boards and grade bars (explained later) for you to check the slope of the pipeline accurately, as you lay it in the trench. Check the job specifications for the proper grade of the sewer line to install. When specifications are not available, a rule of thumb is to slope the trench 1/4 inch per foot. This is the grade at which sewage flows freely through a pipe and provides proper scouring action to keep the sewage flowing.

When laying a pipeline in stable soil, such as hard clay or shale, excavate the trench below the pipe grade. If you are using bell-and-spigot pipe, make excavation for the bells. See that enough undisturbed earth remains at the bottom of the trench that the pipe, both joints and hubs, rests on and is fully supported by undisturbed earth. In areas where the temperature drops below freezing, the trench must be excavated deep enough for the pipeline to be below the frost line. Pipes that cross under roads or areas of vehicular traffic must be buried in trenches at least 4 feet deep and may require some type of metallic sleeving. Refer to the specifications of the job for details on sleeving pipe.

The sides of excavations, 4 feet or more in depth or in which the soil is so unstable that it is not safe at greater depths, should be supported by substantial and adequate sheeting, sheet piling, bracing, shoring, and so forth, or the sides should be sloped to the angle of repose. Surface areas adjacent to the sides should be well-drained. Trenches in partly saturated, filled, or unstable soils must be suitably braced.

6.2.0 Shoring and Safety Practices

6.2.1 Prevent Cave-Ins

The purpose of shoring is to prevent cave-ins. Cave-ins have claimed the lives of many workers who either neglected to shore the walls of trenches they were working in or did not shore them properly.

6.2.2 Installation of Shoring

Figure 2-41 shows a view of a properly shored trench. Place strong materials such as 3/4 inch exterior plywood sheets or 2 inch x 6 inch boards vertically against the trench walls to form an inner wall. Fasten 2 inch x 4 inch strips of lumber horizontally along the walls near the top, bottom, and in the middle to provide a firm base for shoring jacks. If jacks are not available, use doubled 2 inch x 4 inch cross braces to prevent the walls from collapsing. The shoring jacks extend across the trench between the 2 inch x 4 inch strips which forces the inner wall against the excavated walls. Although shoring jacks may interfere with construction workers' movements, their proper installation may prevent injuries or save lives.

Figure 2-41 — End view of shored trench.

6.2.3 Shoring and Excavation Safety

You must shore a trench if the excavation reaches a depth of 5 feet and you are working in stable soil such as hard packed clay. However, when working in loose or sandy soil, shoring must be installed when a depth of 4 feet is reached.

Alternate the placement of access ladders on each side of the trench at intervals of 50 feet or less. All ladders must extend at least 36 inches above the excavated trench. Ladders provide a very convenient and safe way to enter and exit trenches.

Inspect bracing and shoring frequently, particularly after heavy rains. Repair any suspected or obvious failures immediately. Securely fasten cross braces or shoring jacks in place by some satisfactory means to prevent the walls from collapsing from ground movement or shifting.

6.2.4 Alternative to Shoring

Another simple method to overcome the hazard of cave-ins is to dig the trench walls with steps or shelves. This method of cave-in protection results in a much wider trench. Steps or shelves are used most often in sandy soils where the soil shifts too easily to maintain shoring or when shoring materials are not available. When using this method, remove exposed rock and debris to prevent them from dislodging and rolling into the trench.

When removing shoring jacks, always start from the bottom and work up.

6.3.0 Grading Trenches and Sewer Pipe

Sewer or waste piping collects wastewater from plumbing fixtures (such as water closets, urinals, sinks, and tubs) and transports the wastewater through buried piping systems to a treatment plant. Much of this sewer piping is buried below the frost line (depth at which the soil freezes). The buried piping is installed at a slope to allow gravity flow of the wastewater through the piping system. To install sloped waste piping, you must first grade the floor of the trench. In this section, we will address the procedures for creating sloped trenches.

Proper grading of a trench for drain pipe installation is necessary to keep one end of the pipe lower than the other so wastewater will flow freely (gravity flow) in the desired direction. To determine the location of the proposed trench, refer to the construction plans. The shallow end of the trench will be the inlet end of the proposed piping. The inlet end of the trench should be deep enough to allow installation of the pipe below the frost line. From the shallow end of the trench, dig the ditch gradually deeper towards the outlet end. The grade created should correspond with the desired slope of the installed piping.

Waste pipe may be installed at various grades depending on the diameter of the pipe. Most often, you'll install waste piping at a slope of 1/4 inch per running foot. This means that the grade of the pipe will drop 1/4 inch in depth for each foot of length. Larger diameter pipe may be sloped slightly less. Slope of waste pipe should be designed to transport wastewater at a rate that ensures solids are carried with the water through the piping system. If the flow is too fast, the water flows faster than the solids. This leaves the solids sitting in the pipe to create stoppages. If the water flows too slowly, solids settle out and are left in the pipe to create stoppages. For these reasons, it is critical to grade trenches properly for the installation of sewer piping.

General requirements when digging the trench are: (1) Remove the desired amount of soil to create the desired excavation (undisturbed soil provides the best piping support). (2) Make the walls of the excavation straight or perpendicular to the trench floor. (3) Keep the floor (or bottom) of the trench as smooth and square as possible. (4) Create the desired grade as you dig. (5) Check the trench depth constantly as you continue digging and grading.

The pipe should be laid, so the flow of the sanitary waste in each length of pipe flows from the hub end to the spigot end or we could say the hub end is upstream. Each length of pipe should be placed starting at the lowest elevation and working up the grade; therefore, the spigot is inserted into the hub of the length laid previously. Each length should be checked as to its grade and alignment before the next length is placed.

When you are grading for the proper pitch per foot, use the method shown in *Figure 3-31* as a guide. This figure shows a ditch with batter boards used in transferring line and grade to trench and also shows a stick for checking grade.

Commonly an EA is responsible for setting the batter boards at the proper level for the job at hand. Batter boards are placed across the trench at about 25 to 50-foot intervals. After an EA runs the elevations, place a mark on the stakes at some even-foot distance above the invert (the lowest point on the inside of the pipe) of the sewer. Then drive a nail in the top of the batter boards, and stretch a cord from board to board. Then transfer the center line for the pipe from the cord to the bottom of the trench by means of a plumb bob. Transfer grade by means of a stick, marked in even-foot marks, having a short piece fastened at a right angle to its lower end. Check grade by placing the short piece on the invert of each length of sewer pipe and aligning the proper mark on the grade rod to the cord. See *Figure 2-42* for example of laying pipe to line and grade.

Figure 2-42 — Laying sewer pipe to line and grade.

6.3.1 thods of Grading Trenches

The three methods of grading a trench are: (1) a string line and line level, (2) an engineer’s transit, and (3) a laser device. The most common method utilities workers use to grade a trench is the string line and line level method.

6.3.2 Procedures for Grading Trenches using String line and Line Level

6.3.2.1 String Line and Line Level

The correct procedures for using a string line and line level are:

1. Dig the trench at the minimum required depth and in the location indicated by the construction plans. See *Figure 2-43.*
2. Drive a stake at each end of the trench. A section of 1/2 inch galvanized pipe can be used for a stake.
3. Stretch a string tightly between the two stakes.
4. Level the string by fastening a line level on it and adjusting one end up or down so the bubble in the level is centered between the two black lines in the center of the viewing window. See *Figure 2-44*.
5. Determine the length of the run with a tape measure. Then multiply the length of the run by 1/4 inch (or the desired grade of the pipe). Example: A 24 foot long trench with a 1/4 inch slope has a 6 inch fall on the outlet side (24 feet x 1/4 inch = 6 feet).
6. Next, move the string down on the stake at the outlet end of the trench the distance indicated by the multiplication calculation conducted previously. Now your string is sloped at the same grade that will be required for the floor of the trench.
7. Make a grade stick from a piece of 1 inch x 2 inch piece of lumber. Place the stick in a vertical position directly under the string line and as close as possible to the inlet of the drainage system.

Figure 2-43 — Dig trench to minimum required depth.

Figure 2-44 — Stringing of level between two stakes.

Place a mark on the stick where the string line crosses it. This mark will be your reference point for the entire length of the trench.

8. Grade the trench from the inlet to outlet end. As you are digging soil out of the floor of the trench to achieve the desired grade, set the base of the grade stick on the floor to see if the reference mark is in line with the string. If the reference mark is above the string, remove more soil. If the reference mark is below the string, you've removed too much soil. Make sure the mark on the stick lines up exactly with the string line as you move the stick along the entire length of the trench. Readings should be taken every few feet to determine if soil must be removed or added to obtain the proper grade. See *Figures 2-45* and *2-46*.

Figure 2-45 — Placement of grade stick.

Figure 2-46 — Remainder of soil to be removed for final grading figure.

More accurate methods of grading trenches, including the use of an engineer's transit or a laser device, are necessary when installing long runs of pipe (i.e. sewer mains). Since you will seldom install long runs of sewer piping, we will not address these methods in detail during this course. You will learn more about them when you graduate and begin working in the field.

After grading the floor of the trench, begin installation of the sewer pipe. It is critical to install the pipe properly to ensure proper flow and prevent leaks.

6.3.3 Methods of Grading Pipe

There are several ways to grade pipe. The simplest and most common method is a carpenter's level. However, should you install long runs, use the more accurate engineer's transit or string and batter board methods. Most of the time you'll be installing short runs of piping; therefore, let's address the carpenter's level method in more detail.

6.3.3.1 Carpenter's Level

This is the method most commonly used by UT's to grade pipe. Install the piping in the trench starting at the inlet end. As you assemble each joint, use the carpenter's level to verify you are maintaining the correct slope (*Figure 2-47*). Attach a block of wood to the end of the level using tape. The thickness of the block of wood used will vary with the length of the level and the desired slope of the pipe. For example, when installing pipe at a slope of 1/4" per foot using a:

A. 1 foot level – tape a 1/4 inch block of wood to the end

B. 18 inch level – tape a 3/8 inch block to the end

C. 24 inch level – tape a 1/2 inch block to the end

Figure 2-47 — Grading pipe using a carpenter's level.

6.3.2 Procedures for Grading Pipe Using Carpenter's Level

The general steps are as follows:

1. Select block of wood for length of level and desired slope.
2. Tape the block of wood to the end of the level.
3. Start at inlet end of the trench.
4. Measure and mark bell holes (See *Figure 2-48*).

Figure 2-48 — Bell holes.

5. Assemble bell and spigot joints. The rubber seals on the bell and spigot ends are lubricated. Next, a board is placed firmly against the outlet end of the pipe and then it is struck with a sledge hammer to drive the spigot and bell ends of the pipe together. See *Figure 2-49*.
6. Verify slope of each joint. Using the carpenter's level with the proper size block of wood, grade each joint.

Figure 2-49 — Pipe assembly.

6.4.0 Testing

After you complete the rough-in piping of a project, test and inspect all the piping for leaks. The purpose of testing the pipeline is to make sure the joints are tight enough to withstand working pressure. Since a sewer line of this type flows by gravity drainage, the test procedures are different than those described in later chapters.

Before covering the pipe with dirt, test it for leakage. There are several methods of affecting this test. The most widely used is the water test, although you may use an air test or odor test.

6.4.1 Water Test

Here are the main steps in making a water test. At the lowest point of the pipe section to be tested, insert a test plug in the open end of the pipe or a test tee, like those shown in *Figure 2-50*, and plug other openings. Fill the pipe to its highest level with water; an IO-foot head is required. Leave the water in the pipe for at least 15 minutes before starting the test. This allows the oakum to soak up some water before you look for leaks. If necessary, refill the pipe to overflow and check each joint for leaks.

6.4.2 Air Test

Before making an air test, fill the system with water and allow it to stand until the oakum expands at the joints. Drain the water from the lines and reinsert the test plug. Close all openings and apply air pressure of at least 5 pounds per square inch (psi). In a satisfactory test, the line should hold 5 pounds psi for 15 minutes. If it does not, cover the joints with a soapy water solution and check for bubbles at the leak.

6.4.3 Odor Test

Before making an odor test, plug all openings in the sewer and the branches. After sealing the openings, pour 2 ounces of oil of peppermint in each line or stack. Then pour approximately 1 gallon of boiling water in the stack and seal it. The odor of peppermint at any point in the installation indicates a leak. The inspector, checking the installation for leaks, should not be near the oil of peppermint at any time before the inspection. Such exposure rapidly dulls his or her sensitivity to the odor of peppermint. The peppermint test is not as conclusive as the water and air tests described above, since there is no pressure on the pipe.

Figure 2-50 — Test plugs and test tees.

6.5.0 Backfilling

Backfilling is the replacement of soil into an excavation. Although a relatively simple task, you must follow specific procedures when backfilling a trench.

6.5.1 Draining Excavations

Leaks from improperly installed or damaged piping can saturate the soil surrounding the system. Rain can also saturate soil at the excavation site. Either of these conditions can result in standing water inside the excavation. Standing water may prevent repair or installation of the pipe, and it prohibits visual inspection of the pipe for leaks. Additionally, standing water will not allow compaction of the soil during backfilling. For these reasons, it may be necessary to drain the open pit or trench periodically, using a diaphragm pump (commonly referred to as a mud hog). These pumps are especially suited to this task because of their design. A rubber diaphragm separates the mechanical parts of the pump from the mud and small rocks that are passing through the suction chamber. Centrifugal pumps are also used to remove water from excavations. They are normally used when there is a large amount of water to be removed. **Do not** place the intake hose of a centrifugal pump all the way to the bottom of the excavation because it could pick up mud and small rocks that can damage this type of pump. Do not backfill until the trench is free from standing water.

6.5.2 Purpose of Backfilling

The purpose of backfilling a trench is to support and protect the pipe and to prevent people from falling in. Regardless of the overall size of the trench, the backfilling procedures to be used remain the same.

6.5.3 When to Backfill the Excavation

Backfill excavations as soon as possible after the piping are installed, or after repairs have been made to existing pipe. Inspect piping for leaks *before* backfilling the trench.

6.5.4 Backfill Procedures

6.5.4.1 Use Clean Fill Material Only

Prior to starting backfill operations, remove any rocks, tree roots, and other debris from the fill soil. Rocks, roots, and debris can affect pipe alignment and cause the joints to leak. Debris in the backfill material could rub holes in the pipe surface, causing leaks in the system. Also, large rocks being pushed into the trench could damage unprotected portions of the pipe. Normally, the same soil removed from the trench will be used as backfill material. If the soil removed from the original trench is not enough, haul in additional soil from another location.

6.5.4.2 Backfill in 6 Inch Increments and Tamp by Hand

To protect against lateral movement of the pipe, backfill around the pipe, and tamp by hand. For best results, backfill and tamp in layers of not more than 6 inches**.**

6.5.4.3 Stay Off the Pipe

Do not stand directly on the pipe or the soil directly above the pipe until 1 foot of hand tamped (packed) soil is above the newly installed pipe. This practice ensures workers do not adversely affect the pipe joints during the backfill process.

6.5.4.4 Continue to Backfill and tamp by Hand

Continue to add soil in 6 inch layers and tamp with hand tools until 2 feet of tamped soil exists above the piping.

6.5.4.5 Use Compaction Equipment

When you reach 2 feet of compacted backfill above the pipe, use compaction equipment to backfill the remainder of the trench. Complete the backfilling of the excavation in 6 inch layers and tamp with compaction equipment until the operation is complete.

6.5.4.6 Backfilling in Traffic Areas (Roadways)

In high traffic areas, you must compact the backfill material all the way to the original ground level. Overfilling the trench is not an option since this would cause an irregular surface in the repaired asphalt or concrete road surface.

6.5.4.7 Backfilling in Non-Traffic Areas

Overfill trenches 6 inches above the original ground level in non-traffic areas. The additional 6 inch mound of soil will eventually settle to the level of the surrounding surface.

Test your Knowledge (Select the Correct Response)

6. How many methods are associated with grading a trench?

   A. 1
   B. 2
   C. 3
   D. 4

Summary

Your knowledge and use of basic mathematical skills and electrical theory is essential for the safe conduct and completion of your job as a Utilitiesmen. Basic mathematical skills include addition, subtraction, multiplication, and division of whole numbers, fractions, and decimals. Another important requirement is the conduct of the skill of pipe measurement. UT's must be able to read a tape measure to install piping systems. Knowledge of pipe and fittings, and the characteristics or terms associated with these components is necessary to perform mathematical calculations for the installation of piping. When calculating end to end measurements for threaded pipe assemblies, allow for thread engagement between the pipe and fitting. Also, when calculating end to end measurements for soldered or solvent cemented pipe, allow for pipe engagement.

Trenches and piping systems installed for the transport of wastewater must be correctly graded. To determine the criteria for creating a trench and installing pipe at the correct grade, you must perform some mathematical calculations. It is not only important to know how to use these skills, but also to be knowledgeable of the results of errors.

Another important piece of knowledge is the understanding and application of electrical theory. As an Utilitiesmen, you need the knowledge of the concepts and principles when dealing with alternating and direct current. During your career as an UT, you will apply this and other electrical and electronic theory in your everyday conduct.

Excavations are an inherent part of installing and maintaining buried piping systems. Before excavations are performed, it is essential to process a digging permit. Digging permits are used to identify existing utilities and hazards that may be encountered during the excavation. Shoring is installed in a trench to prevent cave-ins. In sandy soil, steps may be created on the walls of the trench as a substitute for shoring. Open trenches should be barricaded and marked to prevent accidents involving vehicle or pedestrian traffic.

Backfilling is the replacement of soil into an excavation. It is performed to protect and support underground piping.

Review Questions (Select the Correct Response)

1. In order to perform mathematical calculations that involve more than one type of function, you must perform the calculations in a specific order. Which function is conducted after the exponent function calculation?

   A. Multiplication
   B. Division
   C. Addition
   D. Subtraction

2. In whole numbers, how is the value of the number determined?

   A. Subtraction
   B. Placement in number
   C. Addition
   D. Placement of decimal point

3. How many steps are used to multiply decimals?

   A. None
   B. One
   C. Two
   D. Three

4. In accordance with rounding rules, if the number in the thousandth place is a 5, what actions do you take?

   A. Leave as is
   B. Round number down
   C. Nothing, rule applies to hundredths
   D. Round number up

5. What is the top number of a fraction called?

   A. Denominator
   B. Addend
   C. Numerator
   D. Divisor

6. What is the simplest way to convert fractions to the same denominator?

   A. Divide their denominators
   B. Multiply their numerators
   C. Divide their numerators
   D. Multiply their denominators

7. When the numerator is larger than the denominator after adding fractional numbers, what is the result called?

   A. Dividend
   B. Improper fraction
   C. Mixed number
   D. Proper fraction

8. How does one convert a number from a fraction to a decimal?

   A. Divide the numerator by the denominator
   B. Multiply the numerator by the denominator
   C. Divide the denominator by the numerator
   D. Multiply the denominator by the numerator

9. What formula is utilized to determine the volume of a rectangular tank?

   A. V = D x D x 0.7854 x L
   B. V = $\pi R^2 L$
   C. V = L x W x H
   D. V = H x W x 0.7854 x L

10. You are tasked to calculate the volume of an elliptical tank; which of the following formulas would you utilize?

   A. V = $\pi R^2 L$
   B. V = D x D x 0.7854 x L
   C. V = L x W x H
   D. V = H x W x 0.7854 x L

11. What is defined as the actual movement of electrons through a conductor?

   A. Voltage
   B. Current
   C. Resistance
   D. Capacitance

12. The atom consists of how many parts?

   A. 1
   B. 2
   C. 3
   D. 4

13. Electrons carry what type of electrical charge?

   A. Positive
   B. Neutral
   C. Alternating
   D. Negative

14. When current is made to flow through a wire, how many different effects does this create in or around the conductor?

    A. 1
    B. 2
    C. 3
    D. 4

15. As the intensity of the current through the wire increases, what effect (if any) does this have on the associated magnetic field?

    A. No effect
    B. Strength of field increases
    C. Strength of field decreases

16. As a UT, how many different types of current will you encounter during a HVAC installation?

    A. None
    B. 1
    C. 3
    D. 2

17. How does a battery create output voltage?

    A. Electrical action
    B. Mechanical action
    C. Chemical action
    D. Pneumatic action

18. If higher amperage is required, how can you increase the amperage output of batteries?

    A. Wire batteries in parallel
    B. Increase electrolyte levels
    C. Wire batteries in series
    D. Decrease distilled water levels

19. You are using iron as a conductor, and the temperature of the iron increases; what effect does this have on electron flow?

    A. Move towards the heat
    B. No effect on flow
    C. Move away from the heat
    D. Increases electron flow

20. What is the coolest end of a piece of metal referred to as?

    A. Cool conductor
    B. Cool junction
    C. Cold end
    D. Cold junction

21. A generator converts mechanical energy into electrical energy by which of the following principles?

    A. Magnetic induction
    B. Mechanical induction
    C. Magnetic conduction
    D. Electrical conduction

22. Materials with little resistance are also known as what?

    A. Insulators
    B. Conductors
    C. Semi conductors
    D. Inductors

23. What is another term used for resistance inherent to the conductor?

    A. Intentional resistance
    B. Unavoidable resistance
    C. Source resistance
    D. Factor resistance

24. How many factors contribute to the resistance of a conductor?

    A. None
    B. 2
    C. 4
    D. 6

25. If the cross sectional area of a conductor is increased, what effect does this have on the resistance of the conductor?

    A. Decreases
    B. No effect
    C. Increases

26. You want to obtain the least amount of resistance of a wire; what size conductor should be utilized?

    A. Short
    B. Medium
    C. Long
    D. Any size

27. What type of skin condition offers the highest resistance to low voltage shocks?

    A. Clammy
    B. Dry
    C. Wet

28. The resistance of the internal body, hand to foot, is approximately between _ ohms?

A. 100 and 400
B. 200 and 700
C. 400 and 600
D. 1000 and 1500

29. When utilizing portable tools on the job site, what is the maximum resistance that tool can have?

A. One ohm
B. Less than one ohm
C. Zero ohms
D. Five ohms

30. Which of the following pieces of electronic equipment has the capability to store electricity?

A. Inductor
B. Resistor
C. Capacitor
D. Diode

31. A fire breaks out inside a power panel; which type of extinguishing agent is use to combat the casualty?

A. Water
B. AFFF
C. CO2
D. PKP

32. What procedures are used to inform all personnel that a piece of equipment is under repair?

A. Placard placement at job site
B. Material safety data sheet
C. Trouble failure report
D. Lockout

33. A circuit must contain a minimum of how many components to be considered an electrical circuit?

A. 4
B. 1
C. 2
D. 3

34. Resistor converts _ energy to _ energy?

A. Electrical; Mechanical
B. Electrical; Heat
C. Mechanical; Electrical
D. Heat; Electrical

35. Which of the following is NOT an area of concern when properly sizing conductors?

A. Material used
B. Location of conductor
C. Impedance of the wire
D. Size of wire

36. The numbering system used for sizes of different types of wires is commonly known as what?

A. Universal Wire List
B. American Standard Wire Gauge
C. Universal Wiring List
D. American Wire Gauge

37. The symbol for moisture resistant thermoplastic insulation is which of the following?

A. TW
B. RHW
C. T
D. RH

38. **(True or False)** A conductor used in free air will safely carry more current than the same conductor installed along with other conductors inside conduit.

A. True
B. False

39. Which of the following colors represent a grounded neutral wire?

A. Green
B. Black
C. White
D. Red

40. What type of tool is utilized when using No. 10 AWG wire or smaller for splicing operations?

A. Utilitiesmen knife
B. Scissors
C. Wire stripper
D. Wire extender

41. If a series circuit contained three sets of lamps, and the middle lamp went out, what would be the status of the other lamps?

    A. First lamp out, last lamp lit
    B. First lamp lit, last lamp out
    C. On
    D. Out

42. A parallel circuit contains three branch circuits, what is the voltage across the last branch?

    A. One third of applied voltage
    B. Total applied voltage
    C. Unknown without resistance value

43. **(True or False)** Ohm's law only applies to purely resistive AC and DC circuits.

    A. True
    B. False

44. Which of the following is the formula for total voltage in a series circuit?

    A. $E_T = E_{R1} = E_{R2}$
    B. $E_T = E_{R1}/E_{R2}$
    C. $E_T = E_{R1} \times E_{R2}$
    D. $E_T = E_{R1} + E_{R2}$

45. Which of the following is the formula for total current in a series circuit?

    A. $I_T = I_{R1}/I_{R2}$
    B. $I_T = I_{R1}/I_{R2}$
    C. $I_T = I_{R1} = I_{R2}$
    D. $I_T = I_{R1} + I_{R2}$

46. Which of the following is the formula for total current in a parallel circuit?

    A. $I_T = I_{R1} + I_{R2}$
    B. $I_T = I_{R1} = I_{R2}$
    C. $I_T = I_{R1}/I_{R2}$
    D. $I_T = I_{R1}/I_{R2}$

47. How many meters make up a multimeter?

    A. None
    B. 1
    C. 2
    D. 3

48. While utilizing a voltmeter, the first step is to select either AC or DC, what would be your next step?

A. Frequency selection
B. Range selection
C. Connection of leads in series
D. Connection of leads in parallel

49. Voltmeter indicates a voltage when connected; what does this indicate to you?

A. Open in circuit
B. Closed switch
C. Complete circuit
D. Good fuse

50. If the voltmeter gives a reading of zero, what does this indicate?

A. Energized coil
B. Open switch
C. Broken wire
D. Good fuse

51. When using the ammeter, which range selection is recommended to start out?

A. Lowest
B. Highest
C. Midrange

52. How are the leads connected on an ammeter to measure current?

A. Positive lead first
B. In parallel
C. In series

53. How are the leads connected on an ohmmeter for a deenergized circuit to obtain a resistance reading?

A. Positive lead first
B. In parallel
C. In series

54. While using the ohmmeter, its display indicates a value of resistance; what does this indicate?

A. Resistance across motor windings
B. Resistance across a good fuse
C. Resistance across an open coil
D. Resistance across a closed switch

55. How many faults associated with electrical circuits?

A. 1
B. 2
C. 3
D. 4

56. How is an open represented on an ohmmeter's display?

A. Partial resistance after open
B. Low or zero resistance reading
C. Total resistance of circuit
D. Infinity

57. What is defined as an accidental path of little or no resistance which allows current to bypass the load?

A. Cross short
B. Direct short
C. Floating short
D. Hidden short

58. Which of the following is defined as the ungrounded (hot) conductor of one segment of a parallel circuit contacting an ungrounded (hot) conductor of another segment of that circuit?

A. Floating short
B. Cross short
C. Hidden short
D. Direct short

59. Which of the following type of short is the hardest fault to troubleshoot?

A. Cross short
B. Hidden short
C. Floating short
D. Direct short

60. What is an indication of a low power condition?

A. Fast running motors
B. Cool conductors
C. Normal operation
D. Relay chatter

61. Which part of the troubleshooting sequence is used to separate the problem to a particular section of the system?

A. Sectionalization
B. Localization
C. Isolation
D. Operation

62. Which part of the troubleshooting sequence is used to gradually reduce the area until faulty component is isolated?

A. Sectionalization
B. Localization
C. Isolation
D. Repair

63. Which type of pipe is used to distribute natural gas?

A. Galvanized steel
B. Copper
C. Black iron
D. Plastic

64. What is another term for the length of copper tubing that is lost in the assembly?

A. Thread engagement
B. Copper engagement
C. Center engagement
D. Pipe engagement

65. In conducting measurements and calculations on a piping system, what fitting terminology indicates where lines of flow intersect?

A. Center
B. Face
C. Branches
D. Run

66. In conducting measurements and calculations on piping system, what fitting terminology refers to the outer most edge of a run or branch?

A. Center
B. Branch
C. Face
D. Run

67. Which of the following pipe measurement methods is from one end of the pipe to the other end, including both threads?

A. Center to center
B. End to Center
C. End to End
D. Center to back

68. How is the end to center measurement taken?

A. End of the pipe to the end of the fitting
B. Center of fitting to back of other fitting
C. Center of the pipe to the center of the other pipe
D. End of the pipe to the center of the fitting

69. What does a pipe indicate with a fitting at each end?

A. Center to back
B. End to center
C. Back to back
D. Face to face

70. Which of the following measurements encompasses a measurement from the back of one to the back of the other fitting?

A. Face to face
B. Back to back
C. End to back
D. Center to back

71. What is meant by the term frost line?

A. Temperature copper pipe freezes
B. Sewer line cold temperature tolerance
C. Temperature interior plumbing lines need
D. Maximum depth to which the soil freezes

72. Which of the following is the formula used to achieve additional depth digging requirements for a sloped trench?

A. AD = L x DS
B. AD = L/DS
C. AD = DSE – DDE
D. AD = W x DS

73. Whose approval is required prior to excavating any trench used for pipe layout?

A. Crew leader
B. ROICC
C. PWD
D. Crew supervisor

74. How far away does the material removed from an excavation site need to be away from the excavation edge?

A. 6 inches
B. 12 inches
C. 24 inches
D. 36 inches

75. What is the minimum width required for any trench dug by hand?

A. 8 feet
B. 6 feet
C. 4 feet
D. 2 feet

76. How deep do pipes need to be layed when they cross under roads or areas of vehicular traffic?

A. 4 feet
B. 3 feet
C. 2 feet
D. 1 foot

77. What is the purpose of shoring?

A. Prevent pipes from touching the soil
B. Prevent cave-ins of excavation sites
C. Ensure watertight pipe to fitting mating
D. To ensure at least 2 feet of soil is on top of pipe before tamping

78. **(True or False)** If you are working in a trench that is 6 feet deep, and contains hard packed clay, shoring is mandatory.

A. True
B. False

79. What is the depth requirement of a trench containing sandy soil to install shoring material?

A. 1 foot
B. 2 feet
C. 3 feet
D. 4 feet

80. Ladders used in trenches need to alternate from each side at what distance intervals?

A. 50 feet or less
B. 100 feet or less
C. Ladders not authorized for use

81. Ladders, if used, need to extend how many inches above the excavation edge?

A. 6 inches
B. 12 inches
C. 24 inches
D. 36 inches

82. What is the most common method used by UT’s to grade a trench?

A. Engineer’s transit
B. Laser device
C. String line and line level method
D. Carpenter’s level

83. Which of the following is responsible for setting batter boards at the proper level?

A. Builders (BU)
B. Utilitiesmen (UT)
C. Equipment Operators (EO)
D. Engineering Aids (EA)

84. Which of the following is the most common method of grading a pipe?

A. Carpenter’s level
B. String line and line level method
C. Laser Device
D. Engineer’s transit

85. When using an 18 inch level, what size block do you tape to the end?

A. 1/4 inch
B. 3/8 inch
C. 1/2 inch
D. 3/4 inch

86. What is the purpose of testing rough-in piping?

A. Ensure fittings tight
B. Ensure pipe is laid correctly
C. Ensure pipe and fittings can handle working pressure
D. Ensure the joints are tight enough to withstand working pressure

87. When conducting a water test on a pipe laid in a trench, how long must the water been in the pipe prior to starting test (if any)?

A. One hour
B. 30 minutes
C. 15 minutes
D. No time requirements

88. How much air pressure is required to conduct an air test?

A. 5 psi
B. 10 psi
C. 25 psi
D. 60 psi

89. What is the purpose of removing standing water from a trench prior to backfilling?

A. Ensure a clean site
B. Allows for compaction of soil during backfilling
C. Inhibits visual inspection for leaks
D. Remove large rocks and debris

90. When are you authorized to use compaction equipment to tamp down backfill material?

A. Reach 6 inches of compacted backfill above pipe
B. Reach 1 foot of compacted backfill above pipe
C. Reach 2 feet of compacted backfill above pipe
D. Reach 6 feet of compacted fill above pipe

91. How much backfill is required on roads in non- traffic areas?

A. 2 additional inches of backfill
B. No further backfill required due to non-traffic area
C. 6 additional inches of backfill

Trade Terms Introduced in this Chapter

Digits	A symbol used in numerals to represent numbers in positional numeral systems
Place value	A numeral system in which each position is related to the next by a constant multiplier, such as 10.
Positive numbers	A number that is greater than 0, such as 2.
Negative numbers	A number that is less than zero, such as −2.
Oakum	Loose hemp or jute fiber, sometimes treated with tar, creosote, or asphalt, used chiefly for caulking seams in wooden ships and packing pipe joints
Denominators	The name for the bottom part of a fraction. It indicates how many equal parts make up a whole
Numerators	The name for the top part of a fraction. It indicates how many parts of a whole you are working with.
Common denominator	An integer that is a multiple of the denominators of two or more fractions
Lowest common denominator	The least common multiple of the denominators of a set of fractions. The smallest positive integer that is a multiple of the denominators.
Improper fraction	The absolute value of the numerator is greater than or equal to the absolute value of the denominator
Mixed number	The sum of a whole number and a proper fraction, such as 1 2/3.
Primer	a first coat or layer of paint, size, etc., given to any surface as a base, sealer, or the like

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Basic Machines, NAVEDTRA 12199, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

OSHA Regulations (Standards – 29 CFR)

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Naval Construction Force Manual, *NAVFAC P-315,* Naval Facilities Engineering Command, Washington, D.C., 1985.

McPortland, J.E, and Brian J. McPortland, *National Electrical Code® Handbook,* 22d Ed, McGraw-Hill, NY, 2008.

Engineering Aid Basic, NAVEDTRA 10696-A, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Fluid Power, NAVEDTRA 12964, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

National Standard Plumbing Code-Illustrated, National Association of Plumbing- Heating-Cooling Contractors, Washington, DC, 2006.

Safety and Health Requirements Manual, EM-385-1-1, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

MIL-STD-17-1, Mechanical Symbols

MIL-STD-101B

International Plumbing Code 2009, International Code Council

International Mechanical Code 2009, International Code Council

R. Dodge Woodson, *Plumber's Quick-Reference Manual Tables, Charts, and Calculations,* 1st edition, McGraw-Hill, NY, 1996.

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Chapter 3

Fundamentals of Water Distribution

Topics

To hear audio, click on the box.

Overview

Plumbing plays a major role in the construction of all types of residential, commercial, and industrial buildings. Of all the building trades, plumbing is most essential to the health and well-being of the community in general, and to the occupants of the buildings in particular. It is an obligation and responsibility for each and every Utilitiesman (UT) to uphold the vital trust placed in him or her for proper installation of plumbing materials and equipment. Each plumbing installation is governed by the rules and regulations set forth in plumbing codes that have been adopted from standards established at the local, state, and federal level. As you progress in rate as a UT, it becomes your job to ensure that codes established for the job are carried out. You may soon be the supervisor or instructor responsible for training UTs under you.

This chapter will introduce you to the different types of distribution systems used in underground and aboveground piping construction, including the wide array of materials utilized. You will also discover the functions and resources associated with water distribution, service, and storage facilities.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the different types of water distribution systems.
2. Describe the procedures associated with water service.
3. Describe the different types of water storage facilities.
4. Describe the purpose and components of exterior water distribution systems.
5. Describe procedures utilized in tapping water mains.
6. Describe procedures used in building service lines.
7. Describe the purpose and functions of interior water distribution systems.
8. Describe the procedures utilized in the installation of water supply lines.
9. Describe the different types of underground sanitary piping.
10. Describe the different types of above ground sanitary piping.

Prerequisites

None

This course map shows all of the chapters in Utilitiesman Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Utilities Equipment and Maintenance		
Air Conditioning		
Refrigeration		
Heating Systems		U
Steam Distribution Systems		T
Boilers		
Sewage Disposal, Field Sanitation, and Water Treatment		B
Prime Movers, Pumps, and Compressors		A
Plumbing Fixtures		S
Piping System Layout and Plumbing Accessories		I
Structural Openings and Pipe Material		C
Fundamentals of Water Distribution		
Basic Math, Electrical, and Plumbing Operations		
Plans, Specifications, and Color Coding		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.1.1 WATER DISTRIBUTION

Water is circulated from the oceans to the atmosphere by a series of processes and then to the surface of the earth and beneath it. This is known as the water cycle, or hydrologic cycle. An understanding of the occurrence of groundwater is based on a general knowledge of these processes and their relationships to each other. Basically, the cycle consists of the following processes:

- Evaporation of water from oceans
- Condensation of the water to produce cloud formations
- Precipitation of rain, snow, sleet, or hail upon the land surface
- Dissipation of the water by direct runoff into lakes and streams
- Seepage, or infiltration, of rainwater or melted snow into the soil and then into underlying rock formations
- Movement of water through the openings in the rocks and at the surface through springs, streams, and lakes
- Direct evaporation

The cycle usually does not progress through a regular sequence and may be interrupted or short circuited at any point. Moisture that condenses over the ocean may fall into it as rain. Rain that falls upon a heavily forested area soon may return to the atmosphere by direct evaporation or through transpiration by plants. Jungle-covered islands of the Southwest Pacific are known to produce more evaporation than adjacent areas of ocean. Water that seeps into the soil may be retained for a time by soil capillarity, or other means, before moving downward through the unsaturated zone to become a part of the groundwater.

As the rainfall and water cycle repeats itself, depending upon climatic and other conditions, a water supply is built up that can be captured and used for a multitude of purposes.

Water is vitally important to the health and welfare of all personnel. An adequate supply of safe water should be available at all times. This section will familiarize you with some of the basic components of water distribution systems.

Water distribution is the art or method of supplying water, under pressure, from a source or storage point to a user.

This section is an introduction to primary sources of drinking water.

1.1.0 SOURCES

There are three main sources of water: rainwater, surface water, and underground water *(Figure 3-1)*.

1.1.1 Rainwater

Rainwater is used in some areas where water levels in the ground are very deep or nonexistent. Water runoff from roofs is collected in ***cisterns*** and used for irrigation purposes. A cistern is a holding tank for the rainwater. Although rainwater is usually relatively pure, it may be contaminated by the atmosphere or the roof.

1.1.2 Surface Water

Water that runs in streams or is found in depressions, such as lakes, reservoirs, ponds, or oceans, is called surface water.

Figure 3-1 — Sectional view of water sources and relation to the earth.

Most areas ordinarily use surface water for a potable water source. This source is the most plentiful. However, it is also the most easily contaminated. Water must be treated prior to any form of consumption. Depending on the number of contaminants, this process can be quite lengthy and costly.

1.1.3 Underground Water

The underground surface beneath which earth materials, as in soil or rock, are saturated with water is known as the ***water table*** (*Figure 3-2*).

This level does not always remain at the same depth. Depending upon the season or amount of rainfall, it may move up or down. Underground water from a well that has been properly located and constructed is the safest. Commonly in other countries and rural America well water is generally used untreated.

1.1.3.1 Wells

Wells are by far the most common source of water. The object of a well is to make the water lying beneath the water table available for use. If the water table is close to the surface, wells are sometimes dug by hand. Dug wells are rarely deeper than 30 feet.

Figure 3-2 — Water table location.

Hand dug wells may go dry during long rainless periods. When water is not added to the underground supply over a long period, the water table recedes. It can easily go beyond the depth of shallow wells. Hand dug wells are also more susceptible to pollution than are deeper wells.

Another kind of well is called a driven well. The driven well is used in loose, sandy, or highly permeable gravel soils. A device called a well point or drive point (*Figure 3-3*) is screwed into a length of pipe and driven down into the earth with hammer blows. It is one of the easiest methods of establishing a well. However, it is limited to depths of less than 60 feet and to soils that are not too rocky.

Bored wells are shallow (50 feet or less) and dug with a boring rig or a power driven earth auger. Like the drilled well, the bored well is typically lined with concrete tile or galvanized pipe.

Figure 3-3 — Well points or drive points.

Drilled wells are the deepest, (50 feet to up to 1500 feet) the most dependable, and the most pollution free. The Naval Construction Force (NCF) has well drilling capabilities of up to 1500 feet with Table of Allowance (TOA) equipment and specially trained personnel

The wells are drilled down into the water bearing strata. The well is then ***cased***. This means that a large diameter pipe is lowered into the bore. Then, the space around the casing is filled with sand and gravel and then sealed from the surface with a grout made from betonite and cement, to a depth below the polluting effects of the surface. The well pump and draw piping itself is then placed within the casing. Screen sections of well casings allow aquifer water into the casing and the well pump then draws that water from the cased well.

1.2.0 Pressurization and Facilities Types

1.2.1 Low Lift Stations

Lift stations contain the pumps, valves, and electrical equipment necessary to pump water or wastewater from a low elevation to a high elevation. For example, a water lift station pumps source water uphill from a low lying collection point or well to a plumbing system or storage area. Lift stations are also used in a variety of industrial settings, including water management and treatment.

Lift station design includes pumps, level sensing probes, valves and pressure sensors, and may also include a stand-by generator. Lift stations must function in harsh and corrosive environments and are typically made of precast concrete with the pumps and valves accessible through a hatch for cleaning and maintenance.

1.2.2 Booster Pump Stations

In general, there are two types of booster pump station (BPS), open systems and closed systems.

1.2.2.1 Open BPS System

An open BPS system is one which transfers water to a higher pressure zone governed by an atmospheric storage tank (where the water surface is open to the atmosphere), basically pumping from an open air storage tank to a plumbing distribution system.

1.2.2.2 Closed BPS System

A closed BPS system is one which transfers water to a higher pressure zone closed to the atmosphere, pumping from a closed storage tank to a plumbing distribution system.

1.3.0 Water Distribution Systems

1.3.1 oss Connections

Cross connections are direct connections between a potable water supply and system carrying unsafe water.

A cross connection can cause a drastic reduction of the water pressure that could lead to back Siphonage through water pipes.

All pipelines containing unsafe water should be painted red or another color. All these pipelines will have correctly labeled valves and backflow preventers to prevent unsafe water from entering the safe water supply.

1.3.2 Loop System

Loop system will correctly balance and maintain the desired pressure throughout the entire piping system. This system also delivers sufficient water to all use points, meeting maximum demand output.

The system is laid out in a grid or belt arrangement, which prevents dead ends and stagnated water from accumulating in piping.

1.3.3 Direct Piping System

In this system, piping is laid out in a one line configuration (source to fitting). There is no way to balance the load (water supply) to fixtures. If one fixture is open with full pressure, and then another fixture opens, the system will experience a pressure drop throughout. Another disadvantage with this system is that it must be flushed regularly to prevent contamination from stagnated water.

1.4.0 Corrosion Prevention

Corrosion is a constant threat to everything made of metal. It proceeds along its destructive path quietly, and in many instances, unnoticed. Corrosion is a never-ending problem.

Your job will consist of installing and maintaining plumbing systems. This includes the use of pipe, valves, fixtures, and equipment. Most of these items are metal and as such will need protection against corrosion.

1.4.1 finition of Corrosion

Corrosion is the tendency of metal to return to its natural state. This is a result of self-induced electric current flowing from the metal into the soil. Where current leaves a metal, it takes small particles of the metal with it, causing corrosion.

Corrosion is essentially the same in all metal; however, the rate of corrosion will vary in different environments and with different metals. Corrosion is a perpetual problem occurring in all metallic pipelines. In order for any appreciable corrosion to occur, you must have two dissimilar metals in metallic contact with one another and with an electrolyte. Moist soils and water are electrolytes. Water that is 100% pure is not a very effective electrolyte; however, most sources of water contain some degree of impurities.

1.4.2 Types of Corrosion

All corrosion problems and resulting failures of piping systems can be associated with one or more of the basic forms of corrosion. The three types of corrosion we will discuss are galvanic, atmospheric and concentration cell.

1.4.2.1 Galvanic Corrosion

Galvanic corrosion takes place when two dissimilar metals are connected together, commonly copper and galvanized (metal to metal) and in contact with an electrolyte such as water or moist soil. A tool scrape or a cut in the protective coating of a pipe can allow the piping to come into contact with dissimilar metals in the soil. This damage to the protective coating is called a ***holiday***, and can result in accelerated corrosion at the point where the coating is damaged.

1.4.2.2 Atmospheric Corrosion

Atmospheric corrosion normally occurs on aboveground piping due to impurities or corrosive elements in the atmosphere. Water condenses out of the atmosphere and onto the metal. As the water condenses, it absorbs many impurities such as sulfur dioxide, hydrogen sulfide, and carbon dioxide, thus causing corrosion. Atmospheric corrosion is more of a problem in an industrial area or near the sea coast because more corrosive elements will be in the air. Corrosion only occurs while the piping is moist or wet. When the pipe surface becomes dry, atmospheric corrosion stops.

1.4.2.3 Concentration Cell

This form of corrosion is sometimes referred to as “crevice corrosion”, “gasket corrosion”, and “deposit corrosion” because it commonly occurs in localized areas where small volumes of stagnant moisture or solution are present. Normal mechanical construction can create crevices at sharp corners, spot welds, lap joints, fasteners, flanged fittings, couplings, and threaded joints. Deposits that promote concentration cell corrosion can come from a number of sources; other sites for corrosion can occur when electrolyte (moisture) absorbing materials are used for gaskets and the sealing of threaded joints. This form of corrosion can cause severe pitting of the metal surfaces and eventual penetration.

1.4.3 Inspection Procedures

The most important element in fighting corrosion is learning to identify it. Knowing where to look and what to look for is the beginning. Start a visual inspection by looking for signs of corrosion. Check for the physical aspects of corrosion: breaks in protective coatings, dissimilar metal connections, the presence of rust or flaking metal, pitting, and any other signs of corrosion at joints and fittings. Also, look for environmental conditions, such as moisture, polluted air, chemicals and corrosive gases. Any of these conditions will trigger corrosion.

1.4.4 Corrosion Control

According to the Code of Federal Regulations, all metallic pipe installed after July 31, 1971 must be properly coated and have a cathodic protection system designed to protect the entire piping system or other metallic structure. Leaks in systems cause safety hazards, environmental hazards, and interruptions in service.

1.4.4.1 Leak Prevention

There are various reasons for corrosion control. Because of the hazards involved with water and wastewater, and because of environmental concerns, leak prevention is of utmost importance. Using corrosion control methods on metallic piping systems can decrease leaks.

1.4.4.2 System Life

A system will last longer with proper protection installed. Corrosion of buried metallic structures such as mains and service lines are a problem that varies in magnitude from location to location. In some areas metal piping may last more than 30 years. Uncoated or improperly coated pipe may become unserviceable after a period of a year or so depending on location.

1.4.5 Methods of Corrosion Control

There are two common methods of controlling corrosion: Protective coatings and cathodic protection.

1.4.5.1 Protective Coatings

The following are some of the coatings used to protect piping systems. Coatings are used as insulating material. The material isolates the pipe from its surroundings. Coatings may be applied with paint brushes, mops, rags, or at the factory. Before applying the coatings, clean the pipe all foreign matter, such as dirt and debris.

1.4.5.1.1 Asphalt

Asphalt coatings are the most common type of protective coating. Asphalt coatings can take considerable abrasion, impact, and temperature changes without losing effectiveness.

1.4.5.1.2 Coal Tar

Another type of protective coating is coal tar. Although it is less expensive than asphalt and adheres well to the pipe, wide temperature changes could cause the coating to crack.

1.4.5.1.3 Vinyl Coatings

Vinyl paint is a synthetic resin-base paint. This paint dries to a film that is tough, abrasion proof and highly resistant to corrosion. It is odorless, tasteless, non-toxic and nonflammable. The film is especially resistant to oils, petroleum, and solvents. Because of these characteristics, vinyl coatings are often used for gas pipelines.

1.4.5.2 Cathodic Protection

Cathodic protection is the reduction or prevention of corrosion of metal surfaces by making the metal structure to be protected the cathode in the corrosion process instead of the anode. Two types of cathodic protection are (1) ***sacrificial*** anode, and (2) impressed current.

All metals possess a natural electrical potential (Voltage) and each type of metal has a specific natural voltage value. This difference determines which metal will be the anode and which will be the cathode when two dissimilar metals are in direct contact with one another. For example, copper has a natural voltage of +0.34 volts, and iron has a voltage of -0.44 volts. In any electrical system, current flows from negative to positive. When two different metals are connected together, the more positive metal will be the cathode and the more negative metal will be the anode. When these two dissimilar metals are placed in an electrolyte (such as moist soil), electrical current will begin to flow from the anode to the cathode. This electron transfer to the cathode protects the cathode from corroding and causes the anode to disintegrate (corrode).

1.4.5.2.1 Sacrificial Anode (Galvanic Anode)

Use of sacrificial anodes is one method of cathodic protection. The most common type of sacrificial anode is made of magnesium. The anode is packaged in a mixture of gypsum bentonite/sodium sulphate to optimize contact with the electrolyte (soil). The anode is then connected to the pipeline with an insulated wire that is welded to the pipe surface. Electrical current will flow from the anode through the conductor (insulated copper wire) to the pipe. The current then travels along the pipeline and thereby protects it from the effects of corrosion. The anode is corroding by giving off ions that migrate into the soil. Ultimately, the anode will completely dissipate and require replacement. Refer to *Figure 3-4*.

Figure 3-4 — Sacrificial anode.

Sacrificial anode systems are simple and relatively inexpensive when used to protect small systems. Because they rely on the very small naturally occurring voltages between dissimilar metals, their range of protection is limited. Using this type of system on a long pipeline would require the placement of anodes every 40 or 50 feet.

1.4.5.2.2 Impressed Current

Impressed current is designed to protect large metallic distribution systems (such as water supply pipelines). With this method of protection, an AC power source must be available. A rectifier then changes the AC power to DC. The rectifier pulls current from the anodes, and that power flows onto the cathode (the structure to be protected, in this case the pipeline). Simultaneously, the anode is corroding by giving off ions that migrate into the soil. Ultimately, the anodes will completely dissipate and require replacement. See *Figure 3-5*.

Figure 3-5 — Impressed current method of cathodic protection.

The main advantage between a sacrificial anode system and an impressed current system is the range of protection afforded to the pipeline from a single location. Since a galvanic system depends upon the naturally occurring difference in potential (voltage) between the anode and the cathode, its range of protection is limited to a small area. An impressed current system, on the other hand, taps into an external source of electrical power that allows for much higher voltages, multiple anodes, and therefore a much greater range of protection (miles in some cases). In addition, a rectifier allows for greater control and monitoring of the cathodic protection process.

1.5.0 Malfunctions

1.5.1 Reduced Water Flow

Most water contains minerals of one kind or another. They tend to deposit on the inside of water supply pipe, more often on galvanized steel pipe than on brass pipe with its smoother interior. So, after a number of years of use, pipe is likely to become clogged unless it is cleaned out.

Clogged piping reduces the flow of water considerably. These problems can be indicated by insufficient flow, reduced pressure, or head pressure loss. If the pipe is really badly clogged, the best advice is to replace it with new pipe, but there are methods which will clean out some material if the pipe is not too clogged. One is to attach a wire brush to a small metal rod and push it back and forth through a section of pipe, which of course has been removed from the water supply system. Flush it out now and then, and continue until you do not seem to be loosening anything more.

Another method is to take a 2-foot length of small chain that will go through the pipe you desire to clean out. Attach a piece of stout cord which is a little longer than the pipe to be cleaned to each end of the chain. Attach the free end of one cord to a piece of stiff wire and push the wire and then the cord through the pipe.

With the two cords, work the chain back and forth through the pipe several times and then flush out the pipe with water. This method will not clean out everything but it will usually dislodge some of the accumulation of deposits.

A third method is to fill the piece of pipe with diluted ***muriatic*** acid and let it stand overnight or longer. A solution of one part of muriatic acid to seven parts of water is best. Be careful not to spill any on your hands, face, or clothes for muriatic acid is both strong and poisonous. Follow all safety precautions outlined in the Material Safety Data Sheet (MSDS) and all disposal requirements outlined in local Hazardous material (HAZMAT) instructions. Screw a cap over one end of the pipe before pouring in the muriatic acid and cap the other end after the acid is in. Tilt the pipe up and down several times. Later remove the acid and flush out all accumulations it has loosened. Repeat, if necessary.

1.5.2 Pipe Noise

Noise in water pipes is both annoying and indicative of faulty conditions which in time might cause leaks to develop. Steps to eliminate the noise are therefore advisable. Noise in overhead pipes may be the result of lack of sufficient support. When you open a faucet, water rushes through the pipes. When you shut off the faucet suddenly, the momentum of the water is brought to a halt and the pipes vibrate. You may have to install a few pipe hangers. Pipe hangers installed every three or four feet will hold the pipe more rigidly and eliminate vibration.

In cases where pipes cannot vibrate, the momentum of water flowing through them causes what is called "water hammer," a chattering or pounding in the water system when a faucet is turned off. This can be stopped by installing a short piece of pipe next to a faucet to act as a sort of shock absorber.

The water supply line will probably come up to an elbow that turns to come through a wall. Shut off the water, and unscrew the piece of pipe that fits into the faucet. Remove the elbow and replace it with a T connection. Connect a short piece of pipe about 2 feet long with a cap on the end above the T connection, and replace the piece of pipe with the faucet on the end.

1.6.0 Sizing and Specifications

1.6.1 Sizing Factors

You must consider several factors when selecting the correct water supply line size. The following list will provide the minimum factors to consider:

- Water uses: For any structure, identify the use of the water being supplied. For example, does the structure require potable water for cleaning, cooking, or consumption? Will there be installation of water closets (i.e. bathrooms), or is a water supply needed for laundry purposes? Remember, each structure requires water use for fire fighting.
- Peak demand: Water supply lines need to be capable of handling the structure’s peak demand of water supply. For example, High use times such as morning and evening showers and fire fighting supply use.
- Climatic effects: Will the system be installed in a hot, cold, dry, or wet environment? Different kinds of pipes respond differently to different environmental conditions.
- Installation permanency: Will the structure be a permanent or temporary structure? If temporary, you might use a different supply line material then if the structure will be around for many years.

- Minimum size of a supply (main) line will be six inches in diameter. Four inch main may be used with special permission from Naval Facilities (NAVFAC) command.

All of these specifications and pipe sizes will be commonly shown on the project's blueprints and in the written descriptions.

1.6.2 Specifications and Prints

The following pieces of information will be commonly found on specifications sheets and blueprints concerning water supply line installation:

- Pipe material listings
- Trenching requirements
- Bedding requirements
- Backfill requirements
- Valve and fitting requirements
- Any testing procedures required to complete installation
- Any other job information necessary to complete the project

1.6.3 Materials Used

The following table (*Table 3-1*) is a list of materials used in water supply pipe installation, along with the advantages and disadvantages of each:

Table 3-1 — Materials used in pipe installation.

Cast Iron		Asbestos Cement (ACP) Transite		Steel		Plastic	
Advantage	Disadvantage	Advantage	Disadvantage	Advantage	Disadvantage	Advantage	Disadvantage
20 feet lengths	Will not withstand vibration	Free from electrolysis	Low flexibility in small sizes	High tensile strength	Easily corrosive	Lightweight	Easy to rupture or damage
Mech. joints	Heavy to handle/install	Free of corrosion	Subject to impact damage	Flexible	Subject to electrolysis	Easy to use	Storage Issues
Very durable		Excellent flow	More difficult to locate	Withstands great pressure		Impervious to corrosion	
Withstands impact and traffic		Lightweight	Heavy	Choice of connectors		Very flexible	
Easily tapped		Easily tapped		Good flow		Available in several ratings	
Corrosion resistant		Very low maint.				Withstands temperature extremes	
Low maint.		Durable				Excellent flow	
Good flow							
Withstands extreme temps							

1.7.0 Valves, Fittings, and Specialties

1.7.1 Valves

Flexibility in the operation of a water-supply system requires the proper valves for the condition to be controlled. Valves can stop, throttle, or control the flow of water in a pipeline. Other uses include pressure and level control and proportioning flow. The UT rating use a number of different valve designs.

The following is a brief description (more detailed information will be provided in later chapters) of the most common valves you will encounter as a UT.

- Gate – used to stop water flow in main eater lines
- Check – stops the water's reverse flow
- Float – used in wash water tanks and sedimentation basins, and used as an altitude valve in distribution systems
- Globe – controls water by throttling, usually used in small systems
- Altitude – used on inlet lines to stand pipes and elevated tanks to prevent overflow

1.7.2 Fittings

Fittings are essential to the proper operation of water-supply systems. Fittings will be covered more extensively in later chapters. At this time be aware that to reduce water flow resistance, long turn fittings are preferred. When necessary, fittings will be thrust blocked (process of securing pipe bends with concrete to prevent surges in water flow from flexing the pipe or fitting loose). Always remember, the fitting must be compatible with the piping.

1.7.3 Specialties

The following is a brief description (more detailed information will be provided in later chapters) of the most common specialty or accessories you will encounter as a UT.

- Air bleeds – used on high points of systems
- Pressure reducing stations – used when necessary, and placed on lower part of a long downhill run
- Meters – measures leakage and/or branch usage
- Alarms – monitors for reduced pressure, excessive turbidity, chemical makeup, and equipment malfunction
- Chemical feeders – feed chemicals automatically to maintain standards
- Automatic analysis equipment – a continuous and automatic function, which works in conjunction with chemical feeders
- Recording equipment – produces a permanent record of water pressures, chemical makeup and usage

Test your Knowledge (Select the Correct Response)

1. What type of cleaning solution is used to clear mineral deposit build up within the water distribution piping?

    A. Muriatic acid
    B. Adriatic acid
    C. Dutra acid
    D. Boric acid

2.0.0 WATER SERVICE

The water supply system for a building consists of the service pipe, the distribution pipes, and the connecting pipes, as well as fittings and control valves. Water carried by the system must meet accepted standards of purity. Two major functions of a water distribution system are (1) to carry potable water for domestic use and (2) to provide a high rate of flow for fire fighting.

2.1.0 Trenching

Occupational Safety and Health Administration (OSHA) defines a trench as a narrow excavation below the surface of the ground in which the depth is greater than the width, that width not exceeding 15 feet. The stability of soil, weather conditions, excavation depth, and the slope of the sides of a trench all affect the safety of this type of work area.

OSHA requires the use of precautionary measures in unstable work conditions for excavation of a trench that exceeds 5 feet in depth. A ladder must be provided as a means of egress when a trench is 4 feet deep or more, and the ladder must be located no more than 25 feet of lateral travel from the work area.

The slope of the sides of a trench can help ensure a safe workplace. *Figures 3-6 and 3-7* illustrate excavated trenches with stepped (benched) and sloped sides.

Figure 3-6 — Stepped trench.

Figure 3-7 — Sloped trench.

2.1.1 Soil Conditions

The most important factor to determine a safe trench is the soil classification and condition. Various types of soil exist, and their characteristics can change based on temperature and moisture conditions. Soils that provide the safest excavations are cohesive (consistent); if soil conditions vary within a single excavation, the least stable soil is the determing factor in establishing protective measures.

The four basic classifications of soil are described in *Table 3-2*. Each class has its own set of regulations that determines excavation and entry approach. A single type of soil, such as clay, can have several different classifications, depending on numerous factors. Use OSHA standards to train personnel to properly assess different soil classes.

Table 3-2 — Soil classifications.

Class	OSHA Brief Description
Stable Rock	Natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed
A	Cohesive soils with an unconfined compressive strength of 1.5 tons per square foot (tsf)
B	Cohesive soils with an unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf
C	Cohesive soil with an unconfined compressive strength of 0.5 tsf or less
Note: Refer to OSHA information for specific soil types and detailed determinations.	

2.1.2 Safety Issues

Any weight bearing placement near a trench is known as an encumbrance, and the excavated soil is commonly referred to as spoil. Spoil placed too close to the edge of a trench can cause the trench to cave in. Place removed spoil no closer than 2 feet away from edge of a trench. The weight from excavation equipment, vehicles, stored materials, and any other load placed too close to the open edge of a trench creates a safety hazard. A safe trench can become an unsafe job site as a result of rain, temperature changes, vibrations, or other variable occurrences.

Working in any trench raises numerous safety concerns, and each excavation may bring with it unique safety issues. Water in the trench can create a muddy work environment and make it difficult to escape quickly if needed. Water can also cause electrocution if a wire is broken during the excavation phase. Additionally, a trench could potentially become explosive if a propane or natural gas line is leaking. Because of this, locate all underground utilities prior to beginning any excavation.

2.1.3 Additional Requirements

In trenching for waterlines, it is not necessary to set batter boards since laying water pipes to grade does not require great care because the water is under pressure. The pipes in a waterline may follow the contour of the earth’s surface in a trench that is a minimum of 2 feet deep. Minimum depth of the ditch depends upon the depth of the frost line in the area. The trench should be wide enough to permit ease of working around the pipes and to allow placing earth during backfilling. Usually, the trench is not deep enough to require bracing or shoring.

Locate the trench at least 4 feet from a previously dug ditch, or trench, to help prevent cave-ins. Lay water pipes 1 foot above and 10 feet away from nearby sewers. This helps prevent the water distribution system from becoming contaminated by leaks. Sometimes the water main and sewer lines may cross each other. In such cases, the water pipe must cross over the top of the sewer line, so be careful to make all joints tight; however, always check the local specifications and codes before installing them in this manner.

Keep the distribution system free from contamination caused by leaks, back siphonage from faulty plumbing, and cross-connections. The greatest hazard in a distribution system is cross-connection. This is one physical connection to another that is an unsafe or doubtful source of water or a connection or condition that will permit wastewater to enter the potable public supply.

2.2.0 Placing the Pipe

An important phase in the installation of a water system is laying the underground water service pipes.

Regardless of the pipe material you use, anchor sharp bends and dead ends by ***rodding*** or concrete anchors, also referred to as thrust blocks. Where the pipe is setting in saddles, you may use metal straps. Even though the pipe is installed within a ditch, the straps help support and hold the pipe in place. Pipe should be founded on solid trench bottoms. Install automatic air-release and vacuum valves at prominent peaks on long supply mains to permit escape of air while the pipe is being filled and entrance of air when it is being drained. Elsewhere in the distribution system, air normally can be released and taken in through service lines.

Flow in water pipes may be achieved by gravity with an elevated tank or by a pumping system. When pipe must be placed in a sloping trench, make the slope as even as possible to keep the pipe from bending and breaking. After digging the trench, lay the pipe and fittings alongside it. Before you start placing the pipe; shut off the water in the main supply line. The placing should start at the main supply tee.

2.3.0 Backfilling

When you are ready to backfill a ditch, tamp the soil around the pipe by hand or use water. In backfilling, keep the pipe straight and minimize settlement. Soil used to backfill around the pipe should be as free as possible from rocks and debris. Place loose earth free from rocks, broken concrete and frozen chunks in the trench in 6 inch layers and tamp it in place until the crown of the pipe is covered by 12 inches of tamped earth. Throwing fill material directly on the exposed pipe could damage the pipe or move it out of alignment. Drop the fill material on both sides of the pipe at the same time.

When you have water available, use it instead of the tamper, especially when you have a short run to backfill. Fill the ditch completely with loose soil. Attach a piece of pipe to a water hose and push it through the loosely replaced soil until it touches the water main. Turn on the water and let it run until the water appears on the surface. This method allows all the earth to be replaced except the volume equal to that of the pipe.

2.4.0 Water Supply Piping

Some common piping materials used in water-supply systems include cast iron pressure pipe, copper pipe, galvanized pipe, cement asbestos pipe, ductile iron pipe, concrete pipe, and PV-class water pipe. Below are some of the main characteristics of pipe made from these materials and the equipment used.

2.4.1 Cast Iron Pressure Pipe (For Water Mains)

The cast iron pipe used for a water distribution system is somewhat different from that used for waste systems. Some of the major differences are in the length of the pipe, the joints, and the lining. Cast iron soil pipe for waste, as you know, comes in 5 foot and 10 foot lengths. Cast-iron pressure pipe for water mains comes in 20 foot lengths with both bell and spigot or mechanical (gland-type) joints. This pipe may be coated with coal tar pitch or be cement lined; however, uncoated pipe is available if needed for other purposes.

2.4.1.1 Measuring and Cutting

Cast iron pressure pipe is measured by the inside diameter; a ruler or tape is frequently used for measuring. With a cement lining, the lining goes beyond the inside diameter of the pipe, so you have to allow for this reduced inside dimensioning.

To cut cast iron water pipe to the desired length, use either a hand operated chain cutter or a power hacksaw. Because of the construction of this pipe, it does not need reaming after cutting; but, you can use a file to dress down the cut when necessary.

2.4.1.2 Fittings

Three major types of fittings for joining cast iron pipes in water service are tees, elbows, and couplings.

2.4.1.3 Joining

In water service lines, join bell-and spigot cast iron pipe with a sulfur compound. You may also use specially prepared treated paper.

Before making a joint, first check each length of pipe for cracks or splits. After eyeing the pipe for defects, rap it with a hammer. With a little experience, you will know the difference between a good pipe and a bad (cracked or split) pipe.

A sulfur compound is melted on the job. It is then poured into a joint prepared for a cast joint. The fact that it is light in weight is its primary advantage. It requires no caulking and provides a strong joint that is unlikely to blow out. Initially, joints of sulfur compound leak or sweat slightly, but they tighten up in a short time. Since the joints are rigid, do not use them to connect a newly laid line to an old one, as the settlement of a new line can cause a crack. Use a lead joint at the connection.

Mechanical joints are made with rubber sealing rings held in place by metal follower rings bolted to the pipe. This type of joint is designed to permit expansion and contraction of the pipe without injury to the joints.

2.4.2 Copper Pipe

Copper pipe and tubing with soldered joints or flared-tube connectors are used for water service. Copper is highly regarded because of its corrosion resistant properties, flexibility, ease of installation, and low resistance to flow throughout its useful life.

Three types of copper, designated as Types K, L, and M, are commonly used. Type K is used for underground service and general plumbing; Type L for general plumbing; and Type M with soldered fittings only. Types K and L copper come in either straight 20 foot lengths of hard temper or in coils of 50 to 100 feet, soft temper. Type M comes in straight 20 foot lengths, hard drawn only. Vibration can also cause copper tubing to break.

The process used to soften copper is called annealing. The word “anneal” means to soften thoroughly and render less brittle. Copper is unlike steel in many respects. If copper is bent often, it could break when you try to bend it again. Should the pressure on a copper tube increase or decrease too much, the tube could break. Vibration also makes copper tubing break.

To soften steel, heat it to a cherry red and cool it very slowly. The slower it is cooled, the softer the steel becomes. With copper, the opposite is true. Heat copper uniformly to a dull red and then quench (dip) it in water (for water service). The faster it is cooled, the softer the copper becomes.

2.4.2.1 Bending

Copper, properly annealed, can be bent by hand when sharp bends are not desired. Copper partially collapses during the bending process if a tubing bender is not used or if the copper is not filled with some kind of easily removable material, such as sand. You can also make simple

Figure 3-8 — Portable copper pipe and tubing bender.

bends by wrapping the outside of the copper tightly with soft wire and bending the copper by hand; however, if a line must make a 45 or 90-degree bend, use a tubing bender. Hand-tubing benders are available for each size of copper. These benders assist you in making neat, accurate bends easily, quickly, and without marring or restricting the flow through the copper. It is easy to make a bend but difficult to get the bend in the correct location on the copper and to the correct degree. Be certain that you have the correct size bender for the copper you intend to bend. A bender that is either too small or too large for the copper will make a faulty bend. *Figure 3-8* shows one type of tubing bender.

2.4.2.2 Measuring

Seven methods are used in measuring pipe or tubing. They are (1) end to end, (2) center to center, (3) end to center, (4) end to back, (5) center to back, (6) back to back, and (7) face to face. These measurements are also used in measuring threaded galvanized or black iron pipe.

The measurements are generally made with a ruler. Each of the seven methods mentioned above is explained below, and each one is shown in *Figure 3-9*.

2.4.2.2.1 End to End

Indicates a pipe threaded on both ends. The measurement is from one end of the pipe to the other end, including both threads.

2.4.2.2.2 Center to Center

Indicates that there is a fitting on each end of the pipe. The measurement is made from the center of the fitting on one end to the center of the fitting on the other end.

2.4.2.2.3 End to Center

Method applies to pipe having a fitting on one end. The measurement is made from the end of the pipe to the center of the fitting.

2.4.2.2.4 End to Back

Also refers to pipe with a fitting on one end. The measurement is from the back of the fitting to the other end of the pipe.

2.4.2.2.5 Center to Back

Indicates a pipe with a fitting on each end. The measurement is taken from the center of one fitting to the back of the other fitting.

Figure 3-9 — Pipe measurements.

2.4.2.2.6 Back to Back

Measurement refers to pipe with a fitting on each end. Here the measurement is from the back of one fitting to the back of the other fitting.

2.4.2.2.7 Face to Face

Measurement refers to a pipe with a fitting on each end that has an opening directly across from the pipe to which it is connected on both ends. Measure from the face of the opening to the face of the other fitting.

2.4.2.3 Cutting and Reaming

Cut copper with a tubing cutter, when available. Mark the copper where it is to be cut and install the cutter so the cutter wheel is over the mark and you can see the cutting wheel from the top view of the pipe, as shown in *Figure 3-10*. Now turn the adjustment wheel or handle clockwise to force the cutter wheel against the copper. Continue revolving the cutter, turning the adjustment wheel 1/4 turn per rotation until the copper is cut through and separates.

Copper may be cut with a hacksaw, although a tubing cutter is preferable; however, be careful to cut the copper square if it is to be flared. Be sure to use a fine-toothed hacksaw blade, 32 teeth per inch, when cutting copper.

Figure 3-10 — Cutting copper pipe.

Test your Knowledge (Select the Correct Response)

2. When laying water distribution piping underground how far above or below must the piping be from sewer piping?

   A. One foot below
   B. One foot above
   C. Two feet below
   D. Two feet parallel

3.0.0 WATER STORAGE FACILITIES

The operation of storage facilities in the distribution system is largely a matter of maintaining sufficient levels through adequate pumping and controlling water flow through appropriate valves. The two types of water storage are live storage and dead storage.

Live storage, where water is constantly circulating from the supply into the distribution system, is preferred to non-circulating storage because the latter depletes the chlorine in the water and allows tastes and odors to develop. If dead storage is necessary, the operator must maintain a close watch on chlorine residuals and the development of odors and tastes, and report conditions regularly to higher authority.

3.1.0 Types of Storage

CAUTION

Whenever entry is required for confined spaces and storage areas, Only a qualified Gas Free Engineer (GFE) is able to certify a confined space as being safe to enter without the use of respirators. However, the space still requires to be ventilated during entry to ensure adequate supply of breathable air.

Facilities for storage of water include open reservoirs, underground reservoirs, and elevated storage tanks. Ground storage reservoirs may be the same or similar to those shown in *Figure 3-11*. Three types of elevated storage tanks, which you may find at naval activities, are also pictured in *Figure 3-11*. You may also see standpipes used at some activities. Standpipes are, in effect, ground level storage tanks. The distinguishing characteristic of a standpipe is its relatively small diameter and extra height to provide head pressure. Under no conditions should the amount of stored water be reduced to a point below that necessary for fire fighting. Daily records maintained by the operator help ensure against such a condition (*Figure 3-12*).

Figure 3-11 — Types of elevated and ground storage tanks.

Pneumatic water tanks are usually found in use at smaller installations and rural areas with independent wells. They consist of a pressure vessel partly filled with water, and a compressor unit that supplies air pressure to produce the desired water pressure. Pneumatic tanks may be within buildings, on outside surface locations, or underground. While the operation of these units is usually automatic, the operator is responsible for

Figure 3-12 — Standpipe.

the effective operating of pressure equipment. Consult the manufacturer's instructions for methods of starting, stopping, and operating this pressure equipment.

3.2.0 Maintenance of Storage Facilities

Here are the elements in the maintenance of storage facilities: the construction materials- concrete or steel; and the location of the tank-ground level, belowground, or elevated.

3.2.1 Foundations

Commonly all tanks have foundations of either concrete, wood, or steel. Each material has its own maintenance procedures.

Inspect concrete foundations semiannually for settlement, cracks, spalling, and exposed reinforcing. When deterioration has set in, repair the foundation with a mixture of 1 part cement to 1 part sand.

Wood foundations and pads should be inspected for split members, rot, termite infestation, and direct soil contact of untreated wood. Make any repairs necessary to remove the undesirable condition.

Maintenance procedures for steel foundations are similar to those given later in this section for elevated storage tanks.

3.2.2 Concrete Storage Tanks

Concrete storage tanks may be either prestressed or nonstressed design. There is little difference in the maintenance procedures, which depend mainly on the location of the tank—aboveground or belowground.

3.2.2.1 Ground Level Storage

During early spring, inspect ground level storage facilities for water tightness and structural conditions and make repairs as necessary; at other intervals, perform the maintenance procedures set forth in the following paragraphs.

Semiannually, mark exterior walls where leakage or seepage occurs. Every spring, inspect them for seepage or leakage from cracks-breaks or cracks in the interior seal membrane. Dewater the tank and check both the interior and exterior surfaces for spalling caused by frost action, as well as settlement, cracks, and exposed reinforcing.

Remove all loose, scaly, or crumbly concrete and patch the wall with rich cement grout after wetting and painting with Portland cement slurry. Paint hardened grout with iron waterproofing compound or a similar preparation.

Chip out cracks of 1/4-inch width and l-inch depth. Moisten the cleaned crack and paint it with cement slurry. Fill the crack with a rich cement grout, dry enough to stay in place in the crack, but not dry enough to allow it to ***slough*** off. When the grout has hardened, paint it with iron waterproofing compound, or a similar preparation.

When cracks appear in prestressed concrete tanks, refer the problem to the erecting company for recommendations, even if the guarantee has expired or does not cover maintenance.

Every 6 months, check joints for leakage at the juncture of the floor and the walls, and for loose or missing filler, debris, or trash. Clean and repair them as necessary.

Every 6 months, inspect the roof for the condition of the covering. Are roof hatches and other covers locked? Are the screens on the overflow or at other locations in place? Clean them as necessary.

Where the tank rests on an earth embankment, check it for erosion from the lack of full sod or vegetation coverage, and for damage from burrowing animals, improper drainage, ***ponding*** water along the base, or leakage through the embankment or along the outlet piping. When leakage exists through the embankment, drain the tank and inspect the bottom for failure or cracks.

3.2.2.2 Underground Storage

If storage tanks are constructed belowground or are surrounded by an earth embankment, the semiannual inspection and repair cover only the interior walls, roofs, accessories, and embankment. The inspection procedures and maintenance operations are the same as described above for ground level storage facilities. When the earth embankment, surrounding soil, or interior of the tank shows evidence of tank leakage, you may need to excavate the earth and make repairs on the walls.

3.2.2.3 Elevated Storage

Concrete storage tanks elevated aboveground require the same inspection and repairs as outlined above, where applicable.

3.2.3 Steel Storage Tanks

Usually, outside contractors maintain and repair steel tanks. At times, though, you may have to perform various inspection and maintenance duties, such as those discussed in the following sections.

3.2.3.1 Ground Level Storage

Annually, after the winter season, inspect steel storage tanks for ice damage, water tightness, and structural conditions. Twice each year, follow the maintenance procedures set forth in the following paragraphs.

Inspect tank walls (exterior and interior) and bottom (interior) semiannually for rust corrosion, loose scale, leaky seams and rivets, and for the condition of the paint (both inside and out). Adhere to the following maintenance procedures:

1. Replace rivets or patch leaking areas, and follow by cleaning and painting.
2. Check painted surfaces for rust, corrosion, cracking, peeling, ***alligatoring,*** caulking, fading, or complete loss of paint. Empty the tank and examine the interior paint, as corrosion is more likely on the inside. When the interior needs painting, arrange to take the tank out of service. Paint the tank interior as often as the exterior (more often if the stored water is corrosive) unless the tank is equipped with cathodic protection.
    - Make certain that the paint used will protect the metal against corrosion. Consult the applicable guide specifications for paint selection and application.
    - Use only new coat if the previously applied coat is in fair condition. Paint bare spots of steel with a spot or patch coat before applying the finish coat. When the condition of the old paint is bad, use a complete primer coat.

Every 6 months, inspect the roof and its appurtenances, (screens on overflows, hatches, and manholes), as well as the condition of the paint. Adhere to the following maintenance procedures:

1. Make certain that hatch covers and manholes are in place and locked and that screens are in place to prevent the entrance of birds, insects, and animals.
2. If the spider rods under the roof have corroded, remove them, as they are needed only during erection.
3. Paint the roof, selecting the proper paint for the particular location.

As pointed out earlier, standpipes are, in effect, ground level storage tanks. Inspection and maintenance procedures for standpipes are the same as those for ground level steel storage tanks.

3.2.3.2 Underground Storage

When steel storage tanks are constructed belowground or are surrounded by an earth embankment, the semiannual inspection and repair include only the interior of the tank, the roof, and the accessories. The inspection and maintenance procedures are the same as those for ground storage steel tanks.

3.2.3.3 Elevated Storage

Refer to *Figure 3-11*.

Besides the inspection and maintenance procedures set forth above for ground storage steel tanks, the following specific procedures apply to elevated storage steel tanks.

Semiannually, check tower structures for rust and corrosion, loose, missing, bowed, bent, or broken members; loose sway bracing; misalignment of tower legs; and evidence of unstableness. The following items must be covered:

1. Inspect the back surface of the lattice bars and anchor bolts inside of boxed channel columns and the pockets where batten plate connections and column bases form pockets for collecting trash and water. Clean and paint these enclosures, and fill them with concrete as necessary to shed water.
2. Check the bases and the base plates for evidence that water has collected at that point; if you find water, drill a 1 1/2-inch hole through the channel-boxed section to allow complete drainage. Then grout the base plate with a mixture of sand and asphalt to prevent water from running under the plates. Taper the grout from the top edge of the plate to the pier.
3. Check the sway bracing and tighten the turnbuckles if necessary. Examine under clevis pins and rod loops where corrosion may be greatest. Drill holes in the balcony floor to eliminate standing water.

Besides general roof inspection and repair, as described for ground storage steel tanks, inspect obstruction and navigation and relamp them if necessary. Additional items that should be covered are as follows:

1. Check the operation of all other lights; check hoods, shields, and receptacle fittings; look for missing or damaged parts. Repair or replace parts as necessary.
2. Check lightning rods, terminals, cables, and ground connections.

In cold climates, potable water storage tanks (with small riser pipes) and elevated storage tanks (for fire protection only) usually have heating equipment to prevent freezing in severe low temperatures. Conduct the following checks:

1. Annually, 2 months before the freezing season, inspect the riser for deterioration of the frost covering. Seal any openings to reduce heat loss. Also, check the heating system to ensure proper operation during the next cold season.
2. Annually, 1 month before the freezing season, operate the heating system for 8 hours to check all elements under operation.

3.2.3.4 Cathodic Protection Equipment

Only impressed current cathodic protection systems are used for protecting steel water storage tanks against corrosion. This system of protection may be applied to all types of steel water tanks-ground level standpipe, underground, and elevated. Other applicable procedures are as follows:

- Annually, note and record the current flow during the operation. If the current does not flow, check the fuses, electrodes that contact the tank, ground wire connection to the tank, and the immersion of electrodes. If the equipment is operating at voltages or amperages above those listed on the nameplate, the rectifier may be damaged.

⚠ CAUTION ⚠

Make certain that the connections to the rectifier are not reversed. Reversed connections will result in tank damage.

- Annually, check the operating record to determine if the electrodes are immersed at all times, or almost all the time. If the electrodes are not immersed, there will be no damage to the unit; however, the electrodes provide no protection when they are not immersed.
- Annually, check the anode condition and replace the anodes as necessary. Also, check the current flow; if it has diminished since the previous inspection, the anode probably needs to be renewed.
- Annually, in freezing climates, protect electrodes from ice, which may tear them from their hangings or damage them. If ice formation is severe, turn off the current, remove the electrodes, store them until the freezing season is past, and then reinstall them.
- Annually, test the effectiveness of the cathodic protection system in one of two ways.

1. Scrape and polish a spot on the tank wall at a point always immersed. At quarterly intervals, lower the water and inspect the spot; if protection is adequate, the spot will remain uncorroded.
2. Suspend two polished mild steel test plates in the tank at an elevation where they will always be immersed (use No. 6 galvanized steel wire). Ground one plate to the tank wall, but have the other plate insulated from the tank. The extent of corrosion on the grounded plate will come close to the corrosion of the protected tank; the extent of corrosion on the other plate is a measure of the corrosion that would occur if the tank were not protected.

3.2.4 Pneumatic Tanks

As pneumatic tanks are usually on smaller installations, they may be too small for interior inspection, except for observations through a removable hand plate. The size, therefore, determines the inspection procedures to follow. Standard inspection procedures are as follows:

- Always refer to the manufactures instructions if available.
- Quarterly, inspect the air pump and motor to make certain both are operating properly. Check the operating record to determine the time cycle of air pump operation. If the records show a decreasing time cycle, check for possible air line leaks.
- Quarterly check valve operations; particularly, check the pressure relief valve. Repair or replace as necessary.
- Annually, check the tank for signs of corrosion, both internally and externally. If corrosion products are apparent, take the following action:

1. If the tank is large enough to permit the entry of personnel, paint the inside with corrosion resistant paint or line it with cement. If the tank is too small to permit entry, consider changes in operation or in chemical treatment to reduce corrosiveness of water. Corrosion is most likely in areas alternately exposed to air and water.
2. Paint the exterior as needed.

3.2.5 Appurtenances

Every 6 months, ladders, walkways, guardrails, handrails, stairways, and risers should be inspected for rust, corrosion, poor anchorage, loose or missing pieces, or other deterioration or damage. Standard inspection procedures include the following:

1. Be sure to check ladders inside as well as outside the tank. Replace worn, corroded, or missing parts; check for deteriorated lugs and rungs as necessary, and make other repairs to ensure safety for the operators. Check revolving ladders on the roof for the condition of connection at the final hookups.
2. Ensure the bolts, screws, rivets, and other connections are tight.
3. Inspect the condition of the altitude valve vault and the valves for proper operation. Repair, clean, and paint all equipment when necessary.
4. Check the water level indicator for improper operation and repair when necessary.
5. Inspect the cathodic protection equipment and repair when necessary.
6. At semiannual intervals, check the electrical connections to lights, cathodic protection, and so forth, for breaks in the conduit. Remove the conduit inspection plates and examine the internal connections for tightness and adequacy; also check relays for weak springs, worn or pitted contacts, and defective operation. Repair and eliminate all undesirable conditions.

3.2.6 Grounds

At semiannual intervals, remove all accumulations of dirt, trash, debris, and excess foliage in the area surrounding the storage tank.

Test your Knowledge (Select the Correct Response)

3. Water storage tanks are made of what two materials?

   A. Concrete and iron
   B. Concrete and steel
   C. Steel and plastic
   D. Steel and iron

4.0.0 EXTERIOR WATER DISTRIBUTION SYSTEMS

4.1.0 Source

Water may be obtained from several sources, such as lakes, rivers, streams, and reservoirs. Since water is constantly subject to pollution from the natural environment, it must be treated to make it safe for human consumption. Private wells are another source of supply if public water service is not available. Well water must be analyzed by a recognized water-testing laboratory and certified by health authorities before it is used.

4.2.0 Pumps

Pumps convey water under pressure from the source to the point of use. Pumps may be classified as primary, booster, or emergency. Primary pumps are those which provide movement of the water through the system. They are located at the source and treatment plant. Booster pumps may be installed at various points in the system to increase and maintain water pressure. They may be used at pumping stations when water must be moved a long way from the source to the treatment plant. They may also be used to lift water to storage tanks. Emergency pumps are used in case of breakdown or to satisfy fire-fighting requirements. Pumps are available in an incredible variety of designs and sizes. They can also be driven by a variety of power sources and prime movers.

4.3.0 Treatment Plant

Water is pumped from a source to a water treatment facility. After going through the treatment process, the water is potable (fit to drink), and is usually palatable (tastes good).

4.4.0 Piping

The piping system consists of feeder mains *(large pipes that supply water)*, distribution mains, and service lines. Distribution mains are the pipes that distribute the water throughout a base or community. They include any lateral or branch lines. Service lines transport water from the distribution mains to the various buildings and facilities. The two standard designs used for exterior water distribution systems are the tree design and loop design. Rarely will you find a system that does not incorporate some features of both designs.

In a tree design system, smaller lines branch off the main line and come to a dead end. When the system must be worked on, the entire "branch" of the system must be isolated, stopping water service to many facilities in that area. Refer to *Figure 3-13, View A*.

In the loop system, the lines branch off but return to the main line forming an integrated grid or loop. The loop design is preferred over the tree design because if one line breaks in a loop system, it can be isolated without interrupting the flow of water to the majority of users within that area. Refer to *Figure 3-13, View B.*

Figure 3-13 — Tree and loop design networks.

4.5.0 Control Valves

Control valves are installed throughout the distribution piping and are used to start and stop flow. They may vary by type and design, but the majority of them will be gate valves. Many of these valves are located below the ground surface in valve boxes. The valves are placed at strategic points in order to isolate the system for maintenance or repair. Refer to *Figure 3-14*.

Figure 3-14 — Curb stop.

4.6.0 Fire Hydrants

Fire hydrants must be placed in all areas where there is a need for fire protection. Proper operation and use of hydrants is essential to water distribution, economy, and safety. Every fire hydrant should have its own isolation valve for maintenance or repair of the hydrant. Refer to *Figure 3-15*.

4.7.0 Water Usage

The quantity of water needed on a military installation depends on several factors. They include the number of military personnel living on base, the number of civilian employees, fire-fighting needs, irrigation, and industrial use.

Figure 3-15 — Types of fire hydrants.

5.0.0 TAPPING WATER MAINS

5.1.0 Tapping Machine

Taps made in water mains are also the point where water service lines begin. The self-tapping machine, shown in *Figure 3-16*, is a specialized tool for tapping a water main that is under operational pressure.

It consists of a tubular body strapped to the pipe to be tapped. An intermediate tubular section contains a check (flop) valve that can be opened or closed as necessary, and an upper portion with a handle that is turned to tap the pipe. By using this tool, it is possible to tap a hole in an operating water main as shown in *Figure 3-16*, and install a corporation stop while the main is under operating pressure.

Figure 3-16 — Water main self tapping machine.

5.2.0 Tapping Procedures

Excavate the area around the water main. Clear away enough soil from around the main to provide sufficient working space. Thoroughly clean the part of the main where the tapping machine will be installed. Attach the self-tapping machine to the main. Start the tapping process.

NOTE

Many manufacturers produce different types of tapping machines to tap water mains that are under pressure. Their basic principle of operation is the same; however, their operating procedures may vary. For this reason you should always follow the operating instructions provided by each individual manufacturer.

After the combination drill/tap has penetrated through the main, reverse the ratchet to remove the drill bit. Install corporation stop. Remove the tapping machine and check for leaks. Flush the main to remove any debris that may be in the system.

5.2.1 quirements for Tapping Various Pipes

The maximum size of a tap will be determined by the material that the main is made of and the size (diameter) of the main. Water mains are generally made of cast iron, Polyvinyl chloride (PVC), Chlorinated polyvinyl chloride (CPVC), or asbestos cement.

5.2.1.1 Tapping Cast Iron

When tapping cast iron pipe that is 8 inches in diameter or less, the largest tap you should make is 2 inches. A general rule to go by is; the tap should not be larger than one quarter (1/4) the diameter of the pipe. This rule applies to cast iron and PVC mains.

5.2.1.2 Tapping Asbestos Cement Pipe

When tapping asbestos cement pipe 6 inches or less in diameter, the largest tap you can make is 3/4 inch. Use a 1 inch tap for larger pipe.

When larger taps are required, build a manifold or install a tee in the line. Build a manifold by making a series of taps in the main and connecting them. Space the taps at least 10 inches apart (*Figure 3-17*).

5.3.0 Tapping Using a Tapping Saddle

A tapping saddle is installed around the pipe to be drilled. The saddle has a leak proof gasket. A strap is placed around the pipe and tightened to clamp the saddle and gasket in place. The drilling machine is then attached securely to the tapping saddle and used to drill a hole into the main. The corporation stop is screwed into the saddle. See *Figure 3-18*.

The tapping saddle and drilling machine are used to drill holes from 1/8 inch to 2 1/8 inches under normal conditions.

Figure 3-17 — Service line manifold.

Figure 3-18 — Tapping saddle.

6.0.0 BUILDING SERVICE LINES

The water service line, commonly referred to as a “building service line”, begins at the distribution main and extends into the building. A typical water service line is illustrated in *Figure 3-19*. This line is comprised of a corporation stop, a flexible connector, a curb stop, a stop and waste valve, and a meter stop or gate valve.

Figure 3-19 — Water service from main to the building.

6.1.0 Corporation Stop

The corporation stop is the first component in a water service line. It is a valve that is joined directly to the distribution main when the main is initially tapped. It is a quick opening valve that is buried in the open position and not accessible from ground level. Flexible connections protect the corporation stop from damage. See *Figure 3-20* for examples of corporation stops.

Figure 3-20 — Corporation stops.

6.2.0 Flexible Connections

The flexible connection protects the corporation stop from strain or damage that might result from any movement of the water main or service line due to settling, earth movement, and expansion or contraction. There are several types of flexible connectors. The type of connector to be used will depend upon the type of piping material used for the water service line.

6.2.1 Swing Joint

The swing joint is a type of flexible connection commonly used with a galvanized steel service line (*Figure 3-21*). The connection consists of two elbows separated by a short section of pipe or a nipple. A nipple is a short piece of pipe with threads on each end, used for joining valves. The flexibility of the threaded joints at the two elbows will protect the corporation stop from strain or damage in the event of any movement of the pipe after the trench is backfilled.

6.2.2 Expansion Loop

When copper tubing is used to fabricate the service line, form an expansion loop in the line near the connection to the corporation stop. The expansion loop is a short length of soft drawn copper tubing that has been formed into a loop. The loop provides lateral or vertical flexibility depending on which way the line is installed.

Figure 3-21 — Typical swing joint.

6.3.0 Curb Stop

The curb stop (*Figure 3-22*) is a valve that provides an accessible shut-off to a service line. It is located underground on the service line outside the building. Curb stops allow isolation of the service line for repair or maintenance. They are normally gate or ball valves. The curb stop should be installed with a valve box for ease of access and maintenance.

Figure 3-22 — Curb stop.

6.4.0 Stop and Waste Valve

A building service line should be equipped with a stop and waste valve (*Figure 3-23*), which may be used for draining purposes. The stop and waste valve is designed with a drilled passage through the disc on the side of the valve body that provides a way to relieve system pressure or to drain the system. When the valve is closed, the water at the inlet side stops flowing. The water on the outlet or building side of the valve drains through the drilled passage in the valve body.

Figure 3-23 — Stop and waste valve.

6.5.0 Curb Boxes

Curb boxes, often referred to as valve boxes, are installed when underground valves must be accessible for on/off operations at ground level (*Figure 3-24*). This is often the case when the components of the water distribution system require maintenance or repair. Curb stops and meter stops are some of the buried valves that require valve boxes.

Valve boxes are normally made of cast iron, plastic, or concrete. The yoke (or base) must be centered over the valve to provide sufficient space to engage the operating handle. The valve box must then extend upright to ground level. Many manufacturers make valve boxes with extension tubes that can be adjusted by sliding or screwing the extension tube up or down. It is important that the weight of the box does not rest directly on the valve or the piping. You can accomplish this by placing bricks or stone supports under the bottom edges of the valve box. This will prevent the box from settling, which could damage the valve or piping. Valve boxes are often covered with a cap to prevent access by unauthorized personnel and to prevent debris from entering the valve box. It is important to periodically clean and maintain valve boxes so that they fulfill their function of providing protected access to valves.

Figure 3-24 — Curb box.

6.6.0 Sizing of Service Lines

Water pressure is important to consider when sizing a service line. The types of flushing devices in a facility are an important factor in determining water supply pressure. Flushometers require more water pressure than a gravity tank flushing system can provide. The length of the building service line also needs to be considered. The longer it is, the more pressure it will take to transport the water to the building. You must know what type of fixtures and how many there are in order to supply enough water for all of them. You must determine how often the fixtures might be used and the height of the building. Each fixture that is installed must have adequate water supply pressure. Pipe diameters for rough-in of various fixtures are shown in the *International Plumbing Code (IPC) Handbook*, Table 604.5 and *Table 3-3* below.

Table 3-3 — Minimum pipe size for plumbing fixtures.

PLUMBING FIXTURE	PIPE DIAMETER (Inches)
Dishwasher	1/2
Water closet tank	3/8
Water closet with flushometer valve	1
Water closet with flush valve	1
Water closet, one piece	1/2
Urinal with flushometer valve	3/4
Urinal with flush tank	1/2
Lavatory	3/8
Shower bath	1/2
Kitchen sink	1/2
Slop sink	1/2
Scullery sink	3/4
Laundry tray	1/2
Drinking fountain	3/8
Water heater (domestic)	3/4
Bathtub (all sizes)	1/2
Bidet	3/8
Combination sink and tray	1/2
Hose bibs	1/2
Wall hydrant	1/2

As water flows through pipe and fittings there is a resistance. The higher the flow and the smaller the pipe, the higher the resistance. In addition to calculating for head loss you also need to consider friction loss. Determine size of the pipe and the number and type of fittings used along with the distance of the run. Friction loss is also experienced when water needs to be pumped above the service line water level. As the level or height increases, as does friction loss. Booster pump and pressure tanks are used where the normal system pressure is low and needs to be increased.

The stream of water in the pipe can be pictured as a series of layers of water traveling at different speeds with the center moving the fastest. The resistance to flow caused by these layers is called pipe friction. In a small pipe, this friction loss may be overcome by supplying water at a higher pressure than otherwise would be required. In a location where higher water pressure is not available, friction loss may be reduced by increasing the size of the pipe.

Test your Knowledge (Select the Correct Response)

4. Which of the following flexible connections is commonly used with a galvanized steel service line?

   A. Expansion loop
   B. Expansion joint
   C. Swing joint
   D. Swing loop

7.0.0 INTERIOR WATER DISTRIBUTION SYSTEM

The building water distribution system includes all the hot and cold water piping needed to supply installed fixtures. A shutoff valve, commonly a stop and waste valve, is installed just inside the building. The piping extending from this point becomes the cold water distribution main. Water is thus conveyed to various points throughout the building. Most of the piping is installed when the framework of the building is under construction. It is done at this time because it is easy to run the piping to the desired points in the wall for the various fixtures. For this fact it is imperative that you work with Builders (BUs), Steelworkers (SWs) and crew leaders to develop rough-in, installation, test and finishing schedules to maintain the projects critical timelines.

7.1.0 Piping Materials

Galvanized steel piping is used extensively in interior water distribution systems. Swing joints are constructed to allow for flexibility in the water lines. Piping is screwed together with threaded fittings. Galvanized steel piping comes in 21 feet lengths.

Copper pipe or tubing is also used for interior water distribution systems. It is an easy material to work with, which makes it very popular. However, it costs more than other piping materials. Hard drawn copper is the most commonly used; however, soft drawn copper can also be installed.

CPVC is the only plastic pipe used for interior plumbing. It is commonly used for interior distribution systems because it is easy to install, will not rust, rot or corrode, and is very inexpensive. CPVC is a plastic pipe made to withstand temperatures of 180° and 100 psi of pressure.

Cross-linked polyethylene (PEX) is a high-temperature, flexible plastic (polymer) pipe. The cross-linking raises the thermal stability of the material under load. Thus, the resistance to environmental stress cracking, creep, and slow crack growth are greatly improved over polyethylene. PEX pipe is approved for potable hot and cold water plumbing systems. PEX tubing is light weight, and it can withstand operating temperatures of up to 200° F. It is flexible and can easily be bent around corners and obstacles, and through floor systems. Sizes of PEX tubing range from 3/8-inch to over 2 inches.

7.2.0 Cold Water Distribution

Buildings will have a cold water distribution system. As you can see in *Figure 3-25*, branch lines are connected to the distribution main by using a reducing tee, nipple, and a 90° elbow. This arrangement is called a swing joint.

Figure 3-25 — Water supply branch line.

The fixture supply risers are vertical pipes connected to the branch lines by means of a 90° elbow. Risers should be supported at each floor level and at joints. It is also necessary to support these risers near fixture outlets (*Figure 3-26*). These headers and braces will hold the pipe in position.

7.3.0 Hot Water Distribution

The hot water distribution system begins at the water heater. *Figure 3-26* shows both hot and cold supply lines. Branch lines are installed to run horizontally at a slight grade toward the shutoff valve or stop and waste valve (This allows you to drain the system).

Install a gate valve at the base of a riser that supplies a large number of fixtures, such as those in a multistory building. With this arrangement, you can shut off the water

Figure 3-26 — Water distribution pipelines.

supply in any given section without turning off the water supply to other portions of the building.

7.4.0 Sizing Interior Supply Piping

7.4.1 Water Distribution System Design Criteria

In accordance with the IPC, Article 604.3, the water distribution system shall be designed, and pipe sizes shall be selected such that under conditions of peak demand, the capacities at the fixture supply pipe outlets shall not be less than shown in *Table 3-4* below and Table 604.3 of the IPC.

Table 3-4 — Water distribution system design criteria.

Fixture Supply Outlet Serving	Flow Rate (gpm)	Flow Pressure (psi)
Bathtub, balanced-pressure, thermostatic or combination balanced-pressure/thermostatic mixing valve	4	20
Bidet, thermostatic mixing valve	2	20
Combination fixture	4	8
Dishwasher, residential	2.75	8
Drinking fountain	0.75	8
Laundry tray	4	8
Lavatory	2	8
Shower	3	8
Shower, balanced-pressure thermostatic or combination balanced-pressure/thermostatic mixing valve	3	20
Sillcock, hose bibb	5	8
Sink, residential	2.5	8
Sink, service	3	8
Urinal, valve	12	25
Water closet, blow out, flushometer valve	25	45
Water closet, flushometer tank	1.6	20
Water closet, siphonic, flushometer valve	25	35
Water closet, tank, close coupled	3	20
Water closet, tank, one piece	6	20

7.4.2 Size and Length of Fixture Supply Piping

The minimum size of a fixture supply pipe is shown in *Table 3-3*. The fixture supply pipe shall not terminate more than 30 inches from the point of connection to the fixture. A reduced size flexible water connector installed between the supply pipe and fixture shall be of an approved types, as detailed by the IPC. The supply pipe shall extend to the floor or wall adjacent to the fixture.

Test your Knowledge (Select the Correct Response)

5. When installing a service sink, what is the minimum flow pressure value needed?

   A. 2 psi
   B. 4 psi
   C. 6 psi
   D. 8 psi

8.0.0 INSTALLATION OF WATER SUPPLY LINES

All fixtures have different rough-in (piping that is installed in walls, floors, and ceilings during construction phase before wallboard is installed) requirements. In this section we will discuss the water supply
rough-in requirements to fixtures.

8.1.0 Lavatories

8.1.1 ough-In Specifications

If you install a lavatory, it may be a wall hung, pedestal, counter top, or trough type. Therefore, it is important for you to have the manufacturer's rough-in specifications for the installation. You will probably be given a sheet like the one shown in *Figure 3-27*. It will give you the rough-in dimensions you will need to do the job correctly.

8.1.2 Hot and Cold Water Rough-In

Figure 3-27 — Lavatory specifications.

When roughing-in a lavatory, you must install both the hot and cold water supply lines. Install the hot water line on the left side of the lavatory and the cold water on the right. The left and right side are determined while facing the lavatory. The minimum sized pipe used to supply water to a lavatory is 1/2 inch.

8.1.3 Mounting Board

A 2 inch x 6 inch mounting board (hereafter referred to as a backing board) is used to support a wall hung lavatory. The backing board must be nailed between the studs (*Figure 3-28*) before the sheet rock is installed. This board serves as an anchor for the bracket screws because sheet rock is not strong enough to support the weight of the fixture.

8.2.0 Urinals

There are four basic types of urinals; wall hung, pedestal, trough, and stall. Each type is different and the water supply rough-ins to them will also be different.

Figure 3-28 — Mounting board.

8.2.1 ough-In Specifications

To obtain rough-in measurements for a urinal, consult the manufacturer's rough-in specification sheet (see *Figure 3-29*). As you can see, this sheet shows two views of the unit and indicates the measurements you need for rough-in purposes.

8.2.2 Cold Water

The urinal requires only a cold water supply line.

8.2.3 Line for Flushometer

The minimum size pipe used to supply water to a flushometer type urinal is 3/4 inches.

8.2.4 Line for Tank Type Flushing

Figure 3-29 — Flush type wall hung urinal.

In the United States, tank type urinals are rarely found, these types of fixtures however are still common in many European Countries. The minimum size supply line for a tank type urinal is 1/2 inch.

8.2.6 Backing Board

Use a 2 inch X 6 inch backing board to support a wall hung urinal. Use only brass screws and bolts when installing a urinal because of their resistance to corrosion.

8.3.0 Water Closets

Water closets require a considerable flow of water to maintain necessary sanitation. The greatest possibility of contamination exists at these fixtures because of the quick growth of bacteria. Piping systems for water closets must be installed according to the manufacturer's specifications to increase their efficiency and minimize maintenance costs.

8.3.1 ough-In Specifications

Refer to the manufacturer's specification sheet prior to roughing-in a water closet.

8.3.2 Cold Water Supply

Water closets require only a cold water supply.

8.3.3 Supply for Tank Type Flushing

The minimum size pipe used to supply a tank type water closet is 1/2 inch. The rough-in will extend approximately 1 1/2 inch through the wall. Once the wall is "finished", screw an angle stop valve onto the rough-in nipple. *Figure 3-30* shows the specifications of a tank type water closet.

8.3.4 Supply for Flushometer Type Flushing

A flushometer type water closet requires a 1inch supply because of the large volume of water needed for flushing action.

Figure 3-30 — Tank type water closet.

8.4.0 Bathtubs/Showers

8.4.1 ough-In Specifications

Before roughing-in water supplies to a fixture, you must know the type of fixture to be installed. The type of fixture is identified on the blueprints for the particular job. Refer to the manufacturer’s rough-in specifications for the rough-in piping measurements.

Figure 3-31 shows an example of a manufacturer’s rough-in specifications for a bathtub and shower combination. The rough-in sheet gives two views and the necessary measurements for correct location and installation of rough-in piping for the fixture.

8.4.2 ot and Cold Water Supply

The hot and cold water supply risers are connected to the branch by means of a 90° elbow. It will extend above the finished floor to the heights given for that particular fixture indicated in the manufacturer's rough-in specifications. Both hot and cold water supply lines are 1/2 inch in diameter and are installed 8 inches apart.

8.4.3 Mixing Valves

Mixing valves can have three handles, two handles, or only one which can be used to adjust the temperature of the water and control flow. Installation of the mixing valve, the riser for the shower head, and the piping for the tub spout are all part of the rough-in of the fixture.

Figure 3-31 — Rough-in specifications for a shower and bathtub combination.

8.4.4 Header Board

A 2 inch x 4 inch header board is cut to fit snugly between the studs. The header has two holes drilled through it 8 inches apart. They should be drilled only large enough to accommodate the piping. The header will support and align the risers (*Figure 3-32*).

9.0.0 UNDERGROUND SANITARY PIPING

9.1.0 Sanitary Drainage Piping

Among the pipe materials installed underground by UT's are cast-iron soil pipe, vitrified clay pipe, concrete pipe, and plastic pipe.

Figure 3-32 — Header installation.

9.1.1 Cast Iron Soil Pipe (CISP)

Cast-iron soil pipe and fittings are composed of gray cast iron made of compact, close-grained pig iron, scrap iron and steel, metallurgical ***coke***, and limestone. Cast-iron soil pipe is commonly used in and under buildings, protruding from 2 to 10 feet from the building. (The IPC recommends at least 3 feet.) Here it connects into a concrete, plastic, or clay house sewer line. Cast-iron soil pipe is also used under roads or other places of heavy traffic.

When the soil is unstable, it is better to use cast iron soil pipe; however, do not use cast-iron soil pipe in soil containing cinders or ashes; the reason is that the soil may contain sulfuric acids, which cause the pipe to corrode and to deteriorate rapidly.

NOTE

When the soil contains cinders and ashes, instead of using cast-iron soil pipe, use vitrified clay or plastic pipe.

The cast-iron soil pipe used in plumbing installations comes in 5- and 10-foot lengths. Sizes of cast-iron soil pipe are 2, 3, 4, 6, 8, 10, 12, and 15 inches nominal inside diameter. It is available as single hub or double hub in design, as shown in *Figure 3-33*. Note that single-hub pipe has a hub at one end and a spigot at the other. The double hub pipe has a hub at both ends. Hubs, or bells, of cast-iron soil pipe are enlarged sleeve-like fittings. In previous common plumbing practices they were cast as a part of the pipe and were used to make a water and pressure-tight joint with oakum and lead. This is particularly important to know when working on, rehabbing or demoing older plumbing services. These joints were made with a lead compound and are significant lead hazards as such they should be handled with care and reported to your crew leader and safety petty officer immediately.

Figure 3-33 — Single hub and double hub cast iron soil pipe.

Cast-iron soil pipe is generally available in two weights: standard or service (SV) and extra heavy (XH). The extra heavy pipe is used where superior strength is required, for example, under roadways, where the pipe may vibrate or settle slightly, and tall stacks. Standard or service weight pipe is adequate for most Navy base construction.

9.1.1.1 Measuring

Cast-iron soil pipe sections are generally 5 and 10 feet in length, but strictly speaking, this is not true. The reference to a 5-foot length of pipe applies to the laying length, not the overall dimensions. For clarity, first note that cast-iron soil pipe in 2, 3, 4, and 6 inch (inside) diameter sizes are in common use. The length of the bell for the 3 inch diameter pipe is 2 3/4 inches; and for the 4 and 6 inch diameter sizes, the length is 3 inches. Now note that while the laying length of a 4 inch diameter cast-iron soil pipe is 5 feet, the overall length is 5 feet 3 inches.

The most common measurement of cast-iron soil pipe, for a shorter length than 5 feet, is the overall measurement. When making this measurement for 4 inch pipe, take the desired length of pipe for the installation and add 3 inches to it for the bell.

9.1.1.2 Cutting

Before joining cast-iron pipe, you often have to cut the pipe to provide the desired length. Cast-iron soil pipe can be cut with an abrasive cutter, a band saw, a hydraulic manual snap or ratchet cutter (*Figure 3-34, Views A and B*), or a hammer and chisel. The hammer and chisel method is slow and used only when other cutting tools are not available. Here is a step-by-step procedure for cutting with a hammer and chisel.

Figure 3-34 — Ratchet cutter and squeeze cutter.

- Mark or score the pipe with a triangular file or wrap your belt around the pipe and mark the cut line with soap stone.
- Lay the pipe over a board or mound of earth at the point to be cut to support the pipe (*Figure 3-35*) and allow it to turn easily.
- Score the pipe with a cold chisel (not too sharp). Move the chisel a little at a time along the mark, tapping lightly with a hammer until the pipe is evenly scored all around.
- Continue to turn the pipe and strike the chisel with increasingly heavy blows until the pipe breaks on the line evenly.

Figure 3-35 — Supporting soil pipe for cutting.

Another means of cutting a short piece, 1 or 2 inches, is with a hacksaw and an adjustable wrench. Cut a groove with the hacksaw around the pipe to a depth equal to one half of the wall thickness of the pipe. Break away the section of pipe using an adjustable wrench as a lever, as shown in *Figure 3-36*.

A good point to remember is that if you must cut a short piece of CISP, cut it from a piece of double hub pipe. Thus the remaining pipe still has a hub and can be used.

Figure 3-36 — Cutting cast iron pipe with hacksaw and adjustable wrench.

9.1.1.3 Fittings

CISP fittings are used for making branch connections or changes in the direction of a line. Both CISP and fittings are brittle, so exercise care to avoid dropping them on a hard surface. Some of the CISP fittings you may use in your work are described below.

A number of different types of bends are generally used on jobs involving CISP. Some of the common types are the 1/16, 1/8, short sweep 1/4, long sweep 1/4, and reducing 1/4 bend. Look at *Figure 3-37* to get an idea of the shape and appearance of each of these types of bends.

Figure 3-37 — Types of CISP bends.

The 1/16 bend is used to change the direction of a cast-iron soil pipeline 22 1/2 degrees. A 1/8 bend is used to change the direction of a cast-iron soil pipeline 45 degrees. The SHORT SWEEP 1/4 bend is a fitting used to change the direction of a cast-iron soil pipeline 90 degrees in a short space. The LONG SWEEP 1/4 bend is used to change the direction of a cast-iron soil pipeline 90 degrees, but more gradually than the short sweep 1/4 bend. The REDUCING 1/4 bend gradually changes the direction of the pipe 90 degrees, and in the sweep portion, it reduces nearly one size. A 4 by 3 reducing long sweep 1/4 bend has a 4-inch SPIGOT on one end, reducing 90 degrees to a 3 1/4-inch HUB on the other end. Note that for all CISP fittings, the spigot end is always listed first.

Tees connect branches to continuous lines. Learn to recognize the four designs of tees shown in *Figure 3-38*. For connecting lines of different sizes, REDUCING tees are often suitable.

The TAPPED tee is frequently used in the venting system; it is called the main vent tee. The SANITARY tee is commonly used in a main stack to allow the takeoff of a CISP branch.

Figure 3-38 —CISP tees.

The TEST tee is used in stack and waste installations where the vertical stack joins the horizontal sanitary sewer (*Figure 3-39*). It is installed at this point, so the UT can insert a test plug and fill the system with water in testing for tightness. The test tee is also used in multistory construction.

Figure 3-39 — Typical stack and vent installation.

Four types of CISP 90-degree Y-branches are in general use, as shown in *Figure 3-40*. These are normally referred to as combination Y and 1/8 bends.

The STRAIGHT type of 90-degree Y-branch has one section that is straight through and a takeoff on one side. The side takeoff starts out as a 45-degree takeoff and bends into a 90-degree takeoff. This type of branch is used in sanitary sewer systems where a branch feeds into the main, and it is desirable for the incoming branch to feed into the main as nearly as possible in a line parallel to the main flow. Refer to *Figure 3-40, Slide 1*.

The REDUCING 90-degree Y-branch is similar to the straight type; however, as shown in *Figure 3-38*, the branch takeoff of the 90-degree Y-branch is smaller than the main straight-through portion. It is generally used in the same way as the straight type, except the branch coming into the main is a smaller pipe than the main. *Figure 3-40, Slide 2.*

Figure 3-40 — Types of CISP, 90° Y-branch.

The DOUBLE 90-degree Y-branch (or DOUBLE COMBINATION Y and 1/8 BEND) is easy to recognize since there is a 45-degree takeoff bending into a 90-degree takeoff on both sides of the fitting, as shown in *Figure 3-38*. It is very useful as an individual vent. *Figure 3-40, Slide 3.*

The BOX type of 90-degree Y-branch has two takeoffs. It is designed for each takeoff to form a 90-degree angle with the main pipe. The two takeoffs are spaced 90 degrees apart. *Figure 3-40, Slide 4.*

There are two types of cast-iron soil pipe 45-degree Y-branches. These are the reducing and the straight types; both are shown in *Figure 3-40*.

The REDUCING type is a straight section of pipe with a smaller size 45-degree takeoff branching to one side. There are different sizes of this fitting. As an example, a 4 by 4 by 3 reducing 45-degree Y-branch has a 4 inch straight portion with a 3 inch 45-degree takeoff on one side. *Figure 3-40, Slide 5.*

The STRAIGHT type of 45-degree Y-branch, or true Y, is the same as the reducing type, except that both bells are the same size. It is used to join two sanitary sewer branches at a 45-degree angle. *Figure 3-40, Slide 6.*

Cleanout plugs are installed to permit removal of stoppages from waste lines. *Figure 3-41 View A*, shows one type of cleanout plug. It consists of an iron ferrule caulked with the hub of a pipe or fitting. The top opening is taped and threaded, so a pipe plug can be screwed into it. Do not place cleanouts more than 50 feet apart in horizontal 4 inch building drain lines in a straight run. When the change of direction is greater than 45 degrees (or a 1/8 bend), you should install a cleanout plug.

The long hub, or Sisson, type of cleanout (*Figure 3-41, View B*) is used as an insert to an existing line. The long hub allows you to push it up far enough to clear the other bell of the bottom pipe, and then to drop the fitting in place.

Figure 3-41 — Adapter type CISP fittings.

Another type of adapter is a sewer thimble (or saddle). This is a special fitting used to tie into an existing sewer line, as shown in *Figure 3-41, View C*. It has a hub on one end, bending around to almost 45 degrees, with a flange near the opposite end. To install, cut a hole halfway between the top and the center line in the sewer line. The hole should be the same size as the outlet portion of the thimble beyond the flange. Slip the thimble into the opening until the flange seats on the sewer pipe. Using oakum and concrete, grout around the thimble to make a watertight joint.

The increaser (*Figure 3-42*) is used to increase the size (diameter) of a straight-through line. It is often used at the top of a main stack and vent.

Figure 3-42 — Increaser.

A closet bend (*Figure 3-43*) is a special fitting inserted into a soil branch. This enables the soil branch to be fitted to the water closet. It may be untapped or have either one or two side taps for waste to vent use. Closet bends are made in different styles to fit different types of closet flanges (rims for attachment). One type (*Figure 3-43 View A*) has a spigot end for caulking into the branch line and a scored end (marked with lines) to fit into the closet flange. The scoring makes it easier to cut the bend to the desired length for a given connection. Another type, shown in *Figure 3-43 View B*, has a hub connected to the closet flange with a sleeve or short length of pipe. The end attached into the soil line is scored for cutting to size. Still other types may be scored for cutting at both ends or may be of the regular hub-and-spigot pattern.

Figure 3-43 — CISP closet bends.

Regular offsets, *Figure 3-44 View A*, and 1/8 bend offset, *Figure 3-44 View B*, are used to carry the soil or waste lines past an obstruction, such as a part of the building. The 1/8 bend offset gives a smoother transition than the regular one. Fittings for no-hub cast-iron pipe are identical to the others, except there are no hubs.

Figure 3-44 — Offsets.

9.1.1.4 Joining

There are various methods for joining pipe. This means that you must know the procedure to make various types of joints required for the kind of pipe to be joined. Compression joints and no-hub joints are means for connecting pipes. *Figure 3-45* shows these types of joints.

In making attached joints, you need various types of equipment. Because of the importance of this equipment, this section will discuss the common types of attaching equipment and safety procedures to observe when making attached joints.

Figure 3-45 — Various joints used to connect CISP fittings.

In making a compression joint, be sure to clean the internal surface of the hub and the external surface of the pipe and/or fitting to be joined. When using a cut pipe, remove the sharp edge by peening or by lightly filing the rough edge to permit the pipe to slide and NOT gouge into the gasket. Insert the gasket into the hub, and make sure the retaining flange or collar of the gasket is next to the face of the hub. Be sure to use the recommended lubricants available (normally soap or an adhesive type). Apply them to the inside of the gasket. Align the spigot and hub to be joined, keeping the spigot and hub in a straight line. The spigot end of the pipe or fitting can be forced into the gasket with an assembly tool.

To join CISP as a no-hub joint, place a neoprene or an elastomeric gasket on the end of one pipe and the stainless steel shield and clamp assembly, commonly referred to as a no hub coupling, as shown in *Figure 3-46*, on the end of the other pipe. Firmly seat the pipe ends against the integrally molded shoulder inside the gasket. Slide the shield and clamps into position over the gasket and tighten the stainless steel clamps alternately and firmly to about 60 inch-pounds of torque.

Figure 3-54 — No hub pipe and fittings.

No Hub fittings are NOT to be used under slab and must be accessible.

9.1.2 Vitrified Clay and Concrete Pipe

Vitrified clay pipe is made of moistened powdered clay. It is available in laying lengths of 2, 2 1/2, and 3 feet and in diameters ranging from 4 to 42 inches. Like CISP, it has a bell end and a spigot end to make joining easy.

After the pipe is taken from the casting, it is glazed and fired in large kilns to create a moisture proof baked finish. It is used for house sewer lines, sanitary sewer mains, and storm drains. The types of fittings for clay pipe are primarily bends, tees, and Y-branches.

You may have to use plain precast concrete pipe for sewers in the smaller sizes (less than 24 inches). This pipe is not reinforced with steel. This concrete pipe is similar to vitrified clay pipe in measuring, cutting, joining, and handling.

9.1.2.1 Handling and Storage of Clay Pipe

Be careful when you store and handle clay pipe because it is very fragile and cracks easily. Never drop clay pipe or roll it down an embankment without control. Do not drop heavy objects on clay pipe. When backfilling a trench, do not use fill with rocks or other heavy debris in it. Tamp by hand or by pneumatic tampers, bearing in mind the density of the backfill. Lay clay pipe in a trench and bed it evenly and firmly. The more perfect the bedding, the greater the load the pipe can sustain. Common sense can save a lot of time by eliminating rework.

9.1.2.2 Cutting

Vitrified clay and concrete pipe, both available in short lengths, seldom need cutting except for manholes and inlets. If, after measurement, you have to cut vitrified clay or concrete pipe, score it with a chisel, deepening the cut gradually until the pipe breaks cleanly at the desired point. Vitrified clay and concrete pipes may also be cut with CISP "snap-off' or "chain" cutters.

9.1.2.3 Fittings

Figure 3-47 shows some common fittings used with vitrified clay and concrete pipes. Note that these types of pipes are used outside the building. This greatly reduces the number of different types of fittings required.

Figure 3-47 — Gross section of clay or concrete fittings.

9.1.2.4 Joining

Joints on vitrified clay and concrete pipe may be made of cement or ***bituminous*** compounds. Cement joints may be made of grout, which is a mixture of cement, sand, and water. The following procedure may be used as a guide in joining pipe with grout. The procedure for joining pipe with bituminous compounds is very similar.

- Insert the spigot of one length of pipe into the bell of the other and align the two pieces to the desired position.
- Caulk a gasket about 3/4 inches thick into the bell to prevent the grout from running into the pipe.
- Mix grout, using 1 part Portland cement, 2 parts clean, sharp, washed sand, and sufficient water to dampen thoroughly.
- Fill the joint with grout, using a packing iron.
- Recaulk the joint after 30 minutes with a packing iron. You have to close shrinkage cracks that occur after the initial set of the grout.
- Smooth and bevel the grout off with a trowel. In hot weather, cover the joint with a wet burlap sack.
- Remove excess mortar with either a swab or a scraper.

Note that a regular swab, with some additional rags tied to the end to compensate for larger size pipe, is ideal for dragging through each length to remove the excess mortar.

The use of “speed seal joints” (rubber rings) in joining vitrified clay pipe has become widespread. Speed seal joints eliminate the use of oakum and mortar joints for sewer mains. This speed seal is made a part of the vitrified pipe joint when manufactured. It is made of permanent polyvinyl chloride and called a “***plastisol*** joint connection.” This type of joint helps to ensure tight joints that are root-proof and flexible.

One person can quickly and easily install the speed seal, or mechanical seal. To make the joint, first insert the spigot end into the bell or hub.

Then give the pipe a strong push, so the spigot locks into the hub seal. A solution of liquid soap spread on the joint will help it slip into place easily. Other types of mechanical seal joints are also available. They all use about the same method of installation. Special mechanical seal adapters are made to join vitrified clay pipe with CISP or CISP to vitrified clay pipe.

9.1.3 Plastic Pipe

At first, plastic was used for lawn sprinklers, farm water systems, and acid drainage from mines. Now plastic pipe is used for all kinds of applications, from shipboard installations to municipal water treatment and domestic water uses.

The advantages of plastic pipe or as it is commonly referred to, Polyvinylchloride (PVC), include resistance to nearly all acids, caustics, salt solutions, and other corrosive liquids. It does not scale, pit, corrode, or rust. Bacteria do not grow well, and it is also nontoxic. PVC piping has very low-friction resistance because of its smooth, inner surface. Being nonconductive, it is not subject to electrolytic corrosion. PVC piping can be used underground in acid, alkaline, wet, or dry soil without a protective coating. It is strong and can handle operating pressures in most moderate service processes within the temperature range of that particular material. PVC piping is light in comparison to metal. Finally, it can be easily joined in a wide variety of methods. Each method has a certain advantage.

9.1.3.1 Handling and Storing of PVC Piping

When unloading PVC piping, do not drop it on the ground. Remember, scratches and gouges from dragging it on rough surfaces tend to reduce the pressure-carrying capacity. Store PVC piping on racks to prevent sagging. Remove burrs and sharp edges on storage racks before storing the pipe. Store PVC piping in a shaded area away from any source of heat that could cause damage to the pipe. During prolonged storage, do not stack it more than 2 feet high because the weight causes it to flatten or go out of round. Before installing PVC piping, inspect all pipe and fittings for cuts, scratches, buckling, and kinks that should be cut out. Also, store piping out of direct sunlight, as it breaks down the chemical compound makes it brittle and unserviceable.

9.1.3.2 Cutting

When cutting PVC piping, use a miter box, when utilizing the following types of saws: fine-toothed hacksaw, circular saw, band saw, or reciprocating saw with carbide-tipped blades. Pipe and tube cutters can be used when adapted with a deeper cutting blade made for cutting PVC piping. DO NOT USE a tubing cutter. The cutting wheel will not cut deep enough, and the outside diameter (OD) of the pipe will become larger. Use a miter box or hold-down rig to help cut the pipe square. Remove all burrs and chips from both the inside diameter (ID) and OD of the pipe. Level the end of the pipe to approximately 1/16 inch to 3/32 inch at a 10-degree to 15-degree angle. This minimizes the wiping of solvent from the ID of the fitting, as the pipe is put into the socket. You can bevel the end of the pipe with a coarse file or special beveling tool.

9.1.3.3 Fittings

Plastic flanges and flange fittings (*Figure 3-48*) are available in a full range of sizes and may be attached to the pipe. Soft rubber gaskets are preferred with plastic flanges. When tightening flange bolts, pull them down gradually to a uniform tightness and in a diametrical manner, as shown in *Figure 3-49*.

Figure 3-48 — PVC piping fittings.

Figure 3-49 — Diametric order of tightening flange bolts.

9.1.3.4 Joining

There are four methods of joining PVC piping: solvent welding, fusion welding, fillet welding, and threading. These types are mentioned here and explained in detail in chapter 4 of this manual.

9.1.3.5 Placing PVC Piping in the Ground

On hot days, after the plastic pipe has been cement solvent welded, it is a good idea to snake the pipe beside the ditch or if the ditch is wide enough, in the ditch during its required drying time. DO NOT APPLY STRESS TO or DISTURB A JOINT THAT IS DRYING. Snaking gives added length to the pipeline to compensate for thermal contraction as the pipe cools. When the temperature change is less than 30°F, snaking is not necessary. When cement solvent welding on a hot, summer day during the late afternoon, be sure to snake the line. Since the pipe dries during the cool of the night, the thermal contraction of the pipe could stress the joint and pull the pipe apart due to inadequate time for the cement to cure.

9.1.3.6 Testing

Always refer to your Quality Control (QC) department for test procedures and requirements.

Testing should be done in two intervals:

1. The initial test should be a low-pressure hydrostatic test. (Air or gas is NOT recommended.) This test should never exceed 50 pounds per square inch gauge (psig). When testing with a gauge, allow the pipe to remain under pressure for a few hours; then check to see if there is a pressure drop. If the pressure drops, there is a leak. If there is a leak, walk the pipeline and closely inspect it, checking each joint closely. After locating the leak, repair it, and pressurize it again using LOW pressure.
2. After completion of the low-pressure test, place the pipeline in the trench (if not tested in the ditch) and backfill, leaving the joints exposed. Constantly and uniformly support the throughout its entire length. DO NOT SUPPORT WITH BLOCKS. Conduct the high pressure test at 1 1/2 times the working pressure and hold it for at least 12 hours. Leaks found on the pipe itself should be cut out completely and replaced by using fittings (couplings). Backfill in the early morning during hot weather. Cover the pipe 6 to 8 inches with backfill free of rocks and debris. It is advisable to maintain a pressure of 15 to 20 psig on the pipeline while backfilling to keep from damaging it. Support anchors, valves, boxes, and so forth, separately to prevent additional stress or bending from the pipe. Piping, under roadways or railroads, should be done with sleeving (metal or concrete). Isolate the pipe direct contact with the concrete. When pouring concrete anchors, wrap the pipe with rubber or other protective material. If the anchor is for axial movement, use the solvent welding process to weld a split collar to the pipe to provide the needed protection. When solvent welding collars on the pipe, allow 48 hours for drying time before pouring concrete.

9.2.0 Sanitary Drainage Installation

Assemble small pipes and join them in sections on top of the ground and lay them in the trench by hand. Large, heavy pipes are usually laid in the trench and then joined. These pipes may be lowered into the trench by rope, cable, or chain. Larger pipe may require the use of machinery operated by an Equipment Operator (EO) or licensed individual.

When assembling and joining pipes outside the trench, make sure you are a safe distance from the edge of the trench to prevent cave-ins. Also, do not leave tools or materials near the edge of a trench where workers may knock them off and injure themselves or lose their footing and fall into the trench.

Lay sewer pipes on a compacted bed of sand, gravel, or material taken from the trench excavation, if suitable, to provide a slightly yielding and uniform bearing. This step assures safe support for the pipe, the fill, and the surface loads. When pipes are laid on sand, gravel, or similar material, the weight of the pipe usually provides a suitable equalizing bed.

Embed pipelines carefully, so they do not settle at any point. Settling causes suspended matter to collect in the lower portion of the pipe, restricting the flow and reducing the handling capacity of the line.

9.2.1 Trenching and Grading

After you have laid the pipes, your next step is to check the grade and align the pipeline. This is very important in installing an underground sewer system. Remember, sewage does not flow uphill, unless of course you are using forced main or a pump, as a lift station does. Lay the pipe so the flow of the sanitary waste in each length of pipe flows from the hub end to the spigot end or we could say the hub end is upstream. Place each length of pipe starting at the lowest elevation and working up the grade; therefore, the spigot is inserted into the hub of the length laid previously. Check each length for grade and alignment before placing the next length.

When you are grading for the proper pitch per foot, use the method shown in *Figure 3-50* as a guide. This figure shows a ditch with batter boards used in transferring line and grade to trench and also shows a stick for checking grade.

Figure 3-50 — Laying sewer pipe to line and grade.

An Engineering Aid (EA) is responsible for setting the batter boards at the proper level for the job at hand. Batter boards are placed across the trench at about 25 to 50-foot intervals. Elevations are run by an EA, and a mark is placed on the stakes at some even-foot distance above the invert (the lowest point on the inside of the pipe) of the sewer. A nail is then driven in the top of the batter boards, and a cord is stretched from board to board. The center line for the pipe is then transferred from the cord to the bottom of the trench by means of a plumb bob. Grade is transferred by means of a stick, marked in even-foot marks, having a short piece fastened at a right angle to its lower end. Grade is checked by placing the short piece on the invert of each length of sewer pipe and aligning the proper mark on the grade rod to the cord.

9.2.2 Testing

After completing the rough-in piping of a project, test and inspect all the piping for leaks. The purpose of testing the pipeline is to make sure the joints are tight enough to withstand working pressure.

Before covering the pipe, test it for leakage. There are several methods of effecting this test. The most widely used is the water test, although you may use an air test or odor test.

9.2.2.1 Water Test

Here are the main steps in making a water test, commonly referred to as a Stack test. At the lowest point of the section to be tested, insert a test plug in the open end of the pipe or a test tee, like those shown in *Figure 3-51*, and plug other openings. Fill the pipe to its highest level with water; an IO-foot head is required. Leave the water in the pipe for at least 15 minutes before starting the test. This allows the oakum to soak up some water before you look for leaks. If necessary, refill the pipe to overflow and check each joint for leaks.

9.2.2.2 Air Test

Before making an air test, fill the system with water and allow it to stand. Drain the water from the lines and reinsert the test plug. Close all openings and apply air pressure of at least 5 pounds per square inch (psi). In a satisfactory test, the line should hold 5 pounds psi for 15 minutes. If it does not, cover the joints with a soapy water solution and check for bubbles at the leak.

9.2.2.3 Odor Test

Before making an odor test, plug all openings in the sewer and the branches. After sealing the openings, pour 2 ounces of oil of peppermint in each line or stack. Then pour approximately 1 gallon of boiling water into the stack and seal it. The odor of peppermint at any point in the installation indicates a leak. The inspector, checking the installation for leaks, should not be near the oil of peppermint at any time before the inspection. Such exposure rapidly dulls his or her sensitivity to the odor of peppermint. The peppermint test is not as conclusive as the water and air tests described above, since there is no pressure on the pipe.

Figure 3-51 — Test plugs and test tees.

NOTE

Repeat tests as necessary until all the leaks are located and repaired.

Where a system of pipelines has been installed using gaskets, test one floor at a time. Should there be more than one floor to be tested, be sure all bends, changes of direction, and ends of runs are restrained (limited).

9.2.3 Manholes

Normally, it is not your responsibility as a UT to construct manholes. They are made of concrete or brick; however, you may be working with the Builders (BU) in spotting the location for the manholes. *Figure 3-52* shows a typical drop manhole.

Figure 3-52 — Standard drop manhole for sanitary or storm drainage system.

Watertight manholes are made of brick or concrete, 4 feet in diameter at sewer level. Place them at junctions and bends in the line. Space them preferably 300 feet apart for 8 inch pipe, 400 feet apart for 10 to 15 inch pipe, 500 feet apart for 18 to 48 inch pipe, and 600 feet apart for larger sizes. Lay sewers straight to line and grade between manholes; changes in the size of sewer lines must take place only at the manholes. The crown of the outlet pipe from a manhole should be on a line with or below the crown of the inlet pipe. When the invert of the inlet pipe is more than 2 feet above that of the outlet pipe, provide a drop manhole to conduct the sewage to a lower level with minimum turbulence.

9.3.0 Backfilling and Tamping

After all pipelines have been laid and tested, they are ready to be covered; this process is known as backfilling and tamping. Use the method described below for sewer lines.

Tamp fine material, free from stones and other debris, in uniform layers, that are commonly 6 inch lifts, with a small hand or air operated tamper under, around, and over the pipe. Use a hand shovel to backfill the ditch until the pipe has a 2 foot covering. Place this fill in the ditch and tamp it in 4 inch layers or less. It should proceed evenly on each side of the pipe, so injurious side pressure cannot occur. Make sure you do NOT walk on the pipe until you have at least 1 foot of soil tamped over the pipe. Until 2 feet of fill has been placed over the pipe, the filling should be done carefully with hand shovels; after that, machinery may be used for faster backfilling. However, do not let the machinery run over the line.

Puddling, or flooding, with water to consolidate the backfill should NOT be done for a sewer line. The sections of pipe are in short lengths and tend to settle very rapidly to form pockets or low spots in the line.

Test your Knowledge (Select the Correct Response)

6. Which of the following tees are used in stack and waste installations?

   A. Tamped
   B. Test
   C. Tapped

10.0.0 ABOVEGROUND SANITARY PIPING

After the underground piping is installed for a sewer system, the next phase is to install the aboveground piping. The following sections provide information on materials applicable to the installation of aboveground sewage piping. Installation procedures are the same for aboveground and underground sewer pipe.

The sanitary waste system collects wastewater from plumbing fixtures such as water closets, sinks, tubs, showers, and lavatories and allows it to flow by gravity through the piping to a treatment plant. Waste piping systems are installed to allow the waste to gravity flow through the piping as much as possible. Therefore, horizontal piping in the sanitary waste system is generally sloped at 1/4 inch per foot. Large diameter pipe may be sloped slightly less.

Knowledge of these systems are important for two fundamental reasons: (1) During residential construction, detailed drawings of waste systems are not usually available, therefore, you may have to design the system yourself (based on your knowledge of the function and purpose of system components) and, (2) During commercial construction jobs, knowledge of system design and function is required to install more complicated systems within the requirements of the plumbing code.

10.1.0 Terms and Definitions

10.1.1 Soil Pipe

Pipes that carry fecal matter and discharges from water closets.

10.1.2 Waste Pipe

Pipes that carry liquid waste, free of fecal matter and discharges, from fixtures other than water closets.

10.1.3 Stack

Vertical systems of soil, waste, or vent piping extending through one or more stories.

10.1.4 Branch

Any part of the piping system other than a main, riser, or a stack; normally any horizontal pipe in a waste system is generally referred to as a branch.

NOTE

Piping sizes are defined by the length of sections, and by the inside diameter (ID).

10.1.5 Building Drain

The building drain is the lowest part of a building's drainage system that receives the discharge from soil, waste, and other drainage pipes inside the building, and conveys it to the building sewer, which begins two feet outside the building wall.

10.1.6 Building Sewer

The horizontal piping of the drainage system, which extends from the end of the building drain (2 feet outside the building), is called the building sewer. It conveys the discharge it receives from the building drain to a public sewer, private sewer, individual disposal system, or other point of disposal.

Refer to *Figure 3-53* for locations of above terms.

Figure 3-53 — Basic sanitary waste system components.

10.2.0 Types of Pipes

A number of different types of pipes are used in the aboveground and interior parts of a plumbing system. Some of the common types of pipes are discussed briefly below.

10.2.1 Galvanized Wrought Iron Pipe

Excellent material for aboveground plumbing, it is costly. It is available in lengths from 18 to 22 feet. Galvanized wrought iron pipe is constructed of wrought iron dipped in molten zinc to protect it from corrosion and provide high resistance to acid waste.

10.2.2 Acid Resistant Cast Iron Pipe

Composed of an alloy of cast iron and silicon. It is used to serve chemical laboratories and other installations through which acid waste flows. In handling acid resistant pipe, such as Durion™, be careful because it is very brittle and cracks easily. It is cast in 5 foot lengths and comes in single and double hubs.

The types of joints made with cast iron soil pipe are: bell and spigot pipe, which uses a compression gasket; and no hub pipe, which uses no hub couplings. Disadvantages of using cast iron pipe are that it is heavy (which requires more supports) and subject to corrosion. In addition, cast iron piping is difficult to cut and fit.

10.2.3 Brass Pipe

Consists of an alloy of zinc and copper. Brass pipe has a smooth interior and can resist most acids; however, it is expensive. It is available in 20 foot lengths; because it tends to bend, it must be supported at intervals of 8 to 10 feet.

10.2.4 Lead or Lead Lined Steel Pipe

Used to carry distilled water for batteries; however, tin lined, block tin, glass, or some types of plastic pipe must be used where no impurities are acceptable. Because it bends easily, lead pipe must be well supported. It is available in three weights: (1) standard, (2) common, and (3) extra heavy. The standard weight is most commonly used.

Galvanized steel pipe may be used for small drains and vent piping. It should not be used for drains attached to urinals because it will quickly corrode and leak. Most galvanized pipe is standard weight and will be joined by threaded joints.

10.2.5 Copper Pipe

Suitable for use in waste, vent, and water installations. Remember that ammonia and water corrode copper and bronze lines. Also, when you use copper for waste pipe installations, always make sure it is rigid to overcome sagging. You can obtain the pipe in convenient lengths, then cut it to size for the job at hand.

10.2.6 Plastic Pipe

Suitable for use aboveground for sewage, venting, and water.

Plastic pipe is commonly used on interior drainage systems. Plastic piping is lightweight, easy to install and will not rust, rot, or corrode. PVC and Acrylonitrile-butadiene-styrene (ABS) are the most commonly used piping for constructing interior Drainage Waste and Venting (DWV) systems. They will be of either Schedule 40 or DWV thickness and can be joined by specifically formulated solvent glue. PVC is by far the most commonly used plastic pipe material.

10.3.0 Common Sanitary Waste Fittings

There are waste fittings designed for virtually any situation that you may encounter during the installation of a sanitary waste system. The text below addresses only the most commonly used.

10.3.1 Bend

Bends are used for making turns in a run of waste piping. The degree of turn a bend provides may be expressed in terms of degrees or fractions. For example, a bend that makes a 45 degree turn is called a 1/8 bend and a bend that makes a 90 degree turn is called a 1/4 (quarter) bend. See *Figure 3-54*.

10.3.2 Closet Bend

The closet bend is a 90° or 1/4 bend with a long branch designed specifically for making a connection between a closet flange and a soil stack. See *Figure 3-55.*

10.3.3 Wye

A wye is used to change the direction of flow less than 90%. It usually branches off a pipe at a 45% angle. See *Figure 3-56*.

Figure 3-54 — Types of bends.

Figure 3-55 — Closet bend.

Figure 3-56 — Wye connection.

10.3.4 Sanitary Tee

A sanitary tee is used for branching off of a pipe at a 90 degree angle. See *Figure 3-57.* Most often the sanitary tee is used to change the direction of flow from a branch or horizontal drain to a stack. The branch opening of the fitting is gradually sloped to gently guide the wastewater from the branch into the vertical piping of the stack. Branch openings of the sanitary tee may or may not be tapped. The term "tapped" indicates that the opening of the fitting has female pipe threads. A sanitary tee cannot be laid on its back or side because when a sewer auger is used for unclogging, the auger can go in either direction in the line. To avoid this situation a wye or wye and 1/8 (*Figure 3-56*) bend should be used.

Figure 3-57 — Sanitary tee.

10.3.5 Test Tee

The primary purpose of the test tee is to test the system. It is normally the first fitting on top of the stack base. A plug is threaded into the branch opening to seal the system. The plug stays in place except when performing leak tests. If no provisions have been made for cleaning the sanitary sewer system, the test tee can be used as a clean out because it is shaped similar to a sanitary tee. Ensure that you do not damage the threads of the test tee with the auger cable. See *Figure 3-58*.

Figure3-58 — Test tee.

10.3.6 Combination Wye and 1/8 Bend

This fitting is commonly used as a stack base. It is normally installed at the base of soil or waste stacks. Its design allows for use in branches or the building drain to allow for change of direction from a vertical pipe to horizontal pipe. This fitting allows for a 90-degree change of direction off of a run of horizontal pipe. The branch of the fitting is long, sweeping, and provides a more gradual change of direction than a sanitary tee. A combo wye and 1/8 bend can be used either laying on its back or side. See *Figure 3-59*.

10.3.7 Double Tee

(Also referred to as a Waste Cross). Used to connect piping from four different directions. This fitting would be used to connect two fixtures to a single soil or waste stack. See *Figure 3-60*.

Figure 3-59 — Combination wye and 1/8 bend.

Figure 3-60 Double tee.

10.3.8 Double Wye and 1/8 Bend

A four way fitting similar to a combo but with two opposing branch connections. See *Figure 3-61*.

10.3.9 Cleanout

A cleanout fitting consists of a threaded opening and cap. It is designed to allow the utilities worker access to the piping system for removing stoppages. It is common to install a cleanout on the stack base of the building drain during residential construction. Multiple cleanouts are generally installed during commercial construction. See *Figure 3-62*.

Figure3-61 — Double wye and 1/8 bend.

Figure 3-62 — Cleanout.

10.4.0 Traps

A trap is a device or fitting used to provide a water seal, which if properly vented, will prevent sewer gases from entering the building. Sewer gases formed by decomposing organic material in wastewater are potentially explosive and/or combustible. These gases, besides being obnoxious, may also be harmful if inhaled. For these reasons, a trap should be installed on every plumbing fixture. Traps are generally installed at the piping connection between the plumbing fixture and the waste system piping. There are several types of traps that may be installed to protect buildings and their occupants from sewer gases. Note the parts of a trap are labeled in *Figure 3-63*.

Figure 3-63 — Parts of a trap.

10.4.1 ommon P-Trap

A P-trap is the most commonly used trap on plumbing fixtures. It gets its name from its design. It is used mainly on lavatories, sinks, tubs, and shower units. It contains a two inch water seal. See *Figure 3-64*.

Various types of P-traps are available, so designs may differ from one manufacturer to another. The P-trap is usually made of nickel or chrome-plated brass, malleable galvanized; cast iron, other metal alloys, and plastic.

The P-trap is used for fixtures suspended from the walls or supported on pedestals, for instance, lavatories, sinks, and urinals. At times the P-trap may also be suitable in showers, baths, and installations that do not waste large amounts of water.

Figure 3-64 — P-Trap.

When using a P-trap for fixtures suspended from the wall, install it as close to the fixture as possible. Be careful not to install a vertical leg that is too long between the trap and the fixture. It is also important for the horizontal leg connection to the waste system to be short for ventilation purposes.

10.4.2 Deep P-Trap

Deep P-traps are very similar to P-traps. The only physical difference is that the Deep P-trap has 4 inch water seal as opposed to the P-trap’s 2 inch water seal. Deep P-traps are generally installed on fixtures that are seldom used, such as a deep sink in a janitor's closet or a floor drain in a remote location. The Deep P-trap will not evaporate as quickly during periods of non-use and therefore will continue to protect building occupants from sewer gases. See *Figure 3-65*.

10.4.3 Integral Trap

Many plumbing fixtures may be manufactured with a trap as an internal part of the fixture. This type of trap is called an integral trap. A good example of a fixture with an integral trap is the water closet. See *Figure 3-66*. Some urinals are also manufactured with an integral trap.

Figure 3-65 — Deep P-Trap.

10.4.4 Trap Seal Loss

There are several ways the water seal in a trap may be depleted or lost. Again, lack of a sufficient water seal within a trap is dangerous due to the sewer gases that form in a waste system. Therefore, you should be aware of how trap seal loss may occur. In the four paragraphs that follow, you will find a description of ways by which trap seals are lost.

10.4.4.1 Direct Siphonage

Direct siphonage commonly occurs in unvented or improperly vented traps. Direct siphonage starts when water in a fixture exits the fixture abruptly. The water leaving the fixture creates unequal atmospheric pressure on the inlet and outlet sides of the trap seal. The higher pressure on the inlet side pushes the water out of the trap. The result is most of the water in the trap discharges into the vertical pipe that serves as a drain for the fixture. If trap seal loss occurs, sewer gases can then enter the structure, thereby creating a fire or explosion hazard and also offensive odors. The way to prevent direct siphonage is to ensure all traps are adequately vented during installation of the waste system. See *Figure 3-67*.

Figure 3-66 — Integral trap.

Figure 3-67 — Direct siphonage.

10.4.4.2 Siphonage by Momentum

Siphonage by momentum is the loss of a trap's water seal due to the momentum of water passing the trap outlet, which creates a negative pressure on the outlet side of the trap. Consequently, the water is drawn out of the trap and discharged into the vertical pipe that serves as a drain for the fixture. This type of trap seal loss normally occurs in buildings with more than one floor. Water is discharged from the fixture at the upper floor level, and as the water drops in the vertical pipe, it gains momentum. As the water passes the opening of the trap on the fixture at a lower floor level, the water is drawn out of the trap of the lower fixture. Improper venting of fixtures further aggravates this condition. It can be avoided by individually venting each fixture.

10.4.4.3 Capillary Action

This type of trap seal loss is caused by some foreign object lodged in the trap. The object acts as acts as a wick, absorbing water from the trap and dripping the water down the waste piping. Rags, lint, string, hair, and mop strings are common objects that cause this problem.

10.4.4.4 Evaporation

Trap seals can be lost due to evaporation when fixtures are not used for long periods of time. This is especially true in warm or hot climates. When a trap seal evaporates, you can replenish the water seal by running water into the fixture. If this is not possible or convenient, then the drain opening may be sealed with a cap to prevent sewer gases from entering the structure.

10.5.0 Stacks and Vents

10.5.1 Stacks

Vertical main of soil, waste, or vent piping extending through one or more stories. Each type of stack is further defined by the function it performs.

10.5.1.1 Soil Stack

Portion of vertical piping that receives wastewater containing fecal matter, or urine from fixtures such as water closets, urinals, or similar fixtures. See *Figure 3-68.*

10.5.1.2 Waste Stack

A waste stack is vertical piping that receives wastewater discharges from fixtures such as lavatories, sinks, tubs, showers, washing machines, and dishwashers. These fixtures do not normally contain fecal matter or urine. See *Figure 3-69*.

Figure 3-68 — Soil stack.

Figure 3-69 — Waste stack.

NOTE

A *soil stack* can receive discharges from *soil and waste pipes*, however, a *waste stack* can **only** receive discharges from *waste pipes.*

10.5.2 Vents

A vent is a pipe that allows air into a waste piping system to protect trap seals and allow sewer gases to escape. By allowing atmospheric pressure into a waste piping system, equal pressure is provided on both sides of a trap seal. Allowing sewer gases to escape from the piping systems reduces the chance of explosions, fire, and offensive odors inside a structure.

10.5.2.1 Stack Vent

A stack vent is an extension of a soil or waste stack above the highest horizontal drain connected to the stack. It is important to note that stack vents are a part of a soil or waste stack. Remember, each stack is defined by the function it performs. A stack vent is nothing more than a *vent for a stack*.

10.5.2.2 Vent Stack

Vertical pipe installed primarily for the purpose of providing circulation of air to and from any part of the drainage system. Absolutely no fixtures drain into a vent stack. A vent stack could be one lone stack that provides circulation of air through the drainage system, or it could be in the form of a main vent. See *Figure 3-70*.

10.5.2.3 Main Vent

A main vent is a vent stack. It is the principle artery of a venting system to which vent branches are connected. It connects full size at the base of the soil or waste stack below the lowest fixture drain. It extends full size through the roof or connects above the highest fixture branch to a main vent tee. Absolutely NO fixtures drain into a main vent!

Figure 3-70 — Main vent.

10.5.2.4 Individual Vent

A pipe installed specifically to vent one fixture trap and which connects with the vent system above the fixture served, or terminates in the open air. See *Figure 3-71.*

10.5.2.5 Dual Vent

A section of pipe that ventilates two fixtures that are back to back or side by side at the same elevation is called a dual vent. See *Figure 3-72*.

Figure 3-71 — Individual vent.

Figure 3-72 — Dual vent.

10.5.2.6 Wet Vent

A wet vent (See *Figure 3-73*) is a section of vent pipe that also serves as a drain for another fixture. When connecting a wet vent to the drain piping of another fixture, both fixtures must be on the same floor. The advantage of wet venting is that fewer vents will have to be projected through the roof. Although wet venting is permissible, it is not recommended.

10.5.2.7 Loop Vent

This vent is used primarily in single story buildings but may be used on the top floor of multiple story buildings. Loop vents are used to ventilate a battery of fixtures that drain into a common branch pipe. A battery of fixtures is a group of two or more fixtures that share a common drain. A loop vent ties into the branch between the two fixtures that are furthest from the soil or waste stack and "loops" back and ties back into the soil or waste stack. Loop vents may also be used where no adjacent wall is available to house the vent pipe. Refer to *Figure 3-84*.

Figure 3-73 — Wet vent.

10.5.2.8 Circuit Vent

The circuit is basically the same as a loop vent, with the exception that a circuit vent connects back to a main vent and not a soil or waste stack. In multiple story buildings (with the exception of the top floor), circuit vents are used to ventilate a battery of fixtures. Refer to *Figure 3-74*.

10.5.2.9 Relief Vent

The primary function of relief vents is to provide circulation of air between drainage and vent systems. An example of the use of relief vents would be between branch lines and the loop or circuit vents that serve these lines. This type of vent is used to provide additional venting to fixtures located closer to the stack. Refer to *Figure 3-74*.

Figure 3-74 — Loop, Circuit, and Relief vents.

Summary

Water distribution is vital to the success of any mission you and your unit will encounter. Having knowledge of water sources and storage, water well construction, pump placement, and water distribution system selection will enable the safe conduct and completion of your job. Another important aspect of your job is the establishment of water service, including trenching, placement of pipes, and backfilling requirement. The selection and correct measurement of water supply piping and fittings is crucial for the continuous supply of water.

Exterior and interior water distribution systems were covered, including material and component selection, the building of service lines, sizing requirements, and installation of water supply lines to the various fixtures. Above ground and underground sewage drainage systems were discussed, including material selection, joining of components, and the testing requirements unique to each system.

Review Questions (Select the Correct Response)

1. Drinking water is also known as what?

    A. Potable water
    B. Fresh water
    C. Acid free water
    D. Compatible water

2. Water for consumption is obtained from how many different sources?

    A. 2
    B. 3
    C. 4
    D. 5

3. What is the most common source of water?

    A. Storage tanks
    B. Rain water
    C. Well water
    D. Rivers

4. How deep is a dug well excavated to?

    A. 5 feet
    B. 10 feet
    C. 15 feet
    D. 30 feet

5. What type of well is constructed in loose, sandy, or gravelly soil?

    A. Driven
    B. Dug
    C. Drilled
    D. Bored

6. What is the maximum depth of a driven well?

    A. 30 feet
    B. 60 feet
    C. 90 feet
    D. 120 feet

7. Which of the following wells is the most pollution free well?

    A. Dug
    B. Bored
    C. Drilled
    D. Driven

8. What is the maximum depth of a bored well?

   A. 10 feet
   B. 15 feet
   C. 25 feet
   D. 50 feet

9. What is the lift limit of a shallow well pump?

   A. 33.9 feet
   B. 35 feet
   C. 53.5 feet
   D. 56 feet

10. What is the most commonly used shallow well type pump referred to as?

   A. Turbine
   B. Jet
   C. Submersible
   D. Centrifugal

11. What is the minimum depth that a deep well pump is utilized?

   A. 10 feet
   B. 15 feet
   C. 30 feet
   D. 45 feet

12. What is utilized to transfer water from a low elevation to a higher elevation?

   A. Booster pump
   B. Increaser
   C. Turbine pump
   D. Lift Station

13. Which of the following BPS systems is used to transfer water to a higher pressure zone closed to the atmosphere?

   A. Closed
   B. Parallel
   C. Open
   D. Perpendicular

14. Pipelines containing unsafe water are painted what color?

   A. Yellow
   B. Red
   C. White
   D. Green

15. What type of system is used to prevent stagnated water from accumulating in the piping?

    A. Booster
    B. Direct
    C. Loop

16. When self induced electric current flows from the metal into the soil, this is known as what condition?

    A. Perforation
    B. Contamination
    C. Rust
    D. Corrosion

17. How many different types of corrosion are associated with water systems?

    A. 3
    B. 4
    C. 5
    D. 6

18. Atmospheric corrosion normally occurs in which type of piping systems?

    A. Aerial
    B. Aboveground
    C. Underground

19. Which of the following terms is NOT a term used to refer to concentration cell corrosion?

    A. Crevice corrosion
    B. Gasket corrosion
    C. Electrolyte corrosion
    D. Deposit corrosion

20. What is the most common type of protective coating used in corrosion control?

    A. Coal tar
    B. Vinyl
    C. Cathodic
    D. Asphalt

21. Which of the following corrosion control protective coating is often used for gas pipelines?

    A. Vinyl
    B. Coal tar
    C. Asphalt
    D. Cathodic

22. What are the two types of cathodic protection process?

    A. Sacrificial anode and inductance resistance
    B. Impressed current and sacrificial anode
    C. Pressed current and inductors
    D. Resistor and impressed current

23. When utilizing the sacrificial anode system on a long pipeline, what is the minimum distance between anodes?

    A. 10 feet
    B. 20 feet
    C. 40 feet

24. The impressed current system is designed to protect what type of system?

    A. Waste discharge pipelines
    B. Water return pipelines
    C. Waste collection pipelines
    D. Water supply pipelines

25. Noise in water pipes is indicative of what faulty condition?

    A. Leak development
    B. Pipe blockage
    C. Structural support failure
    D. Loose fixtures

26. What is the minimum size diameter of a water main line?

    A. 2 inches
    B. 4 inches
    C. 6 inches

27. Which type of valve is used to control water by throttling?

    A. Gate
    B. Float
    C. Globe
    D. Altitude

28. How many different soil classifications are used to determine excavation and entry approaches for trenching?

    A. 1
    B. 2
    C. 3
    D. 4

29. What is the minimum distance that water pipes are placed from sewer piping?

A. 10 feet
B. 20 feet
C. 30 feet
D. 40 feet

30. Cast iron pressure pipe for water main come in what lengths?

A. 10 feet
B. 20 feet
C. 30 feet
D. 40 feet

31. Which of the following types of copper piping is utilized for general piping projects?

A. Type K
B. Type M
C. Type L
D. Type N

32. How many methods are utilized by UT's to measure piping or tubing?

A. 3
B. 4
C. 5
D. 7

33. Which measuring method is taken from the end of the pipe to the center of the fitting?

A. End to center
B. Center to back
C. End to end
D. Face to face

34. Which measuring method is taken from the back of one fitting to the back of the other?

A. End to back
B. Back to back
C. Face to face
D. End to end

35. Water that is constantly circulating from the supply point into the distribution system is known as what type of storage?

A. Ground
B. Static
C. Live
D. Underground

36. At what intervals should ground level storage tank roofs be inspected?

A. Every month
B. Every three months
C. Every six months
D. Every year

37. During the conduct of an inspection of elevated storage tank, the heating system needs to run prior to the start of the winter season, how long is the heater run to verify proper operation?

A. 2 hours
B. 4 hours
C. 6 hours
D. 8 hours

38. Which type of cathodic protection systems are used for protecting steel water storage tanks against corrosion?

A. Impressed current
B. Sacrificial anode
C. None

39. Which type of pump is used to increase water pressure?

A. Jet
B. Booster
C. Submersible
D. Turbine

40. Which of the following water mains distributes water throughout a community?

A. Feeder
B. Service
C. Distribution
D. Loop

41. What are the two types of standard design systems used for exterior water distribution?

A. Tree and feeder
B. Loop and feeder
C. Feeder and grid
D. Tree and loop

42. What determines the maximum size of a tap when tapping a main line?

A. Material and size of main
B. Pressure thresholds
C. Material and curing requirements
D. Size and shape of main

43. **(True or False)** The tap should NOT be larger than 1/4 the diameter of the pipe.

A. True
B. False

44. A service line consists of all the following EXCEPT what component?

A. Corporation stop
B. Globe valve
C. Flexible connector
D. Stop and waste valve

45. Which of the following is the first component in a service line?

A. Stop and waste valve
B. Meter stop
C. Corporation stop
D. Globe valve

46. When copper tubing is used to fabricate the service line, what type of flexible connection is used?

A. Utilitiesmen saddle
B. Swing joint
C. Water coupling
D. Expansion loop

47. In a small pipe, friction loss may overcome by what means?

A. Supplying water at a higher pressure
B. Eliminate excessive bends in piping
C. Replace smaller pipe with a larger one
D. Remove some fixtures from line

48. CPVC piping can withstand temperatures as high as what?

A. 150°
B. 180°
C. 200°

49. **(True or False)**Risers should be supported at every other floor level and at joints.

A. True
B. False

50. What is the maximum distance that a fixture supply pipe can terminate from the point of connection to the fixture?

A. 10 inches
B. 15 inches
C. 30 inches
D. 45 inches

51. Which of the following pipe sizes is the minimum size to utilize when connecting supply water to a lavatory?

A. 1 1/2 inches
B. 1 inch
C. 3/4 inch
D. 1/2 inch

52. How many types of urinals are there currently in use?

A. 1
B. 2
C. 3
D. 4

53. What is the minimum size utilized in water supply piping for a flushometer type urinal?

A. 3/4 inch
B. 1/2 inch
C. 1/4 inch
D. 1 inch

54. How far apart are cold and hot water lines installed from each ofter?

A. 4 inches
B. 8 inches
C. 10 inches
D. 12 inches

55. What type of piping is used under roads or other places of heavy traffic?

A. PVC
B. Brass
C. CISP
D. Copper

56. When excavating you realize that the soil contains cinders and ashes; which type of piping would be utilized?

A. Copper
B. Brass
C. Cast iron soil
D. Vitrified clay

57. Which of the following fittings is used to change the direction of a CISP 22 1/2 degree?

A. 1/16 bend
B. 1/8 bend
C. Short sweep 1/4 bend
D. Long sweep 1/4 bend

58. Which fitting is used mostly in venting systems?

A. Reducing tee
B. Tapped tee
C. Sanitary tee
D. Test tee

59. Which fitting is useful as an individual vent?

A. Box type 90 degree Y - branch
B. Straight type 45 degree Y - branch
C. Double 90 degree Y - branch

60. Which fitting is utilized to join two sanitary sewer branches at a 45 degree angle?

A. Box type 45 degree Y - branch
B. Double 45 degree Y - branch
C. Reducing 45 degree Y - branch
D. Straight type 45 degree Y - Branch

61. Vitrified piping is typically used in what location?

A. Outside the structure
B. Basement of structure
C. Upper levels of building

62. During prolonged storage, PVC piping should NOT be stacked more than how many feet high?

A. 1 foot
B. 2 feet
C. 3 feet
D. 4 feet

63. How many different ways are there to join plastic piping?

A. 1
B. 2
C. 3
D. 4

64. When testing plastic piping, which test is performed first?

A. Reduced pressure leakage
B. High pressure hydrostatic
C. Flow pressure difference
D. Low pressure hydrostatic

65. When conducting the water test after sanitary drainage installation, how long is the water to remain in the pipe?

A. At least 15 minutes
B. At least 30 minutes
C. At least an hour
D. No time limit associated with this test

66. 15 inch sewer drainage piping has been installed, what is distance required between manholes?

A. 300 feet
B. 500 feet
C. 400 feet
D. 600 feet

67. When performing backfill operations on a trench, how much soil should be placed on the piping before walking on the pipe is authorized?

A. No soil depth requirements
B. 6 inches
C. 1 foot
D. 2 feet

68. Which type of pipe carries fecal matter and discharges from urinals?

A. Waste
B. Stack
C. Branch
D. Soil

69. Which of the following components is the vertical portion of vent piping?

A. Stack
B. Branch
C. Waste
D. Soil

70. Lead pipe is available in how many weight classifications?

A. 2
B. 3
C. 4
D. 5

71. Which fitting is designed for making a connection between a closet flange and a soil stack?

A. Sanitary tee
B. Closet bend
C. Test tee
D. Wye

72. Which fitting is commonly used as a stack base?

A. Sanitary tee
B. Cleanout
C. Double tee
D. Combination wye and 1/8 bend

73. Which CISP fitting is also known as which of the following?

A. Waste cross
B. Combination wye
C. 1/8 bend
D. Cleanout

74. A device or fitting used to provide a water seal in a waste water system is known as what?

A. Cleanout
B. Trap
C. Vent
D. Stack

75. What pressure, if any, is caused by siphonage by momentum trap loss?

A. No pressure created
B. Positive
C. Negative

76. Which type of vent or stack receives waste water that contains fecal matter?

A. Main vent
B. Waste stack
C. Wet vent
D. Soil stack

77. Which type of vent or stack receives waste water discharge from dishwashers?

A. Waste stack
B. Wet vent
C. Main vent
D. Soil stack

78. What type of vertical piping is utilized to provide circulation of air to any part of a drainage system?

A. Main vent
B. Vent stack
C. Soil stack
D. Stack vent

79. What fitting can also serve as a drain for another fixture?

A. Individual vent
B. Dual vent
C. Wet vent
D. Stack vent

Trade Terms Introduced in this Chapter

Potable	Fit or suitable for drinking.
Cisterns	A reservoir, tank, or container for storing or holding water or other liquid.
Water Table	The planar, underground surface beneath which earth materials, as oil and rock, are saturated with water.
Cased	To cover (a surface of a wall, well, or shaft) with a facing or lining.
Oakum	Loose hemp or jute fiber, sometimes treated with tar, creosote, or asphalt, used chiefly for caulking seams in wooden ships and packing pipe joints
Holiday	An unintentional gap left on a plated, coated, or painted surface.
Sacrificial	Pertaining to or concerned with sacrifice.
Impressed	To produce (a voltage) or cause (a voltage) to appear or be produced on a conductor, circuit.
Muriatic	Brine substance.
Rodding	To reinforce (the core of a mold) with metal rods.
Slough	An area of soft, muddy ground; swamp or swamp like region.
Ponding	a first coat or layer of paint, size, etc., given to any surface as a base, sealer, or the like
Alligatoring	To crack and acquire the appearance of alligator hide, as from weathering or improper application to a surface.
Coke	The solid product resulting from the destructive distillation of coal in an oven or closed chamber or by imperfect combustion, consisting principally of carbon.
Bituminous	Substance containing the material bitumen.
Plastisol	A dispersion of resin in a plasticizer, forming a liquid or paste that gels when heated.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Basic Machines, NAVEDTRA 12199, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

OSHA Regulations (Standards – 29 CFR)

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Naval Construction Force Manual, *NAVFAC P-315,* Naval Facilities Engineering Command, Washington, D.C., 1985.

McPortland, J.E, and Brian J. McPortland, *National Electrical Code® Handbook,* 22d Ed, McGraw-Hill, NY, 2008.

Engineering Aid Basic, NAVEDTRA 10696-A, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Fluid Power, NAVEDTRA 12964, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

National Standard Plumbing Code-Illustrated, National Association of Plumbing- Heating-Cooling Contractors, Washington, DC, 2006.

Safety and Health Requirements Manual, EM-385-1-1, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

MIL-STD-17-1, Mechanical Symbols

MIL-STD-101B

International Plumbing Code 2009, International Code Council

International Mechanical Code 2009, International Code Council

R. Dodge Woodson, *Plumber's Quick-Reference Manual Tables, Charts, and Calculations,* 1st edition, McGraw-Hill, NY, 1996.

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Chapter 4

Structural Openings and Piping Material

Topics

To hear audio, click on the box.

Overview

Openings must commonly be cut or drilled in structures for the installation of plumbing systems. To accomplish this task, you will need a fundamental knowledge of how buildings are constructed (structural design), and what tools are necessary for performing the tasks. When you cut or drill structural openings for the installation of pipe, you will need to support the pipe to prevent it from sagging or vibrating, and consequently developing leaks.

This chapter will introduce you to the different types of piping material used in the accomplishment of your job as an Utilitiesman. Part of your job will be the installation of steel and plastic piping, and copper tubing. You will also discover the advantages and disadvantages of each material, as well as the preparation, installation, joining, and support structure requirements associated with each of these materials.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the design and types of structural openings.
2. Describe the different types of steel pipe assemblies.
3. Describe the different types of plastic pipe assemblies.
4. Describe the different types of copper tubing assemblies.

Prerequisites

None

This course map shows all of the chapters in Utilitiesman Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Utilities Equipment and Maintenance	↑	
Air Conditioning		
Refrigeration		
Heating Systems		U
Steam Distribution Systems		T
Boilers		
Sewage Disposal, Field Sanitation, and Water Treatment		B
Prime Movers, Pumps, and Compressors		A
Plumbing Fixtures		S
Piping System Layout and Plumbing Accessories		I
Structural Openings and Pipe Material		C
Fundamentals of Water Distribution		
Basic Math, Electrical, and Plumbing Operations		
Plans, Specifications, and Color Coding		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for

review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 STRUCTURAL OPENINGS

1.1.0 Structural Design

Buildings are constructed of wood, masonry products, metal, or a combination of these materials. Other materials such as drywall, asphalt shingles, paneling and plaster are also used in the construction of buildings. However, wood, masonry products, and metal are the primary materials used to build the major structural components of a building. We will address the most common types of structural design.

1.1.1 Wood

Buildings are constructed using either box or frame type construction. The type of construction will determine how your plumbing system is installed.

1.1.1.1 Box Type

Box type construction uses only a single board thickness in the walls and has only enough framework to support the floor and roof. The studs inside the building are exposed. Most plumbing is exposed. This is considered a temporary building.

1.1.2.1 Frame Type

The frame type is a more permanent type of construction. This type of structure has a framework of studs, usually 2 x 4 inch or 2 x 6 inch, covered on both sides to form a double wall. All water supply and drainage piping located above the floor level are usually concealed within the framework.

1.1.2 Masonry

Most permanent structures are built of some type of masonry material. It may be solid concrete, stone, brick, brick veneer, or cement block. In most masonry buildings, the water piping is exposed because of the possibility of leakage. The drainage system, which is not pressurized, may be covered by a concrete floor after it has been properly inspected. You must, however, install an access point for cleaning in case of stoppages. This access is called a cleanout. If a pipe must pass through a masonry wall, a sleeve (section of plastic pipe) is set in place while the wall is being constructed. This sleeve prevents corrosion between the metal pipe and masonry materials. The pipe can also be wrapped in insulation to prevent corrosion.

1.1.3 Metal

Metal buildings have a framework of structural steel or pipe and are covered with sheet metal. Most water piping in this type of structure is exposed. If metal buildings have a concrete floor, the drainage system may be covered after it has been inspected.

1.2.0 Locating Structural Openings

1.2.1 Building Construction Plans

Since most piping, either supply or drainage is installed to directly serve some type of fixture, you must know the location of all fixtures. You can obtain this information from the floor plans. See *Figure 4-1.*

Figure 4-1 — Floor plan.

1.2.2 Specification Sheets

The specification sheets will indicate the exact model or type of fixture to be used. See *Figure 4-2, View 1 and 2*.

1.2.3 Manufacturer's Rough-In Specifications

These show the required location of all supply and drainage pipe openings. You must know this information when locating the structural openings for the waste and supply piping. One reason for this is because you may need to cut holes through structural members to align the pipe with the fixture location. See *Figure 4-2, View 3.*

1.2.4 Working Drawing

Figure 4-2 — Locating structural openings.

After you check the construction plans, specification sheets, and manufacturer's rough-in specifications, you will prepare a working drawing. This drawing should indicate the location of all fixtures and the routing of all supply and waste pipes. See *Figure 4-2, View 4*.

1.3.0 Stages of Construction

During the construction of a building, the UTs complete the plumbing installation in two major phases. The first phase is referred to as rough-in plumbing. The second phase is referred to as finish plumbing.

1.3.1 Rough-In

Before the concrete slab is poured, you will install horizontal water and drainage piping below ground in trenches. From the horizontal piping in the trench, you will "stub up" vertical piping for each fixture to a height that will terminate at least 12 inches above the proposed finished floor. Then you will wrap any portion of vertical metallic pipe that comes in contact with concrete with insulation to prevent corrosion between the pipe and the concrete. Another method to avoid corrosion is to install a sleeve (short piece of plastic pipe) while the wall is being constructed. The newly installed pipe is tested for leaks and inspected before the trenches are backfilled. The concrete slab is then poured.

Once the building is framed and the exterior walls are installed, you will return to extend vertical and horizontal rough-in piping. It is at this time that most of the structural openings are cut. Portions of water and waste lines will be "stubbed out" past the walls for fixtures that will be installed later.

1.3.2 Finish Plumbing

Once the rough-in plumbing is completed, you will continue with finishing interior and exterior wall coverings. When the job is nearly complete, you will return to install the fixtures and connect the water and drain piping to each fixture. This final stage of plumbing installation is referred to as "finish plumbing.”

1.3.3 Hole Cutting Tools

Most often, you will be using power tools to cut structural openings for the installation of pipe. There are a variety of tools available for this purpose. On occasion, you may have to cut these openings with hand tools.

1.3.3.1 Electric Drills and Hole Saws

Electric drills and hole saws are most often used when cutting holes in wood because the tool cuts a perfectly round hole for pipe installation. The hole saws used with the electric drill are available in diameters to accommodate most sizes of pipe. See *Figure 4-3*.

The electric drill can be used with a variety of bits to drill through wood, steel, and masonry.

Paddle bits are used with electric drills to make round holes in wood. This type of bit only comes in sizes that will accommodate smaller diameter pipe.

Carbide bits can be used to drill holes through steel and some masonry materials.

Figure 4-3 — Electric drills and hole saws.

1.3.3.2 Reciprocating Saw

Reciprocating saws may be used to create large openings for the installation of pipe. Blades for reciprocating saws are available to cut through wood and many types of metal. See *Figure 4-4, View 1*.

1.3.3.3 Jigsaw

Jigsaws are used to cut irregular shaped openings in wood. For a circular shaped opening, a pilot hole is drilled within the area to be cut out of the lumber. The jigsaw is then used to cut out the circular shaped opening. See *Figure 4-4, View 2*.

Figure 4-4 — Reciprocating and jigsaws.

1.3.3.4 Hammer Drill

A hammer drill is used to drill an opening in masonry materials. The drill bit reciprocates and turns simultaneously to bore the hole. See *Figure 4-5, View 1*.

1.3.3.5 Tin Snips

Tin snips are used to cut curved or circular shaped openings in sheet metal. See *Figure 4-5, View 2*.

1.3.3.6 Brace and Bit

A brace and bit is used to manually drill holes in wood when electricity is not available for power tools. See *Figure 4-5, View 3.*

Figure 4-5 — Hammer drill, tin snips, brace and bit.

1.3.3.7 Keyhole Saw

The keyhole saw can be used to cut irregular shaped openings in wood when electricity is not available for power tools. See *Figure 4-6, View 1*.

1.3.3.8 Hammer and Star Drill

When creating openings in concrete it may be necessary to use a hammer and chisel or a hammer and star drill. Using these tools to cut through concrete requires more time and labor than using power tools. See *Figure 4-6, View 2*.

1.4.0 Structural Openings

A structural opening is an opening cut in a structural member that allows the piping to pass through it. When openings are properly reinforced, they can also help to support the pipe. Structural openings are created when notching or drilling holes in a wooden structural member during the installation of pipe. You may need to reinforce structural members whenever you cut them if the cut or hole compromises the strength of the structural member. The following are four basic types of structural openings.

Figure 4-6 — Keyhole saw, hammer and star drill.

1.4.1 Center Cut

The most desirable type of structural opening to use is the center cut (*Figure 4-7, View 1*). A center cut is a round hole cut in the center of the board. It causes less damage to the structural member than any other type of cut. The diameter of the opening should not exceed one-third the width of the board. If a larger hole is cut, the board loses its ability to support weight and stress.

1.4.2 Over Cut

If a center cut cannot be made, an over cut (*Figure 4-7, View 2*) is acceptable. An over cut is made by notching the top of the board. The piping is installed through the notch and the beam provides some support to reduce movement of the pipe. Wedge a block of wood and nail it into the notch. This prevents the beam from sagging.

Figure 4-7 — Center and over cuts.

1.4.3 Under Cut

The under cut (*Figure 4-8*) is a notch in the bottom of the structural member. Again, the piping is installed through the notch. To support the bottom of the pipe and the beam, install strap iron and lag screws on the notch to reinforce the beam. It is important to note that an over cut or an under cut should never be more than 1/2 the width of the beam or it will be weakened considerably.

1.4.4 Notch

A notch is a cut similar to an over cut or an under cut. If the opening (cut) is on a vertical structural member, it is referred to as a notch.

Figure 4-8 — Under cut.

1.5.0 Vertical Supports

Vertical piping must be supported to prevent stress on joints and potential leaking. Listed below (*Table 4-1*) are some of the general guidelines for supporting vertical piping. Support can be provided by structural openings that have been reinforced, or by the installation of pipe supports. Refer to your project specifications for locations. For additional information, refer to the *International Plumbing Codebook 2009, Section 308*.

1.6.0 Horizontal Supports

Horizontal water and waste piping must also be supported to prevent sagging and potential leaking. Again, supports can be in the form of reinforced openings or pipe support materials. Criteria for supporting various types and diameters of pipe are listed below in *Table 4-1*. For additional information, refer to the *International Plumbing Codebook 2009, Section 308*.

Table 4-1 — Piping Support Spacing.

Piping Material	Maximum Horizontal Spacing (Feet)	Maximum Vertical Spacing (Feet)
ABS pipe	4	10
Aluminum pipe and tubing	10	15
Brass pipe	10	10
Brass tubing, 1 1/4 inch diameter and smaller	6	10
Brass tubing, 1 1/2 inch diameter and larger	10	10
Cast iron pipe	5	15
Copper or copper alloy pipe	12	10
Copper or copper alloy tubing, 1 1/4 inch diameter and smaller	6	10
Copper or copper alloy tubing, 1 1/2 inch diameter or larger	10	10
CPVC pipe or tubing, 1 inch and smaller	3	10
CPVC pipe or tubing, 1 1/4 inch and larger	4	10
Lead pipe	Continuous	4
PB pipe or tubing	2 2/3 feet or 32 inches	4
PEX tubing	2 2/3 feet or 32 inches	10
Polypropylene (PP) pipe or tubing, 1 inch or smaller	2 2/3 feet or 32 inches	10
Polypropylene (PP) pipe or tubing, 1 1/4 inches or larger	4	10
PVC pipe	4	10
Steel tubing	8	10
Steel pipe	12	15
NOTE: The maximum horizontal spacing of cast iron pipe hangers shall be increased to 10 feet where 10 foot lengths of pipe are installed.		

1.7.0 Support Materials

A variety of pipe support materials and devices are available. Specialized supports or pipe hangers are made for almost every possible situation you will encounter during your duties as a UT. See *Figure 4-9*.

Figure 4-9 — Types of supports.

Test your Knowledge (Select the Correct Response)

1. Which of these structural opening cuts is most desirable for support of piping?

   A. Center cut
   B. Over cut
   C. Under cut
   D. Notch

2.0.0 STEEL PIPE ASSEMBLY

2.1.0 Measuring Procedures

Before you can thread the pipe, it must be measured and cut to length. There are different methods of measuring steel pipe: (1) end-to-end, (2) end-to-center, (3) center-to-center, and (4) face-to-face.

2.1.1 Thread Engagement (TE)

When trying to obtain the end-to-end measurement from one of the other measurements listed previously, you will add or subtract some different measurements. One of the measurements is referred to as the thread engagement. Thread engagement is the amount of pipe that will be screwed into a fitting to make a watertight seal. This measurement differs depending on the diameter of the pipe to be installed. The common thread engagements that you will encounter are for 1/2 inch and 3/4 inch diameter pipe. The rule of thumb for TE on 1/2 inch and 3/4 inch pipe is approximately the diameter of the pipe. For all other sizes, measure the thread engagement of individual fittings.

2.1.2 Methods

In plumbing systems, measurements must be obtained before you can cut, thread, or ream the pipe to be installed. End-to-end measurement is the measurement that you will use to cut the length of pipe. To find the end-to-end, you must take other measurements first.

During the rough-in of piping systems, structural openings are made for the installation of the piping. The center-to-center is a common measurement used. This measurement is used when two structural openings are made for pipe to be run through. The center-to-center is measured from the center of the two openings. This is also the center of the two fittings to be installed. To convert a center-to-center measurement to an end-to-end measurement, measure the distance from the center of one fitting to the center of the other fitting; subtract the thread engagement from each end, and this will give you the end-to-end measurement for the pipe.

Face-to-face is also used to determine a length of pipe to be installed. The face refers to the opening of the fitting. Often you may have two fittings in place and must obtain a measurement for pipe to be installed between them. This measurement does not allow for thread engagement. To convert a face-to-face measurement to an end-to-end measurement, first measure the distance from the face of one fitting to the face of the next fitting. Next, add one thread engagement for each fitting.

2.2.0 Hand Threading

2.2.1 utting Pipe

The purpose for cutting pipe is to obtain the correct length for installation and/or repair of piping systems. After the pipe has been measured and marked, it should be inserted into the pipe vise with the section to be cut extending beyond the face of the vise. To cut pipe with a pipe cutter, open the jaws of the cutter by turning the handle counterclockwise. Then, place the pipe cutter around the pipe and align the cutting wheel with the mark where the cut is to be made. Tighten the handle until the cutter wheel is forced slightly into the pipe. Revolve the cutter around the pipe one complete turn. Tighten adjustment handle 1/4 turn for every revolution of the cutter. Repeat this procedure until the pipe is cut.

2.2.2 Reaming

The purpose of ***reaming*** pipe is to restore the inside diameter of the pipe by removing any burrs which are created by the cutting of a pipe. Removal of these burrs will prevent flow restriction in the piping. The tool used to remove burrs could be a pipe reamer or a file.

2.2.3 Threading

The threads used on steel pipe are a standard size called the American Standard Pipe Thread. The process uses a 1/32 inch per inch taper with a 60° angle on the upper and inner threads. The angle and taper provide for a watertight seal when tightened. The diameter of the pipe determines the number of threads per inch on the pipe.

2.2.4 Dies

Nonadjustable hand dies with a ratchet type handle may be used to thread pipe from 1/8 inch to 2 inch diameter. Adjustable hand dies can thread pipe 1 inch to 2 inches. Three-way hand dies will thread from 1/2 inch to 1 inch diameter.

2.2.5 Procedures

Before you thread a pipe, inspect the dies to see that they are sharp and free from nicks and excessive wear. Then insert the pipe into the vise. Place the round guide end of the pipe die stock on the pipe (*Figure 4-10*) and push the pipe-threading dies against the pipe with the heel of the hand. (You must wear gloves to do this). Exert strong pressure with the heel of the hand against the pipe die and make three or four short turns in a clockwise direction to start the dies.

Figure 4-10 — Placing die stock on pipe.

When the dies are started, turn the handle of the pipe die (*Figure 4-11*). Apply cutting oil after every two or three downward strokes of the die handle. The oil prevents the pipe-threading dies and threads from overheating, and the threads from becoming dulled and marred. Continue to turn the dies until approximately two newly cut threads project beyond the end of the die segments. When the proper number of threads are cut on the pipe, reverse the ratchet on the die handle and turn the pipe dies counterclockwise until they are free of the threads.

Figure 4-11 — Threading pipe with ratchet and die.

The procedure for threading with an adjustable hand die is similar to the nonadjustable hand die. Adjustable dies have an automatic release that will allow only the correct number of threads to be cut.

2.3.0 Assembly of Threaded Joints

The following steps describe how to make a leak-proof threaded joint.

2.3.1 Clean Threads

To clean the threads of the fitting and pipe, use a wire brush.

2.3.2 Apply Pipe-Joint Compound

There are several reasons for using pipe-joint compounds. They may be used as a lubricant, a corrosion protection agent, or an anti-seize compound. The anti-seize compound is used in case the joints must later be disassembled. The two most common types of pipe joint compound are Teflon tape and pipe dope.

2.3.3 Fitting Connection

Screw the fitting onto the pipe by hand, and tighten about two more turns with the correct size pipe wrench. Do not over-tighten the joint. If you over-tighten, the fitting may stretch or crack, and the joint might leak. Use a backup wrench to keep existing joints from turning and possibly causing a leak (*Figures 4-12* and *4-13*).

Figure 4-12 — Tightening a coupling using two wrenches.

Figure 4-13 — Tightening a pipe using two wrenches.

2.3.4 Wrench Selection

Pipe wrench sizes to be used for the several pipe sizes are as follows:

8 inch wrench for 1/8 inch and 1/4 inch pipe

10 inch wrench for 3/8 inch and 1/2 inch pipe

14 inch wrench for 3/4 inch and 1 inch pipe

18 inch wrench for 1 1/4 inch and 1 1/2 inch pipe

24 inch for 2 inch pipe

2.3.5 Pipe Nipples

Pipe nipples are also used in water systems. Nipples are short pieces of pipe. They come in the same diameter as long pipe, from 1/ 2 inch to 12 inch diameter.

There are three types of nipples: the close nipple or all-thread nipple (*Figure 4-14, View A*); the shoulder nipple, which has a short space between threads (*Figure 4-14, View B*); and the long nipples (*Figure 4-14, View C*) which are made in graduations of 2, 2 1/2, 3, 3 1/2, 4, 4 1/2, 5, 5 1/2, 6, 7, 8, 9, 10, 11, and 12 inches long.

Figure 4-14 — Pipe nipples.

2.4.0 Cold Water Distribution System Installation

2.4.1 Installations Procedures

After you have cut, reamed, and threaded the pipe, you are ready to assemble the threaded joint. Whenever you are assembling threaded joints, be sure to apply joint compound to the male threads. This makes it easier to disassemble the connection. There are many different types of joint compound. The most popular is Teflon tape. After applying the compound, screw the fitting onto the pipe hand tight, then turn the fitting two more revolutions with a pipe wrench.

The proper size wrench is important to the user because of the leverage needed to assemble or disassemble a joint. A back-up wrench is sometimes needed to ensure that the remaining pipe will not turn as you tighten or loosen the joint that you are working on.

Galvanized steel pipe was often used on the water distribution systems of older buildings. However, it will gradually corrode and is difficult to fit and work with. Since much of the work you will do as a UT will involve repairing, replacing, and maintaining in-place systems, you will need to be skilled at working with galvanized piping and fittings.

When assembling a cold water line using galvanized iron pipe, always start at the end of the service line to create the distribution main. Branch lines to individual fixtures are connected to the distribution main by using a reducing tee and nipple and a 90° elbow. The fixture supply risers are vertical pipes connected to the branch lines by means of a 90° elbow. Risers should be supported at each floor level and at joints. Refer to *Figure 4-15* for installation of a branch line and risers.

Figure 4-15 — Installation of a branch line and risers.

The cold water inlet is normally located at the top (right side) of the tank. It will have a dip tube extending from it to direct the cold water to the bottom of the tank. The cold water inlet is 3/4 inch in diameter and has a shut-off valve installed on it.

2.4.2 Supporting Steel Pipe

There are many ways to support steel pipe. You can use pipe hangers, plumbing tape, and other support materials. Be sure to consult the engineer for structural strength. Supporting steel pipe is very important because if the pipe is not supported correctly, the appearance is bad and more importantly, the pipe will sag, possibly damaging the pipe. Commonly you want to support steel pipe horizontally: 3/4 inch and smaller – every 10 feet; 1 inch and larger – every 12 feet. Vertically, support pipe every other floor not to exceed 25 feet. Always refer to the International Plumbing and Mechanical Code books.

2.4.3 Pressure Testing

After the water supply system has been installed and checked for evidence of shifting, the system must be tested to ensure there are no leaks before they are concealed within the walls or under slabs. This is especially important where pipe is to be concealed in walls or ceilings. If a leaking pipe is sealed in the building framing, the water would probably run for a considerable length of time before being discovered. This could result in costly damage to the building. To reduce the possibility of this happening, all pipes in the system are tested at least twice, once after the rough-in, and again after the water supply system is installed. One method of testing is to close off the entire system using plugs or caps screwed onto the nipples and open the supply valve. Another way to test is to close off the entire system, install an air gauge and fill the system with air. Inspect the system for leaks and monitor the air gauge.

Test your Knowledge (Select the Correct Response)

2. When conducting end–to-end measurements for piping, what value is needed to establish a correct length?

   A. Nipple joint length
   B. Thread engagement
   C. Joint length
   D. Nipple engagement

3.0.0 PLASTIC PIPE ASSEMBLY

Plastic is a very versatile material. It can be formed into almost anything. Cars, boats, homes, and of course plumbing have many components made of plastic. Plastic pipe has rapidly become one of the more popular piping materials. It can be used for numerous plumbing installations, including water distribution and the drainage of wastewater.

3.1.0 Install Plastic Piping

3.1.1 Types Used for Water Distribution

3.1.1.1 Polyvinyl Chloride (PVC)

Plastic pipe is often used for distribution mains and building service lines. It has an exceptionally smooth interior surface and, therefore, low friction losses. This enables large diameter plastic pipe to convey water with little or no pressure loss. The material is chemically inert, which makes it completely corrosion proof. Corrosion is probably the biggest contributing factor to the destruction of underground metallic piping systems. The use of plastic eliminates this factor. Plastic pipe commonly comes in 20 foot lengths.

3.1.1.2 Chlorinated Polyvinyl Chloride (CPVC)

In recent years, the use of plastic pipe for the distribution of water in buildings has been widely accepted, especially in domestic homes. Since water distribution system will commonly be concealed in the walls of the building, the piping used must be able to withstand a variance of temperature and pressure and remain completely leak proof. CPVC was formulated to withstand higher temperatures and pressures than PVC. CPVC can withstand temperatures as high as 180 degrees and pressures up to 100 pounds per square inch (psi) depending on the manufacturer.

3.1.2 Joining Plastic Pipe

Usually compression joints (O-ring joints) or solvent welded are used. *Figure 4-16* shows a compression joint. These are simple joints to assemble. Water mains may be equipped with rubber O-rings and a spigot end. The spigot end is beveled to allow the joining pipe to slide into the O-ring and bell. The spigot is lubricated and inserted into the bell. The O-ring compresses around the pipe to seal the joint.

Figure 4-16 — Compression joint.

3.2.0 Applications and Restrictions

The weight of the pipe is basically a description of the thickness of its walls. Plastic pipe comes in two weights, schedule 40 and schedule 80.

3.2.1 PVC Schedule 40

Schedule 40 plastic pipe has the thinnest walls of the two. This lightweight material can be used on most applications systems discussed above, as long as the codes allow it. PVC Schedule 40 is joined by cement, PVC, CPVC, or ABS cement, as it is too thin to be threaded. It can be installed in exterior water lines only.

3.2.2 PVC Schedule 80

Schedule 80 plastic pipe has a thick wall. It is more rigid than schedule 40 plastic so it can withstand higher pressure. PVC pipe cannot be installed in an interior system. PVC Schedule 80 pipe can be joined by cement, PVC, CPVC, or ABS cement or it can be threaded. For more information, reference the International Plumbing Code book for additional information.

3.2.3 CPVC Schedule 40

This is normally installed in interior water distribution systems. The plastic material looks and feels like PVC pipe except for the coloring, which is commonly beige. Schedule 40 can be joined only by solvent glue.

3.2.4 CPVC Schedule 80

It can be joined by solvent glue or threaded into valves and fittings using male adapters. Solvent-welded and threaded plastic (PVC and CPVC) connections will be discussed in depth later in this chapter.

3.3.0 Advantages and Disadvantages

3.3.1 Advantages

There are many advantages to using plastic piping. It is lightweight, takes few tools to assemble, and requires very little maintenance once it has been installed. Plastic pipe is chemically inert so it will not rot or corrode. It is strong and durable material that has an accepted service life of 20 to 50 years, depending on the application, and an indefinite shelf life if stored properly. Keep away from open flame and heat. Keep and store in original container. Keep container closed.

3.3.2 Disadvantages

There are very few disadvantages to using plastic pipe. Small diameter plastic piping can be very flexible and may require substantial means of support. When plastic pipe is assembled using solvent weld, the fumes from the cement, PVC, CPVC, or ABS cement can be harmful and dangerous.

3.3.3 Safety When Using Solvent Glue and Primers

Take great care when using these products. They contain chemicals that can be toxic, flammable, and combustible. Ventilate the area and try to avoid breathing the fumes. Keep solvent glue and primers away from all sources of ignition, heat, sparks, and open flames. Keep all containers tightly sealed and safely stored when not in use. Avoid contact with your eyes. You may be required to use proper eye protection when solvent gluing overhead piping. Avoid contact with your skin, and always wash your hands after use.

3.4.0 Methods of Installation

There are four methods of joining plastic pipe: solvent welding, fusion welding, fillet welding, and threading.

3.4.1 Solvent Welding

Before solvent welding PVC and CPVC plastic pipe, clean the pipe and fittings. Use a clean, dry cloth and wipe away all loose dirt and moisture from inside the fitting and from the outside of the plastic pipe. Ensure the fittings and the pipes are of the same temperature for at least an hour before welding; this will assure they are thermally balanced. With a bristle brush, apply a coating of primer to the outside of the pipe. This removes surface gloss and etches the pipe.

Figure 4-17 — Making solvent weld joints on plastic pipe.

Do the same to the inside of the fittings. If the pipe is so hot the primer evaporates or if the pipe is above 90°F, move it to a shaded area before priming the surfaces. Use notched boards to keep the pipe ends out of the dirt. Clean the pipe ends before cement application.

Dip a brush in cement and apply it to the entire active surface of the pipe to a width slightly more than the depth of the socket of the fitting, as shown in *Figure 4-17, View A*. Then brush a light coating in the depth of the socket. (Avoid excess cement to eliminate the buildup inside the fitting when the pipe is socketed.) Apply the second coating of cement to the end of the pipe to ensure no voids exist. (There should be no problem of too much cement on the pipe because the excess will bead out on the surface of the face of the fitting and can be easily wiped away.) Immediately, upon finishing the cement application, insert the pipe to full socket depth and rotate one quarter turn to ensure complete distribution of cement, as shown in *Figure 4-17, View B*. Hold the pipe together for 10 to 15 seconds so it does not move out of its socket. After joining, immediately wipe the excess cement from the pipe and fitting and gently set the pipe on a level surface. Do NOT move the pipe for about 2 minutes. (As the pipe size increases, it takes longer for the joint to set up.) The pipe SHOULD NOT be joined in temperatures below 40°F and above 90°F or when it is exposed to direct sunlight. The drying time should be at least 48 hours before the joint is moved or subjected to internal or external pressure. The drying time is shorter in hot weather and longer in colder weather.

WARNING

Do not attempt to speed the setting or drying of the cement by applying heat to solvent-welded joints.

Forced rapid drying by applying heat causes cement solvent to boil off‘, forming bubbles and blisters in the cement film. During cool weather, the setting of the cement can be speeded by pre-warming the cement, the pipe, and the fitting, or by shielding the joint from the wind.

CAUTION

Check the shelf life of the cement.

Do NOT use cement that is lumpy or stringy. Do NOT try to thin it out with a thinner or primer. Always follow the instructions on the cement container; the above estimates should in no way be used in the place of application instructions.

Always use the specific glue for the piping to be joined i.e. PVC cement for PVC pipe, CPVC cement of CPVC pipe.

3.4.2 Fusion Welding

Fusion welding requires either a gas- or an electric-heated welding tool, as shown in *Figure 4-18*. As the tool warms up, spray its contact surfaces lightly with a silicone-releasing agent. This prevents the pipe from sticking to the surface of the welding tool. Check the temperature of the tool. Ensure the tool reaches the proper temperature range before placing the pipe on the heating element. Be sure the pipe is squarely on the element. Hold onto the pipe, until a bead appears on the pipe at the entrance of the female tool piece. After the bead appears, remove the pipe and insert it into the fitting, squarely and completely.

Figure 4-18 — Fusion welder.

WARNING

Do not rotate the pipe while it is being joined with the fitting.

3.4.3 Fillet Welding

In fillet welding of plastic pipe, as shown in *Figure 4-19*, maintain uniform heat by using a specially designed heat gun (hot air welder), which produces a jet of hot air that softens both the parts to be joined and a plastic filler rod, all of which must be of the same or a very similar plastic. The plastic welding rod is an extruded rod that is used to weld plastic. Suitable rod materials include ABS, PVC, Polypropylene, polyethylene, PVDF and many other types of thermoplastic. Plastic welding rods are available in a wide range of colors to match a project's color. Along with a uniform application of heat, a uniform pressure needs to be maintained on the rod while welding. Too much pressure on the rod stretches the bead and causes the weld to crack as it cools. The rod should be held at a 90-degree angle to the joint. The rod bends in an arc when proper pressure is applied. When finishing a weld, make the bead overlap the top, NOT alongside itself, for at least 3/8 to 1/2 inch. Never overlap alongside when welds are being spliced.

Figure 4-19 — Fillet welding plastic pipe.

3.4.4 Threaded

Threading reduces a pipes wall thickness and results in lower pressure ratings. Only schedule 80 or heavier pipe should be used when plastic pipe is being threaded. You should never use pipe wrench to tighten plastic pipe; use a strap wrench. However if you must use a pipe wrench to tighten be sure to use an insert within the vise jaws to prevent scoring of the pipe. Use a wood or aluminum plug while the pipe is being threaded to prevent distortion of the pipe and to avoid off-center threads. The dies should be sharp, and for best results with power tools, use a 5-degree negative front rake. When tightening threaded joints, avoid too much torque. One or two turns past hand-tight is sufficient. Teflon tape should be used as an anti seize pipe joint compound.

Test your Knowledge (Select the Correct Response)

3. What is the minimum temperature at which plastic piping should be joined?

   A. 60°F
   B. 55°F
   C. 45°F
   D. 40°F

4.0.0 COPPER TUBING ASSEMBLY

The hot water system is the part of the plumbing installation that heats water and distributes it to various fixtures. There are a number of ways to heat water, but whichever system is used must be able to supply maximum demand. Copper tubing and pipe is the most popular material used for the installation of a hot water supply system. Using copper in a hot water system is especially desirable because of its ability to resist corrosion, which increases in proportion to the temperature of the water.

There was a time when hot water delivered to plumbing fixtures was a luxury and very few people, even those who were considered affluent, were provided with this convenience. Current sanitation standards require some type of hot water system for all residences, so that even the humblest dwelling is provided with this convenience.

Part of your job will be the installation of copper tubing. You should enjoy working with this product, because it is lightweight and easy to install. The joints, easily made using fittings, are as permanent as the tubing itself. Copper tubing and pipe are less resistant to water flow as compared to galvanized steel pipe. Therefore, when you install copper tubing and pipe instead of galvanized steel pipe, you can use smaller tubing and pipe, and still deliver the same amount of water to the point of discharge.

4.1.0 Hot Water Distribution System

4.1.1 Types of Copper Tubing and Pipe

There are four types of copper tubing and pipe: K, L, M, and DWV. These classifications are based on tubing wall thickness.

4.1.1.1 Type K

A green band or green stenciling on the tubing and pipe surface identifies the pipe as type K. It is recommended for underground installation and high-pressure systems. It is ideal for building service lines and compressed air systems. Type K has the thickest wall of the four types of tubing. Type K copper can be purchased in standard lengths of 20 feet for hard drawn copper, or coils of 25 feet to 100 feet for soft drawn copper. Type K can be buried.

4.1.1.2 Type L

A blue band or blue stenciling on the surface of the tubing and pipe identifies the tubing and pipe as type L. It has a medium wall thickness and is recommended for interior use in plumbing and heating installations. Type L copper also can be purchased in standard lengths of 20 feet for hard drawn, or coils of 25 feet to 100 feet for soft drawn.

4.1.1.3 Type M

Type M has a light wall thickness and is used in low-pressure installations. It is identified with a red band or red stenciling on its surface. Both hard and soft drawn are available in 20 foot lengths.

4.1.1.4 Type DWV

The Drain, Waste, and Vent (DWV) have the thinnest wall of all types of copper tubing and pipe. DWV is used in above and below ground installations. It is available in hard drawn only in lengths of 20 feet. It is identified by a yellow color or stencil on its surface.

4.1.2 Measuring Copper Tubing and Pipe

When you measure copper tubing and pipe, be sure that the measurement that you want is correct. If the measurement is too short, the joint will be weak. If the measurement is too long, the joint will be put under strain and the service life of the pipe will be affected.

4.1.3 nding Copper Tubing

4.1.3.1 Hand Method

Probably the simplest method of bending tubing is the hand method. The copper tubing is filled with sand and gripped with your hands apart as shown in *Figure 4-20.* Bend the tubing a little at a time, starting from the outside, and working your thumbs toward the center of the bend. Do not try to make the complete bend by applying pressure from only one position. This procedure will probably kink the tubing some, even though it is filled with sand.

Figure 4-20 — Bending tubing filled with sand.

4.1.3.2 Bending Block

Another method of bending soft copper tubing is using a bending block, as shown in *Figure 4-21*. Mount the block on a table or some other solid structure. During the bending operation, insert one end of the tubing in the loop, and, using both hands; gradually form the tubing over the contour of the block. Hard drawn tubing can be bent with this method if it is ***annealed*** (softened by heat) first.

Figure 4-21 — Bending tubing over a block.

4.1.3.3 Spring Bender

Still another method a UT uses to bend copper tubing without buckling is to use a flexible bending spring. Soft drawn copper tubing must be used when using the spring bender because of the flexibility of the tubing. Bend the tubing by placing the correct size flexible bending spring over the tubing. Then gradually form the tubing with your thumbs while holding it against a table or solid surface. See *Figure 4-22*.

Figure 4-22 — Types of spring benders.

4.1.3.4 Mechanical Bender

Mechanical tube benders are considered the most practical and most accurate method of bending copper tubing. These benders are manufactured in many different sizes. When you place tubing in the bender, raise the right handle of the bender as far as it will go so that it rests in a horizontal position. Raise the clip and place the tubing in the space between the handle and slide block and the bending form. Now place the slip over the tubing and turn the handle slide bar about its pin and to the right. Note that the zero mark on the bending form will line up with the mark on the slide bar. Next, continue to pull the handle to the right (clockwise), until the tubing is bent to the desired angle. When using the mechanical bending tool, you may make bends up to 180° without buckling or kinking the tubing. See *Figure 4-23*.

Figure 4-23 — Mechanical bender.

4.2.0 Joining Copper Tubing

4.2.1 Ferrule Joints

A compression type joint has three parts: the fitting, nut, and ***ferrule***. First, cut the copper tubing to the correct length. Then ream the inside of the tubing to remove the burr. Slip the nut over the tubing, followed by the ferrule. Next, slide the end of the tubing into the fitting and slide the ferrule up against the fitting. Screw the nut onto the fitting. Use either an open-end or adjustable jaw wrench to finish tightening the nut. Tightening the nut compresses the ferrule onto the tubing and against the fitting. This action results in a watertight and airtight seal. Always use a backup wrench when assembling ferrule joints to protect the tubing from damage. See *Figure 4-24*.

Figure 4-24 — Cross section of a ferrule joint.

4.2.2 Flaring

Another joint is flaring. Flaring is an easy and satisfactory method of joining copper tubing. Flare the ends of the tubing and press them against the tapered surface of the flared fitting. Next, screw the flare nut over the end of the fitting as shown in *Figure 4-25*.

An advantage of this type of connection is that it is easily disassembled when repairs are necessary. The only thing required to disassemble this connection is to select the correct size wrench, unscrew the flare nut that makes up the compression-type connection, and separate the fittings. When you make a flare on copper tubing, you must take every precaution to produce an airtight and watertight joint. First, measure and cut the tubing to the proper length with a tubing cutter or hacksaw. Then remove the burr within the tubing by reaming. Copper tubing can be flared with a flaring cone and flaring block or with a plug type flaring tool. *Figure 4-25* shows a flaring block and cone.

Figure 4-25 — Flaring block and cone.

Before a flare is made, slip the compression nut on the tubing and insert the end of the tubing into the correct size hole in the flaring block. Then extend the end of the tubing above the face of the block twice the wall thickness of the tubing.

Next, attach the flaring yoke to the flaring block and center the flaring cone over the end of the tubing as shown in *Figure 4-26*. Force the cone against the flaring block by rotating the handle on the flaring yoke clockwise. This causes the end of the tubing to expand just enough to fit into the compression nut and over the end of the flare fitting.

Figure 4-26 — Positioning the flaring yoke and making the flare.

After the tubing has been flared properly, assembly of the joint is simple. Place the flare against the fitting. Next, slip the compression nut against the flare and screw it on the fitting. This operation compresses the flare of the tubing between the fitting and nut. When these joints are properly constructed and tightened, they will withstand 3,000 psi of internal pressure.

4.2.3 Swedging

Swedging is the process of expanding the end of the tubing to receive the same size tubing. The joint is then sealed by soldering. By swedging, one fitting is eliminated, normally a coupling.

The swedging kit (*Figure 4-27*) consists of a swedging tip that can be changed out to swedge different size pipe. It fits easily inside of the tubing. The kit contains a block that holds the tubing in place while making the swedge. The yoke with a handle is attached to the block. When the handle is turned clockwise, the swedge tip will be forced into the pipe, enlarging the pipe. The swedge kit is very similar to the flaring kit. It uses the same flaring block that was used for flaring copper tubing.

Figure 4-27 — Swedging kit.

4.2.3.1 Procedures

The flaring block has several holes of various sizes (*Figure 4-28, View A*). On the front side of the block the holes are beveled for flaring. On the back side of the block, there are no bevels. This side of the block is used for swedging. To swedge, select the proper size hole in the block and insert the tubing. The distance the tubing should extend above the face of the flaring block is the diameter of the tubing plus 1/8 inch. Select the correct size swedging tip and attach it to the yoke with the handle. Slip the clamp on the block and twist to lock it in place (Figure 4-28, View B). Turn the handle clockwise to drive the swedging tip down, forcing the pipe to expand. Once the swedge tip has been completely inserted, then retract the swedge by turning the clamp handle counterclockwise. Inspect the pipe by inserting the same size copper tubing into the end of the swedge (*Figure 4-28, View C*). The fitting should be snug. Then follow the procedures for soldering that will be explained next.

Figure 4-28 — Swedging process.

4.2.4 Soldering (Sweat)

Soldering (sweating) is a method of joining two metals together by allowing molten solder to run between them and cool. The law of capillary attraction governs the force responsible for bonding in solder joints.

4.2.4.1 Preparing a Soldered Joint

The copper tubing and fittings must be properly prepared before assembling a soldered joint. The metallic surfaces must be cleaned thoroughly to remove oxidation. This can be done by using emery cloth, steel wool, sandpaper or a fitting brush. When cleaning copper tubing, clean the exterior of the tubing and the interior of the fittings. ***Flux*** is then applied to the exterior of the tubing, and the interior of fittings. The flux will prevent oxidation from occurring during the soldering procedure. If oxidation occurs, the solder will not bond to the copper.

4.2.4.2 Torch

Figure 4-29 illustrates a acetylene torch that is ideal for soldering small copper lines. The torch will heat the tubing quickly and evenly. An acetylene torch can be used to solder larger diameter copper tubing and brass fittings.

4.2.4.3 Solder

95/5 solder is used to solder copper tubing. It is 95% tin and 5% antimony and melts at 452° F. It replaced the old 50/ 50 solder that had a very high lead content. Usually, the solder is 1/8 inch in diameter and comes in rolls.

Figure 4-29 — Acetylene torch.

4.2.4.4 Procedures

After cleaning and fluxing the piping and materials, insert the tubing inside the fitting. Apply heat to the fitting with the torch. When soldering small diameter piping and materials, you can hold the flame at one spot on the fitting. With large piping and materials, you will have to move the flame all over the fitting to ensure the heat is applied evenly. Frequently touch the solder to the fitting to see if the melting point has been reached. Once the solder melts and begins to free flow, remove the flame from the fitting. The solder will be drawn into the joint by capillary action. The amount of solder needed will be equal to the diameter of the tubing being joined. For example, it would take 3/4 inch of solder to assemble a 3/4 inch joint. Once enough solder is in the joint, wipe the joint with a wet rag. The rag makes the joint cool faster and will remove any excess solder and flux residue.

4.2.4.4.1 Silver Solder

Procedures are the same as with regular solder. Clean the tubing and fitting thoroughly, and then apply flux to them. Use air acetylene or oxygen acetylene torch to apply heat because of the high temperature required to silver solder. See *Figure 4-30*.

Solder made of silver alloy comes in many sizes, compositions, and

Figure 4-30 — Air acetylene torch.

strengths. To determine the type of solder to use, follow the manufacturer's specifications. The melting point for silver solder is from 1145° F to 1650° F, enabling it to withstand more pressure and temperature than 95/5 solder, which is why it is used on high pressure lines.

4.3.0 Supporting Copper Tubing

During the installation of copper piping you must consider several factors. First consider the weight of the pipe, and then the length of the pipe that will be installed. Will the pipe be supported in a vertical position or a horizontal position? Always refer to the International Plumbing Code and project specifications when you are not sure of the support requirements.

Pipe that is supported horizontally and is 1 1/2 inch or less in diameter is supported every 6 feet. Pipe that is 2 inches and larger is supported every 10 feet. Pipe that is supported vertically will be supported at each floor level, not to exceed 10 feet between supports.

4.4.0 System Layout

When you are ready to determine the system layout, the following items will help you create a successful layout. First, use the building construction plans to determine where the piping system will need to be installed. Working and isometric drawings that you create will help guide your thoughts when considering different aspects of the job. Refer to the building construction plans when creating your working and isometric drawings. Refer to the manufacturer's rough-in specifications for details. (Example: drain line installed 16 inches above the finished floor, and supply lines installed 20 inches above the finished floor). Develop a bill of materials using the working and isometric drawings. This will be a shopping list of the parts that will be needed for the job.

4.5.0 Safety

4.5.1 Safety Equipment

Always wear your safety equipment. Neglecting to wear safety items will increase the chance of injury. All it takes is one slip up for you to receive a permanent injury that could have been prevented. Safety gloves help protect your hands against hot flux and molten solder that can cause burns to the skin. Eye protection, such as goggles or face shields, protect your eyes and face. Long sleeves will protect your arms.

4.5.2 Safety Precautions

All safety precautions directed by the manufacturer or your supervisor will be followed to ensure your safety and the safety of your shipmates. Fire extinguishers should be close by in case of fire, and the area should be well ventilated.

Heat shields are provided to prevent any wood from catching fire. This is a small sheet of metal that you place behind the copper pipe when you are soldering in a tight location and the flame would touch the wood. After you are finished soldering, remove the heat shield. Inspect the job site for any smoldering wood whenever you have finished soldering in tight places.

Test your Knowledge (Select the Correct Response)

4. Which of the following processes is used to expand the end of the tubing to receive the same size tubing?

   A. Ferruling
   B. Flaring
   C. Sweating
   D. Swedging

Summary

Buildings and facilities are constructed from a number of different products, but all require entry and exit of utilities through structural openings. Your knowledge of proper location, construction, and materials utilized in structural openings is key to the successful completion of any project.

Steel, copper, and plastic pipe assembly were covered in this lesson, including methods, material, and component selection. The responsibility of the proper material selection and location for the different distribution systems encountered begins with the UT.

Review Questions (Select the Correct Response)

1. What is a feature of the box type structural design method?

   A. Plumbing is exposed.
   B. Water supply piping is located above floor level.
   C. Studs inside the building are not exposed.
   D. Drainage piping is located within the box type framework.

2. What is required for piping to pass through a masonry wall in a frame type structural design method?

   A. Pipe hangers are required within masonry walls.
   B. Sleeve or plastic pipe is placed around the piping.
   C. Metal sheaving 4 inches wide is placed around piping.
   D. No actions are required for this design method.

3. Where can the locations of plumbing fixtures to be placed inside a storage facility be located prior to construction?

   A. Site plans
   B. Rough- in specifications
   C. Floor plans
   D. Working drawing

4. During the construction of a building (berthing), UTs complete the plumbing installation in how many phases?

   A. 5
   B. 4
   C. 3
   D. 2

5. Before the concrete slab foundation is poured, what needs to be installed first?

   A. Horizontal drainage piping below ground
   B. Corporation stop
   C. Vertical water piping below ground
   D. Curb box

6. When piping is stubbed up, what is the minimum termination height of the pipe in inches?

   A. 6
   B. 12
   C. 18
   D. 24

7. Which of these tools is used to make round holes in wood with an electric drill?

   A. Carbide bit
   B. Keyhole saw
   C. Paddle bit
   D. Star drill

8. If electricity is not available, which of these tools would be utilized to make irregular shaped holes?

   A. Hole saw
   B. Reciprocating saw
   C. Jigsaw
   D. Keyhole saw

9. What type of structural opening is made by notching the top of the structural member?

   A. Over cut
   B. Notch cut
   C. Under cut
   D. Center cut

10. What is the maximum size of an under cut on a beam?

   A. 1/4 the width of the beam
   B. 1/2 the width of the beam
   C. 1/4 the length of the beam
   D. 1/2 the length of the beam

11. Horizontal water and waste piping must be supported to prevent what condition?

   A. Stress
   B. Cracking
   C. Sagging
   D. Pressure drop

12. During the rough-in process, which type of measurement is most commonly used?

   A. End-to-center
   B. End-to-end
   C. Face-to-face
   D. Center-to-center

13. When cutting pipe with a pipe cutter, how do you open the jaws of the cutter?

   A. Turn the handle in a counterclockwise direction.
   B. Loosen set screw and turn handle in downward direction.
   C. Turn the handle in a clockwise direction.
   D. Loosen set screw and turn handle in upward direction.

14. What is the purpose of reaming a pipe after the initial cut?

    A. Ensure threads are perpendicular to each other
    B. Remove burrs from the inside diameter of the pipe
    C. Ensure threads are parallel to each other
    D. Remove burrs form the outside diameter of the pipe

15. What is the desired angle of a locally manufactured piece of pipe threads?

    A. 40°
    B. 50°
    C. 60°
    D. 70°

16. Which of these prevents the threads from becoming dulled during the pipe threading process?

    A. High pressure water
    B. Antiseize compound
    C. Pipe compound
    D. Oil

17. What two pipe-joint compounds are most commonly used?

    A. Teflon tape and pipe dope
    B. Pipe dope and pipe glue
    C. Teflon tape pipe glue
    D. Pipe putty and Teflon tape

18. What is the result of over tightening the joint when connecting fitting connections?

    A. Fitting will sag.
    B. Joint might leak.
    C. Water flow will be reduced.

19. What size pipe wrench is used with a 1 inch pipe?

    A. 8 inch
    B. 10 inch
    C. 14 inch
    D. 18 inch

20. What size pipe wrench is used with a 1/8 inch pipe?

    A. 8 inch
    B. 10 inch
    C. 14 inch
    D. 18 inch

21. How many different types of pipe nipples will you work with as a UT?

A. 1
B. 2
C. 3
D. 4

22. **(True or False)** Whenever you are assembling threaded joints, be sure to apply joint compound to the female threads.

A. True
B. False

23. What is the size of the cold water inlet line for a cold water distribution system installation?

A. 1/4 inch
B. 1/2 inch
C. 3/4 inch
D. 1 inch

24. At what interval is 3/4 inch steel pipe horizontally supported?

A. Every 3 feet
B. Every 5 feet
C. Every 6 feet
D. Every 10 feet

25. By how much space and how many feet is 1/2 inch steel pipe vertically supported?

A. Every other floor not to exceed 25 feet
B. Every floor not to exceed 10 feet
C. Every other floor not to exceed 15 feet
D. Every floor not to exceed 12 feet

26. Before water is applied to a structure, how many pressure tests of the piping are conducted?

A. One
B. Two
C. Three
D. Four

27. Which type of plastic pipe is used for distribution mains?

A. PVC 50
B. CPVC
C. PVC
D. CPVC 50

28. What size does Polyvinyl Chloride piping come in?

A. 5 foot lengths
B. 10 foot lengths
C. 15 foot lengths
D. 20 foot lengths

29. What is the maximum temperature that CPVC piping can withstand?

A. 180° F
B. 200° F
C. 220° F
D. 250° F

30. PVC schedule 40 piping is used in which type of piping system?

A. Exterior drainage lines
B. Exterior water lines
C. Interior waste lines
D. Interior water lines

31. **(True or False)** PVC schedule 80 can withstand a higher pressure than PVC schedule 40.

A. True
B. False

32. PVC schedule 80 piping can be joined by which two materials or methods?

A. Teflon tape and threading
B. Welding and solvent glue
C. Threading and welding
D. Solvent glue and threading

33. Which of these distribution systems utilizes CPVC schedule 40 piping?

A. Interior water
B. Exterior water
C. Interior waste
D. Exterior waste

34. Before solvent welding operations are conducted, how long do the fitting and pipe temperatures need to remain the same?

A. One-half hour
B. One hour
C. Two and one-half hours
D. Four hours

35. At what temperature should the pipe be placed in a shaded area prior to priming the interior of the pipe threading?

A. 70° F
B. 80° F
C. 90° F
D. 100° F

36. When solvent welding, how long do you need to hold the two ends welded together to achieve a good adhesion?

A. 45 seconds
B. 2 minutes
C. 5 seconds
D. 10 to 15 seconds

37. During the solvent welding process, what is the result of rapid drying the connection?

A. Blisters in the cement film
B. Increased cure time
C. Cracking of fitting joint
D. Thread retraction

38. Which type of agent is applied to the contact tip of the fusion electric welding tool?

A. Heat releasing
B. Silicone releasing
C. None

39. During fillet welding operations, what is the result of too much pressure on the rod while welding?

A. Weld will not hold when temperature reaches above 90°F.
B. Bead will form condensation.
C. Weld will crack as it cools.
D. Turbidity will occur at weld point.

40. What is the most popular material used in hot water supply installation operations?

A. CPVC schedule 40 piping
B. Steel piping
C. PVC schedule 80 piping
D. Copper tubing

41. What color designates Type K copper tubing?

A. Green
B. Blue
C. Red
D. Yellow

42. Which type of copper tubing is recommended for use in heating installations?

A. K
B. L
C. M
D. DWV

43. **(True or False)** Type M copper tubing is identified with a red band or red stenciling on its surface.

A. True
B. False

44. Type DWV tubing is available in what size?

A. 5 foot lengths
B. 10 foot lengths
C. 15 foot lengths
D. 20 foot lengths

45. Which method of bending tubing is the simplest?

A. Hand
B. Bending block
C. Spring bender
D. Mechanical bender

46. When using a mechanical bender, you can make bends up to how many degrees?

A. 270°
B. 180°
C. 90°
D. 45°

47. How many parts make up a compression type joint?

A. 1
B. 2
C. 3
D. 4

48. What is an advantage of using a flaring type of copper tubing connection?

A. Cost
B. Ease of assembly
C. Material availability
D. Ease of disassembly

49. **(True or False)** When flared joints are properly tightened, they will withstand 4,000 psi of internal pressure.

A. True
B. False

50. What scientific principle governs the force responsible for bonding in solder joints?

A. Law of increased entropy
B. Law of capillary attraction
C. Law of motion
D. Law of physical attraction

51. Which of the following solder types is used to solder copper tubing?

A. 90/10 solder
B. 50/50 solder
C. 95/5 solder
D. 25/75 solder

52. What is the melting point of silver solder?

A. 1675° to 2165°
B. 945° to 1132°
C. 1145° to 1650°

53. Solder used in joining copper tubing melts at what temperature?

A. 452°
B. 697°
C. 945°
D. 1145°

54. When horizontally supporting copper tubing that is 1 1/2 inch or less in diameter, what are the spacing support requirements?

A. Every 3 feet
B. Every 6 feet
C. Every 10 feet
D. Every 12 feet

Trade Terms Introduced in this Chapter

Reaming	Forming, shaping, tapering, or enlarging (a hole or bore, for example).
Annealed	Freed from internal stress by heating and gradual cooling.
Ferrule	A short plumbing fitting covered at its outer end and caulked or otherwise fixed to a branch from a pipe so that it can be removed to give access to the interior of the pipe.
Flux	A substance used to remove oxides from and prevent further oxidation of fused metal, as in soldering or hot-dip coating.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Basic Machines, NAVEDTRA 12199, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

OSHA Regulations (Standards – 29 CFR)

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Naval Construction Force Manual, *NAVFAC P-315,* Naval Facilities Engineering Command, Washington, D.C., 1985.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

National Standard Plumbing Code-Illustrated, National Association of Plumbing- Heating-Cooling Contractors, Washington, DC, 2006.

International Plumbing Code 2009, International Code Council

International Mechanical Code 2009, International Code Council

R. Dodge Woodson, *Plumber's Quick-Reference Manual Tables, Charts, and Calculations,* 1st edition, McGraw-Hill, NY, 1996.

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Chapter 5

Piping System Layout and Plumbing Accessories

Topics

To hear audio, click on the box.

Overview

Your job as an Utilitiesman (UT) is to prepare the construction site before laying wastewater and water distribution systems. Your work could begin with site surveys using specialized surveying equipment and methods.

This chapter introduces you to the concepts of site surveys, including construction surveys, leveling rods, bench marks, sewer stakeouts, and common errors and mistakes encountered.

In this chapter, you will be provided with information regarding the different types of valves and procedures for installing and repairing them, valve accessories, and pipe fittings. Also discussed are testing of systems, and laying out water distribution systems.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe surveying operations.
2. Describe the operation and use of leveling rods.
3. Identify bench mark as associated with surveying.
4. Identify common errors and mistakes associated with surveying operations.
5. Describe the purpose and components of sewer stakeout.
6. Describe plumbing valves and accessories.
7. Describe the types, purpose, and correct method of reading water meters.
8. Describe water distribution system accessories.

Prerequisites

None.

This course map shows all of the chapters in Utilitiesman Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Utilities Equipment and Maintenance	↑	
Air Conditioning		
Refrigeration		
Heating Systems		U
Steam Distribution Systems		T
Boilers		
Sewage Disposal, Field Sanitation, and Water Treatment		B
Prime Movers, Pumps, and Compressors		A
Plumbing Fixtures		S
Piping System Layout and Plumbing Accessories		I
Structural Openings and Pipe Material		C
Fundamentals of Water Distribution		
Basic Math, Electrical, and Plumbing Operations		
Plans, Specifications, and Color Coding		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for

review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 SURVEYING INSTRUMENTS

The engineer's level, often called the ***dumpy level***, is the instrument most commonly used to attain the level line of sight required for differential leveling. The dumpy level and the self-leveling level can be mounted for use on a tripod, usually with adjustable legs, shown in *Figure 5-1*.

Mount the level by engaging the threads at the base of the instrument, called the footplate as shown in *Figure 5-2*, with the threaded head on the tripod. These levels are the ones most frequently used in ordinary leveling projects. For rough leveling, use the ***hand level***.

Figure 5-1 – Tripod.

1.1.0 Dumpy Level

Figure 5-2 shows a dumpy level and its nomenclature. Notice that the telescope is rigidly fixed to the supporting frame.

Inside the telescope is a ring, or diaphragm, known as the reticle, which supports the cross hairs. The cross hairs are brought into exact focus by manipulating the knurled eyepiece focusing ring near the eyepiece, or the eyepiece itself on some models. If the cross hairs get out of horizontal adjustment, they can be made horizontal again by slackening the reticle adjusting screws and turning the screws in the appropriate direction. Only trained personnel, such as Engineering Aids (EA), should perform this adjustment.

Figure 5-2 – Dumpy level.

The object to which you are sighting, regardless of shape, is called a target. Bring the target into clear focus by manipulating the focusing knob shown on top of the telescope. The telescope can be rotated only horizontally, but before it can be rotated, release the azimuth clamp. Bring the vertical cross hair into exact alignment on the target by rotating the azimuth tangent screw.

The level vial, leveling head, leveling screws, and footplate are all used to adjust the instrument to a perfectly level line of sight once it is mounted on the tripod.

1.2.0 Self-Leveling Level

The self-leveling, or automatic, level, shown in *Figure 5-3* is a precise, time-saving development in leveling instruments. It did away with the tubular spirit level, whose bubble takes time in centering as well as in resetting to its correct position from time to time during operation.

The self-leveling level is equipped with a small bull's-eye level and three leveling screws. The leveling screws, which are on a triangular foot plate, are used to center the bubble of the bull's-eye level approximately. The line of sight automatically becomes horizontal and remains horizontal as long as the bubble remains approximately centered. A prismatic device called a compensator makes this possible. The compensator is suspended on fine, nonmagnetic wires. The action of gravity on the compensator causes the optical system to swing into the position that defines a horizontal sight. The level maintains this horizontal line of sight despite a slight out of level of the telescope or even when a slight disturbance occurs on the instrument.

Figure 5-3 – Self-leveling level.

1.3.0 Hand Level

The hand level, like all surveying levels, combines a level vial and a sighting device. *Figure 5-4* shows the ***Locke level***, a type of hand level. A horizontal line, called an index line, is provided in the sight tube as a ***reference line***. The level vial is mounted atop a slot in the sighting tube in which a reflector is set at a 45° angle. This permits the observer sighting through the tube to see the object, the position of the level bubble in the vial, and the index line at the same time.

To get the correct sighting through the tube, stand straight, using the height of your eye, if known, above the ground to find the target. When your eye height is not known, you can find it by sighting the rod at eye height in front of your body. Since the distances over which you sight a hand level are rather short, no magnification is provided in the tube.

Figure 5-4 – Locke level.

1.4.1 Setting Up a Level

After you select the proper location for the level, your first step is to set up the tripod.

1. Spread two of the legs a convenient distance apart and then bring the third leg to a position that will bring the protector cap, which covers the tripod head threads, about level when the tripod stands on all three legs.
2. Unscrew the protector cap, exposing the threaded head, and place it in the carrying case where it will not get lost or dirty. The tripod protective cap should be in place when you are not using the tripod.
3. Lift the instrument out of the carrying case by the footplate, not by the telescope.

4. Set the instrument squarely and gently on the tripod head threads and engage the head nut threads under the footplate by rotating the footplate clockwise. If the threads will not engage smoothly, they may be cross threaded or dirty. Do not force them if you encounter resistance; instead, back off, and, after checking to see that they are clean, square up the instrument, and then try again gently.
5. Screw the head nut up firmly, but not too tightly. Screwing it too tightly causes eventual wearing of the threads and makes unthreading difficult.
6. After you have attached the instrument, thrust the leg tips into the ground far enough to ensure that each leg has stable support, taking care to maintain the footplate as nearly level as possible.
7. With the instrument mounted and the legs securely positioned in the soil, firmly tighten the thumbscrews at the top of each leg to prevent any possible movement.

Quite frequently, you must set up the instrument on a hard, smooth surface, such as a concrete pavement. When you do, you must take steps prevent the legs from spreading. *Figure 5-5* shows two good ways of doing this. In *View A*, the tips of the legs are inserted in joints in the pavement. In *View B*, the tips are held by a wooden floor triangle.

Figure 5-5 – Methods of preventing tripod legs from spreading.

1.5.0 Leveling a Level

To function accurately, the level must provide a perfectly horizontal line of sight in any direction you train the telescope. To ensure this, you must level the instrument as discussed in the next paragraphs or follow the manufacture’s instructions.

When you first set up the tripod and instrument, make the footplate as nearly level as possible.

Train the telescope over a pair of diagonally opposite leveling screws, and clamp it in that position.

Manipulate the leveling thumbscrews, as shown in *Figure 5-6,* to bring the bubble in the level vial exactly into the marked center position. Manipulate the thumbscrews by simultaneously turning them in opposite directions. This shortens one spider leg, the threaded member running through the

Figure 5-6 – Manipulating leveling thumbscrews.

thumbscrew, while it lengthens the other. It is helpful to remember that the level vial bubble will move in the same direction that your left thumb moves while you rotate the thumbscrews. In other words, when your left thumb pushes the thumbscrew clockwise, the bubble will move towards your left hand; when you turn the left thumbscrew counterclockwise, the bubble moves toward your right hand.

After leveling the telescope over one pair of screws, train it over the other pair and repeat the process. As a check, set the telescope in all four possible positions and be sure that the bubble centers exactly in each.

Various techniques for using the level will develop with experience.

1.6.0 Care of Levels

An engineer's level is a precision instrument containing many delicate and fragile parts. Handle it gently and very carefully at all times; never subject it to shock or jar. Movable parts, if not locked or clamped in place, should work easily and smoothly. If a movable part resists normal pressure, something is wrong. Forcing the part to move will probably damage the instrument. Tightening clamps and screws excessively will also cause wear or damage.

The only proper place to stow the instrument when it is detached from the tripod is in its own carrying box or case. The carrying case is designed to reduce the effect of jarring to a minimum. It is strongly made and well padded to protect the instrument from damage. Before stowing, slightly tighten the azimuth clamp and leveling screws to prevent movement of parts inside the box. When transporting it in a vehicle, place the case containing the instrument as nearly as possible midway between the front and rear wheels. This is the point where jarring of the wheels has the least effect on the chassis.

Never lift the instrument out of the case by grasping the telescope. Wrenching the telescope in this manner will damage a number of delicate parts. Lift it out by reaching down and grasping the footplate or the level bar.

When you attach the instrument to the tripod and carry it from one point to another, set up the azimuth clamp and level screws tightly enough to prevent part motion during the transport but loosely enough to allow give in case of an accidental bump against some object. When you are carrying the instrument over terrain that is free of possible contacts, such as across an open field, you may carry it over your shoulder like a rifle. When there are obstacles around, carry it with the telescope and base close into the front of your body. Carried in this manner, the instrument is always visible to you, and this makes it possible for you to avoid striking it against obstacles.

Test your Knowledge (Select the Correct Response)

1. By what part should you initially remove surveying equipment from the carrying case?

   A. Footplate
   B. Telescope
   C. Legs
   D. Leveling rods

2.0.0 LEVELING RODS

A leveling rod is a vertically supported tape used to measure vertical distance, which is the difference in elevation between a line of sight and a required point above or below it. Although there are several types of rods, the most popular and frequently used is the Philadelphia rod. *Figure 5-7* shows the face and back of this rod.

Figure 5-7 — Back and face of Philadelphia leveling rod.

The Philadelphia rod consists of two sliding sections, which can be fully extended to a total length of 13.10 feet. When the sections are entirely closed, the total length is 7.10 feet. For direct readings, or readings on the face of the rod, between 7.10 and 13.10 feet, the rod is used extended and read on the back by the rodman. If you are in the field and do not have a Philadelphia rod, you can use a 1 by 4 with a mark or a 6-foot wooden ruler attached to a 2 by 4.

In direct readings, the person at the instrument reads the graduation on the rod intercepted by the cross hair through the telescope. In target readings, the rodman reads the graduation on the face of the rod intercepted by a target. In *Figure 5-7* the target does not appear; it is shown in *Figure 5-8*. It is a sliding, circular device that can be moved up or down the rod and clamped in position. The rodman places it on signals from the instrumentman.

The rod shown in the figures is graduated in feet and hundredths of a foot. Each even foot is marked with a large red numeral. Between each pair of adjacent red numerals, the intermediate tenths of a foot are marked with smaller black numerals. Each intermediate hundredth of a foot between each pair of adjacent tenths is indicated by the top or bottom of one of the short, black dash graduations.

Figure 5-8 — Philadelphia rod set for target reading of less than 7000 feet.

2.1.0 Direct Readings

As the levelman, you can make direct readings on a self-reading rod held plumb on the point by the rodman. If you are working to tenths of a foot, it is relatively simple to read the footmark below the cross hair and the tenth mark that is closest to the cross hair. If greater precision is required, and you must work to hundredths, the reading is more complicated, as shown in *Figure 5-9*.

For example, suppose you are making a direct reading that should come out to 5.67 feet. If you are using a Philadelphia rod, the interval between the top and the bottom of each black graduation and the interval between the black graduations each represent 0.01 foot.

Figure 5-9 – Philadelphia rod marking.

This is shown in *Figure 5-10*, where each graduation represents 0.01 foot. For a reading of 5.76 feet, there are three black graduations between the 5.70 foot mark and the 5.76 foot mark. Since there are three graduations, a beginner may have a tendency to misread 5.76 feet as 5.73 feet.

Neither the 5 foot mark nor the 6 foot mark is shown in *Figure 5-10*. Sighting through the telescope, you might not be able to see the foot marks to which you must refer for the reading. When you cannot see the next lower foot mark through the telescope, it is a good idea to order the rodman to "raise the red**."** On the Philadelphia rod, whole feet numerals are in red. Upon hearing this order, the rodman slowly raises the rod until the next lower red figure comes into view.

Figure 5-10 – Direct reading of 5.76 feet on a Philadelphia rod.

2.2.0 Target Readings

For more precise vertical measurements, level rods may be equipped with a rod target that can be set and clamped by the rodman at the direction of the instrumentman. When the engineer's level rod target and the vernier scale are being used, it is possible to make readings of one thousandth of a foot (0.001), which is slightly smaller than one sixty-fourth of an inch. Either the rodman or the instrumentman can read the indicated reading of the target. In *Figure 5-11*, you can see that the 0 on the vernier scale is in exact alignment with the 4 foot mark. If the position of the 0 on the target is not in exact alignment with a line on the rod, go up the vernier scale on the target to the line that is in exact alignment with the hundredths line on the rod, and the number located will be the reading in thousandths.

There are three situations in which target reading, rather than direct reading, is done on the face of the rod:

- When the rod is too far from the level to be read directly through the telescope.
- When a reading to the nearest 0.001 foot, rather than to the nearest 0.01 foot, is desired. A vernier on the target or on the back of the rod makes this possible.
- When the instrumentman wants to ensure against the possibility of reading the wrong foot designation on the rod, indicated by a large red number.

Figure 5-11 – Target.

For target readings up to 7.000 feet, the rod is used fully closed, and the rodman, on signals from the instrumentman, sets the target at the point where its horizontal axis is intercepted by the cross hair, as seen through the telescope. When the target is located, it is clamped in place with the target screw clamp, shown in *Figure 5-8*. When a reading to only the nearest 0.01 foot is desired, the graduation indicated by the target's horizontal axis is read; in *Figure 5-8*, this reading is 5.84 feet.

If reading to the nearest 0.001 foot is desired, the rodman reads the vernier, the small scale running from 0 to 10, on the target. The 0 on the vernier indicates that the reading lies between 5.840 feet and 5.850 feet. To determine how many thousandths of a foot over 5.840 feet, examine the graduations on the vernier to determine which one is most exactly in line with a graduation, the top or bottom of a black dash, on the rod. In *Figure 5-8*, this graduation on the vernier is the 3; so the reading to the nearest 0.001 foot is 5.843 feet.

For target readings of more than 7.000 feet, the procedure is a little different. If you look at the left-hand view of *Figure 5-7* showing the back of the rod, you will see that only the back of the upper section is graduated and that it is graduated downward from 7.000 feet at the top to 13.09 feet at the bottom. You can also see there is a rod vernier fixed to the top of the lower section of the rod. This vernier is read against the graduations on the back of the upper section.

For a target reading of more than 7.000 feet, the rodman first clamps the target at the upper section of the rod. Then, on signals from the instrumentman, the rodman extends the rod upward to the point where the horizontal axis of the target is intercepted by the cross hair. The rodman then clamps the rod, using the rod clamp screw shown in *Figure 5-12*, and reads the vernier on the back of the rod, also shown in that figure. In this case, the 0 on the vernier indicates a certain number of thousandths more than 7.100 feet. Remember that in this case, you read the rod and the vernier down from the top, not up from the bottom. To determine the thousandths, determine which vernier graduation lines up most exactly with a graduation on the rod. In this case, it is the 7, so the rod reading is 7.107 feet.

Figure 5-12 – Philadelphia rod target reading of more than 7000 feet.

2.3.0 Rod Levels

A rod reading is accurate only if the rod is perfectly plumb, or vertical, at the time of the reading. If the rod is out of plumb, the reading will be greater than the actual vertical distance between the height of instrument (HI) and the base of the rod. On a windy day, the rodman may have difficulty holding the rod plumb. In this case, the levelman can have the rodman wave the rod back and forth, allowing the levelman to read the lowest reading touched on the engineer's level cross hairs.

The use of a rod level ensures a vertical rod. A bull's-eye rod level is shown in *Figure 5-13*. When it is held as shown and the bubble is centered, the rod is plumb. Note that the rod is held on a part of the rod where readings are not being taken to avoid interference with the instrumentman's view of the scale.

A vial rod level has two spirit vials, each of which is mounted on the upper edge of one of a pair of hinged metal leaves. The vial level is used like the bull's-eye level, except that two bubbles must be watched instead of one.

Figure 5-13 – Bull's-eye rod level.

2.4.0 Care of Leveling Rods

A leveling rod is a precision instrument and must be treated as such. Most rods are made of carefully selected, kiln-dried, well seasoned hardwood. Scale graduations and numerals on some are painted directly on the wood; on most rods they are painted on a metal strip attached to the wood. Unless a rod is handled at all times with great care, the painted scale will soon become scratched, dented, worn, or otherwise marked and obscured. Accurate readings on a damaged scale are difficult.

Allowing an extended sliding section rod to close on the run by permitting the upper section to drop may jar the vernier scale out of position or otherwise damage the rod. Always close an extended rod by easing the upper section down gradually.

A rod will read accurately only if it is perfectly straight. Anything that might bend or warp the rod must be avoided. Do not lay a rod down flat unless it is supported throughout, and never use a rod for a seat, lever, or pole vault. In short, never use a rod for any purpose except the one for which it is designed or intended.

Store a rod that is not in use in a dry place to avoid warping and swelling caused by dampness. Always wipe off a wet rod before putting it away. If there is dirt on the rod, rinse it off, but do not scrub it off. If you must use a soap solution, to remove grease, for example, use a very mild one. A strong soap solution will soon cause the paint on the rod to degenerate.

Protect a rod as much as possible against prolonged exposure to strong sunlight. Such exposure causes paint to chalk, to degenerate into a chalk-like substance that flakes from the surface.

2.5.0 Colors and Markings

The face of all rods are painted white with graduation marks painted black.

The black graduations on the rod are 0.01 or (one hundredth) of a foot wide and are spaced one hundredth of a foot apart. So each alternate black and white space is 0.01, or one hundredth, of a foot.

The large numbers painted in red represent whole feet, and the small black numbers indicate tenths of a foot.

From the face of the level rod you can determine feet, tenths, and hundredths.

Test your Knowledge (Select the Correct Response)

2. How many sliding portions does a Philadelphia rod have?

   A. 1
   B. 2
   C. 3
   D. 4

3.0.0 BENCH MARK (BM)

A Bench Mark (BM) is a relatively permanent object, natural or artificial, bearing a marked point whose elevation is known. BMs are established over an area to serve as (1) starting points for leveling operations so the topographic parties can determine other unknown elevation points, and (2) reference marks during later construction work. BMs are classified as Permanent or Temporary. Generally, BM indicates a permanent bench mark, and TBM a temporary bench mark. TBMs are established for a particular job and retained for the duration of that job. Throughout the United States, a series of BMs has been established by various government agencies. These identification markers are set in stone, iron pipe, or concrete, and are generally marked to show the elevation above sea level. When the elevation is not marked, you can find out what it is by contacting the government agency that originally set the BM. Be sure you give them the identification number on the marker.

Bench marks may be constructed in several ways. *Figure 5-14* shows brass shaft stocks in the tops of permanent horizontal control points, also known as monuments. Monuments of this type are sometimes also used for vertical control BMs. Original BMs may be constructed in the same manner. When regular BM disks are not available, brass, not steel, 50-caliber empty shell casings may be used. The shank of the empty shell casings should be drilled crosswise and a nail inserted to prevent its being pulled

Figure 5-14 — Horizontal control points used also as bench marks.

out or forced out by either expansion or contraction.

For short lines and a level circuit of a limited area, any substantial object may be used for vertical control BMs. The remark in the field notes should bear the proper identification of the BMs used.

Figure 5-15 shows a mark like those commonly used on tops of concrete walls, foundations, and the like. Lines are chiseled out with a cold chisel or small star drill and then marked with paint or keel. The chiseled figures should be about the same size as the base area of the rod. They should be placed on some high spot on the surface of the concrete structure.

Figure 5-15 – Points on existing structures used as bench marks.

A spike may be driven into the root of a tree or placed higher up on the trunk of the tree when the limb clearance allows higher rod readings. *Figure 5-16* shows the recommended way to do this. Hold the rod on the highest edge of the spike, and mark the elevation on the blazed portion of the tree.

Figure 5-17 shows a spike driven on a pole or post that also represents a BM. Drive the spike in horizontally on the face of the post in line with the direction of the level line. For the reading, hold the rod on the uppermost edge of the spike. After figuring the elevation, mark it on the pole or post for future reference.

Stakes driven into the ground can also be used as TBMs, especially if no frost is expected before they are needed. A detailed description of these points is just as important as one for a monument station.

Figure 5-16 – Spikes used as bench marks on trees and roots.

In most permanent military installations, monument BMs are established in a grid system approximately one-half mile apart throughout the base to have a ready reference for elevations of later construction in the station. These BMs are generally fenced to mark their locations. The fence also serves to protect them from being accidentally disturbed.

BM systems, or level nets, consist of a series of BMs established within a prescribed order of accuracy along closed circuits and tied to a datum. These nets are adjusted by computations that minimize the effects of accidental errors and are identified as being of a specific order of accuracy.

In certain areas, Tidal Bench Marks must be established to obtain the starting datum plane or to check previously established elevations. Tidal bench marks are permanent BMs set on high ground and are tied to the tide station near the water surface.

Figure 5-17 – Spikes used as bench marks on poles or posts.

Tide stations are classified as primary and secondary. Primary stations require observations for periods of nineteen years or more to derive basic tidal data for a locality. Secondary stations are operated over a limited period, usually less than one year, and for a specific purpose, such as checking elevations. The secondary station observations are always compared to, and computed from, data obtained by primary stations.

A tide station is set up, and observations are made for a period that is determined by a desired accuracy. These observations are compared with a primary tide station in the area, then furnished with a mean value of sea level in the area.

A closed loop of spirit levels is run from the tide station over the tidal BMs and is tied back to the tide station. The accuracy of this level line must be the same as or higher than the accuracy required for the BMs.

For permanency, tidal BMs usually are set in sets of three and away from the shoreline where natural activity or future construction will not disturb or destroy them.

4.0.0 COMMON ERRORS and MISTAKES

4.1.0 Instrument Out of Adjustment

Inaccurate adjustment of the instrument: The most common instrument error is caused by a level out of adjustment. The instrument must be adjusted so the line of sight is horizontal when the bubble is in the center of level vial.

4.2.0 Change in Position

Errors due to changes in the position of the instrument: When the instrument is not properly leveled, or if it is set up in an unstable position, errors will result. An unstable instrument setup makes the level bubble tremble slightly, even though it appears to be properly centered. Check the position of the bubble before and after each rod reading to make sure that the bubble has remained in the center of the level vial.

4.3.0 Faulty Handling

Faulty handling of the rod: The rod may not be properly plumbed. If the rod is not held plumb, such as if it leans toward or away from the instrument, the result will be an excessive reading.

Erroneous rod length: Check the length of the extended leveling rod with a steel tape.

Failure to clamp the rod at the proper place when using an extended leveling rod: This error could result in reading the wrong mark on the rod or reading the wrong cross hairs. Inspect the clamped positions before and after each sight to make sure that the extended rod has not slipped down.

4.4.0 Mistakes in Arithmetic

Always double check the addition and subtraction of every reading obtained.

5.0.0 SEWER STAKEOUT

5.1.0 Underground Utilities

For an underground utility, you will often need to determine both line and grade. For pressure lines, such as water lines, it is usually necessary to stake out only the line, since the only grade requirement is maintaining the prescribed depth of soil cover. However, staking elevations may be necessary for any pressure lines being installed in an area that (1) is to be graded downward or (2) is to have other, conflicting underground utilities.

Gravity flow lines, such as storm and Sewer Lines, require staking for grade to be sure the pipe is installed at the design elevation and at the gradient, or slope, the design requires for gravity flow through the pipe.

Grade for an underground sewer pipe is given in terms of the elevation of the invert. The invert of the pipe is the elevation of the lowest part of the inner surface of the pipe. *Figure 5-18* shows a common method of staking out an underground pipe.

Figure 5-18 – Use of batter boards (with battens) for utility stakeout.

Notice that both alignment and elevation are facilitated by a line of batter boards and battens, or small pieces of wood, set at about 25 to 50 foot intervals. The battens, nailed to the batter boards, determine the horizontal alignment of the pipe when placed vertically on the same side of the batter boards and with the same edges directly over the center line of the pipe. As the work progresses, check the alignment of these battens frequently. A sighting cord, stretched parallel to the center line of the pipe at a uniform distance above the invert grade, is used to transfer line and grade into the trench. The center line of the pipe, therefore, will be directly below the cord, and the sewer invert grade will be at the selected distance below the cord. A measuring stick, also called a grade pole, is normally used to transfer the grade from the sighting cord to the pipe, as shown in *Figure 5-18*. The grade pole, with markings of feet and inches, is placed on the invert of the pipe and held plumb. The pipe is then lowered into the trench until the mark on the grade pole is on a horizontal line with the cord.

Figure 5-19 shows another method of staking out an underground sewer pipe without the use of battens. Drive nails directly into the tops of the batter boards so that a string stretched tightly between them will define the pipe center line. Keep the string or cord taut by wrapping it around the nails and hanging a weight on each end. Similarly, the string or cord gives both line and grade.

Figure 5-19 – Batter boards (without battens) for utility stakeout.

5.2.1 Sewer Stakeout Procedure

Refer to *Figure 5-20* for an example of a plan and profile sheet.

1. Obtain data from a plan and profile which will show the following:
   - Horizontal line located in each system
   - Horizontal location and character of each fitting or equipment
   - Invert elevation at each fitting or piece of equipment
   - Gradient of each line

Figure 5-20 – Plan and profile sheet.

2. Stakeout consists of setting hubs and stakes to mark the alignment and indicate the depth of the sewer.

NOTE

Each hub should have a visible guard stake.

- Alignment may be marked by a row of offset hubs and stakes,
- Alignment could also be indicated by both offsets hubs and a row of centerline stakes,

3. Cuts
   - Cuts may be shown on a cut sheet or be marked on the centerline stakes, or both,

- The required grade is always established at the centerline of the project. The amount of change in the elevation, if any, is written on the back of the centerline stake with the symbol known as a crowfoot. The crowfoot is the reference point of the vertical measure or grade.
- On a centerline stake, guide the backhoe operator.
  - Cuts are usually shown in tenths.
  - Generally, represent the cut from the surface of the existing ground to the bottom of the trench taking into account the following: depth of invert, barrel (pipe) thickness, and depth of any sand or gravel bed.
- Cut marks on stakes next to the hubs:
  - Generally are shown to hundredths,
  - Represent the distance from the top of the hub to the invert,
  - Guide the pipe crew,
- The distance between stakes and hubs are generally set at 25-foot intervals.

NOTE

50-foot and 100-foot intervals will suffice if necessary.

4. Sewer hubs are usually offset to 8 feet from the centerline.
   - Before you enter the field, compute from the profile the invert elevation at every station where you will set a hub.
   - The invert elevations at the fittings or pieces of equipment are given on the profile.
   - The gradient (percentage of drop) is also given on the profile.
   - To determine the invert at each station:
     - The distance between each station times the percentage of the gradient
     - To determine elevation of the top of the hub, first find the difference between the invert elevation of the station and the top of the hub; then write the difference on the guard stake for this hub.

6.0.0 PLUMBING VALVES and ACCESSORIES

In this section, you are provided with information regarding types of valves and procedures for installing and repairing them, valve accessories, and pipe fittings.

6.1.0 Valves

Flexibility in the operation of a water-supply system requires the proper valves for the condition that is to be controlled. Valves are used to stop, throttle, or control the flow of water in a pipeline. Other uses include pressure and level control and proportioning flow. A number of different valve designs are used by a Utilitiesman (UT). In this section, different types of valves, their purpose, and maintenance and repair of valves are presented.

6.1.1 Gate Valve

The gate valve (*Figure 5-21*) is used in systems where a straight flow with the least amount of restriction is needed. These valves are commonly used in steam lines, waterlines, fuel oil lines, and fire-main cutouts.

The part of a gate valve that opens or closes the valve flow is known as the GATE. The gate is normally wedge-shaped; however, some are uniform in thickness throughout. When the gate is wide open, the opening through the valve is equal to the size of the piping in which the valve is installed; therefore, there is little resistance in the flow of the liquid. Since regulating the flow of liquid is difficult and could cause extensive damage to the valve, the gate valve should NOT be used as a throttling valve. The gate valve should be left in one of two positions: completely open or closed.

Figure 5-21— Gate valve.

Figure 5-21 shows a cross-sectional view of a gate valve. The gate is connected to the valve stem. Turning of the handwheel raises or lowers the valve gate. Some gate valves have NONRISING STEMS. On these, the stem is threaded on the lower end, and the gate is threaded on the inside; therefore, the gate travels up the stem when the valve is being opened. This type of valve usually has a pointer or a gauge to indicate whether the valve is in the OPEN or in the CLOSED position. Some gauge valves have RISING STEMS. In these valves, both the gate and the stem move upward when the valve is opened. In some rising stem valves, the stem projects above the handwheel when the valve is opened. The purpose of the rising stem is to allow the operator to see whether the valve is opened or closed.

6.1.2 Globe Valve

The name is derived from the globular shape of the valves; however, other types of valves may also have globe-shaped bodies, so do not jump to the conclusion that a valve with a globe-shaped body is actually a globe valve. The internal structure of a valve, not the external shape, is what distinguishes one type of valve from another.

In a globe type of stop valve, the disk is attached to the valve stem. The disk seats against a seating ring or a seating surface that shuts off the flow of fluid. When the disk is removed from the seating surface, fluid can pass through the valve in either direction. Globe valves may be used partially open as well as fully open or fully closed.

The fluid flow is proportionate to the number of turns of the wheel in opening or closing the globe valve. The purpose of the globe valve is for throttling.

Globe valve inlet and outlet openings are arranged in several ways to satisfy different requirements of flow.

Figure 5-22 shows three common types of globe valve bodies. In the straight type, the fluid inlet and outlet openings are in line with each other. In the angle type, the inlet and outlet openings are at an angle to each other. An angle type of globe valve (which is also the UT rate insignia) is commonly used where a stop valve is needed at a 90-degree turn in a line. The cross type of globe valve has three openings, rather than two; it is frequently used in connection with bypass lines.

Figure 5-22 – Types of globe valve bodies.

Globe valves are commonly used in steam, air, oil, and water lines. Globe valves are also used as stop valves on the suction side of many fire room pumps as recirculating valves in the fuel oil system and as throttle valves on most fire room auxiliary machinery. A cross-sectional view of a globe valve is shown in *Figure 5-23*.

Figure 5-23— Globe valve.

6.1.3 Butterfly Valve

The butterfly valve (*Figure 5-24*) in certain applications has some advantages over gate and globe valves. The butterfly valve is light in weight, takes up less space than a globe valve or gate valve, is easy to overhaul, and can be opened or closed quickly.

The design and construction of butterfly valves may vary, but a butterfly type of disk and some means of sealing are common to all butterfly valves.

Figure 5-24 – Butterfly valve.

The butterfly valve shown in *Figure 5-24* consists of a body, a resilient seat, a butterfly type of disk, a stem, packing, and a notched positioning plate and handle. The resilient seat is under compression when it is mounted in the valve body. The compression causes a seal to form around the edge of the disk and both upper and lower points where the stem passes through the seat. Packing is provided to form a positive seal around the stem if the seal formed by the seat is damaged.

To close the valve, turn the handle a quarter of a turn to rotate the disk 90 degrees. The resilient seat exerts positive pressure against the disk, which assures a tight shutoff.

Butterfly valves are easy to maintain. The resilient seat is held in place by mechanical means; therefore, neither bonding nor cementing is necessary. Since the resilient seat is replaceable, the valve seat does not require any lapping, grinding, or machine work.

Butterfly valves serve a variety of requirements. These valves are now being used in salt water, fresh water, JP-5 fuel, naval distillate fuel oil, diesel oil, lubricating oil systems, air ventilation systems, and set for specific flow.

6.1.4 Altitude Valve

Altitude valves are used primarily on supply lines to elevated storage tanks. These valves are designed to (1) regulate the water level in the water storage tanks to prevent them from overflowing or running dry, and (2) maintain a constant water level as long as water pressure in the distribution system is adequate. *Figure 5-25* illustrates the altitude valve in relation to an elevated storage tank.

Figure 5-25 — Altitude valve with elevated storage tank.

As stated earlier, altitude valves are used primarily on supply lines to elevated storage tanks. When used on elevated storage tanks, the altitude valve automatically opens when the pressure in the distribution system drops below normal working pressure. Altitude valves will automatically close or shut off the flow into an elevated tank when the water level in the tank reaches a pre-determined level.

6.1.5 Ball Valve

A ball valve is a quick opening/closing device with a low-pressure drop. Ball valves, like gate valves, are used to start or stop the flow of water through plumbing components or piping systems. They are used on water or other types of supply lines in place of gate valves. Ball valves are not designed for throttling service.

The basic components of the ball valve are the handle, a stem, a disc (ball), and a seat, which are machined into the valve body. *Figure 5-26* illustrates a ball valve. A quarter turn of the handle opens or closes the valve. When the handle is in line with (parallel to) existing piping, the valve is fully open. When the handle is across (perpendicular) to the piping, the valve is fully closed. The disk in a ball valve is a ball with a hole drilled through it. In the open position, the port (opening) in the ball is aligned with the inlet and outlet ports in the valve body.

Figure 5-26 – Ball valve.

Before installing a ball valve, you must consider the type of fluid the valve will be servicing. The steel (carbon, forged and stainless) ball valve is used for steam and high-pressure applications. Brass ball valves are used on water services. Finally, you can also use the plastic ball valves on water services, but they are not well adapted for use when a high resistance to acids is required. The type of ball valve and piping will dictate what type of joint that is used to install the valve. The common joints used to install ball valves include the threaded, soldered, mechanical, and solvent- glued. Finally, ball valves can be installed in the vertical or horizontal positions, but again, remember to make certain that the handle is accessible.

6.1.6 Check Valve

Check valves permit liquids to flow through a line in one direction only; for example, they are used in drain lines where it is important that there is no backflow. Considerable care must be taken to see that valves are installed properly. Most of them have an arrow, or the word “inlet,” cast on the valve body to indicate direction of flow. If not, you must check closely to make sure the flow of the liquid in the system operates the valve in the proper manner.

The port in a check valve may be closed by a disk, a ball, or a plunger. The valve opens automatically when the pressure on the inlet side is greater than that on the outlet side. They are made with threaded, flanged, or union faces, with screwed or bolted caps, and for specific pressure ranges.

The disk of a SWING-CHECK valve (*Figure 5-27*) is raised as soon as the pressure in the line below the disk is of sufficient force. While the disk is raised, continuous flow takes place. If for any reason the flow is reversed or if back pressure builds up, this opposing pressure forces the disk to seat, which, in turn, stops the flow. Swing-check valves are used in horizontal lines and have a small amount of resistance to flow.

The operation of a LIFT-CHECK valve (*Figure 5-28*) is basically the same as that of the swing-check valve. The difference is the valve disk moves in an up and down direction instead of through an arc. Lift-check valves are used in lines where reversal of flow and pressures are changing frequently. This valve does not chatter or slam as the swing-check valve does, but it does cause some restriction of flow.

Figure 5-27 – Swing check valve. **Figure 5-28 – Lift check valve.**

6.1.7 Stop Check Valve

As we have seen so far, most valves are classified as either stop valves or check valves; however, some valves function either as a stop valve or as a check valve, depending upon the position of the valve stem. These valves are known as STOP-CHECK VALVES.

The cross section of two stop-check valves is shown in *Figure 5-29*. As you can see, this type of valve looks much like a lift-check valve. The valve stem is long enough so when it is screwed all the way down, it holds the disk firmly against the seat, thereby preventing the flow of any fluid. In this position, the valve acts as a stop valve. When the stem is raised, the disk can then be opened by pressure on the inlet side. In this position, the valve acts as a check valve and allows the flow of fluid in one direction only. The amount of fluid allowed to pass through is regulated by the opening. The opening is adjusted by the stem.

Figure 5-29 — Stop check valve.

6.1.8 Pressure-Reducing Valve

Pressure-reducing valves are automatic valves used to provide a steady pressure lower than that of the supply pressure. Pressure-reducing valves can be set for any desired discharge pressure that is within the limits of the design.

Several types of reducing valves are used in the Navy; however, you will be working mostly with those in the water service system. These are normally single-seated, direct-acting, and spring-loaded, as shown in *Figure 5-30*. Water passing through this valve is controlled by means of a pressure difference on both sides of the diaphragm. The diaphragm is secured to the stem. Reduced water pressure

Figure 5-30— Spring-loaded diaphragm type of pressure-reducing valve.

from the valve outlet is then led through an internal passage to a diaphragm chamber located below the diaphragm. An adjusting spring acts on the upper side of the diaphragm. A leather cup washer or a neoprene O ring makes the water seal between the valve inlet and the diaphragm chamber. This seal is located halfway down the valve stem.

The amount of water pressure applied to the underside of the diaphragm varies according to the discharge pressure. When the discharge pressure is greater than the spring pressure, the diaphragm is forced up. Since this is an upward-seating valve, the upward movement of the stem tends to close the valve or at least to decrease the amount of discharge. When the discharge pressure is less than that of the spring pressure, the diaphragm and the valve stem are forced down, opening the valve wider and increasing the amount of discharge. When the discharge pressure is equal to the spring pressure, the valve stem remains stationary and the flow of water through the valve is not changed.

The amount of pressure applied by the spring to the top of the diaphragm can be adjusted by turning an adjusting screw. Turning the adjusting screw CLOCKWISE increases the pressure applied by the spring to the top of the diaphragm, which, in turn, opens the valve. Turning the adjusting screw COUNTERCLOCKWISE decreases the amount of spring pressure on top of the diaphragm, which, in turn, decreases the amount of discharge. Opening and closing of the valve continues as long as the discharge pressure fluctuates.

Figure 5-31 shows a different type of spring-loaded pressure-reducing valve. In this valve, water enters on the inlet side and acts against the main valve disk, tending to close the main valve; however, water pressure is also led through ports to the auxiliary valve, which controls the admission of water pressure to the top of the main valve piston. This piston has a larger surface than the main disk; therefore, a relatively small amount of pressure acting on the top of the main valve piston tends to open the main valve and also allow water at reduced pressure to flow out the discharge side.

Figure 5-31— Spring-loaded pressure-reducing valve.

6.1.9 Pressure Relief Valve

This type of valve discharges water from pipes or systems when the maximum desired pressure is exceeded. Normally, the valve starts to open at the set pressure and continues to open gradually until the pressure has reached 20 percent above the set pressure, and then the valve opens completely. Pressure relief valves are installed on low-pressure systems fed through pressure-reducing valves from high-pressure supplies to ensure against damage if the pressure reducing valves fail to operate.

Pressure relief valves are also used on pump headers, discharging into large supply mains to relieve the high-surge pressure that builds up between the time a pump is started and the time required for water in the main to reach full velocity. Relief valves are essentially pressure-reducing valves in which the control mechanism responds to pressure on the inlet, rather than the outlet end.

6.1.10 Hydraulic Control Valve

Hydraulic control valves are used in many sprinkler systems. On some stations, they are installed in the sections of the fire main that supply water to the magazine sprinkling system. This type of valve may be operated from one or more remote control stations by a hydraulic control system.

The hydraulic control valve shown in *Figure 5-32* is a piston-operated globe valve. It is normally held in the CLOSED position by both a spring force and by the fire-main pressure acting against the disk. When hydraulic pressure is admitted to the underside of the piston, a force is created that overcomes both the spring tension and the fire-main pressure, thereby causing the valve to open.

Figure 5-32 — Hydraulic control valve.

When hydraulic pressure is released from under the piston, the spring acts to force the hydraulic fluid out of the cylinder and back to the remote control station, thus closing the valve.

A ratchet lever is fitted to the valve so in an emergency, the valve can be opened by hand. After the valve has been opened by hand, you should first restore the stem to its normal CLOSED position with the ratchet lever. Then, line up the hydraulic system from a remote control station, so the hydraulic fluid in the valve cylinder can return to the storage tank at the control station. The full force of the closing spring acts to seat the disk, thereby closing the valve.

The valve shown in *Figure 5-32* is equipped with a test casting in the body of the valve. The bottom cover can be removed so you can check the valve for leakage.

6.1.11 Valve Boxes

Underground valves must have a means of access whereby you can use your hand or a valve key to reach the operating nut or handle. Valve boxes can be made of cast iron, cement, or plastic. Some have covers with lock nuts to prevent unauthorized access. They also protect the valve and piping against mechanical damage (pedestrian and vehicular traffic), and adverse weather if located outside.

Take care when installing the valve box over the pipe. Never allow the weight of the valve box to rest on the pipe; instead, let the soil around the pipe support the valve box. Clean debris out of the valve box periodically and ensure elevation and alignment are correct. A valve box that is full of debris or is not aligned properly does not allow proper alignment of the valve key on the operating nut or easy access to the handle. Debris also causes corrosion of valve handles, making it hard to turn off the valve.

Maintenance of valve boxes should be done twice a year, like the valve maintenance schedule for operation.

Maintenance consists of cleaning out debris in the box, checking for corrosion, checking the elevation of the top, and checking alignment of the box, so the valve key can be inserted readily. When the valve box has corroded and is no longer serviceable, remove it and replace it with a new unit. When changes in street or ground level have left the valve box too high or too low, adjust the height so the cover is at street or ground level.

6.1.12 Gear Boxes

Most large manually operated valves are operated through gears, as are motor-operated valves. These gears are housed in gear boxes.

Monthly or quarterly, lubricate the gearing under the manufacturer’s instructions.

Semi-annually, check gear operation through a complete cycle of opening and closing. Listen for undue noise and observe smoothness of operation of the valve opening, and check for lubricant leakage from the flanges. Upon finding any evidence of improper operation, the operator should open the gearbox, inspect the gears, and make necessary repairs.

Annually, inspect the housing for corrosion; clean and paint it as necessary.

6.1.13 Valve Position Indicators

Different types of valves have different types of valve position indicators. Non-rising-stem gate valves may have indicators on the floor stand. Filter plant valves may have indicators on the filter operating table, and butterfly valves, or other valves used for flow control or throttling, may have indicator units that are controlled electrically and look like an ammeter. The care required depends on the design of the indicator unit; for example, post indicators require lubrication quarterly, and position indicators that are controlled electrically should be checked for contact, wiring, and so on, yearly.

6.2.0 Valve Repair

Periodic maintenance is the best way to extend the service life of valves and fittings. As soon as you see a leak, check to see what is causing it; then apply the proper remedy. This remedy may be as simple as tightening a packing gland nut. A leaking flange joint may need only to have the bolts tightened or to have a new gasket inserted. Dirt and scale, if allowed to collect, can cause leakage. Loose hangers permit sections of a line to sag. The weight of the pipe and the fluid in these sagging sections may strain joints to the point of leakage.

Whenever you intend to install a valve, make sure you know its function. In other words, is it supposed to prevent backflow, start flow, stop flow, regulate flow, or regulate pressure? Look for the information stamped on the valve body by the manufacturer: type of system (oil, water, gas), operating pressure, direction of flow, and other information.

You should also know the operating characteristics of the valve, the type of metal it is made of, and the type of end connection it has. Operating characteristics and material affect the length and type of service a valve can provide. End connections indicate whether or not a particular valve is suited for installation in the system.

Valves should be installed in accessible places and with enough headroom to allow for full operation. Install valves with stems pointing upward whenever possible. A stem position between straight up and horizontal is acceptable, but avoid the inverted position (stem pointing downward). When the valve is installed in the latter position, sediment collects in the bonnet and scores the stem. When a line is subject to freezing temperatures, liquid trapped in the valve bonnet may freeze and rupture it.

Globe valves may be installed with pressure either above or below the disk. It depends upon what method is best for the operation, protection, maintenance, and repair of the machinery. You should ask what would happen if the disk became detached from the stem. This is a major consideration in determining whether pressure should be above the disk or below it. Check the blueprints for the system to see which way the valve should be installed. Pressure on the wrong side of the disk can also cause serious damage.

Valves that have been in constant service over a long period of time eventually require gland tightening, replacing, or a complete overhaul. When a valve is not doing the job, it should be dismantled and all parts inspected. For proper operation, parts must be repaired or replaced.

6.2.1 Spotting-In Valves

Spotting-in is the method used to determine visually whether or not the seat and the disk make good contact with each other. To spot-in a valve seat, first apply a thin coating of Prussian blue evenly over the entire machined face surface of the disk. Then insert the disk into the valve and rotate it a quarter turn, using light downward pressure. The Prussian blue adheres to the valve seat at those points where the disk makes contact. *Figure 5-33* shows what correct and imperfect seals look like when they are spotted-in.

Figure 5-33 — Examples of spotted-in valve seats.

After you have examined the seat surface, wipe all the Prussian blue off the disk face surface. Apply a thin, even coat of blue to the contact face of the seat. Again, place the disk on the seat and rotate the disk a quarter of a turn. Examine the blue ring that appears on the disk. It should be unbroken and of uniform width. If the blue ring is broken in any way, the disk does not fit properly.

6.2.2 Grinding-In Valves

Grinding-in is a manual process used to remove small irregularities by grinding together the contact surfaces of the seat and disk. Grinding-in should not be confused with refacing processes in which lathes, valve reseating machines, or power grinders are used to recondition the seating surfaces.

To grind-in a valve, first apply a small amount of grinding compound to the face of the disk. Then insert the disk into the valve and rotate the disk back and forth about a quarter of a turn. Shift the disk-seat relationship from time to time, so the disk is moved gradually, in increments, through several rotations. During the grinding-in process, the grinding compound is gradually displaced from between the seat and disk surfaces; therefore, it is necessary to stop every minute or so to replenish the compound. When you do this, wipe both the seat and the disk clean before applying the new compound to the disk face.

When it appears that the irregularities have been removed, check your work by spotting-in the disk to the seat in the manner described previously.

Grinding-in is also used to follow up all machine work on valve seats or disks. When the seat and disk are first spotted-in after they have been machined, the seat contact is very narrow and located close to the bore. The grinding-in, using finer and finer compounds as the work progresses, causes the seat contact to become broader. The contact area should be a perfect ring covering approximately one third of the seating surface.

Be careful that you do not over-grind a seat or disk. Over-grinding tends to produce a groove in the seating surface of the disk. It may also round off the straight, angular surface of the disk. Over-grinding must be corrected by machining.

6.2.3 Lapping Valves

When a valve seat contains irregularities that are too large to be removed by grinding-in, you can remove them by lapping. A cast-iron tool, also known as a LAP tool, of exactly the same size and shape as the disk is used to rule the seat surface. Two lapping tools are shown in *Figure 5-34*.

Here are the most important points to remember while using the lapping tool.

1. Do not bear heavily on the handle of the lap.
2. Do not bear sideways on the handle of the lap.
3. Change the relationship between the lap and the seat so the lap gradually and slowly rotates around the entire seat circle.

Figure 5-34 – Lapping tools.

4. Keep a check on the working surface of the lap. If a groove develops, have the lap refaced.
5. Always use a clean compound for lapping.
6. Replace the compound often.
7. Spread the compound evenly and lightly.
8. Do not lap more than is necessary to produce a smooth, even seat.
9. Always use a fine grinding compound to finish the lapping job.
10. When you complete the lapping job, spot-in and grind-in the disk to the seat.

Use only approved abrasive compounds to recondition seats and disks. Compounds for lapping and grinding disks and seats are supplied in various grades. Use a coarse grade compound when there is extensive corrosion or deep cuts and scratches on the disks and seats. Use a compound of medium grade to follow up the coarse grade. It may also be used to start the reconditioning process on valves that are not severely damaged. Use a fine grade compound when the reconditioning process nears completion. Use a microscopic fine grade for finish lapping and for all grinding-in.

6.2.4 Refacing Valves

Badly scored valve seats must be refaced in a lathe with a power grinder or with a valve reseating machine. Use the lathe, rather than the reseating machine, to reface disks and hard-surfaced seats. Work that must be done on a lathe or with a power grinder should be turned over to machine shop personnel. This discussion applies only to refacing seats with a reseating machine.

To reface a seat with a reseating machine (*Figure 5-35*) attach the correct 45-degree facing cutter to a reseating machine. With a fine file, remove all high spots on the surface of the flange upon which the chuck jaws must fit. Note that a valve reseating machine can be used ONLY with a valve in which the inside of the bonnet flange is bored true with the valve seat. If this condition does not exist, the valve must be reseated in a lathe and the inside flange bored true.

Figure 5-35 – Valve reseating machine.

Before placing the chuck in the valve opening, open the jaws of the chuck wide enough to rest on the flange of the opening. Tighten the jaws lightly so the chuck grips the sides of the valve opening securely. Tap the chuck down with a wooden mallet until the jaws rest on the flange firmly and squarely. Then tighten the jaws further.

Adjust and lock the machine spindle in the cutting position and begin cutting by turning the crank slowly. Feed the cutter slowly so very light shavings are taken. After some experience, you can tell whether or not the tool is cutting evenly all around. Remove the chuck to see if enough metal has been removed.

Be sure the seat is perfect. Then remove the 45-degree cutter and face off the top part of the seat with a flat cutter. Dress the seat down to the proper dimensions as follows. Refer to *Table 5-1*.

Table 5-1 — Seat to Valve Size Chart.

Width of Seat	Size of Valve
1/16 inch	1/4 to 1 inch
3/32 inch	1 1/4 to 2 inches
1/8 inch	2 1/2 to 4 inches
3/16 inch	4 1/2 to 6 inches

After the refacing, grind-in the seat and disk. Spot-in as necessary to check the work. A rough method of spotting-in is to place pencil marks at intervals of about l/2 inch on the bearing surface of the seat or disk. Then place the disk on the seat and rotate the disk about a quarter of a turn. If the pencil marks in the seating area rub off, the seating is satisfactory.

6.2.5 Repacking Valve Stuffing Boxes

When the stem of a valve is in good condition, stuffing box leaks can usually be stopped by setting up on the gland. If this does not stop the leakage, repack the stuffing box. The gland must not be set up or packed so tightly that the stem binds. If the leak persists, a bent or scored valve stem may be the cause of the trouble.

Coils (string) and rings are the common forms of packing used in valves. The form to be used in a particular valve is determined, in part, by the size of the packing required. In general, rings are used in valves that require packing larger than 1/4 inch. When a smaller size is required, string packing is used.

When you repack a valve stuffing box, place successive turns of the packing material around the valve stem. When string packing is used, coil it around the valve stem. Bevel off the ends to make a smooth seating for the bottom of the gland. Then put on the gland and set it up by tightening the bonnet nut or the gland bolts and nuts. To prevent the string packing from folding back when the gland is tightened, wind the packing in the direction in which the gland nut is to be turned. Usually, where successive rings are used, the gaps in the different rings should be staggered.

Valves are made to back seat the stem against the valve bonnet when the valve is fully opened. Back seating of valves is a safety feature to eliminate the stem being forced out under pressure while the valve is fully opened. Back seating makes repacking of the stem stuffing box possible under pressure; however, you should attempt this only in emergencies and with extreme caution.

Test your Knowledge (Select the Correct Response)

3. Which of the following valves allows water flow in one direction only?

   A. Swing
   B. Check
   C. Pressure-reducing
   D. Globe

7.0.0 WATER METERS

Water meters measure the flow of water within a line to a point of distribution, such as laundries, housing areas, and so on. There are various types of water meters. One type is the disk type of volume meter. This water meter is used chiefly for services supplied through pipes less than 1 l/2 inches in diameter, although water meters are made in sizes up to 6 inches.

Figure 5-36 — Nutating disk meter.

Figure 5-36 shows the nutating disk volume meter. This type of meter is mainly used for individual service connections, as it is accurate for very low flow. A flow above normal causes rapid wear. The disk type of meter contains a measuring chamber of definite content in which a disk is actuated by the passage of water. Each cycle of motion of the disk marks the discharge of the contents of the measuring chamber. By means of gearing, the motion of the disk is translated into units of water volume on the register dial.

When installing a water meter, make sure it is horizontal and that it operates under back pressure. The meter should be located near the pressure-reducing valve at underground level; so in freezing temperatures, ensure the meter is protected from exposure.

Water is measured in terms of rate-of-flow (volume passing in a unit of time) or total volume. Units and equivalents usually are as follows. Refer to *Table 5-2*.

Table 5-2 — Unit to Equivalent Chart.

Unit	Equivalent
Cubic feet per second (cfs)	6448.83 Gallons per minute (gpm)
Cfs	46, 315 gallons per day (gpd)
Gpm	1,440 gpd
Million gallons per day (mgd)	1.547 cfs
mgd	694.4 gpm
Cubic feet (Cu ft)	7.48 gallons

NOTE

In reading a meter, you should first determine whether it is measuring the water flow in cubic feet or in gallons.

7.1.0 Meter Dials

Two general types of meter dials are used: the straight-reading type and the circular-reading type. Each type is discussed in the following paragraphs.

The STRAIGHT-READING DIAL shown in *Figure 5-37* may be read in the same way as mileage on an automobile. When the meter register has one or more fixed zeros, always be sure to read them in addition to the other numerals.

Figure 5-37 — Straight-reading meter dial.

In the CIRCULAR-READING DIAL, when the hand on a scale is between two numbers, the lower number is read. If the hand seems exactly on the number, check the hand on the next lower scale. If that hand is on the "1" side of zero, read the number on which the hand lies; otherwise, read the next lower number. The procedure for reading the circular reading dial, shown in gallons in *Figure 5-38*, is to begin with the "1,000,000" circle and read clockwise to the "10" circle, the scales registering 9, 6, 8, 7, 2, and 1 respectively, making a total of 968,721 gallons.

Figure 5-38 — Reading the circular-reading meter dial in gallons.

7.2.0 Obtaining Current Reading

Since the registers are never reset while the meters are in service, the amounts recorded for any period of time must be determined by subtraction. To obtain a current reading, subtract the last recorded reading from the current dial reading. Remember, the maximum amount that can be indicated on the usual line meter before it turns to zeros and begins all over again is 99,999 cubic feet, or 999,999 gallons. Thus, to obtain a current measurement when the reading is lower than the last previous one, add 100,000 to the present reading on a cubic foot meter, or 1,000,000 to the present reading on a gallon meter. The small denomination scale, giving fractions of one cubic foot or ten gallons, is disregarded in the regular reading. It is used for testing only.

8.0.0 INSULATION

The primary purpose of insulation is to prevent heat passage from steam or hot-water pipelines to the surrounding air or from the surrounding air to cold-water pipes. Thus hot-water lines are insulated to prevent loss of heat from the hot water, while drinking waterlines are insulated to prevent absorption of heat in drinking water.

Insulation keeps moisture from condensing on the outside of cold pipes. An example of condensation is the formation of droplets of moisture on the outside of a glass of ice water on a warm day. The same thing happens to the outside of a pipe containing cold water when the outside of the pipe is exposed to warm air. Insulation also prevents water from freezing in a pipe, especially when the pipe runs outside a building or in a building without heat.

Insulation is used on heating and air-conditioning ducts. The two kinds of duct insulation are (1) inside and (2) outside. The outside insulation is for the protection of heat loss, whereas the inside insulation is used for protection against noise and vibration from heating or air-conditioning equipment.

Insulation subdues noise made by the flow of water inside pipes, such as water closet discharges. Bathrooms directly above living rooms should be insulated. Insulation is vital in high buildings where water falls a long way, especially when the water falls in soil stacks and headers. Insulation also protects refrigerated and chilled waterlines that cool electrical and motor-driven equipment.

Insulation is made in two forms: (1) rigid preformed sections and (2) blankets. Rigid preformed sections are used on pipe runs and for the protection of other objects which they are designed to fit. Blanket-type insulation, manufactured in strips, sheets, and blocks, is wrapped around objects that are irregular in shape and in large, flat areas. Blanket-type insulation protects against heat loss and fire. This type of insulation is used on boilers, furnaces, tanks, drums, driers, ovens, flanges, and valves. It comes in wool-felt and hair-felt rolls, aluminum foil rolls, and in an irregular preformed covering.

Blanket insulation comes in different widths and thicknesses, depending upon the type of equipment to be insulated. It resists vermin, rodents, and acid. It is also fireproof.

8.1.0 Piping

Some of the insulating materials on the market today for insulating pipe are sponge felt paper, cork pipe covering, wool felt, flex rubber, fiberglass, magnesia, and types called antisweat and frost-proof.

Sponge felt paper is composed of asbestos paper with a maximum amount of sponge evenly distributed within it, as shown in *Figure 5-39, View A*. Sponge felt paper is manufactured to fit most pipe sizes. It comes in 3-foot lengths and from 1 to 3 inches in thickness.

Figure 5-39 — Types of pipe insulation.

Sponge felt paper can be purchased in blocks of straight and preformed shapes for valves and fittings.

Cork pipe covering is a granulated material processed from the bark of cork trees. Granulated cork is compressed and molded to size and shape and finished with a coating of plastic asphalt. Cork pipe covering, as shown in *Figure 5-39, View B*, is an ideal covering for brine, ammonia, ice water, and all kinds of cold waterlines, and it insulates well over a wide low-temperature range. Cork pipe covering does not rot or support combustion. Clean, sanitary, and odor free, it is available in a wide variety of sizes and shapes to fit various sizes of pipes and fittings.

Wool felt is made of matted fibers of wool, wool and fur, or hair, worked into a compacted material by pressure rolling. It is used on cold-water service and hot-water return lines. Wool felt preformed pipe covering is manufactured in thicknesses of l/2 to 1 inch, with a canvas jacket, as shown in *Figure 5-39, View C.* It is manufactured in 3-foot lengths for straight runs of pipe.

Flex rubber insulation, shown in *Figure 5-39, View D*, is a tough, flexible rubber material constructed of millions of uniform closed cells. It has good insulating qualities, good cementing qualities, excellent weather-aging qualities, and it is ideal for the prevention of sweating cold-water lines. In addition, it is water and flame resistant. Flex rubber insulation is recommended for covering tubing used in refrigeration and cold-water lines in homes, as well as in industrial plants and commercial buildings. This rubber insulating material comes in random lengths, with a wall thickness size of 3/8 to 3/4 inch. It is made to fit pipe sizes up to 4 inches.

Flex rubber insulation can be installed on pipes and tubing by slipping the insulation over the pipe when it is being assembled or by slitting the rubber lengthwise and sealing it with cement. Before installing flex rubber insulation on iron or galvanized pipes, paint the pipes with an asphaltic base primer to prevent corrosion caused by condensation.

Fiberglass pipe insulation, shown in *Figure 5-39, View E*, is composed of very fine glass fibers, bound and formed together by an inactive resin type of mixture. It is formed into a flexible hollow cylinder and slit along its length for applying to pipes or tubing. It is furnished in 3-foot lengths with or without jackets. The insulation comes in thicknesses from l/2 to 2 inches and fits pipes from l/2 to 30 inches. Fiberglass insulation has a long life; it will not shrink, swell, rot, or burn. It is easily applied and light in weight, saves space, and has excellent insulating qualities.

Antisweat insulation, shown in *Figure 5-39, View F*, is designed for cold-water pipes. It keeps the water colder in the pipes than most types of insulation; and when installed properly, it prevents condensation, or sweating, of the pipes.

The outstanding feature of antisweat insulation is its construction. It is composed of an inner layer of asphalt-saturated asbestos paper, a 1/2-inch layer of wool felt, two layers of asphalt-saturated asbestos felt, another l/2-inch layer of pure wool felt, and an outer layer of deadening felts with asphalt-saturated felts. The outer layer has a flap about 3 inches long that extends beyond the joint to help make a perfect seal. A canvas jacket is placed around each 3-foot length to protect the outer felt covering.

Frost-proof insulation, shown in *Figure 5-39, View G*, is manufactured for use on (1) cold-water service lines that pass through unheated areas, and (2) those lines exposed to outside weather conditions.

Frost-proof insulation is generally constructed of five layers of felt. There are three layers of pure wool felt and two layers of asphalt-saturated asbestos felt. Frost-proof insulation is 1 l/4 inches thick and comes in 3-foot lengths with a canvas cover.

The pipe coverings shown in this section are installed easily, primarily because each section is split in half and has a canvas cover with a flap for quick sealing. Joint collars are furnished to cover joint seams on insulation exposed to outside conditions.

Cheesecloth is used on some types of insulation instead of canvas. To install the cheesecloth, use a paste to hold it in place. Allow enough cheesecloth to extend over the end of each 3-foot section to cover the joints.

After you have applied the cheesecloth and smoothed it out, install metal straps to hold the insulation firmly in place, as shown in *Figure 5-39, View H*.

8.2.0 Valves and Fittings

Cover valves and fittings with wool felt, magnesia cement, or mineral wool cement of the same thickness as the pipe covering. These materials are molded into shape to conform to the rest of the insulation. When magnesia or mineral wool cement insulation is used, cover the insulation with cheesecloth to help bind and hold it in place.

8.3.0 Boilers and Storage Tanks

If the boilers and storage tanks are unjacketed, cover them with an approved insulation. Use only insulation approved by the Military Standard (MIL-STD). Some of the approved types of insulation for boilers and tanks are magnesia, mineral wool, calcium silicate, cellular glass, or other approved mineral insulation at least 2 inches thick. Insulation may be of either the block or the blanket type and must be wired securely in place in an approved manner. When applying insulation to the outside of a boiler or storage tank, put it over 1 1/2-inch wire mesh. The mesh is held away from the metal surface by metal spacers that provide an air space of at least 1 inch. When you use blanket or block material, fill the joints in the insulation with magnesia, mineral wool, or other suitable cement. Cover the surface of the insulation with a thin layer of hard-finished cement, troweled smooth, and reinforced with 1 l/2-inch wire mesh.

Test your Knowledge (Select the Correct Response)

4. Which of the following types of pipe insulation has excellent weather-aging qualities?

   A. Antisweat
   B. Cheesecloth
   C. Fiberglass
   D. Flex rubber

9.0.0 WATER DISTRIBUTION SYSTEM ACCESSORIES

The last section of this chapter explains the procedures for providing a water source. The water-supply system for a building starts from a single source: the water main and continues through the distribution system.

9.1.1 Distribution System Elements

The elements of a distribution system include distribution mains, arterial mains, storage reservoirs, and system accessories (including booster stations, valves, hydrants, main-line meters, service connections, and backflow preventers).

Distribution mains are the pipelines that make up the distribution system. Their function is to carry water from the water source or treatment works to users.

Arterial mains are large-size distribution mains. They are interconnected with smaller distribution mains to form a complete gridiron system.

Storage reservoirs are structured to store water. They may serve to equalize the supply or pressure in the distribution system.

System accessories include the following:

- Booster stations that pump water from storage or a relatively low pressure main to the distribution system; they may serve a portion of the system that is at a higher elevation as well.
- Valves that serve to control the flow of water in the distribution system by isolating areas for repair or by regulating system flow or pressure.
- Hydrants that are designed to allow water from the distribution system to be used for fire fighting purposes.
- Main line meters that serve to record the flow of water in a part of the distribution system.

- Service connections that connect either an individual building or other plumbing system to the distribution system mains.
- Backflow preventers that protect the water source from contamination.

9.2.0 System Layout and Size

When distribution systems are carefully planned, the pipes are usually laid out in a grid or belt system. A network of large pipes divides the community or base into areas of several blocks each. The streets within each area are served by smaller pipes connected to the larger ones. When possible, the network is planned so the whole pipe system consists of loops, and no pipes come to a dead end. In this way, water can flow to any point in the system from two or more directions; hence, the water supply need not be cut off for maintenance work or a break in a pipe.

Older water systems frequently were expanded without planning and developed into a treelike system. This consists of a single main that decreases in size as it leaves the source and progresses through the area originally served. Smaller pipelines branch off the main and divide again, much like the trunk and branches of a tree. A treelike system is not desirable because the size of the old main limits the expansion of the system needed to meet increasing demands. Also, there are many dead ends in the system where water remains for long periods of time, causing undesirable tastes and odors in nearby service lines.

9.3.0 Main Location

Mains should be located along streets to provide short hydrant branches and service connections. Mains should not be located under paved or heavily traveled areas. They should be separated from other utilities to ensure the safety of potable water supplies so the maintenance of one utility causes a minimum of interference with other utilities.

9.4.0 Valve Location

The purpose of installing shutoff valves in water mains at various locations within the distribution system is to allow sections of the system to be taken out of service for repairs or maintenance without significantly curtailing service over large areas. Valves should be installed at intervals generally not greater than 5,000 feet in long supply lines and 1,200 feet in main distribution loops or feeders, refer to local and state codes for placement. All branch mains connecting to feeder mains or feeder loops should have valves installed as close to the feeders as practical, so branch mains can be taken out of service without interrupting the supply to other locations. In the areas of greatest water demand or when the dependability of the distribution system is particularly important, maximum valve spacing of 500 feet may be appropriate. At intersections of distribution mains, the number of valves required is normally one less than the number of radiating mains; the valve omitted from the line is usually the one that principally supplies flow to the intersection. Valves are not usually installed on branches serving fire hydrants on military installations. As far as practical, shutoff valves should be installed in standardized locations (that is, the northeast corner of an intersection or a certain distance from the center line of a street), so they can easily be found in emergencies. For large shutoff valves (approximately 30 inches in diameter and larger), it may be necessary to surround the valve operator or entire valve with a vault to allow for repair or replacement. In important installations and for deep pipe cover, pipe entrance access manholes should be provided so valve internal parts can be serviced. When valves, vaults, or access manholes are not provided, all buried valves, regardless of size, should be installed with special valve boxes over the operating nut to permit operation from ground level by the insertion of a special long wrench into the box.

9.5.0 Hydrant Location

Proper clearance should be maintained between hydrants and poles, buildings, or other obstructions so the hose lines can be readily attached and extended. Generally, hydrants are located at least 50 feet from a building and in no case are they located closer than 25 feet to a building, except where building walls are blank fire walls. Hydrants may be located adjacent to blank portions of substantial masonry walls where the chance of falling walls is remote, always check local and state codes for placement.

Street intersections are the preferred location for fire hydrants because fire hoses can then be laid along any of the radiating streets. However, the likelihood of vehicular damage to hydrants is greatest at intersections, so the hydrants must be carefully located to reduce the possibility of damage. Normally hydrants should not be located less than 6 feet nor more than 7 feet from the edge of a paved roadway surface. When hydrants exceed this distance, consider stabilizing or surfacing a portion of the wide shoulders adjacent to the hydrants to permit connection of the hydrant and pumper with a single 10-foot length of suction hose. If you cannot meet this criteria, you would normally not exceed 16 feet (two sections of hose) to the pumper.

Hydrants normally should not be placed closer than 3 feet to any obstruction nor in front of any entranceway. The center of the lower outlet is normally not be less than 18 inches above the surrounding grade, and the operating nut should not be more than 4 feet above the surrounding grade.

In aircraft fueling, mass parking, servicing, and maintenance areas, the tops of hydrants are normally not higher than 24 inches above the ground, with the center of the lowest outlet not less than 18 inches above the ground. The pump nozzle should face the nearest roadway.

9.6.1 Safety Procedures

Here are some rules for plumbing safety.

1. Keep the job clean.
2. Pick up scrap pieces of pipe.
3. Keep all tools and materials off the job when not in use.
4. Keep the shop floors dry and clean.
5. Keep the stockpiled materials carefully braced and blocked to prevent falling.
6. Lift with your legs, not your back.
7. Use pipe tongs for carrying heavy pipe sections.
8. Use proper tools for the job at hand.
9. Keep tools in good condition.
10. Use care in handling torches and hot lead.
11. Do not pour hot lead into a wet joint.
12. Use safety goggles when required.
13. After installing fixtures, test the pipes for leaks and proper drainage before leaving the job.

Summary

Proper surveying techniques and equipment are vital for the proper placement and distribution of water and drainage systems. This chapter covered the basics in equipment and technique, and common errors which may be encountered.

Knowing the correct valve for the job is essential for the uninterrupted flow of water to a building or structure. This chapter covered the most currently utilized valves. Your combination of knowledge and skill in valve repair may prevent a minor leak from becoming a major system shutdown. Included in this chapter were the types of water meters and the correct method of reading them, and also the different types of pipe insulation currently being used.

The responsibility of the proper material selection and location for the different distribution systems encountered begins with the UT. This chapter covered the basic requirements for installing water mains, valves, and hydrants.

Review Questions (Select the Correct Response)

1. The engineer's level is also referred to as what kind of level?

   A. Dumpy
   B. Hand
   C. Self-leveling
   D. Surveyor's

2. How are the vertical cross hairs brought into exact alignment on the target?

   A. By releasing the azimuth clamp
   B. By rotating the azimuth tangent screw
   C. By releasing the tangent clamp
   D. By rotating the tangent screw

3. When the hand level is used, the reflector inside the sighting tube is set at what degrees?

   A. 15
   B. 30
   C. 45
   D. 60

4. For a level to function accurately, the level must provide what type of line of sight in any direction?

   A. Azimuth
   B. Vertical
   C. Tangent
   D. Horizontal

5. When you turn the left thumbscrew counterclockwise on a level, the bubble inside the vial will move in what direction?

   A. Towards your right hand
   B. Towards your feet
   C. Towards your left hand
   D. Towards your head

6. Leveling rods are used to measure vertical distance, which is the difference in elevation between a required point and what other requirement?

   A. Azimuth
   B. Line of sight
   C. Tangent
   D. Gradient

7. The Philadelphia rod can be extended to what total length in feet?

   A. 3.45
   B. 7.10
   C. 13.10
   D. 15.45

8. When both sections of the Philadelphia rod are entirely closed, what is the total length of the rod in feet?

   A. 1.10
   B. 3.65
   C. 5.35
   D. 7.10

9. What color are the even-foot numeral markers on a Philadelphia rod?

   A. Red
   B. Black
   C. White
   D. Magenta

10. What readings are possible when using the vernier scale and dumpy rod target?

   A. Tenths of a foot
   B. Hundredths of a foot
   C. Thousandths of a foot
   D. Ten thousandths of a foot

11. Which of the following is NOT a reason for target reading, vice a direct reading approach?

   A. When the instrumentman wants to ensure an accurate reading
   B. When a reading to the nearest 0.0001 foot is desired
   C. When the rodman recommends the target reading
   D. When the rod is too far from the level to be read

12. When is a rod reading accurate?

   A. Rod is perfectly plumb throughout the entire setup.
   B. Rod is perfectly horizontal at the time of the reading.
   C. Rod is perfectly horizontal throughout entire setup.
   D. Rod is perfectly plumb at the time of the reading.

13. How many spirit vials are associated with the vial rod level?

   A. 1
   B. 2
   C. 3
   D. 4

14. What is the coloring scheme on all rods?

    A. Painted white with graduation marks painted red
    B. Painted white with graduation marks painted black
    C. Painted black with graduation marks painted white
    D. Painted black with graduation marks painted red

15. The large numeral values on the rod represent whole feet; what do the small numerical values painted black represent?

    A. Tenths of a foot
    B. Hundredths of a foot
    C. Thousandths of a foot
    D. Ten thousandths of a foot

16. What term is used for a permanent object, natural or artificial, bearing a marked point whose elevation is known?

    A. Gradient point
    B. Azimuth value
    C. Route marker
    D. Bench mark

17. If no frost is expected before surveying and construction commence, what type of TBMs are allowed?

    A. Flags
    B. Stakes
    C. Steel rods
    D. String line

18. Monument bench marks on permanent military installations are established in what type of system?

    A. Grid system, 1 mile apart from each other
    B. Centric system, 1/2 mile apart from each other
    C. Grid system, 1/2 mile apart from each other
    D. Centric system, 1 mile apart from each other

19. Tide stations associated bench marks are classified two ways, primary and secondary; what observation period, in years, is required prior to a tide station being designated primary?

    A. 7
    B. 11
    C. 15
    D. 19

20. What is the most common type of mistake associated with surveying operations?

A. Level that is out of adjustment
B. Faulty or rough handling of equipment
C. Change in position of level
D. Mistakes in computations

21. **(True or False)** For underground utility construction, you need only to stake out the line; determining the grade of the piping is not necessary.

A. True
B. False

22. What is used to transfer the grade from the sighting cord to the pipe?

A. Leveling rod
B. Invert stick
C. Grade pole
D. Reaming pole

23. Which of the following is NOT presented on the plan and profile sheet?

A. Horizontal line located in each system
B. Invert elevation at each fitting
C. Horizontal location of each fitting
D. Azimuth of each piece of equipment in each system

24. The crowfoot symbol located on the centerline stake represents what reference point?

A. Vertical grade
B. Centerline stake
C. Horizontal grade
D. Water supply pipelines

25. What is the distance in feet between stakes and hubs?

A. 5
B. 10
C. 12
D. 25

26. At what distance in feet are sewer hubs offset from the centerline?

A.4
B.6
C.8
D. 10

27. Where can the percentage of drop value of a sewer hub be located?

A. Field notes
B. Cut sheet
C. Plot plan
D. Plan and profile sheet

28. What type of valve is used where a straight flow of water with the least amount of restriction is needed?

A. Gate
B. Check
C. Butterfly
D. Globe

29. What distinguishes one type of globe valve from another?

A. Material used in valve body
B. Internal structure of valve
C. Material used in valve seat
D. Exterior structure of valve

30. What valve is ideal when frequent throttling operations are required?

A. Pressure-reducing
B. Gate
C. Globe
D. Hydraulic control

31. In which of the following types of globe valves are the inlet and outlet openings in line with each other?

A. Menda
B. Cross
C. Angle
D. Straight

32. What type of valve is used as a stop valve on the suction side of a fire room pump?

A. Globe
B. Check
C. Butterfly
D. Gate

33. What material is provided to form a positive seal around the stem if the seal formed by the seat is damaged on a butterfly valve?

A. Valve seat
B. Packing
C. Loctite compound
D. Stem

34. What happens to the altitude valve if the pressure in the distribution system drops below normal working pressure?

A. Cycles between open and shut.
B. Automatically closes.
C. Automatically opens.
D. Remains in position indicated.

35. When operating a ball valve, you notice the handle is in line with the piping; what position is the valve in?

A. A to C position
B. Shut
C. Mid position
D. Open

36. Brass ball valves are used in which of the following applications?

A. Water service lines
B. High resistance to acid piping
C. Steam pressure lines
D. High pressure water piping

37. What happens to the position of the check valve if the pressure on the inlet side is greater than that on the outlet side?

A. Shuts manually
B. Opens automatically
C. Shuts automatically
D. Opens manually

38. Which type of check valve is used in horizontal lines?

A. Lift
B. Swing
C. Stop
D. Relief

39. Which type of valve is used to maintain pressure lower than supply pressure?

A. Hydraulic control
B. Pressure-relieving
C. Swing check
D. Pressure-reducing

40. In what direction is the diaphragm inside the pressure reducing valve forced if the discharge pressure is greater than the spring pressure?

A. Up
B. Down
C. Left
D. Right

41. How is the amount of spring pressure reduced on a pressure-reducing valve?

   A. By opening the valve seat
   B. By turning the adjusting screw counterclockwise
   C. By closing the valve seat
   D. By turning the adjusting screw clockwise

42. At what percentage above the set pressure will the pressure relief valve fully open?

   A. 5
   B. 10
   C. 20
   D. 35

43. **(True or False)** The hydraulic control valve is normally held in the closed position by both the diaphragm force and by fire main pressure acting against the disk.

   A. True
   B. False

44. How often is maintenance of valve boxes conducted?

   A. Twice a year
   B. Once a year
   C. Every six months
   D. Every three months

45. Gear boxes are inspected at what interval?

   A. Daily
   B. Monthly
   C. Semi-annually
   D. Annually

46. Where are the position indicators located on the non-rising stem gate valve?

   A. Filter plant
   B. Swing joint
   C. Floor stand
   D. Operating table

47. What is the result of installing a valve stem upside down?

   A. Direction of use will be reversed.
   B. Sediment collects in valve handle.
   C. Smaller piping cannot be connected to flow gages.
   D. Sediment collects in the bonnet.

48. Which of the following methods determines visually whether or not the seat and disk make good contact?

A. Spotting-in
B. Grinding-in
C. Lapping
D. Refacing

49. **(True or False)** Spotting-in is NOT required for conduct at the completion of the grinding-in method.

A. True
B. False

50. What method is required at the completion of the lapping method?

A. Spotting-in
B. Grinding-in
C. Spotting-in and Grinding-in
D. Refacing

51. Which compound grade is utilized for finish lapping?

A. Coarse
B. Medium
C. Fine
D. Microscopic fine

52. Which type of water volume meter is used with pipe less than 1 1/2 inches in diameter?

A. Disk
B. Rotating
C. Vernier
D. Centric

53. Where is the water meter located?

A. Top of pressure-reducing valve
B. Near the pressure-reducing valve
C. Near the main line shutoff valve
D. Always aboveground

54. How many different types of meter dials are used?

A. 1
B. 2
C. 3
D. 4

55. In the circular-reading dial, when the hand on a scale is between two numbers, which number is read?

A. Even number
B. Higher
C. Lower
D. Actual needle reading

56. What is the primary purpose for insulation of piping?

A. Prevent heat passage from steam piping to outside air.
B. Prevent cold passage from air conditioning piping to compressor.
C. Prevent heat passage from cold water piping to hot water piping.
D. Prevent any moisture from entering piping.

57. Of the two types of insulation used with heating ducts, what is the purpose of the inside insulation?

A. Reduce heat loss.
B. Reduce vibration.
C. Increase heat transfer.
D. Reduce ducting sagging.

58. Rigid preformed sections of insulation are used on what type of equipment?

A. Pipe hangers
B. Boilers
C. Pipe runs
D. Ovens

59. Which type of insulation is ideal covering for ice water piping?

A. Asbestos sheeting
B. Wool felt
C. Sponge felt paper
D. Cork pipe covering

60. What type of base primer is used to prevent corrosion caused by condensation?

A. Asphaltic
B. Enamel
C. Asbestos
D. Lacquer

61. Antisweat insulation is designed for which type of piping?

A. Hot water
B. Cold water
C. Steam
D. Freon

62. How many layers compose the antisweat insulation sheeting?

A. 2
B. 4
C. 6
D. 8

63. How thick is frost-proof insulation?

A. 1/4 inch
B. 1/2 inch
C. 1 inch
D. 1 1/4 inches

64. When wire mesh is utilized as a covering base, what is the distance in inches from the piping that needs to be maintained?

A. 1/4
B. 1/2
C. 3/4
D. 1

65. What distribution element is used to carry water from a treatment center to the users?

A. Booster stations
B. Arterial mains
C. Hydrants
D. Distribution mains

66. **(True or False)** Mains can be located under paved roads.

A. True
B. False

67. In the construction of long water supply lines, at what intervals, in feet, should shutoff valves be placed?

A. Not greater than 1200
B. Not greater than 5000
C. Not less than 5000
D. Not less than 1200

68. How many feet from a building should fire hydrants be located?

A. 10
B. 25
C. 50
D. 100

69. Hydrants should not be placed more than how many feet from the edge of a paved roadway?

A. 2
B. 3
C. 5
D. 7

70. Hydrants should not be placed closer than how many feet from the front of any entranceway?

A. 3
B. 5
C. 7
D. 9

71. The operating nut for a fire hydrant should not be placed more than how many feet above the surrounding grade of the land?

A. 2
B. 4
C. 6
D. 8

72. In mass parking and maintenance areas, the tops of the fire hydrants must not be higher than how many inches above the ground?

A. 12
B. 36
C. 24
D. 48

Trade Terms Introduced in This Chapter

Dumpy level	A surveying instrument consisting of a telescope rigidly attached to a vertical spindle. Used to determine relative elevation.
Hand level	In surveying, a hand-held sighting level having limited capability.
Locke level	A hand level.
Reference line	A series of two or more points in line to serve as a reference for measurements.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Basic Machines, NAVEDTRA 12199, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

OSHA Regulations (Standards – 29 CFR)

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Naval Construction Force Manual, *NAVFAC P-315*, Naval Facilities Engineering Command, Washington, D.C., 1985.

McPortland, J.E, and Brian J. McPortland, *National Electrical Code® Handbook,* 22d Ed, McGraw-Hill, NY, 2008.

Engineering Aid Basic, NAVEDTRA 10696-A, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1995.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Fluid Power, NAVEDTRA 12964, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

National Standard Plumbing Code-Illustrated, National Association of Plumbing- Heating-Cooling Contractors, Washington, DC, 2006.

Safety and Health Requirements Manual, EM-385-1-1, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

MIL-STD-17-1, Mechanical Symbols

MIL-STD-101B

International Plumbing Code 2009, International Code Council

International Mechanical Code 2009, International Code Council

R. Dodge Woodson, *Plumber's Quick-Reference Manual Tables, Charts, and Calculations,* 1st edition, McGraw-Hill, NY, 1996.

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Chapter 6

Plumbing Fixtures

Topics

To hear audio, click on the box.

Overview

"Roughing-in," as applied to plumbing and pipe fitting, is a term used for the installation of concealed piping and fittings at the time a building is being constructed or remodeled. As the building nears completion, the final connection of the plumbing fixtures is made. Once construction is complete, continuous maintenance and repair on the entire water and sewer systems will be necessary. In this chapter, you will be introduced to various procedures and methods to install, maintain, and repair water and sewage systems. Use the information given here as a foundation on which to build a wider and broader knowledge of the Utilitiesman rating.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the different types of plumbing fixtures.
2. Describe the procedures associated with plumbing repairs.
3. Describe the procedures for locating pipe leakage.
4. Describe water closet installation and repair.
5. Describe flushometer installation and repair.
6. Describe faucet installation and repair.
7. Describe procedures associated with sewer maintenance and repair.
8. Describe procedures for clearing stoppages in plumbing fixtures.
9. Describe water heater installation and replacement.
10. Describe lavatory installation and replacement.
11. Describe water closet installation and replacement.
12. Describe urinal installation and replacement.
13. Describe shower installation and replacement.

Prerequisites

None

This course map shows all of the chapters in Utilitiesman Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Utilities Equipment and Maintenance		
Air Conditioning		
Refrigeration		
Heating Systems		U
Steam Distribution Systems		T
Boilers		
Sewage Disposal, Field Sanitation, and Water Treatment		B
Prime Movers, Pumps, and Compressors		A
Plumbing Fixtures		S
Piping System Layout and Plumbing Accessories		I
Structural Openings and Pipe Material		C
Fundamentals of Water Distribution		
Basic Math, Electrical, and Plumbing Operations		
Plans, Specifications, and Color Coding		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for

review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 PLUMBING FIXTURES

Plumbing fixtures include faucets, tanks, and receptacles in kitchens and bathrooms. There are many types and styles of fixtures; some are general, while others have been adapted to meet special applications, such as for hospitals, prisons, and similar institutions. Military installations usually are planned to house large numbers of personnel, and the plumbing fixtures ordinarily are installed in batteries. Instructions for installing fixtures are given either by the manufacturer or by specifications. Sometimes you may have to design and lay out a fixture or battery of fixtures. You must know what water supplies and stack sizes are needed and work these into your design.

Standard plumbing fixtures are individually tested so that the amount of liquid waste that can be discharged through their outlet ***orifices*** in a given interval is measured. The fixture unit value for different plumbing fixtures is shown in *Table 6-1*. The basis for the fixture unit system comes from the fact that the washbasin, one of the smaller fixtures discharges 1 cubic foot of water per minute.

Table 6-1 — Plumbing Fixture Unit Values.

FIXTURE	UNITS
Lavatory or washbasin	1
Kitchen sink	2
Bathtub	2
Laundry tub	2
Combination fixture	3
Urinal	5
Shower bath	2
Floor drain	1
Slop sink	3
Water closet	6
180 square feet of roof drained	1

Plumbing fixtures must be furnished with water at a rate of flow that will fill it within a reasonable time, as well as, with a waste pipe of sufficient capacity to carry off all water supplied to it quickly and quietly.

Table 6-2 shows the minimum supply pipe diameters, according to the *National Standard Plumbing Code*

Table 6-2 — Minimum Size Fixture Supply.

FIXTURE	Supply Pipe Diameter Min. Size
Water closet (tank type)	1/2 inch
Water closet	1 inch
Flushometer urinal with flushing valve	3/4 inch
Laundry tubs	1/2 inch
Kitchen sink	1/2 inch
Lavatory	1/2 inch
Slop sink	1/2 inch
Drinking fountain	1/2 inch
Shower	1/2 inch

1.1.0 Rough-In Measurements

Figure 6-1 shows general rough-in measurements for various fixtures. These measurements vary depending on the type of fixture and the manufacturer. It is your responsibility to identify the fixtures you will be using so you can obtain the proper rough-in measurements.

Figure 6-1 — Rough-in measurements for various fixtures.

Service connections for steam radiators depend upon their sizes and location. The same holds true for water tanks used for storing or heating.

After roughing-in, you can easily install the plumbing fixtures and trim work. Instructions are given here for the installation of various fixtures and accessories. Even though not every type of fixture is included. if you learn to install the fixtures covered in *Figure 6-1*, you should not have any problems with other types.

1.2.0 Water Closets

Water closets, devices designed to receive human waste and dispose of it properly in a sanitary sewer system, come in various shapes, designs, and colors. Most water closets mount on the floor, but some models are wall-hung. Modem water closets have various design features which create different flushing actions.

1.2.1 Installation

To install a water closet, shown in *Figure 6-2*, follow these procedures as a general guide.

1. Slip the water closet flange over the closet bend and slide it down until it is level with the finish floor.
2. With a hammer and cold chisel, break off the portion of the closet bend that projects above the water closet flange. Do not break the closet bend below the flange.
3. Place the two brass closet hold-down bolt heads in the slots of the flange.
4. On the bottom of the water closet, as shown in *Figure 6-3, View A*, slip the preformed sealing ring over the horn to form a sealing gasket for the water closet against the face of the flange. Do not use putty as it will dry out and leave a possible sewer gas leak.
5. Turn the water closet bowl right side up and set it on the flange with the horn projecting down into the flange. Place a wedge under the low side of the water closet if unlevel. In setting the bowl on the flange, as shown in *Figure 6-3, View B*, guide the two hold-down bolts up through the bolt holes on either side of the base of the water closet. Use your full weight to press down and twist

Figure 6-2 — Water closet (tank type).

Figure 6-3 — Setting a closet bowl.

slightly to settle the bowl and the wax ring into position. The bowl should be perfectly level when settled.

6. Install nuts on the hold-down bolts and tighten them alternately. Do not over tighten them as this may crack the base of the water closet.
7. A wall-mounted water closet is attached to the wall by a chair carrier, similar to the one shown in *Figure 6-4.* The chair carrier is positioned and bolted to the floor. A standard fitting is used to connect between the drain and the closet bowl after the chair carrier is bolted down. The fittings are for 4-inch iron or soil pipe. The bolt holes in the chair carrier are slotted to facilitate installation of the closet bowl.

When mounting a close-coupled tank on a closet bowl, note that two bolts hold the tank on the bowl, as *Figure 6-5* illustrates. The water supply pipe is between the bolts and drops the water directly into the bowl. A specially designed gasket is installed between the tank and bowl to make the connection waterproof. The bolts are tightened from underneath the closet bowl. Do not apply too much pressure when you tighten these bolts, because you may crack the bottom of the tank or the back of the bowl.

Figure 6-4 — Wall-mounted water closet.

Figure 6-5 — Mounting a close coupled tank.

After the tank is firmly attached to the bowl, connect the water supply pipe to the tank inlet with a riser tube, as shown in *Figure 6-6*. The jiffy connector used here is the same as the connector used to connect the water supply to the faucets of a lavatory. The rubber washer shown in *Figure 6-6* is commonly referred to as a doughnut washer because of its thickness.

1.2.2 Flushometer Valves

Because of how they operate, flushometers are referred to in two categories, piston and diaphragm. In some applications they are used in place of a tank-type valve. When a flush valve is used, no tank to hold the flushing mechanism or water is required, therefore, larger pipe diameters are required.

Figure 6-6 — Closet tank water supply line.

Flush valves require less water volume per flush than a tank-type valve, provide quicker multiple flushing capability, and lower maintenance costs in commercial applications; however, they are noisier, initially cost more, and require a higher operating pressure than tank-type valves. These items usually require larger pipe sizes. Basically, the flush valve is suited more for the commercial or industrial application, and the flush tank is used in small buildings or single family dwellings.

A backflow preventer or vacuum breaker, such as the type shown in *Figure 6-7*, should be installed on the discharge side of a flushometer and on the supply line of a float valve in a water closet tank, if the tank outlet is below the flood level rim of the closet bowl.

Figure 6-7 — Flushometer valve showing a backflow preventer.

A detail of a diaphragm type of flushing valve is shown in *Figure 6-8*. The diaphragm type of valve consists of an upper and lower chamber. These chambers are separated by the diaphragm and relief valve. The lower chamber is connected directly to the incoming water supply. This incoming water is the flushing water and also shuts the valve off after the flushing period. The valve is flushed by the diaphragm and the water pressure in the upper chamber. Water is forced into the upper chamber through a small orifice (hole) in the diaphragm. Water pressure, passing through this orifice into the upper chamber, creates the pressure required to force the diaphragm down and shuts off the flushing water. When the flushing handle is moved, the relief valve tilts open. Then pressure decreases in the upper chamber to less than that of the incoming and flushing water. The action allows the flushing water pressure to raise the diaphragm off the flushing seat and recycle.

Figure 6-8 — Diaphragm type of flushing valve.

Figure 6-9 shows a piston type of valve. With this type of flush valve, the piston is drawn up when the flushing begins, then to its closed position by the filling of the upper chamber through the expeller orifice tube.

Flush valve assemblies on urinals and water closets may be protected from unnecessary damage and wear by installing a grip handle or guard firmly over the handle housing. This grip handle increases the operating life of flush valves and thereby reduces service calls on the repair of flush valve assemblies and plumbing fixtures.

Figure 6-9 — Piston type of flushing valve.

1.3.0 Urinals

Two major types of urinals in use are the floor-mounted and wall-mounted urinals. We will discuss some of the main items relating to the installation of the wall-hung urinal (*Figure 6-10*). Before installing a floor-mounted urinal, refer to local codes to ensure it is legal.

In setting the wall-mounted urinal, see that the rough-in of the waste pipe and water supply are at the correct height from the finished floor so after installation the urinal is within reach of the user. Commonly the lip of the urinal should be from 20 to 25 inches from the floor. If the rough-in already installed in the building places the height of the urinal above or below these general measurements, the rough-in should be removed then the water supply and waste pipe should be brought in at the proper height. It is imperative to refer to manufactures rough in drawings or make you own rough in drawings from prints, details, specs, and measurements from the flush valves and fixtures to avoid rework. Since the wall-hung urinal sometimes has an integral trap (a trap contained in the fixture), it is not always necessary to provide the waste pipe with a separate chrome or iron trap. Integral trap urinals have a back spud fitting that connects the waste pipe and urinal together with a rubber seal in between. Install a mounting board on the wall where a urinal is to hang. This board will provide firm support for the urinal, and should be used for installing fixtures on hollow wall, like dry wall, not concrete or masonry structures. The last step in the installation of the wall-hung urinal is the connection of a flushing mechanism, such as the diaphragm type of flushing valve.

Figure 6-10 — Wall-mounted urinal.

1.4.0 Bidets

A bidet is equipped with running cold and hot water and is used for bathing external genitals and posterior parts of the body. The bidet is installed mainly overseas; however, the bidet is becoming very popular in the United States.

The water is controlled by faucets similar to those found on many lavatories. The flow of water may rise from the center of the bowl or around the rim. The bowl contains a stopper which holds water in the bowl if desired.

1.5.0 Sinks

Sinks are made in different patterns, each intended to serve specific purposes. Two common types of sinks are the kitchen sink and the service sink (slop sink).

1.5.1 Kitchen Sink

The kitchen sink is available in different sizes and may have either a single or a double bowl made of various materials like stainless steel, enameled steel, plastics, or cast iron.

A kitchen sink must be built into a cabinet or hung from a bracket that is screwed to a mounting board. The bracket should be screwed into the mounting board in a position where the sink, when mounted, is at a convenient height for use. As a rule of thumb, the distance between the top of the drain board and finished floor should not be less than 36 inches.

After screwing the bracket into place, lower the sink into position on the bracket, so the lugs, cast into the back of the sink, fit down into the corresponding notches in the bracket. Screw the strainer and tailpiece into the sink bowl and connect the trap to the rough-in waste. To complete the installation, select a suitable faucet. Install the faucet on the sink and connect the water supply to it, as shown in *Figure 6-11*.

Figure 6-11 — Kitchen sink water supply hookup.

Then install and connect the waste lines to the sink, as shown in *Figure 6-12*.

Figure 6-12 — Kitchen sink waste hookup.

1.5.2 Service Sink

A service sink, also referred to as a slop sink, is especially useful for filling a bucket or washing out a swab. It has a deep bowl and is generally constructed of cast iron and finished in enamel, but can also be made of other various materials.

The slop sink installation is similar to the kitchen sink installation. The slop sink is also mounted on a bracket and mounting board. In addition to the hanger, the slop sink has a built-in adjustable stand trap that bolts to the floor and provides a pedestal support (*Figure 6-13*). The stand trap should be adjusted to take most of the weight off the hanger and prevent the unit from sagging.

Figure 6-13 — Service (slop) sink.

After the fixture has been set in place and the waste supply has been connected, suitable faucets are installed and connected to the water supply, and the unit is ready for use.

1.5.3 Lavatories

The wall-hung lavatory, the most common type in use, is suspended from a bracket screwed to the wall. It may or may not be additionally supported by legs. Refer to the manufacture's instructions to install this fixture, and complete the following steps:

1. Mark the wall at the correct height for a lavatory and secure a hanger to the wall.
2. Position the lavatory on the hanger.
3. Install the lavatory faucets using a basin wrench.
4. Install the permanent opening (P.O.) plug drain, as shown in *Figure 6-14, View A,* or the pop-up type of drain, as shown in *Figure 6-14, View B*.

Figure 6-14 — Lavatory drains.

5. Connect the water-supply lines to the faucets, as shown in *Figure 6-15, View A*.
6. Connect the waste-supply line to the lavatory, as shown in *Figure 6-15, View B*.

1.5.4 Faucets

As an Utilitiesman, you may often be called upon to install or make repairs to faucets. There are many types of faucets in general use, such as the bib, lavatory, bath, and kitchen combinations.

The hose bib faucet, shown in *Figure 6-16, View A,* is used where outside hose connections are needed.

You probably recognize the combination faucets shown in *Views B, C,* and *D* of the figure. These faucets generally are used to combine the flow from hot-and cold water pipes. A main feature of these faucets enables the water to be tempered as it is discharged through a single spout. They are commonly used on lavatories, and in baths and kitchens.

Figure 6-16 — Types of faucets.

Figure 6-15 — Lavatory water supply and waste hookups.

1.6.0 Shower and Tub Combination

Several types of bathtubs are on the market today, such as the recessed, the corner recessed, the sunken, and the leg type. Tubs sizes range from 4 to 6 feet in length, and they are designed as right- or left-hand tubs, depending on the location of the drain. When you face the tub, if the drain is on the right end, it is a right-hand tub; if on the left end, a left-hand tub. Most bathtubs today are made of enameled cast iron, enameled pressed steel, or fiberglass, which is most commonly used for the built-in type.

The installation of both the bathtub and shower is simple. Tubs and showers come in many different applications: tubs, showers, tub-and-shower combinations, and gang showers (large room with no privacy partitions or dividers).

To install a tub, like the type shown in *Figure 6-17, View A*, place the rim of the tub on the 2- by 4-inch support nailed to the 2- by 4-inch studs, as shown in *Figure 6-17, View B*. Check to be sure the tub is level.

Figure 6-17 — Bathtub and support.

Once the tub is in place, hook up the water-supply lines, as shown in *Figure 6-18*. In a bathtub and shower combination, water is furnished by a faucet and spray nozzle. Two valves usually control the flow of water to these units. Ordinarily, when the valves are opened, the water runs into the bathtub from the bathtub faucet. However, for water to run through the shower head, the valves are opened as for filling the bathtub; the diverter, which is located in the bathtub faucet, must be raised. This combination allows the bather to take a bath or a shower.

Figure 6-18 — Bathtub and shower piping combination.

A tub drain and overflow are usually similar to that shown in *Figure 6-19*. The drain assembly is installed in the space provided by the studs at the end of the tub. The overflow and waste drains are made of chrome. The fittings are 1 l/2 inches in diameter and come with a pop-up waste or a rubber stopper fastened to the overflow by a chrome chain. This drain and overflow combination is connected to the P trap with slip-joint nuts and rubber washers to seal off the leaks. The drain in the bottom of the tub is sealed against leaks with plumber’s putty and rubber rings.

The wastewater supply lines, as shown in *Figure 6-20*, are then connected to the tub.

Figure 6-19 — Bathtub combination waste and overflow.

Figure 6-20 — Tub waste hookup.

The faucet and shower combination for a bathtub and shower is connected to the hot and cold waterlines that were installed when the piping was roughed-in. The manufacturer’s specifications should be used to determine the height of the riser. The height, however, may be specified by the user. The shower and bathtub piping and fittings installed within the wall are made of rough brass; those that extend through the finished wall have a chrome finish. A typical bathtub and shower piping arrangement is shown in *Figure 6-21*. When you make this type of bathtub and shower installation, be sure to locate the bathtub spout from 2 to 4 inches above the rim of the tub. Spacing the spout above the rim of the tub prevents siphoning of the water from the tub in case the valve is left open and the water drops at the same time. This installation prevents cross-connection between potable and non-potable water.

The mixing valves in the shower system supply a uniform temperature of water for the shower or tub. The temperature of the water may be regulated between the limits of the temperature of the cold-water supply and the hot-water supply. The manual, pressure, and thermostatic mixing valves control the temperature of the water.

Figure 6-21 — Bathtub and shower piping arrangement.

The manually controlled mixing valves consist of two hand-operated valves in one body with outlets for both valves that feed the shower head. The valves are turned by hand to control the temperature of the water. Manually controlled valves require a piping arrangement similar to the one shown in *Figure 6-21*. This water tempering setup does not protect against sudden changes of temperatures due to slugs of hot or cold water from varying pressures or water temperatures in the supply lines.

The pressure-controlled mixing valve, like the one shown in *Figure 6-22, View A*, consists of a mixing chamber that contains a sliding piston. The piston has jets to allow hot and cold water to pass through them and mix when the handle of the valve is operated. The setting of the handle controls the water temperature by establishing the mixing ratio. A change in pressure on one side of the piston causes the piston to move and increases the flow from the low-pressure supply to maintain a nearly constant pressure.

The thermostatically controlled mixing valve, similar to the one

Figure 6-22 — Shower mixing valves.

shown in *Figure 6-22, View B*, is sensitive to changes in both temperature and pressure. The temperature of the water delivered by the valve remains constant regardless of the temperature and pressure changes in the hot and cold waterlines. The thermostatic mixing valve is used for showers only.

The shower head is attached to a 45-degree fitting mounted on a chrome pipe. There are two general types of shower heads: circular and economy. The circular spray head, shown in *Figure 6-23*, has notches or grooves around the outer edge of its face. The spray in this type of head can be regulated. The economy head, also shown in *Figure 6-23*, has a restricted nozzle that provides a finer spray and uses less water. Both shower heads have a ball-and-socket joint for adjusting the direction of the spray.

Figure 6-23 — Types of shower heads.

Shower heads are usually made of chrome- or nickel-plated brass. Newer types of shower heads are made of noncorrosive plastic. Deposits tend to form on the shower head because of the chemical content of the water; therefore, occasional maintenance using cleaning and soaking solutions is required to keep them functioning properly.

The most important requirement in a shower installation is the absolute waterproofing of walls and floors. Walls are less of a problem than floors since they are subject only to splashing of water and do not have water standing or collecting on them. Careful installation of tile or other impervious material with waterproof cement generally suffices to provide a waterproof wall installation. In the installation of the floor, an impervious waterproof subbase must be put under the shower floor, or water standing on the floor will gradually seep through and cause leaks.

Concrete shower pans, used with prefabricated steel shower stalls, are relatively easy to install. In many cases, steel shower stalls are set up after the original construction. In this case, the cement base is usually not recessed into the floor but is laid directly on top of the floor.

Generally, steel fabricated shower stalls are being replaced with fiberglass and plastics. All of the units are installed in the same manner. The dimension for the finished interior of a shower stall should be at least 30 inches. The shower head should be a minimum of 68 inches above the level of the drain on the shower pan (*Figure 6-24*).

Figure 6-24 — Shower stalls and sections.

Figure 6-25 shows a cutaway view of a shower pan. All pipe openings in the wall of the stall should be sealed. Be sure to follow the manufacturer's instructions that accompany the fixtures and trim. The shower pan is connected to a P trap following the shower pan manufacturer's instructions.

1.7.0 Drinking Fountains

Most types of drinking fountains should be installed with the orifice located from 30 to 40 inches above the floor, depending upon the general height of the users or specific requirements for a facility. One type of wall-hung drinking fountain is shown in *Figure 6-26*.

Figure 6-25 — Cutaway view of a shower pan drain.

The mounting of the fixture should be sturdy and strong enough to hold more weight than that of the fixture itself. Most drinking fountains are installed with a 1 1/4-inch P trap, but a few are available with integral traps. The electrically cooled drinking fountain requires an electrical outlet nearby for power. Because of the many variations in style of drinking fountains, the manufacturer’s installation procedures and specifications should be followed in each case.

Figure 6-26 — Wall-mounted drinking fountain.

1.8.0 Floor Drains

Floor drains are used to carry contaminated water to the sanitary or storm sewer. Sanitary sewage very rarely passes through a floor drain, unless other fixtures in a system overflow and sewage backs up into the floor drains.

Floor drains are divided up into two groups: those that are designed with a water seal and those that are not. Floor drains used in connection with a sanitary sewer by code must have a water seal (*Figure 6-27, Views A* and *B*). The water seal prevents gases and odors from the sewer from coming into the building or structure containing the floor drain. Drains without a water seal (*Figure 6-28*) may be used when the floor drains are connected in a system that feeds into a storm sewer system.

Figure 6-27 — Integral trap with ball check valve.

A floor drain that is 2 inches in diameter is rated at two drainage fixture units. A floor drain that is 3 inches is rated at three drainage fixture units. The load of fixture units for floor drains is added to the sanitary system, not the vent system. Most code requirements do not require floor drains to be vented if they are installed within 25 feet of a vented drainage pipe line.

Figure 6-28 — Drain without a water seal.

1.9.0 Water Heaters

Clean, hot water is required in many installations for domestic and industrial use. Since boiler water cannot be used for this purpose because of the chemicals added, it is necessary to heat additional water. The water may be heated in tanks equipped with coiled piping through which the boiler water or steam circulates. Or it may be heated in independent units that heat by electricity, gas, solar, or oil.

Domestic water heaters are built in various sizes from zero capacity instant heat to 50-gallon storage capacities. Industrial type water heaters are designed to heat thousands of gallons of water, depending upon the use.

Modern water heaters are self-contained and require very little attention, since they are fully automatic. These units are cylindrical in shape and have diameters ranging from about 12 to 30, 40, and 50 inches, depending upon their capacity. The tank is constructed of galvanized sheet metal, which may be lined with a composition of glass to resist corrosion of the tank lining and prevent contamination of the water. The combustion chamber is in the lower section, which is vented by a baffled flue that extends through and ends at the top of the tank. The entire tank is insulated to prevent the escape of heat. It is also equipped with a thermostat which can be adjusted to maintain a certain water temperature. Automatic safety features are built into the units.

Both the cold-water inlet and the warm-water outlet are at the top of the tank. These tappings are usually marked “INLET” and “OUTLET.” However, if there is a question in your mind as to which is which, just remember that the cold-water inlet pipe extends over halfway into the tank, but the outlet pipe does not. There is usually a drain valve at the bottom of the tank.

You must ensure the dip tube is installed on the cold-water side or inlet to allow the cold water to go to the bottom of the heater and not cool the water at the top.

Gas water heaters must be installed with a Pressure Temperature Release Valve (PTRV), which is a safety device, is normally located in the top of the shell. The PTRV is set to open on a temperature or a pressure rise of an unsafe limit. PTRVs differ from safety valves in that a PTRV opens gradually at a set point. Normally the valve opens at 210 degrees or at 125 psi at a minimum. The pipe that carries the relieved water or steam from the tank must extend to within 18 inches of the deck to prevent a hazardous condition.

Always remember that water in a closed vessel will expand when heated and cause the pressure to rise. If, for some reason, a control fails to turn the heat source off, the pressure will be relieved by the PTRV. The water that comes out of the outlet of a PTRV will flash off due to the pressure change; steam along with scalding water will be discharged from the tank.

Test your Knowledge (Select the Correct Response)

1. What two types of urinals are most commonly used by the Seabees?

   A. Floor- and wall-mounted
   B. Floor- and side beam-mounted
   C. Parallel and perpendicular mounted
   D. Wall- and diagonal mounted

2.0.0 PLUMBING REPAIRS

This portion of the chapter will deal with some of the more common plumbing repairs that will be necessary from time to time to keep plumbing systems operating properly. Proper repairs and maintenance techniques save money by extending the life of plumbing systems. For example, one water faucet that is leaking one drop of water each second wastes about 2,300 gallons of water per year.

2.1.1 Water Breaks

Water distribution piping at one time or another will require repair on a leak or a break in the line. The following are problems you may have during a waterline break:

- The water supply for fire protection is reduced or does not exist.
- Escaping water under pressure undermines structures, damages foundations, destroys landscaping, or causes a serious erosion problem.
- A broken pipe causes a health hazard because the distribution system can become contaminated by external sources.
- The water supply for normal domestic or industrial use can be completely cut off.

To ensure proper repair of a water break, keep red line prints and as built drawings on hand that show the water distribution system, existing conditions, and locations. Ensure that you red line your set of prints every time you make a repair or line change. Additionally, notify engineering of your line repair or line change, and they will update the master set of base prints.

At some activities, electronic devices are available for subsurface survey and pipe location work. Sometimes you may have to find points of interconnection, pipe diameters, and the condition of exterior surfaces or coatings. For future use, make notes on the maintenance prints to show the general condition of the system. Use a symbol that stands out to show the approximate age of the installation or its parts. Prints should be complete and up-to-date. In maintenance or repair, these prints help in planning maintenance. Many times they offer clues to the most probable location and probable cause of trouble. Now and then, the system should be flushed through hydrants and blow-offs to remove scale and accumulation in pipes and fittings. When performing this operation, start at the hydrants or blow-offs nearest the source of supply to conserve water and to stir up less of the distribution system. Each point should be flushed until the water comes out reasonably clear. All valves should be in their normal operating positions before you go on to the next point. Flushing dead ends is vital. When flushing does not induce enough velocity to scour the mains clean, night flush them with a large discharge. Night operation lessens work disruption caused by water shutoff or decreased water pressure.

2.2.1 Water Mains

Since water main breaks must be repaired as fast as possible, personnel must be trained and repair plans made in advance. The following procedures are essential:

1. Post the telephone numbers of the fire department and key personnel and have alternate personnel available in case members of the regular repair crew cannot be reached at the time of a break. Notify the public works officer at the time the break is reported.
2. Always keep the following items readily available: valve keys, hand tools, digging tools, pavement breakers, trench shoring, a portable centrifugal or diaphragm pump, floodlights, an emergency chlorinator, and calcium hypochlorite powder.
3. Maintain enough pipe repair materials and supplies. As a temporary measure, wooden plugs can be used to stop small holes in a main. These plugs can be replaced later with metal plugs, or repairs may be made by other means. Wooden plugs can also be used temporarily to plug the ends of a pipe up to 8 inches in diameter, but such plugs must be braced to withstand existing main pressure. After repairs are completed, the main must be disinfected.

2.3.0 Thawing Frozen Pipes

In cold weather, a water-supply system can freeze. Because of the lack of protection against freezing, and sometimes regardless of it, pipes frequently freeze in temperate zones. When this happens, the pipes must be thawed. Breaks must be found, if possible, before natural thawing to prevent damage to material and property. Alert personnel to watch for the signs of a broken line. The prevention of freezing pipes can sometimes be accomplished by using heat tapes and cables.

Before starting to thaw a frozen pipe, open faucets affected by the freeze. Frozen pipes can be thawed by applying heat at the lowest open end of the frozen section. (Do NOT start in the middle of a frozen section because a pocket of steam could develop and an explosion or damage to the pipe can occur.) Where there is no danger of fire, simply heat the pipe with a blowtorch, applying the flame on the outside of the pipe.

Using hot water is the preferred method for thawing frozen water pipes or heating pipes inside of buildings. Do NOT use an open flame. A safe method is to wrap the frozen section of pipe with cloth and pour hot water on it until the ice gives way. Remember to protect the floor by catching the water in buckets or by covering the floor with material to absorb the water.

A good method of thawing water pipes that are underground or otherwise hard to get to is shown in *Figure 6-29*. When using this method, remove the fittings (see illustration) and insert one end of the small pipe or tube into the frozen pipe. Now add an elbow and a piece of vertical pipe to the outer end of the thaw pipe. Place a bucket under the opening to the frozen pipe and insert a funnel in the open end of the vertical pipe. With that done, start pouring boiling water through the funnel into the pipe. As the ice melts, push the thawed pipe forward. Where necessary, add pipe at the outer end until a passage is made through the ice.

Figure 6-29 — Thawing an underground or otherwise inaccessible pipe.

Withdraw the thaw pipe quickly after the flow starts and do not stop the flow until the thaw pipe is fully removed and the pipe cleared of ice.

Instead of a funnel, a small force pump can be used. This pump is useful for thawing a long piece of pipe. When available, you can use steam in place of hot water. The above method can also be used without the elbow and piece of vertical pipe, as shown in *Figure 6-29*. Simply connect the funnel to the outer end of the thaw pipe with rubber tubing. Have the tubing long enough so you can hold the funnel above the level of the frozen pipe. In this way, you give the hot water a head, forcing the cooled water back to the opening where it runs out into the pail. The advantage of the elbow and vertical pipe is that they increase the head of the water and make the use of the funnel easier.

2.3.1 Electrical Thawing

Electrical thawing of frozen service lines is quick and cheap. The electrical current for the thawing operation consists of a source of current (a DC generator, such as a welding outfit, or a transformer connected to an AC outlet) and two insulated wires connecting the current source and the pipe (*Figure 6-30*).

Figure 6-30 — Connection points for thawing frozen service lines.

Only qualified personnel should use power lines as a source of current. As current flows through the pipe, heat is generated, and the ice within the pipe begins to melt. As the water starts to flow, the rest of the ice is melted by contact with the flowing water. The wires from the current source may be connected to nearby hydrants, valves, or exposed points at the ends of the frozen sections. Some data on current and voltage required for electrical thawing of various sizes of wrought-iron and cast-iron pipes are presented in *Table 6-3*.

Table 6-3 — Relation of current and voltage required for thawing.

Type of pipe	Pipe Size (in.)	Pipe Length (ft.)	Approximate	Approximate (amps)
Wrought Iron	3/4	600	60	250
	1	600	60	300
	1	600	60	350
	1/2	500	55	400
	2	400	40	450
	3	400	50	500
Cast Iron	4	400	50	600
	6	300	40	600
	8			

The time for electrical thawing may vary from 5 minutes to over 2 hours, depending on pipe size and length, intensity of freezing, and other factors. The best practice is to apply current until the water flows freely.

Use the following procedures in electrical thawing:

1. DC Generator. To thaw pipes with a welding generator or similar DC source, set the generator to the correct amperage for the pipe to be thawed and connect the leads to the pipe.
2. AC Circuit. Transformers are required to adjust amperage of an AC circuit to the pipe being thawed. To reduce hazards, have a competent Construction Electrician (CE) set and connect transformers, make the connections, and assist in the thawing process. Where frequent thawing is necessary at different points, the transformers may be mounted on a trailer for ready use.

Some precautions in electrical thawing are given below:

- Avoid a higher current than listed in *Table 6-3*. When in doubt, use low current for a longer period.
- Select contact points on the pipe as close as possible to the frozen section.
- Assure that contact points are free of rust, grease, or scale.
- Remove meters, electrical ground connections, and couplings to buildings with plumbing in the pipeline to be thawed.
- If there are gaskets or other insulation at pipe joints, thaw the pipe in sections between such joints, or use copper jumpers to close the circuit across insulated points.

2.3.2 Steam Thawing

Steam thawing of frozen systems is slower than electrical thawing and should be used only when insulating materials in pipes (plastic, transite, and wood), pipe joints, or couplings make the use of electricity impractical. In steam thawing, a hose connected to a boiler is inserted through a disconnected fitting and gradually advanced as the steam melts the ice.

2.3.3 Variation of Water Pressure

A change of water pressure can cause much discomfort to persons using the plumbing system. The mixture of hot and cold water from a shower can suddenly vary in temperature or rate of flow when water is turned on at another outlet. Failure to remedy this condition could injure somebody, especially if the temperature is scalding.

When a switch in pressure and water flow occurs often, look at the water pipes. Check the pipes to see if they are the proper size in diameter for their length and height as originally installed. Also look for liming and corrosion inside the pipes. Enough liming and corrosion can reduce the diameter of the pipe, causing restrictions that lead to low pressure and slow water flow.

Sometimes the trouble occurs after more fixtures have been installed in the system. When this happens, the piping is probably overloaded because of the extra fixtures. Pressure and water flow may also change when there is too much friction in the pipe, too many fittings, or changes in the direction of the piping.

If the pressure in showers changes only when other outlets are open, you can usually correct the trouble by installing automatic mixing valves. The only answer to an increase in the water flow from pipes that are too small is to replace them with larger pipes.

Test your Knowledge (Select the Correct Response)

2. When thawing frozen water pipes or heating pipes inside buildings, which method is preferred?

    A. Open flame
    B. Hot Water
    C. Electrical thawing unit
    D. Steam thawing unit

3.0.0 PIPE LEAKS

When a leak develops at a threaded joint of pipe, one of the most likely suspects is a fractured or ruptured pipe. Fractures often occur at the end of a length of pipe because of strain imposed by vibration of water hammer. It occurs at the end of the pipe because the wall thickness is decreased and weakened by threading. The risk of fracture becomes even greater when the threads are not cut true. In cold climates, freezing sometimes causes pipes to rupture, in which case replacement becomes necessary. A loose or cracked fitting can also cause leakage at the threaded joint of a pipe. These and other common failures resulting in pipe leakage make it important for you to determine the exact location and cause of failure before beginning any repairs to the piping.

3.1.0 Locating Leaks

Find and repair leaks in the water piping system as quickly as possible to prevent serious damage to footings, walls, floors, plaster, and other parts of the structure, and to conserve water. Also, sanitation and hygiene issues are associated with water leaks, such as mold, insect’s sanitary system and disease. Find leaks systematically by inspecting exposed piping and valves and by examining walls, floors, and ceilings around concealed piping. You should also check gauges, meters, and other water flow recording devices for evidence of abnormal flow, which might reveal loss through leakage.

In galvanized pipe installations, where the fittings on either side of the leak are not readily available, the leaking section may be cut out (*Figure 6-31*). In this operation, one person holds the pipe with a backup wrench to keep it from being over tightened or loosened in the adjacent fittings, and another person cuts a thread on it while it is in place using a hand type of pipe threader. The cutout section is then replaced with a coupling, a pipe section of the required length, and a union.

Figure 6-31 — Replacing a leaking section of pipe.

You may also have to repair leaks in copper piping. If a copper pipe leaks, cut out the damaged section and replace it with a new section, using either soldered joints or compression fittings. When a piece of cast-iron pipe less than full length is needed for replacement, cut it from a double-hub pipe, so the remaining piece has a hub left for use in other work.

If you need a fitting for a short space or if existing work cannot be removed easily, use short spigot ends for sleeves. Closely observe *Figure 6-32*. This figure shows how to install a fitting in a restricted space.

Figure 6-32 — Installing a fitting in a restricted space.

When the job calls for adding connections to an outside vitrified clay sewer line, here is one step-by-step method, shown in *Figure 6-33*.

1. Remove a section of the existing sewer pipe that is long enough to receive a new Y-fitting.
2. Break half of the hub rim of the new Y-fitting, as shown in *Figure 6-33, View A.*

3. Insert the spigot end of the Y-fitting into the hub of the existing pipe. At the same time, place the remaining half of the hub end of the Y-fitting over the cut end of the existing pipe with the Y-branch pointing away from the new inlet. (See the first position of *Figure 6-32, View B*).
4. Rotate the Y-fitting, so the broken half of the hub is up and the Y-branch is in the correct position to receive the new inlet connection. (See the final position *Figure 6-32, View B*).
5. Pour the joint carefully; round over the broken half of the hub with plenty of concrete or mastic compound, as shown in *Figure 6-32, View C*.

Figure 6-33 — Adding connections to an outside vitrified clay sewer pipe.

3.2.0 Emergency Temporary Repairs

At times, a pipe may start leaking and the materials needed to repair it permanently are not on hand. Here, you may have to use a temporary or emergency repair. Keep in mind that a permanent repair should always be made when the proper tools or materials are available.

One simple method of making a temporary repair of a leaky pipe is to use a length of rubber hose. After turning off the water supply, remove the defective section of the pipe by cutting it with a hacksaw. Then take a piece of rubber hose, slightly longer than the section of pipe you removed, and slip it over the ends where the cut was made (*Figure 6-34, View A*). Ensure the inside diameter of the hose matches the outside diameter of the pipe. Use hose clamps to hold the hose securely in place.

Another temporary method of repair for a leaky pipe is to wrap the leaky area with sheet rubber, and then place two sheet metal clamps, one on each side of the pipe, on the sheet rubber covering, as shown in *Figure 6-34, View B*. Fasten the clamps with bolts and nuts. Sheet metal clamps for this type of repair can be made from scrap material from the sheet metal shop. You may want to make up a few of these clamps to keep on hand for an emergency repair job.

You can also secure the water supply, drain the water from the pipe, clean the pipe surfaces thoroughly, apply flux, and then wrap clean copper wire over the rupture and solder.

Figure 6-34 — Temporary types of repairs of a leaky pipe.

3.3.0 Water Tank Failures

Where a plumbing system has been in use for some time, two failures in water tanks are (1) leaky seams and (2) corroded areas requiring welded patch plates. To repair a defective seam, first drain the water tank dry. Then clean the surfaces to be repaired. By welding or brazing, you can then make the leaky portions watertight.

As an effective tank patch for a large hole, you need both a temporary and a permanent patch. One temporary patch is a tapered softwood plug. Insert the plug in the hole, and tap it lightly with a hammer until the seal is watertight. Then saw off the top of the plug so it is flush with the tank wall.

Next, clean the area around the plug to be covered by the permanent patch by wire brushing. Drain the tank; now you are ready to apply the permanent patch. One type of permanent patch includes a rubber gasket and a metal plate. Rubber sheeting, at least 6 inches by 6 inches and l/16 inch thick, may be used for the gasket, and it should be centered on the plug and cemented with adhesive. The patch plate of black steel or nonferrous (no iron) metal should be of the same material and thickness as the tank wall but a lot larger than the hole. Cover the hole with the metal plate, keeping an equal overlap around the edges, and braze or weld the plate to the tank, using a continuous seam.

Test your Knowledge (Select the Correct Response)

3. What is the most common reason a threaded pipe joint will leak?

    A. Sagging joints
    B. Crooked piping
    C. Fractured pipe
    D. Leaky sealing compound

4.0.0 WATER CLOSETS

Moisture on the floor at the base of a water closet bowl usually means the seal or gasket between the closet and its outlet has failed; however, it can result from condensation on the tank or piping or from leakage of the tank, flush valve, or piping. When the seal leaks, remove the water closet bowl and install a new seal to prevent damage to the building. This also prevents entry of sewer gas into the room.

In servicing plumbing fixtures, you have the job of clearing stoppages in water closets. Information on tools and chemicals used in clearing stoppages in water closets and other fixtures is given later in this chapter.

4.1.0 Flush Tank

Knowing the principles of operation of a flush tank will enable you to find the source of trouble when a flush-type water closet tank is not operating properly. *Figure 6-35* shows the parts of a flush tank, though in different types of flush tanks you may find some changes in the method of operation.

Figure 6-36 explains the principal operations of a water closet flush tank. Simple though it may seem, you must understand the operation in order to troubleshoot an inoperative flush tank.

Stage 1

When the flush handle is pushed downward, the rubber stopper ball or flap valve is raised from the valve seat to allow the water from the tank to go into the discharge pipe.

Figure 6-35 — Water closet flush tank.

Stage 2

As the water lowers in the tank, the ball or flap lowers and the movement of the float arm opens the inlet valve, allowing water to start flowing into the tank slowly.

Stage 3

As the water flows from the tank to the discharge pipe, the ball or flap seats and incoming water holds the ball or flap in place and the tank fills.

Stage 4

As the water continues to fill the tank, the ball or flap rises until

Figure 6-36 — Flush tank process.

the arm allows the valve to close.

4.2.0 Flush Tank Repairs

When water continues to run into the closet bowl after the flush tank is full, the trouble is in some part of the inlet valve assembly (ball cock assembly) or the stopper valve is not seated. The plunger has failed to close the inlet valve as it should, and thus the excess water that continues to flow in (after the tank has reached the proper level) is being discharged through the overflow pipe into the bowl.

In checking for the source of trouble, several defects you should look for are a leak in the float ball, a bent float arm, a worn washer on the bottom of the plunger, or a worn valve seat. Start with the float ball, keeping in mind that a leaky, waterlogged float prevents the plunger from closing properly. A small leak in a copper float ball can be remedied by soldering. If it has a large leak, though, simply replace the float ball with a new one. A damaged float arm should also be replaced with a new one. Sometimes the float arm is bent or does not allow the valve to close. In this case, bend the float arm downward a bit to push the valve tighter into its seat. To replace the washer on the bottom of the plunger, start by shutting off the water (*Figure 6-37, View B*). Then unscrew the two thumbscrews that pivot the float rod lever and the plunger lever (*Figure 6-37, View A*). Push the two levers to the left, drawing the plunger lever through the head of the plunger. Lift out the plunger, unscrew the cap on the bottom, insert the new washer, and reassemble the parts. If the cap is badly corroded, replace it with a new one. When replacing the washer, examine the seat for nicks and grit. The seat may need regrinding.

Figure 6-37 — A. Ball cock. B. Plunger washer and cap.

If water continues to run into the closet bowl after flushing, yet the tank does not refill, some part of the flush valve assembly is at fault because the flush valve is not closing properly. To locate the trouble and get the tank back in order, proceed as follows.

First, stop the inflow to the tank by holding up the float ball or supporting it with a stick. Then drain the tank by raising the rubber stopper ball or the flapper. Examine the stopper ball to see if it is worn or out of shape, or has lost its elasticity. If so, unscrew the lower lift wire from the ball and replace the ball with a new one; if it is a flapper valve, remove the flapper and replace it. There are no lift wires or wire guides to adjust on the flapper valve type of flush valve. Ensure the lift wire is easily fitted over the center of the valve by means of the adjustable guide holder. By loosening the thumbscrew, you can raise, lower, or locate the holder over the overflow tube. The horizontal position of the guide is fixed exactly over the center of the valve by loosening the locknut and turning the guide screw.

The upper lift wire should loop into the lever arm hole directly above the center of the valve. The tank should empty within 10 seconds. Because of lengthening of the upper lift wire and insufficient rise from its seat, emptying the tank may be longer than 10 seconds and the flush weak. In this case, shorten the loop in the upper lift wire. Also, a drop or two of lubricating oil on the lever mechanism makes it work more smoothly.

If you have a water closet tank that sweats and drops water on the deck, check the temperature of the water in the tank. If the temperature is very cold, this is the problem. The moisture in the air surrounding the tank is condensing on the tank. Solutions to the problem are placing a terry cloth on the tank to catch the water, placing a styrofoam insert in the tank, or installing a water tempering valve, which places some warm water in the tank while the tank is filling.

5.0.0 FLUSHOMETERS

Two major problems with flush valves are that the valve runs continuously, instead of shutting off at the right time, or that it fails to deliver the desired amount of water (short flushing). Since flush valves are installed to avoid waste, they must be properly maintained. Once you understand the operation of a valve, you can keep a flushometer in good repair.

5.1.0 Operation of Diaphragm Flushometer

Figure 6-38 shows the operation of a diaphragm-type flushometer.

Stage 1

The diaphragm valve is in the ready position. In this position the upper and lower chambers contain the same amount of pressure. Therefore, the diaphragm remains seated on the seat.

Stage 2

When the handle is moved in any direction, the plunger opens the relief valve, which allows the water from the upper chamber to flow into the lower chamber and causes the diaphragm to rise off its seat. Water now continues to flow down the barrel and into the fixture.

Figure 6-38 — Operation of diaphragm flushometer.

Stage 3

As the valve lifts the diaphragm, water begins to flow slowly through the bypass orifice until the pressure rises enough to equalize the pressure in the upper and lower chambers, seating the valve.

5.2.0 Operation of a Piston Type Flushometer

The piston-type flushometer valve, shown in *Figure 6-39*, is opened by a lever which discharges the water from the ***dashpot*** chamber. The reduced water pressure in the dashpot chamber then forces the piston assembly upward, which allows the water to enter the fixture. The closing of the valve is automatically controlled with a bypass through which the water enters the dashpot chamber. This forces the piston assembly down onto its seat and stops the water flow. The closing of the valve is regulated by a screw that controls the amount of time the valve stays open.

Figure 6-39 — Piston type flushometer valve.

5.3.0 Repairs

Flush valves give years of adequate and trouble-free operation when they are properly installed and maintained. Continuous flow of water through a piston type of flush valve is almost always caused by failure of the relief valve to seat properly or by corrosion of the bypass valve. In both cases, there is not enough force on the piston to force it to seat. If the relief valve fails to seat as it should, the leakage may be enough to prevent the upper chamber of the valve from filling, and the piston remains in the open position.

Inspect the relief valve seat for dirt or other foreign substances that may be causing the relief valve to tilt; disassemble the piston, wash the parts thoroughly, and reassemble. Replace washers that are worn, making sure that the surface upon which the washer sets is perfectly clean; scrape off old rubber if any sticks to the metal surface.

Corrosion of the bypass valve in the center of the top plate also causes continuous flow; the water cannot pass into the upper chamber of the valve, and no force is exerted on the piston to move it downward to its seat. Very dirty water passing through the system can clog the bypass and deprive the upper chamber of water. When pipelines in a new installation are not thoroughly flushed before they are placed in operation, the pipe dope or dirt in them can stop up the bypass valve.

Likewise, in a diaphragm valve, if chips or dirt carried by the water lodge between the relief valve and the valve seat, the relief valve cannot seat securely. The water leakage prevents the upper chamber of the valve from filling with water. The valve then remains in the open position since there is no pressure to force the diaphragm to its seat.

Short flushing can occur in a diaphragm type of valve. If the valve seat, diaphragm, and guide cover have not been tightly assembled, you should reassemble the valve to ensure proper operation. Sometimes you may find the bypass tube has been tampered with, enlarging it so the water passes rapidly into the upper chamber and closes the valve before the desired volume is delivered.

Avoid getting oil or grease on the valve parts, which can lead to swelling of the rubber parts causing them to become unserviceable.

Another commonly used unit is the pressure valve-head flushometer (*Figure 6-40*). The most common problem with this type of flushometer is the rubber cap. To replace the rubber cap is a simple task; remove the retaining screws, lift out the plate, and remove and replace the cap.

6.0.0 FAUCETS

Different types of faucets are used in plumbing installations. If you can repair the compression washer faucet, you should have no trouble in repairing other types of faucets. A cutaway view of a compression faucet is shown in *Figure 6-41*. This faucet, with a disc washer and a solid or removable seat, requires frequent attention to maintain tight closure against water pressure.

When a faucet is turned off, the washer on the end of the stem rubs against the seat. Frequent use wears down the washer and eventually causes the faucet to drip. A small, steady leak in a faucet wastes water. The remedy for a dripping faucet is simply to replace the washer. Be sure to replace flat or beveled washers with washers of the same design.

Figure 6-40 — Pressure valve head flushometer.

Figure 6-41 — Compression faucet.

6.1.1 Standard Faucets

To repair a standard washer faucet, follow these steps.

1. Shut off the water supply to the faucet and open the faucet all the way.
2. Remove the faucet handle, bonnet, and stem.
3. Remove the brass screw holding the washer to the bottom of the spindle. Replace the washer with a new one which is flat on one side and slightly rounded on the other so it can get both horizontal and vertical pressure and provide a firm seat. Use a good quality hard-composition washer because leather or soft washers do not give long service, particularly in hot water lines.
4. If the brass screw is in poor condition, replace it with a new one (*Figure 6-42, View A*).
5. Examine the valve seat and repair or replace it with a new one (*Figure 6-42, View B*), if necessary, before replacing the spindle; otherwise, a new washer provides adequate service for only a short time.
6. Reface or ream solid seats (*Figure 6-42, View C*) with a standard reseating tool consisting of a cutter, stem, and handle. Rotate the tool with the cutter centered and held firmly on the worn or scored seat. Take care to prevent excessive reaming. Remove all grinding residue before reassembly. A solid seat can be replaced with a renewable seat by tapping a standard thread into the old solid seat and inserting a renewable seat.
7. Remove renewable seats with a regular seat-removing tool or Allen wrench. When the seat is frozen to the body, apply penetrating oil to loosen it. Faucet seats can usually be tapped, reseated, or replaced without removing the faucet from its fixture.
8. To stop leakage at the bonnet, replace the stem packing and the bib gasket.

Figure 6-42 — Inspecting, removing, and refacing faucet seats.

Occasionally, you may find ball-bearing washer holders installed in faucets at some activities. The ball bearings between the stem and washer holder permit movement of the “washer” free of the movement of the stem. This allows the washer to stop its rotation on the slightest contact with the seat, thereby reducing the frictional wear of the washer.

6.2.0 Shower Heads

Shower heads that supply an uneven or distorted stream can usually be repaired by removing the perforated faceplate and cleaning the mineral deposits from the back of the plate with fine sandpaper or steel wool. You can open clogged holes with a coarse needle or compressed air.

7.0.0 SEWER MAINTENANCE and REPAIR

Remember, before entering a manhole, ensure the air is safe. You are NOT permitted to enter a manhole or any confined space until you have an entry permit identifying all of the conditions that must be satisfied before the entry begins. Additionally, an attendant person must be stationed outside the manhole at all times. The attendant’s sole responsibility is to observe those working in the manhole. The attendant should have no other responsibilities or duties during the observation. For more information on entering confined spaces, refer to *29 CFR Part 1926, Construction Safety Standards.*

When you are working with sewers, most of your troubles are with stoppages and breaks. A common cause of a stoppage in a sewer system is tree roots. Other causes include sand, gravel, and greasy or tar-related materials. A lot of sand, gravel, or just plain mud reveals a broken or loose sewer joint or pipe.

Trouble calls concerning stoppages or slow drainage are received occasionally. The first step in correcting the trouble is to determine the cause. A sewer line can be inspected from manhole to manhole by using a flashlight or a reflecting mirror or both. One person acting as an observer can look up the sewer line toward the flashlight held by the second person in a preceding manhole. Thus the condition of the line can be noted to determine whether roots or other obstructions need cleaning out.

Explosions in sewers are not uncommon and should be prevented. Check with your safety officer for the most current regulations and information. Systematic inspection and maintenance permit early correction of faults before major defects and failures develop. Sewage gases are very toxic as well as explosive. Routine sewer maintenance includes flushing, cleaning, and immediate repair of defective sewers. Information pertaining to flushing, cleaning, and repairing sewers is given below.

7.1.0 Flushing

Flushing helps remove loose organic solids and sand or grit deposits from sewers. Flushing is not an efficient method of sewer cleaning unless a high velocity can be maintained between manholes on a short run; in other words, you depend on the high velocity for complete scouring action of the sewer. Flushing may be done by a number of methods, two of which are with a fire hose and with a pneumatic ball. When flushing with a fire hose, you need enough fire hose to reach between manholes. When using this method, string a rope or light cable through the sewer with sewer rods if a plain fire nozzle is used. Start at the upper end of the system and draw the flowing nozzle through the sewer. If a self-propelling turbine type of nozzle is used, the rope is not required. Try to use a 2 1/2-inch fire hose. Paint the sewer-flushing hose at the ends with an identifying color (yellow, non-potable water) to prevent use for emergency potable water connections.

In pneumatic-ball flushing, inflate a light rubber ball, such as a beach ball or volleyball bladder, to fit snugly in the sewer, and place it in a small canvas or burlap bag with a light rope attached. Place the ball in the sewer, hold the line until the sewage backs up in the manhole, and allow the ball to move to the next manhole.

When an obstruction is reached, the pressure pushes the ball against the crown of the sewer, causing a jet at the bottom (*Figure 6-43*). As much as 4 miles of sewer can be cleaned in 8 hours by this method, and it works for sewers up to 30 inches in diameter. A wooden ball with a diameter of 1 inch less than the sewer can also be used. Where sewage flow is low, the addition of water to the upper manhole may be required. In the sand cup method, a sand cup with an auger is attached to flexible steel sewer rods to run through the sewer. The rubber cup is perforated to provide flushing action.

Figure 6-43 — Ball method of sewer flushing.

7.2.0 Water Pressure Bag (Blow Bag)

Water pressure bags are made of various types of rubber and canvas material. The blow bag is very efficient and requires less time to operate than other types of drain cleaning equipment. Various sizes of the blow bags are available. To operate a blow bag, connect a water source to one end and insert the blow bag into the line to be cleared or flushed. Ensure that you are using a blow bag that is compressed when placed into the line. When the water pressure is turned on, the blow bag will expand in size, increasing the pressure and holding the blow bag in the line. Keep in mind that once the water is turned on, any lines connected will receive high-pressure water. We do NOT want to turn water closets and lavatories into cool water geysers or bidets.

7.3.0 Cleaning

Routine sewer cleaning includes putting a tool through the line to indicate a clean sewer, removing partial obstructions, or determining the necessity for a detailed job, such as grease removal, root cutting, or sand removal.

Sectional wooden sewer rods, to which a variety of end tools may be attached, have been used in sewer cleaning for many years. End tools for piercing an obstruction first, and cutters and scrapers for root and grease removal are available. Rods are pushed into the sewer from the bottom of a manhole. A device, as shown in *Figure 6-44*, is useful for pushing the rods. Wooden rods are useful for stringing a cable through a partially obstructed sewer.

Another method of sewer cleaning is to use lightweight, spring-steel sectional rods coupled into a continuous line with several types of augers and sand cups as end tools

Figure 6-44 — Pushing device for wooden sewer rod.

(*Figure 6-45*). The tool and rod are fed into the sewer until the obstruction is reached; then the obstruction is removed by either by twisting the rod by hand, or using a small gasoline engine or electric motor drive unit.

NOTE

When using power-driven equipment, ensure that it is maintained under the manufacturer's recommendations.

Flushing methods described in the previous section remove all but heavy sand deposits. Accumulated sand and grit dislocated by flushing should be removed from the sewer at a manhole. A sand trap, made from a stovepipe ell and sheet metal to fit the sewer pipe, may be used, as shown in *Figure 6-46*, to collect the sand. Commercial traps are available with adjustable slots to lower the water level below the top of the trap. Sand is removed by scoops or buckets.

For heavy sand deposits, a cable-drawn bucket is used, especially for storm sewers and larger sanitary sewers. The cable may be pulled by a hand winch, a power winch, or a truck with the cable through an anchored sheave. The sewer can be damaged if the bucket catches on misaligned joints, improper house connections, or other fixed obstructions, especially with power-driven buckets.

Figure 6-45 — Root removal by steel rod and auger, manual operation.

Figure 6-46 — Sand trap.

Turbine-driven tools (*Figure 6-47*) clean sewers with difficult obstructions and grease coatings. These tools are powered by water under pressure from a fire hose. The tool and hose are pulled through the sewer by a cable.

Figure 6-47 — Turbine-driven tools.

Various types of power-driven sewer-cleaning machines are available. These machines normally have a 3/4-horsepower electrically reversible motor and weigh about 90 pounds. They are especially designed for clearing sewer pipelines ranging from 1 l/2 inches to 10 inches in diameter and up to 200 feet in length. Some have a cable counter indicator so the operator knows the distance the tool is in the line. Others have a headlight to aid you in working the dark areas.

A major difficulty with sewer systems buried in the ground is caused by tree roots in the line. These are hard to detect just by looking in the manholes. With trees growing rather close to a sewer line, you can expect roots to cause a break in the line. Such trees as poplars, willows, and elms are the most troublesome when it comes to root growth. When these trees are growing within 100 feet of a line, you can look for trouble from roots sooner or later. Take a close look at *Figure 6-48*, which shows tree roots penetrating a line.

One method for removing roots in a sewer is to apply copper sulfate (blue vitriol). Another method is to use cable drawn scrappers; these may be homemade or equipment as shown in Figure 6-45. Try copper sulfate first since this is the most economical solution.

Figure 6-48 — Roots growing into sewer pipe.

7.4.0 Repairing

Sewer breaks and obstructions must be repaired at once. Sewers under roadways, crushed by settling, must be encased in concrete or sleeved with steel piping. In difficult situations get technical assistance from higher authority or specifications, codes and requests for information (RFI).

Bypassing the sewage flow is usually required during repairs. The usual method is by blocking the upper manhole outlet with sand bags or an expandable rubber test plug, using portable pumps to discharge the sewage to a lower manhole through a fire hose or a temporary pipeline.

Excavations over 5 feet must be shored and ladders provided under safety requirements for excavation, building, and construction. Adequate guards and warning signs must be placed around the excavations in roadways. Details on the requirements mentioned are found in *29 CFR Part 1926, Construction Safety Standards.*

8.0.0 CLEARING STOPPAGES in FIXTURES

Stoppages in fixtures are usually caused by materials lodged in the drain, trap, or waste line. Obstructions often can be removed by manually operated devices, chemicals, or both.

The method depends upon the seriousness and nature of the stoppage. The obstruction should be entirely removed and not merely moved from one place to another in the line. After the stoppage has been relieved, pour boiling water into the fixture to ensure complete clearance. Some of the methods used in clearing stoppages in fixtures are explained below.

When using a snake or sewer tape, keep track of the length of tape in the pipe so you can determine the break or stoppage location. Also, with plastic pipe, exercise care not to use sharp ends that could cut through the wall of a pipe or fitting.

The force cup plunger is commonly used for clearing stoppages in service sinks, lavatories, bathtubs, and water closets. One type of force cup has a round, rubber suction cup, about 5 inches in diameter, fastened to a wooden handle, as shown in *Figure 6-49, View A*. When using the force cup, partly fill the fixture with water. Place the force cup over the drain opening and work the handle up and down to provide alternate compression and suction. Take care not to raise the cup off of the drain opening. The downward pressure or upward suction often clears the stoppage.

Figure 6-49 — Tools for clearing stoppages in plumbing fixtures.

Another type of force cup, shaped to fit the opening of a water closet drain, works more efficiently than the round type in clearing stoppages in water closets.

The closet auger and plumber's snake are used for opening clogged water closet traps, drains, and long sections of waste lines (*Figure 6-49, Views B* and *C*). The closet auger is a cane-shaped tube with a coiled spring or "snake" inside and a handle for rotating the coiled hook on the end of the snake. To insert the closet auger into the trap of the water closet, retract the coiled spring all the way up into the cane line curve of the closet auger. Hook the cane end, with its projecting hook, into the trap. Then start turning the handle to rotate the coiled spring as it is pushed down into the trap of the water closet. Rotate the handle continuously until the snake reaches the obstruction in the drain. Turn the handle slowly until the obstruction is caught on the coiled hook of the closet auger. Continue rotating the handle and pull back at the same time to bring the obstruction up into the water closet where you can remove it.

NEVER assume that the water closet is clear after one object is brought up and removed. Insert the snake of the closet auger again and repeat the procedure until the closet auger passes down into the closet bend and branch. Withdraw the closet auger. Put four or five pieces of toilet paper in the water closet and flush them through the fixture to make sure that it is completely open. Look for remnants or tattered pieces of toilet paper remaining in the bowl, this is a tell tale sign of an obstruction still remaining in the fixture.

Trap and drain augers, such as the one shown in *Figure 6-49, View D*, are used in clearing obstructions in traps and waste pipes. Trap and drain augers, also known as sink snakes, are made of coiled, tempered wire in various lengths and diameters. They are very flexible and easily follow bends in traps and waste lines when pushed into them. In clearing stoppages from lavatories, service sinks, and bathtubs, first use a plumber's force cup. When the obstruction is in the trap and is not cleared by the action of the plunger, clear the trap by inserting a wire or snake through the cleanout plug at the bottom of the trap. If the trap is not fitted with such a plug, remove the trap. Protect the finish of the packing nut with adhesive tape or wrap a cloth around the jaws of the wrench.

Do not use a heavy steel-spring coil snake to clear traps under lavatories, sinks, or bathtubs. Use a flexible wire or spring snake that easily follows the bends in the trap. Use a spring snake for clearing stoppages in floor drains. Remove the strainer or grate and work through the drain, or insert the snake through the cleanout plug opening nearest the obstruction. Stoppage clearance tools should be used with caution.

One reason why safety is so important is that a ***caustic*** chemical may have been poured into the stopped-up fixture in an effort to clear it. Caustic agents can cause serious injury if splashed into your face by a force cup. These caustic agents can also burn your hands while using a sink snake. When manually operated devices fail to clear stoppages, however, there are several types of chemicals that you can use to dissolve or burn them out. These chemicals are discussed briefly below.

8.1.0 Caustic Potash (Potassium Hydroxide)

Stoppages can be burned out by pouring a strong solution of caustic potash (potassium hydroxide) and hot water into the line through the fixture opening. Pour the mixture slowly into the pipe through a funnel. Since this solution can cause serious bums, personnel must wear goggles and rubber gloves. This chemical damages glazed earthenware, porcelain, and porcelain-enameled surfaces.

8.2.0 Caustic Soda (Sodium Hydroxide)

Kitchen and scullery sink stoppages are often tough problems because of grease, oil, or fat washed into the drain along with coffee grounds and small bits of garbage. Grease congeals and acts as a binder for solid particles but can usually be cleared by successive applications of a chemical cleaner. Effective cleaners include caustic soda (sodium hydroxide) with bauxite (an aluminum compound or ore) and other ingredients to intensify their action, or sodium hydroxide mixed with sodium nitrate and aluminum turnings. Adding water creates ammonia gas, which helps change grease to soap. This gas causes boiling and heating and helps dissolve the grease. When clearing a partially blocked drain, drop a small quantity of cleaner (2 to 8 ounces) into the open drain and follow with scalding hot water. Such cleaning agents cannot be satisfactorily used when the drain is completely plugged, since some flow is required to loosen the obstruction. A completely blocked drain must first be partially cleared with a plumber’s snake before you can use the chemical cleaner effectively.

9.0.0 WATER HEATER INSTALLATION

The hot-water system is the part of the plumbing installation that heats water and distributes it to various fixtures. There are a number of ways to heat water; whichever system is used must be able to supply maximum demand. Copper tubing is the most popular material used for the installation of a hot-water supply system. Using copper in a hot-water system is especially desirable because of its ability to resist corrosion, which increases in proportion to the temperature of the water.

There was a time when hot water delivered to plumbing fixtures was a luxury, and very few people, even those who were considered affluent, were provided with this convenience. Current sanitation standards require some type of hot water system for all residences, so that even the humblest dwelling is provided with this convenience.

9.1.0 Install Water Heater

9.1.1 Electric Water Heater Components and Functions

An electric water heater **does not** require a ***flue*** or a gas line. Electrical wiring is required for the heating elements. The electric water heater is quieter and cleaner in operation than the gas heater.

9.1.1.1 Cold Water Inlet

The cold water inlet is normally located at the top (right side) of the tank. It will have a dip tube extending from it to direct the cold water to the bottom of the tank. The cold water inlet is 3/4" in diameter and has a shut off valve installed on it. *Figure 6-50* shows the components of a water heater.

Figure 6-50 — Electric water heater components.

9.1.1.2 Hot Water Outlet

The hot water outlet is also located at the top of heater. It is the same size as the inlet.

9.1.1.3 Temperature and Pressure Relief Valve

Few people realize that a single pound of water, under certain pressure and temperature conditions, can release over 2 million foot-pounds of explosive energy. This is more than could be released by a pound of nitroglycerin, and is more than enough force to shatter a building. Water heaters are equipped with a safety valve called a temperature and pressure (T&P) relief valve. This valve is set to discharge at 125 psi or 210° F. T&P relief valves protect the water heater against excessive temperatures and pressures.

When a temperature and pressure relief valve is installed, the valve stem or thermal element extends into the tank. The valve should be installed within six inches from the top of the tank. The element of the valve should be in direct contact with the hot water flow. The outlet of a temperature and pressure relief valve must not be connected to the drainage system. The extension tube must be at least 12" from the floor or directed outside the building, and the outlet should be turned downward.

9.1.1.4 Thermostat

The thermostat measures the temperature of the water inside the tank and ensures that the heating elements heat the water to the pre-set temperature. The temperature control knob is used to set the water temperature; it is part of the thermostat. The thermostat controls both the upper and lower heating elements.

9.1.1.5 Heating Elements

The heating elements are powered by electric current. They are similar to the heating elements on an electric stove. The elements protrude into the tank to heat the water. There are usually two heating elements in electric water heaters. The upper heating element heats the water at the top of the tank, and the lower heating element heats the water at the bottom of the tank.

9.1.1.6 Tank

The tank is made of steel with a glass liner and has fiberglass insulation wrapped around the tank to keep the water hot. The tank and insulation are covered by a thin metal shell that has been coated with baked-on enamel paint. A drain valve is located at the bottom of the tank.

9.1.1.7 Quiet and Clean Operation

The electric water heater is quieter and cleaner in operation than the gas water heater because there is no burner or flue .When the burner of a gas water heater is operating properly, the thermostat will cause the burner flame to enlarge, which will produce some noise. The flue of the gas water heater collects and channels burned fumes to the outside of the building.

9.1.2 Gas Water Heater Components and Functions

The gas water heater, shown in *Figure 6-51*, consists of a steel tank, a burner, and a flue. All gas water heaters are tested to operate at a pressure of approximately 300 psi. However, the normal working pressure of the water heater will be approximately the same as the water pressure in the distribution system. The steel tank is covered with insulation which in turn is covered with a sheet metal casing coated with a baked enamel finish. The flue in the tank has a spiral shaped diverter which baffles the burned gases to extract as much heat energy as possible before exiting the flue. The draft diverter is designed to prevent down drafts and updrafts. It also eliminates excessive cooling drafts through the heater flue. An anode, usually made of magnesium, extends into the water heater to prevent corrosion inside the tank.

Figure 6-51 — Gas water heater components.

9.1.2.1 Temperature and Pressure Relief Valve

Gas water heaters also have a temperature and pressure relief valve. It serves the same purpose on both types of water heaters.

9.1.2.2 Cold Water Inlet

A “dip tube” installed on the cold water inlet extends from the top (right side) of the tank to within a few inches of the bottom of the tank. It keeps the incoming cold water from mixing with the hot water at the top of the tank and directs it to the bottom of the tank to be heated by the burner. The inlet pipe is 3/4" in diameter and has a shut-off valve installed on it.

9.1.2.3 Hot Water Outlet

The hot water outlet is located at the top of the tank.

9.1.2.4 Thermostat

The thermostat, as in electric heaters, is used to control the temperature of the water.

9.1.2.5 Drain Valve

A drain valve with a hose connection should be located near the bottom of the tank. It is used to drain the tank for maintenance or to flush any accumulation of debris from the heater.

9.1.2.6 Burner Assembly

The burner assembly heats the water in a gas-fired water heater. It has several components. One component is the pilot light, which is used to light the burner. It produces a small flame that warms a thermocouple, a safety device connected to the main gas valve of the assembly. As long as the pilot light heats the thermocouple, gas flows through the main valve and fuels the burner. If the pilot light goes out and the thermocouple cools down, gas flow through the main valve and pilot light ceases. This prevents gas from accumulating in the building if the pilot light goes out. The pilot light can be adjusted by either the air shutter or the pilot light adjustment screw. The pilot light is adjusted properly when it has a soft blue flame approximately 3/4" high. The air shutter also adjusts the burner flame. The main valve controls the burner assembly. It consists of a control knob that has three settings: On, Off, and Pilot; a “thermostat adjusting dial” is used to set the water temperature.

9.2.0 Piping Requirements

There are many different types of piping that you can use for the installation of water supply lines to a water heater. Galvanized pipe can be used for the cold and hot water supply lines; however, because of its tendency to corrode internally, it is not used in most new installations. The minimum size pipe that can be installed is 3/4 inch. All piping is connected using threaded pipe and fittings.

Copper pipe is very popular for interior water lines, and is preferred over galvanized iron pipe. The minimum size copper pipe that can be installed is also 3/4 inch. All connections should be soldered together for a leak-proof installation. Ensure that all the connected copper joints are clean when making the soldered connection.

NOTE

When installing copper water lines, ensure you use dielectric fittings (i.e., dielectric unions) when connecting to the water heater inlet and outlet. All transitions from copper to iron or vice versa, require dielectric unions or fittings, to prevent accelerated corrosion.

CPVC pipe is a very flexible and durable material. It can withstand pressures up to 100 psi and temperatures up to 180 degrees. All connections should be solvent glued. Additional guidelines pertaining to gas piping can be found in Chapter 12 of the UPC.

Piping used to provide natural gas to a gas water heater should normally be black iron, steel, or copper tube. All copper tubing should be brazed, flared, or screwed joints.

Flared joints should be made with approved gas tubing fittings, and should not be used in concealed or inaccessible locations. The minimum size iron or steel pipe used for a gas line is 1/2 inch.

9.3.0 Water Heater Location

When you install a water heater, you must first determine the size of pipe used for the hot and cold water lines and then determine where the heater is to be located within the structure. You must also determine the location of the electrical wiring that will supply power to the unit. After you install the heater, you must check it for proper operation.

In a new installation, check the blueprints or plans for the correct location of the water heater. You should install water heaters as close as possible to piping which supplies the fixtures. When hot water is drawn, all the cold water in the pipes must flow before the hot water will reach the fixture. After the fixture is turned off, the water in the pipes will cool. If the water heater cannot be placed near the fixtures, the efficiency of the hot water system can be improved by covering long runs of piping with some type of insulation. Remember that anytime you install a water heater; be sure to refer to the manufacturer's specifications and the Uniform Plumbing Code. Water heaters are authorized in mechanical rooms, utility rooms, garages (if raised 18" above the floor), and other approved locations. Because gas water heaters require combustion air, they are prohibited in locations like bathrooms that open to a bedroom, sleeping area, or clothes closets. There are other parameters pertaining to the location and installation of water heaters that are specifically defined in the UPC.

9.4.0 Installation Procedures

9.4.1 Electric Water Heaters

Refer to the manufacturer's specifications and the uniform plumbing code. Place a water heater at the approved location. Install all nipples into the top of the water heater and connect the elbows and unions. Install a water supply shut-off valve near the top inlet to the water heater (usually a gate or ball valve). Install a temperature and pressure (T&P) relief valve. Install the overflow line; ensure the line is able to safely drain from the facility. Make wiring connections (electric water heaters only). The wiring is normally 220 volts. Fill the tank with water (open the relief valve to expel air from tank). If the air is not expelled from an electric water heater, the heating elements will burn open. Check for leaks. Turn on the electrical power to the water heater and regulate the temperature by adjusting the temperature control knob.

9.4.2 Gas Water Heaters

Refer to the manufacturers specifications. Install the water heater in much the same manner as the electric water heater, except for gas as opposed to electrical wiring, and adequate combustion air. Once you have installed the gas line and valve, install the flexible gas connection to the control box. Ensure all gas fittings are tight. Place a soapy solution on the gas line fittings to check for any leaks. To light the heater, turn the knob to the pilot position, press and hold down the pilot control knob, and light the pilot. After approximately 30-60 seconds you should release the button. The pilot light should stay lit. Turn the control knob to the ON position.

10.0.0 LAVATORY INSTALLATION and REPLACEMENT

Lavatories are available in many different shapes and sizes. Likewise, the installation procedures are not the same. Always refer to the manufacturer's specifications for guidance prior to installation.

10.1.0 Types of Lavatories

10.1.1 Wall Hung

Lavatories are manufactured in many styles and colors. They may be oblong, circular, square, or oval in shape and are made of vitreous china, porcelain, steel, or enameled cast iron. The wall-hung lavatory illustrated in *Figure 6-52, View A* is the one used most often. It has an integral soap receptacle, overflow, and shelf-back that contribute to the convenience of the user and to sanitation as well. A special wall mount must be used with a wall-hung lavatory to secure it to the wall. A wall-hung lavatory is easy to clean and is widely used in public facilities.

Figure 6-52 — Types of lavatories.

10.1.2 ounter Top

A popular trend in lavatories is the built-in or vanity design. This style provides more top surface area and is more attractive than most other designs. Counter top lavatories (also called flat rim) are available in various sizes, shapes, and colors (*Figure 6-52, View B*). Therefore, it is necessary to refer to the manufacturer's rough-in specifications before you begin installation. A vanity or cabinet surrounds this type of lavatory. The lavatory is held firmly in place in the cabinet by retaining clips. Counter top lavatories can be customized to match the design of a bathroom or kitchen. The attractive design of the counter top lavatory makes it a favorite among hotels and private homeowners.

10.1.3 Pedestal

Pedestal lavatories are bolted, cemented to the floor, or held in place by drainage piping that passes through the floor instead of the walls (*Figure 6-52, View C*). It is commonly used in barbershops and beauty salons. Pedestal lavatories usually drain through S-traps. S-traps are subject to direct siphonage and are prohibited. Pedestal type lavatories are being replaced by wall-hung or countertop lavatories as modifications are made to facilities.

10.1.4 Trough

A trough lavatory is manufactured in a circular and a semi-circular shape (*Figure 6-52, View D*). A trough lavatory is used in metal and wood shops, automobile garages, and other work areas where multiple users are washing at the same time. A trough lavatory is also called an industrial lavatory or "birdbath."

10.2.0 Installation/Replacement of Lavatories

10.2.1 nufacturer’s Rough-In Specifications

A special mounting bracket is used to secure a wall-hung fixture to the wall. The bracket is fastened by brass screws to a 2 inch x 6 inch board (called a backing board). This board is nailed securely between two studs at a height recommended by the manufacturer; they are used in wood framed construction and should be installed before walls are finished. The backing board is normally installed when the waste outlet and water supply lines are roughed in.

10.2.2 Lip Height

The bracket must be level. If there are no manufacturer’s specifications available, the bracket must be installed so the lavatory rim is 31 inches above the finished floor. If possible, it should be centered over the waste outlet.

10.2.3 Drain

The minimum size drain for a lavatory is 1 1/4 inches.

10.2.4 Tailpiece

The tailpiece extends down through the lavatory drain opening. It is used to connect the lavatory to the P-trap.

10.3.0 Installation of Traps

10.3.1 P-Trap

A P-trap provides a water seal against sewer gases and is located below the lavatory. The vertical distance from the fixture outlet to the trap weir should not exceed 24 inches. The trap inlet connects to the tailpiece, and the outlet connects to the trap arm which extends from the P-trap to the drain. Slip joints are used to assemble the components of a P-trap. The components consist of a hex nut (slip nut) and a slip nut washer. Do not over tighten any slip joint.

10.3.2 Types of Stoppers

There are two types of stoppers commonly used in lavatories: the chain stopper (*Figure 6-53, View A*) and the mechanical pop-up type (*Figure 6-53, View B*).

The chain stopper has a chain connected to the faucet on one end and a cup or plug type stopper on the other end. It is inserted into the drain opening by hand and is removed by pulling on the chain.

The mechanical pop-up stopper has a lever arrangement built into the faucet that is used to open or close the stopper. Other items such as cabinets and trim for fixtures

Figure 6-53 — Types of stoppers.

may be added for convenience or appearance, but they have no effect on fixture operation.

10.3.3 Pre-Mounting Procedures

Prior to mounting a fixture to the wall, it is recommended that the faucet, tailpiece and pop-up stopper (if used) be installed on the lavatory first. This will save time and eliminate having to work in tight confined spaces. Follow these steps for pre-mounting procedures:

- Measure and cut tailpiece. Lavatory tailpieces may have to be shortened to accommodate the trap. A fine-tooth hacksaw should be used to cut the chrome tailpiece. This will prevent having a ragged edge which may interfere with assembly. A large tubing cutter could also be used.
- Insert tailpiece. Place a strip of plumber's putty around the underside of the tailpiece flange to form a water tight seal between the tailpiece and the lavatory opening. Insert the tailpiece into the lavatory opening and press firmly on the flange to evenly distribute the putty. Place a cone washer on the tailpiece and install a lock nut.

⚠ CAUTION ⚠

Do not over-tighten the lock nut because it may crack the lavatory.

- Connect tailpiece to inlet side of trap. It is important that the tailpiece to trap connection be as straight as possible to preclude the development of a leak. Ensure that the tailpiece is centered in the P-trap opening. If it is inserted at an angle, the connection will probably leak at that joint. The same principle applies when connecting the outlet side of the trap to the drainage system.

10.4.0 Installation of Faucets

There are many styles and makes of faucets. Most faucets have the same components and are usually installed the same way. First, look at the manufacturer's instructions for any details.

10.5.0 Water Supply Connections

10.5.1 Supply Lines

Flexible water supply lines are used extensively. These lines supply the lavatory with hot and cold water, and connect the lavatory faucet to the angle stop valve. Flexible supply lines are normally made of a flexible steel mesh exterior with a soft plastic interior that can be routed to make connections to fittings very easy.

Another type of flexible line is made of plastic. It is not as flexible as the steel mesh type but it can be bent to make the necessary connections.

Supply lines can also be made of 3/8 inch copper tubing or chrome plated copper tubing for a more luxurious appearance. Although they are more rigid than steel mesh or plastic, they can be configured to make fitting connections easier.

10.5.2 Types of Connections

There are three types of joints used on flexible supplies: flared, ferrule, and cone washer. Use a basin wrench to tighten the nuts at the back of the lavatory.

10.6.0 Inspection of Completed Work

10.6.1 Water Supplies and Controls

Check flexible water supply lines and fitting connections for leaks. Operate the faucet several times to determine if it operates properly and does not leak.

10.6.2 Drain

Inspect the drain for leaks and proper alignment while the water is running. Check all slip joints to make sure they are not over tightened and slip joint nuts are not cracked.

11.0.0 WATER CLOSET INSTALLATION and REPLACEMENT

The water closet is a plumbing fixture designed to receive human waste directly from the user. Water closets are made of vitreous china and are extremely fragile. Caution must be observed during installation to prevent damage to the fixture.

11.1.0 Types of Closet Bowls

The water closet is the most commonly used fixture. From the standpoint of sanitation, it is also the most efficient. It is cast in about thirteen pieces which are molded together by skilled craftsmen to form a closet bowl. The bowl is then treated with liquid glaze, placed in dry kilns, and fired at a temperature of 2500°F. This process renders vitreous china impervious to moisture. Water closets are available according to the type of flushing action desired.

11.1.1 Flushing Actions

Flushing actions include the siphon jet bowl, wash down bowl, wash down bowl with jet, reverse trap bowl, and the pressure-assisted type. All of these types are installed in the same basic manner.

11.1.1.1 Siphon Jet

The flushing action in a siphon jet bowl is accomplished by a jet of water (*Figure 6-54*). Water enters the closet by way of the rim holes and jet. As the water level rises in the bowl, it flows over what is called a “dam” and proceeds down a passageway to the drain. When the passageway completely fills with water, the downward flow of water creates a siphoning action which draws all the water from the bowl. As air again enters the passageway, the siphoning action is broken and flushing stops. With its strong quick flushing action, it is considered the best closet bowl in existence.

Figure 6-54 — Siphon jet bowl.

11.1.1.2 Wash Down Bowl

The proper function of this bowl is dependent upon siphoning action alone. Considered the simplest type of water closet, the trap is located at the front of the water closet. Water flows from under the rim, down the side of the bowl, through the trap and out of the fixture (*Figure 6-55*).

11.1.1.3 Wash Down with Jet

This type is similar to the common wash down, but it has a jet that adds to the siphoning action.

11.1.1.4 Reverse Trap

This type is similar to the wash down bowl except for the location of the trap. The trap is located in the rear of the water closet. This water closet is quieter in operation and holds more water than the wash down.

Figure 6-55 — Common wash down bowl.

11.1.1.5 Pressure Assisted

This is a fairly new type that relies on water pressure rather than water volume to provide the necessary flushing action. There are relatively few of this type in use; however, its use is increasing.

11.2.0 Flushing Devices

Cold water for flushing a water closet is supplied by a closet tank or a flushometer-type flushing valve (*Figure 6-56*). The closet tank is used in residences because it is not as noisy as the flushometer and does not require a large water supply line. A minimum amount of water is effective in quietly and efficiently flushing the closet bowl. Water closets equipped with a tank require a 1/2 inch waterline. Flushometer type flush valves are the best type to use in installations where noise and economy are not a concern. The required size waterline for a water closet equipped with a flushometer is 1 inch.

Figure 6-56 — Flushometer.

11.3.0 Tank Components and Functions

Generally there are two types of tanks, the wall-hung and the close-coupled tank. The wall-hung tank will hang on the wall above the closet bowl. A close-couple tank will connect directly to the closet bowl.

11.3.1 Installation/Replacement Procedures

11.3.1.1 Flushometers

There are two types of flushometers used on water closets: the piston type and the diaphragm type. A one- inch supply line is needed for a flushometer type water closet. The flushometer is connected to the water supply with an angle valve. The outlet of the flushometer connects to the water closet with a tail piece and a spud (*Figure 5-57*).

To install a water closet properly, you should refer to the manufacturer's instructions furnished with the fixture. The need for instructions for each separate installation is important because there are so many different designs and models.

Figure 6-57 — Types of flushometers.

11.3.1.2 Attachment of Water Closet

11.3.1.2.1 Wall-Hung

The wall-hung water closet allows easier cleaning of the floor. To support the wall-hung water closet, either a horizontal or vertical chair carrier is used. This adjustable combined fitting and chair carrier permits each wall-hung closet to be set at a uniform height from the floor when installed with a battery of similar fixtures.

11.3.1.2.2 Floor-Mounted

All drawings indicate how far the opening must be from the wall or floor. Even though you should follow the measurements, some manufacturers allow up to 1/2 inch variation in their installation. Most of the water closets used in the Navy are floor-mounted. To set the floor-mounted bowl, you simply place two closet bolts in the slots provided in the closet flange.(*Figure 6-58*). If, however, a particular bowl design requires four bolts, then place the closet on the floor over the flange. Mark the locations on the floor for the additional front closet screws. Install the closet screws into the floor at the place marked. (These screws have threads

Figure 6-58 — Water closet bolts and screws.

for wood at one end and machine threads at the other.)

11.4.0 Inspection of Completed Work

Once all the components have been installed, pressurize the system and inspect the operation of the water closet. Look for any leaks or malfunctions. Flush the water closet once or twice. Any leaks will be visible at this time.

12.0.0 URINAL INSTALLATION and REPLACEMENT

Urinals are fairly simple to install. The most important thing to remember is to always follow the manufacturer's rough-in specifications.

12.1.0 Types of Urinals

There are four basic types of urinals: wall-hung, pedestal, trough, and stall. The wall-hung and the pedestal types are the ones most commonly used by the military. The trough and stall type urinals are not approved for use in new construction or if the fixture is to be replaced.

12.1.1 Wall-Hung

The wall-hung urinal (*Figure 6-59*) is made of solid porcelain, cast iron with enamel finish, or vitreous china and is suspended from the wall with four bolts or brass screws.

Wall-hung urinals come in different designs, such as a (1) siphon jet fixture with integral trap, (2) urinal with an outside or exposed trap, and (3) siphon jet urinal with side shields. All of these designs are proper for installations having tile or other kinds of impervious flooring in which a drain may be installed.

Figure 6-59 — Wall- hung urinals.

12.1.2 Pedestal

The pedestal-type urinal is shown in *Figure 6-60***.** The rough-in is made with a 4-inch closet bend and floor flange. The urinal is sealed to the floor flange by using a wax ring in the same manner that you would install a water closet bowl. The fixture is then fastened to the floor flange with brass bolts and brass chrome-plated nuts.

Figure 6-60 — Pedestal urinal.

12.1.3 Trough

The trough urinal (*Figure 6-61*) is installed similar to the wall-hung urinal. The main difference is the trough type provides a large area where several people may use it at the same time. This fixture cannot be properly flushed to wash the entire surface area of the fixture. Therefore, it is considered unsanitary.

12.1.4 Stall

Stall type urinals (*Figure 6-62*) are used in public buildings where the height of the personnel using it will vary and would require the installation of several wall-hung urinals at different heights. The stall-type urinal, like the trough type, is not as sanitary as the wall-hung or pedestal type.

Figure 6-61 — Trough urinal.

Figure 6-62 — Stall urinal.

12.2.0 Traps

Wall-hung and pedestal urinals have either a wash down or a siphon jet flushing action. Siphon jet urinals have integral traps. The wash down type may have an external or integral trap. Trough and stall urinals are always wash down, and therefore have external traps. The stall urinal's external trap is in or under the floor.

12.3.0 Flushometers

Flushometers are used to flush urinals and water closets in public facilities. There are two types of flushometers: the piston type and the diaphragm type.

12.3.1 Piston

The piston type flushometer has a piston with a bypass which controls the amount of time the fixture will flush. This type of flushing device is an alternative to tank type flushing. The piston type flushometer requires a 3/4 inch supply line due to the amount of water it discharges.

12.3.2 Diaphragm

The diaphragm type flushometer uses a flat rubber diaphragm to control water entering and leaving the device. It is very similar to the piston type flushometer. It also requires a 3/4 inch supply line.

12.4.0 Installation and Replacement Procedures

12.4.1 Wall Hung

Use the manufacturer's specifications because the tolerance during installation is much closer than with other models. This fixture is fastened to the wall and must have supports. The lip height of a wall hung urinal is between 20 to 25 inches from the finished floor. A 2 inch x 6 inch backing board is used to support the urinal. It is nailed between the studs before the sheet rock is put in place. Because they do not corrode easily, brass screws and bolts are used to fasten the urinal in place.

The minimum size drain for a urinal is 2 inches in diameter and should not be lower than 24 inches from the fixture in order to prevent direct siphonage of the trap. A spud (short piece of pipe) is used to connect the porcelain urinal to a tailpiece. The tailpiece connects to a P-trap (when the urinal has an exposed trap). The P-trap connects to the drain. The minimum size P-trap for a urinal is 1 1/2 inches. P-traps usually use slip-joint connections.

12.4.2 Pedestal

Refer to the manufacturer's specifications when installing pedestal urinals. Pedestal urinals are normally installed like a water closet. (1) Install a wax ring on the underside of the fixture. (2) Install flange bolts. (3) Place pedestal over flange (flange bolts will protrude through the openings at the bottom of the fixture). (4) Gently rock pedestal in place. (5) Tighten bolts; do not over tighten. (6) Install a spud in the top of the fixture. (7) Attach a tailpiece and flushometer to the angle valve.

12.4.3 Trough

The trough urinal is to unsanitary for use. They should not be used in new construction. When possible, a trough urinal should be replaced by a battery of wall-hung urinals.

12.4.4 Stall

The stall urinal is considered to be unsanitary for use because urine could splatter on the shoes and clothing of the people using it. They should not be used in new construction or as maintenance replacements. When possible, replace stall urinals with a battery of wall-hung or pedestal urinals.

12.4.5 nimum Water Supply

The minimum size supply for a flushometer type urinal is 3/4 inch.

12.4.6 Angle Water Supply

An angle valve is screwed onto the 3/4 inch supply line. The flushometer is then connected to the angle valve. This connection must be leak-proof. A compression joint (metal-to-metal) is used in this area. A rubber O-ring may also be present. It will be located on the end of the inlet of the flushometer and inserted inside the angle valve.

12.4.7 Tailpiece

A chrome plated tailpiece is used on the outlet side of the flushometer. The top of the tailpiece is large and has openings. This area is to accommodate a vacuum breaker. The tailpiece then tapers down to 3/4 inch.

12.4.8 Vacuum Breaker

The vacuum breaker is installed inside the tailpiece. This component prevents contaminated water from being siphoned into the potable water supply. The vacuum breaker has a flexible opening that opens and allows water to pass through during the flush cycle, but closes when the cycle is complete.

12.4.9 Spud

A 3/4-inch spud is used to connect the flushometer tailpiece to the urinal. A spud wrench is needed to tighten the spud onto the urinal. Make sure that a friction ring is installed between the flanged nut and the spud gasket to prevent binding. If binding occurs, it could cause a leak.

12.5.0 Inspection of Completed Work

12.5.1 Piston

An operational inspection of the flushometer should be made once you have finished installation or repairs. Activate the flushometer and time the flush cycle; it should be between 7 to 10 seconds**.** To make adjustments, use the adjustment screw at the top of the flushometer.

12.5.2 Diaphragm

Check the volume. If the volume is too high, the water could splatter on the user or overflow onto the floor. Use the screw on the angle valve to adjust the volume of water. As stated before, there should be no leaks when you finish installing the urinal.

Let's now discuss some areas that could leak and some remedies for the situation. If a leak occurs at the angle valve connection that uses a compression joint, check the alignment between the flushometer and angle valve. Make sure they are parallel with each other before they are joined together. If an O-ring is used, check the O-ring for wear and replace it if necessary. A new vacuum breaker is required if there is leakage through the vent openings during the flush cycle. For leaks at the bottom of the tailpiece, check the tightness of the spud nut or change the rubber washer.

Leaks at the spud can be very annoying. First, check the tightness of the flange nut. If that does not stop the leak, change the spud gasket. Be careful when using the spud wrench. You could pull the spud out of the fixture with the wrench.

Leaks at the trap can be stopped by tightening slip joint nuts or changing the slip joint washer. Over-tightening nuts may also cause leaks.

Leaks at the flushometer handle could occur. These can be stopped by replacing the cone shaped seal at the end of the handle. This is called the ***hycar*** seal.

13.0.0 SHOWER INSTALLATION

Bathtubs and showers are basically simple in design with few moving parts. The mixing valve is the most complicated component of the system, followed by the drain assembly. These components will be discussed in the following section.

Showers are essential fixtures. For this reason, we will discuss the shower and the shower mixing valve which furnishes the water. Ordinarily, when the mixing valve is opened, water runs into the bathtub through the spout. However, when it is desired for the water to run through the shower head, the diverter (which is located in the bathtub faucet or spout) is repositioned.

13.1.0 Types of Showers

There are many manufacturers of tubs and showers, which vary in shapes, sizes, and materials. You must carefully read the manufacturer's specifications before you attempt to install one.

13.1.1 General Classes

There are two general classes of showers: those that discharge into a bathtub and those that discharges into a separate receptor.

Tub and shower combinations serve as both a bathtub and a shower. Gang showers consist of multiple shower heads to accommodate more than one individual. An individual shower arrangement accommodates one individual. The most important parts of the shower are the mixing valve and shower head.

13.2.0 Types of Mixing Valves

A manual mixing valve allows for individual operation of either hot or cold water. The pressure-controlled mixing valve (*Figure 6-63)* compensates for a change in pressure in the system but does not control water temperature. Only one handle protrudes through the wall to control both the hot and cold water. The thermostatic mixing valve is similar to the pressure controlled valve. It is sensitive to both temperature and pressure. This valve maintains a constant temperature regardless of temperature or pressure changes in the system. The thermostatic mixing valve is used on showers only.

Figure 6-63 — Pressure controlled mixing valve.

13.2.1 Shower Head

The shower head is connected to a 45° chrome-plated pipe called a shower arm. The two general types of shower heads are circular and economy. The circular (*Figure 6-64)* has notches or grooves around the outer edge of the face that allow regulation of the spray. The economy head has a restricted nozzle that provides a fine spray. The economy head uses less water than other types of heads.

Figure 6-64 — Shower heads.

13.3.0 Installation Procedures

13.3.1 Tub and Shower

Bath, shower, and bathtub/shower combination mixing valves come with different styles of trim. The mixing valve may have one, two, or three handles. The style of the faucet trim will vary with the type of faucet. Different manufacturers use different ***escutcheons*** and adjustable trim around the valve stems and diverters. A diverter in the spout directs the water to the shower head. This valve will return to its normal position when the water is turned off. A third valve located between the mixing valves could take the place of the diverter at the spout. This valve will remain in position to direct the flow of water to the shower head or to the spout even if the water is turned off. The spout is located from 2 to 4 inches above the rim of the tub. This prevents the water in the tub from being siphoned into the water supply system. Mixing valves with shutoff valves have oblong escutcheons on the hot and cold valve stems to allow the water to be shut off in that area for maintenance. This eliminates the need to shut off a large area.

13.3.2 Prefabricated Stall

Many modern homes and apartments use prefabricated shower stalls. These stalls are made of many different materials, plastic and fiberglass being the most popular. The stalls are considered as a rough-in item and should be thoroughly supported during installation. They can be bolted, screwed, or nailed to the studs in the walls.

13.3.3 Tiled Shower

The shower pan is part of the rough-in. The pan will be constructed of fiberglass, plastic, or asphalt. The sides of the pan that are against the shower walls must be at least 3 inches above the height of the finished dam or threshold. The dam or threshold is the portion of the shower that prevents the water from spilling onto the bathroom floor while at the same time providing access. The height of the dam must be at least 2 inches but not more than 9 inches above the shower drain.

13.4.0 Inspection of Completed Work

Once the work has been completed, inspect for any visual defects, leaks, or malfunctions. When the job is finished, put away all tools and clean the job site.

Summary

As a UT, you will be involved with the installation, operation, and maintenance of various plumbing fixtures such as water closets, urinals, sinks, showers, water heaters, or drinking fountains. You must be capable of identifying and correcting plumbing and piping leaks by utilizing the most current manufacturer specification and maintenance procedures.

You will also be involved in sewer maintenance and repair such as flushing, cleaning, removing stoppages, and repairing water mains for supply and drainage.

Review Questions (Select the Correct Response)

1. The mechanisms used to transport body wastes into a sanitary sewer system are known as what type of fixtures?

   A. Plumbing
   B. Collection
   C. Sanitary
   D. Excavation

2. Liquid waste is discharged through which piece of equipment?

   A. Branch line
   B. Orifice
   C. Vent stack
   D. Drain cortex

3. What type of hold-down bolts are used in the installation of water closets?

   A. Steel
   B. Copper
   C. Brass
   D. Soft iron

4. How is a wall-mounted water closet attached to a wall?

   A. Hold-down flange
   B. Foot connection
   C. Backboard
   D. Chair carrier

5. Which piece of equipment associated with water closets carries the weight of the entire closet independent of the walls?

   A. Foot
   B. Hold-down flange
   C. Back brace
   D. Stem support

6. What item is not required to be installed on a water closet if a flush valve is used?

   A. Drain trap
   B. Tank
   C. Chair carrier
   D. Hold-down flange

7. Which application is best suited for flush valve usage?

    A. Medical
    B. Residential
    C. Commercial
    D. Theater

8. What item is installed on the supply line of a float valve in a water closet tank if the outlet is below the flood level rim?

    A. Check valve
    B. Restrictor plate
    C. Locknut
    D. Backflow preventer

9. What shuts off the flushing water during a flushing cycle?

    A. Water pressure passing through the upper chamber
    B. Flushing handle being released
    C. Float ball reaching predetermined level
    D. One gallon of water being sensed by inlet valve

10. The lip of the wall mounted urinal is how many inches from the floor?

    A. 10 to 15
    B. 20 to 25
    C. 25 to 30
    D. 35 to 50

11. Along with the kitchen sink, which other sink is most commonly installed?

    A. Recessed
    B. Deep well
    C. Slop
    D. Self-draining

12. As a rule of thumb, the distance between the top of the drain board of a kitchen sink and the finished floor should not be less than how many inches?

    A. 6
    B. 12
    C. 24
    D. 36

13. A service sink is also known as what?

    A. Slop
    B. Common
    C. Standard
    D. Deep well

14. What type of faucet is used where outside hose connections are needed?

    A. Bath
    B. Hose bib
    C. Lavatory
    D. Combination

15. What is the main feature of a combination faucet?

    A. Faucet's use as a hose connection
    B. Leak guard installation
    C. Capability of the water to be tempered
    D. Resistance of water spray

16. When you are facing the tub and the drain is on the right end, what type of tub is it?

    A. Water-tempered
    B. Left-handed
    C. Tub/shower combination
    D. Right-handed

17. What piece of equipment allows water flow from the shower head when the faucet is turned on?

    A. Diverter
    B. Bypass valve
    C. Spray nozzle
    D. Drain plug

18. When installing a bathtub/shower combination plumbing fixture, where should you place the bathtub spout ?

    A. 1 to 3 inches above rim of tub
    B. 2 to 4 inches above rim of tub
    C. 1 to 3 inches below rim of tub
    D. 1 to 3 inches below rim of tub

19. Thermostatic mixing valves are only used in which plumbing fixture?

    A. Bathtub only
    B. Bathtub/shower combination
    C. Shower only
    D. Sink

20. How many types of shower heads are generally used when installing a shower?

    A. 8
    B. 6
    C. 4
    D. 2

21. **(True or False)** The shower head should be a minimum of 68 inches above the level of the drain on the shower pan.

A. True
B. False

22. How many inches above the floor should the orifice of a drinking fountain be located?

A. 20 to 30
B. 30 to 40
C. 40 to 50
D. 50 to 60

23. Floor drains used in connection with a sanitary sewer must contain what piece of equipment?

A. Positive suction inlet
B. Discharge outlet
C. Water seal
D. Storm filter screen

24. A floor drain that is 2 inches is rated at how many drainage fixture units?

A. 5
B. 4
C. 3
D. 2

25. Where is the combustion chamber in a water heater located?

A. Lower section
B. Top of unit
C. Upper section
D. Suction inlet side

26. Where are the cold and warm water inlets located on a water heater?

A. Suction inlet valve
B. Top of tank
C. Discharge manifold
D. Bottom of tank

27. On a gas water heater, at what temperature, in degrees, does the relief valve open?

A. 165
B. 186
C. 210
D. 225

28. Wooden plugs can also be used temporarily to plug the ends of a pipe up to how many inches in diameter?

A. 2
B. 4
C. 6
D. 8

29. What is the first step before starting to thaw a frozen pipe?

A. Open all faucets affected by the freeze.
B. Remove the section of the piping that is frozen.
C. Shut all faucets affected by the freeze.
D. Secure the entire line the frozen piping is connected to.

30. Where is the heat applied to commence thawing operations?

A. Highest closed end
B. Lowest open end
C. Highest open end
D. Lowest closed end

31. Which thawing application is the quickest and cheapest?

A. Hot water
B. Steam
C. Electrical
D. Chemical

32. Steam thawing is used dependent upon what condition?

A. Type of steam-generating equipment employed.
B. Type of piping material.
C. Type of material to be pumped.
D. Type of insulating material inside piping.

33. What can cause low water pressure and flow in piping?

A. Liming
B. Removal of plumbing fixtures from system
C. Increase in water temperature
D. Water density

34. What type of valve will correct the problem of shower pressure dropping when other fixture outlets are opened?

A. Vent
B. Automatic mixing
C. Discharge stop
D. Turbine supply

35. Fractures often occur at which location of a pipe?

A. Middle
B. Top
C. End
D. Bottom

36. What is installed after a section of copper piping is replaced for a leak?

A. Vertical stroke enhancer
B. Copper mesh sleeving
C. Discharge stop valve
D. Compression type joint

37. What is the first step when making a temporary repair on a pipe using a rubber hose?

A. Turn off water supply.
B. Open faucets on piping.
C. Shut all faucets on piping.
D. Decrease temperature of inlet water.

38. Moisture on the floor at the base of a water closet indicates the failure of what part?

A. Float arm
B. Seal gasket
C. Diaphragm
D. Flush valve

39. What opens the inlet valve on a water closet flushing cycle?

A. Rubber stop ball action
B. Flush handle position
C. Movement of float arm
D. Water pressure

40. What assembly is the likely cause for water to continue to run in a water closet even after the flushing cycle is completed?

A. Sensor output
B. Flush tank
C. Suction/Discharge
D. Flush valve

41. What causes the diaphragm to remain seated on the seat?

A. Upper and lower chambers contain the same amount of pressure.
B. Upper chamber holds more pressure than lower chamber.
C. Lower chamber holds more pressure than upper chamber.
D. Flush handle is in the down position.

42. How is the piston type flushometer opened?

    A. Discharge stop valve position is open.
    B. Lever which discharges water from dashpot chamber is engaged.
    C. Main piston position in is open bypass position.
    D. Floating ball assembly is activated.

43. **(True or False)** When pipelines in a new installation are not thoroughly flushed before placed in operation, the pipe dope or dirt contained in them can stop up the discharge valve.

    A. True
    B. False

44. What is the most common cause of a dripping faucet?

    A. Stem bonnet is loose.
    B. Stem packing is destroyed.
    C. Bib gasket is torn.
    D. Stem washer is worn down.

45. When flushing a sewer line with a fire hose, what size fire hose is preferred for use?

    A. 2 1/2 inch
    B. 2 inch
    C. 1 1/2 inch
    D. 1 inch

46. Sewer cleaning machines are designed for use in pipelines up to how many feet in length?

    A. 100
    B. 200
    C. 300
    D. 400

47. Which chemical is added to a sewer pipeline in the attempt to remove tree roots?

    A. Green vitriol
    B. Potassium hydroxide
    C. Copper sulfate
    D. Sodium Chloride

48. What type of material needs to encase a sewer line that passes under roadways?

    A. Brass sleeving
    B. Soft iron
    C. Concrete
    D. Copper sleeving

49. **(True or False)** Excavations over 5 feet must be shored and ladders provided.

A. True
B. False

50. Which tool is commonly used for clearing stoppages in service sinks?

A. Sewer snake
B. Force cup
C. Sewer tape
D. Wooden ball

51. Trap and drain augers are also known as what?

A. Sewer snakes
B. Force cups
C. Sink snakes
D. Plumber's friend

52. What type of snake is used to clear floor drains?

A. Sink
B. Sewer
C. Shower
D. Spring

53. Which chemical is used to burn out stoppages?

A. Potassium hydroxide
B. Blue vitriol
C. Sodium chloride
D. Hydrochloric acid

54. Which chemical is used to clear stoppages in kitchen sinks?

A. Hydrochloric acid
B. Sodium hydroxide
C. Boric acid
D. Potassium hydroxide

55. What piece of equipment is not required for an electric heater?

A. Cold water inlet
B. Pressure relief valve
C. Flue
D. Thermostat

56. What is the diameter, in inches, of the cold water inlet for an electric inlet?

A. 1/8
B. 1/4
C. 1/2
D. 3/4

57. Where is the hot water inlet valve located on an electric heater?

A. Top
B. Rear
C. Bottom
D. Front

58. The temperature and pressure relief on an electric heater is set to lift at what pressure, in psi?

A. 100
B. 125
C. 150
D. 175

59. All gas water heaters are tested to operate at what pressure, in psi?

A. 100
B. 200
C. 300
D. 400

60. By what means is the pilot light adjusted on a gas water heater?

A. Pilot light valve
B. Air exciter
C. Inlet steam valve
D. Air shutter

61. What type of fittings is used when installing copper water lines?

A. Dielectric
B. Copper
C. Brass
D. Steel

62. CPVC piping can withstand temperatures up to how many degrees?

A. 150
B. 180
C. 275
D. 525

63. What is the minimum diameter, in inches, of steel piping used for a gas line?

A. 1/8
B. 1/4
C. 1/2
D. 1

64. What is the minimum size drain, in inches, used for a lavatory installation?

A. 1/4
B. 1/2
C. 1
D. 1 1/4

65. How many types of joints are associated with flexible supply lines for lavatories?

A. 3
B. 4
C. 5
D. 6

66. Which bowl is NOT a type of flushing action?

A. Pressure assisted
B. Reverse jet
C. Siphon jet
D. Wash down

67. Where on a water closet is the trap located when the water closet uses a reverse trap flushing action?

A. Front
B. Top
C. Rear
D. Bottom

68. **(True or False)** Water closets equipped with a tank require a 3/4-inch waterline.

A. True
B. False

69. What is the required waterline size, in inches, for a water closet equipped with a flushometer?

A. 1/4
B. 1/2
C. 3/4
D. 1

70. Which is NOT a type of urinal?

A. Gang
B. Wall-hung
C. Stall
D. Trough

71. How many different designs are associated with the wall-hung type urinal?

A. 2
B. 3
C. 4
D. 5

72. By what means is the pedestal urinal sealed to the floor flange?

A. Excessive glue
B. Brass hold-down bolts
C. Wax ring
D. Epoxy sealant compound

73. What type of trap is installed on siphon jet urinals?

A. External
B. Interconnection
C. Diffuser
D. Integral

74. The lip height of a wall-hung urinal is between how many inches from the finished floor?

A. 20 to 25
B. 14 to 29
C. 10 to 15
D. 25 to 30

75. What is the minimum diameter, in inches, of a drain used for wall-hung urinals?

A. 1
B. 2
C. 3
D. 4

76. What component prevents contaminated water from being siphoned into the potable water supply through the flushometer?

A. Diffuser
B. Moisture separator
C. Vacuum breaker
D. Diverter

77. What is the average time, in seconds, of a flush cycle?

A. 1 to 4
B. 4 to 7
C. 5 to 8
D. 7 to 10

78. How many general types of shower heads are associated with shower installations?

A. 2
B. 3
C. 4
D. 5

79. Which shower head has a restricted nozzle?

A. Flat head
B. Economy head
C. Circular head
D. Spray head

80. The sides of the pan that are against the shower walls must be how many inches above the height of the finished dam or threshold?

A. 1
B. 2
C. 3
D. 4

Trade Terms Introduced in this Chapter

Vitreous	Of the nature of or resembling glass, as in transparency, brittleness, hardness, glossiness.
Orifices	An opening or aperture, as of a tube or pipe; a mouth-like opening or hole; mouth; vent.
Dashpot	A device for cushioning, damping, or reversing the motion of a piece of machinery, consisting of a cylinder in which a piston operates to create a pressure or vacuum on an enclosed gas or to force a fluid in or out of the chamber through narrow openings.
Escutcheons	A protective plate around plumbing fixtures.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Basic Machines, NAVEDTRA 12199, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

OSHA Regulations (Standards – 29 CFR)

Construction Safety Standards, 29 CFR, Part 1929

Naval Construction Force Manual, *NAVFAC P-315*, Naval Facilities Engineering Command, Washington, D.C., 1985.

McPortland, J.E, and Brian J. McPortland, *National Electrical Code® Handbook,* 22d Ed, McGraw-Hill, NY, 2008.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

National Standard Plumbing Code-Illustrated, National Association of Plumbing-Heating-Cooling Contractors, Washington, DC, 2006.

Safety and Health Requirements Manual, EM-385-1-1, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

International Plumbing Code 2009, International Code Council

International Mechanical Code 2009, International Code Council

R. Dodge Woodson, *Plumber's Quick-Reference Manual Tables, Charts, and Calculations,* 1st edition, McGraw-Hill, NY, 1996.

Fire Protection Handbook, 17th ed., National Fire Protection Association, Quincy, MA, 1991.

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Chapter 7

Prime Movers, Pumps, and Compressors

Topics

To hear audio, click on the box.

Overview

Part of your job as an Utilitiesman (UT) is to install, maintain, and repair prime movers, pumps, and air compressors. Your knowledge in this area is key to the successful completion of a job or unit mission.

This chapter introduces you to the fundamental operating principles, parts, and maintenance of prime movers, pumps, and air compressors, and operating problems which you may experience.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Describe the purpose and components of prime movers.
2. Describe the different types of pumps.
3. Describe the different types of air compressors.

Prerequisites

None

This course map shows all of the chapters in Utilitiesman Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Utilities Equipment and Maintenance	↑	
Air Conditioning		
Refrigeration		
Heating Systems		U
Steam Distribution Systems		T
Boilers		
Sewage Disposal, Field Sanitation, and Water Treatment		B
Prime Movers, Pumps, and Compressors		A
Plumbing Fixtures		S
Piping System Layout and Plumbing Accessories		I
Structural Openings and Pipe Material		C
Fundamentals of Water Distribution		
Basic Math, Electrical, and Plumbing Operations		
Plans, Specifications, and Color Coding		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for

review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 PRIME MOVERS

Prime movers are often called “driving equipment” because they are the primary source of mechanical energy or power. The mechanical energy produced by the prime mover is transmitted to another machine or mechanism, such as a pump or air compressor, to do some form of useful work. The mechanism, or linkage, that transmits the mechanical power developed by the prime mover is called the drive.

Electric motors and internal combustion engines are commonly used as prime movers. For this reason, this section briefly covers electric prime movers, gasoline-operated prime movers, and diesel-operated prime movers.

1.1.0 Electric Motors

As prime movers, electric motors receive electrical energy from some external source and transform it into the mechanical energy needed to produce work. Electric motors are either Direct Current (DC) or Alternating Current (AC). Because most of the electrical power generating systems that Seabees come in contact with produce AC, only the AC motor will be discussed.

1.1.1 Induction AC Motor

Of the various types of AC motors available, you will work primarily with the rotating-field induction AC motor. The popularity of this motor is due largely to its reliability and simplicity of construction. The basic induction motor has two main assemblies or components--a rotor and a stator, as shown in *Figure 7-1*.

Figure 7-1 — Rotor and stator assemblies of an induction motor.

The mechanical rotation of the rotor is produced through the principle of electromagnetic induction. AC flows through the stator (a circular assembly of stationary coils or windings) which surrounds the rotor. The AC flow in the stator produces a constantly rotating magnetic field. This magnetic field induces a current flow in the conductors of the rotor (a cylindrical or drum-like assembly of copper bars mounted on a shaft). The induced current in the rotor then produces a magnetic field of its own. The magnetic field of the rotor is produced so it opposes the magnetic field of the stator, that is, the two fields repel each other. This continuous repulsion of the rotor field by the stator field results in a continuous rotation of the rotor assembly around its axis or shaft. Thus electrical rotation (in the stator) is transformed into mechanical rotation (in the rotor).

The rotational speed of the stator field remains constant unless the frequency of the electrical power source varies. The rotational speed of the rotor is also constant and is more or less independent of the workload imposed on it. This is not to say, however, that an induction motor cannot be overloaded. Under heavy or excessive loads, the motor tends to draw more current to maintain speed; this can result in overheating and burned-out windings.

Induction motors are usually named by the method used for starting the motor. Two fairly common types of induction motors classified in this manner are the split-phase motor and the capacitor-start motor. Split-phase induction motors are designed to operate on single-phase current. Induction motors require two or more out-of-time-phase currents to produce the continuously rotating magnetic field in the stator. For this reason, induction motors that must run on a single-phase power supply are provided with split-phase windings that make two phases of the single-phase current. Split-phase motors can be used to drive a variety of equipment, such as washing machines, oil burners, small pumps, and blowers. The capacitor-start induction motor is a variation of the split-phase motor, but it has a high capacity, electrolytic capacitor. The primary function of this device is the storage of electricity to provide more power during the start.

There are a number of mechanical modifications to induction motors. The most important are as follows:

- Splash-proof motor
- Totally enclosed, fan-cooled motor
- Explosion-proof motor

The splash-proof motor is constructed so dripping or splashing liquids cannot enter the motor. The motor is self-ventilated, but since moisture-saturated air may be circulated through the motor, the windings are made moisture-resistant. Motors of this type are most often used to drive pumps and other machinery where the moisture content of the air is high.

The totally enclosed, fan-cooled motor has totally enclosed windings and rotor. Cooling air is circulated over the enclosure to remove heat. This motor is used in locations where the surrounding air may contain a high proportion of dust, as in a carpenter shop.

The explosion-proof motor is similar to the totally enclosed fan-cooled motor, but it is constructed to prevent any explosion within the motor from igniting combustible gases or dust in the surrounding air. This motor is extensively used in sewage treatment plants and at other locations to ensure safe operation.

The operation and operator maintenance of electric motors have four main aspects:

1. Lubrication of moving or rotating parts
2. Proper alignment of drives
3. Safety
4. Cleanliness of windings and rotors

Pay careful attention to each of these factors to ensure motor efficiency and, in many cases, to prevent motor breakdown.

1.1.1.1 Lubrication

Electric motors are fitted with bearings which reduce friction. The types of bearings most often used are sleeve bearings, roller bearings, or ball bearings. For these bearings to remove the heat generated by friction, they must be properly lubricated. The lubricant used is usually either grease or oil.

Some motors are equipped with ball bearings permanently lubricated or packed with grease when the motor is assembled at the factory. These bearings are usually covered with a nameplate that reads *Do Not Lubricate.* Most electric motor bearings, however, must be lubricated at frequent intervals. In such cases, the lubricant is fed to the bearings through a pressure fitting or grease nipple from a hand-operated grease gun, or the lubricant may be metered to the bearings from a grease or oil cup which must be periodically turned or screwed down by hand to keep the bearings supplied with lubricant (*Figure 7-2*).

Figure 7-2 — Grease lubricated ball bearings.

Some rotating shafts are fitted with sleeve bearings that usually are soft brass cylinders that fit around the machine-shaft journal like a sleeve. In some installations, the lubricating oil is circulated through the sleeve bearings under pressure. Some sleeve bearings, however, may be lubricated by means of an oil ring or rings, as shown in *Figure 7-3*. The weight of the ring hanging on the journal is enough to cause it to revolve as the shaft revolves. As the oil ring rotates, it dips into an oil reservoir directly beneath the shaft journal. The oil picked up by the ring is then diffused along the shaft between the shaft journal and sleeve bearing. Proper lubrication of ring-oiled sleeve bearings depends on maintaining a sufficient oil level in the reservoir. For this reason, most sleeve bearings have oil filler gauges or overflow fittings installed to aid the operator in maintaining the oil at a proper level.

Figure 7-3 — Ring oiled sleeve bearing.

When the electric motor is in operation, as the operator you are required to make frequent checks and inspections for proper lubrication of bearings and for overheated bearings. Check for heat radiated to your hand or check with a thermometer. Note that one of the most frequent conditions that cause bearings to overheat is excessive lubrication. This is a very common problem in the case of grease-lubricated bearings. Too much grease around the bearings insulates and seriously hinders the conduction of heat away from the bearing. The specific lubrication requirements and inspection procedures vary according to the type of bearings and the motor installation. You should always consult your local operator maintenance schedules and instructions for guidance. Other than the inspections cited, you should check for the leakage of lubricants from the bearings, especially lubricant oozing toward the windings or other electrical conductors.

At less frequent intervals, maintenance schedules require additional and more detailed inspections for proper lubrication. This requirement often includes dismantling parts of the bearing housing because bearing housings and pressure fittings must be cleaned periodically.

To lubricate grease-lubricated bearings properly, you must flush old grease from the bearing with solvent and add fresh grease. Sleeve bearings must be examined at various intervals and the oil reservoir flushed, cleaned, and refilled.

1.1.1.2 1.2 Maintenance and Alignment of Drives

The mechanism, or linkage, that transmits the motion and the power of the prime mover to the driven equipment is the drive. The drive must be maintained and operated properly because its alignment and mechanical efficiency affect both the prime mover and the driven equipment. Two fairly common types of drives used with electric motors are the flexible coupling and the belt drive.

The coupling shown in *Figure 7-4* connects or couples the shaft of the prime mover to the shaft of the driven equipment. The coupling is designed to permit very slight misalignment between the two shafts. This flexibility permits the coupling to absorb some of the torque, or twisting force, resulting from the inertia of the driven equipment when the motor is started and brought up to speed. Caution must be taken, because any misalignment in excess of these small tolerances causes rapid wear of the coupling hubs and bushing pins, vibration of the shafts, and a reduction in the transmission of power from the prime mover. Vibration is transmitted through the shafts to moving or rotating parts of both the prime mover and the driven equipment. Vibration inevitably results in excessive wear of the various bearings that support the moving or rotating parts, which in turn results in more misalignment, vibrations, and wear. The point is that small vibrations, which at first may seem insignificant, can develop into major casualties and breakdowns.

Figure 7-4 — Flexible coupling.

While the motor is in operation, check the coupling for any unusual noise or vibration. At prescribed intervals, maintenance schedules require the operator to check the alignment of the coupling with a straightedge, a dial indicator, a thickness gauge, or a wedge, and realign the coupling as necessary. For detailed instructions for the proper realignment procedure, consult the manufacturer's instructions.

Various belt and pulley arrangements are also used as drives on electric motors. These belt drives are somewhat similar to the fan belt arrangements that drive the fan, the water pump, and the alternator on automobiles. The belt, made either of rubber or leather, rides on grooved pulleys or sheaves--one sheave connected to the shaft of the prime mover and the other sheave connected to the shaft of the driven equipment. In this way, the rotation of the electric motor is transmitted to the shaft of the driven equipment.

Belt drive maintenance requires proper belt tension. If the belt is too loose or slack, the power of the prime mover is not transmitted efficiently. Belt slippage also results in excessive rubbing and wear of the belt on the sheaves. Sheaves worn or out of alignment can also contribute to excessive belt wear. Additionally, belt slippage can be caused by an accumulation of oil or grease on the sheaves. If the belt is too tight, on the other hand, the stress is transmitted to the bearings in the sheaves and along the shafts. This condition causes excessive bearing wear and misalignment.

A properly adjusted belt has a very slight bow in the slack side when running. When idle, the belt has an "alive" springiness when thumped with the hand. Lack of this springiness indicates too little tension. A belt that is too tight feels dead when thumped with the hand.

While the motor is in operation, you should visually inspect the belt drive periodically for any indication of improper tension or slippage. Also, be careful to keep the belt and sheaves clean and free of grease or oil at all times. At prescribed intervals, inspect the belt for fraying, cracks, or other unusual wear. You should also inspect and check the alignment of the sheaves. Excessive belt rubbing on the sheaves is an indication of belt slippage. Sheaves that are out of alignment are normally a result of excessive belt tension.

Occasionally, it may be necessary to replace a worn and frayed belt. If the drive has multiple belts, ALL the belts must be replaced with a set of matched belts. The belts in a matched set are machine-checked to ensure equal size and tension.

In addition to the maintenance and inspections outlined above, the operator must test and inspect other items related to the motor, such as control switchboards, pilot lamps, alarms, and circuit breakers. You must also periodically inspect electrical connections and conductors for proper insulation and security.

1.1.1.3 Safety

Because of the danger in working with electric motors, you should observe all manufacturer's safety precautions. In operating electric motors and in performing operator maintenance on electric motors, remember that you are working on a device that carries a force of energy that is not only useful but also deadly.

1.1.1.4 Cleanliness

Cleanliness of electric motor operation and maintenance is largely a matter of prevention rather than inspection and correction. As an operator, you must develop clean housekeeping and maintenance habits. Dirt, dust, and other foreign objects that accumulate on and inside an electric motor can reduce ventilation and foul moving parts. When dirt and grit accumulate on windings, the cooling or ventilation of these electrical conductors is seriously reduced. During the inspection routines, prevent lubricants and lubricant fittings from getting contaminated. Dirt in lube oil, in many cases, settles to the lowest point in the system before doing any extensive damage; however, dirt or grit that gets into lubricating grease can remain suspended indefinitely and result in abrasion of bearings and moving surfaces.

The maintenance schedule usually requires periodic inspection and cleaning of the rotor and the stator windings. You can use low-pressure compressed air to blow out the dirt and dust; however, in the stator, this method can sometimes result in dirt being driven deeper into the windings. Instead, you should use vacuum suction. In fact, vacuum suction is always the preferred method for removing dust and dirt from stator windings or from any other motor component when compressed air could force dirt and abrasive particles deeper into the mechanism. Accumulations of grease and oil can be removed with the proper type of petroleum solvent. In any case, consult local maintenance schedules and instructions for the specific and precise cleaning method.

1.2.0 Internal Combustion Engines

An internal combustion engine is a machine that produces mechanical energy by burning fuel in a confined space (the engine cylinder). The term applies to both diesel and gasoline engines.

The Utilitiesman (UT) should have a basic knowledge of the principles of diesel and gasoline operation, since the UT has to operate and hold first-echelon maintenance of the engine used to drive various types of pumps and compressors.

1.2.1 Operation and Maintenance of Diesel Engines

Diesel engines change heat energy into mechanical energy. Heat is developed when a mixture of compressed fuel and air burns inside a cylinder.

To keep diesel engines in peak operating condition, as the operator you must give careful attention to the following factors—doing the prestart inspection, starting the diesel, securing the diesel, and carrying out operator maintenance.

You should always follow the manufacturer’s specific instructions. Before a diesel can be started, you must perform a prestart inspection to ensure the engine is ready for operation. The specific inspection routine varies somewhat according to each engine. The basic procedure, however, requires you to inspect the engine for a sufficient supply of fuel oil, lube oil, and cooling water. The operator must also be alert for any leakage of these fluids. When replenishment of cooling water is necessary for the radiator, use clean or soft water to keep the engine water jackets and coolant circulating system free of sediment. If the engine is still hot from previous operation, do not add large amounts of cold water. Sudden cooling can crack cylinders or cylinder heads and may cause unequal contraction of the structural and working parts and lead to seizing of the pistons. When topping off batteries, use distilled water.

Inspect accessories and drives for loose connections and mountings. If the diesel starting system is battery-equipped, check the batteries for cracks and leaks, and ensure the battery cables and vent caps are clean and secure.

As a safety precaution, inspect the fire extinguisher for ease of removal, full charge, security, and cleanliness of valves and nozzles before starting the engine.

Diesel engines rely on some external source of power for starting. The starting mechanism may be an electric motor, an auxiliary gasoline engine, compressed air, or even a hand-cranking mechanism. Whatever system is used, the starter forces the pistons to reciprocate and compresses the air drawn into the cylinders. When sufficient compression has been developed with the aid of the starter, the temperature of the air in the cylinders will be high enough to ignite the injected diesel fuel. Thus internal combustion takes place and the engine begins to crank under its own power. Once the engine has been started, you must take the following actions:

1. Throttle the engine to normal (fast idle) warmup speed. The diesel should not be permitted to slow idle for any appreciable length of time because this causes the engine-driven blower to deliver an insufficient amount of air for complete combustion. This condition results in partially burned fuel oil, forming heavy carbon deposits that foul the valves, the piston rings, and the exhaust system.
2. Immediately check the lube oil pressure gauge. If the gauge does not indicate positive and sufficient lube oil pressure within 30 seconds, stop the engine immediately and report the difficulty to the proper authority.
3. Observe the temperature gauge during the warm-up period. The engine must not be placed under load until it reaches the proper warm-up temperature. Placing a cold engine under full load can result in serious damage to the engine because of poor lubrication at low temperature and uneven rates of expansion.

While the engine is in operation, other inspections and checks are required, such as checking the lube oil and fuel oil levels, filters and strainers, accessories and drives, and engine operating temperatures and pressures. Normally, the operator records the results of these inspections in an operating log.

When the diesel is secured, if the engine installation permits, let the engine low idle without load for a short time before stopping to allow for a gradual reduction of engine temperature. Once the diesel has been shut down, the standby lube oil pump should be kept in operation for a short time to allow the lube oil to further cool the engine. The cooling water should also be kept circulating for 15 to 30 minutes to bring the working parts to a low temperature without danger of distortion from one part cooling faster than another.

While the engine is cooling, determine if there is an operator must check to determine the need for adjustment, repair, or replacement or renewal of parts. The required actions are as follows:

- Check the fuel, oil, and water as in the prestart inspection.
- Check the engine instruments or the gauges for proper readings.
- Check the accessories and drives as in the prestart inspection.
- Inspect the air cleaners and breather caps.
- Inspect the fuel filters.
- Inspect the engine controls and the linkage.
- Inspect the batteries as in the prestart inspection.
- Inspect all electrical wiring, insulation, and security of connections.

According to the prescribed maintenance schedules, the engine operator performs other inspections and maintenance duties. These maintenance routines occur at timed intervals prescribed by manufacturers. Examples of tasks that can be required by a maintenance schedule are as follows:

- Removing and cleaning the oil filter elements.

- Inspecting the fuel lines, the fuel filters, and the fuel pump.
- Cleaning the battery casings and the terminal posts; checking for proper ***electrolyte*** level and specific gravity.
- Inspecting and lubricating the starting mechanism.
- Inspecting, cleaning, and lubricating the generator; inspecting and testing the voltage and current regulator.
- Inspecting the radiator; inspecting the water pump, the fan, and the drive belts.
- Disassembling and cleaning the air filters and breather caps.
- Inspecting the crankcase, valve covers, timing gears, and clutch housing.
- Inspecting the cylinder heads and gaskets.

1.2.2 Operation and Maintenance of Gasoline Engines

Like the diesel engine, the gasoline engine changes heat energy into mechanical energy. The physical construction of the gasoline engine is very much the same as that of the diesel. Pistons, cylinders, valves, connecting rods, a crankshaft, and an engine block are in each. A cooling system carries heat away, a lubrication system reduces friction of moving parts, an air system supplies air for combustion in the cylinders, and a fuel system supplies fuel.

Most gasoline engines operate on the four-stroke cycle (*Figure 7-5*). The difference between gasoline and diesel engine operation is the method of introducing the fuel and the air into the cylinders and the means by which the compressed fuel and air are ignited in the cylinders.

In a diesel engine, the air is admitted to the cylinder on the intake stroke of the piston, as shown in *Figure 7-5, View A*. The fuel oil is sprayed into the chamber AFTER the air has been compressed. In a gasoline engine, the fuel (gasoline) and air are mixed together BEFORE being admitted to the cylinder. The intake stroke of the piston sucks air through the air cleaner into the carburetor. In the carburetor, the clean air is mixed with gasoline (vaporized) from the fuel tank. The air and gas mixture continues on to the intake manifold that is connected to the cylinder head. An intake valve admits the air-gas mixture into the cylinder.

The diesel engine produces combustion by using the heat of compression, as shown in *Figure 7-5, View B*. In a gasoline engine, an electric SPARK is provided by the spark plug to ignite the air-gas mixture. Ignition occurs as the piston completes its compression stroke. The ignited gases expand and

Figure 7-5 — Four-stroke cycle.

the piston is pushed down on the power stroke, as shown in *Figure 7-5, View C*. The exhaust stroke of the piston forces the burned gases out of the cylinder chamber, as shown in *Figure 7-5, View D*.

The operating procedures and operator maintenance routines for gasoline engines are essentially the same as those for diesel engines. Starting procedures for gasoline engines are also much the same as those for diesels; however. there is one important exception. Most gasoline engines are equipped with priming or choking devices to aid in starting a cold engine. Generally, these priming devices simply dump raw fuel into the cylinders, that is, the fuel is not thoroughly mixed with air or atomized before induction into the cylinders. This rich mixture of fuel aids in achieving initial combustion; however, not all of the fuel is burned. In other words, we have incomplete combustion. Prolonged or excessive choking during and after the start can lead to carbon deposits being built up in the engine. For this reason, the operator should always use care and restraint in choking or priming the engine, both during and after the start.

Securing procedures for gasoline engines are also basically the same as those for diesels, although some gasoline engine installations may not permit circulation of lube oil and coolant after the engine has been stopped.

As you might expect, operator maintenance routines for gasoline engines differ from those for diesels because of the slight differences in design and construction of gasoline engines. In other words, gasoline engine maintenance and inspection schedules must provide for the inspection, adjustment, and maintenance of such items as carburetors, chokes, ignition coils, wiring, distributors, and spark plugs.

1.2.2.1 Safety

Anytime gasoline or diesel engines are secured for maintenance and inspection purposes, the operator should always guard against intentional or inadvertent starting of the engine by uninformed personnel. This rule applies to all types of prime movers, including electric motors. It also applies to maintenance and inspection operations being performed only on the driven equipment, regardless of whether the work is being done on the prime mover itself or on the driven equipment alone. Unintentional starting of the prime mover during the maintenance operation can result in serious damage to the machinery and serious injury to maintenance personnel. For this reason, YOU are responsible for using the equipment tag-out procedures contained in the current OPNAVINST 3120.32. In most situations, it may be a good idea to disable the starting mechanism completely, so even if personnel fail to see or read the tag, the prime mover cannot be started.

During the maintenance operation, you must keep a strict accounting of all tools and parts. Tools, nuts and bolts, or any other material left adrift can foul a moving part and completely disable the machinery during subsequent operation. There is another reason for keeping a strict accounting of parts whenever components are disassembled: Parts that work together wear together. The various parts of valve assemblies, bearing assemblies, and so forth should be carefully marked and grouped during disassembly and replaced in the same position from which they were removed; otherwise, discrepancies in fitting and joining can result and reduce the mechanical efficiency of the moving parts. This can eventually lead to a breakdown.

WARNING

During inspection of an engine or a motor that is in operation, the operator should always be cautious while working near moving parts. Loose clothing, rags hanging from pockets, dangling key chains, and so forth can easily become entangled with or drawn into moving parts, resulting in a serious accident.

1.2.2.2 Cleanliness

Engine maintenance and inspection require cleanliness. Dirt allowed to accumulate on and around an engine can find its way inside that engine. It may be carried into the engine with air, fuel, lube oil, or water, or careless personnel may introduce it. Dirt can cause sludge and scale deposits that impair circulation of fuel, oil, and water, and erode moving parts. Large accumulations of dirt on external surfaces can insulate the surface and reduce cooling.

Normally, there are specific instructions available locally concerning cleanliness precautions while handling fuel and lube oil. You must know and observe these precautions. Some fundamental cleanliness precautions are as follows:

- Never use waste or linty rags around fuel or lube oil containers, fuel inspection equipment, or carburetors.
- Keep fuel and lube oil handling equipment such as measures, funnels, and containers clean and covered when not in use.
- Use clean, soft water in engine radiators and coolant systems to keep the engine water jackets free of sediment, and use distilled water in topping off batteries.
- Keep engine air intake filters clean to maintain sufficient induction of air.

Test your Knowledge (Select the Correct Response)

1. Which common type of drive is used with electric motors?

   A. Flexible coupling
   B. Strap drive
   C. Rigid coupling
   D. Drive shaft

2.1.1 PUMPS

A UT is required to work with pumps of many shapes and sizes. Some of the primary uses of pumps are as follows:

- To supply feedwater to boilers.
- To deliver fuel oil to oil-fired boilers.
- To circulate coolants and lubricants in internal combustion engines.
- To supply chemical feed in water purification systems.
- To lift water from cells and distribute it throughout a system.
- To discharge sewage into setting tanks or mains.
- To pressurize and move liquids through a distribution system.

The principles of pump operation, suction force, suction lift, and head pressure are discussed in this section, along with the types of valves used in pump operation, the different types of pumps, pump installation, and safety precautions that a UT has to know in order to operate and maintain the various types of pumps used today.

2.1.1 Pump Operation

Pumps are used to move any substance that flows or can be made to flow. Most commonly, pumps are used to move water, oil, and other liquids; however, steam and other gases are also fluid and can be moved with pumps, as can molten metal, sludge, and mud.

A pump is a device that uses an external source of power to force fluid to move from one place to another. A pump develops no energy of its own; it merely transforms energy from the external source, such as a gasoline or electric motor, into mechanical kinetic energy, which is manifested by the motion of the fluid. This kinetic energy is then used to do work, for example, to raise liquid from one level to another, as when water is raised from a well; to transport liquid through a pipe, as when oil is moved through an oil pipeline; to move liquid against some resistance, as when water is pumped to a boiler under pressure, or to force liquid through a hydraulic system against resistance. Every pump has a POWER END, whether it is a combustion engine, or some type of electric motor. Each pump also has a FLUID END, where the fluid enters (suction) and leaves (discharges) the pump.

The addition of energy to a liquid by a pump usually results in an increase in pressure, which is generally referred to as HEAD. In pump operation, you should know that there are four types of head--net positive suction head, suction head, discharge head, and total discharge head. The definitions of the types of head are as follows:

- The NET POSITIVE SUCTION HEAD (NPSH) is the suction pressure minus the vapor pressure expressed in feet of liquid at the pump suction. Fluid can only be pulled so hard up a pipe before bubbles occur and suction is lost.
- The SUCTION HEAD on a pump means the total pressure of the liquid entering the pump.
- The DISCHARGE HEAD means the pressure of liquid leaving the pump or the level of liquid with respect to the level of the pump on the discharge side.
- The TOTAL DISCHARGE HEAD is the net difference of pressure between the suction head and the discharge head.

NOTE

When positive, suction head is usually expressed in feet of water. When negative, it is expressed in inches of mercury.

When a pump operates below the level of a liquid, its suction end receives the liquid under a gravity flow. When the pump is located above the level of the liquid being pumped, the pump establishes a vacuum at the inlet to move the liquid into the pump. Atmospheric pressure acting on the surface of the liquid then provides the necessary pressure to move the liquid into the pump.

2.2.0 Suction Force

The principle of suction force, or suction lift, as applied to reciprocating pumps, is shown in *Figure 7-6*. In View A, the piston cylinder is open at both the top and bottom, so the liquid level at A and B is the same. In View B, the cylinder is closed at the bottom. A piston has been inserted and partly withdrawn, thus creating a partial vacuum. When the foot valve (check valve) at the bottom of the cylinder opens (View C), as a result of the lower pressure in the cylinder, the liquid rises up into the cylinder, which causes the liquid level in the well to drop. Assuming the liquid is water and there is a perfect vacuum below the piston, atmospheric pressure pushes water up into the cylinder to a height of 34 feet, even though the piston may be raised higher than 34 feet.

Figure 7-6 — Views showing the principles of suction force or suction lift.

You must understand that the preceding example is for the theoretical condition of a perfect vacuum. In practice, leakage between the piston and the cylinder, friction (fluid) in piping, and gases dissolved in the liquid limit the suction lift of a pump to a height of approximately 22 feet, as shown in View D of *Figure 7-6*.

When a pump is pumping certain liquids, such as hot water, oil, or gasoline, some of the liquid vaporizes because of the vacuum on the suction side of the pump. The pump may become vapor bound and reduce the possible suction lift; this is called "cavitation."

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

2.3.0 Valves Used With Pumps

Every pump is equipped with devices for controlling the direction of flow, the volume of flow, and the operating pressure of the pump. A device that performs one or more of these control functions is called a valve.

A valve that permits liquid flow in only one direction is classified as a check valve. In most cases, check valves open and close automatically, that is, they are kept closed or seated by spring tension or by the force of gravity until the liquid pressure above or below the valve overcomes the spring or gravity resistance and causes the valve to open. Check valves of this type are used with centrifugal pumps to control the suction and discharge of the liquid in the pump end at the proper time automatically. *Figure 7-7* shows a vertical check valve. In this case, the valve is kept seated by its own weight or the force of gravity. If desired, it could also be kept closed by a spring.

Figure 7-7 — Vertical check valve.

Another type of valve in pump systems is the stop valve. Stop valves are usually opened or closed manually by means of a handwheel. They are used primarily to start or stop the flow of liquid through the pump during certain phases of operation. Thus stop valves are often placed on suction and discharge lines, so the pump is isolated or sealed off from the rest of the liquid system. *Figure 7-8* shows the operation of a gate valve. A gate valve is a type of stop valve. A gate, or wedge, is raised or lowered by turning the handwheel. Some types of stop valves are used for throttling purposes, that is, to regulate the flow of liquid. However, gate valves are never recommended for throttling service because the flow of liquid past the partially opened gate can rapidly erode the gate face. Instead, the gate valve can be replaced with a tapered needle valve (another type of stop valve) which gradually opens or closes through the valve seat.

Figure 7-8 — Operation of a gate valve.

A third type of valve generally found on most types of pumps is the relief valve. As you can see from *Figure 7-9*, most relief valves are similar in their design to check valves. These valves are designed to open when the liquid pressure in the pump becomes dangerously high. In most cases, the outlet of the relief valve is connected to a recirculating line that passes the excess liquid back to the suction side of the pump. Almost all pressure relief valves are fitted with an adjusting nut or screw that permits the spring tension to be regulated. In this way, the pressure at which the valve is opened can be varied.

2.4.0 Types of Pumps

Pumps are classified according to the type of movement that causes their pumping action. The five broad categories of pumps are rotary, reciprocating, centrifugal, air lift, and jet pumps.

2.4.1 Rotary Pumps

All rotary pumps use the principle of entrapment and displacement of fluid by the rotating elements of various designs. These rotating parts, which may be gear teeth, screws, lobes, or vanes, trap the fluid at the suction inlet and remove it to the discharge outlet. Instead of "throwing" the water as in a centrifugal pump, a rotary pump traps it, pushes it around inside a closed casing, and discharges it in a continuous flow. Since rotary pumps move liquid by this method, they are often classified under the broad heading of positive displacement pumps.

Figure 7-9 — Relief valve.

Most rotary pumps have stuffing boxes provided at the rotor shafts to prevent excessive leakage at the shaft joint. In addition, various types of bearings can be fitted at the ends of the rotor shaft to minimize friction.

Generally, rotary pumps are self-priming, that is, the pump end need not be filled with liquid to initiate pumping action. Instead, the movement of the rotating elements creates a partial vacuum sufficient to lift or draw liquid into the pump and begin the pumping process. Note that self-priming and good suction lifts are characteristics of the whole class of positive displacement pumps. Rotary pumps are less expensive and considerably simpler in construction. In the utilities field, rotary pumps are used for pumping fuel oil in boiler houses, for pumping chemical feed in water purification systems, for priming larger pumps, and for special applications such as emergency pumps at fire-fighting stations.

2.4.1.1 Types of Rotary Pumps

The classification of a rotary pump is determined by the type of rotating element it has. However, no matter what form of rotating element is used, the basic principles of pump operation remain the same. In this section, two types of rotary pumps are discussed--the gear pump and the screw pump.

The gear pump is shown in *Figure 7-10*. This type of pump uses two spur gears that rotate in opposite directions and mesh together at the center of the pump. One of the gears is coupled to the prime mover (usually an electric motor) and is called the

Figure 7-10 — Gear type rotary pump.

driving gear. The other gear, which receives its motion by meshing with the driving gear, is called the driven gear. Note that liquid moves as the gear teeth rotate against the casing of the pump, thereby trapping the liquid and pushing it around to the discharge outlet. The meshing together of the two gears does not in itself move or pump liquid. The meshing of the gear teeth, in effect, forms a constant seal between the suction and discharge sides of the pump and thus prevents liquid from leaking back toward the suction inlet.

Very small clearances are permitted between the meshing gears and between the gear teeth and pump casing to avoid unnecessary friction and to allow the liquid being handled to act as a lubricant for the rotating parts. It is clear that when excessive clearances are allowed to develop between the gear teeth and casing or between the gears where they mesh, the efficiency of the pump is considerably reduced. For this reason, rotary pumps are rarely, if ever, used to handle corrosive or abrasive liquids.

Among the several types of screw pumps, the main difference is the number of intermeshing screws and the pitch of the screws. *Figure 7-11* shows a positive displacement, double-screw, and low-pitch pump. Screw pumps are primarily used for pumping ***viscous*** fluids, such as JP-5 and diesel oil. Hydraulic systems use the screw-type pump as the pressure supply for the system. The pump may be either motor-driven or turbine-driven.

Figure 7-11 — Positive displacement, double screw, low pitch pump.

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

2.4.1.2 Operation and Maintenance of Rotary Pumps

The rotary pump is susceptible to hydraulicing; therefore, the discharge stop valve must be in the OPEN position before the pump is started. In addition, it is a good operating practice to prime these pumps before operation when possible, even though rotary pumps are self-priming. This is particularly critical when the pump has been standing idle for a period of time. Because the liquid handled in the pump lubricates the rotating elements of these pumps, filling the pump end with fluid before starting prevents unnecessary friction and wear of the rotating elements.

Rotary pump maintenance schedules stress that proper clearance be maintained between rotating parts. For this reason, there should be periodic checks for slippage. In addition, when the pump is dismantled, the actual clearances should be carefully measured and compared with the manufacturer's specifications.

2.4.2 ciprocating Pumps

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

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

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

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

2.4.2.1 Types of Reciprocating Pumps

Reciprocating pumps are usually classified as follows:

- Direct acting or indirect acting
- Simplex (single) or duplex (double)
- Single acting or double acting
- High pressure or low pressure
- Vertical or horizontal

The reciprocating pumps used by the Seabees are usually one of the following types—direct acting, simplex, double acting, or vertical. The types most often used are direct acting pumps. In a direct acting pump the rod is a direct extension of the piston rod, and, therefore, the piston in the power end is directly connected to the plunger in the liquid end. In an indirect acting pump, there is some intermediate mechanism between the piston and pump plunger. The intermediate mechanism may be a lever or a cam. This arrangement can be used to change the relative length of strokes of piston and plunger or to vary the relative speed between piston and plunger. Or the pump may use a rotating crankshaft, such as a chemical proportioning pump in a distilling unit.

The diaphragm pump shown in *Figure 7-12* is a direct acting reciprocating pump. It is commonly used by UTs to pump water from a ditch or sump.

Figure 7-12 — Portable diaphragm pump.

Diaphragm pumps use a flexible diaphragm to move the liquid. The prime mover is usually a small gasoline or diesel engine with an eccentric connecting rod arrangement that converts rotary motion to reciprocating motion. On the suction stroke, the diaphragm is drawn upward into a concave configuration. This movement of the diaphragm results in a partial vacuum that causes the suction ball valve to unseat (and at the same time keeps the discharge ball valve seated) and to admit the liquid to the pump cylinder. On the discharge stroke, the diaphragm is pushed downward, forcing the trapped liquid out through the discharge valve. Thus the liquid is made to move by the reciprocating motion of a flexible diaphragm.

Since the diaphragm forms an almost perfect seal in the pump cylinder between the liquid being pumped and the rest of the pump and driving mechanism, there is some danger of liquid abrasion or corrosion of moving parts behind the diaphragm. For this reason, diaphragm pumps are especially reliable for pumping mud, slime, silt, and other wastes or heavy liquids containing debris such as sticks, stones, or rags. Liquid strainers are fitted at the suction inlet to prevent large objects from fouling the suction and discharge valves or from damaging the diaphragm.

You can use the diaphragm pump for dewatering trenches where sewer lines or waterlines are to be laid or for repairing breaks in waterlines or sewer lines.

Two of the most popular types of diaphragm pumps are the mud hog (closed discharge) and the water hog (open discharge). The mud hog is for pumping heavy and thick liquid long distances away from the pump. The pump is fitted with discharge hose connections, and the ball valves and chambers are designed to prevent fouling by sticks, stones, rags, and so on. The water hog is used for pumping thinner and less viscous liquids; however, it can handle liquids containing sand, gravel, and mud. The discharge outlet from the water hog is open to permit free flow and increased discharge capacity. Thus the liquid is discharged directly at the pump. However, a discharge hose can be fitted to the pump if desired, but, the efficiency is reduced. Both the mud hog and water hog can be of either the simplex or duplex type.

Because of the nature of the liquids handled by diaphragm pumps, operator inspection during pump operation becomes particularly important. Make frequent inspections of the suction inlet strainer to prevent accumulation of debris that can reduce suction efficiency. Most diaphragm pump installations also permit easy access to the suction and discharge ball valves. The valve mechanisms can be inspected frequently to detect scoring, fouling, and improper valve seating. Because the diaphragm and ball-check valves are subjected to the corrosive action of such material as sand and gravel, they require frequent attention. Therefore, operator maintenance schedules stress a continuing program of inspection and cleaning of these parts. In most cases, it is not practical to repair damaged or worn diaphragms and valves. They should be replaced with new ones; therefore, keep an adequate supply of these parts readily available.

The reciprocating pump is called a single or simplex pump because it has only one liquid cylinder. Simplex pumps are either direct acting or indirect acting. A single-acting pump only discharges water when the piston rises (if mounted vertically) and the down stroke is utilized simply to displace more water into the working space ready for the next stroke. It is possible to arrange things so that while one side of the piston displaces water to discharge it, the other induces more water, so that discharge takes place on both the up and the down stroke. Such pumps are known as "double-acting" pumps and are significantly more productive for their size than single-acting ones.

In a single acting pump, the liquid is drawn into the liquid cylinder on the first or suction stroke and is forced out of the cylinder on the return or discharge stroke. In a double acting pump, each stroke serves both to draw in the liquid and to discharge the liquid. As one end of the cylinder is filled, the other end is emptied; on the return stroke, the end that was just emptied is filled and the end that was just filled is emptied. The pump shown in is double acting, as are most of the reciprocating pumps used in the Seabees.

The reciprocating pump is designed to operate with a discharge pressure higher than the pressure of the liquid it is pumping; in other words, it is a high-pressure pump. In a high-pressure pump, the piston is larger in diameter than the plunger in the liquid cylinder. Since the area of the piston is greater than the area of the plunger in the liquid cylinder, the total force exerted by the liquid against the piston is concentrated on a smaller working area of the plunger in the liquid cylinder.

This pump is also classified as vertical because the piston and the pump plunger move up and down. Most reciprocating pumps in naval use are vertical; however, you may occasionally encounter a horizontal pump where the piston moves back and forth instead of up and down.

2.4.2.2 Operation and Maintenance of Reciprocating Pumps

The piston-type valve gear, commonly used for automatic timing, consists of a piston-type slide valve and a pilot slide valve. In all reciprocating pumps, there are check valves on the suction and discharge. Fluid flows through the suction valve and into the chamber as the plunger, piston, or diaphragm recedes. At the end of the stroke, the chamber is at its maximum size. The suction valve closes, the plunger moves forward into the chamber, forcing the fluid out the discharge valve. The flow from each chamber is a pulse flow. If the pump has several chambers, they are timed to have sequential pulses to minimize the overall pulsation.

Reciprocating pumps are easy to operate and usually are very reliable units; however, they require routine maintenance and occasional repair work. Consult the manufacturer’s technical manual for details on the repair of a specific unit. Before repairing or examining a pump, assemble the pertinent blueprints, drawings, and available data. These drawings and data furnish the required clearances, tools to be used, measurements, information on materials to be used, and other important data. In addition, you should have the complete history of the pump being repaired so you know what has been done, when repairs were last made, and what kind of trouble has been encountered before with this pump.

Most reciprocating pump troubles result from fouled water cylinders, worn valves, or faulty conditions in the pipe connections external to the pump.

2.4.3 ntrifugal Pumps

When a body or a liquid is made to revolve or whirl around a point, a force is created that impels the body or fluid to move outward from the center of rotation. This phenomenon is called centrifugal force. It is from this force that the centrifugal pump got its name.

The basic centrifugal pump has only one moving part--a wheel or impeller that is connected to the drive shaft of a prime mover and rotates within the pump casing. The design, or form, of the impeller varies somewhat. However, whatever its form, the impeller is designed to impart a whirling or revolving motion to the liquid in the pump. When the impeller rotates at relatively high speeds, sufficient centrifugal force is developed to throw the liquid outward and away from the center of rotation. Thus the liquid is sucked in at the center or eye of the impeller (center of rotation) and discharged at the outer rim of the impeller. Note that by the time the liquid leaves the impeller, it has acquired considerable velocity. In this connection, a fundamental law of liquid physics states, in part, that as the velocity of a fluid increases, the pressure or pressure head of that fluid decreases. Therefore, the liquid discharge from the impeller has a high velocity but low pressure. Before the liquid can be discharged from the pump, an increase in pressure is necessary. In other words, the primary concern in practically all pumping systems is to maintain the discharge pressure so liquid can be distributed effectively throughout the system. In centrifugal pumps, a device is required to decrease the velocity of the impeller discharge and thereby increase the liquid pressure at the discharge outlet.

One method of increasing the discharge pressure of centrifugal pumps is by providing additional impellers. Pumps with only one impeller are single-stage. Pumps with two or more impellers are multi-stage. In multi-stage pumps, two or more impellers are placed on a common shaft (within the same pump housing) with the discharge of the first impeller being led into the suction of the next impeller, and so on. As the liquid passes from one stage to the next, additional pressure is imparted to it. In this fashion, the final discharge pressure of the pump can be increased considerably.

2.4.3.1 Types of Centrifugal Pumps

Centrifugal pumps are also horizontal or vertical, depending upon the position of the pump shaft. Generally, large, multi-stage, high-capacity pumps are horizontal. Most other pumps are vertical. The impellers used on centrifugal pumps may be single-suction or double-suction. The single-suction impeller allows liquid to enter the eye from one direction only; the double-suction type allows liquid to enter the eye from two directions.

Impellers are closed or open. Closed impellers have sidewalls extending from the eye to the outer edge of the vane tips; open impellers do not have these sidewalls. Most

Figure 7-13 — Volute pump.

centrifugal pumps in the Seabee force have closed impellers.

In the ***volute*** type of centrifugal pump shown in *Figure 7-13*, the impeller discharges into a volute or gradually widening channel in the pump casing. As the liquid passes into the expanding neck of the volute, its velocity is considerably diminished, and, with this decrease in velocity, the pressure increases.

Another variation is the diffuser or volute turbine type of centrifugal pump shown in *Figure 7-14*. In this pump, the impeller discharges into stationary diffuser vanes surrounding the impeller. The diffuser vanes force a rather radical change in the direction of the impeller discharge, and this, in turn, slows down the discharge. In addition, the diffuser vanes form volutes of their own that further diminish the velocity of the discharge. Finally, the discharge from the diffuser vanes flows along the pump casing which, like the simple volute-type pump, is also in the form of a volute. Thus the diffuser-type pump provides for a nearly complete decrease in velocity and consequently an increase in discharge pressure.

The types of centrifugal pumps used for pumping sewage do not use diffuser vanes because the rapid change in the direction of the impeller discharge can cause suspended matter in the liquid to come out of suspension and form deposits that corrode and foul moving parts.

Figure 7-14 — Diffuser type centrifugal pump.

Other types of centrifugal pumps, known as turbine well pumps, are used to pump wells. To produce sufficient discharge pressure, you must equip these pumps with a multi-stage impeller arrangement that is contained in volutes, referred to as bowls. To ensure satisfactory suction, set the impellers and bowls below the lowest drawdown or pumping level that the water in the well is expected to reach.

2.4.3.2 Use of Centrifugal Pumps

The applications of centrifugal pumps are numerous; however, these pumps are most often used in buildings for the following purposes:

- To pump the general water supply, including both the overhead and pneumatic tank systems. In general water supply systems where the pump takes off directly from the city pressure main or where no suction lift is required, a centrifugal pump can be used. When a centrifugal pump is being used with a suction lift requirement of no more than 15 feet, a pump with an automatic primer or a suction line equipped with a foot valve may be used.
- To provide booster service. In booster service, centrifugal pumps with in-take pressures from the city main operate only to boost this pressure. They may run continuously or automatically. When the automatic type is not operating, the water flows by city pressure through the impellers.
- To pump the domestic water supply. In domestic water supply systems, the centrifugal pump is used in shallow wells (suction lift of not over 22 feet), in deep

wells (for greater depths than 22 feet), and in a complete pneumatic system with electric motors or gasoline engines.

- To support the fire protection systems. Fire pumps usually are the centrifugal type, either single- or multi-stage. Electricity, steam, or gasoline may drive them. Whatever the power supply, it must be permanent and, if steam, must have a constant minimum pressure of 50 pounds of steam. The pumps should agree with the specifications of the National Fire Protection Association (NFPA).Booster fire pumps have a low head to boost the pressure of the already available city supply.
- To provide a hot water circulating service. Hot water circulating pumps are centrifugal. They move water in a closed system and thus usually require only a low head, though the static pressure in the systems may be high. The pumps should be selected with attention to strength of casing, efficient stuffing box, freedom from air and vapor binding, and flexible mounting.
- To provide sump drainage. Sump pumps are not classified as sewage pumps; however, they can be used as such. They may be vertical or horizontal centrifugal. The vertical type sump pump usually has the impeller submerged and the motor mounted above the pit. Units are equipped with an automatic switch operated by the float and are available in single- or duplex-type (*Figure 7-15*).
- To pump sewage. Sewage ejector pumps for dry-pit installations have a connection on the suction end of the pump that is piped to a separate wet pit.

Figure 7-15 — Vertical submerged type of centrifugal pump for sewage.

The dry-basin type of sewage ejector pump equipment includes the following:

- The pump with suction and discharge piping up to the floor plate
- An electric motor, a steel ejector basin with separate sewage, and pump compartments
- A high water alarm
- An automatic alternator
- Float switches
- A floor-mounted control panel
- Motor switches

- Automatic starters
- An iron access ladder
- Complete basin covers welded or riveted to the basin

The wet-basin (duplex, wet-basin, non-clog sewage ejector) type of sewage ejector pump equipment includes the following:

- The pump and fittings
- Electric motors
- Float switches
- An automatic alternator
- High water alarm
- Motor switches
- Automatic starters

The centrifugal type of sewage pump has non-clogging impellers. It can be installed in either a horizontal configuration or in a vertical configuration with a suction lift. The centrifugal pump can be placed in either a wet or dry pit and is equipped with a float or diaphragm for automatic operation.

2.4.3.3 Advantages and Disadvantages of Centrifugal Pumps

The advantages of centrifugal pumps include simplicity, compactness, weight saving, and adaptability to high-speed prime movers. One disadvantage of centrifugal pumps is their relatively poor suction power. When the pump end is dry, the rotation of the impeller, even at high speeds, is simply not sufficient to lift liquid into the pump; therefore, the pump must be primed before pumping can begin. For this reason, the suction lines and inlets of most centrifugal pumps are placed below the source level of the liquid pumped. The pump can then be primed by merely opening the suction stop valve and allowing the force of gravity to fill the pump with liquid. The static pressure of the liquid above the pump also adds to the suction pressure developed by the pump while it is in operation. Another disadvantage of centrifugal pumps is that they develop cavitation. Cavitation occurs when the velocity of a liquid increases to the point where the consequent pressure drop reaches the pressure of vaporization of the liquid. When this happens, vapor pockets, or bubbles, form in the liquid and then later collapse when subjected to higher pressure at some other point in the flow. The collapse of the vapor bubbles can take place with considerable force. This effect, coupled with the rather corrosive action of the vapor bubbles moving at high speed, can severely pit and corrode impeller surfaces and sometimes even the pump casing. In extreme instances, cavitation has caused structural failure of the impeller blades. Whenever cavitation occurs, it is frequently signaled by a clearly audible noise and vibration (caused by the violent collapse of vapor bubbles in the pump).

Several conditions can cause cavitation, not the least of which is improper design of the pump or pumping system. For example, if the suction pressure is abnormally low (caused perhaps by high suction lift or friction losses in the suction piping), the subsequent pressure drop across the impellers may be sufficient to reach the pressure of vaporization. A remedy might be to alter the pump design by installing larger piping to reduce friction loss or by installing a foot valve to reduce suction lift.

Cavitation can also be caused by improper operation of the pump. For instance, cavitation can occur when sudden and large demands for liquid are made upon the pump. As the liquid discharged from the pump is rapidly distributed and used downstream, a suction effect is created on the discharge side of the pump. Think of it as a pulling action on the discharge side that serves to increase the velocity of the liquid flowing through the pump. Thus, as the pressure head on the discharge decreases, the velocity of the liquid flowing across the impellers increases to the point where cavitation takes place. Perhaps the easiest way to avoid this condition is to regulate the liquid demand. If this is not possible, then increase the suction pressure by some means to maintain pressure in the pump under these conditions.

2.4.3.4 Operation and Maintenance of Centrifugal Pumps

The operating procedures and maintenance schedules for centrifugal pumps are generally similar to those of the other pumps we have discussed previously. Centrifugal pumps are also fitted with stuffing boxes and various types of bearings that, of course, require periodic maintenance and inspection. Always refer to the manufacturer's instructions and locally prepared maintenance schedules for operating and maintenance procedures.

One operating practice is common to nearly all types of centrifugal pumps. Unlike positive displacement pumps, the discharge stop valve on centrifugal pumps must be closed before starting the pump. This action allows the pump to work against the sealed discharge and build up an effective pressure head before attempting to move and distribute the liquid downstream. After the pump is up to speed and the discharge valve is opened, the pump continues to maintain that pressure head unless the operating conditions are altered. Note that there is no danger of hydraulicking while the pump is run with the discharge closed. If the centrifugal pump were to continue operation with the discharge sealed, it would simply build up toward its maximum discharge pressure. It would then begin to churn the liquid, that is, the discharge pressure would overcome the suction pressure and the liquid would continually slip back to the suction side of the pump. Nothing more would happen, except the pump would build up heat since the liquid would not be able to carry away the heat generated by the moving parts.

There are several exceptions to the rule outlined above. For instance, when there are other pumps operating in parallel with the centrifugal pump discharging into a common system, these pumps provide the centrifugal pump with an effective pressure head to start against. Another exception is the turbine well pump. This pump always has a pressure head to start against, provided by the weight or static pressure of the water above the impellers. Therefore, a turbine well pump can usually be started with the discharge valve in the open position. In the paragraphs below a few important aspects of

Figure 7-16 — Packing installation procedures.

pump operation and maintenance are discussed in detail.

One aspect of pump operation and maintenance is packing. Although this topic is included here under the general heading of centrifugal pumps, packing is used on many other types of pumps as well. *Figure 7-16* shows packing installation procedures for centrifugal pumps. Packing is a general term that refers to many different types of materials used to seal moving machinery joints (sliding pistons and piston rods, rotating shafts and valve stems, etc.) against leakage of steam or liquids. As such, packing can be thought of as a close fitting bearing that must not only prevent leakage but must do so without causing excessive friction and undue wear of the moving part. Although most packing has definite lubricating qualities of its own, lubrication is enhanced by permitting small amounts of liquid or steam to leak past or through the packing. If the pump is used for corrosive or abrasive fluids, then some other form of lubricant, such as grease or oil, must be fed to the packing through external means.

Packing usually takes the form of coils, rings, or spirals. The packing is inserted into a stuffing box fitted around the sliding or rotating joint. The compression of the packing around the joint is controlled by hand-adjusted gland nuts.

The selection of the proper type of packing for a pump is important. There is no general-purpose or all-purpose packing. The specific type of packing that must be used depends on several factors, such as whether the packing seals a rotating or sliding joint and what type of liquid the pump handles. In any event, you do not have to select the packing. Locally prepared guides and manufacturer’s instructions specify what type of packing material to use. Upon receipt of the packing, note its condition and the use date stamped on the package to help you determine the shelf life of the packing. If a package has become unsealed, reseal it. Better yet, ensure the packing is used before its expiration date.

Packing requires frequent inspection and adjustment, particularly while the pump is in operation. The gland nuts must be adjusted with care so that all the packing is compressed evenly and equally around the joint. If not, excessive and uneven wear of the packing can result, and the rotating or sliding shaft could become scored or grooved.

When a pump is first started, lubrication of the packing may be relatively poor. Because of initial friction, the packing may heat up and expand, thereby compressing itself around the joint and further reducing lubrication or leakage. Merely loosening or backing off the gland nuts is not always the best solution, because the liquid pressure in the pump can force the complete set of packing to move outward in the stuffing box. In this instance, the pump has to be shut down and the stuffing box allowed to cool. Several restarts may be necessary before the stuffing box runs cool.

Figure 7-17 — Type 1 mechanical seal.

Additional packing procedures are too extensive to be covered here. The primary purpose of this discussion of packing is to alert you to the importance of this pump component. It has been said that the proper inspection, adjustment, and upkeep of the packing are the most abused aspects of pump operation and maintenance.

Another important aspect of pump operation and maintenance is the understanding of mechanical seals. Mechanical seals are rapidly replacing conventional packing as the means of controlling leakage on centrifugal pumps. Pumps fitted with mechanical seals eliminate excessive stuffing box leakage that results in pump and motor bearing failures and motor winding failures. Mechanical seals are ideal for pumps operating in closed systems, such as air-conditioning and chilled water systems.

Type 1 mechanical seal is shown in *Figure 7-17*. Spring pressure keeps the rotating seal face snug against the stationary seal face. The rotating seal and all of the assembly below it are affixed to the pump shaft. The stationary seal face is held stationary by the seal gland and packing ring. A static seal is formed between the two seal faces and the sleeve. System pressure within the pump assists the spring in keeping the rotating seal face tight against the stationary seal face. The type of material used for the seal faces depends upon the service of the pump. Most water service pumps use a carbon material for the seal faces. When the seals wear out, they are replaced. New seals should not be touched on the sealing face because body acid and grease cause the seal face to pit prematurely and deteriorate.

Mechanical seals should be replaced whenever the seal is removed for any reason or whenever the leakage rate exceeds 5 drops per minute.

Mechanical seals are positioned on the shaft by means of stub or step sleeves. Mechanical seals should not be positioned by the use of setscrews. Shaft sleeves are ***chamfered*** on outboard ends to provide ease of mechanical seal mounting. Mechanical seals ensure that positive liquid pressure is always supplied to the seal faces and that the liquid circulates well at the seal faces to minimize the deposit of foreign matter on the seal parts.

When a stuffing box is fitted with a lantern ring, be sure to replace the packing beyond the lantern ring at the bottom of the stuffing box, and be sure that the sealing water connection to the lantern ring is not blanked off by the packing (*Figure 7-18*). Sleeves fitted at the packing on the pump shafts must always be tight. These sleeves are usually made secure by shrinking or keying them to the shaft. Be careful to ensure the water does not leak between the shaft and the shaft sleeves.

In some pumps, the shaft sleeve is pressed onto the shaft tightly by means of a hydraulic press,

Figure 7-18 — Stuffing box on centrifugal pump.

and the old sleeve must be machined off in a lathe before a new one can be installed. On other centrifugal pumps, the shaft sleeve is a snug slip-on fit, butted up against a shoulder on the shaft and held securely in place with a nut. On some small pumps, new sleeves can be installed by removing the water end casing, impeller, and old shaft sleeves. New sleeves are carried as repair parts, or they can be made in the machine shop. On large pumps, the sleeves are usually pressed on; these pumps must be disassembled and taken to the machine shop, a repair ship, or a Navy yard to have the old sleeve machined off and a new one pressed on.

Some sleeves are packed to prevent water leakage between the shaft and the sleeve, while some have O rings between the shaft and the abutting shoulder. For detailed information, consult the appropriate manufacturer's technical manual or applicable blueprints.

Shaft alignment must be checked frequently. When the shafts are out of line, the unit must be realigned to prevent shaft breakage and damage to the bearings, the pump casing wearing rings, and the throat bushings. Shaft alignment should be checked with all piping in place.

A flexible coupling may connect the driving unit to the pump. You should remember that flexible couplings (*Figure 7-19*) are intended to take care of only slight misalignment. Misalignment should never exceed the amount specified by the pump manufacturer. When there is excessive misalignment, the coupling parts are punished severely, and pins, bushings, and bearings have to be frequently replaced.

Figure 7-19 — Grid type flexible coupling.

The driving unit may be connected, or coupled, to the pump by a flange coupling. Frequent realignment of the shaft may be necessary. Each pump shaft must be kept in proper alignment with the shaft of the driving unit. Abnormal temperatures, abnormal noises, and worn bearings or bushings indicate misalignments.

Wedges, or shims, are placed under the bases of both the driven and driving units to facilitate alignment when the machinery is installed. Jacking screws can also be used to level the units. When the pump or driving unit, or both, need to be shifted sideways to align the couplings, side brackets are welded in convenient spots on the foundations, and large setscrews are used to shift the units sideways or endwise. When the wedges or other packing have been adjusted so the outside diameters and faces of the coupling flanges run true as they are manually revolved, the chocks should be fastened, the units should be securely bolted to the foundation, and the coupling flanges should be bolted together.

These alignments must be checked from time to time and misalignments promptly corrected. There are three devices in use for checking the alignments: a 6 inch scale, thickness gauge, and dial indicator.

Shaft alignment should be checked whenever the pump is opened up and whenever a noticeable vibration is observed. When shafts are found out of line or inclined at an angle to each other, the unit should be aligned to avoid shaft breakages and renewal of bearings, pump casing wearing rings, and throat bushings. The appropriate technical manual should be consulted when you are aligning the pump.

In a centrifugal pump installation fitted with an internal water-lubricated bearing inside the pump casing (such as condensate pumps), an adequate supply of clean water must be supplied to the bearing for lubricating and cooling. Several of the following types of materials are used for internal water-lubricated bearings: laminated phenolic material-grade fabric-based Bakelite or Micarta (FBM), high lead content bronze, graphite bronze, and lignum vitae.

The condition of all types of internal water lubricated bearings should be checked frequently to guard against excessive wear which can result in misalignment and shaft failure.

As for oil-lubricated sleeve or shell-type bearings, the bearing clearances should be measured following procedures described for the pump, and clearances should be maintained within the limits specified in the manufacturer's technical manual.

The clearance between the impeller wearing ring and the casing-wearing ring (*Figure 7-20*) must be maintained, as shown in the manufacturer's plans. When clearances exceed the specified figures, the wearing rings must be replaced. This replacement requires the complete disassembly of the pump. Information on disassembly of the unit, dimensions of the wearing rings, and reassembly of the pump is in the manufacturer's technical manual. (Wearing rings are located on the main feed pump.)

Figure 7-20 — Impeller, impeller wearing ring, and casing wearing ring for a centrifugal pump.

When deciding whether the wearing rings need renewing, you must consider the capacity of the pump and the discharge pressure of the pump. On low pressure pumps, the wearing ring diametrical clearance may be 0.015 to 0.030 inch more than the designed amount without any appreciable effect on the capacity of the pump. For pumps with a discharge pressure up to 75 pounds per square inch (psi), a wear of 0.030 to 0.050 inch is permissible.

The percentage of capacity loss with a 0.030-inch wearing ring clearance in excess of standard may be large with a small pump but comparatively small with a large pump. For high-pressure boiler feed pumps, the effect of increased wearing ring clearance is readily noticeable in the efficiency and maximum capacity of the pump. For high-pressure pumps, the wearing rings should be renewed when the clearance shown on the manufacturer's plans is exceeded by 100 percent. It is usually not necessary to renew wearing rings unless the wear is at least 0.015 inch. If a pump has to be disassembled because of some internal trouble, you should check the wearing rings for clearance. Measure the outside diameter of the impeller wearing ring with an outside micrometer and the inside diameter of the casing-wearing ring with an inside micrometer; the difference between the two diameters is the wearing ring diametrical clearance. By checking the wearing ring clearance with the maximum allowable clearance, you can decide whether to renew the rings before reassembling the pump.

The amount of work in disassembling the pump, the length of time the pump can be out of commission (OOC) without affecting the command, and whether a repair shop or other repair activity is needed are some factors to consider when determining whether to renew wearing rings.

2.4.3.5 Operating Troubles

Some of the operating troubles with centrifugal pumps and probable causes are given in *Table 7-1*.

Table 7-1 — Centrifugal pump operating troubles.

Indication of Trouble	Cause
No liquid delivered	Pump needs primed or speed too low
	Discharge head or suction lift too high
	Incorrect pump rotation
	Impeller installed backwards or plugged up
Not enough liquid delivered	Suction pipe or stuffing box air leak
	Pump speed too low or rotation incorrect
	Impeller installed backward or partially clogged
	Suction lift too high or insufficient suction
	Suction line not completely submerged
	Worn rings, impeller, stuffing box packing, seal, or sleeves
Low pressure	Pump speed low
	Air or gas in liquid
	Pump rotation incorrect
	Pump impeller installed backward
	Mechanical defects
Pump works and then fails to deliver	Air leak in the suction line or stuffing box
	Stuffing box water seal plugged
	Suction line not completely submerged
	Suction lift too high

Stuffing box leaks excessively	Speed too high
	Misaligned or bent shaft
	Interference between rotating and stationary parts
	Worn journal bearings or shaft sleeves
	Rotor out of balance
	Sealing liquid contains dirt and grit
Short life of packing	Speed too high
	Misaligned or bent shaft
	Interference between rotating and stationary parts
	Worn journal bearings or scored shaft sleeve
	Wrong type of packing or installed wrong
	Rotor out of balance
	Packing gland too tight
	Sealing liquid contains dirt and grit
Pump consumes too much power	Pump speed too high
	Specific gravity or liquid viscosity is higher than pump is designed to handle
	Mechanical parts misaligned or worn
	System head is different than pump rating
Overheating or seizing	Pump speed too high or rotor out of balance
	Misalignment, bent shaft
	Excessive bearing temperature
	Bearing incorrectly installed
	Bearing rusted from water entering housing

When the pump fails to build up pressure and the discharge valve is open and the pump speed is increased, the procedure to use consists of four steps as follows:

1. Secure the pump.
2. Prime the pump and ensure that all the air is expelled through the air cocks on the pump casing.
3. Open all valves on the pump suction side.
4. Start the pump again.

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

2.4.4 Air-Lift Pumps

Air-lift pumps are commonly used in well pumping. Unlike the pumps studied earlier, the air-lift pump needs no moving or rotating mechanism to produce liquid movement. Instead, the pump uses compressed air to move or lift the liquid.

The air-lift pump operates on the principle that water mixed with air has less weight, or is more buoyant, than water without air. When compressed air is introduced, a mixture of water and air is formed in one leg of the U-shaped pipe, as shown in *Figure 7-21*. The solid column of water in the other leg now has greater weight or is exerting a greater static pressure than the column containing air. Thus the air-water column is forced upward until it discharges over the top of the U-shaped pipe.

Figure 7-21 — Principles of an air-lift pump.

In practice, of course, wells are not dug in a U-shape. *Figure 7-22* shows a central air-lift pump. Compressed air is led down an air pipe to a nozzle or foot piece submerged well below the water level. Notice that the foot piece is suspended within a discharge pipe which, in turn, is contained within the well casing. Notice also that the discharge pipe is open at the bottom, directly beneath the foot piece. When compressed air is discharged through the foot piece, a column or mixture of air is formed above the foot piece in the discharge pipe. The solid column of water in the well casing, resting high above the foot piece and discharge pipe inlet, now has greater weight or static pressure. This effect forces the air-water mixture upward in the discharge pipe where it is vented to the atmosphere through an open discharge outlet. In effect, the flow of water has a U-shape down the well casing, around the foot piece, and up the discharge pipe. The air-water discharge then strikes a separator or deflector that relieves the water of air bubbles and entrained air vapor. The discharge then settles in a collector tank.

The air-lift pump can deliver considerable quantities of water in the manner just described. The discharge pressure at which it is delivered, however, is relatively low. For this reason air-lift pumps cannot be used to discharge directly into a water distribution system. They do not develop sufficient pressure to distribute water horizontally above the ground for any appreciable distance, and the discharge can be collected only at the well for ground storage.

The capacity of the air-lift pump depends largely on the percentage of submergence of the foot piece, that is, the greater the submergence of the foot piece below the water level in the discharge pipe, the greater the volume (column) of water the pump can deliver per unit of time. However, the deeper the foot piece is submerged, the greater the compressed air pressure must be to lift the column of water. In other words, a higher column of water (in the discharge pipe) above the foot piece exerts a greater weight or pressure at the foot piece. The greater the static water pressure at the foot piece, the greater the air pressure must be to infuse air with the water.

Starting air pressure is always greater than working air pressure. When the pump is started, the static (at rest) level of water is drawn down somewhat to a pumping or working level. In effect, the column of water above the foot piece is decreased or lowered, and this, in turn, decreases the air pressure required to infuse the water with air. In wells where the drawdown is rather large, the pump is sometimes equipped with an auxiliary air compressor, connected in series with the main compressor, for starting. Once the pump has been started and the pumping level reached, the auxiliary compressor is no longer required and is secured.

Air-lift pumps have a low discharge pressure and require more depth so the foot piece can submerge deep enough. Additionally, the entrained oxygen in air-lifted water tends to make it more corrosive. In spite of these drawbacks, air-lift pumps have several advantages, especially their simplicity of construction and lack of maintenance problems. Particularly useful in emergencies for deep well pumping, air-lift pumps can be used to pump crooked wells and wells with sand and other impurities. They can also pump hot-water wells with ease.

Figure 7-22 — Central air-lift pump.

In air-lift pump operation, compressed air has to be regulated correctly. The amount of compressed air should be the minimum needed to produce a continuous flow of water. Too little air results in water being discharged in spurts, or not at all. Too much air causes an increase in the volume of discharge but at lower discharge pressure. If air is increased still further, discharge volume begins to decrease.

The air-lift pump is so simple in design that nearly all operating and maintenance inspections and procedures relate to the air compressor, which is described later.

2.4.5 Jet Pumps

Pumps that use the rapid flow of a fluid to entrain another fluid and thereby move it from one place to another are jet pumps. A jet pump contains no moving parts.

Jet pumps are ejectors that use a jet of steam to entrain air, water, or other fluid, and eductors that use a flow of water to entrain and thereby pump water. The basic principles of operation of these two devices are identical. The basic principle of operation of a simple jet pump of the ejector type is shown in *Figure 7-23*. Steam under pressure enters the chamber through pipe A, which is fitted with a nozzle, B. As the steam flows through the nozzle, the velocity of the steam is increased. The fluid in the chamber at point F, in front of the nozzle, is driven out of the pump through the discharge line by the force of the steam jet. The size of the discharge line increases gradually beyond the chamber to decrease the velocity of the discharge and thereby transform some of the velocity head into pressure head. As the steam jet forces some of the fluid from the chamber into the discharge line, pressure in the chamber is lowered and the pressure on the surface of the supply fluid forces fluid up through the inlet, D, into the chamber and out through the discharge line. Thus the pumping action is established.

Figure 7-23 — Principle of operation of an ejector-type jet pump.

2.5.0 Installation of Pumps

From time to time, you will be installing prime movers, pumps, and air compressors. The secret of success in operating prime movers, pumps, and air compressors is their proper installation. That puts the success of their operation directly in your hands. If you do your job right and the equipment is properly installed, it should perform satisfactorily for a long time. Of course, proper care and maintenance are also essential for continued efficient operation; however, even with the most perfect care and maintenance, you will find it difficult or impossible to overcome faulty installation.

Since the procedures for installing prime movers, pumps, and air compressors are almost the same, only the basic steps of pump installation are discussed in this section. Remember that pumps, especially the centrifugal type, are built in many designs and for different purposes. Study the manufacturer’s instruction manual for the equipment you are installing. Where specific directions or requirements are furnished, follow them.

When you receive a pump unit from the MLO or supply outlet, there are a few points to check. First, ensure it is the correct pump for the job by checking the nameplate data against that of the bill of material. Next, check the unit to ensure there are no missing or loose parts. If the unit certain it is removed before being installed.

When pumps are to be installed, the locations usually are determined in advance by higher authority and indicated on blueprints or sketches. However, you may have to decide where to put a pump. In most cases, place the pump as close as possible to the source of the water supply or other liquid, so the suction pipe is short and direct and the suction lift is comparatively low. With high-temperature liquids, a suction head is necessary. Place the pump where it can be readily inspected during operation, and see that headroom (a trap or ceiling opening) is there for the use of a crane, hoist, or tackle. If possible, select a dry place to protect the pump from the weather.

The foundation of a pump must be strong enough to absorb vibration and also to serve as a rigid support for the pump base plate. A concrete foundation or a solid base is best. Foundation J-bolts are embedded in the concrete foundation according to a blueprint or template. The bolts should be longer than needed (3/4 to 1 inch) to allow for shimming up the pump to make it level and for grouting under the pump base. A pipe sleeve, about 2 1/2 times the diameter of the bolt, allows for final positioning. If the bolt shown in *Figure 7-24* were 1 inch in diameter, a 2 1/2-inch pipe sleeve should be used. A small pump is normally aligned and the two major parts bolted together before leaving the factory. The parts normally do not require alignment after the pump has been set on the foundation. Be careful that you do not spring them out of alignment. Level the pump properly and secure it to the foundation. In setting the pump, you need a spirit level; place the level on the machined surfaces in two directions. To level, you may have to remove the top casing or bearing cover. If a large pump is shipped in sections, you have to align the water ends with the power ends after they have been placed on the foundation. In leveling a pump unit, first use small metal wedges (*Figure 7-25*) and then place metal blocks and shims close to the foundation bolts. In each case, space the supports directly under the part carrying the most weight and close enough to give uniform support. Leave a gap of about 3/4 to 1 inch between the base plate and the foundation for grouting with cement. (Grout is a mixture of cement, sand, and water, making up a thin mortar.) *Figure 7-26* shows a base plate of a pump unit grouted to the foundation, making angular alignment.

Figure 7-24 — Pipe sleeve and foundation bolt.

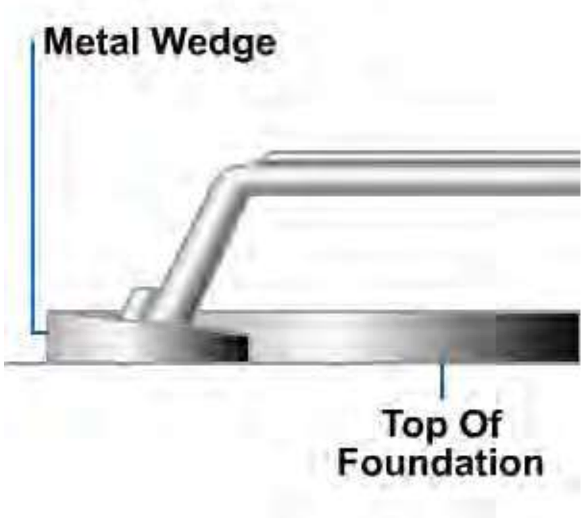

Figure 7-25 — Wedging a base plate.

Figure 7-26 — Base plate of a pump unit grouted to the foundation.

Adjust the supports or wedges until the shafts of the pump and the driver are level. Use a level to check the coupling faces and suction and discharge flanges to ensure that they are plumb and level. Correct the positions by adjusting the supports or wedges as required.

In addition to checking for parallel alignments, you should check the angular alignment between the pump shaft and the drive shaft. Insert a taper gauge or feeler at four points between the coupling faces, as shown in *Figure 7-27*. The points should be spaced at 90-degree intervals around the coupling. When the measurements are all alike and the coupling faces are the same distance apart at the four points, the unit is in angular alignment. Correct any misalignment by adjusting the wedges or shims under the base plate. Remember that an adjustment in one direction can disturb adjustments in another direction.

Figure 7-27 — Making angular alignment.

Many of the pumps used by the Seabees are centrifugal pumps. *Figure 7-28* shows a typical installation of a centrifugal pump. There are two types of assembly in which centrifugal pumps are delivered.

Figure 7-28 — Typical installation of a centrifugal pump.

One group has the pump and the driver mounted on a common base plate at the factory. The other group has only the pump mounted at the factory, so the driver must be positioned at the place of installation. In the former group, factory alignment may not have been maintained, as all base plates are somewhat flexible. Therefore, you must realign the unit after it has been leveled on the foundation. To do this, first disconnect the coupling halves. Then follow the same alignment steps that have just been given. After completing these steps, reconnect the coupling and check it again for parallel and angular alignment. To install a centrifugal pump of the second group, you have a little extra work. After you have placed the base plate with the pump on the foundation, you level, align, and bolt it. Next, place the driver on the base plate according to the blueprints. Adjust the position of the driver and shim it up until the pump and driver half couplings are aligned. Then bolt it securely and proceed as in the other installation.

After you have correctly aligned the pump, tighten the foundation bolts evenly, but not too firmly. Then completely fill the base plate with grout. Try to grout the leveling pieces, the shims, or the wedges in place. Foundation bolts should not be fully tightened until the grout has hardened, usually about 48 hours after pouring.

After the grout has set and the foundation bolts have been properly tightened, the pump should be checked again for parallel and angular alignment. You are now ready to connect the piping.

2.5.1 Piping

When installing the pump piping, be sure to observe the following precautions:

- Piping should always be run to the pump.
- Do not move the pump to the pipe. This could make final alignment impossible.
- Both the suction and discharge piping should be independently supported near the pump and properly aligned, so the strain is not transmitted to the pump when the flange bolts are tightened.
- Use pipe hangers or other supports at necessary intervals to provide support. When expansion joints are used in the piping system, they must be installed beyond the piping supports closest to the pump.

- Tie bolts should be used with expansion joints to prevent pipe strain. Do not install expansion joints next to the pump or in any way that would cause a strain on the pump resulting from system pressure changes.
- It is usually advisable to increase the size of both the suction and the discharge pipes at the pump connections to decrease the loss of head from friction.
- Install piping as straight as possible, avoiding unnecessary bends. Where necessary, use 45-degree or long sweep 90-degree fittings to decrease friction losses.
- Make sure that all piping joints are airtight.
- Where flange joints are used, you must ensure that their inside diameters match properly.
- Remove burrs and sharp edges when marking up joints.
- Do not “spring” piping when marking connections.
- Provide for pipe expansion when hot fluids are to be pumped.

2.5.1.1 Suction Piping

When installing the suction piping, observe the precautions shown in *Figure 7-29*. The sizing and installation of the suction piping are extremely important. The piping must be selected and installed so that pressure losses are minimized and sufficient liquid can flow into the pump when it is started and operated. Many net positive suction head (NPSH) problems can be directly attributed to improper suction piping systems.

Suction piping should be short in length, as direct as possible, and never smaller in diameter than the pump suction opening. If the suction pipe is short, the pipe diameter can be the same size as the suction opening. If longer suction pipe is required, pipes should be one or two sizes larger than the opening, depending on piping length.

Suction piping for horizontal double-suction pumps should not be installed with an elbow close to the suction flange of the pump. The only exception to this rule is when the elbow is in the vertical plane. A suction pipe of the same size as the suction nozzle approaching at any angle other than straight up or straight down has the elbow located ten pipe diameters from the suction flange of the pump. Vertically mounted pumps and other space limitations require special piping.

Figure 7-29 — Suction pipe installations.

There is always an uneven turbulent flow around an elbow, and when it is in a position other than the vertical, more liquid enters one side of the impeller than the other (*Figure 7-30*). This results in high unequalled thrust loads that overheat the bearings and cause rapid wear in addition to affecting hydraulic performance.

When operating on a suction lift, you should ensure the suction pipe slopes upward to the pump nozzle. A horizontal suction line must have a gradual rise to the pump. Any high point in the pipe becomes filled with air and thus prevents proper operation of the pump. When reducing the piping to the suction opening diameter, use an eccentric reducer with the eccentric side down to avoid air pockets.

Figure 7-30 — Unbalanced loading of a double suction impeller.

CAUTION

When operating on a suction lift, you should never use a straight taper reducer in a horizontal suction line, as it tends to form an air pocket in the top of the reducer and the pipe.

To clean the pump liquid passage without dismantling the pump, bolt an increasing suction nozzle to the suction flange. If this is not done, a short section of pipe (Dutchman or spool piece), so designed that it can be readily dropped out of the line, can be installed adjacent to the suction flange. With this arrangement, any matter clogging the impeller is accessible by removing the nozzle (or pipe section).

2.5.1.2 Discharge Piping

If the discharge piping is short, the pipe diameter can be the same size as the discharge opening. If the piping is long, the pipe diameter should be one or two sizes larger than the discharge opening. On long horizontal runs, it is desirable to maintain as even a grade as possible. Avoid high spots, such as loops, that collect air and throttle the system or lead to erratic pumping.

2.5.1.3 Valves in Piping

When installing valves in the suction piping, observe the following precautions:

If the pump is operating under static suction lift conditions, a foot valve should be installed in the suction line to avoid the necessity of priming each time the pump is started. This valve should be of the flapper type, rather than the multiple spring type, and sized to avoid excessive friction in the suction line. (Under all other conditions, a check valve, if used, should be installed in the discharge line.)

When foot valves are used or where there are other possibilities of “water hammer,” close the discharge valve slowly before shutting down the pump.

When two or more pumps are connected to the same suction line, install gate valves so any of the pumps can be isolated from the line. Gate valves should be installed on the suction side of all pumps with a positive pressure for maintenance purposes. Install gate valves with horizontal stems to avoid air pockets. Globe valves should not be used, particularly where NPSH is critical.

The pump must never be throttled by the use of a valve on the suction side of the pump. Suction valves should be used only to isolate the pump for maintenance purposes and should always be installed in positions to avoid air pockets.

When installing valves in the discharge piping, you should install a check valve and gate valve in the discharge piping. The check valve, placed between the pump and the gate valve, protects the pump from excessive back pressure and prevents liquid from running back through the pump in case of power failure. The gate valve is used in priming, starting, and shutting down the pump.

2.5.1.4 Pressure Gauges

Properly sized pressure gauges should be installed in both the suction and the discharge nozzles in the gauge taps. The gauges enable the operator to observe the operation of the pump easily and also to determine if the pump is operating according to the performance curve. If cavitation, vapor binding, or other unstable operation occurs, widely fluctuating discharge pressure will result.

2.5.2 Stuffing Box

Contaminants in the pumped liquid must not enter the packing space. These contaminants can cause severe abrasion or corrosion of the shaft or shaft sleeve, and rapid packing deterioration; they can even plug the stuffing box flushing and lubrication system. The stuffing box must be supplied at all times with a source of clean, clear liquid to flush and lubricate the packing. The most important consideration is to establish optimum flushing pressure to eliminate contaminants from the packing. If this pressure is too low, the fluid being pumped may enter the stuffing box. If the pressure is too high, excessive packing wear can result; in addition, extreme heat may develop in the shaft, causing higher bearing temperatures. The most desirable condition, therefore, is to use the lowest possible flushing pressure that the operating conditions will permit. If the pump system pressure conditions vary during the day, the packing problem becomes difficult. Consideration should be given to using a mechanical seal. (See "Mechanical Seals" below.)

One recommended method to minimize error in regulating flushing is a "controlled pressure system" (*Figure 7-31*). Most important is that the pressure-reducing valve be adjusted to a valve slightly exceeding the maximum stuffing box operating pressure (assuming it is reasonably constant). A flow-indicating device serves to indicate a failing of the bottom packing rings, allowing leakage into the pump. With this arrangement, the packing gland must be tightened only against the lowest necessary pressure. Longer packing life is possible with the "controlled pressure system," if it is properly installed and operated.

Figure 7-31 — Controlled pressure system for stuffing box.

The actual stuffing box operating pressure may be obtained by installing a pressure gauge on the box. This is done with an extra seal cage temporarily replacing the two rings of packing in the bottom of the box to obtain accurate gauge readings. Take gauge readings with the pump running under various head and capacity conditions. Then set the pressure of flushing or lubricating liquid at a value of 5 to 10 psi above the maximum expected stuffing box operating pressure.

Even under the best conditions, a properly packed stuffing box should be watched closely. When pressure conditions change slightly, there is a resultant change in packing (seating) which should be compensated by a change in gland adjustment. Consideration should also be given to the lubrication pressure. A wide variation in pressure indicates a need for a mechanical seal.

A tapped hole is supplied in the stuffing box directly over the seal cage to introduce a clean, clear sealing medium. Apply sealing water at a rate of 0.5 to 1.0 gpm and at 5 to 10 psi above the stuffing box operating pressure.

Piping that supplies sealing liquid to the stuffing box must be sized to supply a sufficient volume of water at the required pressure, based on the location of the pump (or pumps) with respect to the liquid source. A small pipe can be used for the connection to the stuffing box. A valve should be installed to adjust and regulate sealing liquid, and a gauge should be installed to check the pressure to the box.

External sealing liquid should be adjusted to the point where the packing runs only slightly warm with a slow drip from the stuffing box. Excessive pressure from an external source can be destructive to packing. More pressure is required, however, for abrasive slurries than for clear liquids. Examination of the leakage will indicate whether it is necessary to increase external pressure. If slurry is present in the leakage, increase the pressure until only clear liquid drips from the box. If the drippage is corrosive or may be harmful to personnel, it should be collected and piped away.

A common error is to open the external piping valve wide and then control the drippage by tightening the packing gland. Actually, a combination of both adjustments is essential to arrive at the optimum condition. The life of the packing and the sleeve depends on this careful control more than any other factor.

2.5.3 Packing

Standard pumps are normally packed before shipment. If the pump is installed within 60 days after shipment, the packing should be in good condition with a sufficient supply of lubrication. If the pump is stored for a longer period of time, it may be necessary to repack the stuffing box. In all cases, you should inspect the packing before starting the pump.

The standard packing is made of a soft, square asbestos material that is impregnated with oil and graphite. A soft, well-lubricated packing reduces stuffing box resistance and prevents excessive wear on the shaft, or shaft sleeve. Many brands of packing on the market have the desired qualities. For specific recommendations, consult the manufacturer’s manual.

When a pump with fiber packing is first started, it is advisable to have the packing slightly loose without causing an air leak. As the pump breaks in, tighten the gland bolts evenly. The gland should never be drawn to the point where packing is compressed too tightly and no leakage occurs. This causes the packing to burn the shaft or shaft sleeve to be scored, and prevents liquid from circulating through the stuffing box and cooling the packing. The stuffing box is improperly packed or adjusted when friction in the box prevents the rotating element from being turned by hand. A packed stuffing box that is operating properly should run lukewarm with a slow drip of sealing liquid. After the pump has been in operation for some time and the packing has been completely run in, drippage from the stuffing box should be at least 40 to 60 drops per minute. This indicates that there is proper packing, that the shaft sleeve is adequately lubricated, and that it is cooled properly.

CAUTION

Erratic operation of the shaft or shaft sleeve through the packing could result in excess leakage. Correction of this defect is extremely important.

Packing should be checked frequently and replaced as service indicates. Six months might be a reasonable expected life, depending on operating conditions. It is impossible to furnish an exact prediction. A packing tool may be used to remove old packing from the stuffing box. Never reuse old and lifeless packing or merely add some new rings. Make sure the stuffing box is thoroughly cleaned before new packing is installed. Also, check the condition of the shaft or shaft sleeve for possible scoring or eccentricity, making replacements as necessary.

Place new packing carefully into the stuffing box. If molded rings are used, open them sideways and push the joints into the stuffing box first. Install the rings one at a time, seat each ring firmly, and stagger the joints so they are not in line. Keep the joints toward the upper side of the shaft about a 90-degree angle from each preceding joint.

If coil packing is used, cut one ring to accurate size with either a butt or mitered joint. An accurately cut butt joint is superior to a poor fitting mitered joint. Fit the ring over the shaft to assure proper length. Then remove and cut all other rings to the size of this first sample. When the rings are placed around the shaft, you should form a tight joint. Place the first ring in the bottom of the stuffing box. Then install each succeeding ring, staggering the joints as described above, making sure each ring is firmly seated.

Make sure the seal cage is properly located in the stuffing box under the sealing water inlet. The function of the seal cage is to establish a liquid seal around the shaft, to prevent leakage of air through the stuffing box, and to lubricate the packing. If it is not properly located, it serves no useful purpose.

2.5.3.1 Internal Liquid Lubrication

Pumped liquid may be used to lubricate the packing when the following conditions exist:

The liquid is clean, free from sediment and chemical precipitation, and compatible with seal materials.

- Temperature is above 32°F and below 160°F.
- Suction pressure is below 75 pounds psig.
- Liquid has adequate lubricating qualities.
- Liquid is non-toxic and non-volatile.

2.5.3.2 External Liquid Lubrication

When the liquid being pumped contains solids or is otherwise not compatible with packing materials, an outside supply of seal liquid should be furnished. In general, external-injection liquid (from an outside source) is required when the following conditions exist.

- Liquid being pumped contains dirt, grit, or other impurities.
- The temperature of the pumped liquid is below 32°F or above 160°F.
- The liquid being pumped has non-lubricating properties.
- The liquid is toxic or volatile.
- The suction pressure is above 75 psig, vacuum or high lift.

2.5.4 Mechanical Seals

Mechanical seals are preferred over packing on some applications because of better sealing qualities and longer serviceability. Leakage is eliminated when a seal is properly installed, and normal life is much greater than that of packing on similar applications. A mechanical shaft seal is supplied in place of a packed stuffing box when specifically requested. The change from packing to an alternate arrangement may be made in the field. Conversion kits may be ordered from the manufacturer.

2.5.4.1 Single Seal

Pumps containing single mechanical seals normally use pumped liquid to lubricate the seal faces. This method is preferred when the pumped liquid is neither abrasive nor corrosive. If the liquid being pumped is not suitable, an external flush should be provided. (See “External Liquid Lubrication” above.)

2.5.4.2 Double Seal

A double mechanical seal consists of two single seals mounted back to back and a suitable sealing liquid that is introduced into the seal chamber. The sealing liquid (preferably clear water) is injected into the box at a higher pressure than exists at the entrance to the seal cavity on the pump side. The pressure differential isolates the sealing faces from the pumped liquid. Double mechanical seals are normally preferred in pumps handling sewage, slurries, or any other solids suspended in the pumped liquid.

Sealing liquid that is introduced through the tap in the seal cavity provides lubrication for the double seal. The sealing liquid pressure must always be higher than the pressure on the seal closest to the suction side. If sufficient sealing pressure is not maintained, the pressure within the pump can force open the lower seal and allow the pumped liquid to enter the box. This can damage the seals.

Two methods are used to provide sealing liquid to the stuffing box. The first method uses a pressure line installed from a tap on the discharge nozzle to the tap in the stuffing box cartridge. A filter is installed in the line to trap the solid particles. The filter must be capable of screening out all particles above 25 microns in size. Since the liquid is bypassed from the high pressure (discharge) side of the pump and dead-ended in the stuffing box cartridge, there are no problems in maintaining a sufficient pressure differential, provided the filter is not clogged. The second method uses clear, clean water supplied from an external source. City water can be used if there is an air break between the water supply and the water being provided to the pump. Various municipal ordinances require this break to prevent contamination of the city water supply.

General instructions for operation of the various mechanical sealing arrangements are included below. It is not feasible to include detailed instructions for all mechanical seals in this chapter because of the almost unlimited number of possible combinations and arrangements. For more information, refer to the manufacturer's instructions.

Mechanical seals are precision products and should be treated with care. Use special care when handling seals. Clean oil and clean parts are essential to prevent scratching the finely lapped sealing faces. Even light surface scratches on these faces could result in leaky seals. Normally mechanical seals require no adjustment or maintenance except routine replacement of worn or broken parts.

A mechanical seal that has been used should not be placed back into service until the sealing faces have been replaced or relapped. (Relapping is generally economical only in seals that are 2 inches and greater in size.)

Four important rules that you should always follow for optimum seal life are as follows:

1. Keep the seal faces as clean as possible.
2. Keep the seal as cool as possible.
3. Ensure the seal always has proper lubrication.
4. If the seal is lubricated with filtered fluid, clean the filter frequently.

2.6.0 Pump Maintenance

Operating conditions vary so widely that to recommend one schedule of preventive maintenance for all centrifugal pumps is not possible. Yet some sort of regular inspection must be planned and followed. You should maintain a permanent record of the periodic inspections and maintenance performed on a pump. This procedure will assist you in keeping the pump in good working condition and prevent costly breakdowns.

One of the best rules to follow in the proper maintenance of a centrifugal pump is to keep a record of actual operating hours. Then, after a predetermined period of operation has elapsed, the pump should be given a thorough inspection. The length of this operating period varies with different applications and can be determined only from experience. New equipment, however, should be examined after a relatively short period of operation. The next inspection period can be lengthened somewhat. This system can be followed until a maximum period of operation is reached, which should be considered the operating schedule between inspections.

2.6.1 ring Lubrication - Grease

Grease-lubricated bearings are packed with grease at the factory and ordinarily require no attention before starting, provided the pump has been stored in a clean, dry place before its operation. The bearings should be watched the first hour or so after the pump has been started to see that they are operating properly.

The importance of proper lubrication cannot be overemphasized. It is difficult to say how often a bearing should be greased, since that depends on the conditions of operation. It is important to add 1 ounce of grease at regular intervals, but it is equally important to avoid adding too much grease. For average operating conditions, it is recommended that 1 ounce of grease be added at intervals of 3 to 6 months, and only clean grease should be used. It is always best if the unit can be stopped while the grease is added to avoid overloading. Always refer to the manufacturer's instructions.

CAUTION

Excess grease is the most common cause of overheating.

The bearing frame should be kept clean, since contamination by foreign matter in the housing can destroy the bearings within a short period of time. When cleaning bearings, use a bearing or an industrial cleaning solvent. Do not use gasoline. Use a lint-free cloth. Do not use waste rags.

A regular bearing grease should be used, but a standard commercial vaseline can be substituted if necessary. Do not use graphite. A No. 1 or a No. 2 grease is generally satisfactory for operation at ordinary temperatures; the lighter grease should be used for operation at high speed or at low room temperature.

Mineral grease with a soda soap base is recommended. Grease made from animal or vegetable oils is not recommended because of the danger of deterioration and the forming of acid. Most of the leading oil companies have special types of bearing grease that are satisfactory. For specific recommendations, consult the manufacturer's manual.

The maximum desirable operating temperature for bearings is 180°F. Should the temperature of the bearing frame rise above 180°F, the pump should be shut down to determine the cause. Grease-lubricated bearings should not be used where the temperature of the pumped liquid exceeds 350°F.

CAUTION

A bearing frame that feels hot to the touch is not necessarily running hot. Check the temperature with an accurate measuring device to be sure.

2.6.2 ring Lubrication - Oil

An oil-lubricated pump normally has an oiling ring. In these, the oil is picked up from the reservoir by a rotating oil ring and deposited on the shaft and the bearings inside the bearing housing. Some may have an oil slinger that creates a shower of fine droplets of oil over the entire interior of the bearing cavity.

After the pump has been installed, flush the bearing housing to remove dirt, grit, and other impurities that may have entered the bearing housing during shipment or erection. Then refill the bearing housing with proper lubricant. The oil level to be maintained is shown by a line in the sight glass or oil level indicator.

Lubricating oils can be furnished by any of the major oil companies, and the oil vendor are responsible for supplying suitable lubricants. Experience has shown that oils meeting the following specifications provide satisfactory lubrication.

● Saybolt viscosity at 100°F	150 SSU-200 SSU
● Saybolt viscosity at 210°F	43 SSU
● Viscosity index, minimum	95
● API gravity	28-33
● Pour point, maximum	20°F
● Flash point, minimum	390°F
● Additives	Rust and oxidation inhibitors

CAUTION

Oils from different suppliers should not be mixed. The oil must be well-refined, good grade, straight cut, and filtered mineral oil. It must be free from water, sediment, resin, soaps, acid, and fillers of any kind. It should also be non-foaming with a viscosity of about 150 to 200 SSU at 100°F (approximately SAE-20).

In installations with moderate temperature changes, humidity, and dirt, the oil should be changed after approximately 160 hours of operation. The oil should be inspected at this time to determine the operating period before the next oil change. Oil change periods may be increased from 2,000 to 4,000 hours based on an 8,000-hour year. Check the oil frequently for moisture, dirt, or signs of "breakdown."

CAUTION

Do not over oil, as this causes the bearings to run hot. The maximum desirable operating temperature for bearings is 180°F. Should the temperature of the bearing frame exceed 180°F, shut down the pump to determine the cause.

2.6.3. Grease Lubrication

Pump stuffing boxes are also suitable for grease lubrication. Several types of grease lubricators are available. When you use a grease lubricator, grease pressure to the stuffing box should be equal to the pump discharge pressure.

2.6.4 Maintenance Timetable

Equipment cannot operate well without proper care. To keep the pump at top efficiency, follow the recommended installation and servicing procedures outlined in the manufacturer's manual. *Table 7-2* is a recommended maintenance timetable for use in keeping a pump at maximum operating capacity with a minimum amount of downtime.

Table 7-2 — Maintenance Timetable.

Every Month	Check bearing temperature with a thermometer. If bearings are running hot (over 180°F), it may be the result of too much lubricant. If changing the lubricant does not correct the condition, disassemble and inspect the bearings.
Every 3 Months	Check grease-lubricated bearings for saponification. This condition is incurred by the infiltration of water or other fluid past the bearing shaft seals and can be noticed immediately upon inspection, since it gives the grease a whitish color. Wash out the bearings with a clean industrial solvent and replace the grease with the proper type as recommended.
Every 6 Months	Check the packing and replace if necessary. Use the grade recommended. Be sure the seal cages are centered in the stuffing box at the entrance of the stuffing box piping connection. Check shaft or shaft sleeve for scoring. Scoring accelerates packing wear. Check alignment of pump and motor. Shim up units if necessary. If misalignment recurs frequently, inspect the entire piping system. Unbolt piping at suction and discharge flanges to see if it springs away, thereby indicating strain on the casing. Inspect all piping supports for soundness and effective support of load.
Every Year	Remove the rotating element. Inspect thoroughly for wear, and order parts if necessary. Check wearing clearances. Remove any deposit or scaling. Clean out stuffing box piping. Measure total dynamic suction and discharge head as a test of pipe connection. Record the figures and compare them with the figures of the last test. This is important especially where the fluid being pumped tends to form a deposit on internal surfaces. Inspect foot valves and check valves, especially the check valve which safeguards against water hammer when the pump stops. A faulty foot or check valve will reflect also in poor performance of the pump.

Between regular maintenance inspections, be alert for signs of motor or pump trouble. Common symptoms are listed in *Table 7-3*. Correct any trouble immediately and avoid costly repair and shutdown.

Table 7-3 — Troubleshooting.

1. Lack of prime	Fill pump and suction pipe completely with liquid
2. Loss of prime	Check for leaks in suction pipe joints and fittings; vent casing to remove accumulated air.
3. Suction lift too high	If no obstruction at inlet, check for pipe friction losses. However, static lift may be too great. Measure with mercury column or vacuum gauge while pump operates. If static lift is too high, liquid to pump must be raised or pump must be lowered.
4. Discharge head too high	Check pipe friction losses. Large piping may correct condition. Check that valves are open.
5. Speed too low	Check if motor is directly across the line and receiving full voltage. Or frequency may be too low; motor may have an open phase.
6. Wrong direction of rotation	Check motor rotation with directional arrow on pump casing.
7. Impeller completely plugged	Dismantle pump and clean impeller.
Not Enough Liquid Delivered	
8. Air leaks in suction piping	If liquid pumped is water or non-explosive, and explosive gas or dust is not present, test flanges for leakage with flame or match. For such liquids as gasoline, the suction line can be tested by shutting off or plugging the inlet and putting the line under pressure. A gauge will indicate a leak if pressure drops.
9. Air leaks in stuffing box	Increase seal lubricant pressure to above atmosphere.
10. Speed too low	See Item 5.
11. Discharge head too high	See Item 4.
12. Suction lift too high	See Item 3.
13. Impeller partially plugged	See Item 7.
14. Cavitation; insufficient NPSH	a. Increase positive suction head on pump by lowering pump. b. Sub-cool suction piping at inlet to lower entering liquid temperature. c. Pressurized suction vessel.
15. Defective impeller	Inspect impeller, bearings, and shaft. Replace if damaged or vane sections badly eroded.
16. Defective packing	Replace packing and sleeves if badly worn.

No Liquid Delivered	
17. Foot valve too small or partially obstructed	Area through ports of valve should be at least as large as area of suction pipe--preferably 1 1/2 times. If strainer is used, net clear area should be three to four times area of suction pipe.
18. Suction inlet not immersed deep enough	If inlet cannot be lowered or if eddies through which air is sucked persist when it is lowered, chain a board to suction pipe. It will be drawn into eddies, smothering the vortex.
19. Wrong direction of rotation	Symptoms are an overloaded drive and about 1/3 rated capacity from pump. Compare rotation of motor with directional arrow on pump casing.
20. Too small impeller diameter	Check with factory to see if larger impeller can be used; otherwise, cut pipe losses or increase speed--or both, as needed. Be careful not to overload drive.
Not Enough Pressure	
21. Speed too low	See item 5.
22. Air leaks in suction piping	See Item 8.
23. Mechanical defects	See Items 15, 16, and 17.
24. Obstruction in liquid passages	Dismantle pump and inspect passages of impeller and casing. Remove obstructions.
25. Air or gases in liquid reducing pressure on liquid to pressure in the suction line. Watch for bubble formation.	May be possible to overrate pump to a point where it will provide adequate pressure despite condition. Better to provide gas separation chamber on suction line near pump, and periodically exhaust accumulated gas. See Item 14.
26. Too small impeller diameter	See Item 20.
Pump Operates for Short Time, Then Stops	
27. Incomplete priming	Free pump, piping, and valves of all air. If high points in suction line prevent this, they need correcting.
28. Suction lift too high	See Item 3.
29. Air leaks in suction piping	See Item 8.
30. Air leaks in stuffing box	See Item 9.
31. Air or gases in liquid	See Item 25.
32. Head lower than rating, thereby pumping too much liquid	Machine impeller's OD to size advised by factory.
33. Cavitation	See Item 14.
34. Mechanical defects	See Items 15, 16, and 17.
35. Suction inlet not immersed enough	See Item 18.

36. Liquid heavier than allowed for	Use larger driver. Consult factory for recommended size. Test liquid for viscosity and specific gravity.
37. Wrong direction of rotation	See Item 6.
38. Stuffing boxes too tight	Release gland pressure. Tighten reasonably. If sealing liquid does not flow while pump operates, replace packing. If packing is wearing too quickly, replace scored shaft sleeves and keep liquid seeping for lubrication.
39. Casing distorted by excessive strains from suction or discharge piping	Check alignment. Examine pump for friction between impeller and casing. Replace damaged parts.
40. Shaft bent due to damage	Check deflection of rotor by turning on bearing journals. Total indicator run-off should not exceed 0.002 on shaft and 0.004 inch on impeller wearing surface.
41. Mechanical failure of critical pump parts	Check bearing and impeller for damage. Any irregularity in any of these parts will cause a drag on shaft.
42. Misalignment	Realign pump and driver.
43. Speed may be too high	Check voltage on motor.
44. Electrical defects	The voltage and frequency of the electric current may be lower than that for which motor was built, or there may be defects in motor. The motor may not be ventilated properly due to a poor location.
45. Mechanical defects in turbine, engine, or other type of drive exclusive of motor	If trouble cannot be located, consult factory.

Test your Knowledge (Select the Correct Response)

2. Lubricating oils can be furnished by any of the major oil companies, and it is the responsibility of the oil vendor to supply suitable lubricants. Which of the following temperatures is the minimum amount allowed for lubricating oil?

   A. 350°F
   B. 375°F
   C. 390°F
   D. 400°F

3.0.0 AIR COMPRESSORS

Air compressors are devices or machines that compress air. In compression, air at a normal atmospheric temperature is taken in and squeezed or pressed by a moving element within a confined space. The volume of air is thus reduced, but the pressure, or force, of the volume of air exerted has increased considerably. Thus the air develops energy or power that can be put to some useful purpose in other machines. The compressed air need not be put to work immediately but can be stored in tanks to preserve and maintain its pressure.

Compressed air can be taken from storage bottles or flasks and used to start diesel engines, that is, the compressed air is introduced into the diesel cylinders where, by its pressure, it forces the pistons to reciprocate until ignition temperature is reached. We have seen how compressed air forces water to rise in wells. Air compressors also drive, or power, a wide variety of pneumatic tools in construction work. The types of air compressors include reciprocating, centrifugal, and rotary; however, only reciprocating compressors are discussed in the following paragraphs. In basic design and function, these compressors are similar to the pumps with the same names. In fact, air compressors are sometimes referred to as air pumps. Rather than discharging liquid at relatively high pressure, air compressors discharge air (which is considered a fluid) at high pressure. Like pumps, compressors require some external source of mechanical power to do this work. Prime movers for air compressors may be electric motors, internal combustion engines, steam turbines, and so on. The majority of air compressors used throughout the Seabee ratings are driven by electric motors.

Pressure and Uses

Compressed air usually falls into one of three categories--power service, process service, or control purposes.

Power service is when compressed air either moves something or exerts a force. Examples of power service uses are pneumatic tool operation, air lifts, clamps, and cylinders.

Process service is when compressed air is used as part of the process itself. An example is the use of compressed air in a combustion process. Compressed air provides oxygen for the combustion, and in turn becomes a part of the combustion products and is no longer identifiable as air.

Control purpose is when compressed air is used to govern and/or regulate various equipment by monitoring pressure or flow rates of some substance. A pneumatically controlled combustion system is an example of such an application.

Compressed air is distributed at low, medium, or high pressure. A low-pressure system delivers air up to 125 psig. When several different pressures are required within that range, the plant is usually designed for the highest pressure. Typical low-pressure systems include the following: air motors, crane drives, starting motors for combustion engines, shops, laundry and dry-cleaning plants, and general service (tools, cleaning, painting, and soot blowing for HTW generators and steam boilers).

Medium-pressure systems deliver air from 126 to 399 psig. Normally, this type of system provides an individual compressor located near the load. Typical applications are starting diesel engines, hydraulic lifts, and retread tire molds.

Low-pressure and medium-pressure systems use black steel pipe. Preferably, the joints are welded. Special conditions may require stainless steel and copper tubing with appropriate fittings. Connections to removable equipment are always flange fittings, except when using small threaded pipe.

High-pressure compressed air systems range from 400 to 6,000 psig. To minimize the hazard that exists with higher pressures and capacities, you can use separate compressors for each required pressure. Some applications are torpedo workshops, ammunitions depots, catapults, wind tunnels, and testing laboratories.

High-pressure systems use seamless steel pipe with butt welded fittings. Screwed fittings, when used, have their ends sealed by fillet welds and exposed pipe threads covered with weld.

3.1.0 Reciprocating Air Compressors

One of the most commonly used air compressors in the Seabees service is the reciprocating air compressor. It compresses air in the same manner as a diesel engine. A reciprocating piston alternately draws in and then compresses the trapped air in a cylinder. Since there is no internal combustion, the cycle of the reciprocating air compressor is reduced or simplified to two strokes--suction (intake) and compression. Instead of operating the valves by cam action, as in internal combustion engines, the intake and discharge valves of the reciprocating air compressor operate on the principle of differential pressure overcoming spring tension, much the same as the check valves operate in reciprocating pumps. The suction stroke occurs as the piston moves downward to create a partial vacuum and causes the intake valve to open. Air, at normal atmospheric pressure, is then drawn into the cylinder, as the piston continues downward. When the piston moves on the upward stroke, the intake valve closes. The trapped air is compressed as the piston continues upward. As the piston reaches the top of its compression stroke, the air pressure developed overcomes the resistance of the spring-loaded discharge valve.

The discharge valve opens momentarily and the compressed air charge then passes into the discharge line. When higher pressure is desired, more cylinders or stages may be provided (*Figure 7-32*).

Figure 7-32 — Air compressor assembly.

The discharge of the first stage is led to the intake of the second stage, and so on. The principle here is almost the same as that in the multistage impeller arrangements used to increase the discharge pressure on centrifugal pumps. *Figure 7-33* shows a more detailed view of a two-stage reciprocating air compressor. You can see that the second-stage cylinder is noticeably smaller than the first. If there were more cylinders, each would be smaller. This is the compression process, whereby the volume of the air charge is continually reduced as it passes from one stage to the next, and at the same time the pressure becomes greater.

Figure 7-33 — Two stage reciprocating air compressor.

Figure 7-34 shows an alternate type of low-pressure air compressor.

Figure 7-34 — Low pressure reciprocating air compressor, vertical W configuration.

3.2.0 Compressor Components

The pistons are either trunk pistons or differential pistons. Trunk pistons, as shown in *Figure 7-35, View A*, are driven directly by the connecting rods. Since the upper end of a connecting rod is fitted directly to the piston (also referred to as wrist or trunk) pin, the piston tends to develop a side pressure against the cylinder walls. To distribute the side pressure over a wide area of the cylinder walls or liners, use pistons with long skirts. This type of piston minimizes cylinder wall wear. Differential pistons, as shown in *Figure 7-35, View B*, are modified trunk pistons with two or more different diameters. These pistons are fitted into special cylinders arranged so more than one stage of compression is achieved by one piston. The compression for one stage takes place over the piston crown; compression for the other stage(s) takes place in the annular space between the large and small diameters of the piston.

Figure 7-35 — Air compressor pistons: A. Trunk type; B. Differential type.

Drain cocks are provided at the bottom of the compressor suction control and the engine speed control. These cocks should be left open when the unit is standing idle, particularly in freezing weather. They must be closed before starting the engine. Check the oil level in the oil storage tanks as indicated by the gauge. If necessary, add oil according to the oil specifications given in the manufacturer's lubrication manual. Drain any condensate that has accumulated in the bottom of the oil storage tanks. A drain cock is provided on the piping at the bottom of the left-hand oil storage tank. Open this cock and keep it open as long as water is draining out. Close the cock quickly when oil starts draining.

3.3.0 Lubrication System

Except for oil-free (non-lubricated) compressors, high-pressure air compressor cylinders are generally lubricated by an adjustable force-feed lubricator driven from a reciprocating or rotary part of the compressor. Oil is fed from the cylinder lubricator by separate lines to each cylinder. A check valve is installed at the end of each feed line to keep the compressed air from forcing the oil back into the lubricator. The oil is distributed to the top of each main bearing, to spring nozzles for reduction gears, and to outboard bearings. The crankshaft is drilled so oil fed to the main bearings is picked up at the main bearing journals and carried to the crank journals. The connecting rods contain passages that conduct lubricating oil from the crank bearings up to the piston pin bushings. As oil leaks out from the various bearings, it drips back into the oil sump (in the base of the compressor) and is recirculated. Oil from the outboard bearings is carried back to the stirrup by the drain lines.

Low-pressure air compressor lubrication is shown in *Figure 7-36*. This system is similar to the running gear lubrication system or the high-pressure air compressor.

Figure 7-36 — Lubricating oil system of a low pressure air compressor.

Non-lubricated reciprocating compressors have lubricated running gears (shaft and bearings) but no lubrication for the pistons and valves. This design produces oil-free air. The lubrication chart in the operator's manual for the make and model of compressor you are operating shows you where the unit should be lubricated, how often to lubricate, and what lubricant to use. The frequency depends upon operating conditions. Operating under abnormal conditions requires more frequent service.

CAUTION

Before servicing the compressor air system or compressor oil system, open the service valves to the atmosphere to relieve all pressure in the systems.

3.4.1 Unloading Systems

Air compressor unloading systems are installed to remove all but the friction loads on the compressors, that is, they automatically remove the compression load from the compressor while the unit is starting and automatically apply the load after the unit is up to operating speed. For units with start-stop control, the unloading system is separate from the control system. For compressors equipped with constant-speed control, the unloading and control systems are integrated. A few typical compressor unloading methods are discussed in the paragraphs that follow. These methods include the following:

- Closing or throttling the compressor intake
- Holding intake valves off their seats
- Relieving intercoolers to the atmosphere
- Relieving the final discharge to the atmosphere (or opening a bypass from the discharge to the intake)
- Opening up cylinder clearance pockets
- Using miscellaneous constant-speed unloading devices
- Combinations of the above

As an example of a typical compressor unloading device, consider the magnetic-type unloader. *Figure 7-37* shows the unloader valve arrangement. This unloader consists of a solenoid operated valve connected with the motor starter. When the compressor is at rest, the solenoid valve is deenergized to admit air from the receiver to the unloading mechanism. When the compressor reaches near-normal speeds, the solenoid valve is energized to release the pressure from the unloading mechanism and to load the compressor again. For details on the unloading devices, refer to the pertinent manufacturer's technical manuals for compressors installed in your command.

Figure 7-37 – Magnetic type unloader.

Since compressors draw in ambient air, or the air surrounding the compressor, the intake is fitted with an air intake filter. This filter keeps the intake air free of dust and other airborne particles. If dust-laden air enters the compressor, internal combustion, triggered by the heat of compression, can take place within the cylinders.

Moist or humid air drawn into the compressor cylinders poses another problem. The air intake filter cannot prevent this water vapor from being taken into the compressor. Instead, the water vapor is usually squeezed out of the air during compression and transformed into steam by the heat of compression. The steam condenses to form moisture droplets downstream from the compressor as the compressed air charge is cooled. Since moisture can damage some of the machines that use compressed air (pneumatic tools, for example), the moisture must be removed from the air before it is sent to the storage tank. So, a filter and a moisture separator assembly are placed between the compressor and the storage tank. The assembly removes most of the moisture, or any other impurities, entrained in the air before it is sent on to storage. The assembly is fitted with a valve or drain cock, so accumulations of water and dirt can be drained now and then by the operator.

The tank that stores the compressed air is called the air receiver, as shown in *Figure 7-38*. In this way, demands for compressed air are made upon the receiver, rather than directly on the compressor itself. And there is little chance of the demand for air exceeding the supply. To this end, the air receiver has with it some type of control system or device to monitor the supply of compressed air in the receiver. The control device may be a pressure switch that senses predetermined thresholds or levels of pressure. When the compressor has sufficiently charged the receiver with compressed air, the pressure switch automatically opens and shuts down the compressor. If and when the demand for compressed air begins to drain the receiver to a preset pressure threshold, the pressure switch closes and automatically starts the compressor.

Figure 7-38 — LP air compressor piping arrangements.

In systems where the demand for air is more or less constant and prolonged, a type of constant speed control can be used. The compressor is permitted to run continuously to keep the receiver charged with air, while the constant-speed control functions somewhat like a pressure relief valve. If the pressure of the compressed air in the receiver rises, because of a momentary drop in demand within the system, the control simply vents the excess compressed air to the atmosphere, rather than shut down the compressor.

3.5.0 Cooling System

The generation of heat always accompanies the compression of air. In most low-pressure air compressors, the heat from compression is dissipated before the temperature gets too high. Aluminum cylinders have cooling fins, and a fan forces cooling air past the cylinders. In most medium-pressure and high pressure air compressors, the compressor has to be cooled with pump-circulated water. The cooling water is circulated in much the same fashion as in an automobile engine with the coolant passing through jackets in the cylinder walls, cylinder heads, and so on. In addition, compressors are fitted with other cooling devices, known as intercoolers and aftercoolers. Generally, these devices consist of a series of tubes, either air-cooled or water-cooled, through which the compressed air charge flows after leaving the cylinders. These devices cool the compressed air. Intercoolers are placed between the stages or cylinders of multistage compressors. Thus they cool the compressed air charge before it is drawn into the next cylinder. The aftercoolers cool the final discharge of air from the compressor. Both the intercoolers and the aftercoolers are of the same general construction, except the aftercoolers are designed to withstand a higher working pressure.

Perhaps the most important advantage of these coolers is they aid in keeping the air charge in a compressed state. In other words, hot air has a tendency to expand, and if the compressed air charge is not cooled, it, too, tends to expand and thereby liberate much of its pressure or energy.

3.6.0 Compressor Location

Locate the compressor unit so that it is reasonably level. Some unit designs permit a 15-degree lengthwise and a 15-degree sideways limit on out-of-level operation. Ensure you always refer to the Manufactures Instructions for tolerances before installation begins. The engine, not the compressor, is the limiting factor. When the unit is to be operated out of level, keep the engine crankcase oil level near the high level mark (with the unit level) and have the compressor oil gauge show nearly full (with the unit level). The mechanical parking brake lever is near the bumper. Set the brake by pulling or pushing the lever as directed by a decal or a stencil located beside the lever on the unit. The parking brake should always be set once the air compressor is on location to prevent accidental rolling of the unit, which could cause not only mechanical damage but also possible injury to personnel. As an added precaution, the wheels should be chocked when possible.

Open the side curtains on both sides of the enclosure and leave them open whenever the unit is in operation. When the side curtains are closed and the engine running, the flow of air through the oil cooler and engine radiator is restricted. The curtains may be left closed for a few minutes during starting procedures in cold weather to ease engine warm-up. However, when the compressor goes to work, open the side curtains. For specific operating instructions, check the instruction plate attached to the unit being used.

3.7.0 Engine

The heart of the compressor is the engine that furnishes power for the compressor and produces air for the pneumatic tools used during drilling. Know how to start, operate, and maintain the compressor engine properly. In most cases, the general operating and prestart procedure is similar to that of vehicle prestart. Check the engine oil level. If necessary, add oil as recommended in the engine manual. Do not overfill.

Check the engine cooling system. The radiator should be filled to the bottom of the filler neck. If necessary, add soft, clean water until full. In cold weather, use permanent antifreeze with a rust inhibitor. Ethylene glycol solutions are recommended because they do not evaporate and only water is added to maintain a full system. Two fuel tanks are furnished-one on each side. The two tanks are cross-connected to permit filling from either side of the unit. Clean fuel is vitally important. Ensure clean fuel is poured or pumped into the tanks. Be sure no condensate (water) lies in the bottom of the fuel tanks. Drain off any water that may be there. Clear away obstructions in the vents of the fuel tank.

Lubricate all parts of the engine as recommended in the manufacturer's engine manual. Make periodic checks of the oil filter, the fuel filter, and the fuel oil pump screen. Ensure the rain cap on the exhaust pipe swings freely so a back pressure on the engine exhaust cannot be created. Check the battery cells for the proper liquid level. A pair of two-stage dry-type air cleaners filters the intake air for the compressor suction and engine air-intake manifold. Both cleaners are under the canopy at the compressor end of the unit.

The first stage of the air cleaner uses centrifugal pre-cleaning which rotates the intake air and separates a large portion of the dust collected in the dust cup. The dust cup should be checked and emptied daily.

The second stage of the air cleaner consists of a group of cylindrical pleated paper elements. The ends of the pleats are molded into a flexible plastic faceplate that seals the cartridge in place in the air cleaner housing without additional gaskets. On the side of the air cleaner housing is mounted a service indicator. As the second-stage cartridge loads up with dirt, a red indicator flag gradually rises in the window. When the cartridge is completely loaded, the window shows all red, and the flag is locked in place. This is the time to replace the second-stage cartridge. Discard the old cartridge and reset the red flag so the window shows clear. Do not clean used paper cartridges.

3.8.0 Operation and Maintenance of Air Compressors

Before the compressor is started, the operator should make inspections to ensure that both the compressor and the auxiliary components are ready for operation. This procedure includes the following: checks of the control and unloading systems; inspection of safety valves or pressure relief valves; draining condensate from the coolers, the separator, and the receiver, and turning on cooling water services and opening valves to ensure proper circulation of water through the compressor and coolers.

Once the compressor is in operation, the operator must periodically check the temperature and pressure of the cooling water, the lube oil, and the compressed air. The lube oil level must also be checked and maintained at the proper level. Coolers must be inspected for correct temperature and flow of water. Accumulations of moisture in the coolers, the separator, and the air receiver must be drained periodically. In addition, maintenance schedules require more detailed inspections (monthly, quarterly, etc.). In many cases, these inspections require dismantling parts of the compressor and auxiliary equipment. For instance, the operator may be required to inspect intake and discharge valves, cylinders, and pistons. The air intake filter must be inspected periodically and cleaned as necessary. The coolers and the receiver must also be inspected for corrosion and accumulations of dirt and oil.

The lubrication system on most compressors is somewhat similar to that on an automobile engine. Normally, the compressor base is used as the lube oil sump and oil pump housing. The oil level can be measured by a dipstick or an oil level sight gauge mounted on the base. The lube oil is distributed through various passages to lubricate bearings, valves, pistons, and other internal parts. An oil film is also distributed over the cylinder walls. Although small amounts of lube oil may mix with the compressed air, it is usually filtered out at the separator assembly. Note that one of the periodic operator inspections on air-lift pumps is to check the air-water discharge from the pump for contamination by lube oil entrained in the compressed air.

The lube oil used in the cylinders must be of the right type. The auto-ignition point (temperature at which oil vapor bums without the presence of a spark or flame) of these oils must always be well above the highest heat of compression; otherwise, there is the danger of internal combustion in the compressor cylinders. An example of a Seabee-operated and maintained compressor is discussed in the paragraphs below. The 600 ft3/min, portable air compressor is a single cylinder, sliding vane, oil-cooled, positive displacement rotary compressor, connected through a friction disk clutch to a heavy-duty industrial diesel engine. The complete assembly is equipped with a semi-elliptical spring mounting, pneumatic tires, and drawbar.

The portable compressor comes equipped with all components essential for proper operation, including the following:

A heavy-duty, single, dry-type air cleaner to provide clean air for the compressor and engine with a minimum of service requirements.

Large, cool radiator elements with ample capacity for efficient, dependable cooling of the compressor oil and engine coolant.

Oil filters with replaceable cartridges for efficient filtration of the compressor oil and engine crankcase oil. Automotive-type instrument panel with easy-to-read gauges and electrical instruments.

Pneumatic regulating controls that provide for economical engine operation under all loads.

A combination thermostatic valve and bypass to assure rapid warm-up and optimum compressor performance over a wide range of surrounding air temperatures.

An electrically operated shutdown system to stop the engine if a malfunction occurs in the compressor and/or engine.

A blowdown valve to relieve the pressure in the receiver and air-flow system automatically each time the engine is shut down.

An oil flow system that eliminates the need for an oil circulating pump.

3.9.0 Compressed Air Distribution

Compressed air is a powerful energy source which is very useful in military and industrial applications. It is of particular advantage in applications that require intermittent power at some distance from its source, as the air pressure can be maintained nearly constant at work intervals. The rest of this section will pertain to proper installation techniques of compressed-air systems. When you are assigned a project that includes compressed air lines, follow the prints and specifications.

3.9.1 Piping

Distribution piping is either aboveground or underground. Both aboveground and underground piping systems have advantages and disadvantages. The advantages of each system are presented in *Table 7-4* below:

Table 7-4 — Distribution piping advantages.

ABOVEGROUND	UNDERGROUND
Lower initial cost	Less vulnerable target
Less maintenance	Less obstruction to target
Easy detection of failure	Less unsightly
Higher continuous operating efficiency	Freeze protected when buried
Longer life	

Some other factors considered are permanent versus temporary use, existence of high water table, annual ownership, operation and maintenance costs, and degree of hazard (for example, potential danger that overhead piping may cause to aircraft operations).

Piping supports are held in place by U-shaped or similar types of hangers firmly secured to support structures. Support hangers must fit closely around the pipe, but may allow for slight movement. Aboveground pipe is pitched downward a minimum of 3 inches per 100 feet of length in the direction of the airflow to low points where the condensate is collected and drained through drip legs. The drip legs are at all low points, the bottom of all risers, and every 200 to 300 feet from horizontally pitched pipe.

Underground piping is normally placed as direct burial. Because this type of placement generally lowers the temperature of the air in the piping, more condensation will form within the pipe than in an aboveground system. The provisions to remove the condensation may be building basement drip legs or requiring manholes. If the soil is corrosive, cathodic protection may be needed. Underground lines are pitched the same as aboveground lines at 3 inches per 100 feet; however, drip legs differ from aboveground lines in that belowground lines require a drip leg at not over 500 feet. Insulation on buried compressed air piping should be shop-coated, wrapped, tested, and handled according to the NAVFAC specifications.

3.9.3 Auxiliary Equipment

Air filters--Air filters are provided on compressor intakes to prevent atmospheric dust from entering the compressor and causing scoring and excessive wear. Two types of air filters are used--the dry type and the oil-wetted type. Generally, the dry-type filter is more efficient than the oil-wetted type in trapping and removing very fine, solid particles from the incoming air; however, dry-type filters require cleaning and replacement more often than the oil-wetted types. Oil-wetted types are usually used under very dusty, dirty atmospheric conditions.

Silencers--Air compressors are fitted with silencers (*Figure 7-39*) that are sound-absorbing devices attached at the intake and output of the compressor. In general, air noise silencers are cylindrical housings containing acoustically tuned baffles and sound absorbing material.

Figure 7-39 — Compressor intake silencer.

Intercoolers and Aftercoolers--Intercoolers and aftercoolers are used to reduce the heat buildup due to the compression of air. The two mediums used are water and air. Normally air is used on smaller compressors. The air-cooled heat exchanger is simply a set of fins and/or tubular radiator. No liquid of any sort is used for cooling. The water-cooled heat exchanger operates as a shell and tube design (*Figure 7-40*). The tubes commonly consist of a single bundle of tubes enclosed in a cylindrical shell. The air to be cooled passes through the tubes while the water circulates around the outside of the tubes absorbing the heat from the compressed air. The baffles are used to direct the water flow across the heat exchanger tubes in the most efficient manner. The intercooler is located between the discharge of one cylinder and the intake of the next cylinder on a multi-stage compressor. The intercooler reduces the temperature and volume of the compressed air for delivery to the next compression stage. The aftercooler is located at the discharge of the last cylinder to cool the air, to reduce the volume, and to liquefy any condensable vapors.

Figure 7-40 — Water-cooled heat exchanger.

Separators—Separators remove oil and water from compressed air. *Figure 7-41* shows a centrifugal moisture separator. The air enters the unit in a swirling motion. Centrifugal action forces the moisture to the walls of the separator and then the moisture drains to the bottom of the separator.

Another type of separator is the baffle type. This separator causes the air entering the separator to make sudden changes in direction, causing the heavier moisture particles to strike the baffles and walls and drain to the bottom.

Figure 7-41 — Centrifugal moisture separator.

Traps—Compressor plant traps drain moisture from intercoolers, aftercoolers, receivers, and distribution piping. Common traps used are the ball float, the bucket, and the inverted bucket traps (*Figure 7-42*).

Figure 7-42 — Traps: A. Float; B. Upright bucket; C. Inverted bucket.

Air Receivers—The receiver is nothing more than a tank designed to hold the air that is compressed to meet supply peak demands in excess of the compressor capacity. Additionally, receivers function as pulsation dampers on reciprocating compressor installations. *Figure 7-43* shows an air receiver.

Figure 7-43 — Air receiver.

Dryers—Dryers remove moisture from compressed air that would condense in air lines, air tools, and pneumatic instruments. Condensation can cause damage to equipment by corrosion, freezing, and water hammer, and will cause instruments to malfunction. The three types of dryers are adsorption, deliquescent, and refrigeration.

The adsorptive dryer is made of some type of desiccant, such as silica gel or activated alumina. The desiccant adsorbs and holds the water vapor from the air. Adsorption-type dryers (*Figure 7-44*) consist of two drying towers, each containing an adsorbent, plumed in parallel. The drying towers are cycled manually or automatically so one tower is on stream and the other tower is being reactivated. Reactivation is accomplished by heating the desiccant which drives the moisture out to waste.

Only one type of dryer was discussed in this chapter. Other types of dryers, maintenance, operation of controls, and other interesting information about compressors can be found in NAVFAC MO-206, *Maintenance and Operation of Compressor Plants.*

Figure 7-44 — Flow diagram of an electric absorption dryer.

3.9.4 Safety Precautions

Listed below are some safety tips on how you can avoid air compressor accidents.

- Keep the hose connections on portable air compressors tight, and inspect these connections often to ensure they remain tight.
- Check the safety valves and gauges frequently to make sure they are working correctly.
- Use fixed tow bars, not chains or ropes, when moving portable air compressors.
- Check the wheels of portable air compressor carriages to ensure proper operation.
- When an air compressor is started, check the safety valves, the pressure controls, and the regulators to determine that they are working properly.
- DO NOT leave the area of an operating compressor unless you are sure that the control, the unloading, and the governing devices are working properly.
- Do NOT run a compressor faster than the speed recommended by the manufacturer.
- Be sure that air at the compressor intake is cool and free from flammable gases, vapors, and dust.
- Do NOT permit wood or other flammable material to remain in contact with the air discharge pipe.
- Immediately secure a compressor when the temperature of the air discharge from any stage rises unduly or exceeds 400°F.
- Do NOT install a check valve or drop valve between the compressor and receiver unless a relief valve is also fitted between the compressor and the stop or check

valve. (If the compressor is started against a closed valve or defective check valve, an explosion can result.)

- Pressure gauges must be in working order unless you have to remove them for repair.
- NEVER kink a hose to stop the air flow, and always keep clamps on the hose tight.
- Keep compressor pipes and tanks clean to guard against an oil vapor explosion. Clean intake air filters periodically.
- Turn off the motor before adjusting and repairing an air compressor.
- Use only soapy water or another suitable nontoxic, nonflammable solution for cleaning compression intake filters, cylinders, or air passages. NEVER use benzene, kerosene, or other light oils to clean these portions of a system. These oils vaporize easily and form a highly explosive mixture under compression.
- Know what compressors can do and the real dangers associated with them, and then use them safely

3.9.5 Maintenance of Air Distribution Systems

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 prove costly to the Seabees. It also requires more extensive repair to system components. As a UT, you must be able to conduct various maintenance efforts. An understanding of the maintenance required for each component will assist you in carrying out this type of duty.

Distribution systems require a minimum of maintenance. Checking valve operation and hose connectors, draining condensation (manually or automatically), 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.* 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.

Commonly at a Public works division or in a camp maintenance unit Standing Job Orders (SJO) are established to maintain these types of equipment. When in doubt always refer to the manufactures instructions.

3.9.5.1 5.1 Monthly Inspection of Aboveground Systems

Inspect for the following items:

Leaks. It is very important that air distribution lines be kept free from leaks. A l/16-inch hole on an air line carrying compressed air at 100 psig pressure wastes approximately 2,200,000 cubic feet of air per year if operated continuously. This approximates the entire output of a 500 cubic feet per minute compressor operating during nine 8-hour days.

Look for moisture and dirt. Check traps, strainers and dehumidifiers for proper operation according to manufacturers’ recommendations and operating environment.

Abnormal Pressures. Insufficient pressure may indicate excessive leakage, line obstructions preceding the using station, clogged strainers, defective compressor operation or controls, or improper operation of pressure reducing stations. Excessive pressures may indicate malfunctioning of the compressor control, improper setting or defective operation of the air receiver safety valve, or malfunctioning of pressure reducing stations.

Excessive Pressure Drops. An overloaded pipeline or an obstructed line will show an excessive pressure drop.

Vibration. Vibration may be caused by inadequate or defective supports, and/or improper anchorage.

Corrosion. The external surfaces of air lines should be protected by corrosion-proof paint or by adequate covering.

Operation of Associated Equipment. Ensure correct operation of associated equipment, such as moisture traps, strainers, pressure reducing stations, dehumidifiers, and auxiliary equipment.

3.9.5.2 Yearly Inspection of Aboveground Systems

Inspect the following items:

Check for corrosion, leakage, loose joints, and damaged or missing supports of piping systems.

Settling or shifting of poles, hangers, or other supporting members. This can be determined by checking the grade of the lines.

Check valves for leakage, corrosion, defects in stems, packing glands, hand wheels, seats, bodies, flanges, and gaskets.

Valve pits for clogged vents, structural damage, missing covers, and accumulation of dirt and debris.

Condition of flanged fittings.

Condition of expansion joints, if any.

Condition of hangers, guides, supports, and anchors.

Condition of traps, strainers, dehumidifiers, and moisture separators.

Condition and adjustment of pressure reducing stations.

Setting of relief and safety valves.

Condition of air receivers.

Condition and calibration of instruments.

Test your Knowledge (Select the Correct Response)

3. Which desiccant compound is utilized in the air dryer?

   A. Silicon gel
   B. Camisole hemp
   C. Silica gel
   D. Agrium paste

Summary

As a UT, you will be involved with the installation, operation, and maintenance of prime movers, pumps, compressors, and compressed air systems. You must be capable of identifying and directing the proper construction techniques for installation of associated fittings and components.

You will also be involved in the maintenance of prime movers, pumps, compressors, and systems, including both preventive and corrective maintenance procedures. The information presented in this chapter will help you be effective in carrying out these responsibilities.

Review Questions (Select the Correct Response)

1. The mechanism or linkage that transmits the mechanical power developed by the prime mover is also known as what?

    A. Drive
    B. Crankshaft
    C. Starter
    D. Engine

2. Of the different types of AC motors available, which one will you primarily utilize?

    A. Stationary-field induction
    B. Rotating-field induction
    C. Stationary-field capacitance
    D. Rotating-field capacitance

3. What electrical principle is used to produce the mechanical rotation of a rotor?

    A. Electromagnetic capacitance
    B. Internal combustion
    C. Electromagnetic induction
    D. Internal distribution

4. The rotational speed of the stator field will remain constant unless which of the following occurs?

    A. Rotor rotational speed lowers.
    B. Induction motor fails to detect two or more out of time phase currents.
    C. Splash-proof motor casing develops a leak.
    D. Frequency of electric power source varies.

5. Split phase induction motors are designed to operate on how many phase currents?

    A. One
    B. Two
    C. Three
    D. Four

6. What is the primary purpose of the capacitor-start induction motor?

    A. To draw more current to maintain speed.
    B. To store electricity for more power during startup.
    C. To prevent moisture-laden air from entering motor casing.
    D. To produce continuous rotating magnetic field.

7. Which of the following bearings is NOT used with electric motors?

   A. Sleeve
   B. Roller
   C. Ring
   D. Ball

8. What is the result of any misalignment in excess of tolerances in the flexible coupling?

   A. Rapid wear of bushing pins
   B. Rapid wear of linkage
   C. Excessive motor casing vibration
   D. Stator winding wear down

9. What does a lack of springiness in a belt drive indicate?

   A. Pulley gear misaligned
   B. Too little tension
   C. Excessive grease on belt
   D. Too much tension

10. What does excessive belt rubbing on the sheaves indicate?

    A. Belt tension
    B. Pulley gear misaligned
    C. Belt slippage
    D. Excessive grease on belt

11. When replacing a drive belt on a multi-belt drive system, what must occur during replacement procedures?

    A. Replacement of faulty belt is required.
    B. All belts and pulley gear require replacement.
    C. Faulty belt and pulley gear require replacement.
    D. All belts require replacement.

12. When conducting cleaning procedures on a stator, which device should be used to remove dirt accumulations?

    A. Vacuum
    B. Low pressure air
    C. Soap and water
    D. High pressure air

13. Diesel engines convert what type of energy into mechanical energy?

    A. Chemical
    B. Heat
    C. Solar
    D. Hydraulic

14. What could result from sudden cooling of a diesel engine?

    A. Water jacket leakage
    B. Engine stall
    C. Crack cylinder heads
    D. Battery terminal cracking

15. What causes the formation of heavy carbon deposits in the piston rings?

    A. Lube oil pressure not constant after 30 seconds.
    B. Diesel engine at a fast idle for any appreciable length of time.
    C. Engine placed on load before temperature stabilization.
    D. Diesel engine at a slow idle for any appreciable length of time.

16. A diesel engine should be stopped if the lube oil pressure does NOT indicate positive pressure after what time frame?

    A. 30 seconds
    B. 45 seconds
    C. 1 minute
    D. 2 minutes

17. Once the diesel engine is secured, how long should cooling water remain circulating?

    A. 5 to 15 seconds
    B. 15 to 30 seconds
    C. 30 to 45 seconds
    D. 45 to 60 seconds

18. Most gasoline engines operate on a _ _ stroke cycle

    A. 2
    B. 3
    C. 4
    D. 5

19. When is the fuel mixed with air in a gasoline engine?

    A. After the air has been compressed
    B. Before the air is admitted into the carburetor
    C. After the compression stroke
    D. Before being admitted to the cylinder

20. How does the diesel engine produce combustion?

    A. Heat of compression
    B. Compression stroke
    C. Expansion stroke
    D. Mistakes in computations

21. **(True or False)** Pumps are used to move only water that flows or can be made to flow.

A. True
B. False

22. How many types of head are there in pump operation?

A. 2
B. 3
C. 4
D. 5

23. Which type of head is defined as the total pressure of the liquid entering the pump?

A. Net positive suction
B. Discharge
C. Total discharge
D. Suction

24. Which type of head is defined as the pressure of liquid leaving the pump?

A. Discharge
B. Net positive suction
C. Total discharge
D. Suction

25. Which type of head is defined as the net difference between the suction head and the discharge head?

A. Discharge
B. Total discharge
C. Net positive suction
D. Suction

26. Suction head is expressed in what form when a negative condition exists?

A. Feet of water
B. Temperature
C. Inches in mercury
D. Pounds per square inch

27. When the pump becomes vapor bound and the suction lift pressure reduces, what is this condition known as?

A. Vaporization
B. Condensation
C. Evaporation
D. Cavitation

28. What type of valve is used to permit liquid flow in only one direction?

A. Check
B. Gate
C. Butterfly
D. Globe

29. How are pump types classified?

A. By impeller blade size
B. By the type of movement causing their pumping action
C. By the material used in the gear housing
D. By the type of pump casing utilized

30. What is another term used for rotary pumps?

A. Reciprocating
B. Diaphragm
C. Positive displacement
D. Jet fusion

31. Which application is associated with rotary pumps?

A. Priming of smaller size pumps
B. Transport of JP-5 fuel
C. Pumping of sludge water
D. Chemical feed in water purification systems

32. Rotary pumps are classified by the type of ______.

A. rotating element employed
B. pumping action
C. material to be pumped
D. prime mover utilized

33. What materials are primarily transferred with a screw type rotary pump?

A. Sludge water
B. JP-5 fuel
C. Chemical feed water
D. Water

34. What needs to be opened on the rotary pump before the pump is started?

A. Vent valve
B. Bypass manifold
C. Discharge stop valve
D. Turbine supply valve

35. Which pump moves water by means of a piston that moves back and forth inside a cylinder?

A. Jet
B. Screw
C. Rotary
D. Reciprocating

36. Which of these elements is NOT used to designate the size of a reciprocating pump?

A. Vertical stroke pressure
B. Diameter of steam piston
C. Diameter of pump plunger
D. Length of stroke

37. Which type of reciprocating pump is most often used by the Seabees?

A. Simplex
B. Direct acting
C. Single acting
D. Double acting

38. Which pump is used to pump water from a ditch or sump?

A. Direct acting pump
B. Jet
C. Diaphragm
D. Sludge

39. Which type of diaphragm pump can handle liquids that contain sand or mud?

A. Hydro hog
B. Mud hog
C. Sludge hog
D. Water hog

40. What is another term for a reciprocating pump which has only one liquid cylinder?

A. Simplex
B. Duplex
C. Single acting
D. Double action

41. **(True or False)** As the velocity of a fluid increases, the pressure or pressure head of that fluid decreases.

A. True
B. False

42. Large multi-stage, high capacity centrifugal pumps are in what position?

A. Horizontal
B. Vertical
C. Parallel
D. Perpendicular

43. Most centrifugal pumps utilized by the Seabees have what type of impellers?

A. Open
B. Closed
C. Fused
D. Angular

44. What piece of equipment is NOT used in centrifugal pumps used for pumping sewage?

A. Impellers
B. Volutes
C. Diffuser vanes
D. Discharge stop valve

45. Which type of centrifugal pump is used to pump wells?

A. Volute turbine well
B. Sediment well
C. Jet
D. Turbine well

46. Centrifugal pumps are used in wells not exceeding which depth in feet?

A. 22
B. 28
C. 32
D. 38

47. **(True or False)** If steam is used to support the fire protection system, the pump must have a constant minimum pressure of 60 pounds of steam.

A. True
B. False

48. The violent collapse of vapor bubbles in the pump causes what condition?

A. Throttling
B. Grinding
C. Vibration
D. Cavitation

49. Which valve needs to be closed prior to starting a centrifugal pump?

A. Turbine bypass
B. Swing check
C. Valve control assembly vent
D. Discharge stop

50. Which of the following forms is NOT taken by pump packing?

A. Disk
B. Coils
C. Rings
D. Spirals

51. What type of material is used for the seal faces in water service pumps?

A. Rubber
B. Carbon
C. Silica
D. Plastic

52. Mechanical seals should be replaced when the leakage rate exceeds what amount?

A. 1 drop per minute
B. 2 drops per second
C. 5 drops per minute
D. 5 drops per second

53. What is used to level pumping units?

A. Elevation screws
B. High riser
C. Flange coupling
D. Jacking screws

54. On low pressure pumps, the wearing ring diametrical clearance is what value in inches?

A. 0.0015 to 0.0030
B. 0.0030 to 0.0045
C. 0.0045 to 0.0060
D. 0.0075 to 0.0095

55. What type of pump is exclusively used in well pumping?

A. Rotary
B. Air lift
C. Water lift
D. Reciprocating

56. What substance does an air lift pump use to move or lift a liquid?

A. Atmospheric air
B. Water
C. Compressed air
D. Hydraulic oil

57. The capacity of the air lift pump depends largely on what factor?

A. Allowable air inlet pressure
B. Water flow at outlet connection
C. Distance between pump inlet and outlet
D. Percentage of submergence of the foot piece

58. What effect does the increase of the discharge line have on the velocity of the discharge?

A. Decreases
B. Increases
C. Rapid decrease, then gradual increase
D. No effect

59. How long, in inches, are the bolts utilized in pump foundation setup?

A. 1/2 to 3/4
B. 3/4 to 1
C. 1 to 2
D. 2 to 4

60. What type of level is used in setting up the pump?

A. Engineers transit
B. Carpenters
C. Spirit
D. Potters

61. Angular alignment of pump setup is taken between which two pieces of equipment?

A. Flexible coupling and pump shaft
B. Pump shaft and pump foundation
C. Drive shaft and flexible coupling
D. Pump shaft and drive shaft

62. What is the recommended number of hours to wait for grout to harden before tighten foundation bolts?

A. 48
B. 24
C. 12
D. 6

63. What type of bolt is used with expansion joints associated with pump piping?

A. Foundation
B. Tie
C. Beveled
D. Self locking

64. What needs to be installed if the pump is operating under static suction lift conditions?

A. Pressure regulator
B. Valve control assembly
C. Foot valve
D. Vent valve

65. What type of valve is installed when two or more pumps are connected to the same suction line?

A. Swing check
B. Globe
C. Hook
D. Gate

66. **(True or False)** When installing valves in the discharge piping, you should install both a check valve and gate valve in the discharge piping.

A. True
B. False

67. What value is the pressure of flushing or lubricating liquid set above the maximum expected stuffing box operating pressure?

A. 1 to 5 psi
B. 5 to 10 psi
C. 10 to 15 psi
D. 20 to 30 psi

68. Within how many days of shipment is an installed pump packing considered good for operation?

A. 10
B. 25
C. 60
D. 100

69. The filter contained in a double seal mechanical seal must be capable of screening out all particles above how many microns?

A. 10
B. 15
C. 20
D. 25

70. What is the most common cause of overheating of pumps?

A. Excessive grease
B. Misaligned gears
C. Loose drive belts
D. Too much input power

71. For average operating conditions, it is recommended that 1 ounce of grease be added at what monthly intervals?

A. 1 to 3
B. 3 to 6
C. 6 to 9
D. 9 to 12

72. What is the maximum desirable operating temperature for bearings?

A. 120°F
B. 140°F
C. 180°F
D. 200°F

73. In installations with moderate temperature changes and humidity, the oil should be changed after approximately how many hours of operation?

A. 100
B. 120
C. 140
D. 160

74. What are air compressors sometimes referred to as?

A. Air breakers
B. Air pumps
C. Air chargers
D. Air sumps

75. The majority of air compressors used throughout the Seabees are driven by what power source?

A. Hydraulic oil
B. Water pressure
C. Electric
D. Air

76. What causes the intake valve on an air compressor to open?

A. Discharge stroke
B. Piston motion upward
C. Cam action of valves
D. Suction stroke

77. The pistons contained within the air compressor are called by what terms?

A. Trunk or differential
B. Differential or distributive
C. Trunk or cylindrical
D. Connecting or trunk

78. Which piston minimizes cylinder wall wear?

A. Connecting
B. Trunk
C. Distributive
D. Cylindrical

79. What piece of equipment on compressors allows for the unloading and control systems to be integrated?

A. Throttle intake valve
B. Cylinder clearance manifold
C. Constant speed control
D. Unloader valve arrangement

80. When the compressor reaches near normal speeds, the solenoid valve will be in what state?

A. Deenergized
B. Voltage seeking
C. Frequency shifting
D. Energized

81. **(True or False)** Intercoolers cool the compressed air charge before it is drawn into the next cylinder.

A. True
B. False

82. As the second stage cartridge on a compressor engine loads up with dirt, what color indicator will be displayed to the operator?

A. Black
B. Red
C. White
D. Yellow

83. What assures rapid warm-up and optimum compressor performance over a wide range of surrounding air temperatures?

A. Thermostatic valve
B. Bypass
C. Combination of thermostatic valve and bypass
D. None of the above

84. Compressed air falls into how many different categories?

A. None
B. 1
C. 2
D. 3

85. A low pressure air system delivers air up to how many psig?

A. 125
B. 700
C. 1250
D. 4500

86. What is the upper psig value of a high pressure air system?

A. 4000
B. 6000
C. 8000
D. 10000

87. What is a typical application associated with a medium air pressure system?

A. Wind tunnel
B. Crane drive
C. Hydraulic lifts
D. Catapults

88. What type of pipe is used in low and medium air pressure systems?

A. Brass
B. Seamless steel
C. Cooper
D. Black steel

89. Aboveground pipe is pitched downward a minimum of how many inches per 100 feet of length?

A. 3
B. 4
C. 5
D. 6

90. How many different types of air filters are used in air compressors?

A. 1
B. 2
C. 3
D. 4

91. What three types of dryers are used with air compressors?

A. Absorption, refrigeration, and descendant
B. Descendant, deliquescent, and absorption
C. Refrigeration, deliquescent, descendant
D. Absorption, refrigeration, and deliquescent

92. What action is required when the air discharge temperature on the 1st stage exceeds 400°F?

A. Secure compressor.
B. Increase coolant flow.
C. Replace filter.
D. Decrease air inlet pressure.

93. Which inspection is conducted annually on aboveground systems?

A. Dirt accumulation in strainers
B. Condition of flanged fittings
C. Obstructed pipelines
D. Excessive leakage

Trade Terms Introduced in this Chapter

Electrolyte	Any substance that dissociates into ions when dissolved in a suitable medium or melted and thus forms a conductor of electricity.
Viscous	Having relatively high resistance to flow.
Volute	The spiral casing surrounding the impeller of a volute pump.
Chamfered	To cut off the edge or corner of; bevel.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Basic Machines, NAVEDTRA 12199, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

OSHA Regulations (Standards – 29 CFR)

Blueprint Reading and Sketching, NAVEDTRA 12014, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

Naval Construction Force Manual, *NAVFAC P-315,* Naval Facilities Engineering Command, Washington, D.C., 1985.

McPortland, J.E, and Brian J. McPortland, *National Electrical Code® Handbook,* 22d Ed, McGraw-Hill, NY, 2008.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Fluid Power, NAVEDTRA 12964, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

National Standard Plumbing Code-Illustrated, National Association of Plumbing-Heating-Cooling Contractors, Washington, DC, 2006.

Safety and Health Requirements Manual, EM-385-1-1, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

MIL-STD-17-1, Mechanical Symbols

International Plumbing Code 2009, International Code Council

International Mechanical Code 2009, International Code Council

R. Dodge Woodson, *Plumber's Quick-Reference Manual Tables, Charts, and Calculations,* 1st edition, McGraw-Hill, NY, 1996.

Fire Protection Handbook, 17th ed., National Fire Protection Association, Quincy, MA, 1991.

Maintenance and Operation of Air Compressor Plants, NAVFAC MO-206, Naval Facilities Engineering Command, Alexandria, VA, 1989.

Maintenance of Steam, Hot Water and Compressed Air Distribution Systems, NAVFAC MO-209, Naval Facilities Engineering Command, Alexandria, VA, 1989.

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Chapter 8

Sewage Disposal, Field Sanitation, and Water Treatment

Topics

To hear audio, click on the box.

Overview

This chapter provides you with basic information on definitions, requirements, materials, installation, and maintenance of the various types of sewer utilities in collecting and transporting raw sewage to the treatment facilities. Completion of this chapter will allow you to be able to discuss the purpose and use of wastewater treatment facilities in the Naval Construction Force.

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.

As a Utilitiesman, you will also perform major duties involving the treatment and purification of water so it is safe to use for drinking, cooking, and bathing. The operational unit cannot function without potable water, and a unit can lose its capabilities quickly if this task is not completed correctly.

Objectives

When you have completed this chapter, you will be able to do the following:

1. Identify the different classifications of waste water collection systems.
2. Describe maintenance procedures utilized for sewer maintenance.
3. Describe the different health hazards associated with waste water collection.
4. Describe the different types of waste water treatment facilities.
5. Identify the principles associated with cesspools.
6. Identify the principles for septic tanks.
7. Identify the principles of field latrines.
8. Describe the capabilities of soil leaching.
9. Identify the principles of leaching fields.
10. Describe the purpose, functions, and equipment associated with water treatment.

Prerequisites

None

This course map shows all of the chapters in Utilitiesman Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Utilities Equipment and Maintenance		
Air Conditioning		
Refrigeration		
Heating Systems		U
Steam Distribution Systems		T
Boilers		
Sewage Disposal, Field Sanitation, and Water Treatment		B
Prime Movers, Pumps, and Compressors		A
Plumbing Fixtures		S
Piping System Layout and Plumbing Accessories		I
Structural Openings and Pipe Material		C
Fundamentals of Water Distribution		
Basic Math, Electrical, and Plumbing Operations		
Plans, Specifications, and Color Coding		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for

review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.0.0 WASTE WATER COLLECTION SYSTEMS

1.1.0 Classifications of Drains

1.1.1 Sanitary Systems

Sanitary systems are designed to remove domestic sewage only. All surface or raw water should be excluded from the sanitary system to avoid treatment plant overloading. A typical sanitary collection system (*Figure 8-1*) consists of the following:

1.1.1.1 House Sewer

The house sewer connects a single building's sanitary plumbing facilities. It extends 3 to 5 feet from foundation to a common sewer, and is usually 4 to 6 inches in diameter.

1.1.1.2 Lateral Sewer

The lateral sewer connects to a branch or other sewer and has no common sewer ***tributary***.

1.1.1.3 Branch Sewer

The branch sewer serves a relatively small area.

Figure 8-1 — Sanitary collection system.

1.1.1.4 Main Sewer

The main sewer connects two or more branches.

1.1.1.5 Trunk Sewer

The trunk sewer has many branches and provides an outlet for a large area.

1.1.1.6 Interceptor Sewer

The interceptor sewer is a main line intercepting a number of main sewers and connecting to a treatment plant.

1.1.1.7 Forced Main

The forced main is a pipe carrying sewage under pressure from a pumping station.

- Requires pressure pipe, is sloped, and has a minimum size of 4 inches.
- Is self-cleaning, with a minimum velocity of 3 feet per second (fps).
- Has the disadvantage of creating dangerous gases.

1.1.1.8 Pumping Station

The pumping station is equipment that lifts sewage to a higher elevation, and is also known as a lift station.

1.1.1.9 Outfall Sewer

The outfall sewer is a treatment plant line leading to the final disposal point (bay, ocean, or river).

1.1.1.10 Manhole

The manhole is a sewer system component permitting a sewer system's inspection, repair, and cleaning (*Figure 8-2)*.

Manholes may be classified by the materials or form of construction. Four main types are widely used: precast concrete chamber rings, brick, concrete, or shafts (usually constructed from precast reinforced concrete segments). All manholes are constructed from 36 to 48 inches in diameter.

Precast concrete ring manholes have the widest application. The availability of precast concrete units and a standardized design allow for economic construction, particularly when combined with open trench construction of sewers.

Figure 8-2 — Standard drop in manhole.

Brick and concrete manholes are more appropriate to specific locations where constraints on sewer layout or site restrictions apply. Because of its incremental nature and easily manageable component materials, brick construction is often best suited for modifications to existing structures or new manholes on existing sewers in urban locations. Concrete construction is more likely to be used on open sites for large chambers at relatively shallow depths.

These three types of manhole structures are built from the base upwards. Construction is carried out within an oversized excavated area which must provide sufficient space to the outside of the structure to enable work to be undertaken externally.

Shaft manholes are also used for particular situations; they have a number of advantages which give them wide application and allow some standardization of design. The advantages are as follows:

- Construction can be undertaken in a wide variety of ground conditions.
- Construction to considerable depths (up to 130 feet) is possible.
- Shafts can be built in large sizes to suit complex sewer layouts, to accommodate large sewers, or to provide working shafts for tunneling or renovation works.
- The site area required for construction is relatively small and ground disturbance is minimized.

Shafts usually are constructed from the top downwards and are lined as excavation proceeds to provide continuous ground support.

When placing manholes, always refer to local codes and specifications, normally manholes are placed at the following intervals:

- 300 feet apart up to 8 inch sewer lines
- 500 feet apart for 15 to 48 inch sewer lines
- 600 feet apart for larger lines

1.1.1.11 Terminal Cleanout

The terminal cleanout is located at branch or lateral sewer ends. Used to clean, flush, or insert an inspection light, it is constructed of long radius cast iron soil pipe (CISP) fittings and pipe.

1.1.1.12 Catch Basin

The catch basin is used (1) in storm sewers to remove grit from waste, and (2) as an inlet or a receptacle for waste from several inlets.

1.1.2 Industrial Waste Systems

Classification of industrial wastes, according to their composition, depends on their source, chemical nature, corrosiveness, and response to stabilization by various treatment methods.

These wastes result from various manufacturing processes not normally found aboard Naval installations. These include the following:

- Food processing wastes
- Paper mills
- Textiles

- Petroleum plants
- Chemical wastes

Industrial collection systems deal with specific, adverse effects on the environment caused by manufacturing various organic and inorganic products. Industrial waste should have a separate facility and process do to the following:

- Oxygen depletion
- Foam production
- Toxic materials
- Excessive suspended solids
- Excess plant growth (aquatic)

1.1.3 Storm Drainage Systems

The design of a storm drainage system is similar to the sanitary system. It includes laterals, branches, interceptors, and forced mains.

It is commonly separated from the sanitary systems for several reasons:

- They are normally larger in size.
- Storm and surface drainage do not require treatment.
- If incorporated with sanitary sewer, they would overtax treatment facilities.

Storm drainage systems should be large enough to drain all surface water and to prevent damage to structures and grounds, and should not interrupt normal traffic flow.

Some municipalities still run on one set. Always refer to local codes to verify

1.1.4 Gravity Systems

The gravity system is the most economical system. Sewage flows on a descending grade from the source to the treatment facility. Slope must maintain a minimum velocity of 2 fps or 1/4 inch per foot for a standard system.

1.1.5 ombination Sewer

The combination sewer conveys both storm and sanitary waste.

1.2.0 Sanitary Drain Types

1.2.1 Soil Pipe

Soil pipe conveys the discharge of water closets and/or fecal matter regardless of other fixtures to the building drain or building sewer.

1.2.2 Waste Pipe

Water pipe conveys all other waste except fecal matter, and is generally smaller than soil pipe.

1.2.3 Soil and Waste Pipe

Soil and waste pipe are treated as a soil pipe.

1.2.4 Soil and Waste Stack

The soil and waste stack is that part of a drainage system which carries soil and waste and is vertical (offsets of 45° or less are treated as vertical).

1.2.5 Branch

The branch runs horizontal (offset more than 45° from vertical) and is treated as a branch depending on whether the drain is vertical or carries soil and/or waste to the main horizontal stack. Size of pipe computation is dependent on whether drain is vertical or horizontal.

1.2.6 Building Drain

The building drain is that part of the lowest horizontal piping of a building drainage system which receives and conveys the discharge from soil, waste, and drainage pipes from within the walls or footings of any building to the building sewer.

Both the cold-water inlet and the warm-water outlet are at the top of the tank.

2.0.0 SEWER LINE MAINTENANCE

2.1.0 Stoppages

When you are working with sewers, most of your troubles are with stoppages and breaks. A common cause of a stoppage in a sewer system is tree roots. Other causes include sand, gravel, greasy or tar-related materials, and other manmade obstructions.

2.1.1 Tree Roots

Plumbing problems from a plugged sewer line can be nasty. Often the cause of backup problems can be traced to tree roots that have invaded a sewer line (*Figure 8-3*). The tree roots are drawn to sewer lines as they constantly and randomly search for food and water resources. The roots enter very small cracks in the pipe joints and find the water and nutrients in sewage. This problem is very prevalent if trees are within 100 feet of the sewer line.

The best way to stop the roots that have joined the sewer is to convince them to go elsewhere by using copper sulfate (blue ***vitriol***) in the soil around the sewer line. Cutting devices, such as a revolving cutter or a cable-drawn cutter, may also be used.

Be advised, no method will provide a permanent resolution. Tree roots will return, so a comprehensive preventive maintenance program must be established.

Figure 8-3 — Tree root sewer stoppage.

2.1.2 Sand or Gravel

Flushing helps remove loose organic solids and sand or grit deposits from sewers. Flushing is not an efficient method of sewer cleaning unless a high velocity can be maintained between manholes on a short run; in other words, you depend on the high velocity for a complete scouring action of the sewer.

Flushing may be done by a number of methods, two of which are the pneumatic ball method or the revolving cup and auger method.

In pneumatic-ball flushing, inflate a light rubber ball, such as a beach ball or volleyball bladder, to fit snugly in the sewer, and place it in a small canvas or burlap bag with a light rope attached. Place the ball in the sewer, hold the line until the sewage backs up in the manhole, and allow the ball to move to the next manhole. When an obstruction is reached, the pressure pushes the ball against the crown of the sewer, causing a jet at the bottom (*Figure 8-4*). As much as 4 miles of sewer can be cleaned in 8 hours by this method, and it works for sewers up to 30 inches in diameter.

Figure 8-4 — Ball method of sewer flushing.

In the revolving cup and auger method, a sand cup with an auger is attached to flexible steel sewer rods to run through the sewer (*Figure 8-5*). The rubber cup is perforated to provide flushing action.

Figure 8-5 — Revolving cup and auger method.

2.1.3 Grease/Tar

Stoppages in sanitary sewers are commonly caused by fats, oils, and grease. Pouring food or industrial wastes down the drain results in the grease or oil coating the inside of sewers and restricting the flow of sewage. The buildup of grease in sewers eventually blocks the lines and causes sewage to back up. It can even cause discharges of raw sewage, threatening the public health.

High pressure cleaners (HPC) are the best equipment for servicing grease- impeded sewer lines. The sewer line section immediately downstream from the problem is flushed from downstream to upstream and from manhole/clean-out to manhole/clean-out. Flushing continues through each subsequent section until no more grease is encountered. Service of these potential problem sewer lines is done every three to six months, depending upon the amount of grease encountered.

2.1.4 Excessive Obstructions

Many people do not realize that sanitary sewer lines are designed to accept toilet paper and human waste ONLY. If you flush anything else down the drain line, regardless of what the manufacturers of those products state, you are asking for trouble. Do not flush the following items down your sewer line: feminine sanitary products, dental floss, Q-Tips, prophylactics, Handi-Wipes, baby wipes, diapers, dead goldfish (or other small deceased pets), paper towels, facial tissue. Introduction of this material in mass quantities is another cause for sewer stoppages and water treatment plant servicing.

Snaking and high velocity flushing to a central collecting point are the only methods of clearance.

Test your Knowledge (Select the Correct Response)

1. Which sanitary sewer system is used to connect two or more branches?

   A. Main
   B. Lateral
   C. House
   D. Trunk

3.0.0 HEALTH HAZARDS

3.1.0 Atmospheric

Sewer gas is a complex mixture of toxic and non-toxic gases that can be present at varying levels depending upon the source. It is formed during the decay of household and industrial waste. Highly toxic components of sewer gas include hydrogen sulfide and ammonia. Atmospheric gases are of the utmost importance for safety concerns.

Sewer gas also contains methane, carbon dioxide, sulfur dioxide, and nitrous oxides. In addition, chlorine bleaches, industrial solvents, and gasoline are frequently present in municipal and privately owned sewage treatment systems.

3.2.1 Bacterial

A sewage backup will commonly present a serious health hazard mainly caused by bacteria, viruses, and parasites. Sewage backup is dangerous due to the many ways it transmits diseases and the difficulty of predicting it.

Exposure to sewage or its products may result in a number of illnesses, including the following:

- ***Gastroenteritis***
- ***Hepatitis***
- Occupational asthma
- Infections of skin or eyes

3.3.1 Safety and Protection

Since micro-organisms are an inherent part of sewage, this hazard cannot be eliminated. However, a proper assessment of risk is required.

Exposure to sewage should be eliminated or minimized by using remote-controlled robotic cameras for sewer inspection, drying sludge before disposal, incinerating sludge, injecting sewage into land rather than spreading it, or damming and bypass pumping sewer sections prior to reconstruction.

The following measures can further reduce the risk of infection and illness:

- Ensure personnel are fully trained and understand the risks.

- Provide suitable personal protection equipment (PPE) that includes waterproof/abrasion-resistant gloves, footwear, and eye and respiratory protection.
- Provide adequate welfare facilities, including clean water, soap, nailbrushes, disposable paper towels, eyewash stations, and where heavy contamination is foreseeable, showers. For remote locations portable welfare facilities should be provided.
- Provide adequate first-aid equipment, including clean water or sterile wipes for cleansing wounds, and a supply of sterile, waterproof, adhesive dressings.

Remember to check with your unit safety officer and crew supervisor for any additional requirements or safety standards.

4.0.0 WASTEWATER TREATMENT FACILITIES

4.1.0 Wastewater Terminology

4.1.1 Activated Sludge

Activated sludge consists of sludge particles produced in raw or settled wastewater (primary ***effluent***) by the growth of organisms in ***aeration*** tanks in the presence of dissolved oxygen. The term "activated" comes from the fact that the particles are teeming with bacteria, ***fungi***, and ***protozoa***. Activated sludge is made up of sludge particles containing many living organisms which feed on the incoming wastewater.

4.1.2 Activated Sludge Process

The activated sludge process is a biological wastewater treatment process speeding up decomposition of wastes in wastewater being treated. Activated sludge is added to wastewater, and the mixture (mixed liquor) is aerated and agitated. After some time in the aeration tank, the activated sludge settles out by ***sedimentation*** and is disposed of (wasted) or reused (returned to the aeration tank) as needed. The remaining wastewater undergoes more treatment.

4.1.3 Aerobic Digestion

Aerobic digestion is waste breakdown by microorganisms in dissolved oxygen. Waste sludge is placed in a large aerated tank where ***aerobic*** microorganisms decompose the organic matter in sludge. This is an extension of the activated sludge process.

4.1.4 Anaerobic Digestion

Anaerobic digestion occurs when wastewater solids and water (about 5% solids, 95% water) are placed in a large tank where bacteria decompose the solids in the absence of dissolved oxygen. At least two general groups of bacteria act in balance: (1) ***Saprophytic*** bacteria break down complex solids to volatile acids, and (2) Methane Fermenters break down the acids to methane, carbon dioxide, and water.

4.1.5 Bacteria

Bacteria are microscopic living organisms consisting of a single cell. Most bacteria use organic matter for their food and produce waste products as the result of their life processes.

4.1.5.1 Aerobic Bacteria

Aerobic bacteria live and reproduce only in environments containing oxygen for their respiration (breathing), namely atmospheric oxygen or oxygen dissolved in water. Oxygen combined chemically, such as in water molecules (H2O), cannot be used for respiration by aerobic bacteria.

4.1.5.2 Anaerobic Bacteria

Anaerobic bacteria live and reproduce in an environment containing no "free" or dissolved oxygen. They obtain their oxygen supply by breaking down chemical compounds which contain oxygen, such as sulfate.

4.1.5.3 Facultative Bacteria

Facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials such as sulfate or nitrate ions. In other words, ***facultative*** bacteria can live under aerobic or anaerobic conditions.

4.1.5.4 Pathogenic Bacteria

Pathogenic bacteria, viruses, or ***cysts*** can cause disease (***typhoid***, ***cholera***, and ***dysentery***). There are many types of bacteria, however, which do not cause disease and which are not called ***pathogenic***. Many beneficial bacteria are found in wastewater treatment processes, actively cleaning up organic wastes.

4.1.5.5 Saprophytic Bacteria

Saprophytic bacteria are organisms (bacteria) living on dead or decaying organic matter. They help natural decomposition of the organic solids in wastewater.

4.1.6 Baffle

A baffle is a flat board, plate, deflector, guide, or similar device constructed or placed in flowing water, wastewater, or ***slurry*** systems to cause more uniform flow velocities, absorb energy, and divert, guide, or agitate liquids.

4.1.7 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is the rate microorganisms use oxygen in water or wastewater while stabilizing decomposable organic matter under aerobic conditions. In decomposition, organic matter serves as food for the bacteria, and energy results from its oxidation.

4.1.8 omminution (Shredding)

Comminution is a mechanical treatment process that cuts large pieces of waste into smaller pieces so they will not plug pipes or damage equipment.

Note

In terms of sewage, comminution and shredding usually mean the same thing.

4.1.9 Diffuser

A diffuser is a device (***porous*** plate, tube, and bag) used to break the air stream from the blower system into fine bubbles in an aeration tank or reactor.

4.1.10 Digester

A digester is a tank where sludge is placed to allow decomposition by microorganisms. Digestion may occur under aerobic or (more commonly) anaerobic conditions.

4.1.11 Disinfection

Disinfection is the process that kills most microorganisms in wastewater, including essentially all pathogenic bacteria. There are several ways to disinfect, with chlorine being most frequently used in water and wastewater treatment plants.

4.1.12 Dissolved Oxygen

Dissolved oxygen is molecular oxygen dissolved in water or wastewater, usually abbreviated DO.

4.1.13 Dissolved Solids (Filterable Residue)

Dissolved solids are solids in water or wastewater consisting mainly of inorganic salts, small amounts of organic matter, and dissolved gases that will pass through a filter with the water.

4.1.14 Distributor

The distributor is the rotating mechanism that distributes the wastewater evenly over the surface of a trickling filter or other process unit.

4.1.15 Effluent

Effluent is wastewater or other liquid (raw, or partially or completely treated) flowing from a basin, treatment process, or treatment plant.

4.1.16 Headworks

Headworks are the facilities where wastewater enters a wastewater treatment plant. The headwork may consist of bar screens, comminutors, a wet well, and pumps.

4.1.17 Imhoff Tank

The Imhoff tank is a deep two-story tank having an upper, continuous sedimentation chamber and a lower, sludge-digestion chamber.

4.1.18 Influent

Influent is wastewater or other liquid (raw or partially treated) flowing into a reservoir, basin, treatment process, or treatment plant.

4.1.19 Inorganic Waste

Inorganic waste is waste material such as sand, salt, iron, calcium, and other mineral materials which are only slightly affected by the action of organisms. Inorganic wastes are chemical substances of mineral origin, whereas, organic wastes are chemical substances usually of animal or vegetable origin.

4.1.20 Nutrients

Nutrients are substances required to support living plants and organisms. Major nutrients are carbon, hydrogen, oxygen, sulfur, nitrogen, and phosphorus. Nitrogen and phosphorus are difficult to remove from wastewater by conventional treatment processes. They are water-soluble and tend to recycle.

4.1.21 Organic Waste

Organic waste is waste material from animal or vegetable sources. Organic waste generally can be consumed by bacteria and other small organisms.

4.1.22 Percolation

Percolation is the movement or flow of water through soil or rocks.

4.1.23 Pollution

Pollution is any change in the natural state of water which interferes with its beneficial reuse or causes failure to meet water-quality requirements.

4.1.24 Pretreatment (Preliminary Treatment)

Pretreatment is the removal of metal, rocks, rags, sand, eggshells, and similar materials which may hinder the operation of a treatment plant. Pretreatment is accomplished using equipment such as rocks, bar screens, comminutors, and grit removal systems.

4.1.25 Primary Treatment

Primary treatment is the wastewater process that takes place in a rectangular or circular tank and allows those substances in wastewater that readily settle or float to be separated from the water being treated.

4.1.26 Scum

Scum is wastewater solids floating at the surface, buoyed up by entrained gas, grease, or other substances.

4.1.27 Secondary Treatment

Secondary treatment is the wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. Usually, the process follows primary treatment by sedimentation. The process commonly is a type of biological treatment process followed by secondary clarifiers that allow solids to settle out from the water being treated.

4.1.28 Seed Sludge

In wastewater treatment, seed, seed culture, or seed sludge refers to a mass of sludge containing very concentrated populations of microorganisms. When seed sludge is mixed with wastewater or sludge being treated, biological decomposition takes place more rapidly.

4.1.29 Septic Tank

The septic tank is the settling tank that retains the sludge in immediate contact with the wastewater flowing through it. Sludge is retained long enough to secure satisfactory decomposition of organic solids by anaerobic bacterial action.

4.1.30 Sewage

Sewage is the used water and solids from homes flowing to a treatment plant. The preferred term is “wastewater.”

4.1.31 Shock Load

The shock load is the arrival at a plant of waste which is toxic to organisms in sufficient quantity or strength to cause operating problems. Possible problems include odors and sloughing off of the growth or slime on the trickling filter media. Organic or hydraulic overloads also can cause a shock load.

4.1.32 Sludge

Sludge is the settable solids separated from liquids during processing, or deposits of foreign materials found on a stream bottom or any body of water.

4.1.33 Suspended Solids (Non-filterable Residue)

Suspended solids are (1) solids that either float on the surface of, or are in suspension in water, wastewater, or other liquids, and are largely removable by laboratory filtering, or (2) the quantity of material removed from wastewater in a laboratory test, also referred to as non-filterable residue.

4.1.34 Supernatant

Supernatant is liquid removed from settled sludge, and commonly refers to the liquid between the sludge on the bottom and the scum on the surface of an anaerobic digester. This liquid is usually returned to either the influent wet well or to the primary clarifier.

4.1.35 Tertiary Treatment (Advanced Waste Treatment)

Tertiary treatment is any process of water renovation that upgrades treated wastewater to meet specific reuse requirements. It may include general cleanup of water or removal of specific parts of wastes insufficiently removed by conventional treatment processes. Typical processes include chemical treatment and pressure filtration.

4.1.36 Weir

A weir is a wall or plate placed in an open channel used to measure the flow. The depth of flow over the weir can be used to calculate the flow rate, or a chart or conversion table may be used. A weir also is a wall or obstruction used to control flow (from clarifiers) to assure uniform flow and avoid short-circuiting.

4.1.37 Wet Well

A wet well is a compartment or room in which wastewater is collected. The suction pipe of a pump may be connected to the wet well, or a submersible pump may be located in the wet well.

4.2.0 Types of Waste Discharge

4.2.1 Domestic Waste

4.2.1.1 Organic Waste

- Soap and detergents
- Fecal discharges
- Food from garbage disposal
- Wastewater from sinks and showers

4.2.1.2 Inorganic Waste

- Domestic wastewater containing some inorganic matter

4.2.2 Industrial Waste

4.2.2.1 Organic Waste

- Vegetable and fruit packing
- Dairy processing
- Meat packing
- Oil refineries
- Paper and fiber mills

4.2.2.2 Inorganic Waste

- ***Chromium*** or copper
- Water softening processes (salt brine discharges)
- Gravel washing plants (soil, sand, grit)

4.2.3 Thermal Heated Waste

Generally this waste is associated with power-generating plants, refrigeration cooling water, and various industrial processes.

4.2.4 Radioactive (Nuclear) Waste

This waste is generated and controlled from hospitals, research laboratories, and nuclear power plants.

4.3.1 Effects of Untreated or Improperly Treated Wastes and Reasons for Treating Wastewater

Sludge and scum accumulations in receiving waters can be found in the following locations:

- Accumulated on banks of bodies of water
- Settled on the bottom of bodies of water forming sludge deposits
- Floated to the surface of a body of water forming scum rafts

Oxygen depletion of receiving waters causes aquatic and plant life to die due to the increase of wastewater. With this increase, bacteria begin to feed on the waste, causing oxygen levels to fall. Simply put, more waste equals less oxygen.

4.3.1 Human Health

If pathogenic bacteria are not treated and are deposited into receiving waters, the following diseases may occur:

- Typhoid
- Cholera
- Dysentery
- Polio

- Hepatitis

4.3.2 Reasons for Water Treatment

- Domestic use (human health)
- Aquatic life
- Recreational use
- Industrial use

4.4.0 Types of Solids in Wastewater

4.4.1 Total Solids

This is the total residue of solid waste contained in wastewater.

4.4.1.1 Dissolved Solids

This is residue which is filterable. It includes substances such as mineral and salt products.

4.4.1.2 Suspended Solids

This category is broken down into four separate areas.

4.4.1.2.1 Settlable Solids

Large-sized particles tend to settle more rapidly than smaller particles. The amount of settlable solids in raw wastewater should be estimated when designing plant equipment. Measuring settlable solids entering and leaving the settling basin helps calculate the basin's efficiency.

4.4.1.2.2 Non-Settlable Solids (Colloids)

Particles that do not readily settle out are known as non-settlable solids. Some have been calculated to settle one inch in five years.

4.4.1.2.3 Floatable Solids

Floatable solids are undesirable in plant effluents from an aesthetic viewpoint. Floatables in receiving waters may indicate inadequately treated wastewater.

4.4.1.2.4 Organic and Inorganic Solids

Organic solids include animal and vegetable matter, which can be very harmful to receiving waters.

Inorganic solids are materials such as sand, clay, grit, or eggshells.

Test your Knowledge (Select the Correct Response)

2. How many different categories are associated with suspended solids?

    A. 1
    B. 2
    C. 3
    D. 4

5.0.0 SEWAGE DISPOSAL PRINCIPLES/CESSPOOLS

Leaching 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 well's leaching capacity is exhausted when the solids accumulate and clog the soil (*Figure 8-6*). The use of chemicals in an effort to extend the useful life of a cesspool is NOT recommended.

5.1.0 Cesspool Uses

Various facilities are used for the treatment and disposal of sewage at installations where common sewers are not available.

Figure 8-6 — Typical cesspool.

These facilities include cesspools, septic tanks, and field-type latrines. Information on cesspools is provided below.

5.2.0 Operation

The primary function of a cesspool is to collect solid waste and discharge liquids to a leaching field. Sewage flows in from wastewater fixtures and leaches out into surrounding soil. As stated earlier, floating solids collect at the top of cesspool and settling solids collect at the bottom. The leaching capacity of the cesspool is exhausted when the solids accumulate and clog the surrounding soil.

Cesspools must be covered with plank at least 2 inches thick to keep personnel safe and to prevent the breeding of flies and mosquitoes.

5.3.0 Additions

When the first cesspool becomes filled, a second well may be constructed 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. Leaching cesspools should be placed at least 20 feet apart by out-to-out measurement of walls (*Figure 8-7*). Septic tanks may be placed advantageously ahead of a leaching cesspool in larger installations.

Figure 8-7 — Exhausted cesspool with addition.

5.4.0 Location and Construction

Leaching cesspools should be used only where the subsoil is porous to a depth of at least 8 feet and where the ground water is normally below this elevation. When they are located in fine sand, surrounding the walls with graded gravel can increase the leaching area.

5.5.0 Sizing of Cesspools

The required number and size of cesspools depend on the quantity of sewage and the leaching characteristics of the total extensor percolating area above the ground water table, including bottoms and sidewalls below the maximum flow line. The allowable rate recommended leaching test is provided in *Table 8-1*. Soils that require more than 30 minutes for a fall of 1 inch are unsatisfactory for leaching, and some other disposal method(s) must be used.

Table 8-1 — Cesspool allowable discharge rate.

Sizing Table	
Time for water to fall 1 inch in minutes	**Allowable rate of sewage in gallons per square feet per day**
1	5.3
2	4.3
5	3.2
10	2.2
30	1.1

6.0.0 SEWAGE DISPOSAL PRINCIPLES/SEPTIC TANKS

6.1.0 General Information

Septic tanks with tile fields or other methods of effluent disposal are most appropriate when naval activities are too small to justify a daily operator or when power installations and permanent pumping stations must be avoided, such as at an advanced based camp. In general, septic tanks are used for groups of up to 500 people, but consideration should be given to alternate forms of treatment when the group of people reaches the upper limit. Septic tanks do not require continuous operation, and may be sodded over near habitation without nuisance except during cleaning. However, their effluents become inferior with accumulations of solids and may need uneconomical dosages of chlorine before disposal into watercourses.

6.2.0 Design and Construction

Septic tank design should be simple. For emergency and temporary construction, septic tanks are made of wood or non-reinforced concrete with wood covers and baffles. Reinforced concrete construction is more suitable for permanent installations (*Figure 8-8*). All tanks must have two compartments, except the very small one from which solids can be bucketed without throwing the unit out of service. There are baffles only at the inlet and outlet ends, or pipes turned down to act as baffles to reach the cleaner liquid between the thick scum and sludge.

Figure 8-8 — Typical septic tank design.

Although elbows or tees may be used at inlet and outlet connections, straight connection or baffles are better for rodding (cleaning out). In most cases, wooden or concrete baffles, located approximately 18 inches from the inlet and outlet of the tank and extending 18 inches below and 12 inches above the flow line, are provided. Elevation 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 connection should be sufficiently buried or otherwise protected to prevent damage by traffic and frost. Inlets of small tanks may be vented to the surrounding area. Manholes should be provided over the inlet and outlet pipes and over the low points in the bottom of hopper type tanks, and the manholes should extend at least to ground surface.

Tank bottoms should slope gently to a low point to which the still broken-up scum can be flushed by hosing after the tank is partially empty.

6.3.0 Capacity/Sizing

The tank capacity should equal a full day's flow, plus an allowance from 15 to 25 percent for sludge capacity, with a detention time of 24 hours at the average rate of flow; for tanks serving a population approaching 500, allow a 23-hour detention period plus an extra 25 percent capacity for sludge. More capacity may be desired to store sludge longer and reduce the nuisance of frequent cleaning. The minimum desirable size of the tank is 1000 gallons. In constructing a septic tank, calculate its length at not less than 2 nor more than 3 times the width. The liquid depth should not be less than 4 feet for the smaller tanks and not less than 6 feet for the larger type tank.

6.4.0 Dosing Tanks

Dosing tanks with an automatic siphon to keep the disposal field from remaining saturated should be provided for all septic tanks handling sewage from 20 or more persons. When effluent is disposed of by tile fields, provide sand-filter trenches or open sand filter beds. Dosing tanks may not be necessary when disposal is into leaching trenches or when sewage is pumped in and out of a septic tank. Dosing tanks should be designed to discharge at 3 to 4 hour intervals at a volume equal to 60 to 75 percent of the distribution tile capacity. The high water level in the dosing tank should not be less than 3 inches below the liquid level in the septic tank.

6.5.0 Salt Water in Septic Tanks

Flushing with salt water slows sludge digestion in the septic tank when the salt concentration exceeds 1.2 percent. Fresh water and saline toilet wastes entering the tank separately rather than in mixture may cause shock changes, although these are lessened in warm climates by the continuous mixing and agitating action of ***gasification***. For better settling efficiency, a two-compartment tank should be used when saltwater wastes are discharged.

6.6.0 Septic Tank Inspection

Although properly designed septic tanks require little operating attention, they must be inspected periodically, the frequency being 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. When inspecting, make sure that the inlet and outlet are free from clogging, the depth of scum and sludge accumulations is not excessive (less than about 1/4 of total tank capacity), and the effluent passing to subsurface disposal is relatively free from suspended solids. Do not assume from a high concentration of suspended solids that septic tanks liquefy all solids, they never need cleaning, and the effluent is pure and free from germs. Perhaps 40 to 60 percent of the suspended solids are retained, and the rest is discharged in the effluent. A monthly inspection must be made to determine the depth of the scum and sludge, as excessive scum causes a high solids content and often considerable odor. Resting the tank digests this scum best, but hosing may break up excessive scum. Lime added to scum aids digestion. Scum with a large amount of grease should never enter the effluent pipe, and the scum layer should never extend below or near the bottom of the effluent baffle or drop pipe.

6.7.0 Safety Precautions

6.7.1 Health Problems

The following conditions can help prevent health problems caused by infection(s):

- Adequate toilet and washing facilities are made available.
- Emergency first aid is available.
- Employees are inoculated.

6.7.2 Mechanical Hazards

The following mechanical safety precautions should be taken when installing a septic tank system:

- Fencing, railing, and stairways as needed for personnel safety
- Protective guards and warning signs

6.7.3 Gas Hazards

The following conditions are associated with gases encountered with septic tanks:

- Serious fires may result from a buildup of gases.
- Asphyxiation may occur without the proper use of PPE.

Always check with local safety officers and Gas Free Engineer (GFE) prior to entering any septic tank for maintenance or inspection.

Test your Knowledge (Select the Correct Response)

3. At what percentage of salt concentration is salt water used in flushing to arrest sludge digestion in a septic tank?

   A. 1.1
   B. 1.2
   C. 1.3
   D. 1.4

7.0.0 SEWAGE DISPOSAL PRINCIPLES/FIELD LATRINES

7.1.1 General Information

The methods of human waste disposal will vary with the situation. At permanent and semi-permanent camps, water-borne sewage systems like those of our cities are provided away from these bases. Military units in the field must adopt the following devices that are generally used for disposal of human waste:

- Straddle trench latrines
- Deep pit latrines
- Mound latrines
- Bore hole latrines
- Pail or burn out type latrines
- Urine soakage pits

7.2.0 Latrine Construction

The following general rules apply to the construction of all types of latrines.

To ensure food and water will be protected from contamination, latrines should be built at least 100 yards from the mess area and the nearest water source. The latrine should not extend below the water level in the ground nor in a place where it may drain into a water source. Usually, latrines are built a minimum of 30 yards from the perimeter of the camp area but within a reasonable distance for easy access. At night, if the military situation permits, the area should be lighted. If lights cannot be used, a piece of cord or tape may be fastened to trees or stakes to serve as a guide to the latrine.

A canvas or brush screen should be placed around each latrine, or the latrine may be enclosed within a tent. In cold climates this shelter should be heated. The screen or the tent should have a drainage ditch dug around its edges to prevent water from flowing over the ground into the latrines. For fly control, these shelters should be sprayed twice weekly with an approved insecticide.

On the outside of each latrine enclosure a simple hand-washing device should be installed. This device should always be kept filled with water and should be easy to operate (*Figure 8-9*). This shows a simple hand-washing service installed outside a straddle trench latrine for 100 personnel.

Figure 8-9 — Straddle trench latrine for 100 personnel, with hand washing

Latrines should be policed every day. Certain unit personnel should be assigned the responsibility of ensuring that the latrines are being properly maintained.

When a latrine has been filled to within one foot of the surface, or when it is to be abandoned, it should be closed in the following manner. Spray the contents of the pit, the sidewalls, and the ground surface to a distance of two feet from the sidewall with an approved residual insecticide. Then fill the pit to the ground surface with successive 3-inch layers of earth. Pack each layer down and spray its surface with insecticide before adding the next layer. Then mound over the latrine pit with at least one foot of dirt. The purpose of this method of closing is to prevent any immature fly that may hatch in the closed latrines from getting out. The location of the latrines should be plainly indicated with a sign that is marked “CLOSED LATRINE” and date of closing.

7.3.0 Straddle Trench Latrines

A straddle trench latrine is dug 1 foot wide, 2 1/2 feet deep and 4 feet long. This will accommodate two personnel at the same time. The number of trenches provided should be sufficient to serve at least 8 percent of the unit strength at one time. Thus, for a unit of 100 personnel, at least 1.6 feet of trench, or 4 straddle trenches are needed (*Figure 8-8*). The trenches should be at least two feet apart. There are no seats in this type of latrine, but boards may be placed along both sides of the trench to provide better footing. Toilet paper should be placed on suitable holders and protected from bad weather by a tin can or other covering. The earth removed in digging is piled at the end of the trenches and a shovel or paddle is provided. This is done so that each person can promptly cover their excreta and toilet paper. When the unit leaves the area, or when the straddle trenches are filled to within one foot of the surface, the trenches should be closed and clearly marked as described above.

7.4.0 Deep Pit Latrines

The deep pit latrines are used with a latrine box. The standard type box provides four seats and is 8 feet long and 2 1/2 feet wide at the base (*Figure 8-10*).

Another type of latrine box used is shown in *Figure 8-11*, the only difference being, one is square and the other rectangular. A unit of 100 personnel requires 16 feet of latrine space, or two latrine boxes.

Fly-proof the holes with strips of wood or nail tin over them. Place a metal deflector inside the front of the box to prevent urine from soaking into the wood. The size of the pit to be dug will differ depending on which latrine design is used. For the type in *Figure 8-10*, dig the pit 2 feet wide and 7 1/2 feet long. This will give the latrine box 3 inches for support on all sides. Dig the latrine box in *Figure 8-11* 3 1/2 feet long and 3 1/2 feet wide to allow the 3 inches of support of all sides. The depth of the pit will depend on the estimated length of time the latrine is to be used. As a rough guide, allow a depth of 1 foot for each week of estimated use, plus 1 foot of depth for the dirt covering when closing the pit.

Figure 8-10 — Deep pit latrine.

Figure 8-11 — Four seat latrine.

Generally it is not advisable to dig the pit more than 6 feet deep because the walls may cave in. Rock or high ground-water levels often limit the depth of the pit. In some types of soil, a support of planking or other material for the sides may be necessary to prevent wall cave-ins. Pack earth tightly around the bottom edges of the box to seal any wall cave-ins. Pack earth tightly around the bottom edges of the box to seal any openings through which flies might enter. After digging the pit and before placing the boxes, excavate a 4-foot-wide margin around the pit to a depth of 6 inches, as shown in *Figure 8-12*. Lay a layer of oil-soaked burlap in this excavation, soak the excavated earth with oil, and then replace and tamp down the earth, to keep out surface water.

Figure 8-12 — Margin of oil-soaked earth around latrine boxes.

In order to prevent fly breeding in the pit and to reduce odors, it is necessary to keep the latrine box clean, the seat lids closed, and the cracks sealed; also, a good fly control program must be maintained in the area. The use of lime in the pit or the burning out of the pit contents is not effective for fly or odor control, and is not recommended. For fly control, spray the interior of the box and the contents of the pit twice weekly with a residual fly spray. Scrub the box and the seats of the latrine daily with soap and water. When a unit leaves the area, or when deep pit latrines are filled within one foot of the ground surface, close the latrine in the manner described above in Section 7.2.0.

7.5.0 Mound Latrines

This type of latrine may be used when a high ground-water level or a rock formation near the ground surface prevents the digging of a deep pit. A dirt mound makes it possible to build a deep pit latrine and still not have the pit extending into the water or rock (*Figure 8-13*). A mound of earth having a top of at least 6 feet wide and 12 feet long should be constructed so that a 4-hole latrine box may be placed on its top. The mound should be high enough to meet the pit's requirement for depth, allowing 1 foot near the base of the pit to the water or the rock level. Before building the mound, break up the area where it is to be placed, or plow it in order to aid seepage of liquids from the pit. Then build the mound in 1 foot layers. Roughen the surface of each layer before adding the next. When the desired height has been reached, dig the pit into the mound. It may be necessary to brace the walls with wood, sandbags, or other suitable material to prevent cave-ins. The size of the base of the mound will depend on the type of soil in the area; it should be made larger if the slope is too steep. It may be necessary to build steps up the slope. Fly-proof the mound latrine in the same manner as the deep latrine. Close it off in the same manner as the deep pit latrine also.

Figure 8-13 — Mound latrine.

7.6.0 Bored Hole Latrine

This type of latrine consists of a hole about 18 inches in diameter and from 6 to 20 feet deep, covered by a 1-hole latrine box (*Figure 8-14*). A converted metal drum may be sunk in the ground for use as a box. Remove both ends of the drum and fly-proof the seat cover with a self-closing lid made to fit the top of the drum. This type of latrine is satisfactory for small units, provided the necessary mechanical equipment for boring the hole is available.

7.7.0 Pail Latrine

A pail latrine may be built when conditions are such that a box latrine cannot be used, e.g., in populated areas, rocky soil, and marshes. A standard type latrine box may be converted for use as a pail latrine by placing hinged doors on the rear of the box, adding a floor, and placing a pail under each seat. If the box is located in a building, place it against the outer wall so that the rear of the box opens directly to the outside of the building (*Figure 8-15*). The seats and rear doors should be self-closing and the entire box made fly-proof. Make the floor of the box with an impervious material (concrete, if possible) and slope it toward the rear to facilitate rapid drainage of washing water. A urinal may also be installed in the latrine enclosure with a drainpipe leading to a pail outside. This pail also should be enclosed in a fly-proofed box. Clean the pails at least once daily, more often if necessary. The

Figure 8-14 — Bored hole latrine.

contents may be buried, burned, or disposed of by other sanitary methods. After cleaning, return the pails to the boxes with 1 inch of pine oil disinfectant or a similar type disinfectant.

Figure 8-15 — Pail latrine (within building or tent).

7.8.0 Other Types of Field Latrines

There are two additional types of field latrines, the 8-seat box type and 4-hole burn-out types. After placing the two 4-seat boxes, straddle a 3-foot by 7-foot pit with the oil-soaked burlap area extending approximately 18 inches around the pit as discussed for a 4-seat latrine. The depth should at least 4 feet if used for a 2-week period or less. Add 1 foot for each additional proposed week of usage. Provide surface water control by excavating a 4-foot by 6-inch deep pit around the entire enclosure.

Two trough urinals (4 feet x 6 inch types) are furnished with most 8-seat latrines. Urinals are mounted on a frame with a 2-inch drainpipe leading from the trough to a urinal seepage pit located outside the latrine. The 8-seat latrine can be expanded to 16 seats by adding more box latrines.

The 4-hole burn-out latrine is another type of field latrine. This type latrine is used at most advanced or temporary bases. The burn-out latrine is kept in an orderly condition (daily) by the camp maintenance personnel or an assigned sanitation crew; two personnel can effectively and efficiently dispose of the excremental waste of 500 persons. There are two easy ways of maintaining the burn out latrine: by spreading lime over the waste material, or by using diesel fuel to burn the waste material. Locate the burning pit for the waste materials so that the resulting smoke, fumes, odors, and blowing ashes will not interfere with any operations or the health and well-being of personnel.

The 4-hole burn-out type latrine is 2 feet high by 3 feet wide by 8 feet long. Both the front and back are 8 feet long, but the back portion has 2-feet by 2-feet clean- out doors for the catch drums.

Catch drums are 18 inches high with welded handles centered under each of the 4 openings.

7.9.0 Urine Disposal Facilities

These types of facilities should be provided for at least 5 percent of the entire command. For example, for 100 personnel, 5 pipe-type urinals would be required. When trough urinals are utilized, allow 100 feet of trough for every 100 personnel.

7.9.1 Urinal Soakage Pits

Urinal soakage pits are the best urine disposals in the field (*Figure 8-16*).

The pit should be 6 feet long by 6 feet wide. The depth is determined in the field, but the recommended depth is 6 feet, because a 6-feet seepage pit will handle 100 personnel or an 8-seat latrine.

Fill the pit with stones to within 6 inches of the top and then cover the stones with a piece of scrap canvas or dunnage. Drill two 6-inch vents with 1 inch holes drilled randomly. Construct an insect screen cover and place it on the sides of the excavated pit. The outlet of the urinal trough should be at the same level as the stones. Once this is done, tamp 6 inches of oil-soaked earth over the scrap canvas or dunnage.

Figure 8-16 — Urinal soakage pit.

7.9.2 Pipe Urinals

For this type of urinal, use pipe material at least 1 inch in diameter, and extend it at least 8 inches below the surface of the pit (*Figure 8-17*). Construct the pit with the same dimensions as the urine seepage pit.

Place urine tubes at each corner of the pit and halfway between the corners. Place a funnel of tar paper, sheet metal, or similar material in the top of the pipe. Extend the pipes at least 30 inches above the ground surface. Fill the funnels with grass or straw, and change them daily, to keep out flies.

Figure 8-17 — Typical pipe urinal soakage pit.

7.9.3 nal Troughs

The urinal trough should be 1 foot wide by 4 1/2 inches long and approximately 8 inches deep. Construct the trough out of 24-gauge sheet metal, and the frame out of lumber.

7.10.1 Proper Operation of Urine Disposal Facilities

Adhere to the following guidelines for the proper operation of urine disposal facilities:

- Use the trough or pipes; do not urinate on the surface of the pit.
- Change the straw or grass daily and burn or bury the old material.
- Wash the funnels or trough daily with soap and water.
- Replace the funnels when necessary.
- Do not let oil or grease into the pit; these will cause clogging and necessitate digging a new one.
- If the latrine is located some distance from the sleeping area:
  - A large can or pail can be placed at a convenient location for use at night.
  - Empty it into the soakage pit every morning.
  - Wash it with soap and water before reusing it.
- When the soakage pit is abandoned or is clogged:
  - Spray it with an approved insecticide.
  - Mound it over with 2 feet of earth.
  - Mark it with a sign labeled “Closed Soakage Pit.”

8.0.0 SOIL LEACHING CAPABILITIES

This section will provide you with knowledge needed to perform a percolation test, and utilizing the results of that test, to determine the number and size of cesspools required to support a given number of personnel, and to determine the size leaching field required for a given size septic tank.

8.1.1 Planning and Locating Sewage Disposal Systems

Soil conditions for a proposed sewage disposal system are determined through percolation tests performed at the proposed site. Percolation tests determine a soil's ability both to filter liquid in a downward direction and to absorb water.

Soils with good leaching abilities include the following types:

- Sandy
- Porous
- Loamy (consisting of sand, clay, silt, and organic matter)

Undesirable qualities of soil being considered for a sewage disposal system include the following:

- Clay consistency
- Poor water absorption rate
- High water table which will not allow liquid to be absorbed

The topography of the site should provide easy gravity flow from the building to the septic tank and distribution field. A well drained, level area is preferred to a sloping ground area.

The location of the sewage disposal system is very important. It should be placed a safe distance from your water supply system. It is imperative that you notify your medical department representative for placement and camp regulations before starting your projects to avoid rework. The National Plumbing Code (NPC) handbook calls for cesspools and septic tanks to be located at least 100 feet from water supply systems and 10 feet from buildings.

8.2.1 Sizing Disposal System

Use the percolation test results to determine the fall per minute rate and soil quality.

Perform the percolation test (*Figure 8-18*) as follows:

- Dig a pit one-half the proposed depth of the cesspool.
- Dig a test hole 1 foot x 1 foot x 1 foot at the center of the bottom of the pit and pound a stake in the center bottom of the hole and mark in 1" increments to the 6" mark.
- Fill the test hole with 6 inches of water.
- Allow the water to drain off.
- Add another 6 inches of water to the test hole.
- Express the downward rate of percolation in minutes.

Figure 8-18— Sizing disposal system.

When sizing cesspools, use the per capita value system in relation to the percolation test results. Remember, use 25 gallons per day for advanced base camps. Use *Table 8-2* for sizing cesspools.

Table 8-2 — Cesspool sizing table.

TIME FOR 1 INCH FALL	ALLOWABLE SEWAGE RATE
1 minute	53 gallons/square feet/day
2 minutes	43 gallons/square feet/day
5 minutes	32 gallons/square feet/day
10 minutes	22 gallons/square feet/day
30 minutes	1.1 gallons/square feet/day
Soils that require more than 30 minutes for a fall of 1 inch are unsatisfactory for leaching and some other method should be used.	

When sizing leaching fields perk test results in relation to septic tank size. Utilize *Table 8-3* for sizing leaching fields.

Table 8-3 — Leaching fields sizing table.

TIME FOR 1 INCH FALL	ALLOWABLE SEWAGE RATE
1 minute	4.0 gallons/square feet/day
2 minutes	3.2 gallons/square feet/day
5 minutes	2.4 gallons/square feet/day
10 minutes	1.7 gallons/square feet/day
30 minutes	0.8 gallons/square feet/day

Test your Knowledge (Select the Correct Response)

4. Which test is used to determine the fall per minute rate of a disposal system?

   A. pH
   B. Harness
   C. Percolation
   D. Salinity

9.0.0 SEWAGE DISPOSAL PRINCIPLES/LEACHING FIELDS

9.1.1 Tile Fields (Leaching Fields)

Tile fields (more commonly known as leaching fields) are used to dispose of settled sewage into the surrounding ground. The following construction materials are used during erection of tile fields:

- Concrete (open joints)
- Clay tiles (open joints)
- Perforated polyvinyl chloride (PVC) pipe
- Fiber pipe (orangeburg), which has the following advantages:
  - Light weight
  - Easily laid in trench
  - Pipe size ranging from 2 inches to 8 inches in diameter
  - Lengths from 5 feet to 8 feet long
  - Particularly valuable in soil where other types may settle unevenly

9.2.1 Proper Functioning of Tile Field

To have a properly functioning tile field, the following conditions must be met:

- Groundwater well below the level of the field
- Soil of satisfactory leaching characteristics within a few feet of the surface, extending several feet below the tile
- Sub-surface drainage away from the field
- Adequate area for tile field installation

- Freedom from the possibility of polluting drinking-water supplies, particularly shallow dug or driven wells

9.3.0 Testing

A soil leaching test should be conducted at the proposed site of the tile field. The test is the same as for cesspool leaching except the test hole extends only to the approximate depth the tile field is to be laid. If there is a possibility of a large area tile field, several tests need to be conducted to determine the best location and average conditions should exist during testing.

You can derive the rate of sewage application to the total bottom area of the trench from the test results. A result of over 30 minutes from the drop of 1 inch of water in the test hole would indicate an unsatisfactory tile field location, and some other method of sewage disposal will need to be used.

9.4.1 Trench Width

The minimum widths of trenches depend on the soil where the trench will be constructed. The following soil types determine trench width:

- Sand and sandy loam, 1 foot
- Loam and sand and clay mixture, 2 feet
- Clay with some gravel, 3 feet

9.5.0 Pipe Size

The recommended inside diameter pipe size is 4 to 6 inches. Larger pipe has a greater storage capacity for solids, as well as a larger area at the joint for the solids to escape into surrounding gravel. Remember, pipe size should provide for the adequate handling and storage of some solids, and for the elimination of clogging near joints.

NOTE

There should be a containment area for solids to be collected before liquid waste can enter the tile field, however some solid materials may enter so pipe sizes should be adequate to handle it.

9.6.0 Laying the Pipe

9.6.1 Type of Pipe

9.6.1.1 Fiber Pipe

Fiber pipe must have a 3/8 inch clear opening between the joints, with tar paper covering the top part of the joint.

9.6.1.2 Bell and Spigot

Wood block spacers are required along the bottom two thirds of joints.

9.6.2 Slope

There must be a slope of 6 inches per 100 feet when discharge is taken directly from septic tank, and 4 inches per 100 feet when it is from a dosing tank.

9.7.0 Tile Beds

Lay tile beds 6 inches deep on a bed of screened coarse gravel, with 3 inches of coarse gravel around and over the pipe. Coarse screened stone or gravel passing through a 2 ½-inch mesh screen and retained on a ¾-inch screen is highly recommended.

Place a 3-inch layer of medium screened gravel over the coarse stone layer. Once the middle layer is complete, place a 3-inch layer of either fine or screened gravel, or suitable bank run gravel, over the medium stone layer. Then backfill the tile bed area with earth, and grade it

9.8.0 Layout of Leaching Fields

The layout of any leaching field needs to be carefully planned and designed. The lengths of ***lateral*** runs should be no greater than 75 feet.

When tile is laid in sloping ground, the flow must be distributed so that each lateral gets a fair portion of waste, the flow is prevented from discharging down the slope to the lowest point, and individual lines are laid as nearly parallel as possible to land contours. Tile fields are commonly laid out in either a herringbone pattern or with laterals at right angles to the main distributor.

The distance between laterals is 3 times the width of the trench. The most economical type trench is usually 24 inches wide or more.

9.9.1 Types of Distribution Boxes

Distribution boxes are designed to distribute effluent evenly to each distribution line or section of the leaching field. The design of the boxes varies with the size and design of the field.

Materials used in the construction of distribution boxes are as follows:

- Wood for temporary or emergency
- Brick or block for permanent use

Piping leading out of the box must be sealed to prevent surface water from filling the box and flooding the distribution lines.

9.10.1 Protecting the Tile Field

Take the following actions once the field is set:

- Protect the tile field from being crushed or damaged.
- Construct a fence around the tile field.
- Post signs to warn personnel that a tile field is in the area.
- Do not plant trees or shrubs over the tile field, as roots tend to clog the tile lines.
- Do plant grass over the lines, as this aids in the removing of moisture and keeps the soil open.

10.0.0 WATER TREATMENT

Water is never absolutely pure. Impurities in water vary from dissolved gases, chemicals, and minerals, to suspended matter like disease germs and dirt. Some impurities can be seen and some cannot; others can be detected by taste or odor or only by laboratory tests. This section will explain the water cycle, quality of water, chlorination equipment, water treatment quality control, and water testing procedures. Water treatment is vital to the health and well-being of the troops. Improper treatment of water can allow the spread of infectious intestinal diseases and skin fungus. The unit commander and the Navy Medical Service share the responsibility of ensuring a supply of pure water in the Seabees. As an Utilitiesman, you will perform major duties involving the treatment and purification of water so it is safe to use for drinking, cooking, and bathing.

10.1.1 Water Cycle

Water is circulated from the oceans to the atmosphere by a series of processes and then to the surface of the earth and beneath it. This is known as the water cycle, or hydrologic cycle (*Figure 8-19*). You need to understand these processes and their relationships to each other and to groundwater. Basically, the cycle consists of the following processes:

Figure 8-19 — The hydrologic cycle.

- Evaporation of water from oceans
- Condensation of the water to produce cloud formations
- Precipitation of rain, snow, sleet, or hail upon the land surface
- Dissipation of the water by direct runoff into lakes and streams
- Seepage, or infiltration, of rainwater or melted snow into the soil and then into underlying rock formations
- Movement of water through the openings in the rocks and at the surface through springs, streams, and lakes
- Direct evaporation

The cycle usually does not progress through a regular sequence and may be interrupted or short circuited at any point. Moisture that condenses over the ocean may fall into it as rain. Rain that falls upon a heavily forested area soon may return to the atmosphere by direct evaporation or through transpiration by plants. Jungle-covered islands of the Southwest Pacific are known to produce more evaporation than adjacent areas of ocean. Water that seeps into the soil may be retained for a time by soil capillarity or other means before moving downward through the unsaturated zone to become a part of the groundwater.

As the rainfall and water cycle repeats itself, depending upon climatic and other conditions, a water supply is built up that can be captured and used for a multitude of purposes. Roughly, this basic water supply is divided into two categories--surface water and groundwater.

10.1.1 Surface Water

Surface water is water that is flowing in our streams or rivers, resting in our lakes and ponds, or flowing into the sea. Its origin lies in the water that falls from the atmosphere, together with that which flows from the ground under certain circumstances. The water precipitated upon the surface of the earth from the atmosphere can be in the form of rain, snow, sleet, fog, or dew. Depending upon the character of the soil, this precipitated moisture is partly absorbed by the soil, or partly evaporated or transpired by plant growth, with the remainder caught in surface depressions or flowing over the surface to natural stream beds where it continues on its way to the sea or into the crevices of the earth.

It was once thought that the vast underground water storage reservoirs were tied by surface streams. This is only partly true. In many cases where geological conditions permit, the groundwater sources feed the stream instead. It is true that the underlying beds of some surface streams are composed of sand and gravel, and that other materials were deposited through the ages by sedimentation or glacial action. In these cases, water from the stream sometimes trickles down by gravity through the stream bottom into the underlying sands or gravel. When this happens, the water in the bottom gravel generally flows in the same direction as the stream itself. In other cases, it may be held in storage by natural barriers in the path of its flow. These underlying sands and gravel, generally referred to as ***alluvium***, are discussed in the section covering groundwater. In many cases, riverbeds become completely dry while the flow through the alluvium continues. This occurs in many cases in the western sections of the United States and on the Pacific Coast of North America.

10.1.2 Groundwater

Groundwater is water or moisture that has fallen from the atmosphere upon the surface of the earth and has been absorbed by the soil and collected below a certain level called the waterline. The waterline is of utmost importance and interest. The uppermost part of the surface of the earth is composed of layers of various materials. There is a layer of topsoil capable of sustaining plant growth. This topsoil is composed of minute particles of rock mixed with decayed vegetable matter or other material.

A layer of material generally referred to as “soil” underlies the top soil. Soil is composed of minute particles of rock mixed with various materials, sometimes of vegetable or animal origin, but often containing nothing more than materials of mineral origin. The depth of the soil bed is not fixed and may vary from a few inches to several feet.

Under the soil layer is the top layer of rock which is decomposed in some measure and which at a deeper level becomes more solid. Ultimately this rock becomes solid, as it was in the original cooling process. That part of the crust of the earth between this solid rock and the surface of the earth is of interest in discussing groundwater. Again, the depth of this outer layer is a variable because in many locations the virgin rock appears at the surface with no overlying decomposed rock or soil. Groundwater, of course, could not be found at such locations.

Now, consider the layer of decomposed rock which is between the uppermost layer of soil and the solid or virgin rock itself. Here, during the ages, many things have happened. The action of the elements, atmospheric conditions, earthquakes and upheavals, volcanic action and chemical reactions, as well as pressure conditions and other influences, have caused this layer to become anything from a semisolid rock to a conglomeration of layers of various materials. These layers of materials are referred to as “strata.”

The layers normally follow the contour of the surface of the earth; however, in some cases, they outcrop at the surface and slant downward. These strata may be composed of sand, gravel, broken stone of all sizes and character, minerals of all kinds, and even layers of solid rock. Some of the softer materials are shales, chalk, clays, and ***gypsum***. The harder materials consist of limestone, granite, ***quartzite***, flint, ***silica***, ***dolomite***, and other minerals. The types of material depend on the geographical location and the conditions under which the topmost layers of rock were formed. In the formation process, because of earth movement and other influences, these varying strata were bent, folded, and broken in such fashion that it is not possible to follow their exact course through the upper part of the crust of the earth. Their presence and their position relative to each other are important to the storage and production of groundwater.

Depending upon the composition of these various strata, they either absorb the water which falls from the sky or flow at a level above them, or they reject this water and form a bed upon which the water flows in one direction or the other. The capacity of the material composing any stratum to transmit water under pressure is called its “permeability.” The property of the material of any stratum to contain interstices, or openings, is called its “porosity.” Both the permeability and porosity of the rock formation determine whether groundwater can be found in suitable amounts at any particular location.

When water falls on the ground, the part of it that becomes groundwater by reason of the soil or surface characteristics is absorbed into the earth. It is then either held in suspension or flows downward by gravity to a point beyond which it cannot pass. It then flows in any direction allowed by the permeability of the particular stratum holding it. When the permeability of the stratum does not permit flow, the water remains confined at that point. As more water percolates downward through the soil or rock, the top level of the confined water rises until flow becomes possible in one direction or the other through a more permeable formation. More water must come from a higher level to sustain such a flow.

Finally, the amount of water percolating from the higher levels balances the amount of water flowing laterally away, and the top level of the main body of groundwater is stabilized. The upper surface of this main body of groundwater, when stabilized under any condition of flow, constitutes the water table for any specific locality. However, the water table is not fixed because it rises and falls according to the varying amounts of water percolating from above (called the “influent” supply) and those amounts flowing away or withdrawn (called the “effluent” flow). A stratum that bears groundwater is termed an aquifer.

Water beneath the surface of the earth occurs in three zones (*Figure 8-20*):

Figure 8-20 — Classification of underground water.

1. The zone of soil moisture is where water is temporarily held in pore spaces by capillarity and other soil conditions. Water in the zone of soil moisture may evaporate directly or through transpiration by plants, or it may percolate downward into the zone of aeration and then to the zone of saturation.
2. The zone of aeration, or zone of percolation, is beneath the soil layer where both water and air are present in the pore spaces. Wells ending in the zone of

aeration produce no water. Sometimes in the cooling-off process or because of other external and internal influences, a stratum of material that does not permit the passage of water has been heaved about into a cup-shaped formation at a point in the zone of aeration higher than the established water table. In time, this cup is filled with groundwater and a “perched” or false water table is established. This is a serious problem to those attempting to develop a groundwater supply. The perched supply, if pumped, is soon exhausted and requires seepage from above for replenishment. Many of these perched supplies result from folded clay formations in the zone of aeration that stop the percolation of water downward. Perched water never forms a dependable water supply.

3. The zone of saturation is where all pore spaces are filled with water. The top of the saturated zone is called the water table. It is not flat, but has a variable depth beneath the surface, depending upon surface topography, rainfall, and direction of water movement, rock structure, and porosity. Permeable rocks in the zone of saturation yield water for wells.

10.2.0 Quality of Water

The quality of available water is very important. Whether the water comes from the surface or underground, the supply must suit its intended use. Either source may produce water with too high a concentration of mineral salts, color, suspended matter, incrusting or corrosive agents, or a bacterium that prevents the use of the water in its natural state for the purpose intended. If suitable water cannot be found, then other available sources must be used unless the water can be treated to remove those elements that make its direct use impossible. For human consumption, all harmful bacteria must be destroyed and the concentration of certain mineral salts and suspended matter reduced to a level that makes the water safe to drink or to use in preparing food.

Industries sometimes have to treat their raw-water supply to meet the requirements of the manufacturing processes. Boiler feedwater, for example, must often be treated to prevent sludge from forming in the boiler and ***scale*** from forming on the metal surfaces. Most towns and municipalities must treat their water supply by some method before distributing it as potable water. Water, whatever the source, must be available in quantity and quality to meet its intended use.

10.2.1 Waterborne Diseases

In this section, you will be given information on various diseases caused by the use of impure and unsafe water, as well as information on some of the methods of treatment and purification used in the field to eliminate impurities in water. Additionally, you will be introduced to types of purification equipment with which you, as a UT, should be familiar.

Water flowing over the surface of the earth picks up dirt, disease organisms, chemicals, and anything else in its path that can be dissolved or moved. Water that soaks into the ground loses many of its suspended impurities as it filters through the earth. Although the water becomes clearer, it dissolves minerals and other chemicals at the same time. Groundwater may be clear, but it is not pure and may contain harmful disease organisms and chemicals.

Waterborne diseases do not appear immediately after drinking contaminated water. Disease-producing organisms need time to grow and multiply inside a person before they cause illness. The time between drinking contaminated water and the appearance of the disease is called the ***incubation*** period. Absence of disease symptoms for several days after drinking untreated water is no guarantee that the water is pure. Lack of disease symptoms in the natives is no test either, as they may have become immune.

10.2.2 Impurities in Water

Any water supply can be a source of danger and destruction because of the many impurities often found in it. Impurities in water can be broken down into two major categories--dissolved impurities and suspended impurities. Dissolved impurities are organic or inorganic materials or chemicals that cause an unpleasant taste, color, or odor in the water. Suspended impurities include organisms as well as organic and inorganic materials that usually make the water turbid or muddy looking. Suspended impurities are usually more dangerous to health than dissolved impurities. The suspended impurities consist of mineral matter such as sand, silt, or clay; of disease organisms, such as bacteria or ***protozoa***; and of water plants, such as algae. It is absolutely necessary to remove or destroy the disease-producing organisms in water that will be consumed by people.

10.2.3 Types of Waterborne Diseases

Disease-producing organisms carried by water occur in two classes--those readily destroyed by chlorination and those that are chlorine-resistant. Although the chlorine-resistant organisms require careful treatment, they can be destroyed by purification methods. Waterborne diseases caused by dangerous organisms include typhoid, paratyphoid, cholera, amoebic dysentery, schistosomiasis, and diarrhea. The following discussion stresses continual care and inspection of the water supply, because waterborne diseases spread if not treated properly.

10.2.3.1 Typhoid Fever

Typhoid fever is an intestinal disease caused by the bacterium known as bacillus typhosus. Symptoms of this disease are rose-colored eruptions of the skin accompanied by a high fever (lasting about 4 weeks) and frequent bowel movements. Typhoid fever organisms are readily destroyed by field chlorination methods.

10.2.3.2 Paratyphoid Fever

Paratyphoid fever is similar to typhoid in its sources of infection and symptoms, and, like the typhoid bacillus, the organisms are readily destroyed by field chlorination methods. The incubation period is from 4 to 10 days. An attack gives the person immunity from a second attack of paratyphoid, but does not give immunity from typhoid.

10.2.3.3 Cholera

Cholera germs are discharged from the body in feces where they live for several days. When water in any form contacts this germ, it is carried along and multiplies.

10.2.3.4 Amoebic Dysentery

Amoebic dysentery is an infectious intestinal disease. The symptoms are eruptions of the skin and frequent bowel movements. This disease, which is caused by a small animal (amoeba) instead of bacteria, resists ordinary chlorination. It is carried by amoebic cysts that form in the intestines and then are discharged in the feces. The cysts (shell or sack) protect the amoebae and, when allowed to remain moist, they live for many days; however, drying destroys them. The ***diatomite*** filter removes the cysts, and super chlorination destroys the amoebae.

10.2.3.5 Schistosomiasis

Schistosomiasis is caused by a small worm that enters the body through consumption of contaminated water, or through the skin while a person is bathing or swimming in contaminated water. Eggs of this parasite (commonly called blood flukes) are discharged from an infected person through the urine or feces. In freshwater, these eggs hatch into very small, free-swimming larvae which are not infectious to humans. However, if these larvae can find freshwater snails to enter, they develop into the next form “cercariae,” and become highly infectious to human beings. In water, larvae can live for only 24 hours and cercariae for only 36 hours. The effective remedy is to destroy all the snails at the water source. Once the snails are destroyed, the cycle is broken and the disease ceases.

10.2.3.6 Diarrhea

Diarrhea is a name given to several intestinal diseases characterized by cramps and frequent bowel movements with watery feces. Inadequate sanitary protection of food and water can cause diarrhea. When the disease is caused by food, it is restricted to those who consume the contaminated food; however, waterborne infection is likely to be widespread. Proper chlorination measures will eliminate waterborne causes of diarrhea.

In addition to the specific waterborne diseases discussed above, there are several nonspecific disorders caused by impure water. One example is the staining or discoloring of teeth because of the presence of fluorides in drinking water.

10.2.4 Treatment and Purification of Water

Various methods of treatment and purification are used to eliminate impurities in water and make it pleasant to drink. You should be familiar with some of the principal methods, keeping in mind that safe, pure water is essential to naval operations everywhere. How well you carry out your duties in the treatment and purification of water concerns the health and welfare of all personnel using the water. Methods used in various combinations of field treatment and purification of water include coagulation, flocculation, sedimentation, filtration, and disinfection.

10.2.4.1 Flocculation

Figure 8-21 — Process of flocculation.

Coagulation is a formation of ***gelatinous*** particles in water as a result of chemical action. Flocculation is the combination of these particles into a heavy precipitate (floc) that absorbs color and entangles bacteria and other suspended matter as it settles. A common floc-forming chemical is aluminum sulfate (filter alum). When sufficient natural alkali is not present in the water to form a good floc, additional alkali (soda ash) must be added. *Figure 8-21* shows how flocculation works. Mechanical devices such as mixers, agitators, and baffles are an advantage in flocculation because they keep the precipitate suspended in the water long enough to produce a heavy floc.

10.2.4.2 Sedimentation

If you were to dip up a glassful of water from a moving stream and promptly observe its contents, you would probably discover a number of solid particles being held in suspension in the liquid. At first these particles are more or less equally dispersed, but as the water becomes still, they start settling to the bottom of the glass. The settling of solids in this manner is caused by the natural action of gravity. In the field of water treatment, clearing water of turbidity (foreign suspended matter) by this natural settling process is known as sedimentation. Sedimentation is accomplished in settling tanks where the water is held for a time to allow the floc to form and settle out the ***turbidity***. In conventional treatment, settling immediately follows flocculation. The ideal detention period for settling after slow mixing is about 1 1/2 hours.

10.2.4.3 Filtration

There are many types and methods used for water filtration, from silica (sand) to carbon (charcoal) and many manufactured filters utilizing closely spaced fibers. We will talk about a few of the more common filters.

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 a bed 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 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.

Another type of filter used in the filtration process is the diatomite. Because it is lightweight, this filter is widely used at overseas bases. It removes suspended matter from water by passing it through a porous mat of diatomaceous silica, which is the skeletal remains of tiny algae, called diatoms, found in marine deposits that have been lifted above sea level. The diatomite (also called diatomaceous earth or filter aid) is supported by a filter element, a supporting base porous enough to permit maximum flow. It is also fine enough to support the filter cake that coats the element. Diatomite filters are backwashed by reversing the flow of water and drawing filtered water through the filter to keep the filter output from falling off. The turbidity of the water is largely determined by the frequency of backwash.

Activated Carbon filters are also an extremely effective filter for removing impurities from water. They are selective in which impurities they block, for instance, they allow sodium to pass straight through but block organics. Carbon is a substance that has a long history of being used to absorb impurities and is perhaps the most powerful absorbent known to man. One pound of carbon contains a surface area of roughly 125 acres and can absorb literally thousands of different chemicals. Activated carbon is carbon that has a slight electro-positive charge added to it, making it even more attractive to chemicals and impurities. As the water passes over the positively charged carbon surface, the negative ions of the contaminants are drawn to the surface of the carbon granules.

10.2.4.4 Disinfection

Except in rare instances, all water supplies require disinfection. Disinfection is the chemical destruction of bacteria. Because of its economy, dependability, efficiency, and ease of handling, chlorine is almost always used for this purpose. For this reason, the term chlorination generally means the same as disinfection.

Disinfection is a necessary step in ensuring a safe water supply. All new, altered, or repaired water supply facilities must be disinfected before they are placed in service. Water from surface supplies may be disinfected before filtration or before coagulation and sedimentation to prevent the growth of organisms. This procedure is known as pre-chlorination. The water must also be disinfected after filtration to destroy organisms that still remain and to provide a safeguard against recontamination. This procedure is known as post-chlorination.

Chlorine is the disinfectant specified for Navy use. In the form of chlorine gas or hypochlorites that yield chlorine in water, chlorine is presently the only widely accepted agent that destroys organisms in the water and leaves an easily detectable residual that serves as an indicator of the completeness of treatment. The sudden disappearance of residual chlorine may signal contamination in the system. Under ordinary temperatures and pressures, chlorine gas is greenish yellow and is heavier than air. Its effectiveness as a disinfectant depends on the temperature and the hydrogen-ion concentration (pH) of the water to which it is added. Disinfecting action is faster at higher temperatures, but is retarded by a high pH. When the pH is above 8.4, the rate of disinfection decreases sharply.

Ozone, ***potassium permanganate***, ***bromine***, and iodine are also used to a limited extent as disinfectants. If excess lime is used for softening water, it makes the water alkaline and disinfects after about 10 hours of contact. However, the general applicability and economic advantage of chlorine have established it as the preferred disinfectant.

10.2.4.5 Chlorine Disinfection

Chlorine disinfectants are available in a number of different forms.

Liquid chlorine is liquefied gas under pressure and is shipped in seamless steel cylinders under the regulations established by the Interstate Commerce Commission (ICC). The standard sizes of shipping containers are 150-pound cylinders, 1-ton containers, and 30-ton tank trailers.

Each pound of liquid chlorine produces about 5 cubic feet of chlorine gas at atmospheric pressure and at a temperature of 68°F. A standard chlorine institute valve and a protective valve hood are screwed into the neck of each cylinder. The valve has a safety plug containing fusible metal that softens between 157°F and 162°F to protect the cylinder from bursting in case of fire. All cylinders must be factory tested every 5 years; 150-pound cylinders are tested at 500 pounds of pressure, and 1-ton containers are tested at 800 pounds of pressure.

High-test calcium hypochlorite is a relatively stable, dry granular solid or powder that is readily soluble to form a chlorine solution. It is furnished in 3- to 100-pound containers and has 65 to 70 percent available chlorine by weight. Because of its concentrated form and ease of handling, calcium hypochlorite is preferred over other hypochlorites.

Sodium hypochlorite is generally furnished as a solution that is highly alkaline, and therefore reasonably stable. Federal specifications call for solutions with 5 and 10 percent available chlorine by weight. Shipping costs limit its use to areas where it is available locally. It is also furnished as powder. The powder generally consists of calcium hypochlorite and soda ash that react in water to form sodium hypochlorite. Ordinary household bleach is a sodium hypochlorite solution containing 2.5 percent available chlorine and is sometimes used at small installations.

Chlorinated lime, also known as chloride of lime or bleaching powder, is seldom used in water disinfection. It is a mixture of calcium chloride and calcium oxychloride that yields about 35 percent available chlorine when fresh. It deteriorates rapidly in a hot, moist atmosphere and should be purchased in small packages that can be kept sealed. Chlorinated lime contains an excess of insoluble lime; therefore, the solution should be prepared in a separate container, the lime permitted to settle, and the liquid decanted into a separate tank for use.

10.2.4.6 Chlorine Terms

When chlorine gas is introduced into pure water, some of it reacts to form hypochlorous acid, and the rest remains as dissolved chlorine. These forms of chlorine are termed “free available” chlorine because their oxidizing and disinfecting ability is fully available. Because most natural water contains small amounts of ammonia and nitrogenous organic substances, free available chlorine reacts with these substances to form ***chloramines*** and other complex chlorine-nitrogen compounds. These forms of chlorine compounds are termed “combined available” chlorine because part of the chlorine oxidizing disinfecting ability is lost. Both free available chlorine and combined chlorine react with oxidizable substances in water until their oxidizing and disinfecting ability is depleted. The amount of chlorine consumed in reacting with organic substances in water in a given time (usually 10 minutes) is called the chloride demand. Chlorine remaining in excess of the chlorine demand is the total chlorine residual or residual chlorine. Residual chlorine is composed of both free available chlorine and combined available chlorine. The time elapsing between the introduction of chlorine and use of the water is 30 minutes, and is termed the “contact period.”

10.2.4.7 Bactericidal Effectiveness

The bactericidal effectiveness of chlorine depends upon the pH chlorine residual, contact period, and temperature. The pH value is a measure of the acidic or alkaline nature of the water. The pH of water is technically defined as the negative logarithm of the hydrogen in concentration. The pH value ranges from 0 to 14. A value of 7 is neutral. Values decreasing downward from 7 represent increasing numbers of hydrogen ions. Values increasing upward from 7 represent decreasing numbers of hydrogen ions. A low pH value indicates a very strong acid solution. A high pH value indicates a very strong alkaline solution. The alkalinity of water is the amount of “alkaline” substances in a given sample of water when titrating downward to a pH of 4.2 with sulfuric acid. The acidity of water is the amount of “acid” substances in a given sample of water when titrating upward to a pH of 4.2 with sodium carbonate. The pH value of natural water can vary from 3.4 to 9.0, depending on the impurities present in the water.

Figure 8-22 — pH scale.

The pH influences the corrosiveness of the water, the amount of chemical dosages necessary for proper disinfection, and the ability of an analyst to detect contaminants. The pH scale is shown in *Figure 8-22*.

Chlorine effectiveness increases rapidly with an increase in the residual. However, free available chlorine is 20 to 30 times as effective as combined chlorine under the most favorable conditions of pH (7.0) and water temperature (68°F to 77°F). Therefore, the relative amounts of free and combined available chlorine in the total residual are important.

Within normal limits, the higher the chlorine residual, the lower the required contact period. If the residual is halved, the required contact period is doubled. The effectiveness of free available chlorine at 35°F to 40°F is approximately half of what it is at 70°F to 75°F. The effectiveness of free chlorine is highest at pH 7 and below. At pH 8.5, it is one sixth as effective as at pH 7, and at pH 9.8, it may require 10 to 100 times as long for a 99 percent bacteria kill as at pH 7.

10.2.4.8 Points of Application

Plain or simple chlorination is the single application of chlorine as the only treatment before discharge to the distribution system, as in the chlorination of groundwater supplies and previously unchlorinated purchased supplies. Pre-chlorination is the application of chlorine to raw water before coagulation, sedimentation, or filtration. Post-chlorination is the application of chlorine after filtration, but before the water leaves the treatment plant. Rechlorination is the application of chlorine into the distribution system or into a previously chlorinated purchased supply to maintain the chlorine residual.

The above applications are normally continuous. Very heavy chlorination for a limited period is sometimes applied at specific points in the distribution system to destroy localized contamination.

10.2.4.9 Others Uses of Chlorine

Chlorine is also used to control tastes and odors in water. It reacts with the substances causing taste and odor, such as hydrogen sulfide, minute organisms, algae, and organic compounds.

If the reaction is incomplete, the taste and odor of some substances may be intensified or become more objectionable. Chlorine is also used to a limited extent to oxidize iron and manganese and to remove color.

10.2.4.10 Safety

Safety is important in the handling of chlorine. Some of the important precautions are as follows:

⚠ CAUTION ⚠

Chlorine is an impurity that we put in water to disinfect it. It is a corrosive poison and should be handled according to applicable safety instructions and procedures.

- Provide self-generating oxygen-breathing apparatus or self-contained oxygen-breathing apparatus designed to cope with chlorine.
- Maintain only the supply of chlorine in any chlorinator room that will do for normal daily demands. Store the main supply in a detached noncombustible building or in a fireproof room that is vented only to the outside and separated from the main part of the building. Keep the chlorinator and chlorine storage building or rooms

locked to prevent the entrance of unauthorized personnel and restrict these areas from any other use.

- Allow only reliable and trained personnel to handle chlorine.
- Handle containers carefully to avoid dropping or bumping them.
- Avoid hoisting containers; if hoisting is necessary, use safe lifting clamps.
- Store cylinders in a cool place, away from dampness, steam lines and fire, and in an upright position secured from tilting and falling.
- Keep protective valve caps on containers when not in use; never tamper with safety devices on containers.
- Never connect a full cylinder to a manifold with another cylinder unless the temperatures of both are nearly the same.
- When not withdrawing chlorine or when cylinders are empty, keep the valves closed.
- Disconnect the valves as soon as the containers are empty, and check for chlorine leaks at the valve outlets. Test for leaks by passing an opened bottle of strong ammonia solution around the valve. White fumes of ammonium chlorine will appear if there is any leakage. Leaks around fittings, connections, and lines can be detected in the same way. Do not apply ammonia solution to plated metal parts, as it will remove the plating.
- When chlorine is noticed, workers should avoid panic, refrain from coughing, keep mouths closed, avoid deep breathing, keep heads high, and get out of the affected area. Only qualified personnel with suitable respiratory equipment should be assigned to investigate and correct the cause of chlorine leaks. If chlorine is being discharged, close the container valve immediately. If chlorine is escaping in liquid form, turn the containers so the chlorine escapes as gas. This will reduce leakage. Do not apply water to the leak; this dangerous practice causes corrosion that may increase the leakage. Electronic chlorine gas detector warning devices are widely used in plants and mechanical rooms that contain chlorine.
- The handling of a persistent chlorine leak in a plant is best left to the chlorine supplier or local fire department.
- Never apply a flame, blowtorch, or other direct heat to chlorine containers; discharge them in a room with a temperature of about 70°F.
- Never ship a defective or leaky cylinder unless it is completely empty. Paint "DEFECTIVE" plainly on all such cylinders.
- Follow all regulations on shipping, storing, and using compressed gas cylinders.
- Provide proper means of exit from areas where chlorine is stored or used.
- Never use a chlorine cylinder except to hold chlorine gas.

10.3.1 Chlorination Equipment

Chlorination equipment used to feed chlorine gas or hypochlorite solution may be classified by type, depending on the methods of control. The three methods of control are manual, semiautomatic, and fully automatic.

1. The manually controlled-type equipment must be started and stopped manually, and the rate of feed must be manually adjusted to the rate of water flow.
2. In the semiautomatic type, equipment starts and stops automatically as water flow starts and stops; however, it must be manually adjusted to the rate of water flow. This type is normally used with water pumped at a fairly uniform rate.
3. In the fully automatic type, the rate of feed is automatically adjusted to the rate of flow of the water being treated through pressure of a metering device.

In all three types, the ratio of feed to water treated, or dosage, is set by manual adjustment.

Chlorinators may also be classified generally by type of feed. Here you have two types of machines— direct feed and solution feed. Direct-feed machines are designed to operate without a pressure water supply, feeding the chlorine gas directly into the flow to be treated. Solution-feed machines dissolve the gas in a minor flow of water and inject the resultant solution into the flow to be treated; these require a pressure water supply for operation.

Another method of classifying chlorinators is by the type of diaphragm used in controlling the chlorine feed. There are two types--the water diaphragm and the mechanical diaphragm. The water diaphragm is always a vacuum type, solution -feed machine and has the advantages of being friction-free and puncture-proof. The mechanical diaphragm machine may be either direct- or solution-feed pressure type or solution-feed vacuum type only.

10.3.1 Direct Feed Chlorinators

Direct-feed chlorinators are used chiefly as emergency equipment and on small installations where it is not possible to obtain a water supply suitable for operating a solution-feed machine. They cannot be used where the pressure of the water being treated is more than 20 psi, and are limited in the types of semiautomatic and automatic controls that may be used. Because the chlorine is under pressure as a gas at all times, direct-feed machines may easily leak gas into a confined or poorly ventilated space where the leakage could corrode adjacent equipment and structures. If you should be called upon to operate a direct-feed chlorinator, carefully follow the recommendations and instructions of the equipment manufacturer. You, as the operator, must be thoroughly familiar with the equipment to ensure its proper operation, adjustment, and minor repair.

10.3.2 Solution Feed Chlorinators

A solution feed chlorinator introduces chlorine gas into the water supply by means of a chlorine solution. This supply is usually formed by drawing chlorine gas into a jet stream of water at the low pressure point of the injector mechanism of the chlorinator.

The chlorinator (*Figures 8-23* and *8-24*) controls and indicates the rate of flow of chlorine, provides a simple means of manually setting the feed rate, mixes chlorine gas and water, and delivers the solution to the point of application. *Figures 8-24* and *8-25* show a typical cylinder connection and scales.

Figure 8-23 — V-notch gas feeder typical installation, 3 to 200 lb/24 hr.

Figure 8-24 — V-notch gas feeder typical installation, 250 to 500 lb/24 hr.

Figure 8-25 — V-notch chlorinator typical installation, 3 to 200 lb/24 hr.

Figure 8-26 — V-notch chlorinator typical installation, 250 to 500 lb/24 hr.

The chlorinator operates under a vacuum produced by a flow of water through the injector. The installation must allow a 5-inch vacuum.

Chlorine gas under pressure enters the chlorinator at the chlorine inlet connection where it is electrically heated to reduce the deposit of impurities and to prevent reliquefaction of the gas when the chlorinator is shut down with the supply turned on. Chlorine expands into a gas at a ratio of 1:460, that is, 1 cubic inch of chlorine expands into 460 cubic inches of gas. This volummetric expansion can rupture lines. For the same reason, there should be no dips or traps in any piping installation.

Figure 8-26 shows a typical chlorine piping installation. A vacuum will pull on the diaphragm in the gas pressure-regulating valve and open the inlet valve. The entrance of chlorine will hold this vacuum at a fairly constant value. Since the vacuum on the upstream side of the V-notch variable orifice is somewhat higher, the vacuum-regulating valve is designed to maintain a constant drop across the V-notch variable orifice. The V-notch plug can be manually, electrically, or pneumatically operated.

NOTE

For variable vacuum operation, the injector vacuum must be at least 10 inches of mercury.

10.3.3 Other Types of Chlorinators

You may find other types of chlorinators at naval activities. Among other types that may be at your activity are the vacuum-type mechanical-diaphragm chlorinator, the volumetric vacuum-type chlorinator, the vacuum-type diaphragm-controlled chlorinator, and the pulsating-type chlorinator. Regardless of the type of chlorinator, make sure that you follow the manufacturer's recommendations and instructions applicable to the operation and maintenance of the equipment.

10.3.4 Hypochlorinators

Hypochlorinators are solution chemical feeders that introduce chlorine into the water supply as a hypochlorite solution. They are usually modified positive displacement piston or diaphragm mechanical pumps. However, hydraulic displacement hypochlorinators are also used. Fully automatic types are actuated by the pressure differentials produced by orifices, venturis, valves, meters, or similar devices. Hypochlorinators are sometimes used as standby equipment for gas chlorinators. Portable equipment is also available which may be used for main disinfection or during emergencies. Hypochlorinators can also be used to feed chemicals for scale and corrosion control. Since a UT may have to use various types of hypochlorinators, the following discussion on additional types should be of interest to you.

The Proportioneers Chlor-O-Feeder is a positive displacement diaphragm-type pump with an electrically driven or hydraulically operated head. The electrically driven Proportioneers Chlor-O-Feeder is shown in *Figure 8-27*. The capacity of the most popular type, the heavy-duty Midget Chlor-O-Feeder, is 95 gallons of solution in 24 hours.

Figure 8-27 — Electrically driven Proportioneers Chlor-O-Feeder.

The motor-driven type of hypochlorinator may be electrically interconnected with the pump motor controls for semiautomatic operation (*Figure 8-28*). The hydraulic type can be synchronized with pump operation by means of a solenoid valve.

Motor-driven types of hypochlorinators are made fully automatic by use of a secondary electrical control circuit actuated by a switch inserted in a disk or compound-meter gearbox (*Figure 8-29*). This switch closes momentarily each time a definite volume of water passes through the meter, thus starting the feeder. A timing element in the secondary circuit shuts off the feeder after a predetermined, adjustable number of feeder strokes. In the hydraulic type, the meter actuates gears in a gearbox, which in turn controls operation of a pilot valve in the water or air supply operating the feeder. The dosage rate is controlled by water flow through the meter, thus automatically proportioning the treatment chemical. The opening and closing frequency of the valve determines the frequency of operation of the hypochlorinator.

Figure 8-28 — Hypochlorinator arrangement.

Other types of hypochlorinators available include the Model S. The Model S hypochlorinator is a positive displacement diaphragm pump with a manually adjustable feeding capacity of 3 to 60 gallons per day. A motor-driven eccentric cam reciprocates the diaphragm, injecting the solution into the main supply. The use of chemically resistant plastic and synthetic rubber in critical parts contributes to its long operating life.

Figure 8-29 — Motor-driven hypochlorinator with fully automatic control.

10.3.5 Location of Equipment

Chlorination equipment must be properly located with proper ventilation. All gas chlorinating equipment and chlorine gas cylinders, filled or empty, should be in a separate room opening only from the outside, and should not be in the same room or enclosure with operating equipment, other than equipment required for chlorination. If these conditions do not exist, take up the matter with your supervising petty officer.

If the floor of the chlorination room is not at an elevation level with or above the surrounding ground area, an exhaust fan (positive pressure blower type) should be installed to remove gas or air at the floor level. Mechanical exhaust ventilation should be provided at floor level in any case. Doors should open outward, and two way lighting switches should be provided, both outside and inside the room. If standard design conditions have not been met, get advice on what to do from your supervising petty officer.

It is normal to put hypochlorinators in the same room with other equipment such as pumps, switchboards, meters, and the like. However, because of the corrosiveness of the solutions, it is better to put them in a separate room. If adequate floor drains have not been provided for waste water, spillage, sludge, and wash-down water, a 6-inch curbing should be provided around the entire area used for this purpose, whether in a separate room or in the same room with other equipment.

10.3.6 Locating Leaks

Even small leaks can be detected because of the characteristically sharp chlorine odor. When a chlorine odor is noted, authorized personnel should start the ventilating system, put on self-contained or self-generating oxygen breathing apparatus, and locate the leak by holding an open bottle of ammonia water close to pipes, fittings, and valves. Ammonia vapor and chlorine gas form heavy white fumes, thus revealing the location of the leak. If the leak is in a line, shut off the flow of chlorine and repair the leak. If it is in the cylinder head and cannot be stopped by closing the valve, waste the gas from the cylinder outdoors in a good wind or run it into a caustic soda solution.

For emergencies, a standby alkali absorption system with a suitable tank should be provided. The alkali should be stored so a solution can be readily prepared. Chlorine should be passed into the solution through a suitable connection properly submerged and weighted to hold it secure. DO NOT IMMERSE CHLORINE CONTAINERS IN SOLUTION. *Table 8-4* shows a chemical equivalent. Try to use quantities in excess to allow absorption.

Table 8-4 — Recommended alkaline solutions for absorbing chlorine.

Container Capacity	Caustic Soda		Soda Ash Water		Hydrated Lime Water	
	100	Water				
lb (net)	lb	gal	lb	gal	lb	gal
100	125	40	300	100	125	125
150	188	60	450	150	183	183
2000	2500	800	6000	2000	2500	2500

10.3.7 Hypochlorites

To prevent accidents caused by the corrosive action of hypochlorite solutions, use ***vitreous*** crocks or steel tanks lined with rubber or chlorine-resistant plastic as solution containers. Store calcium hypochlorite in a dry, cool location, and keep the cans sealed. Wear rubber gloves and protective aprons when preparing and handling hypochlorite solutions.

The liquid CO, recarbonization system uses carbon dioxide gas to lower the pH of softened and settled potable water. This unit is designed for operation between -10°F and +3°F that corresponds to pressure of 242.8 psig and 306.8 psig. The pressure vessel is designed for temperatures as low as -20°F and up to 350 psig. The unit comes with or without a vaporizer, depending on the quantity of CO, required. (If large amounts of CO_2 are removed, it is possible to cause the temperature to go below -20°F.) Once the unit is installed and in proper operation, it requires little attention. At the beginning and end of each day, the operator should check the pressure and liquid level gauges. The supply valve should be turned off when the unit is not in use. The standard unit is equipped with a pressure vessel, piping and valves, safeties, a refrigeration unit, and a vaporizer. All of these devices require normal maintenance.

10.3.8 Ammonia

Ammonia fumes are poisonous, but even small concentrations of ammonia are quickly noticeable by its characteristic odor. Because the gas is extremely soluble, a water spray can pick up ammonia which has escaped. The same precautions used with chlorine are used in handling ammonia, with the following exceptions and additions:

- Because ammonia is lighter than air, install vents at the top of the room.
- Ammonia cylinders do not have fusible plugs because no fusible ammonia-resistant material is available. This presents an acute hazard because an ammonia cylinder filled to the legal limit becomes completely liquid at 145°F, and higher temperature results in a buildup of hydrostatic pressure. Cylinders are tested at 700 psi under ICC regulations.
- Test for leaks in ammonia gas piping with a bottle of diluted muriatic acid. White fumes form as with chlorine.
- Ammonia solution or aqua ammonia can be stored indefinitely, but ammonia gas is created at about 80°F if the container is open. Store it in a cool place and keep the container tightly plugged. Dilute with cool water to 15 percent ammonia content before feeding. Keep the room housing the feeder well ventilated.

10.3.9 Sulfur Dioxide

Precautions in storing and handling chlorine also apply to sulfur dioxide (SO). Leaks are located with a bottle of ammonia water.

10.4.0 Water Treatment Quality Control

Frequent chemical analyses and bacteriological examinations of raw and treated water are required to determine and control treatment to ensure safe, potable water. Chemical analyses will determine the safety of the water and proper water treatment in respect to chemical content. Bacteriological examinations will determine the necessity for disinfection, as well as the safety of the water following the treatment in terms of bacteria content.

You may be called upon to collect samples of water for chemical analysis and bacteriological examination. You may also have to make various types of treatment control tests. This information will aid you in performing these duties. Safety precautions to be observed by personnel engaged in laboratory work are also covered.

10.4.1 Sampling Methods

The collection of samples for testing for quality control and safety is an important function because, unless the water sample is representative and uncontaminated, test results will not indicate the actual condition of the water supply. Sample containers should be of materials that will not contaminate the sample and, before use, should be cleaned thoroughly with a detergent and freshwater rinse to remove all surface dirt. Chemically resistant glass is a suitable material for all sample containers, and polyethylene may be used for samples for chemical analyses. The size of the sample container used will depend upon the amount of water needed for a test.

To make certain that representative, uncontaminated samples are obtained; you must observe normal precautions against accidental contamination. Always rinse sample containers and caps thoroughly with the water to be tested. Avoid direct hand contact with the mouth of the container or with the cap. Take samples with a minimum of splashing.

10.4.2 Chemical Analysis Samples

When collecting samples for chemical analysis, you will find that a gallon of water is usually sufficient to determine the mineral content. To obtain accurate test results, flush the sampling lines thoroughly. Rinse out the bottles several times with the water to be collected. Procedures for obtaining samples from water supplies for chemical analysis are given below. Follow these procedures carefully.

10.4.2.1 Wells

To obtain a representative sample from a well, pump the well until the normal drawdown is reached. Rinse the chemically cleaned sample container and cap several times with the water to be tested and then fill the container with a minimum of splashing.

10.4.2.2 Surface Supplies

When sampling surface supplies, fill chemically cleaned raw water sample containers with water from the pump discharge ONLY after the pump has operated long enough to flush the discharge line. Take the sample from the pond, the lake, or the stream at the intake depth and location with a submerged sampler. Submerged samplers are equipped with automatic or manual valve systems that permit the collection of water at the desired depth.

10.4.2.3 Treatment Plants

Take samples inside a treatment plant from channels, pipe taps, or other points where good mixing is obtained. At some Navy installations, special sample taps are provided for this purpose.

10.4.2.4 Distribution System Taps

In the case of taps on a distribution system, let the tap run long enough to draw water from the main before taking samples.

10.4.3 Bacteriological Examination Samples

In obtaining samples for bacteriological examination, avoid contaminating the bottle, stopper, or sample because contamination often causes a potable water supply to be reported as non-potable. Follow the following precautions and get valid results.

10.4.3.1 Sample Containers

Use only clean, sterilized bottles furnished by the medical department of the installation or another qualified laboratory. If bottles are not available from these sources, sterilization may be carried out in emergencies. The tops and necks of sample bottles with glass closures should be covered with metal foil, rubberized cloth, or heavy impermeable paper or milk bottle cover tops before sterilization. Before sterilizing the sample bottle to be used for a chlorinated water sample, place 0.02 to 0.05 gram of thiosulfate, powdered or in solution, into each bottle to neutralize the chlorine residual in the sample. Keep the sterilization temperature under 393°F to avoid decomposition of the thiosulfate.

10.4.3.2 Sampling From a Tap

When sampling from a tap, heat the outlet with an alcohol or gasoline torch for a few seconds to destroy any contaminating material that may be on the tip of the faucet. Occasionally, extra samples may be collected without flaming the faucet to determine whether certain faucet outlets are contaminated.

Flush the tap long enough to draw water from the main. Never use a rubber hose or another temporary attachment when drawing a sample for bacteriological examination from the tap.

Next, without removing the protective cover, remove the bottle stopper and hold both the cover and the stopper in one hand. Do not touch the bottle mouth or the sides of the stopper. Fill the bottle without rinsing (to avoid loss of thiosulfate). Replace the cap and fasten the protective covering carefully.

10.4.3.3 Sampling from Lakes, Ponds, Streams, and Pools

When collecting samples from standing water, remove the stopper as above, and plunge the bottle, mouth down, and hold it at about a 45° angle at least 3 inches below the surface. Tilt the bottle and allow air to escape and fill, moving it in a direction away from the hand holding it, so water that has touched the hand does not enter the bottle. Discard a quarter of the water and replace the stopper.

When collecting a sample from lakes or ponds, use a boat or pier to take water that is at least 25 feet from the shore and preferably at least 4 feet deep. Do not collect the sample at the shore.

Collect a stream sample where the water is flowing, not from still areas. In a meandering stream, collect the sample where flow velocity is normal. Use the procedure given above for standing water samples.

When collecting water from a swimming pool, take the water from the side of the pool near the deepest part. Sample the pool while it is in use, preferably during the heaviest bathing load. Use the bottle containing thiosulfate. Fill according to the sampling procedure given above for standing water.

10.5.0 Treatment Control Test Procedures

Various analyses of water must be performed by trained chemists or skilled laboratory technicians. As a UT, however, you must be able to perform various types of treatment control tests. These tests are used during treatment to ensure proper operation and the output of safe water of acceptable quality. We will describe the procedures to follow in carrying out a number of treatment processes, such as chlorination, corrosion control, and clarification.

Before proceeding, note that certain tests which we will cover are based on the simple principle of adding a chemical to the sample that forms a color with the substance to be measured and matching the treated sample with color standards containing known amounts of the substance. There are several colorimeter sets available commercially which vary slightly in use and operation. For that reason, make a careful study of the manufacturer's instructions before using such equipment. Other tests are performed by titration or by special instruments. Titration means finding out how much of a substance is in a given solution by measuring how much of another substance or reagent has to be added to the given solution to produce a given reaction.

Various reagents required for the tests discussed below are available from a number of manufacturers and laboratory supply houses. Some of these reagents require special preparation and handling before test use. This is customarily the responsibility of the laboratory technician, since, in some cases, the preparation of reagents requires a thorough knowledge of the chemical procedures. For complete information on the preparation of reagents, refer to the manufacturer's instructions or consult your supervising petty officer.

10.5.1 Chlorine Residuals

Two tests are frequently used in testing water for chlorine residuals: the orthotolidine test and the orthotolidine-arsenite (OTA) test. Each of these tests is discussed separately below.

10.5.1.1 Orthotolidine Test

Chlorine residuals can be measured easily by using a commercial comparator and orthotolidine reagents.

10.5.1.1.1 Equipment

Either a disk or slide comparator may be used in performing the orthotolidine test. A disk comparator is shown in *Figure 8-30*. This comparator consists of a standard color disk and two sample tubes. Water to be tested is placed in both tubes. Reagent is added to one and the resulting color matched with the disk. The other tube is placed behind the disk to eliminate any color error that might be caused by turbidity in the test sample.

Figure 8-30— Disk comparator kit.

A slide comparator, also referred to as a block comparator, is shown in *Figure 8-31*. This comparator consists of standard color ***ampoules*** for more accurate color matching. The other two sample tubes are used as compensators and are placed behind the color ampoules.

CAUTION

The only reagent used is a standard orthotolidine solution.

The general procedure consists of four steps:

1. Fill the tubes to the mark with the water.
2. Place the compensating tube or tubes behind the color standard.
3. Add 10 to 15 drops of orthotolidine to the test sample; mix and let stand for 5 minutes. Keep the sample in the dark during the 5-minute color development to reduce false color caused by manganese and nitrate compounds. If a blue color appears after 5 minutes, add more orthotolidine. If water is colder than 50°F, warm it by holding the tube in your hand. Place the sample tube in the comparator and match the color, holding the comparator toward the light, preferably daylight.
4. Select the standard color nearest that of the sample and read the residual. If color appears to be halfway between two standards, report the residual as an average of two standards. Thus, if color appears halfway between 0.3 and 0.4 ppm, report the residual as 0.35 ppm.

Figure 8-31 — Slide comparator.

Note that the orthotolidine test is not wholly accurate because the false color introduced by nitrates and manganese compounds cannot be entirely eliminated. However, the orthotolidine-arsenite test, described in the following section, does eliminate the false color error completely.

10.5.1.2 Orthotolidine Arsenite Test

The orthotolidine-arsenite (OTA) test permits the measurement of relative amounts of total residual chlorine, free available chlorine, and combined available chlorine. This test has some limitations. Samples containing a high proportion of combined available chlorine may indicate more free available chlorine than is actually present, while samples containing a low proportion of combined available chlorine may indicate less free available chlorine than is actually present. Precise results depend on strict adherence to the conditions of the test. The conditions are the time intervals between the addition of reagents and the relative concentration of free available chlorine and combined available chlorine in the sample and the temperature of the water. The temperature of the sample under examination should never be above 68°F. The precision of the test increases with decreasing temperature.

10.5.1.2.1 Equipment

You will need a color and turbidity-compensating residual chlorine comparator with commercial permanent standards.

10.5.1.2.2 Reagents

The reagents used are orthotolidine (OT) and arsenite (A).

10.5.1.2.3 Test Procedures

In testing, follow the procedures outlined below.

1. Label three comparator cells A, B, and OT.
2. Use 0.05 milliliter (ml) of OT reagent for each ml of the sample taken. For example, use 0.5 ml of OT reagent for a 10-ml sample and 0.75 ml for a 15-ml sample. Use the same volume of a reagent as is specified above for OT reagent.
3. To tube A, first add OT reagent, then add a measured volume of the water sample; mix quickly.
4. Within 5 seconds, add arsenite reagent; mix quickly.
5. Compare with color standards as rapidly as possible.
6. Record the result; the value obtained represents free available chlorine and interfering colors.
7. To tube B, first add arsenite reagent, then add a measured volume of water sample; mix quickly.
8. Immediately add OT reagent; mix quickly.
9. Compare with color standards as rapidly as possible.
10. Record the results as the B-1 value.
11. Compare the color standards again in exactly 5 minutes and record the results as the B-2 value; these values represent the interfering colors present in the immediate reading B-1 and in the 5-minute reading B-2.
12. To tube OT, containing orthotolidine reagent, add a measured volume of the water sample.
13. Mix quickly and compare with color standards in exactly 5 minutes.
14. Record the result; the value obtained represents the total residual chlorine present and total interfering colors.

10.5.1.2.4 Calculation of Results

In calculating results of the orthotolidine-arsenite (OTA) test, follow the procedure below.

Total residual chlorine. From the value of OT, subtract the value of B-2. The difference equals total residual chlorine.

$$(OT) - (B\text{-}2) = \text{total residual chlorine}$$

Free available chlorine. From the value of A, subtract the value of B-l. The difference equals free available chlorine.

$$(A) - (B\text{-}1) = \text{free available chlorine}$$

Combined available chlorine. From the value of total residual chlorine, subtract the value of free available chlorine. The difference represents combined available chlorine.

(Total residual chlorine) - (free available chlorine) = combined available chlorine

10.5.2 pH Test

The pH test measures the strength of acid or alkali in water. It is reported on a scale that ranges from 0 to 14. A pH reading of 7 is neutral (in a technical sense), values below 7 are acidic, and those above 7 are alkaline. Color comparators can be used to find pH by methods similar to those for determining chlorine residuals.

10.5.2.1 Indicators

Many pH indicators are available, each with a limited range. The indicators used for treated water supplies are shown in *Table 8-5:*

Table 8-5 — pH indicator ranges.

pH RANGE	INDICATOR
5.2 to 6.8	Chlorphenol red
6.0 to 7.6	Bromthymol blue
6.8 to 8.4	Phenol red
7.2 to 8.8	Cresol red

The correct standards must be used with each indicator.

10.5.2.2 Procedures

In making the pH test, proceed as follows:

1. Fill the tubes to the mark with the sample.
2. Add the indicator to one tube in the amount specified by the manufacturer.

NOTE

Usually this amount is 0.5 ml (10 drops) for a 10-ml sample tube and proportionately more for larger tubes.

3. Mix and place the tube in the comparator.
4. Match for color and read the pH directly.
5. If the color matches the standard at either the upper or the lower end of the range of the indicator, repeat the test with the next higher or lower indicator. For instance, if bromthymol blue is used and the sample matches the blue color of the 7.6 standard, the pH is 7.6 or higher. Therefore, use a phenol red indicator to check this value.

10.5.3 Salinity Tests

At times you may be assigned to perform salinity tests with field water using a quality control kit. These tests identify the mineral characteristics of the water.

The quality control kit provides the necessary materials and equipment for the tests. Two bottles of reagents, one small and one large, are included. As the solution is used up during the test, the small bottle is refilled from the larger bottler The test bottles have two marks--the lower one at 50-ml capacity and the upper one at 100-ml capacity. The test solutions are measured with pipettes. These pipettes deliver a total of 1 ml from the upper graduation mark and are calibrated in 1/10-ml divisions. Each pipette is to be used only for the test for which it is marked in the pipette case and is to be returned directly to its place when the test is completed.

Four types of salinity tests which you may perform are the alkalinity test, the hardness test, the chloride test, and the sulfate test. Each of these tests is discussed in subsections below.

10.5.3.1 Alkalinity Test

Alkalinity of water results from the presence of bicarbonate, carbonate, hydroxides of calcium, magnesium, sodium, and other minerals. The term alkalinity has little or no relation to the pH of the water but refers to the acid-neutralizing capacity of the water. In other words, alkalinity of water refers to the amount of various alkalies in the water that are capable of neutralizing acids. One method of determining the alkalinity of a water sample is by titration with standard sulfuric acid first to the phenolphthalein (PT) end point, and then to the methyl purple or methyl orange end point. Although methyl orange is the “standard indicator,” methyl purple is much easier for the average operator to use because its color change is easier to see, and the results obtained with it are good enough for almost all uses.

10.5.3.1.1 Reagents

The reagents used in testing the alkalinity of water are as follows:

- Phenolphthalein (PT) Indicator Solution
- Methyl Purple Indicator Solution
- Methyl Orange Indicator Solution
- Standard Sulfuric Acid (N/50)

10.5.3.1.2 Procedure with Methyl Purple

In determining the alkalinity of water with methyl purple, use the following procedure:

1. Measure 100 ml of the clear sample (filtered if necessary) into an evaporating dish or Erlenmeyer flask.
2. Add 4 drops of phenolphthalein indicator solution. If a pink or red color develops, phenolphthalein alkalinity (alkalinity fraction contributed by hydroxide and half of carbonate) is present.
3. Fill the ***burette*** with acid and add to the sample slowly just until the pink color disappears.
4. Record the ml of acid used.
5. Now, add 2 to 4 drops of methyl purple indicator.
6. Continue titration, adding the acid in 0.5-ml portions until a greenish tint appears where the acid hits the sample. Then continue the addition more slowly, about 3 drops at a time. The color will change from green to gray and then to purple. The appearance of the purple tint marks the end point.
7. Record the total ml of acid required to reach this end point. This includes the ml of acid used in the phenolphthalein alkalinity titration and that used in the methyl purple titration.

10.5.3.1.3 Procedure with Methyl Orange

In determining the alkalinity of water with methyl orange, follow the procedure given below.

1. Measure 100 ml of the clear sample (filtered if necessary) into an evaporating dish or Erlenmeyer flask.

NOTE

If an evaporating dish is used to get a white background for better color observation, the sample must be stirred with a stirring rod during addition of the standard acid.

2. Add 4 drops of phenolphthalein indicator solution. If a pink or red color develops, phenolphthalein alkalinity (alkalinity fraction contributed by hydroxide and half of carbonate) is present.
3. Fill the burette with the acid and add to the sample slowly just until the pink color disappears.
4. Record the ml of acid used.
5. Now, add 2 to 4 drops of methyl orange indicator.
6. Continue titration, adding the acid in 0.5-ml portions until the reddish color that appears where the acid hits the sample begins to persist. Then continue the addition more slowly, about 3 drops at a time, until the first pinkish tinge is seen throughout the sample. This is the end point.
7. Record the total ml of acid required to reach this end point. This includes the ml consumed in the phenolphthalein alkalinity titration and that consumed in the methyl orange titration.

10.5.3.1.4 Calculations

The phenolphthalein (PT) alkalinity is calculated as ppm of calcium carbonate by multiplying the ml of acid used in the phenolphthalein titration by 20.

ppm PT alkalinity as calcium carbonate = ml of acid used in step × 20

The total alkalinity, as ppm of calcium carbonate, is found by multiplying the total number of ml of acid used (Step 6 above) by 20. This applies to both the methyl orange and the methyl purple procedures.

ppm total alkalinity as calcium carbonate = total ml acid used × 20

10.5.3.2 Hardness Test

The titration method for determining water hardness is vastly superior. The procedure is based on the fact that when a sample of water is titrated with a solution of EDTA (sodium ethylene, diamine tetraacetate), calcium and magnesium react with the EDTA to form soluble compounds in which calcium and magnesium are tied up so firmly that they cannot react with other materials. Standard EDTA solution is added to a water sample and the end point is detected by an indicator that is red in the presence of calcium and magnesium ions and blue in their absence. A total hardness test set (EDTA) is shown in *Figure 8-32*.

Figure 8-32 — Total hardness test set.

10.5.3.2.1 Reagents

The following reagents are used in testing for water hardness:

- EDTA solution
- Hardness indicator powder
- Hardness buffer
- Hardness reagent

10.5.3.2.2 Procedures

In determining water hardness, here is the procedure to follow.

1. Place a 50-ml sample in a 250-ml Erlenmeyer flask.
2. Add 1 dipper of hardness indicator powder.
3. Add 0.50 ml of hardness buffer to hold the pH at around 10. The color of the mixture will be red if any hardness is present.
4. Add the hardness reagent from a burette until the red color just disappears, giving way to a pure blue.

10.5.3.2.3 Calculations

The burette reading in ml is multiplied by 20 to give the total hardness.

$$\text{ppm total hardness as calcium carbonate} = \text{ml burette reading} \times 20$$

10.5.3.3 Chloride Test

The purpose of the chloride test is to measure the amount of chloride ions and common salt (NaCl) in water. This test also indicates the presence of possible sewage pollution.

10.5.3.3.1 Reagents

The reagents used in making the chloride tests are as follows:

- Phenolphthalein Indicator
- Methyl Orange Indicator
- Potassium Chromate
- Silver Nitrate Standard
- Aluminum Hydroxide
- Sulfuric Acid (1 to 3)

10.5.3.3.2 Procedures

When making a chloride test, follow the procedure below.

1. Pipette 50 ml of the sample into a 6-inch white porcelain evaporation dish.
2. Place the same quantity of distilled water into a second dish for color comparison.
3. To both dishes, add 1 ml of potassium chromate. Titrate the dish with the sample. Add standard silver nitrate solution (2.4 grams per liter) from a burette, a few drops at a time, with constant stirring until the first permanent reddish coloration appears. (This can be determined by comparison with the distilled water blank.) Record the ml of silver nitrate used.
4. If more than 7 or 8 ml of silver nitrate solution is required, the entire procedure should be repeated by using a smaller sample diluted to 50 ml with distilled water.

10.5.3.3.3 Calculations

When making calculations for chloride, use the formula below.

$$Ppm\,chloride(C1) = \frac{ml\ of\ \ AgNo_3\,used - 0.2\ x\,500}{ml\ of\ \ sample}$$

Three precautions to bear in mind are as follows:

1. If the sample is highly colored, it should be decolorized by shaking with washed aluminum hydroxide and filtering.
2. If the sample is highly acid, add 10 percent sodium carbonate solution until it is slightly alkaline to methyl orange.
3. If the sample is highly alkaline, add diluted sulfuric acid until it is just acid to phenolphthalein.

10.5.3.4 Sulfate Test

The sulfate test determines whether sulfates are present in sufficient quantities in water to cause undesirable physiological effects because sulfates can cause diarrhea in human beings. In the sulfate test, the sulfate value is found by trial, as the test merely determines approximate values. For this reason, you may have to repeat the test several times. The test is begun by testing for sulfates at 100 ppm as follows:

1. Fill a clean test bottle to the 100-ml mark with the water sample.
2. Add 1 ml of barium chloride solution to the same and use a barium chloride pipette. Shake intermittently for 10 minutes.
3. Tear a piece of filter paper into small pieces and place the pieces in the solution.
4. Shake the bottle for 5 minutes or until the paper becomes fluffy and gelatinous.
5. Place a funnel and filter paper in a second bottle.
6. Filter about 25 ml of the sample into the second bottle. Rinse the second bottle with this amount of filtrate, and discard the filtrate. Replace the funnel and continue filtration until 50 ml of filtrate is collected.
7. Add 1 ml of barium chloride solution to the filtrate with the barium chloride pipette. Shake for 5 seconds, and observe immediately for a precipitate or clear solution.

If a clear solution is obtained, record the sulfates as less than 100 ppm. As an immediate precipitate or milky solution indicates the sulfates are greater than 100 ppm, a new sample must be tested for 200-ppm sulfate. For each additional 100-ppm sulfate test required, add 1 ml of barium chloride solution. Therefore, 3 ml of barium chloride solution must be added to test for 300-ppm sulfate. However, the 1 ml of barium chloride solution added after filtration is not changed.

If a clear solution is obtained, the sulfates are less than the ppm for which they were tested, and the value is recorded as being between the values of the last preceding tests. A precipitate or milky solution requires that a new sample of the water be tested for the next higher value.

10.5.4 Color Test

Color in water is due to various materials in solution, although suspended turbidity occasionally adds an apparent color to water that may add to or disguise the true color. In water with low turbidity, the apparent color corresponds closely to the true color. However, if turbidity is high, the apparent color may be misleading. To determine the true color, first filter the water through clean white filter paper before it is compared with the standards. Because the filter paper often removes some true color from the first portion of the sample, discard the first 100-ml which pass through the filter and use the next portion for the color comparison. Make the color determination by matching the sample color with color standards in a color comparator.

10.5.5 Taste, Odor, and Threshold Odor Test

Unless the water has a definite taste (sweet, sour, salty, or bitter), the sensation produced upon the observer is generally due to the presence of odor, rather than taste. These two senses work in unison. Sulfur water, for instance, apparently tastes “terrible” when it is really only its rotten egg odor that is registering on our senses. In measured observations, odor determinations are much to be preferred to taste determinations. There is no method for measuring tastes quantitatively.

The threshold odor test is the most widely used method of determining odor levels. It consists of comparing different dilutions of the sample (diluted with odor-free water) to an odor-free standard. The dilution at which the odor can just be detected is called the threshold point. The odor at the threshold point is expressed quantitatively by the threshold number. This is simply the number of times the odor-bearing sample is diluted with odor-free water. For example, if odor-bearing water requires dilution to ten times its volume with odor-free water to make the odor just perceptible, its threshold number will be 10. More concentrated odor-bearing water will require dilution to 100 times its volume to make the odor just perceptible; its threshold number will be 100. Here are some basic principles of measuring odor values consistently.

1. Some practice with the test is desirable to develop consistent threshold sensitivity. The consistency can be developed readily in most individuals. An acute sense of smell is not essential.
2. An adequate supply of freshly prepared odor-free water must be available before starting the test.
3. All glass must be clean and free of odor. Rinse all glassware several times with odor-free water before each test and between dilutions.
4. Tests should be run in a room free from foreign odors. Odors caused by fresh paint, volatile solvents, tobacco smoke, food, and the like will decrease the accuracy of the observations.
5. Each dilution should be compared with the odorless standard to check judgment and minimize reliance on odor memory.

10.5.5.1 Equipment

The following items of equipment are needed to carry out the threshold odor test:

- Six 500-ml Erlenmeyer flasks with ground glass stoppers
- Two thermometers (0°C-110°C)
- One 250-ml graduated cylinder
- One 100-ml graduated cylinder
- One 50-ml graduated cylinder
- One 25-ml graduated cylinder
- One 10-ml Mohr pipette
- One large hot plate
- One odor-free water generator
- Several large flasks for collecting and heating odor-free water

10.5.5.2 Procedures

In carrying out the threshold test, determine first the approximate range of the threshold odor number. Carefully follow these steps.

1. Add 250-ml, 63-ml, 16-ml, and 4-ml portions of the odor-bearing water to separate 500ml glass stoppered Erlenmeyer flasks.
2. Dilute the last three to 250 ml with odor-free water.
3. Add 250 ml of odor-free water to another flask that will be the reference for comparison.
4. Heat the flasks to 140°F (60°C) on a hot plate.
5. Shake the odor-free flask, remove the stopper, and sniff the vapors.

6. Do the same with the flask containing the least amount of odor-bearing water and observe by comparison whether it contains an odor, and, if so, what type of odor. (See *Table 8-6*)

Table 8-6 — Types of odors commonly found in water supplies.

Aromatic (spicy)	Disagreeable
Balsamic (flowery)	Fishy
Sweetish	Pigpen
Chemical	Septic (sewage)
Chlorinous	Earthy
Hydrocarbon (gasoline)	Peaty
Medicinal	Grassy
Sulfuretted (rotten egg)	Musty
Moldy	Vegetable

7. Repeat steps 5 and 6 using the sample containing the next higher concentration of the water sample.
8. Continue the process until all dilutions have been observed.
9. Record which flasks contain an odor and which do not. Experience will enable an operator to estimate the approximate odor range by sniffing the undiluted sample, thereby eliminating the preliminary test.
10. Based on the results obtained in the preliminary test, prepare a set of dilutions and use the amount of the sample diluted with odor-free water in the range corresponding to the lowest dilution in which the odor was detected. For example, if odor was detected in the 63-ml dilution, but not in the 16-ml dilution, use series II in *Table 8-7*.

Table 8-7 — Dilution series for determining the threshold odor number.

Series	I	II	III
Amount of sample diluted to 250 ml	250	63	16
	177	44	11
	125	31	8
	88	22	5.5
	63	16	4

11. Repeat steps 5 through 9. The threshold number is read from *Table 8-8*.

Table 8-8 — Threshold odor numbers.

Amount of sample diluted to 250 ml	Threshold odor number
250	1
177	1.4
125	2
88	2.8
63	4
44	5.6
31	8
22	11
16	16
11	22
8	32
5.5	45
4	64

10.5.6 Jar Test (Coagulation)

The jar test is a reliable method for determining the proper chemical dosages and conditions for coagulation of water to remove color and turbidity.

The type of chemicals that should be used for coagulating raw water can be determined by using the results from jar tests or plant tests, or by using the data shown in *Table 8-9.* Theoretically *Table 8-9* 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 soft, colored waters, ferric coagulants 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 coagulants (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 8-9*.

Table 8-9 — Optimum pH ranges for common coagulants.

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

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 a jar 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 supernatant 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.

10.5.7 Turbidity Test

Special instruments are available for measuring turbidity (*Figure 8-33*). These instruments greatly simplify the work of the operator performing a turbidity test. Results are reliable and accurate. Complete instructions are available from manufacturers of these instruments. In general, however, the principles of operation are the same. Usually an easy, five-step procedure is followed.

1. Fill the sample tube with the water to be tested.
2. Insert the glass plunger into the tube.
3. Place the tube in the instrument.
4. Turn the dial at the side of the instrument until the field seen in the eyepiece becomes uniform.
5. Read the value indicated on the dial and determine the turbidity content of the sample being tested directly from the chart furnished with the instrument.

Figure 8-33 — Total hardness test set.

10.5.8 Records

Results of all findings made in the laboratory should be recorded on laboratory data forms. Two forms for recording data are the Potable Water Supply and Distribution Operating Record and the Potable Water Treatment Plant Operating Record.

The Potable Water Supply and Distribution Operating Record are designed as a management tool for analysis of operating data and evaluation of the potable water supply and distribution performance. Complete instructions on the method of daily entries on this form are on its reverse side.

The Potable Water Treatment Plant Operating Record is designed as a management tool for the analysis of operating data and the evaluation of potable water treatment plant performance. A separate form should be prepared for each potable water treatment plant at an activity. Complete instructions on the method of daily entries on this form are on its reverse side.

Both of these records should be prepared in duplicate, and both should be summarized at the end of the month. The original should be retained on file and the carbon copy forwarded to the district public works officer not later than the tenth of the following month. Activity files should include records of the current and two preceding years.

Keep forms clean, concise, and hand print them with a pencil or a pen to avoid smearing. Information on forms must be understandable and legible for future reference. Constant reference is made to the data as a means of checking and increasing plant efficiency. The information provides a control measure to obtain the maximum efficiency of operation and to SAVE, not WASTE, chemicals used in water treatment.

Test your Knowledge (Select the Correct Response)

5. Which test is used for determining the proper chemical dosages for the coagulation of water to remove turbidity?

   A. Jar
   B. Turbidity
   C. Hardness
   D. Salinity

Summary

As a UT, you will be involved with the installation, operation, and maintenance of various waste water collection systems and waste water treatment facilities. You must be capable of identifying and correcting stoppage problems associated with sewer lines by utilizing various maintenance procedures and equipment.

You will also be involved in the construction, operation, inspection, maintenance and repair of cesspools, septic tanks, field latrines, and leaching fields. Another aspect sometimes overlooked is the process of water treatment and purification, but as a UT you will be responsible for the chlorination equipment, the quality control of water treatment, and the test procedures associated in water treatment. Remember, you will be the first line of defense in the prevention against waterborne contaminants and diseases.

Review Questions (Select the Correct Response)

1. How many feet away from the structure's foundation should the house sewer extend?

   A. 3 to 5
   B. 1 to 3
   C. 5 to 8
   D. 8 to 10

2. Which sanitary system sewer connects to a branch and has no common sewer tributary?

   A. House
   B. Lateral
   C. Main
   D. Branch

3. Which sanitary system sewer contains many branches, providing an outlet for a large area?

   A. Lateral
   B. Forced
   C. Trunk
   D. Interceptor

4. Forced main piping carrying sewage under pressure to a pumping station requires a minimum velocity speed of what value, in fps?

   A. 1
   B. 2
   C. 3
   D. 4

5. Which sanitary system sewer contains the treatment plant line leading to a final disposal point?

   A. Outfall
   B. Trunk
   C. Branch
   D. Outlet

6. Which construction material is NOT used in the making of manholes?

   A. Brick
   B. Shale concrete
   C. Precast reinforced concrete
   D. Concrete

7. Which type of manhole construction material has the widest application use?

   A. Precast reinforced concrete
   B. Concrete
   C. Precast concrete ring
   D. Brick

8. Which type of construction material is best suited for modifications to existing structures?

   A. Precast reinforced concrete
   B. Concrete
   C. Precast concrete ring
   D. Brick

9. Shaft type manholes can be constructed to a depth of how many feet?

   A. 130
   B. 140
   C. 150
   D. 160

10. When a 36-inch sewer line is utilized, how many feet apart are manholes placed?

   A. 300
   B. 500
   C. 600
   D. 800

11. Why are storm drainage systems separated from sanitary systems?

   A. Storm drainage systems are normally smaller in size.
   B. Storm drainage requires treatment.
   C. Storm and surface drainage do not require treatment.
   D. Combining systems would be too expensive.

12. Within how many feet from sewer lines are tree roots a prevalent problem?

   A. 100
   B. 200
   C. 300
   D. 400

13. What promotes the growth of sludge particles in aeration tanks?

   A. Hydrogen chloride
   B. Dissolved oxygen
   C. Sulfur acid
   D. Sodium potassium

14. What term is also used to refer to waste breakdown by microorganisms in dissolved oxygen?

   A. Activated sludge process
   B. Aerobic digestion
   C. Anaerobic digestion
   D. Activated sludge

15. The process that kills essentially all pathogenic bacteria in wastewater is known as what?

   A. Digestion
   B. Comminution
   C. Disinfection
   D. Shredding

16. Which waste water treatment is used to convert suspended materials into a form more readily separated from the water being treated?

   A. Preliminary
   B. Shock
   C. Primary
   D. Secondary

17. What term is used to refer to the settable solids separated from liquids during processing?

   A. Sludge
   B. Baffle
   C. Weir
   D. Floatables

18. Which material is designated as domestic organic waste?

   A. Vegetable packing waste
   B. Fecal discharges
   C. Salt brine discharges
   D. Meat packing waste

19. What substance will decrease as a result of an increase of wastewater in a body of water?

   A. Hydrogen
   B. Bacteria
   C. Oxygen
   D. Pathogenic agents

20. The total residue of solid waste contained in wastewater is known as _ solids.

A. dissolved
B. settable
C. floatable
D. total

21. **(True or False)** Organic material which includes vegetable matter is a type of solid material found in wastewater.

A. True
B. False

22. Cesspools must be covered with plank of what minimum thickness, in inches, for prevention of breeding flies?

A. 1
B. 2
C. 3
D. 4

23. How many feet apart should cesspools be constructed?

A. 5
B. 10
C. 20
D. 25

24. When cesspools are located in fine sand, what can be done to increase the leaching field?

A. Add more stones to the bottom of cesspool.
B. Surround the walls with medium sand.
C. Provide a trapped outlet at the bottom of cesspool.
D. Surround the walls with graded gravel.

25. Soils that require more than 30 minutes for a fall of how many inches are unsatisfactory for leaching?

A. 1
B. 2
C. 3
D. 4

26. The bottom of the inlet sewer should be how many inches above the water level of the tank?

A. 2
B. 3
C. 5
D. 7

27. When a septic tank is to be installed, what is the minimum desirable size, in gallons?

A. 250
B. 500
C. 1000
D. 1500

28. Excessive scum in septic tanks results in which condition?

A. Odor decrease
B. Low solids content
C. Baffling
D. Odor increase

29. To ensure food and water will be protected from contamination, latrines should be placed how many yards from mess areas?

A. 100
B. 200
C. 300
D. 400

30. Straddle trenches are built how many feet long?

A. 2
B. 4
C. 6
D. 8

31. A unit containing 100 personnel requires how many feet of latrine space?

A. 4
B. 8
C. 16
D. 32

32. What type of latrine is used when you have a high groundwater level?

A. Bored hole
B. Deep pit
C. Straddle
D. Mound

33. After cleaning the pails used with the pail latrine, what substance is added to the pail prior to placing it back in service?

A. Pine oil disinfectant
B. Lime
C. Gasoline
D. Insecticide

34. What is the depth, in feet, of an 8-seat box type latrine in use for 2 weeks or less?

A. 2
B. 4
C. 6
D. 8

35. Which urine disposal facilities are the best for field use?

A. Pipe urinals
B. Urinal troughs
C. Urine soakage pits
D. Recessed urine pits

36. Pipes utilized with the pipe urinal system should extend how many inches above the ground surface?

A. 15
B. 26
C. 30
D. 36

37. Which type of soil does NOT have good leaching abilities?

A. Sandy
B. Porous
C. Loam
D. Rocky

38. Which condition need NOT be met to have a properly functioning tile field?

A. Subsurface drainage towards the field
B. Groundwater well below the level of the field.
C. Soil of satisfactory leaching characteristics.
D. Adequate area for tile field installation.

39. When fiber pipe is used to lay pipe in a trench, what is the distance requirement, in inches, between the joint openings?

A. 1/2
B. 3/8
C. 3/4
D. 7/8

40. The distance between laterals during the layout of leaching fields is how many times wider than the trench?

A. 1
B. 2
C. 3
D. 4

41. The water cycle associated with water treatment is also known by what term?

A. Disinfection
B. Circulation
C. Treatment
D. Hydrologic

42. The capacity of the material composing any stratum to transmit water under pressure is known as what?

A. Permeability
B. Crossover
C. Porosity
D. Briggsfication

43. **(True or False)** Wells ending in the zone of aeration produce no water.

A. True
B. False

44. The time between drinking contaminated water and the appearance of a disease is known as what period?

A. Aeration
B. Incubation
C. Presentation
D. Inoculation

45. Impurities in water can be broken down into how many different categories of impurities?

A. 1
B. 2
C. 3
D. 4

46. How many methods are currently in use by the Seabees in field water treatment and purification?

A. 3
B. 4
C. 5
D. 6

47. Which is a common floc-forming chemical used in flocculation?

A. Chlorine
B. Bromine
C. Iodine
D. Aluminum sulfate

48. Each pound of liquid chlorine produces how many cubic feet of chlorine gas at atmospheric pressure and at a temperature of 68 degrees?

A. 5
B. 10
C. 15
D. 20

49. **(True or False)** The bactericidal effectiveness of chlorine depends upon the pH chlorine residual, contact period, and pressure.

A. True
B. False

50. What type of solution does a low pH value indicate?

A. Very weak acid
B. Very strong alkaline
C. Very strong acid
D. Very weak alkaline

51. Which is NOT a consideration in the safe handling of chlorine?

A. Never connect a full cylinder to a manifold with another cylinder unless temperatures are the same.
B. When not withdrawing the chlorine, keep outlet valves shut.
C. Disconnect all hoses once the cylinder is empty.
D. Ensure that the storage area contains high humidity.

52. Discharge of cylinders containing chlorine should be conducted in a room with a temperature of _ degrees Fahrenheit.

A. 50
B. 60
C. 70
D. 80

53. Direct feed chlorinators cannot be used where the pressure of the water being treated is more than how many pounds per square inch?

A. 10
B. 20
C. 30
D. 40

54. The chlorinator operates under how many inches of vacuum?

A. 1
B. 2
C. 3
D. 5

55. The dosage rate of a hypochlorinator is controlled by what piece of equipment?

A. Meter
B. Pilot valve
C. Feeder container
D. Gearbox

56. When locating chlorination equipment in a room with other pieces of equipment, you should install curbing how many inches high around the chlorination equipment?

A. 2
B. 4
C. 6
D. 8

57. To prevent accidents caused by the corrosive action of hypochlorite solutions, the solution container is lined with which type of material?

A. Chlorine resistant iron
B. Ammonia resistant steel
C. Chlorine resisted plastic
D. Ammonia resistant plastic

58. Cylinders containing ammonia gas will liquefy at a temperature of how many degrees Fahrenheit?

A. 130
B. 135
C. 145
D. 150

59. Water samples from a lake should be taken how many feet out from the shore?

A. 10
B. 15
C. 20
D. 25

60. In an orthotolidine test, how many minutes should the sample sit after adding the orthotolidine solution?

A. 5
B. 10
C. 15
D. 20

61. In an OTA test, the temperature of the sample should never be above a temperature of how many degrees Fahrenheit?

A. 58
B. 68
C. 78
D. 88

62. A pH reading of 7 indicates what condition?

A. Acidic
B. Corrosive
C. Neutral
D. Alkaline

63. How many salinity tests can be performed to determine the salt concentration of a sample of water?

A. 1
B. 2
C. 3
D. 4

64. Which method of determining water hardness is vastly superior to other tests?

A. Salinity
B. Methyl orange
C. Titration
D. Methyl purple

65. Which type of odor test is most widely used to determining odor levels?

A. Fragrance
B. Threshold
C. Briggs
D. Stark

66. For how many years are water sampling test results kept?

A. 1
B. 2
C. 3
D. 4

Trade Terms Introduced in this Chapter

Tributary	A stream that flows to a larger stream or other body of water.
Gastroenteritis	Inflammation of the stomach and intestines.
Vitriol	Any of various sulfates of metals such as ferrous sulfate, zinc sulfate, or copper sulfate.
Aerobic	A microorganism that uses oxygen for cellular respiration and requires some free molecular oxygen in its surroundings to support growth.
Saprophytic	Those bacteria who live and get nutrients of living from dead plants/animals.
Chromium	Is a steely-gray, lustrous, hard metal that takes a high polish and has a high melting point.
Alluvium	Is typically made up of a variety of materials, including fine particles of silt, clay, and larger particles of sand gravel.
Incubation	Is the time elapsed between exposure to a pathogenic organism and when symptoms and signs are first apparent of disease.
Hepatitis	Inflammation of the liver caused by a virus or a toxin and characterized by jaundice, liver enlargement, and fever.
Effluent	Sewage that has been treated in a septic tank or sewage treatment plant.
Aeration	Exposure to the action or effect of air or to the circulation of air.
Fungi	Comprising all the fungus groups and sometimes also the slime molds
Protozoa	A major grouping or superphylum of mostly single-celled animals of the kingdom Protista.
Sedimentation	The act or process of depositing sediment.
Facultative	Having the capacity to live under more than one specific set of environmental conditions, as a plant that can lead either a parasitic or a non-parasitic life or a bacterium that can live with or without air.
Cysts	Closed, bladder-like sacs formed in animal tissues, containing fluid or semi-fluid matter.

Typhoid	An infectious, often fatal, febrile disease, usually of the summer months, characterized by intestinal inflammation and ulceration, caused by the typhoid bacillus, which is usually introduced with food or drink.
Cholera	An acute, infectious disease, endemic in India and China and occasionally epidemic elsewhere, characterized by profuse diarrhea, vomiting, cramps, etc.
Dysentery	An infectious disease marked by inflammation and ulceration of the lower part of the bowels, with diarrhea full of mucous and blood.
Pathogenic	Capable of producing disease.
Slurry	A thin mixture of an insoluble substance, as cement, clay, or coal, with a liquid, as water or oil.
Porous	Full of pores, permeable by water or air.
Gasification	Conversion into a gas.
Lateral	An extension directed toward the side, as a branch or shoot.
Gypsum	A very common mineral, hydrated calcium sulfate, occurring in crystals and in masses, soft enough to be scratched by the fingernail.
Quartzite	A granular metamorphic rock consisting essentially of quartz in interlocking grains.
Silica	The dioxide form of silicon, occurring as quartz sand, flint, and agate.
Dolomite	A white or light-colored mineral.
Scale5	A coating or incrustation, as on the inside of a boiler, formed by the precipitation of salts from the water.
Diatomite	A fine siliceous earth compound.
Gelatinous	Having the nature of or resembling jelly.
Turbidity	Not clear or transparent because of stirred-up sediment or the like; clouded; opaque; obscured.
Potassium Permanganate	A very dark purple, crystalline, water-soluble solid.
Bromine	An element that is a dark-reddish, fuming, toxic liquid.
Chloramines	An unstable, colorless liquid, with a pungent odor, derived from ammonia.

Ampoules A sealed glass or plastic bulb containing solutions.

Burette A graduated glass tube commonly having a stopcock at the bottom, used for accurately measuring or measuring out small quantities of liquid.

Additional Resources and References

This chapter is intended to present thorough resources for task training. The following reference works are suggested for further study. This is optional material for continued education rather than for task training.

Basic Machines, NAVEDTRA 12199, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

OSHA Regulations (Standards – 29 CFR)

Naval Construction Force Manual, *NAVFAC P-315*, Naval Facilities Engineering Command, Washington, D.C., 1985.

Facilities Planning Guide, NAVFAC P-437, Volumes 1 and 2, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Fluid Power, NAVEDTRA 12964, Naval Education and Training Professional Development and Technology Center, Pensacola, FL, 1994.

National Standard Plumbing Code-Illustrated, National Association of Plumbing- Heating-Cooling Contractors, Washington, DC, 2006.

Safety and Health Requirements Manual, EM-385-1-1, Department of the Army, U.S. Army Corps of Engineers, Washington, DC, 1992.

MIL-STD-17-1, Mechanical Symbols

International Plumbing Code 2009, International Code Council

International Mechanical Code 2009, International Code Council

R. Dodge Woodson, *Plumber's Quick-Reference Manual Tables, Charts, and Calculations,* 1st edition, McGraw-Hill, NY, 1996.

Domestic Wastewater Control, MIL-HDBK-1005/8

Maintenance and Operation of Water Supply Treatment, & Distribution Systems, NAVFAC MO-210, Naval Facilities Engineering Command, Alexandria, VA, 1984.

Sewage & Sewage Treatment Facilities, NAVFAC MO-212, Naval Facilities Engineering Command, Alexandria, VA, 1982.

Water Testing Kit, Chemical Agent: M272, Technical Operations Manual, TM 3- 6665-319-10, Department of the Army, Washington, DC, 1983

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Chapter 9

Boilers

Topics

To hear audio, click on the box.

Overview

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

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

Objectives

When you have completed this chapter, you will be able to do the following:

1. State the steam generation theory.
2. Describe boiler design requirements.
3. Describe the different types of boilers.
4. Describe the different types of boiler fittings and accessories.
5. Identify the automatic controls associated with boilers.
6. Describe the different types of instruments and meters.
7. Describe the procedures associated with boiler water treatment and cleaning.
8. Describe the procedures for cleaning boiler firesides and watersides.
9. Describe the procedures associated with boiler maintenance.

Prerequisites

None

This course map shows all of the chapters in Utilitiesman Basic. The suggested training order begins at the bottom and proceeds up. Skill levels increase as you advance on the course map.

Utilities Equipment and Maintenance		
Air Conditioning		
Refrigeration		
Heating Systems		U
Steam Distribution Systems		T
Boilers		
Sewage Disposal, Field Sanitation, and Water Treatment		B
Prime Movers, Pumps, and Compressors		A
Plumbing Fixtures		S
Piping System Layout and Plumbing Accessories		I
Structural Openings and Pipe Material		C
Fundamentals of Water Distribution		
Basic Math, Electrical, and Plumbing Operations		
Plans, Specifications, and Color Coding		

Features of this Manual

This manual has several features which make it easier to use online.

- Figure and table numbers in the text are italicized. The figure or table is either next to or below the text that refers to it.
- The first time a glossary term appears in the text, it is bold and italicized. When your cursor crosses over that word or phrase, a popup box displays with the appropriate definition.
- Audio and video clips are included in the text, with an italicized instruction telling you where to click to activate it.
- Review questions that apply to a section are listed under the Test Your Knowledge banner at the end of the section. Select the answer you choose. If the answer is correct, you will be taken to the next section heading. If the answer is incorrect, you will be taken to the area in the chapter where the information is for

review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

- Review questions are included at the end of this chapter. Select the answer you choose. If the answer is correct, you will be taken to the next question. If the answer is incorrect, you will be taken to the area in the chapter where the information is for review. When you have completed your review, select anywhere in that area to return to the review question. Try to answer the question again.

1.1.1 STEAM GENERATION THEORY

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

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

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

1. All of the water in a vessel, when held at the boiling point long enough, will change into steam. As long as the pressure is held constant, the temperature of the steam and boiling water remains the same.
2. An increase in pressure results in an increase in the boiling point temperature of water.

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

The equation for figuring out the steam temperature is:

$$\sqrt{\text{Steam Pressure}} \times 14 + 198 = \text{Steam Temperature}$$

Let P = Steam Pressure

Let T = Steam Temperature

Example 1:

$$\sqrt{1} \times 14 + 198 = 212$$

Example 2:

$$\sqrt{100} \times 14 + 198 = 338$$

$$10 \times 14 + 198 = 338$$

$$140 + 198 = 338$$

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

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

Test your Knowledge (Select the Correct Response)

1. At what temperature Fahrenheit does water reach the boiling point?

   A. 200°
   B. 212°
   C. 232°
   D. 275°

2.0.0 BOILER FITTINGS and ACCESSORIES

A sufficient number of essential boiler fittings (*Figure 9-1*) and accessories are discussed in this section to provide a background for further study. As a reminder, and in case you should run across some unit or device not covered here, check the manufacturer's manual for information on the details of its construction and method of operation.

Figure 9-1—Boiler fittings.

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

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

2.1.0 Air Cock

An air cock is located in the uppermost steam space of a boiler, as shown in *Figure 9-2*. This design allows for air to enter and escape during filling and draining of the boiler. Before firing a cold boiler with no steam pressure, open the air cock to allow air to escape during the heating of the water. When steam begins to come out of the air cock piping, close the valve.

2.2.0 Chimneys, Draft Fans, and Breechings

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

Figure 9-2 — Aircock.

The forced draft fan forces air through the fuel bed, or fuel oil burner, and into the furnace to supply air for combustion. The induced draft fan draws gases through the setting, thus facilitating their removal through the stack. Breechings (see Item 1 in *Figure 9-1*) are used to connect the boiler to the stack. They are usually made of sheet steel with provision for expansion and contraction. The breeching may be carried over the boilers, in back of the setting, or even under the boiler room floor. Keep breechings as short as possible and free from sharp bends and abrupt changes in area. The cross-sectional area should be approximately 20 percent greater than that of the stack to keep draft loss to a minimum. A breeching with a circular cross section causes less draft loss than one with a rectangular or square cross section.

2.3.0 Blowdown Valves

Blowdown valves on boilers are located on the water column and on the lowest point of the water spaces of the boiler (*Figure 9-3*). The blowdown valves on a boiler installed at the bottom of each water drum and header are used to remove scale and other foreign matter that have settled in the lowest part of the water spaces. Boilers are also blown down to control concentration of dissolved and suspended solids in boiler water. The water column blowdown permits removal of scale and sediments from the water column. Additionally, some boilers have what is called a surface blowdown. The surface blowdown is located at the approximate water level so as to discharge partial steam and water. The surface blowdown removes

Figure 9-3 — Blowdown valve.

foaming on the top of the water surface and any impurities that are on the surface of the water.

2.4.0 Fusible Plugs

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

Figure 9-4 — Fusible plug.

The fire-actuated plug is filled with an alloy of tin, copper, and lead with a melting point of 445°F to 450°F. It is screwed into the shell at the lowest permissible water level. One side of the plug is in contact with the fire or hot gases, and the other side is in contact with the water (*Figure 9-4*). As long as the plug is covered with water, the tin does not melt. When the water level drops below the plug, the tin melts and blows out. Once the core is blown out, a whistling noise will warn the operator. The boiler then must be taken out of service to replace the plug.

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

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

2.5.0 Water Column

A water column is a hollow vessel having two connections to the boiler (*Figure 9-5*). Water columns come in many more designs than the two shown in *Figure 9-5*; however, they all operate to accomplish the same principle. The top connection enters the steam drum of the boiler through the top of the shell or drum. The water connection enters the shell or head at least 6 inches below the lowest permissible water level. The purpose of the water column is to steady the water level in the gauge glass through the reservoir capacity of the column. Also, the column may eliminate the obstruction on small diameter, gauge-glass connections by serving as a sediment chamber.

Figure 9-5—Typical water columns.

The water columns shown are equipped with high- and low-water alarms that sounds a whistle to warn the operator. The whistle is operated by either of the two floats or the solid weights shown in *Figure 9-5*.

2.5.1 Water Level Control

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

The float-operated type of feedwater control, similar in design to the feedwater control shown in *Figure 9-6*, is attached to the water column. This control uses a float, an arm, and a set of electrical contacts. As a low-water cutoff, the float rises or lowers with the water level in an enclosed chamber. The chamber is connected to the boiler by two lines, a setup which allows the water and steam to have the same level in the float chamber as in the boiler. An arm and linkage connects the float to a set of electrical contacts that operate the feedwater pump when the water lowers the float. When the water supply fails or the pump becomes inoperative and allows the water level to continue to drop, another set of contacts operates an alarm bell, buzzer, or whistle, and secures the burners.

The combination float and mercury switch type of water level control shown in *Figure 9-6, Frame 1* reacts to changes made within a maintained water level by breaking or making a complete control circuit to the feedwater pump. It is a simple two-position type control, having no modulation or differential adjustment or setting. As all water level controllers should be, it is wired independently from the programmer. The control is mounted at steaming water level and consists of a pressurized float, a pivoted rocker arm, and a cradle-attached mercury switch. The combination float and mercury switch type of water-level control functions as follows: As the water level within the boiler tends to drop, the float lowers. As the float lowers, the position of the mercury switch changes. Once the float drops to a predetermined point, the mercury within the tube runs to its opposite end. This end contains two wire leads, and when the mercury covers both contacts, a circuit is completed to energize the feedwater pump. The pump, being energized, admits water to the boiler. As the water level within the boiler rises, the float rises. As the float rises, the position of the mercury switch changes. Once the float rises to a predetermined point, the mercury runs to the opposite end of its tube, breaking the circuit between the wire leads and securing the feedwater pump. The feedwater pump remains off until the water level again drops low enough to trip the mercury switch.

Figure 9-6 — Combination float and mercury switch type of feedwater control.

Because of the hazards associated with mercury, these switches are being phased out. The electrode probe type of feedwater control and low-water cutoff and the solid state (*Figure 9-6, Frame 2*) type of switches are replacing them. The solid state components are controlled by a ground wire connected to the side of the reservoir and a probe that extends into the water column. When the water is at the acceptable level, current is available and the switch remains closed. When the water level drops, the current is reduced and the switch is activated thus turning on the water pump. If the water level drops too far down the probe, the burner cutout switch is activated and the burner will not come on until the water reaches the appropriate level.

The electrode probe type of feedwater control and low-water cutoff consists of an electrode assembly and a water level relay (*Figure 9-7*). The electrode assembly contains three electrodes of different lengths corresponding to high, low, and burner cutout in the boiler drum.

To understand the operation of a boiler circuit, refer to *Figures 9-7*and *9-8* as you read the information in *Table 9-2*. Although this information is not complete, it is presented here to acquaint you with the operation of the electrode type of boiler water-level control.

Figure 9-7 — Electrode type of water-level control.

Figure 9-8—Typical boiler circuit.

Table 9-2 — Operation of a boiler circuit.

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

2.5.2 Try Cocks

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

WARNING

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

2.5.3 Gauge Glass

The gauge glass allows the boiler operator to see the water level in the boiler. Normally there are two valves associated with the gauge glass. One valve is located at the top and one is located at the bottom of the gauge glass. These two valves, named gauge cock valves, secure the boiler water and steam from the gauge glass. Another valve located in line with the gauge glass is used to blow the gauge glass down.

2.6.0 Safety Valve

The safety valve shown in *Figure 9-9* is the most important of boiler fittings. It is designed to open automatically to prevent pressure in the boiler from increasing beyond the safe operating limit. The safety valve is installed in a vertical position and attached directly to the steam space of the boiler. Each boiler has at least one safety valve; when the boiler has more than 500 square feet of heating surface, two or more valves are required.

There are several different types of safety valves in use, but all are designed to open completely (POP) at a specific pressure and to remain open until a specified pressure drop (BLOWDOWN) has occurred. Safety valves must close tightly, without chattering, and must remain tightly closed after seating.

Figure 9-9 — Spring-loaded safety valve.

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

Several different types of safety valves are used on boilers; however, they all lift on the same general principle. In each case, the initial lift of the valve disk, or feather, is caused by static pressure of the steam acting upon the disk, or feather. As soon as the valve begins to open, however, a projecting lip, or ring, of the larger area is exposed for the steam pressure to act upon. The resulting increase in force overcomes the resistance of the spring, and the valve pops, that is, it opens quickly and completely. Because of the larger area now presented, the valve reseats at a lower pressure than that which caused it to lift originally.

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

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

2.7.0 Steam Injector Feed System

The steam injector is a boiler feed pump that uses the velocity and condensation of a jet of steam from the boiler to lift and force a jet of water into the boiler (*Figure 9-10*). This injection of water is many times the weight of the original jet of steam.

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

Figure 9-10 — Cross-sectional view of a steam injector.

The installation of an injector is not a difficult operation because the unit is mounted on the side of the boiler. The four connections to the injector are as follows (*Figure 9-11*):

1. The discharge line to the boiler feedwater inlet
2. The steam supply line from the boiler
3. The water overflow line
4. The water supply line from the reservoir.

Figure 9-11 — Injector piping.

The controls for the injector include the following (*Figure 9-11*):

A. Steam supply valve

B. Water supply valve

C. Discharge valve to the boiler

D. Check valve in the discharge line

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

When starting the injector, first open the water supply valve (*Figure 9-11B*) about one full turn. Next quickly turn the steam supply valve (*Figure 9-11A*) all the way open. At this point, steam rushes into the combining tube of the injector. As the steam speeds past the water supply opening, it creates a suction that draws water through the opening into the combining tube. Water and steam are now mixed together inside the injector, and the pressure opens a valve that leads to the boiler. Meanwhile, there is an excess of water in the injector; this excess is discharged through the overflow valve. As the next step of the procedure, slowly turn the water supply valve (*Figure 9-11B*) toward the closed position until the overflow stops. The overflow valve has now closed, and all of the water being picked up from the supply line is going into the boiler. Remember, this feedwater system is used on boilers only as a standby method for feeding water.

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

2.8.0 Handholes and Manholes

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

2.9.0 Boiler Accessories

Figure 9-12 provides a graphic presentation of important boiler accessories. Refer to it as you study *Table 9-3*, which gives a brief description of each accessory, its location, and function.

Figure 9-12 — Boiler accessory equipment.

Table 9-3 — Boiler accessories, location, and function.

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

		dead ends	
10	Temperature regulating valve (TRV)	Install in the steam supply line close to equipment needing temperature regulation	Control steam flow through a vessel or heating equipment.
11	Heat exchanger	Locate as close as practical to the source for which it is going to supply heated water or oil	An unfired pressure vessel that contains a tube nest or electrical element. Used to heat oil or water.
12	Strainer	Install in steam and water lines just ahead of PRVs, TRVs, steam traps, and pumps	Prevent malfunction or costly repairs to equipment and components by trapping foreign matter such as rust, scale, and dirt.
13	Condensate line	Return line extends from the discharge side of steam traps to the condensate/makeup feedwater tank	Carry condensated steam back through piping for reuse in the boiler or heating vessel.
14	Condensate/makeup tank	Close to the boiler as practical and at a higher level than the boiler feed-pump suction line	Provide storage space for condensate and makeup/feedwater and vent noncondensable gases to the atmosphere.
15	Feed pump	Installed between the condensate/makeup/feedwater tank and the boiler shell or steam drum.	Supplies water to boiler as required.
16	Feedwater pipe	This line extends from the discharge side of the feedwater pump to the boiler shell or drum (installed below the steaming water level)	Provide feedwater to the boiler when required.
17	Relief valve	Between the feed pump and the nearest shutoff valve in the external feed line	Relieve excessive pressure should the external feed line be secured and the feed pump started accidently. A ruptured line or serious damage to the feed

			pump could occur if there were no relief valve.
18	Feed check valve	Between the feed pump and the stop valve in the feed water pipe	Prevent backflow from the boiler through the feedwater line into the condensate/feedwater tank during the off cycle of the pump.
19	Feed stop valve	In the feedwater line as close to the boiler as possible between the boiler and feed check valve	Permit or prevent the flow of water to the boiler.

Test your Knowledge (Select the Correct Response)

2. What is the melting point of a fire-actuated fusible plug filled with an alloy of tin, copper, and lead?

   A. 415°F
   B. 425°F
   C. 435°F
   D. 445°F

3.1.1 TYPES of BOILERS

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

The basis for identifying the two types is as follows:

- Water-tube boilers are those in which the products of combustion surround the tubes through which the water flows.
- Fire-tube boilers are those in which the products of combustion pass through the tubes and the water surrounds them.

3.1.0 Water-Tube Boilers

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

3.1.1 Straight Tube

The straight-tube class of water-tube boilers includes three types:

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

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

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

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

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

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

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

3.1.2 nt Tube

Bent tube boilers usually have three drums. The drums are usually of the same diameter and positioned at different levels. The uppermost or highest positioned drum is referred to as the steam drum, while the middle drum is referred to as the water drum, and the lowest, the mud drum. Tube banks connect the drums. The tubes are bent at the ends to enter the drums radially.

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

Many types of baffle arrangements are used with bent-tube boilers. Usually, they are installed so that the inclined tubes between the lower drum and the top front drum absorb 70 to 80 percent of the heat. The water-tube boilers discussed above offer a number of worthwhile advantages. For one thing, they afford flexibility in starting up. They also have a high productive capacity ranging from 100,000 to 1,000,000 pounds of steam per hour. In case of tube failure, there is little danger of a disastrous explosion of the water-tube boiler. The furnace not only can carry a high overload, it can also be modified for firing by oil or coal. Still another advantage is that it is easy to get into sections inside the furnace to clean and repair them. There are also several disadvantages common to water-tube boilers. One of the main drawbacks is their high construction cost. The large assortment of tubes required for this boiler and the excessive weight per unit weight of steam generated are other unfavorable factors.

3.2.0 Fire-Tube Boilers

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

3.2.1 Scotch Marine Boiler

The Scotch marine tire-tube boiler is especially suited to Seabee needs. *Figure 9-13* shows a portable Scotch marine tire-tube boiler. The portable unit can be moved easily and requires only a minimal amount of foundation work. A completely self-contained unit, its design includes automatic controls, a steel boiler, and burner equipment. These features are a big advantage because no disassembly is required when you must move the boiler into the field for an emergency.

Figure 9-13 — Scotch marine type of fire-tube boiler.

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

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

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

Access for cleaning, inspection, and repair of the boiler watersides is provided through a manhole in the top of the boiler shell and a handhole in the ***water leg***. The manhole opening is large enough for a person to enter the boiler shell for inspection, cleaning, and repairs. On such occasions, always ensure that all valves are secured, locked, and tagged, and that the person in charge knows you are going to enter the boiler. Additionally, always have a person located outside of the boiler standing by to aid you in case of an incident that would require assistance. The handholes are openings large enough to permit hand entry for cleaning, inspection, and repairs to tubes and headers.

Figure 9-14 shows a horizontal fire-tube boiler used in low-pressure applications. Personnel in the UT rating are assigned to operate and maintain this type of boiler more often than any other type of boiler. Refer to *Table 9-1* for equipment location.

Figure 9-14—Horizontal fire-tube boiler used in low-pressure applications.

Table 9-1 — Horizontal fire-tube boiler parts location.

1. Vents	7. Water Level Gauge	13. Fuel Oil Supply Connection
2. Air Damper	8. Burner Switch	14. Fuel Oil Pressure Gauge
3. High Limit Pressure Control	9. Priming Tee	15. Ignition Cable
4. Steam Pressure Gauge	10. Oil Unit, Two Stage	16. Ignition Cable Box
5. Gauge Glass Shutoff Cock	11. Solenoid Oil Valve	17. Nameplate
6. Low Water Control	12. Service Connection Box	

3.2.2 Vertical-Tube Boiler

In some fire-tube boilers, the tubes run vertically, as opposed to the horizontal arrangement in the Scotch boiler. The vertical-tube boiler sits in an upright position *(Figure 9-15)*. Therefore, the products of combustion (gases) make a single pass, traveling straight up through the tubes and out the stack. The vertical fire-tube boiler is similar to the horizontal fire-tube boiler in that it is a portable, self-contained unit requiring a minimum of floor space. Handholes are also provided for cleaning and repairing. Though self-supporting in its setting (no brickwork or foundation being necessary), it MUST be level. The vertical fire-tube boiler has the same disadvantages as that of the horizontal-tube design—limited capacity and furnace volume.

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

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

Figure 9-15—Cutaway view of a vertical fire-tube boiler.

3.2.3 orizontal Return Tubular Boiler

In addition to operating portable boilers such as the Scotch marine and vertical fire-tube boilers, the UT must also be able to operate stationary boilers, both in the plant and in the field. A stationary boiler can be defined as one having a permanent foundation and not easily moved or relocated. A popular type of stationary fire-tube boiler is the horizontal return tubular (HRT) boiler shown in *Figure 9-16*.

Figure 9-16—Horizontal return tubular (HRT) fire-tube boiler.

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

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

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

3.2.4 Firebox Boiler

Another type of fire-tube boiler is the firebox boiler that is usually used for stationary purposes. A split section of a small firebox boiler is shown in *Figure 9-17.*

Figure 9-17—Split section of a small firebox boiler.

Gases in the firebox boiler make two passes through the tubes. Firebox boilers require no setting except possibly an ash pit for coal fuel. As a result, they can be quickly installed and placed in service. Gases travel from the firebox through a group of tubes to a reversing chamber. They return through a second set of tubes to the ***flue*** connection on the front of the boiler and are then discharged up the stack.

4.1.1 BOILER DESIGN REQUIREMENTS

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

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

NOTE

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

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

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

5.0.0 AUTOMATIC CONTROLS

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

5.1.0 Float Control

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

A float is often used to measure the change in fluid level and to operate the controlled valve to restore the balance. It may be arranged to increase the flow when the fluid level drops. *Figure 9-18* shows one of the methods used to accomplish this. Here, the float is connected to the control valve.

Figure 9-18 — Float controller.