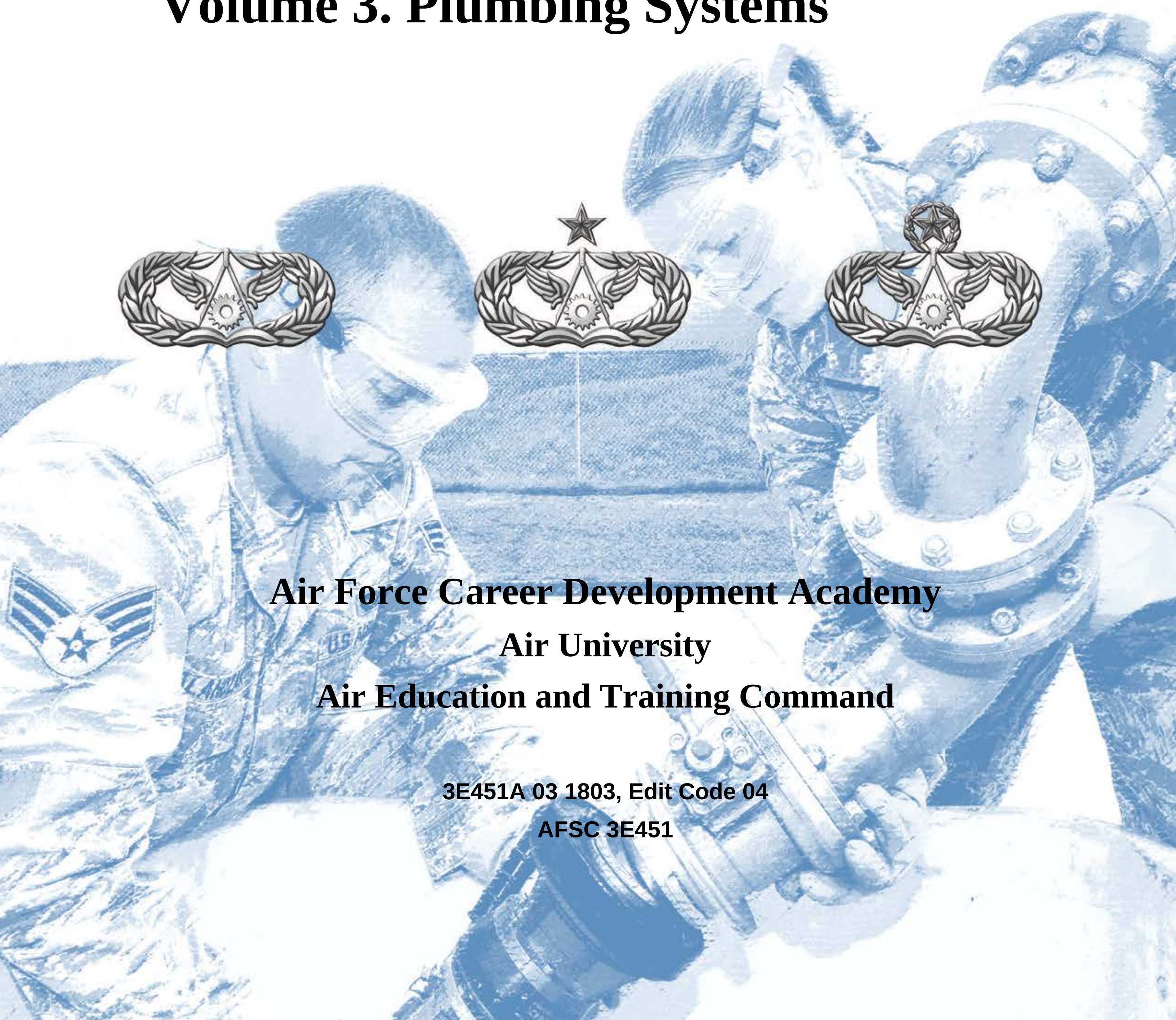
CDC 3E451A
Water and Fuel Systems Maintenance Journeyman

Volume 3. Plumbing Systems



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THIS COURSE was designed with you, the student, in mind. In this volume, the most recent information taught at the Water and Fuel Systems Maintenance (WFSM) technical school has been expanded upon. You will find that the information in this course is to the point and relies on supervisor involvement. Please do your part and answer the questions about the subjects covered.

This volume contains four units. Unit 1 covers plumbing fundamentals. In unit 2 we discuss water distribution. In unit 3, we cover wastewater collection, and in unit 4, we discuss plumbing equipment and components.

As you complete this course, you'll gain the knowledge that, if applied with on-the-job training, will give you the skills required to advance beyond the apprentice level. Read and study each lesson, do the self-test questions and complete the mentioned training qualification packages, and you will master the contents of this course.

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This volume is valued at 18 hours and 6 points.

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NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

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Unit 1. Plumbing Fundamentals

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THE PROCEDURES FOR MEASURING, cutting, and assembling pipe and tubing are extremely important in the Water and Fuel Systems Maintenance (WFSM) career field. If you make an error in any of these steps, you may have to repeat the entire job, costing time, manpower, and taxpayers' dollars, not to mention your reputation. You must also understand that the materials selected for a job are crucial for the proper installation of water and fuel systems. This unit will take you through the proper selection of tubing, piping, and fittings. Then, we will finish with measuring, cutting, and assembling the different materials needed to complete the job.

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1–1. Piping

Your knowledge of the piping and fittings is essential to planning projects and performing your job. In this section, we discuss the different types of piping and associated fittings. We also cover the different methods to properly measure and cut piping; this includes the procedures for joining them. The knowledge you gain from this section will enhance your ability to plan projects and perform your job.

401. Types of pipe and tubing

There are many different types of pipe, tubing, and fittings used in a plumbing and fuel systems. This lesson will focus on common types currently found in our career field. This section does not cover all pipe types in existence; you may encounter piping you have never seen before on the job. Always ask an experienced member of your shop for clarification.

Plastic pipe

We use hard and flexible plastic pipe for water, waste, and gas systems. It is commonly available in sizes from $^1/_2$ inch (") to 18" in diameter. Rigid lengths are usually manufactured in 20-foot (') lengths, while flexible forms come in lengths or long coils for large and smaller pipe. Positive characteristics of pipe include that they are easy to use and will not rust, rot, or corrode. There are many types of plastic pipes; seven types are listed and defined in the following table.

Type	Use
ABS (acrylonitrile-butadiene-styrene)	ABS is a rigid pipe used for building drain, waste, and vents (DWV). We normally connect, or join, two pieces of ABS by solvent welding or, in waste systems, with no-hub clamps.
PVC (polyvinyl chloride)	PVC is a rigid pipe normally used in water distribution systems. Join PVC by solvent welding on smaller pipe—4" and smaller—or O-ring joints are used to connect larger pipe. PVC piping typically comes in schedule 40; schedule 80; and DWV. Schedule 80 PVC is thicker and stronger than schedule 40. Use DWV in sanitary waste systems only.
CPVC (chlorinated polyvinyl chloride)	CPVC is a rigid pipe similar to PVC but has been specially developed to withstand higher temperatures than other plastics. It is normally rated for 180°F at 100 pounds per square inch (psi). Because of its excellent resistance to chemicals, CPVC is now available in larger sizes in DWV applications. CPVC is typically used for hot water distribution systems and joined by solvent welding.
PB (polybutylene)	PB is flexible tubing used for cold water building supply and underground sprinkler systems. Join it by flaring, heat fusion, compression couplings, or with insert fittings, since solvent welding is *not* possible. PB is widely used in mobile homes due to its expansion/contraction characteristics.
PP (polypropylene)	PP is rigid piping used for industrial applications (water and wastewater treatment) involving corrosive media. PP may be used at temperatures to 150°F, in continuous pressure service, and at temperatures to 180°F, with gravity flow conditions. PP is very lightweight and has good chemical resistance. PP is commonly available in schedule 40/80 and is typically joined by heat fusion welding.
PE (polyethylene)	PE is flexible piping used for industrial piping systems, as well as for buried gas and water pipelines. The major benefits of PE are that it's virtually unbreakable due to impact and low temperatures, exceptionally resistant to abrasion, and has good chemical resistance. PE is commonly joined by heat fusion welding. PE typically comes in three strengths—low, medium, and high density.
PEX or XLPE (cross-linked polyethylene)	PEX tubing is predominantly used in water distribution systems, hydronic radiant heating systems, and natural gas systems. PEX systems provide a safe, economical, and energy-efficient piping alternative for water distribution, radiant floor heating, municipal water supply, geothermal climate control, snow melt, and drip irrigation. PEX delivers clean, safe potable water and is chlorine-resistant, corrosion-resistant, freeze-damage and abrasion-resistant. The excellent thermal properties of PEX are ideal for hot and cold water distribution. PEX tubing is available in stick, spool, or coil. The systems involve tubing, manifolds, fittings, valves, and accessories.

Before proceeding further, we need to define a couple plumbing terms.

- **Hub, bell, or socket**—describes the flared or bell shape end of a pipe or fitting capable of receiving the spigot or no-hub end of a pipe or fitting.
- **Spigot or no-hub**—describes the straight or unflared end of a pipe or fitting capable of being inserted into a hub, bell, or socket end of a pipe or fitting or a no-hub coupling.

Cross-linked polyethylene pipe

PEX pipe is the newest plastic type being used for plumbing in North America. It is very flexible and capable of making turns greater than 90 degrees (°); therefore, it requires using fewer fittings. PEX pipe can be used for hot or cold service and, with the proper fittings, can easily be connected to existing pipes of different materials. PEX offers you different connection methods, which are copper crimp ring, copper crimp sleeve, stainless steel sleeve, and "Push 'N Go". These connection methods are described next with the connection procedure for each.

Copper crimp ring

Follow these steps to make a connection with the copper crimp ring:

1. Cut the pipe to length squarely. A rough, jagged, or irregular cut may result in a failed connection.
2. Slide the correct sized copper crimp ring over the end of the PEX pipe. Slide the ring approximately 2” past the end of the pipe.
3. Push the fitting into the pipe until it touches the fitting shoulder. Position the crimp ring $^{1}/_{8}$” to $^{1}/_{4}$” from the end of the tube. This distance ensures that the crimp ring is positioned directly over the ribs on the barb.
4. Center the crimping tool (fig. 1–1) jaws over the ring. Hold the tool at 90 degrees to the fitting and close the jaws completely. Crimp only one time; if crimped more than once, you must cut out the connection and begin again at Step 1.
5. Use the go/no-go gauge (fig. 1–2) to check every crimp joint. An improper crimp has been formed when (1) the “go” side does not fit over the ring or, and (2) the “no” side does fit over the ring. If the joint fails either of these two tests, then cut out the joint and return to Step 1.

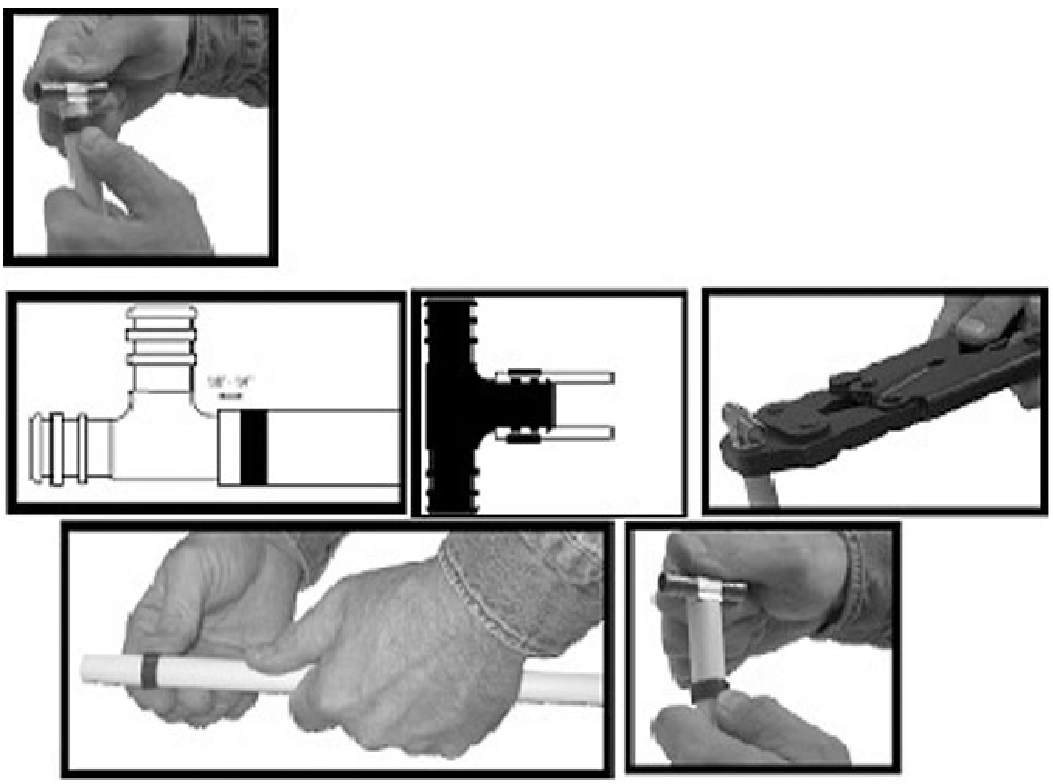
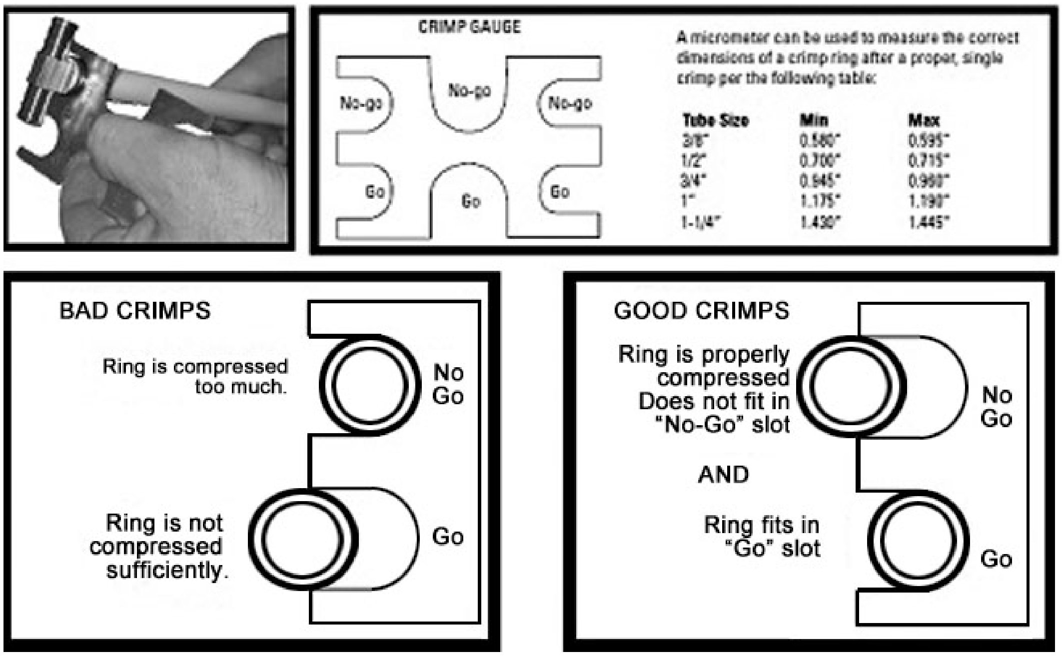


Figure 1–1. Crimping tool.



Tube Size	Min	Max
3/8"	0.580"	0.595"
1/2"	0.700"	0.715"
3/4"	0.945"	0.960"
1"	1.175"	1.190"
1-1/4"	1.430"	1.445"

Figure 1–2. Go/no-go gauge.

Copper crimp sleeve/stainless steel sleeve

Follow these steps to make a connection with the copper crimp or stainless steel sleeve:

1. Cut the pipe to length squarely. A rough, jagged, or irregular cut may result in a failed connection.
2. Slide the correct sized stainless steel sleeve over the end of the pipe until it bottoms out. Look at the view hole on the side to see if it is over the pipe.
3. Push the fitting into the pipe until it touches the fitting shoulder.
4. Center the sleeve tool jaws over the ring. Hold the tool at 90 degrees to the sleeve and close the jaws completely. Crimp only one time. If crimped more than once, you must cut out the connection and begin again at Step 1.
5. Visually inspect the completed connection. If the pipe can be seen from the view hole on the side of the sleeve and a "W" shaped crimp has been formed around the sleeve, then a good connection has been made (fig. 1–3).

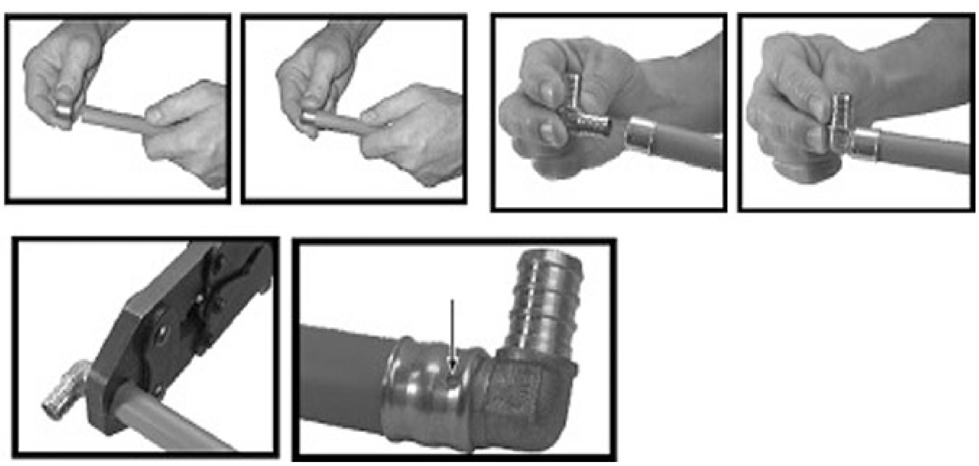


Figure 1–3. Sleeve tool.

Push 'N Go

For the Push 'N Go connection, follow these procedures:

1. Get your pipe and fitting ready to connect.
2. Push pipe into the fitting until it stops, and you're done (fig. 1–4).

Figure 1–4. Quick-connect fitting.

Features and benefits

The many features and benefits for using the PEX pipe are as follows:

- Quick-connect fittings can be used in potable water systems.
- Made of polyphenylsulfone, this has been proven in extensive tests for cleanliness, pressure, flow, longevity, chemical exposure, and chlorine resistance.
- Works with plastic and copper tube size (CTS) tubing.
- No tools, crimp, or solder required; simply push the pipe into the fitting.
- Easy to disassemble; push in the gripper ring and pull out the pipe.
- Available from $^{1}/_{2}$" through $^{3}/_{4}$".
- Locking clips are available for behind the wall installation.

Copper/stainless steel tubing

We use copper tubing for water supply and drainage systems, as well as for fuel valves and components. It is lightweight, easily installed, and resists corrosion. The American Society for Testing and Materials (ASTM) designates standard ASTM B88 as the copper tubing used for drinking water and is available in hard (rigid) or soft (flexible) drawn forms. Both forms are available in different wall thicknesses, commonly labeled K, L, M (high pressure [HP], medium pressure [MP], and low pressure [LP] respectively), and DWV. The type of tubing you use depends on the system and location of installation. Hard-drawn copper tubing is available in 20-foot lengths or less and soft-drawn (sizes up to 1" diameter only) in 25' to 100' coils. Copper tubing is joined by soldering or by compression-type fittings. For fuel and other applications, ASTM B75, or B280 (alloy 122, soft drawn), are commonly used.

Stainless steel tubing is used primarily for fuel systems. It can be ordered in different lengths, strengths, and thicknesses (ASTM A213, or A269, Type 304, or 316). A tubing bender is used to configure it into the different shapes needed for the job. Compression-type fittings are used to join this tubing to fuel components.

Steel pipe

Steel pipe comes in two basic types: galvanized and black iron. Black-iron pipe is actually steel pipe painted black. Its name was carried over when the pipe was first made of only iron. Steel is composed of an iron-carbon alloy which increases its strength. Black-iron is used for natural gas distribution lines and fuel system piping. Galvanized pipe is primarily for cold and hot water distribution systems, drainage systems, and vent installations in buildings. Steel pipe is manufactured in standard lengths of

21’ with diameters from $^{1}/_{8}$” to 24”. Galvanizing extends the pipe’s life span by reducing corrosion, such as rust; however, galvanizing does not strengthen the pipe itself. Steel pipe is threaded for assembly. The threads on the pipe, as well as those in the fittings, are tapered to assure a tight joint. For fuel systems, black iron pipe sections are joined by welds and welded flanges for pipe sizes 2” and over.

NOTE: Galvanized pipe and fittings are never used in fuel systems because the chemicals used in processing the metal can leach into and contaminate the fuel.

Stainless steel pipe

Stainless steel pipe is used to carry liquids that are corrosive to other metals due to its iron-carbon-chromium alloy composition. It is commonly found in newer hydrant fuel systems, but because of its cost, is rarely found in water and waste systems. In fuel systems, stainless steel pipe 2” and under can have threaded ends, but for sizes 2” and over, welds and welded flanges must be used to join pipe sections.

Cast-iron water pipe

Cast-iron water pipe comes in sizes of 3 to 48” in diameter and 18’ lengths. The bell and spigot, flanged, and mechanical joints are three types of joints used in the assembly of cast-iron water pipe. (We look at some of these joints later in the course.)

Cast-iron soil pipe

Use cast-iron soil pipe in drainage systems. Manufacturers produce cast-iron soil pipe in service weight and in extra heavy weights. Each section is usually 5’ or 10’ long and joined with bell and spigot or hubless joints. The pipe is produced in diameters of 2” to 15”.

Vitrified clay tile pipe

Use vitrified clay tile pipe in the sewer system. It comes in 2’ to 6’ lengths and diameters of 4” to 36”. It has bell and spigot ends similar to cast-iron soil pipe.

Asbestos-cement pipe

Asbestos-cement pipe for water and sewer mains are still found in the field today. It was installed in lengths up to 13’. There are three classes (pressure ratings) of asbestos-cement pipe: 100, 150, and 200. Sizes range from 3” to 36” in diameter. Use appropriate sleeve couplings and material to repair this pipe. Depending on your location, this type of pipe may be prohibited due to the presence of asbestos fibers.

As repairs are needed to older piping systems made of iron, clay, and asbestos-cement, they are being replaced by WSFM civil engineers (CE) with improved, safer, and cost-efficient materials available today.

402. Types of pipe fittings

Fittings are prefabricated plumbing parts used to connect pipes together, make bends in pipelines, and attach fixtures to piping. The ability to identify and select specific fittings for the appropriate application will greatly increase your effectiveness as a WFSM journeyman.

Pipe threading sizes

Threaded pipe fitting sizes found in the United States (US) will conform to National Pipe Thread (NPT) standards. This ensures that threaded pipe and fittings, when screwed together, will not damage the threads. If in an overseas location and purchasing materials on the local economy, be aware that fittings may conform to the metric standard and should not be combined with NPT standard pipe threads or fittings. You need to plan your job according to the materials available in your deployed location. If they use metric sizes, order metric. Do not mix NPT and metric pipe and fittings.

Fitting sizes are determined by the size of the pipe that the fitting can accommodate. Measure the angle of fittings in fractions of 360°. Thus, we call a 90° turn a $^1/_4$ bend or an elbow, and a 45° turn a $^1/_8$ bend or elbow. If the pipefitting has a side branch, it is normally called a "tee" (because it is shaped like the letter "T") or a wye (because it is shaped like the letter "Y"). Measure the angle of the branch in degrees.

There are also combinations such as a wye and $^1/_8$ bend, which combines a wye and a $^1/_8$ bend. Externally threaded ends of fittings are called male ends, and internally threaded ends are referred to as female; figure 1–5 shows various fittings. Study it while you read the descriptions in the following table.

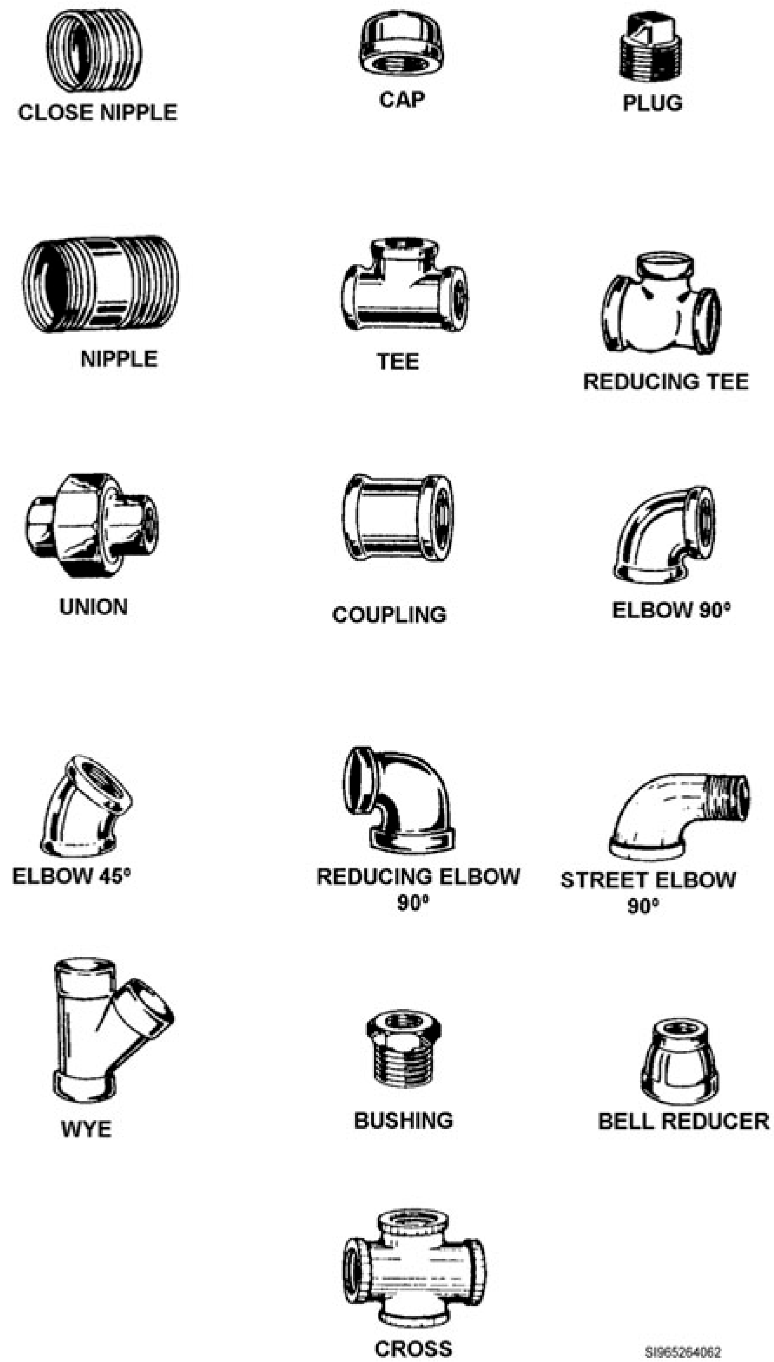


Figure 1–5. Types of fittings.

Type of Fitting and Its Use	
Coupling	Couplings connect two pipes end to end if they need not be disconnected later. Use a reducing coupling, smaller on one end, to join pipes of different sizes.
Union	Use a union to connect two pipes end to end if you need to disconnect them later, such as for maintenance, in a line where a branch line may be inserted later, or where a single piece of pipe is not practical because of length or cost. A union consists of *three* basic parts: two shoulders that are attached to two ends of pipe and a collar that mates the two shoulders. On the first shoulder, a lip acts as a restriction for the collar. The second shoulder is externally threaded so that it can be joined to the lipped shoulder using the collar ring. Both shoulders also have internal threads (for attachment to a pipe end).
Elbow	Elbows are pipefittings used for changing the direction of a pipeline. Elbows are also used to avoid an obstruction. A pipeline may be returned to its original direction by using two elbows. Standard and reducing elbows join pipes at 45° or 90° angles. 45° elbows are preferred because they cause less friction in the line. Street elbows differ in that they have one female and one male end. Street elbows are used for applications that require close work.
Tee	Use standard or reducing tees to join three pipes. The three types of tees are straight, short-turn, and long-turn. A straight tee connects two pipes end to end and a third at a right angle (90°). The short-turn tee is usually used vertically within wall partitions. The long-turn tee is installed vertically or horizontally where space permits and can be used at 90° turns.
Wye	Use a wye (Y) branch to connect two pipes end to end and a third pipe at a 45° angle. We often use wyes in drainage systems because branches must enter drains at a 45° angle. You can put a plug on the top of a wye and use it as a clean out.
Cross	Use crosses to connect four pipes at 90°. Manufacturers produce standard (all openings are the same size) and reducing crosses enabling us to connect pipes of different sizes.
Plug	Use a plug to close a female end of a fitting. When a plug is installed, it is meant to stay there for an indefinite period. Plugs are used to stop flow or allow access to a pipeline at a later date, such as in a clean out. Plugs have “male” threads.
Cap	Use a cap to close the male end of a pipe. Just like a plug, a cap is also designed to remain for an indefinite period of time. Caps are also used to stop flow in a pipeline. A cap can be used on a riser to provide for pressure fluctuations.
Bushing	Bushings have internal and external threads. We use bushings to connect a smaller pipe to a larger pipe. The smaller pipe goes into the female part of the bushing. The male part of the bushing fits into the female end of a pipe. There are three types of bushings: face, eccentric, and plain hexagon. Face bushings are used when appearance is important. Eccentric bushings are used when condensation (like in a vent) needs to drain away. A hex bushing is six-sided.
Bell Reducer	Bell reducers are similar to couplings in that they both have female threads on both ends. The bell reducer is shaped like a bell and is used to reduce pipe sizes.
Nipple	Nipples are short pieces of pipe in various lengths. These nipples vary in length from close nipples (virtually all thread) to a shoulder nipple (only a small section of the nipple is not threaded) on up to 6” in length. Lengths are graduated in ½” increments. Nipples also are available in lengths of 7” to 12” in 1” graduations.

CAUTION: Metal fittings should always be of the same material as the pipe unless there is some way to isolate the different or *dissimilar* metals like the insulating gaskets of a dielectric union used on hot water heaters. Without this insulation, corrosion and rust (oxidation) will occur where the two metals meet, eventually causing a leak.

Cast-iron pipefittings

The structural characteristics of gray iron paired with the manufacturing process and coal tar coating create a strong and corrosion-resistant cast iron pipefitting. Cast-iron pipe and fittings also produce some of the quietest drainage systems due to their wall thickness. Other thinner types of pipe readily transmit drainage noise. Cast iron’s main disadvantage is its weight. Cast-iron pipefittings are available with bell and spigot, no-hub and threaded connections.

Bell and spigot

Bell and spigot fittings have a bell, or hub, cast at one end of the fitting into which you insert the spigot, or plain end, of another pipe or fitting to join them together. The space between the hub and the plain end of the pipe is sealed with a mechanical compression joint. Some examples of bell and spigot fittings are shown in figure 1–6. Manufacturers produce cast-iron fittings in service and extra heavy weights. The two are not interchangeable due to the wall thickness of the fittings.

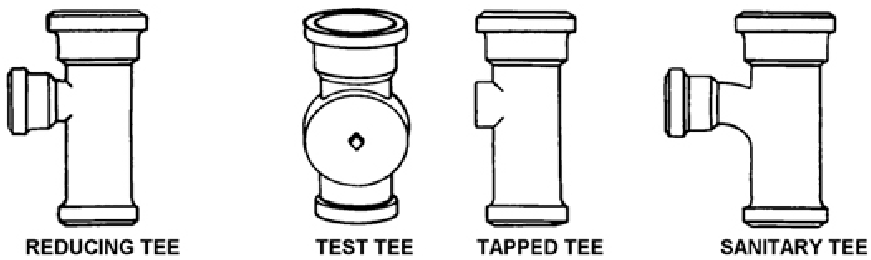


Figure 1–6. Types of bell and spigot cast iron fittings.

No-hub

No-hub fittings were devised to not only enable easier assembly of cast-iron piping but also to help the cast-iron industry compete with other types of pipe that were easier to assemble such as plastic. Join no-hub pipe and fittings with a mechanical joint made of a neoprene sleeve and a stainless steel band. Figure 1–7 shows some no-hub fittings.

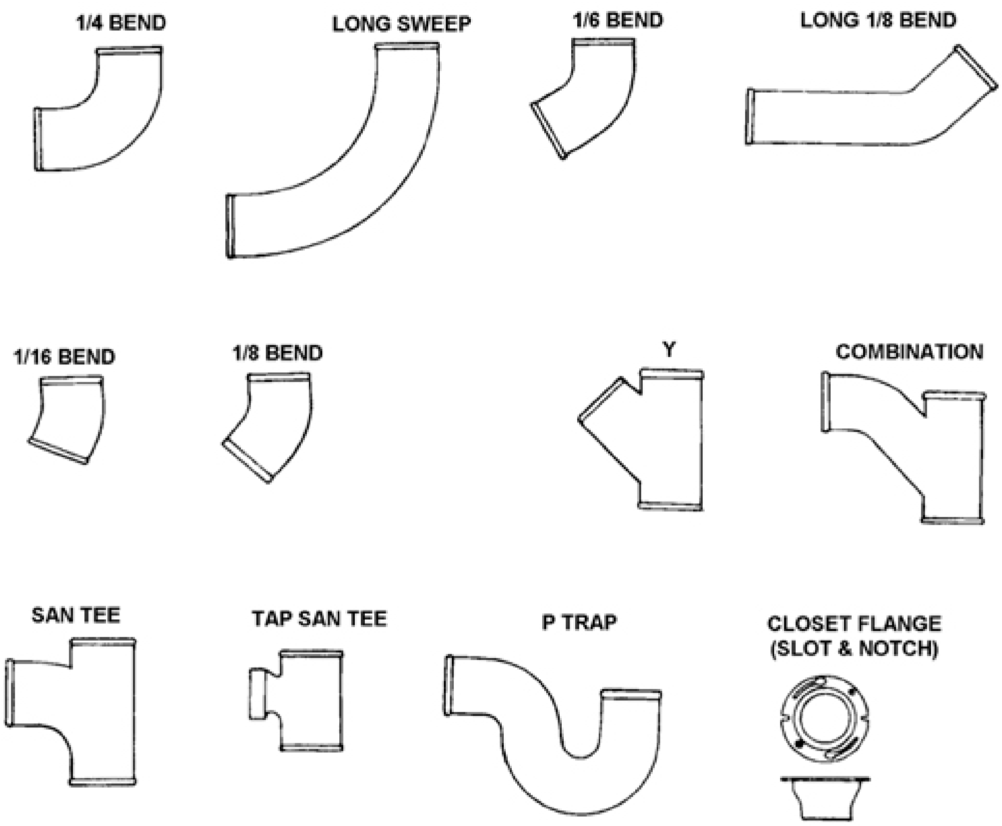


Figure 1–7. Types of no-hub fittings.

Cast-iron recessed drainage fittings

These fitting are cast with a recessed shoulder to provide a smooth interior surface so that proper installation leaves no obstruction to the flow of waste material through the pipe. Figure 1–8 illustrates a sectional view of a cast-iron recessed drainage elbow with the threaded joint properly installed. Another difference in these drainage fittings is that they have slightly pitched outlets (¼" per foot) for connection to horizontal drainage pipes that must be pitched or graded. Another name for the cast-iron recessed drainage fittings is the Durham fittings. Figure 1–9 shows some of the common cast-iron recessed drainage fittings.

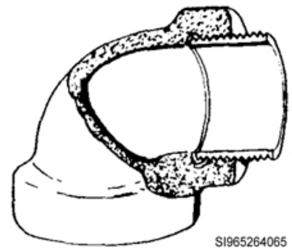


Figure 1–8. Inside view of a recessed drainage fitting.

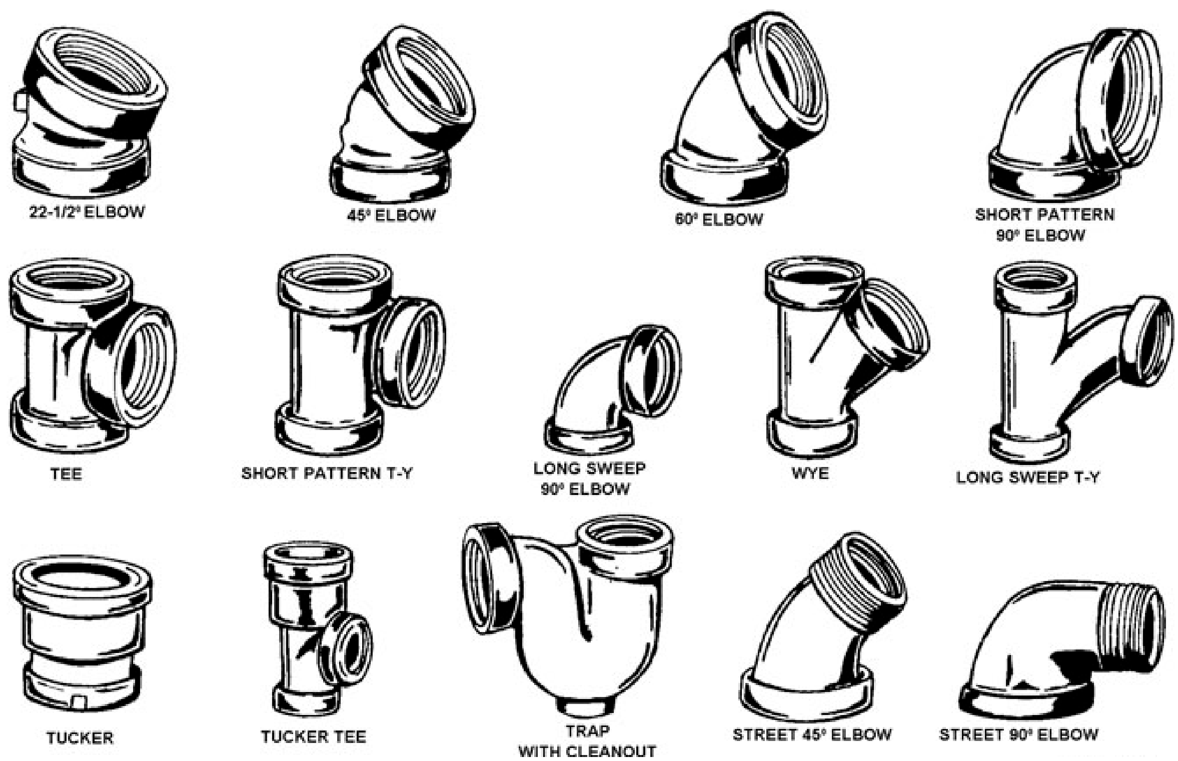


Figure 1–9. Types of recessed drainage fittings.

Steel pipe fittings

Often referred to as malleable iron fittings, steel fittings are available with a plain uncoated finish—black iron, stainless steel, or with a galvanized coating. Black iron fittings are used in natural gas and fuel applications. Malleable fittings are manufactured like gray cast iron, but unlike gray cast, they are cooled over a longer period which gives the fitting a much stronger structure. Malleable fittings should never be reheated because it changes the metal back to gray cast iron. Figure 1–10 shows some of the common steel pipefittings.

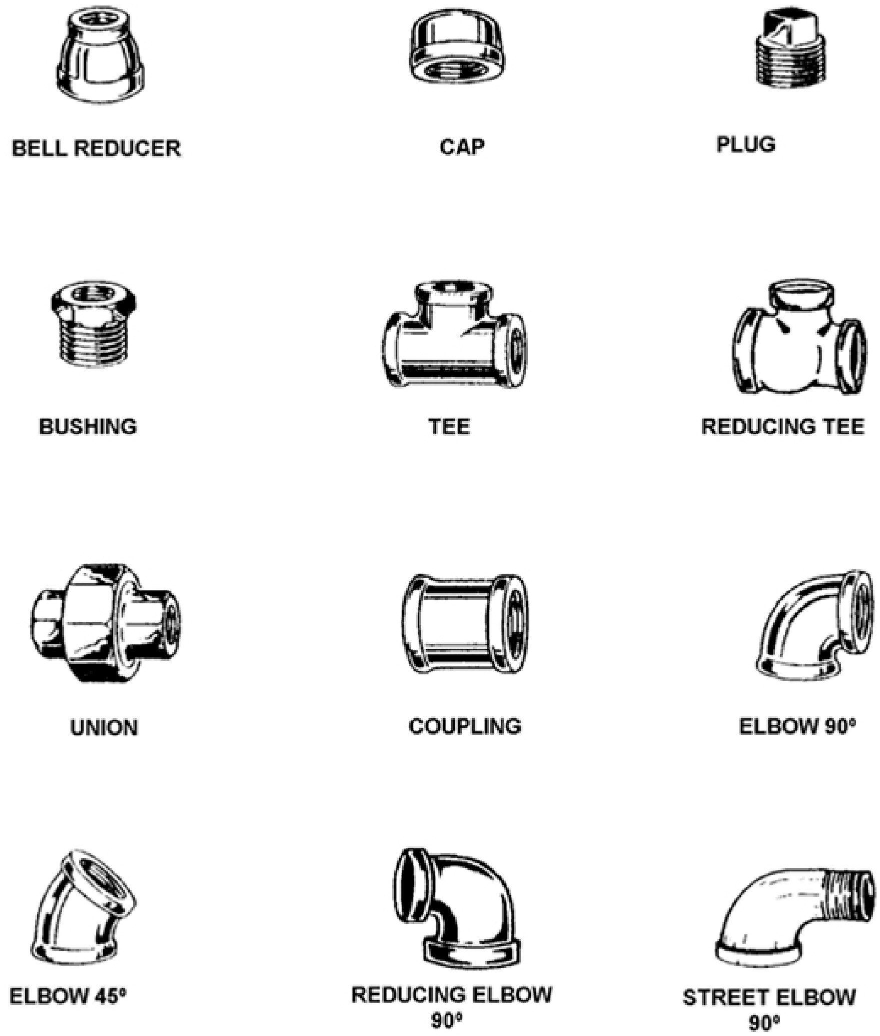


Figure 1–10. Types of steel fittings.

Copper and stainless steel tubing fittings

Copper tubing fittings are made of brass—an alloy of copper and zinc; cast bronze—an alloy of copper; and tin or wrought copper. There is virtually no difference among the three types of fitting materials in cost or installation. User preference, and/or fitting availability, will determine which fittings are used.

Pressure fittings

Use copper solder joint pressure fittings mainly with types L and M (hard drawn) tubing for water supply piping. Copper pressure fittings (fig. 1–11) have a short radius sweep on elbows, tees, and other fittings because the water flowing through them is under pressure. These fittings also have a deeper solder socket than the DWV copper fittings because of the higher pressures. These fittings normally come in sizes ranging from ½" to 3" and will slide over the end of the pipe. Solder is *sweated* or melted into the gap between the pipe and the fitting creating a leak-proof seal.

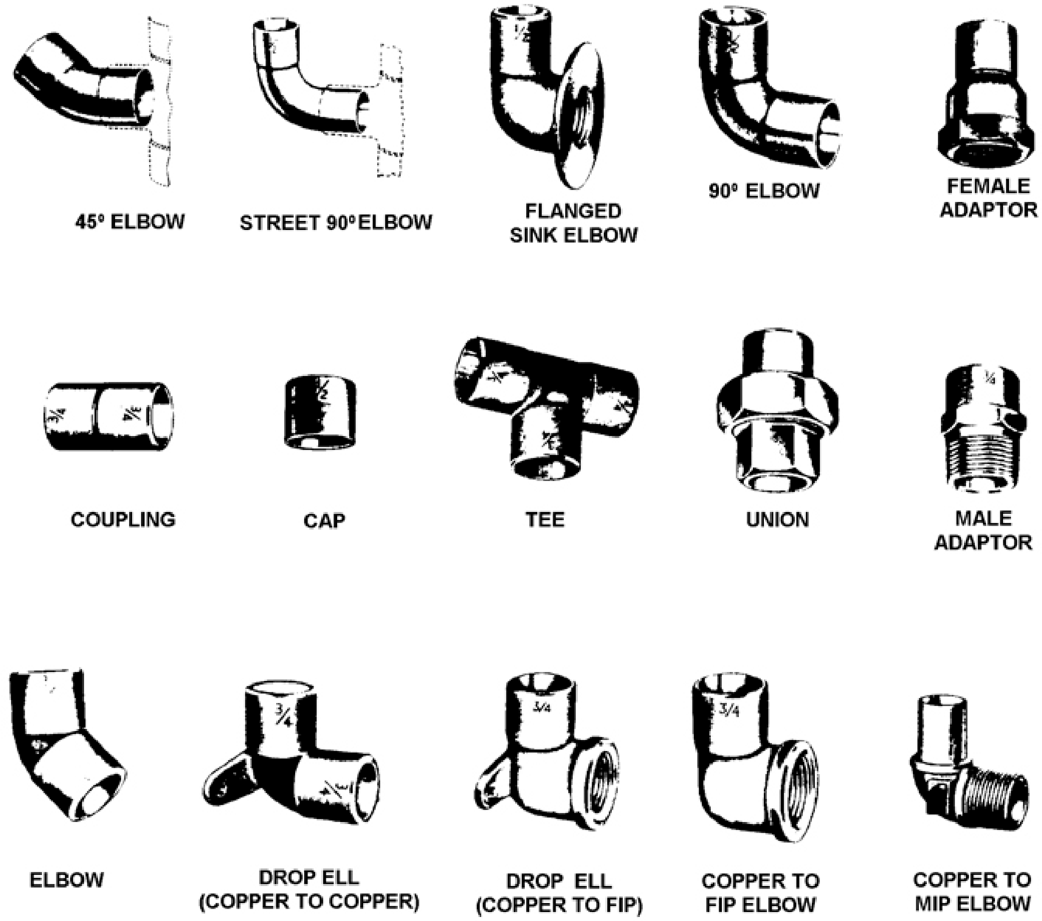


Figure 1–11. Types of copper fittings.

Compression fittings

Use *flare* or *flared* fittings, shown in figure 1–12, with types K and L (soft drawn) and general-purpose flexible copper tubing. In plumbing applications, flared fittings are usually used below ground on water service lines.

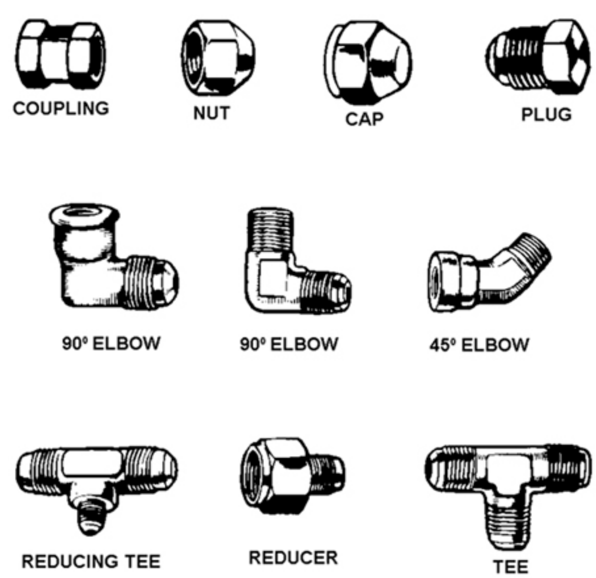


Figure 1–12. Types of flared-joint fittings.

For fuel systems, the general-purpose flexible copper tubing is used with the brass flared fittings. These are normally found on automatic valves and other fuel components. To use flared fittings, the end of the copper tubing must be flared or widened like the top of a funnel. Then the fitting flare nut is tightened to squeeze the tubing flare against the rounded surface of the fitting end to create the sealing surface. All fitting sizes must match the tubing size, which normally ranges from ¼” to ¾”.

Stainless steel tubing uses stainless steel *ferrule*-type fittings. Stainless steel fittings use rings called *ferrules* located inside the fitting. Stainless steel tubing is not flared, so the tubing end is placed through the hole in the compression nut and the ferrule(s) until the tubing makes contact with the fitting bottom. The compression nut is then tightened, *crimping* the ferrules around the tubing providing a leak-proof seal between the tubing and the fitting. These fittings come in single and double ferrule design, the double ferrule fitting is the most efficient. Ferrule fitting’s casting is similar to the flared fitting design, but without the rounded end for the tubing flare.

DWV copper fittings

Use these solder joint fittings with type DWV hard-drawn copper tubing for drainage, waste, and vents. You can identify them by their long radius or sweep in elbows, tees, and other fittings. A long radius allows easy gravity flow of waste material draining through them. These fittings also have a shallow solder socket since they are not normally subject to pressure.

Plastic fittings

Plastics are the most commonly used material in the plumbing field. They are lightweight and easy to work with. Just like metal fittings, plastic fittings should be used on pipe of the same material. Different glues are used to join plastic pipe and fittings made of specific material (i.e., ABS glue for ABS pipe). If you use different materials, the glue will not bond and seal properly eventually causing a leak. Also like metal fittings, threaded plastic fittings come in NPT and metric standards. Figures 1–13 through 1–16 show some commonly used plastic fittings.

Figure 1–13. Types of plastic fittings.

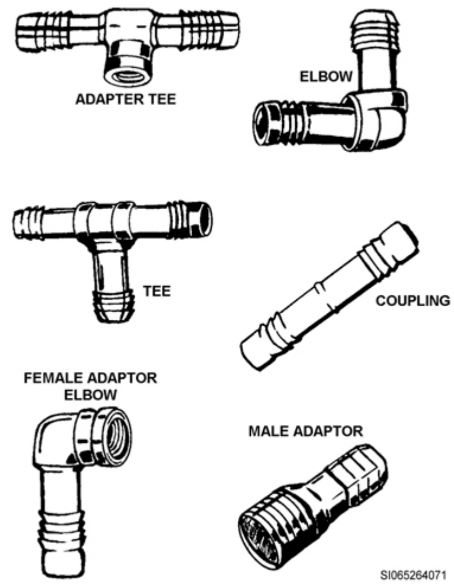


Figure 1–14. Types of insert fittings for PE applications.

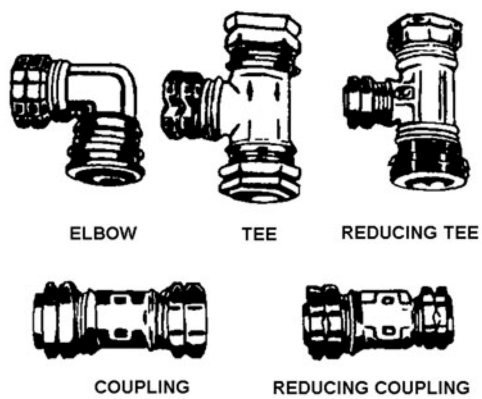


Figure 1–15. Types of mechanical joint fittings for PB applications.

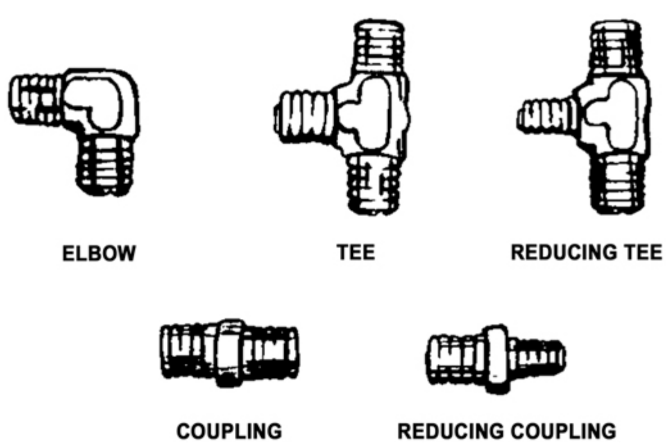


Figure 1–16. Types of insert fittings for PB applications.

Interpret fittings

In addition to being able to recognize the various types of fittings, we must learn to "read" the more common types of plumbing fittings. Figure 1–17 shows few common fittings and descriptions of how the fittings are read. When we look at figure 1–17, the order of reading the fittings is sequenced by the letters A, B, and C. To identify fittings, it is customary to read the run (horizontal or vertical openings) first and then the branches. For instance in figure 1–17, the "wye" fitting has a 4" run and a 45°, 2" branch. Identify this fitting as a 4 x 2 "wye" fitting.

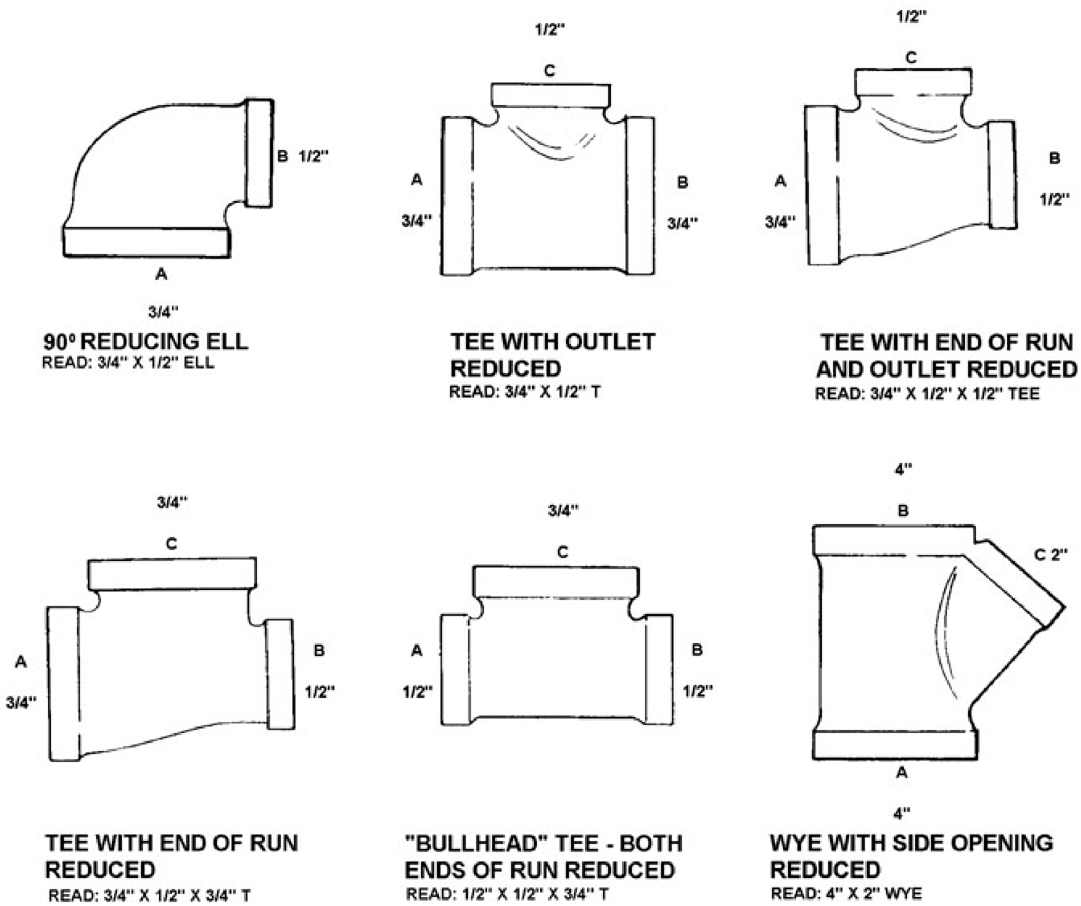


Figure 1–17. Reading fittings.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

401. Pipe and tubing

1. Match the types of pipes in column B with their features in column A. Column B items may be used only once.

Column A

____ (1) Manufactured in sizes from ½” to 18” in diameter and rigid and flexible forms; it is used in water, waste, and gas systems.
____ (2) Available in wall thicknesses of K, L, M, or DWV.
____ (3) Produced in standard lengths of 21’ and is available with galvanized coating and joined by the use of threads.
____ (4) Used to carry liquids that are corrosive to most metals.
____ (5) Produced in sizes from 3” to 48” in diameter; it is joined by bell and spigot, flanged, or mechanical joints.
____ (6) Available in diameters 2” to 15”, it is used in drainage systems.
____ (7) Produced in 2’ to 6’ lengths and 4” to 36” diameters; it is used in sewer systems.
____ (8) Available in 13’ lengths, three classes, and 3” to 36” diameters.

Column B

a. Cast-iron water pipe.
b. Vitrified clay tile pipe.
c. Asbestos-cement pipe.
d. Stainless steel pipe.
e. Plastic pipe.
f. Copper tubing.
g. Cast-iron soil pipe.
h. Steel pipe.

402. Types of pipe fittings

1. Match the terms in column B with the correct statements in column A. Column B items may be used only once.

Column A

____ (1) Refers to externally threaded ends of fittings or pipe.
____ (2) Refers to internally threaded ends of fittings or pipe.
____ (3) Available in various lengths up to a maximum of 12”.
____ (4) Joins two pipes end to end that may have to be taken apart later.
____ (5) Has female threads at both ends and is used to join pipes at 45 or 90°.
____ (6) Has male and female threads and is used to change directions 45 or 90°.
____ (7) Used to join three pipes at 90°.
____ (8) Used to close the female end of a fitting.
____ (9) Used to close the male end of a pipe.

Column B

a. Tees.
b. Female ends.
c. Nipples.
d. Cap.
e. Plug.
f. Street elbows.
g. Male ends.
h. Elbows.
i. Unions.

2. What are the two essential differences between a pressure fitting and a recessed drainage fitting (Durham fittings)?

1–2. Plumbing Mathematics

WFSM Journeymen are required to be able to make accurate measurements and calculations. Without this knowledge, it is unlikely that you will be able to accomplish the standards of work required of a journeyman. If you do not make accurate measurements it shows in your estimates, actual installations, and on your reputation. Plumbing measurements cannot be “close enough”—they have to be “on the money.” In this section, we will look at measuring, subtracting, adding, and computing offsets. These are the basics of plumbing math.

403. Understanding tape measures

How could you possibly cut a piece of pipe accurately or even estimate how much pipe you need for an application if you do not know how to read a tape measure? This sounds simple because most people know how to read a tape measure to the half-inch or quarter-inch mark. When it comes down to the nitty-gritty, though, the eighth-inch, sixteenth-inch, or even thirty-second-inch mark is a different story.

Numerators and denominators

Most people always get these two words mixed up. In the quarter-inch fraction (¼), one (1) is the numerator and the four (4) is the denominator. As the fraction becomes smaller than ½, the denominator (bottom number) always becomes exponentially greater than the numerator (top number). The following table of fractions and their explanations illustrates this principle well.

Understanding Proportionately Increasing Denominators

Fraction	*Pronunciation*	*Decimal equivalent*
$^1/_2$	Half	.500
$^1/_4$	Quarter	.250
$^1/_8$	Eighth	.125
$^1/_{16}$	Sixteenth	.0625
$^1/_{32}$	Thirty-second	.03125
$^1/_{64}$	Sixty-fourth	.015625

As you can see from the table of fractions, the denominator (bottom number) of the fraction becomes greater as the actual value of the fraction becomes smaller. Notice that this principle even applies to the fractions’ decimal equivalent.

Reading tape measures

Knowing the value of a fraction and its meaning will help you read tape measures accurately. Most tape measures used in our trade go down to the sixteenth inch ($^1/_{16}$). On a sixteenth-inch tape measure, each inch is subdivided sixteen times. Think of an inch as sixteen-sixteenths. Look at figure 1–18 and follow the subdivisions of each example until you see the same tape subdivided in sixteenths (bottom tape). The sixteen-sixteenth increment always ends and begins on the inch mark. In other words, the first sixteenth mark after each inch subdivision is always $^1/_{16}$. You cannot have, for example, $2^{17}/_{16}$”. You should read $3^1/_{16}$”.

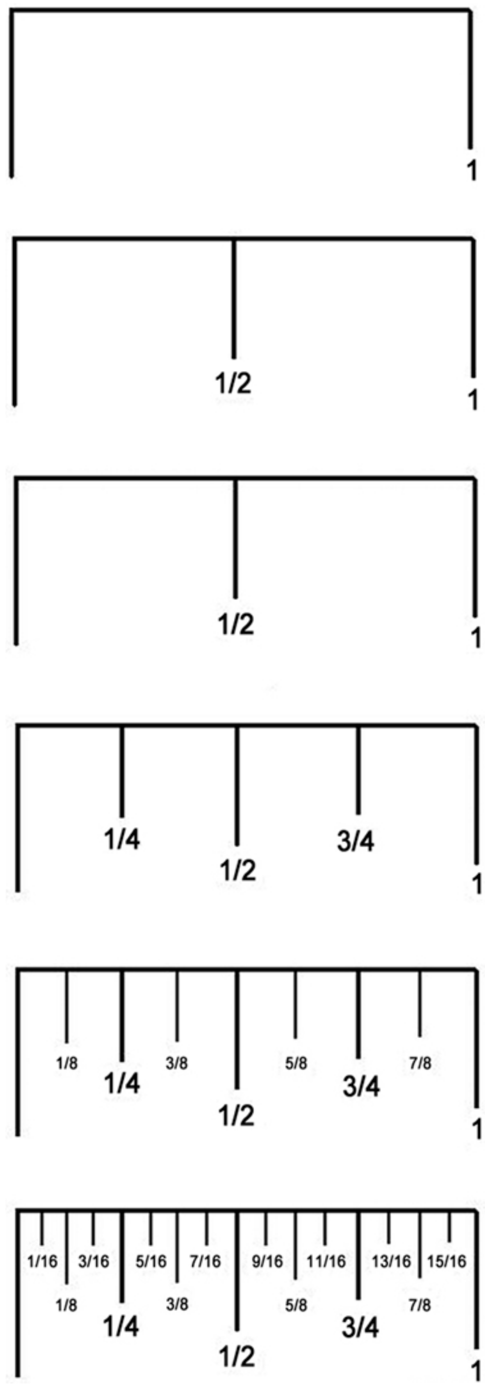


Figure 1–18. Dimensions of a sixteenth-inch tape measure.

Interpreting measurements

Normally, measurements are read out in eighths (remember that two sixteenths equals an eighth). This is mainly due to simplicity. Know that in every other sixteenth subdivision, an eighth measurement can be called out. When you are measuring a piece of pipe, calling out or writing down $^{1}/_{2}$” is easier than saying $^{8}/_{16}$”. To measure something, stretch the tape across what you want to measure and look very closely at where the end of the object to be measured compares with the subdivisions on your tape measure. If the end of your pipe is on a mark *in between* any eighth measurement, call out the addition of the closest sixteenth subdivision.

Look at the examples in figure 1–19. The top tape in the example is marked at $2^7/_8$". The very *next* subdivision mark is $2^{15}/_{16}$". Same thing applies with the second tape from the top on figure 1–19. The very *next* subdivision mark after 1¾ make the measurement $1^{13}/_{16}$. Study figure 1–19 until you thoroughly understand this principle.

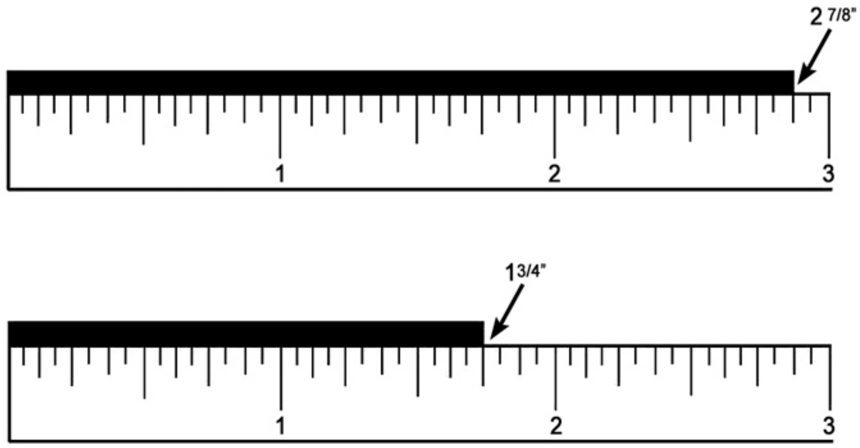


Figure 1–19. Rule markings.

404. Adding and subtracting tape measurements

Fractions are usually hard for people to understand, much less add and subtract. Knowing how to add and subtract tape measurements in "real time" from each other will greatly enable you to do a "professional" job every time. WFSM Journeymen add and subtract measurements using real time and fractions.

Real time

Now that you already know how to *read* a tape measure, you will also be able to add and subtract fractions in real time—as you are measuring. This will really be easy now that you already understand the subdivisions of the inch.

Let us say that you wish to subtract $1^3/_8$ from $2^{13}/_{16}$. Simply grab a hold of two tape measures and hold them side by side, numbers faced up towards you as demonstrated in figure 1–20. Locate $1^3/_8$ and $2^{13}/_{16}$ on the bottom tape measure. Next, align the tip of your top tape measure with the $1^3/_8$ mark on the bottom tape measure. Now locate $2^{13}/_{16}$ on the bottom tape measure. The measurement on the top tape measure that aligns with $2^{13}/_{16}$ on the bottom tape measure will be the difference between $1^3/_8$ and $2^{13}/_{16}$. That measurement is exactly $1^7/_{16}$ difference as indicated by the top tape measure.

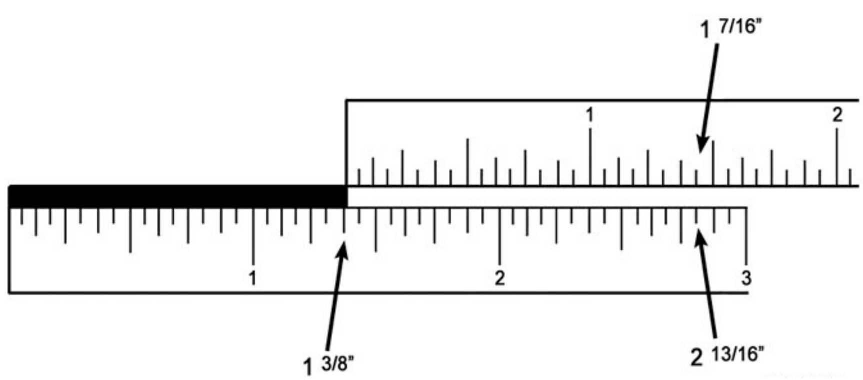


Figure 1–20. Real-time method.

Fractions

Trade journeymen such as plumbers, carpenters, and masons (just to name a few) usually use the real-time method on the everyday short measurements. You can do the same subtractions and additions that we discussed above by adding and subtracting fractions.

Adding fractions

Adding and subtracting fractions involves the use of a common denominator. Early on in this discussion, it was noted that the denominator was the bottom number of the fraction. When fractions are not the same, a common denominator must be found before proceeding.

Remember also from earlier discussions that a fraction such as $^3/_8$ can be considered as part of a whole inch—or $^6/_{16}$. If you look where your measurement is on a sixteenth inch tape, you can count the number of $^1/_{16}$ inch marks leading up to your mark. Let's take a look at a few examples in the following table.

Adding Fractions		
	Step	**Explanation**
A.	$2\ ^3/_8\ +\ 2^{15}/_{16}$	As you can see, we cannot add $^3/_8$ to $^{15}/_{16}$ until we find a common denominator. We can consider $^3/_8$ as being the same as $^6/_{16}$. Let us write this problem differently.
B.	$2^6/_{16} +\ 2^{15}/_{16}$	When we add these two fractions, the numerator will be greater than the denominator. Now we have a common denominator of 16.
C.	$4^{21}/_{16}$	We must convert $^{21}/_{16}$. Remember that there are $^{16}/_{16}$ in an inch. $^{21}/_{16}$ is the same as saying $1^5/_{16}$. 16 will divide into 21 once, with a remainder of 5.
D.	$21 \div 16 = 1^5/_{16}$	Now that we have converted $^{21}/_{16}$, we must add it to 4 to get the answer.
E.	$4 + 1^5/_{16} = 5^5/_{16}$	Our answer is $5^5/_{16}$.

Subtraction

Subtraction basically involves the same procedures we used for addition. You still have to have a common denominator. Let's take a look at a few examples in the following table.

Subtracting Fractions		
	Step	**Explanation**
A.	$2^3/_8\ -\ 2^5/_{16}$	Here again, we cannot subtract these two fractions until we find a common denominator. The $^3/_8$ mark is exactly $^6/_{16}$ on a tape measure. Let us write this differently.
B.	$2^6/_{16}\ -\ 2^5/_{16}$	We have a simple problem here. We do not need to convert anything. 2–2=0. Now all we have to do is subtract the fractions themselves.
C.	$^6/_{16}\ -\ ^5/_{16}$	Pretty simple here. Subtract 5 from 6.
D.	$^1/_{16}$	There is your answer.

Reducing fractions

Another factor you must take into account is the need to simplify fractions by reducing them to simplest terms. For example, the fraction $^2/_{16}$ is easier to understand when you think of it as being $^1/_8$. Let us see how this works: in $^2/_{16}$, 2 will divide into 2 once (this gives you the 1 in $^1/_8$; 2 goes into 16 eight times—hence the 8 in $^1/_8$).

As you can see, adding and subtracting fractions is not complicated. It is actually very easy once you know just a few simple rules. As a WFSM Journeyman, you must know how to read tape measures and add or subtract fractions quickly and accurately.

Changing dimensions

Many applications of our field require the conversion of inches to feet and vice versa. This is because distances are not always given in one form, but rather different ones depending on the application. You would not convey the area of a house in square inches. You would want that information given in square feet. In the same fashion, you would not refer to a small length of pipe that is less than one foot as .5'. Rather, you would say 6". You already know that there are 12" in a foot. Therefore to convert feet to inches or inches to feet, use the following guidance:

- Feet to inches—multiply the number of feet by 12.
- Inches to feet—divide the number of inches by 12.

405. Measuring pipe offsets

Pipe offset situations are common in our career field. Knowing how to figure the amount of pipe you need in a pipe offset will ensure that you do a professional job each time you have this type of situation.

Definitions

You need to know the language before you can use it. Let us first define a few basic terms that relate to understanding offset principles. The three terms you need to know first are offset, run, and travel. Learn to apply these terms when looking at an offset problem.

Offset

In plumbing, an offset is the vertical or horizontal distance between two sections of pipe that must be joined—that is, the actual distance in between two pipes that run parallel to each other. Look at figure 1–21 as we progress along in this discussion. The offset in this diagram is clearly marked.

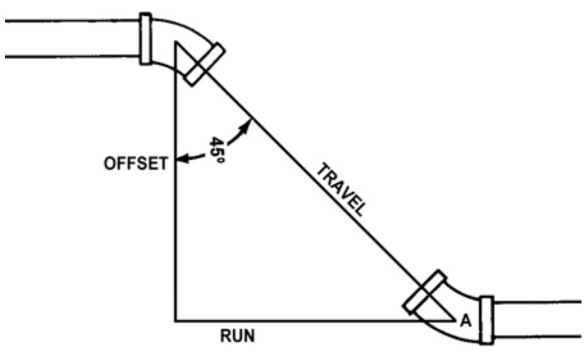


Figure 1–21. Pipe offset.

Run

If the two pipes in figure 1–22 were not parallel and were instead in-line with each other, then the distance you would need to connect them is called the run. Unfortunately, pipes are not always in-line. They are offset in this fashion to avoid obstructions.

Travel

The "travel" is a term coined to mean the *diagonal* distance between to offset pipes running parallel to each other. Figure 1–22 demonstrates this well. The travel distance is the length you have to determine prior to cutting the amount of pipe needed to join two parallel sections of pipe together.

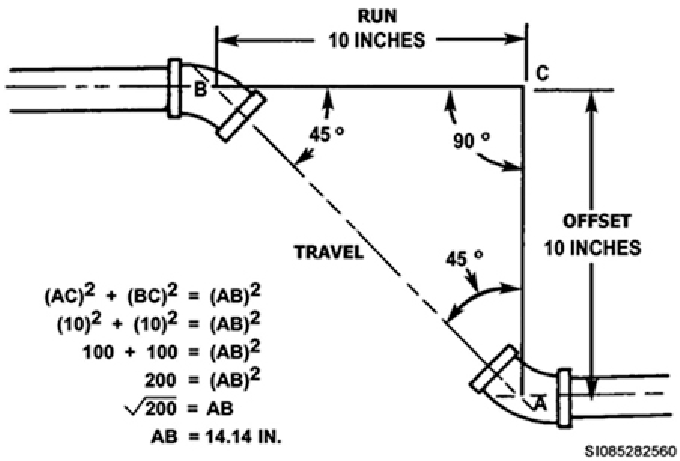


Figure 1–22. Pythagorean triangle.

Computing pipe offsets

There are quite a few ways to compute pipe offsets. The method you end up using is usually a matter of preference. We will discuss two ways of computing pipe offsets: the Pythagorean Theorem and the plumbers' rule.

Pythagorean Theorem

The Pythagorean Theorem states that the "*square of the hypotenuse* (side opposite 90º) of a right-angle triangle is *equal* to the *sum of the squares of the other two sides*." What? Sounds like double-talk doesn't it? Look at figure 1–22 as we try to make sense out of this.

Pythagorean Theorem explained

Remember when we were talking about these words—travel, offset and run? The hypotenuse of a triangle is the "travel." The other two sides mentioned in the theorem are the "run" and the "offset." According to the theorem, we can say that the "travel" (hypotenuse) times itself is equal to the sum of the offset and run times themselves. Look at the following formulas for further explanation.

- $(AB)^2 = (AC)^2 + (BC)^2$

  OR

- Travel x travel = (offset x offset) + (run x run)

As long as at least one angle of the triangle (or pipe offset) is 45° this relationship between the hypotenuse and its adjacent sides remains unchanged.

Application of the Pythagorean Theorem

Using the Pythagorean Theorem and its formula, we get an initial calculation of the hypotenuse (travel) expressed in a value that has been squared. To get the actual travel value that we need, the result must be square-rooted. Look at the calculation in figure 1–22. You will notice that 200 $[(10)^2 \times (10)^2]$ is a squared value. We must have the square root of 200 in order to have a value that can be used to determine or "travel"; therefore,

$$\sqrt{200} \quad =14.14"$$

Let us practice this one more time. Suppose that in figure 1–22, AC=25" and BC=35". What would the travel (AB) be? Using our formula as stated in the Pythagorean Theorem, let's look at this computation in the following table.

Sample Computation	
$(AB)^2 = (AC)^2 + (BC)^2$	As defined in the Pythagorean theorem, the square of the hypotenuse will be equal to the sum of the other two sides squared.
$(AB)^2 = (25)^2 + (35)^2$	Plug the offset (AC) and the run (BC) into the formula.
$(AB)^2 = 625 + 1225$	Enter the result of 25 times 25 plus 35 times 35.
$(AB)^2 = 1850$	This is the dimension of the hypotenuse. Remember that this figure is still squared. We now need to find the square root of 1850.
$\sqrt{1850}$	Using a calculator, find the square root of 1850.
43.01”	The approximate amount of pipe you will need.

Another matter we need to discuss here is the conversion of decimal parts of an inch to fractions. Remember that we need to know the fraction to actually measure and cut a piece of pipe.

Our previous exercise got us a result of 43.01. If you look at the conversion table on figure 1–23, you can see that .01 is equal to $^1/_{64}$. Remember that plumbers use $^1/_{16}$” tapes. To visualize a $^1/_{64}$ tape, divide one inch into 64 equal parts. $43^1/_{64}$ is practically on 43 even. Cut right on 43 and allow for blade width and fitting allowance.

FRACTIONS TO DECIMALS TO MILLIMETERS

Fraction	Decimal	mm	Fraction	Decimal	mm
1/64	0.0156	0.3969	33/64	0.5156	13.0969
1/32	0.0312	0.7938	17/32	0.5312	13.4938
3/64	0.0469	1.1906	35/64	0.5469	13.8906
1/16	0.0625	1.5875	9/16	0.5625	14.2875
5/64	0.0781	1.9844	37/64	0.5781	14.6844
3/32	0.0938	2.3812	19/32	0.5938	15.0812
7/64	0.1094	2.7781	39/64	0.6094	15.4781
1/8	**0.1250**	**3.1750**	**5/8**	**0.6250**	**15.8750**
9/64	0.1406	3.5719	41/64	0.6406	16.2719
5/32	0.1562	3.9688	21/32	0.6562	16.6688
11/64	0.1719	4.3656	43/64	0.6719	17.0656
3/16	0.1875	4.7625	11/16	0.6875	17.4625
13/64	0.2031	5.1594	45/64	0.7031	17.8594
7/32	0.2188	5.5562	23/32	0.7188	18.2562
15/64	0.2344	5.9531	47/64	0.7344	18.6531
1/4	**0.2500**	**6.3500**	**3/4**	**0.7500**	**19.0500**
17/64	0.2656	6.7469	49/64	0.7656	19.4469
9/32	0.2812	7.1438	25/32	0.7812	19.8438
19/64	0.2969	7.5406	51/64	0.7969	20.2406
5/16	0.3125	7.9375	13/16	0.8125	20.6375
21/64	0.3281	8.3344	53/64	0.8281	21.0344
11/32	0.3438	8.7312	27/32	0.8438	21.4312
23/64	0.3594	9.1281	55/64	0.8594	21.8281
3/8	**0.3750**	**9.5250**	**7/8**	**0.8750**	**22.2250**
25/64	0.3906	9.9219	57/64	0.8906	22.6219
13/32	0.4062	10.3188	29/32	0.9062	23.0188
27/64	0.4219	10.7156	59/64	0.9219	23.4156
7/16	0.4375	11.1125	15/16	0.9375	23.8125
29/64	0.4531	11.5094	61/64	0.9531	24.2094
15/32	0.4688	11.9062	31/32	0.9688	24.6062
31/64	0.4844	12.3031	63/64	0.9844	25.0031
1/2	**0.5000**	**12.7000**	**1**	**1.0000**	**25.4000**

Figure 1–23. Conversion table.

The plumber’s rule

When the angle between the travel leg and the run leg is known to be 45°, a plumber’s rule (tape measure) can be used. A plumber’s rule will have its other side in Standard English measurements. These kinds of rules are specifically geared to measure travels that are at a 45° angle. Actually, for every inch in a Standard English rule, the plumber’s rule has 1.414” (1 and $^{13}/_{32}$). If you do not have a plumber's rule, get your measurement using a standard tape measure and multiply your result by 1.414.

Notice that when set side by side, as in figure 1–24, a 3" run on a standard rule is marked off at 4¼" on a plumber's rule. The plumber's rule has taken into account the 45° angle for you. Using a plumber's rule is by far the easiest method of computing any offset—especially when the angle is exactly 45°. It must be noted that the computation will not be accurate if the angle is much greater than 45 degrees. However, when you are installing pipe in an offset situation and you make a visual comparison using two 45-degree elbows and it looks very close—use the plumber's rule.

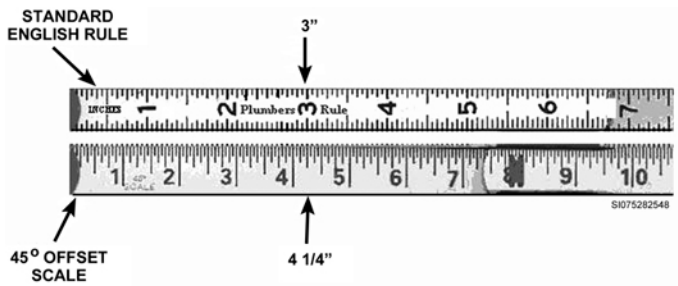


Figure 1–24. Difference and application of a plumber's rule.

Application of the plumber's rule

To find out the travel using a plumber's rule, simply make your measurement of the run as you would normally, except that you use the plumber's rule side of the tape as opposed to the Standard English rule. The measurement you get will be very close to the exact amount you need for your travel leg if the angles we discussed earlier are at 45 degrees.

It is important to remember that in all the applications discussed so far, you should make allowances for blade width and actual fitting depth *before* you cut the pipe.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

403. Understanding tape measures

1. How many times in an inch is a normal tape measure subdivided?

2. What is the simplest way of expressing the fraction $^{8}/_{16}$?

3. What should be the measurement if the object you are measuring falls in between any eighth measurement?

404. Adding and subtracting tape measurements

1. What must you do in adding or subtracting when the fractions are not the same?

2. Subtract $7^5/_{16}$ from $7^3/_8$.

3. Add $4^3/_8$ to $4^5/_{16}$.

405. Pipe offsets

1. What is the proper term for the distance between two pipes that run parallel to each other?

2. What is the proper term for the distance between two pipes that are not parallel to each other but that could be connected in a straight line?

3. What is the proper term for the diagonal distance between two offset pipes?

1–3. Measuring and Cutting Pipe and Tubing

Previously you learned how to make measurements using tapes or rulers. In this section, you will learn how to apply these principles in relation to the assembly of pipe to fittings. Our coverage of measurements will start with cast-iron pipe and fittings and followed by the center-to-center method.

406. Making accurate measurements

To make accurate measurements, you first have to have an idea of what you want to do. You accomplish this by going out to the work site to see what needs to be done. Go prepared! Take a notepad, pencil, and tape measure with you.

Measuring pipes and fittings

There are several ways to measure pipe and fittings. The most common methods are center-to-center, end-to-end, and end-to-center. The type of pipe or fitting determines how the measurement is taken. To measure pipe accurately; you must learn to locate the centers of the fittings. The center is that point where lines drawn through the middle of the fitting intersect, as seen in figure 1–25. If you cannot locate the center of a fitting, you will wind up cutting many pieces of pipe to obtain your desired length. Most pipe drawings are shown as center-to-center measurements. Now let us go through the procedures for using the center-to-center method of measuring.

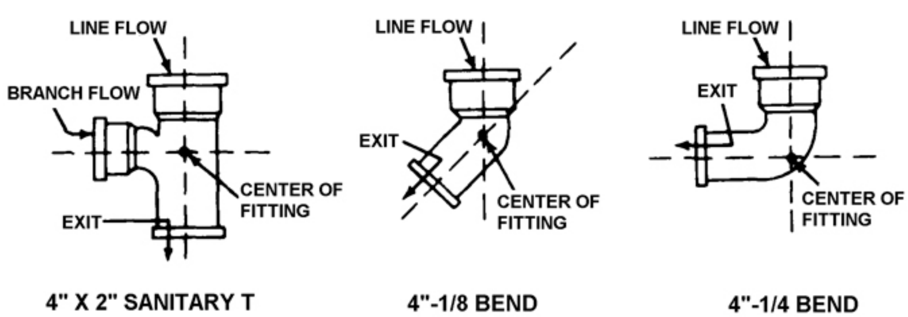


Figure 1–25. Center of fittings.

Cast iron

If the center-to-center measurement (center point of one fitting to center point of a second fitting) must be 36”, then the length of the pipe connecting the fittings can be determined, as shown in figure 1–26. First, measure the distance from the center point to the bottom (base or back) of the hub of one fitting. You should also measure the distance from the center of the other fitting to the edge of the spigot. Add these two measurements, and then subtract this total from the original 36”. The result is the actual pipe length required. You should note that the length of the pipe to be cut is measured from the back of the hub to the spigot end.

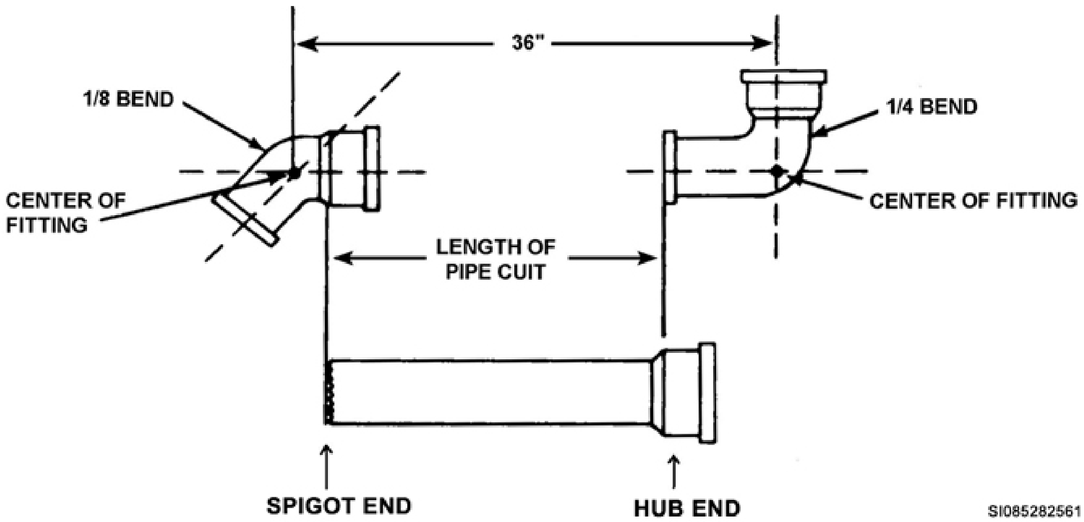
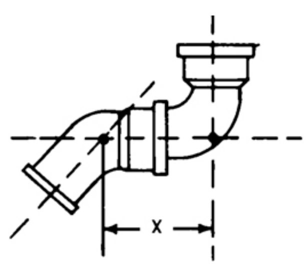


Figure 1–26. Center-to-center measurement.

If you can place two fittings together (fig.1–27), you can subtract the measurement between the center marks on the fittings from the overall measurement of 36” to arrive at the length of pipe required. A fast method for determining pipe length is to let a rule do your figuring. Using this method, place the 36” mark of the rule on the center mark of the fitting on the right (fig. 1–28). The mark on the rule that falls over the left then indicates the length to cut the pipe. This measurement again will be from the back of the hub to the spigot end. Each manufacturer of pipe and fittings provides a catalog for convenience in ordering. Descriptions include dimensions of the many fittings manufactured by the company (fig.1–29).



NOTE-SUBTRACT MEASUREMENT AT X FROM CENTER TO CENTER MEASUREMENT TO FIND LENGTH OF THE CUT

Figure 1–27. Two fittings together.

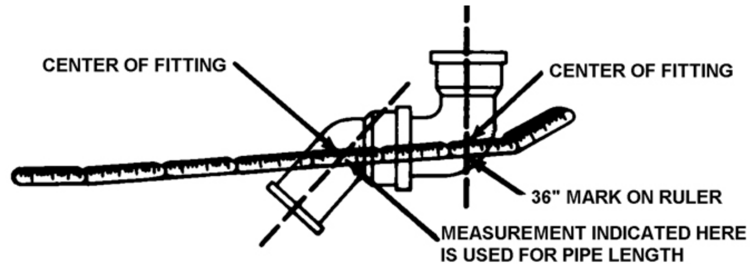
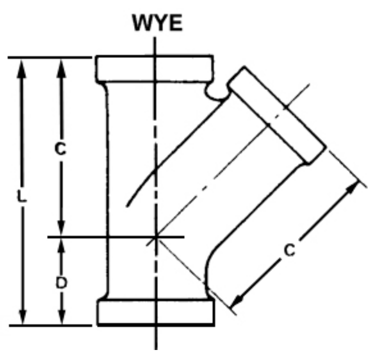


Figure 1–28. Using a ruler to compare pipe lengths.



Nominal Pipe Size	L	C	D
1 1/2"	4 3/4"	3 5/16"	1 7/16"
2"	5 7/8"	4 1/16"	1 13/16"
2" x 1 1.2"	5 7/8"	4 1/4"	1 5/8"
2 1/2" x 2"	6 1/4"	4 5/8"	1 5/8"

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Figure 1–29. Fitting dimensions.

Plastic

Finding the length of plastic, copper, and no-hub pipe is very similar to the bell and spigot pipe. See figure 1–30 as we go through the steps. Locate the center of the fittings and take a center-to-center measurement. Then measure from the center point of each fitting to the bottom of the socket (measurements A and B). Add these two measurements (A + B) and subtract this total from the center-to-center measurement. This will give the end-to-end measurement of the pipe. For example, if the center-to-center measurement is 20”, the wye fitting center to bottom of socket measurement is 1” (A) and the 90° elbow fitting center to bottom of socket measurement is 2” (B), then 20” minus 3” = 17”.

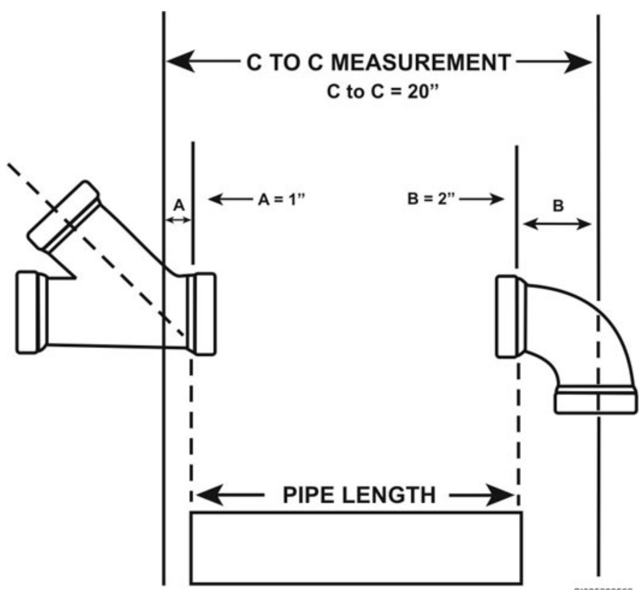


Figure 1–30. Determining plastic and copper pipe lengths.

No-hub

For no-hub pipe, allow for the small ridge in the center of the neoprene seal (fig. 1–31). Subtract the size of this small ridge, which is the separator ring, from your measurements.

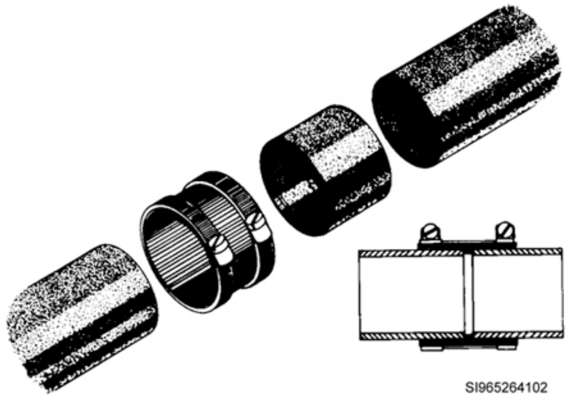


Figure 1–31. Connecting no-hub pipe.

Rather than using a center-to-center measurement as you did for the bell and spigot joint and the plastic socket joints, use another method of measuring called end-to-center. This means measuring from the end of a pipe to the center of the fitting (fig. 1–32). From the total measurement, deduct the measurement from the center of the fitting to the end (measurement A). This gives you the end-to-end measurement of your pipe. For end-to-center measurements on other types of joints, the procedure is similar. The only difference is that you deduct for the socket or hub into which the pipe will be inserted.

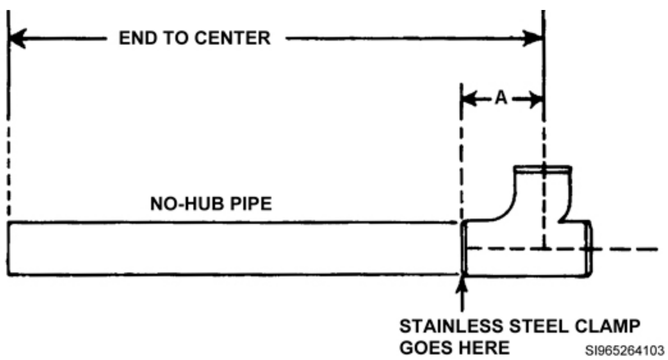


Figure 1–32. End-to-center measurement.

Steel pipe

There are several different methods of measuring steel pipe. Among these are: (1) end-to-center, (2) end-to-end, and (3) center-to-center. An end-to-center measurement is taken from the center of an elbow or tee screwed on one end to the opposite end of the pipe, shown in figure 1–32, drawing A. An end-to-center measurement is made by first tightening an elbow on the threaded end of a pipe. Place the end of your rule exactly in the center of the fitting, measure along the pipe, and mark at the proper length. The end-to-end measurement is the measurement of the pipe without any fittings, as shown in figure 1–33, B. A center-to-center measurement is shown in figure 1–33, C. To make a center-to-center measurement complete the following steps:

1. Put a fitting on the end of the pipe, as shown in figure 1–32, A.
2. Measure from the center of the outlet and mark the pipe, as you did in the end-to-center measurement.
3. Now place the center of the tee on the mark and make a new mark allowing for the pipe screwed into the tee, which is allowance “C” in figure 1–33, C.

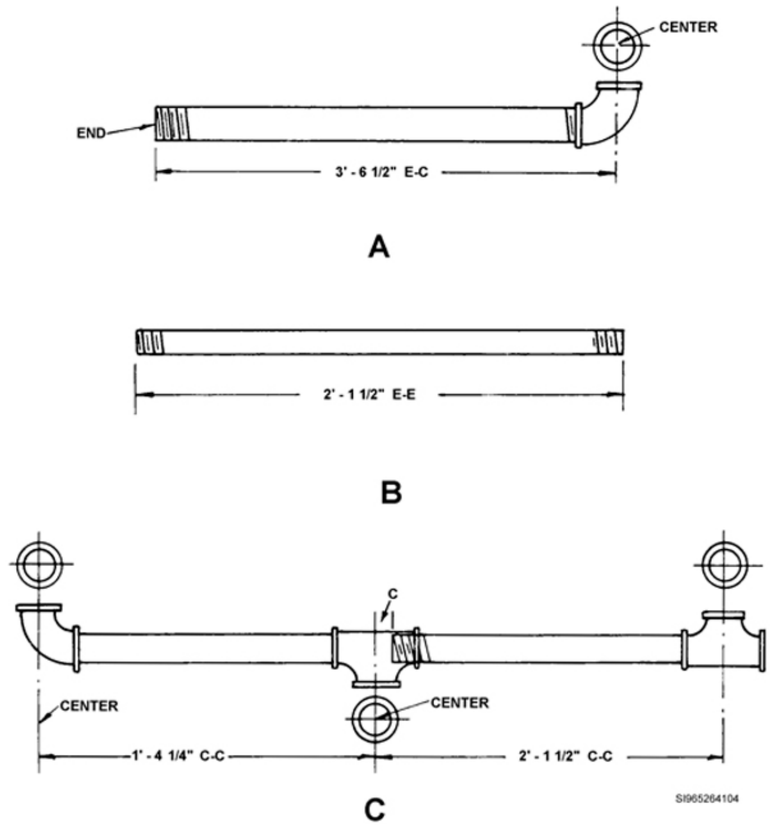


Figure 1–33. Three types of measurements.

Since repair makes up the majority of pipe work in fuel systems, the end-to-end and face-to-face measurements shown in figure 1–33, B and figure 1–34 are used most often. The end-to-end method is used when an old pipe is removed and a new pipe is made to replace it. You simply measure the old pipe from end-to-end. This is the easiest method. If you know the length of pipe needed, all you need to do is cut the pipe that length and thread both ends. The face-to-face method is used to measure pipe while it is still connected in the system. You measure from the face of one fitting to the face of the next fitting. With the face-to-face method, you are not told the overall length. You therefore have to find out how much pipe extends into the fitting. The threaded end screwed into the fitting is called the *thread engagement*.

The table below shows pipe size, outside and inside diameter, standard wall thickness, and the length of the thread engagement. To find the proper length to cut, find the appropriate pipe size in the first column, trace your finger across to the thread engagement column, then multiply this measurement by 2 (the number of fittings your pipe will thread into), and add the sum to the face-to-face measurement.

For example, a $^{3}/_{4}$” pipe you are going to replace measures 22” face to face. Using the table below, $^{3}/_{4}$” pipe thread engagement is $^{9}/_{16}$”. Next, $^{9}/_{16}$” X 2 = $^{18}/_{16}$” or $1^{2}/_{16}$”, which reduces to $1^{1}/_{8}$”. Finally, 22” + $1^{1}/_{8}$” = $23^{1}/_{8}$”.

Pipe Measurements				
Pipe size in inches	**Outside diameter (OD) in inches**	**Inside diameter in inches**	**Wall thickness**	**Thread engagement in inches**
$^{1}/_{8}$	0.405	0.269	0.068	$^{1}/_{4}$
$^{1}/_{4}$	0.540	0.364	0.088	$^{3}/_{8}$

Pipe Measurements				
Pipe size in inches	**Outside diameter (OD) in inches**	**Inside diameter in inches**	**Wall thickness**	**Thread engagement in inches**
$^{3}/_{8}$	0.675	0.493	0.091	$^{3}/_{8}$
$^{1}/_{2}$	0.840	0.622	0.109	$^{1}/_{2}$
$^{3}/_{4}$	1.050	0.824	0.113	$^{9}/_{16}$
1	1.315	1.049	0.133	$^{11}/_{16}$
$1^{1}/_{4}$	1.660	1.380	0.140	$^{11}/_{16}$
$1^{1}/_{2}$	1.900	1.610	0.145	$^{11}/_{16}$
2	2.375	2.067	0.154	$^{3}/_{4}$

Less commonly methods of taking pipe measurements are: (1) back to back, (2) center to back, (3) center to throat, and (4) overall center to center (fig. 1–34). No matter which method you use, do not forget to allow for the fittings.

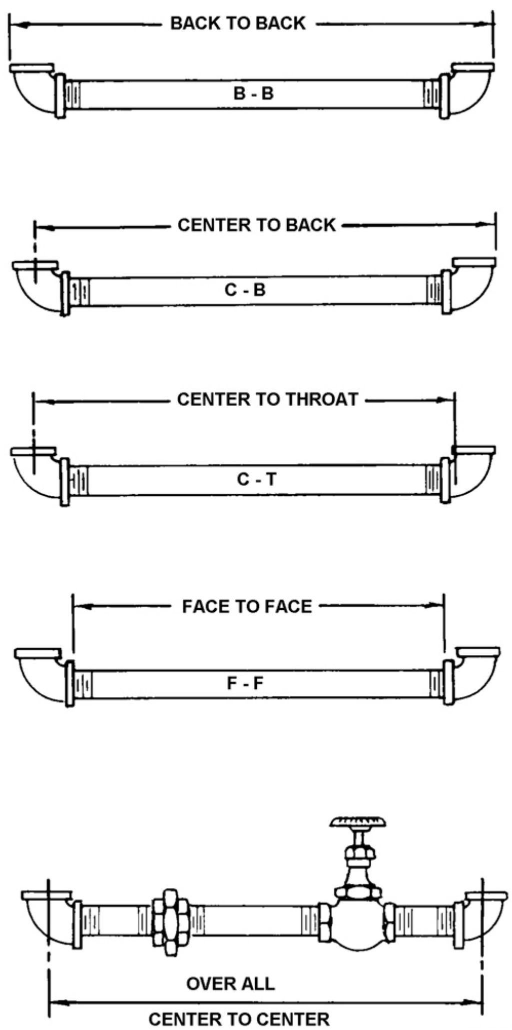


Figure 1–34. Additional types of measurements.

Offsets

Offsets do present a problem, especially at 45° angles. See figure 1–35. You need to consider this fact while making any measurements and prior to cutting your pipe.

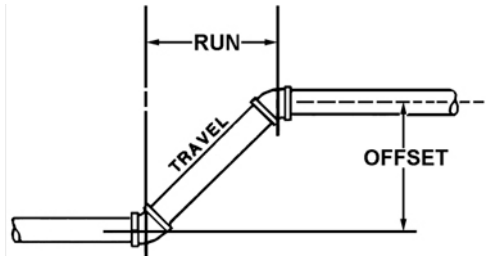


Figure 1–35. Offset.

Tubing

Measuring tubing to the required length takes some experience and finesse because copper and stainless steel tubing, with sizes ranging from $^{1}/_{8}$" to $^{3}/_{4}$", may need to be bent with pipe or tubing benders. If you are replacing an existing piece, simply use a flexible tape measure that will conform to the bends of the tubing being replaced or take the measurement with a piece of string, then measure the string.

When fabricating a new line with bends, estimating the amount of tubing needed can be tricky. With flexible copper tubing, you can have a higher margin of error in estimating how much you need. Making it “fit” usually isn’t a problem unless you severely over or under estimate. Greater accuracy is needed when working with stainless steel tubing since it is more rigid. Once you bend it—it stays bent! Whenever possible, practicing with scrap pieces of stainless steel tubing will help you achieve the accuracy needed to avoid wasting material on the job.

Most copper tubing or copper pipe used in plumbing systems will use sweat-soldered joint fittings. So, just like the thread engagements for iron pipe, before cutting the pipe, you must add on to the overall pipe measurement the length of pipe that will fit into the sweat-solder joint fitting ends.

407. Cutting pipe and tubing

There are as many ways to cut pipe as there are types of pipe. The method you use depends upon the type of job, the working conditions, and the tools that are available. Now that you know how to measure pipe, you are ready to make your cuts. This next section will discuss the proper procedures to cut pipes and the safety precautions involved in it. Always make sure you wear the appropriate protective safety equipment (e.g., face shield and gloves) before cutting.

Cutting cast-iron pipe

One method of cutting cast-iron soil pipe on the job involves using a ballpeen hammer and a cold chisel. You can also use this procedure to cut vitrified clay tile.

To cut the pipe, first make a mark entirely around the pipe at the desired location of the cut. This mark should be true and not ragged or rambling. When you are working inside or on a floor, use two blocks of wood (2 by 6’s work well) to support and level the pipe. The wood also keeps the pipe from shattering since it absorbs the shock of the hammer blows. You should position one block of wood directly under the line or cut. If necessary, use mounds of earth instead of the blocks of wood to support the pipe.

To cut 4” cast-iron pipe, score the pipe around the chalk mark by lightly tapping a 1” cold chisel with a 16-ounce ballpeen hammer. When cutting 2 or 3” cast-iron pipe, use a $^{3}/_{4}$” cold chisel and a 16-ounce ballpeen hammer.

Use light taps at first. Point the chisel toward the center of the pipe and move it around the line of cut in overlapping steps between successive blows. Continue this procedure, rotating the pipe and striking the cold chisel with increasingly heavier blows. Repeat these steps until the pipe breaks and separates at the line of cut.

Be sure to protect your eyes and body from flying chips when you cut cast-iron pipe. Wear goggles, gloves, and a jacket with long sleeves. Remember, the brittleness of cast iron causes a rough edge on the pipe when you break it. Be careful—this rough edge is sharp and often causes cuts.

Sounding

Sometimes, cast-iron pipe is unserviceable because of cracks. These cracks may be a result of rough handling during shipment or a manufacturer defect. Some of the cracks are so fine that they are called *hairline* cracks. These are difficult to see, even when you are handling the pipe. For this reason, sound each length of soil pipe with a hammer both before and after you cut it. To sound the pipe, raise it clear of the supports and strike it lightly with a hammer. A clear, bell-like ring indicates that the pipe is not cracked and may be used. If the pipe has a dull sound, it is cracked. Do *not* attempt to use it. Instead, place it in a scrap barrel for salvage.

Cutting short sections

If you have to remove only 1 or 2” of metal from a length of cast-iron pipe, use a hacksaw and an adjustable jaw wrench. If you try to cut the pipe near the end with a hammer and cold chisel, the pipe will probably break in the wrong place.

To cut 1 or 2” from the end of a pipe, cut a groove with the hacksaw on the line of cut all the way around the pipe. Make the depth of the groove equal to one-half the wall thickness of the pipe. Now break away the section of the pipe to be removed, using an adjustable wrench as a lever, as shown in figure 1–36. Set the wrench opening so the jaws of the wrench fit snugly over the wall thickness at the end of the pipe. Place the wrench over the end of the pipe wall so the tip ends of the wrench jaws are even with the outside edge of the groove you just made. Apply a downward pressure toward the pipe center until the chip breaks off. Repeat this process until all of the material is broken off and a clean cut has been made.

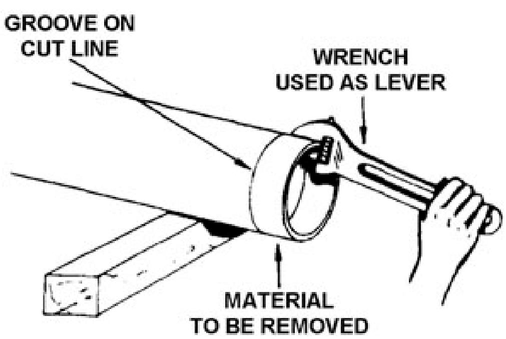


Figure 1–36. Cutting cast-iron pipe with a hacksaw and an adjustable wrench.

Roller chain cutter

Figure 1–37 shows a roller chain cutter. This cutter makes a fast, clean, smooth cut on a cast-iron pipe. We normally use this type of cutter on a piece of pipe 4” in diameter or larger. To use this cutter, turn the handle counterclockwise, loosening enough chain to fit around the pipe. Next, position the cutter on your mark and wrap the chain around the pipe. There is a notch on the cutter into which a knuckle of the chain fits. Put the knuckle into the notch that makes the chain the tightest. Now align the cutter chain with your mark and tighten the chain by turning the handle clockwise. Once the tension is applied, rotate the cutter back and forth until the pipe is cut.

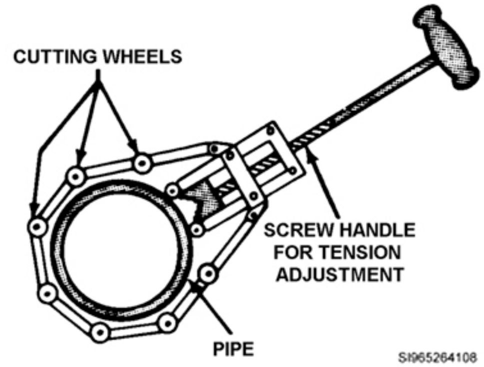


Figure 1–37. Roller chain cutter.

Pipe cutter

You can use an ordinary or hinged pipe cutter on cast-iron pipe Figure 1–38. Normally the ordinary type of cutter has one cutting wheel and two rollers, but some cutter models can be converted to a three-wheel cutter for working in close places. The hinged cutter normally comes with 3 or 4 cuttings wheels. However, the cutter must be equipped with a special cutting wheel for cast iron. Figure 1–39 shows a cross section view of (1) wheel used for steel pipe and (2) one used on cast iron.

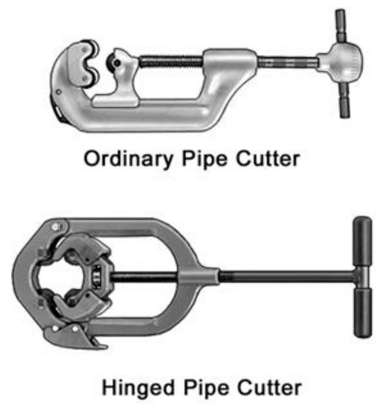


Figure 1–38. Pipe cutters.

To use the cutter with one cutting wheel and two rollers, turn the handle counterclockwise until the cutter will fit on the pipe. Then place the cutting wheel on your mark and snug up the cutter by turning the handle clockwise. Next, rotate the cutter 360° around your pipe. Check the path of the cutting wheel to make sure that it stays on the mark. Tighten the handle no more than one-quarter of a turn for each per revolution you make around the pipe. Continue this procedure until the pipe is cut.

The procedure for using a three- or four-wheel cutter is almost the same as just described, except that you must be more careful when starting a cut. Be certain the cutter is on straight. If it is not on straight, the cutter will travel, or move on the pipe. Since the cutting wheels are positions at different locations around the pipe the cutter does *not* need to be rotated 360° around your pipe, hence working well in tight locations.

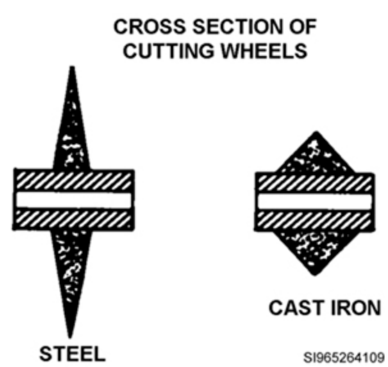


Figure 1–39. Cutting wheels for pipe cutters.

Hacksaw

Cast-iron soil pipe can also be cut with a hacksaw. This method is slow, but produces a smooth, clean cut. Many shops are equipped with powered cutting equipment. Power hacksaws, bandsaws, and hand-held reciprocating saws are fast and make smooth cuts when using the proper blades for the specific metal pipes to be cut. Using a cast-iron blade to cut a steel pipe can cause damage to the equipment, pipe or you. To prevent injury to yourself or damage to the equipment, training will be required to operate these types of powered machines.

Manual snap cutter

Figure 1–40 illustrates a manual snap cutter. The procedure for using this tool is similar to that for using the roller chain cutter. Rotate the handle adjustment counterclockwise. Then place the chain around the pipe. Next, open the handle to a 90° angle and put the knuckle into the notch that makes the chain the tightest. Now close the jaws and tighten the handle adjustment by turning it clockwise. As you do this, the handle begins to rise. When the handle is at about a 70° angle—approximately waist height—stop tightening the handle adjustment. With one foot on the lower handle, grasp the upper handle with both hands. On service weight pipe, snap the pipe with a sharp down thrust. On extra heavy pipe, exert even downward pressure. Once this cutter has been adjusted to cut a certain diameter pipe, no further adjustments are necessary to cut any amount of pipe of the same diameter.

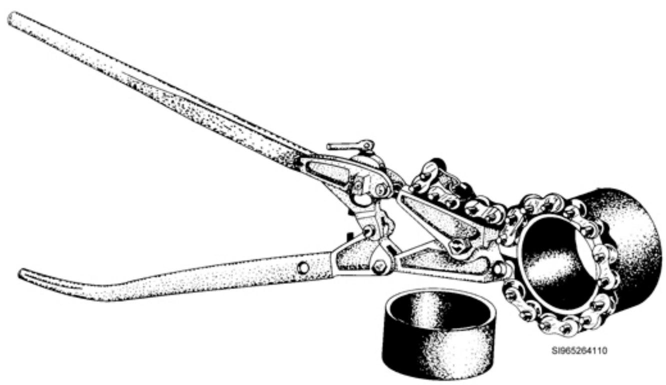


Figure 1–40. Manual snap cutter.

Hydraulic snap cutter

The use of a hydraulic snap cutter is illustrated in figure 1–41. Its operation is simple and causes no strain for the operator. Always align the cutter chain before attempting to make your cut. Make sure you follow the procedure set forth by the manufacturer.

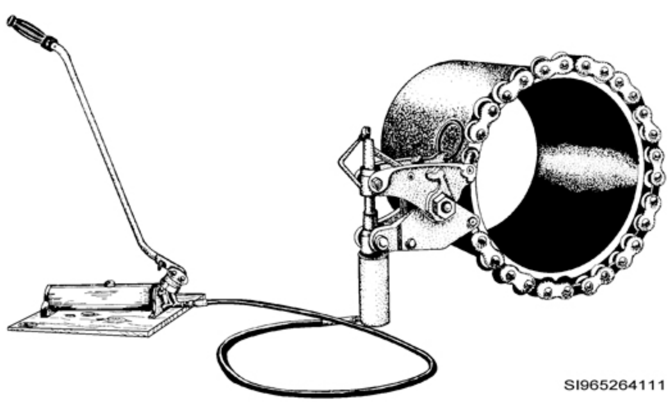


Figure 1–41. Hydraulic snap cutter.

Cutting asbestos cement pipe

When cutting asbestos cement pipe, never dry cut the pipe allowing the asbestos fibers to go airborne. Always keep the pipe wet throughout the cut and only use snap cutters to make the cut. Wear an appropriate respirator, coveralls, and gloves. Remember, asbestos fibers are very dangerous when inhaled, and you must take every safety precaution to prevent the inhalation of the fibers.

Cutting vitrified clay tile pipe

Vitrified clay tile pipe is cut in the same manner as cast-iron pipe.

Cutting plastic

Plastic pipe is cut with just about any type of cutting tool, such as saws or tube and pipe cutters. When you use a saw to cut plastic, select a fine-toothed blade. Place the pipe in a miter box or hold down jig to ensure a square cut as shown in figure 1–42. Regardless of the method used, cutting plastic produces burrs on the pipe. Remove the burrs with a fine-toothed file or deburring tool. Before installation, make sure the pipe is free of chips, burrs, and foreign matter.

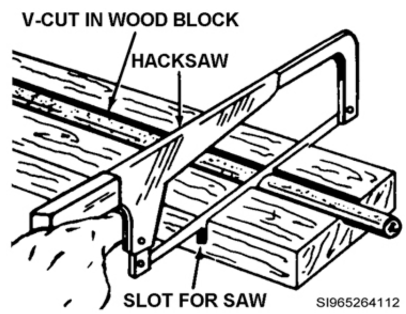


Figure 1–42. Miter box.

Cutting copper and stainless steel tubing

Once you have measured and marked the tubing, you are ready to cut. The desired tool for cutting copper and stainless steel tubing is the tubing cutter. Its operation is no different from that of any other pipe cutter, but do not cut hardened pipe with this cutter, because it will dull the cutting wheel.

First, insert the tubing between the rollers and cutting wheel and turn the handle to apply sufficient pressure to force the cutting wheel into the tubing. Remember, copper tubing is softer than stainless steel tubing. Therefore, be careful when you tighten the cutting wheel against copper tubing, otherwise the tubing may flatten or the cutter wheel may break. Then rotate the tubing cutter completely around the tubing, tightening the handle no more than one-quarter of a turn per revolution made around the tubing. Repeat this action until the tubing is cut. When you use a tubing cutter, be sure that the cutter is sharp and that the shaft is well oiled.

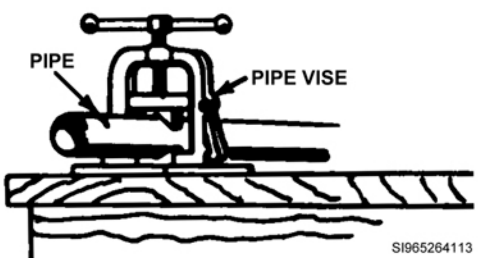


Figure 1–43. Pipe clamped in a vise.

Use a fine-toothed hacksaw blade to cut copper tubing. Using a proper jig is recommended for supporting the tubing while cutting, as shown in figure 1–43. A fine-toothed blade (32 teeth per inch) makes a clean cut and minimizes the tendency of copper to tear. Too much pressure applied to this hacksaw on the forward stroke not only tears the copper, but also flattens the tubing. Regardless of how you cut the tubing, always make sure you file and ream the burrs off the cut end.

Cutting and reaming steel pipe

After you have measured and marked the steel pipe, place it in a pipe vise for the cutting operation. A pipe inserted in a pipe vise, ready to be cut with a pipe cutter or hacksaw, is shown in figure 1–44. A pipe cutter ready to make the first turn on the pipe to be cut is also shown in figure 1–44. To cut a steel pipe with a pipe cutter, first open the jaws of the cutter by turning the handle counterclockwise. Next, place the pipe cutter around the pipe on the mark where the pipe is to be cut. Center the cutter so that the cutting wheel is on the mark. Then close the jaws of the pipe cutter lightly against the pipe by turning the handle clockwise. After the wheels contact the pipe, rotate the handle one-quarter turn more in a clockwise direction. This puts a “bite” on the pipe and cuts a groove in the pipe when the pipe cutter is rotated in the direction of the open end of the cutter. Rotate the pipe cutter one turn to make a complete cutting mark around the pipe before turning the handle again clockwise one-quarter turn to take another “bite” on the pipe. If you do not do this, the pipe cutter will make spiral marks around the pipe instead of making one complete circle.

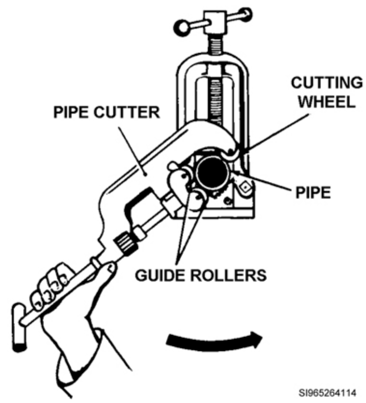


Figure 1–44. Cutting pipe with a pipe cutter.

Repeat these steps until the pipe is cut. Figure 1–45 shows a cutaway of a piece of pipe and the result when it is cut with a pipe cutter. Part A shows how the cutter causes a burr to form within the pipe, and part B shows a cross section of the burr after the pipe has been cut. Remove the burr before you thread or install the pipe because it will hinder the flow of liquids and gases and restores the inside diameter of the pipe.

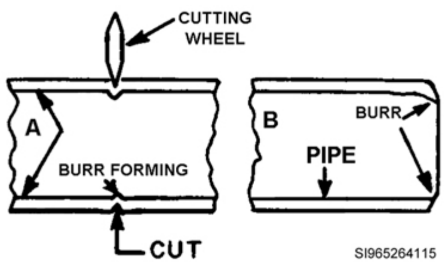


Figure 1–45. Results of cutting pipe with a pipe cutter.

Use a pipe reamer to remove the burr from the end of the pipe. Insert the point of the pipe reamer into the pipe while it is still clamped in the vise, as shown in figure 1–46, and rotate the handle of the reamer in a clockwise direction in short, even strokes until the burr on the inside of the pipe is removed. A cut-a-way of a piece of pipe that is reamed properly is shown in figure 1–47. Remove all burrs from pipe, whether it is used for supply, venting, or waste, and from any line that will carry a gas or liquid. When using a hacksaw to cut steel pipe, use a blade with 18 or 24 teeth per inch. Remember, a hacksaw only cuts during its forward stroke if the blade is inserted correctly.

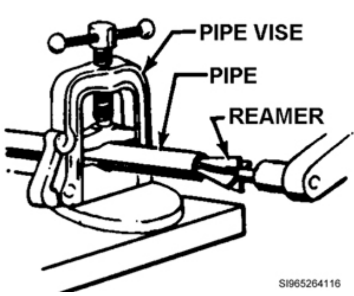


Figure 1–46. Reaming a pipe.

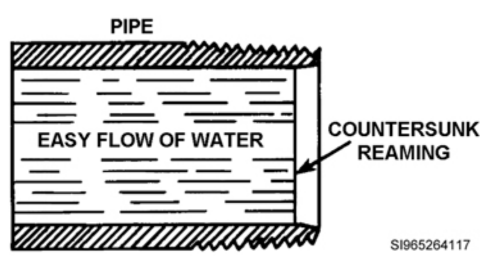


Figure 1–47. Cross section of a reamed pipe.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

406. Making accurate measurements

1. How do you locate the center of a fitting?

2. When measuring cast-iron pipe, what are the two boundaries of the measurement?

3. When measuring plastic pipe, what will be subtracted from the center-to-center measurement?

4. When using no-hub joints, what allowance must you take into consideration?

5. What are the three most common types of measurements used on steel pipe?

6. What are the most common methods of measuring pipe in fuel systems?

7. What allowances do you make regardless of the method of measuring you use?

407. Cutting pipe and tubing

1. How do you cut cast-iron pipe using a ballpeen hammer?

2. How do you sound cast-iron pipe?

3. What observation indicates that a cast-iron pipe is not cracked?

4. What tools are used if you have to remove only 1 or 2” of metal from a length of cast-iron pipe?

5. How is a pipe cutter for cutting cast-iron pipe equipped?

6. What precautions must you take when you start cutting pipe with a three-wheel pipe cutter? Why?

7. At what angle is the handle of the manual snap cutter when you stop tightening the handle adjustment?

8. What procedures are followed when using a hydraulic snap cutter?

9. What can you use to remove the burrs when cutting plastic pipe?

10. What tool is desired for cutting copper tubing?

11. What may happen if too much pressure is applied to the forward stroke of a hacksaw when cutting copper tubing?

1–4. Assembling Pipe and Tubing

There are many types of pipe and tubing, each with its own assembly method. An example is cast-iron soil pipe, which is joined by compression and no-hub joints. This section covers the methods used to join pipe and tubing.

408. Threading steel pipe

After a piece of pipe has been properly cut and reamed, there are quite a few ways to thread steel pipe. In some cases where your application is small or remotely located, you may want to thread the pipe manually. In other instances where a larger job is involved, it may be worthwhile to use power-driven threaders. There are many different kinds of threaders made by different manufacturers, but most operate essentially the same way.

Manually

We use a ratchet style, nonadjustable hand threader, shown in figure 1–48, to manually cut threads on pipe sized from $^1/_8$” to 2” in diameter. This is normally part of a kit which includes a handle, ratchet (also known as the stock) and several die heads that fit into the ratchet for different pipe sizes. The dies are the metal pieces with teeth that are secured in the die head to cut the threads into the pipe. They can be replaced when they become nicked or dull. There are other threaders, such as a three-way (or 3-in-1) pipe threaders, that have three built-in die heads for cutting threads on $^1/_2$”, $^3/_4$”, and 1” pipe.

Figure 1–48. Manual pipe threader (die head, ratchet, and handle).

Before you thread a pipe, ensure the dies are clean, sharp, and free of nicks. Using damaged dies will create damaged pipe threads and cause leaks. Insert the pipe into a vise, place the round guide end of the die head on the pipe, as shown in figure 1–49, and push the dies against the pipe with the heel of your hand. Exert considerable pressure with the heel of your hand against the die head and make three or four short turns in a clockwise direction to start the dies.

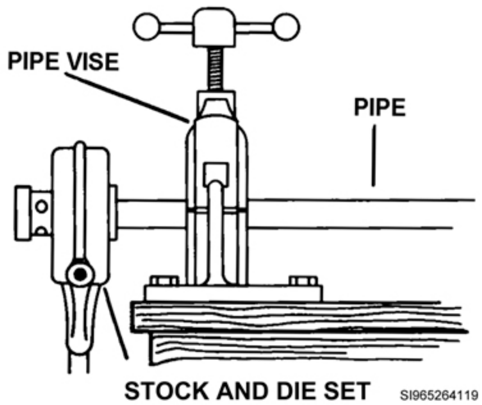


Figure 1–49. Properly placing the die on pipe.

After the dies start cutting, turn the handle of the pipe die stock, as shown in figure 1–50, using an even and steady pressure. To cut clean threads for watertight and airtight joints, use a spray bottle filled with cutting oil on the pipe dies after every two or three downward strokes. Cutting oil is used to cool the pipe threads and threading dies during the pipe threading operation. Overheating will cause thread or die damage.

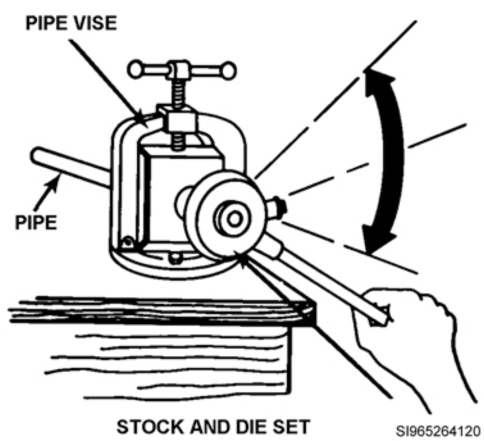


Figure 1–50. Threading pipe using even strokes.

As threading progresses, metal chips from the pipe form around the dies. Never make more than two full turns of the die at a time; always back off $^1/_2$ turn. Lift up and turn the knob on the ratchet for reverse or counter-clockwise operation. Several short motions backward and forward with the handle will break the chips around the dies. Remove these broken chips from the die head before continuing to thread the pipe to prevent thread damage. You know the proper number of threads have been cut and the job is done when approximately two newly cut threads project beyond the end of the die teeth. To remove the hand threader from the pipe, turn the ratchet counterclockwise until the pipe-threading dies are free of the threads. Too many pipe threads are just as bad as too few. Figure 1–51 illustrates a normal set of tapered pipe threads on a pipe. Notice how the pipe die tapers the threads during the cutting procedure.

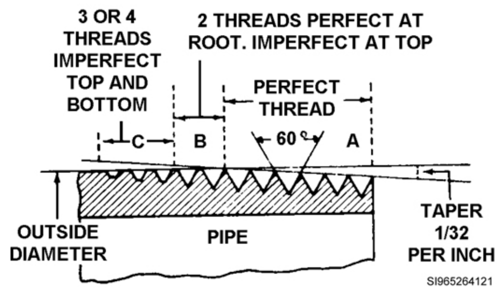


Figure 1–51. Cross section of pipe threads.

In section A of figure 1–51, the threads are all perfect; in section B there are two threads that are perfect at the root and imperfect at the top. In section C, there are three or four threads imperfect at both the bottom and the top. This taper on the pipe makes it possible for you to make a tight, leak-proof joint when a pipe is screwed into a fitting.

Since you may be cutting threads on pipes using hand threaders with adjustable dies, you must know how to cut the correct number of threads when you use this tool. To cut the proper number of threads on a pipe with an adjustable die, run the die on the pipe far enough so that about two full threads extend beyond the end of the die teeth.

NOTE: Some adjustable dies have an automatic release that will only allow the correct number of threads to be cut.

The amount of threads per inch to be cut is determined by the size of pipe according to the NPT standard. Pipe sizes from $^1/_4$ to $^3/_8$” inch have 18 threads per inch; $^1/_2$ and $^3/_4$” pipe sizes have 14 threads per inch; 1 to 2” pipe sizes have $11^1/_2$ threads per inch; and pipe sizes $2^1/_2$” and higher have 8 threads per inch.

Power bench threaders

Every shop usually has a bench-type threading machine, like the one shown in figure 1–52. A bench threader cuts, reams, and threads pipe.

NOTE: This is a motorized machine with moving parts. Do not wear gloves or loose clothing around this machine.

To cut with this machine, insert the pipe into the chuck so that it protrudes about 8” beyond the face of the chuck. Adjust the pipe rest to carry the weight of the pipe that extends beyond the end of the machine. Now tighten the chuck onto the pipe. Ensure that during any operation the component arms (cutter, reamer, and pipe die) not being used are up and out of the way. Drop down into place and advance the pipe cutter until the wheel of the cutter is directly in line with the mark on the pipe. When the cutter is aligned with the mark, turn on the machine and apply pressure to the cutter wheel as the pipe rotates, rotating the handle one-quarter of a turn for each full revolution of the pipe until the pipe has been cut completely through and the separate section you need is available.

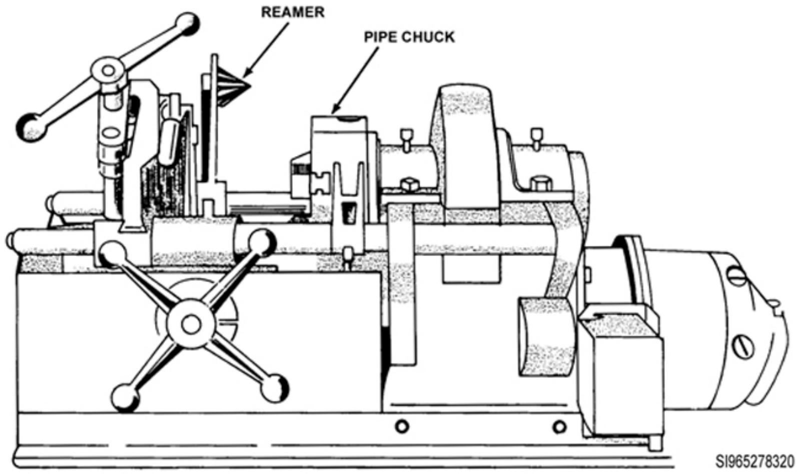


Figure 1–52. Power-driven bench threader.

If the pipe section is long, use a properly positioned pipe rest to keep the pipe level and from dropping, damaging the threads. After the pipe section you want is cut from the rest of the pipe, withdraw the cutter from the pipe and raise it out of the way.

After cutting the pipe, your next operation is to ream it to remove the burr caused by the cutter. To do this, drop the reamer arm into place. Start the reamer rotating and move it towards the protruding pipe until it enters and touches the pipe. Next, apply pressure to the reamer until the pipe has been reamed properly; then withdraw the reamer from the pipe. Ream only enough to remove the burr and restore the pipe's inside diameter. When complete, lift reamer arm out of the way.

Before you thread a piece of pipe on a power-driven threading machine, check the pipe chuck jaw teeth to see that they are clean and free of pipe chips or flakes. If the teeth need to be cleaned, use a stiff wire brush to remove the dirt and chips so that the teeth will clamp against the pipe without slipping. After cleaning the teeth of the chuck and opening the chuck to receive a piece of pipe, select the proper size die to thread your pipe. Then lower the pipe die arm into place and check to see that all of the teeth on the pipe dies are clean and not chipped. Move the die-releasing handle up and down to see that the segments in the dies open all the way and come down the proper distance. Take a short nipple and screw it into the die segments by hand to see that the segments are properly aligned. If you prefer, check the alignment of the segments by putting the nipple into the chuck, start the machine, and run the dies onto the nipple.

When the segments are run the proper distance, release them by lifting the die-release lever. Back off the die and shut off the motor to stop the chuck. After the chuck has stopped, open it and remove the nipple; then check the threads produced with a standard female-tapped fitting. You should be able to hand screw the fitting about half way up the threads. If the fitting screws on more than half way, the segments have been set too deep. However, if the fitting screws on less than half way, the dies are worn out or are improperly set (too shallow).

After cleaning and setting the chuck and dies, you are ready to thread the pipe. Make sure that the release lever is in the closed position and move the dies up to the end of the pipe. Before you apply pressure to the dies, be sure you have the oil running to help start the segments on the pipe. Apply enough pressure so that at least two threads are started and the die will continue to thread itself. Allow the machine to operate until the proper amount of threads has been cut. Then release the segments by lifting up on the release lever. Back off the die stock until it is clear of the pipe in the chuck so that you can remove the threaded pipe from the machine.

NOTE: Clean up the area when you are finished to prevent accidents and promote good housekeeping.

Figure 1–53 shows a stationary bench threader that may be used to thread pipe in sizes $^1/_2$ to 4”.

CAUTION: Never attempt to open the chuck while the threader is in motion. There are many different types of power threading machines. Always check the manufacturer’s operating instructions before using any unfamiliar machine.

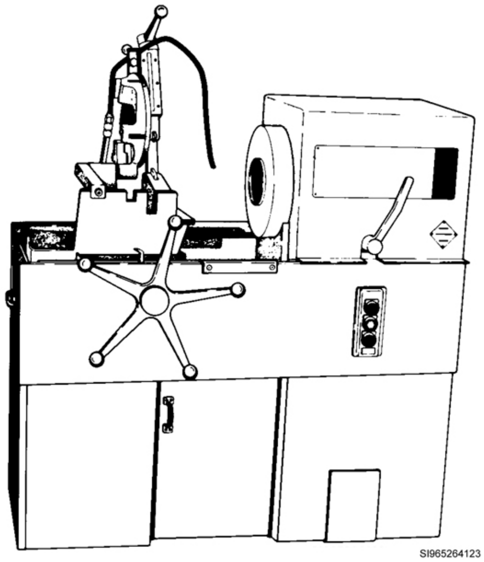


Figure 1–53. Stationary power-driven bench threader.

Portable power-driven vise stand

Another type of thread-cutting machine that you use is the portable power-driven vise stand, shown in figure 1–54. This machine is designed to turn the pipe to be cut or threaded while the threader is resting on the arms of the machine. The pipe to be cut, reamed, and threaded is inserted into the chuck in the same manner as in the power-threading machine we mentioned previously.

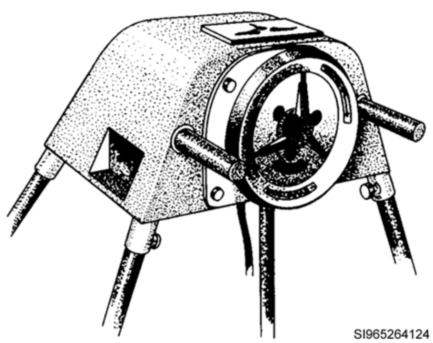


Figure 1–54. Portable vise stand.

The portable power-driven vise stand is equipped with a chuck that grips pipe from $^1/_4$ to 2” in diameter. It is powered by a reversible, variable-speed electric motor. Other equipment used with the vise stand is the pipe cutter, the reamer, and threader. A pipe vise is bolted to the top of some machines.

To operate the portable vise stand, insert the pipe into the chuck and tighten the chuck. Next, turn on the electric motor just long enough to see that the pipe rotates in the proper direction for reaming and cutting threads.

When cutting pipe, place the cutter on the pipe and allow the handle of the cutter to rest against either one or both of the bars as required. Next, start the machine and control the cutting action of the cutter through the handle. The pipe is reamed in a manner similar to cutting the pipe.

To cut threads with a vise stand, start two or three threads on the pipe by hand with a ratchet handle. Start the machine and cut the required number of threads. After the threads have been cut, stop the machine, push the bars back, and turn the threaders off by hand rather than run the machine in a reverse direction.

CAUTION: When you use this machine, be sure to rest the handles of the cutter, reamer, and threaders against the bars. Many people have injured themselves by attempting to hold the handles of these units by hand. Remember, if you let go of the handles, they are likely to strike you or catch in your clothes and pull you off your feet before the machine can be stopped.

Geared-type threaders

Use a geared-type threader to cut threads on steel pipe larger than 2”. When used in the field, the threader is usually operated by hand. A power vise stand can be used to supply power to operate a geared threader in the shop or in the field if electricity is available.

The geared-type threader is turned by power from the vise stand through a flexible shaft or a shaft with two universal joints. To thread pipe after the equipment is set up, as shown in figure 1–55, clamp the pipe to be threaded in the vise. Let it extend far enough beyond the vise to fit into the threader. After the proper-sized segments have been installed in the threader, place the threader over the end of the pipe so that the segments strike or touch the pipe and are in proper alignment. Next, tighten the setscrews on the reverse side of the pipe threader against the pipe so that the sleeve remains stationary while the segments and the outer section of the pipe threader turn. In order to cut the proper amount of standard threads, turn the outer sections until the markings on the head are in alignment before placing the threader on the pipe. When the threader is installed on the pipe, cut two or three threads by hand; then apply power to finish the job.

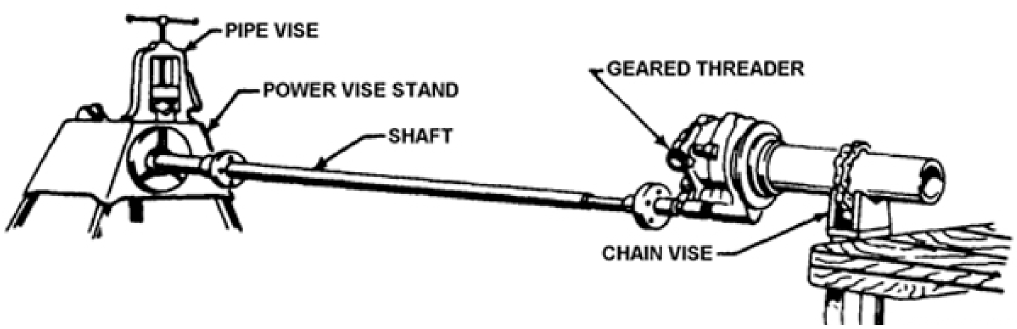


Figure 1–55. Geared-type threader and power vise stand.

After the threads are cut, reverse the powered vise stand and back the die teeth off the new threads. Next, loosen the setscrews and remove the threader from the pipe.

NOTE: Because of the heavy weight of the threader, be careful when installing and uninstalling. You could be injured if you drop it.

409. Assembling threaded joints

After cutting, reaming, and threading metal pipes, fittings are generally screwed to one end of the pipe while it is still in the vise. The assembled pipe and fittings are then screwed into the proper place in the installation.

Proper steps to make a leak-proof joint

The following three steps describe how to make leak-proof joints while the pipe is in a vise:

1. Clean the threads of the fitting and pipe with a wire brush. Apply a small amount of pipe joint compound (pipe dope) and/or Teflon tape to the male threads. Reasons for using pipe joint compounds include lubrication, sealing, corrosion protection, or antiseizing.
2. Screw the fitting hand tight in a clockwise direction, and then tighten with the correct size pipe wrench about two more turns. Overtightening stretches the fitting and causes the joint to leak.
3. Choose your pipe wrench according to the size pipe being worked.
   - 8” wrench for $^1/_8$ and $^1/_4$” pipe.
   - 10” wrench for $^3/_8$ and $^1/_2$” pipe.
   - 14” wrench for $^3/_4$ and 1” pipe.
   - 18” wrench for $1^1/_4$ and $1^1/_2$” pipe.
   - 24” wrench for 2” pipe.

To tighten a fitting, such as a coupling, without the use of a vise, follow these seven steps:

1. Clean the pipe and fitting threads with a wire brush.
2. Apply pipe dope and/or Teflon tape to the male threads.
3. Screw the coupling on the pipe hand tight.
4. Select two pipe wrenches. One, called a backup wrench, holds the pipe or fitting in place so it will not turn. This wrench takes the place of the vise (fig. 1–56).
5. Tighten the coupling on the pipe.
6. Screw in the remaining piece of pipe by hand.
7. Tighten the remaining piece of pipe using the pipe wrenches (fig. 1–56).

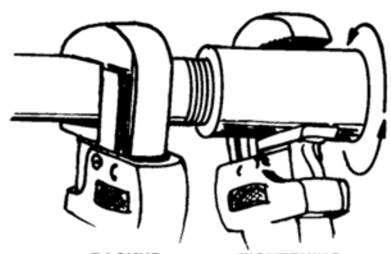


Figure 1–56. Using a back-up wrench.

410. Joining copper pipe and tubing

There are many ways to make copper joints, but we commonly use sweat-soldered joints. Sweat-soldering is a method of joining two metals by allowing molten solder to run between the tubing and fittings. Capillary action is the force responsible for the even sealing of solder joints. The tubing must be cut to length, reamed, and cleaned before you are ready to solder the joint (fig. 1–57).

Soft soldering

Your preparation of joints for soft soldering must be thorough. All of the metal surfaces must be perfectly clean at the joint in order to get a good bond between the base metal and the solder. This means you must remove all dirt, grease, oil, and paint as examples to make the metal bright. Clean the tubing with a wire brush, emery cloth, or steel wool as shown in figure 1–58. You may also use chemical cleaners. Finally, make sure that the parts to be joined are not “out of round” and fit together very closely.

After the inside of the fitting and the outside end of the tubing are cleaned, they must be fluxed (fig. 1–59) to prevent oxidation. Put the fitting into position as shown in figure 1–60, and prepare to heat the joint. A high-temperature concentrated flame that quickly brings the fitting to the melting point of solder is required for “sweating” fittings on copper tubing. Ninety-five/five solder (95 percent tin and 5 percent antimony or any solder with a lead content of 0.20 percent or less) melts at 425°F.

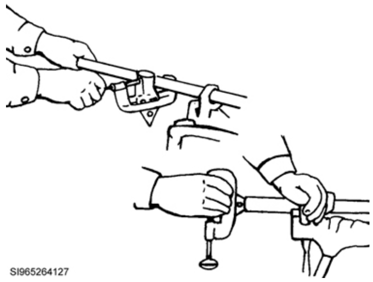


Figure 1–57. Cutting and reaming.

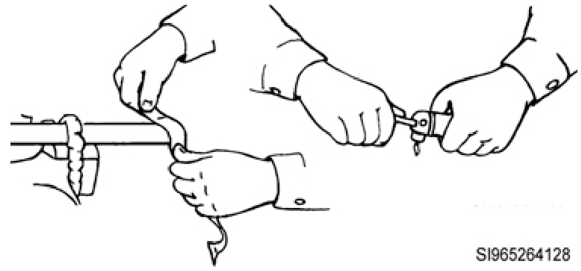


Figure 1–58. Cleaning pipe and fitting.

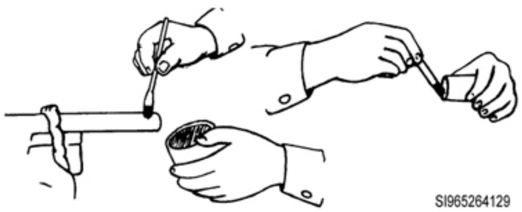


Figure 1–59. Fluxing pipe and fitting.

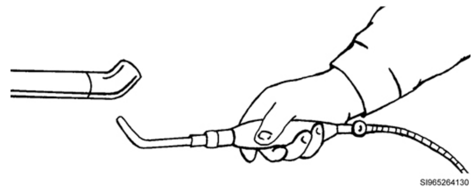


Figure 1–60. Heating the joint.

To produce the necessary heat, use a propane gas torch (fig. 1–61). The propane torch consists of a small portable gas cylinder, a regulator, a hose, and a torch. This torch is very efficient and produces a good flame for soldering.

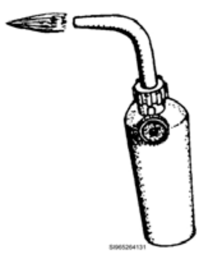


Figure 1–61. Propane torch.

When the fitting and tubing are ready to be joined, apply heat evenly around the fitting. Do this by moving the flame back and forth. This procedure also keeps you from overheating the tube and fitting. Why is this important? If the connection is overheated, the flux burns out, causing oxidation, and the solder does not spread evenly.

In addition, an overheated joint causes the solder to seep through the joint and flow away. You, therefore, need to test the heat by touching the fitting with solder where the tubing and fitting join (fig. 1–62). Normally, thick-wall fittings require more heat than thin-wall fittings. When the tube and fitting melt the solder, the sweating begins.

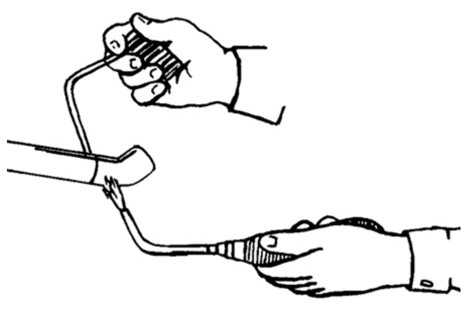


Figure 1–62. “Testing” heat and applying solder.

As soon as the connections are hot enough to melt the solder, remove the flame and apply the solder to the edge of the fitting, where it comes in contact with the tube. At this point, capillary action takes over to draw the solder into the small space in between the fitting and the tube. Solder will even run uphill through capillary action, thus joints can be made in any position.

The amount of solder required for a connection depends upon the diameter of the tube to be sweated. For instance, $^{1}/_{2}$" of solder is sufficient to solder a joint for $^{1}/_{2}$" tubing, $^{3}/_{4}$" of solder for $^{3}/_{4}$" tubing, and so forth.

NOTE: The amounts suggested are based on solder with a diameter of $^{1}/_{8}$".

When a line of solder shows up around the fitting—that is, a bead of solder appears in the groove at the end of the fitting—the joint has all of the solder it will take.

When you apply solder to a tee, feed solder from both ends of the fitting. Reheat the fitting slightly to help the solder penetrate into the metal. Remove the flame and continue to feed the solder to make sure the joint is filled. Remove excess solder with a small brush or cloth (fig. 1–63).

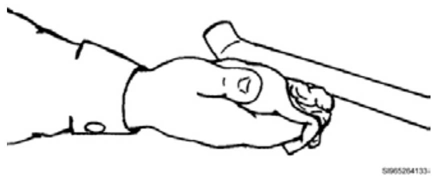


Figure 1–63. Removing excess solder.

Allow the joint to cool for a short while. A rag saturated with water helps this cooling. When you cool male and female adapters, allow more time for the solder to set. These fittings are heavier; therefore, they hold heat longer and do not cool as quickly.

411. Assembling copper tubing connection

The smaller size copper tubing used for supply connections, or jiffy connections, is soft enough to be formed into desired bends where it is necessary to change the direction of a line.

Bending copper

If you do not need sharp bends, copper tubing can be bent by hand, but the slightest excess pressure at any one point flattens or kinks the tubing and renders it useless. Bare hands, bending blocks, and bending springs are the tools to use if bending by hand. If more accurate bending is required, then the lever-type tube bender is your tool of choice.

Using a bending block

One way to bend soft copper tubing is to use a bending block of the correct size (fig. 1–64). Mount the block on a table or some other solid structure. During the bending operation, insert the end of the tubing in the loop, and, by using both hands, form the tubing gradually over the contour of the block.

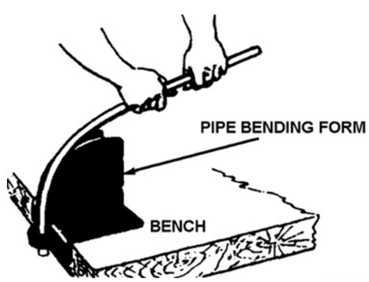


Figure 1–64. Using a bending block to bend copper.

Using a spring

Still another way for you to bend soft copper tubing without collapsing it is to use a flexible bending spring. To use a spring, place the correct size of flexible bending spring over the tubing, and gradually form it with your thumbs while you hold the tubing against a table or solid flat surface (fig. 1–65).

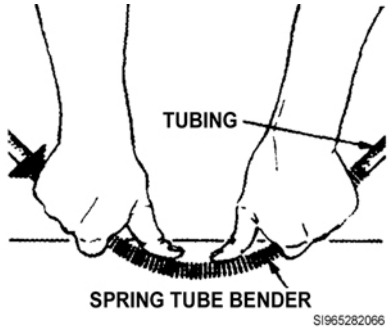


Figure 1–65. Using a flexible bending spring.

Using a tubing bender

Using tubing benders is the most practical way to bend copper tubing. Benders for soft copper tubing come in many sizes and types. The lever-type tube bender is the most efficient. Note the proper way to use the tube bender in figure 1–66. When you put tubing in the bender, raise the right handle of the bender as far as possible so that it rests in a horizontal position (fig. 1–66, A). Raise the clip and put the tubing in the space between the handle slide block and the bending form. Now, put the clip over the tubing and turn the handle slide bar about its pin and to the right (fig. 1–66, B). Note that the zero mark on the bending form coincides with the mark on the slide bar. Next, continue to turn the handle to the right (clockwise, fig. 1–66, C) until you bend the tubing to the angle you want. You can make bends *of any angle up to 180°* with the tube bender. To remove the bent tubing from the bender, lift the handle slide bar back to its horizontal position and raise the clip. This will free the tubing so that you can remove it from the bender.

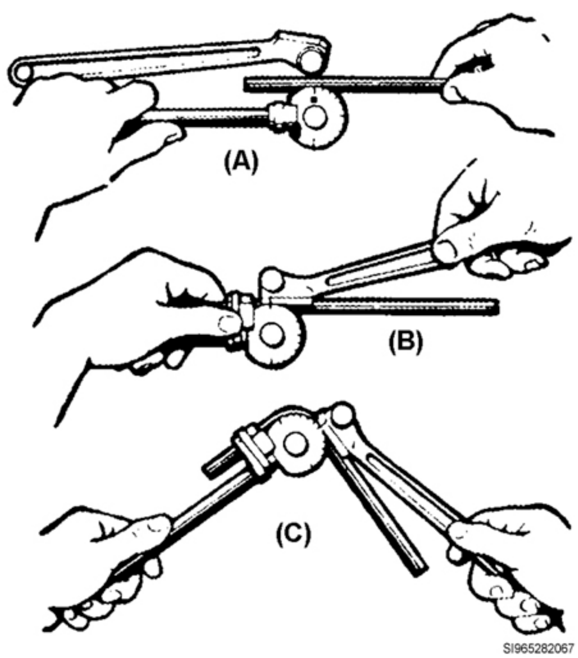


Figure 1–66. Using a tube bender.

Flaring copper

One easy and satisfactory way to join copper tubing is to flare the ends of the tubing and press the flared end against the tapered surface on the fitting. Then, screw the compression nut up tight over the end of the fitting (fig. 1–67). An advantage of this type of connection is that you can disassemble it easily when you need to make repairs. The only thing you have to do to disassemble this connection is to select the correct size wrench, unscrew the compression nut that makes up the compression connection, and separate the fittings. When you make a flare on copper tubing, take every precaution to produce an airtight and watertight joint. First, measure and cut the tubing to the proper length with a tube cutter or hacksaw. Then, remove the burr within the tubing. Copper tubing can be flared with a flaring block and clamp kit or with a plug-type flaring tool.

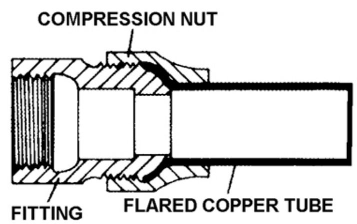


Figure 1–67. Cutaway view of a flared joint.

When making a flaring on tubing using the flaring block, slip the compression nut on the tubing, and insert the end of the tubing into the correct size hole in the flaring block. The flaring block has two different sides. One side is flat and the other beveled around the tube holes. Extend the end of the tubing above the face of the beveled side of the block to a distance that is twice the wall thickness of the tubing, which for most of the tubing we use is the thickness of a nickel (fig. 1–68). The small bit of tubing extending above the block will take the shape of the bevel and allows enough tubing to spread over the taper of the fitting. Next, attach the clamp to the flaring block, and center the flaring face over the end of the tubing (fig. 1–69). Force the flaring face against the tubing end by rotating the T-handle on the clamp clockwise. This causes the end of the tubing to expand just enough to fit into the compression nut and over the end of the fitting.

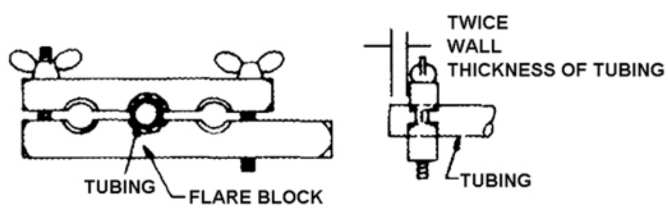


Figure 1–68. Proper placement of tubing in flaring block.

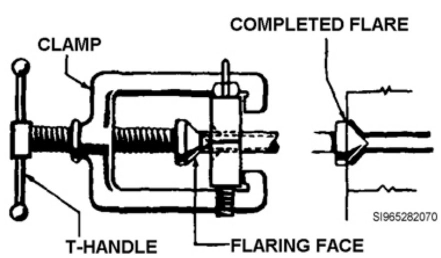


Figure 1–69. Proper placement of flaring clamp over block.

Flaring tubing with a plug-type flaring tool forms the same type of flare as that formed by the flaring block. As in the previous flaring method, the tubing must be cut to the proper length and the burrs removed. Slip the compression nut over the end of the tubing and insert the plug-type flaring tool into the end of the tubing (fig. 1–70). Now, hold the tubing firmly in your hand and strike the end of the plug with a ball-peen hammer until the desired flare is formed. *Do not* expand the flare larger than the inside of the compression nut. When properly formed, the flare should slip freely into the compression nut.

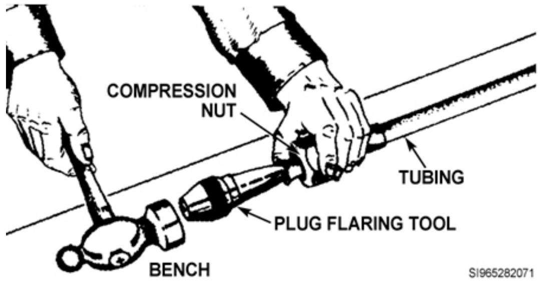


Figure 1–70. Using a flaring plug.

Assembling a flared joint

After the tubing has been flared properly, assembly of the joint is simple. To make the joint requires a fitting that is threaded and formed on both ends to receive the flare of the tubing. Some fittings are designed with only one end to receive the flare, whereas others have a regular tapered pipe thread to fit the threads in a casting or pipe.

When the proper fitting is obtained, place the flare against the fitting. Next, slip the compression nut against the flare and screw it on the fitting. This operation squeezes the flare of the tubing between the fitting and compression nut, making a watertight and airtight joint. When these joints are properly tightened with two wrenches, they withstand pressure of up to 3,000 psi. The wrenches you use to tighten these joints should fit snugly to avoid damaging the connection. Do not use a tool that mars or scars either the tubing or fittings. Be careful during the tightening process—do not strip the threads. It is always advisable to use two wrenches to tighten or loosen these fittings to prevent twisting the tubing. Do not use excessive pressure because copper and brass fittings are soft.

Flared joint fittings

There are many types of flared fittings that you can use when installing a water supply or fuel systems using copper tubing.

Some of the flared fittings that are available are illustrated in figure 1–71. Available in sizes ranging from $^{3}/_{8}$” to 3”, flared fittings are used with types K and L soft- or general-purpose copper. Flared-joint fittings are normally used in underground water service lines, where pipes must be cleaned often, or on fuel system automatic valves and components.

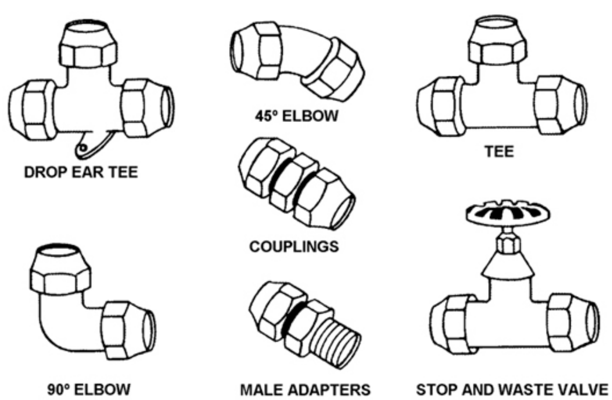


Figure 1–71. Types of flared fittings.

Ferrule joints

Ferrule joints have three parts: the fitting, the nut, and the ferrule or compression sleeve (fig. 1–72). These ferrule joints can be made of several different materials such as plastic (nylon), brass, and stainless steel. Since they function the same way, we will talk about brass fittings with copper tubing as an example. To make this type of joint, first cut the copper tubing to the correct length. Next, ream the inside of the tubing to remove the burr, and file the end to remove any sharp edges. Slip the nut on the tubing first, then, the ferrule. As stated earlier, the fitting will be of a single or double ferrule design. The double ferrule design has two ferrules that may fit together in a particular order to slide onto the tubing. Take note of how the ferrules are positioned when you initially take off the nut in this type of fitting. Now, slide the end of the tubing into the fitting, and slide the ferrule(s) up against the fitting. Screw the nut onto the fitting. Use either a flare-nut wrench or an open-end wrench to finish tightening the nut on the fitting. Tightening the nut crimps the ferrule into the tubing and against the fitting. This makes a water-tight and air-tight seal. As with flared joints, use two wrenches to assemble ferruled joints to protect the tubing from damage.

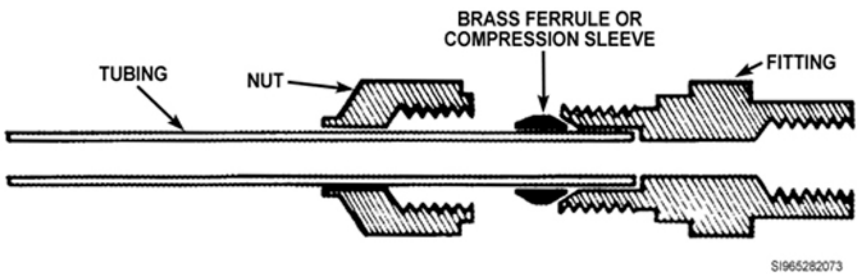


Figure 1–72. Cutaway view of a ferrule joint.

Swaging

Swaging, pronounced “swedging,” is the process of expanding an end of the tubing to receive an end of another piece of the same size tubing (fig. 1–73). You then *solder* the joint to seal it. By swaging, the use of one fitting is eliminated.

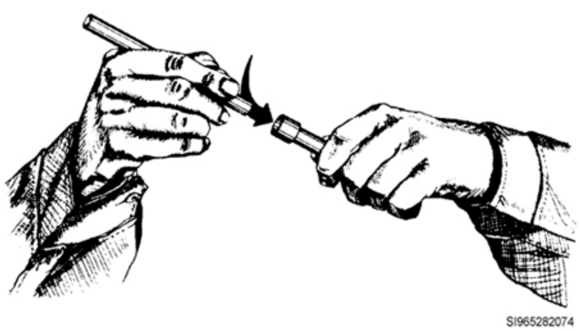


Figure 1–73. Swaged joint.

The swaging kit has a swaging punch and a swaging block (fig. 1–74, right). The swaging punch has a small part (called a pilot) that fits easily into the inside of the tubing and a tapered lead that connects to the pilot with an enlarged portion slightly larger than the OD of the tube. The five swaging steps are as follows:

1. Use the back side of the block (opposite bevel side).
2. Clamp the tube into the proper size hole in the block.
3. Extend the tube above the block a distance equal to the distance from the bottom of the swaging punch to the top of the bevel (fig. 1–74, left).
4. Hold the block firmly in hand.

5. Using a hammer, drive the swaging punch into the tube (the punch should be turned slightly after each stroke).

The properly completed swaging joint has an inside diameter slightly larger than the original OD of the tube and a depth at least equal to the original OD.

NOTE: Do *not* make a swaging joint within 1” of the point where a flare or a bend is located. The swaging portion of tubing has a double thickness, making it very difficult to bend. In flaring, it may be impossible to slip the flare nut back far enough on the tube to clamp the tube into the flaring block properly. If you do swaging properly, the connection is stronger than the tubing itself.

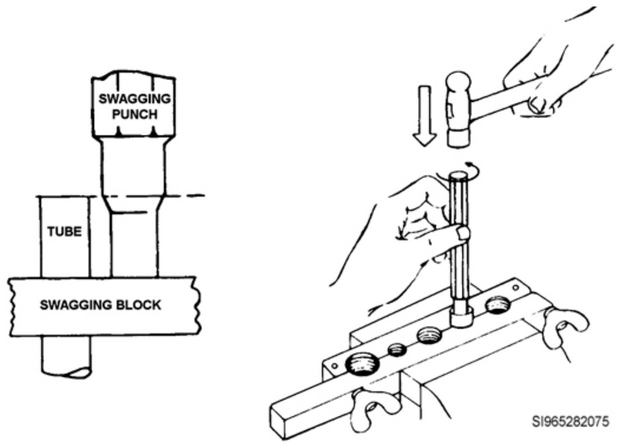


Figure 1–74. Using a swaging kit.

412. Assembling cast-iron and plastic pipes

Proper assembling cast-iron and plastic pipes are important to preventing leaks. Within this lesson we discuss the procedures in the assembling of the two types of pipes.

Cast-iron

The lead and oakum joint (fig. 1–75, top) is an older type seal used in pipe joints and as caulking for wooden ships and barrels long before the invention and application of rubber. You may still find them in old piping both here in the US and overseas. Cast-iron and cast-iron soil pipe will use either a bell-and-spigot compression or a no-hub joint.

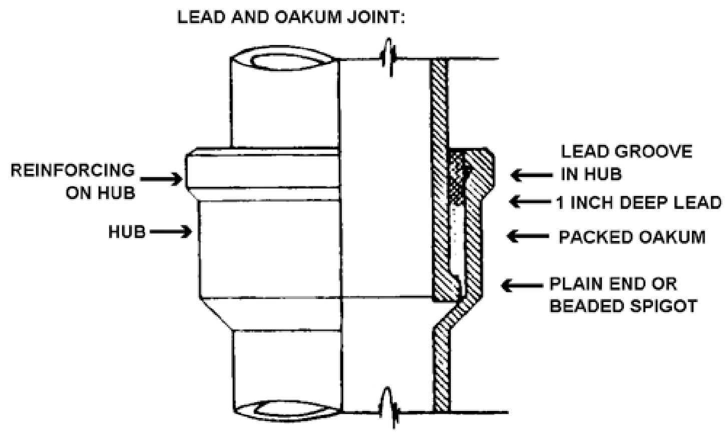
Compression joints

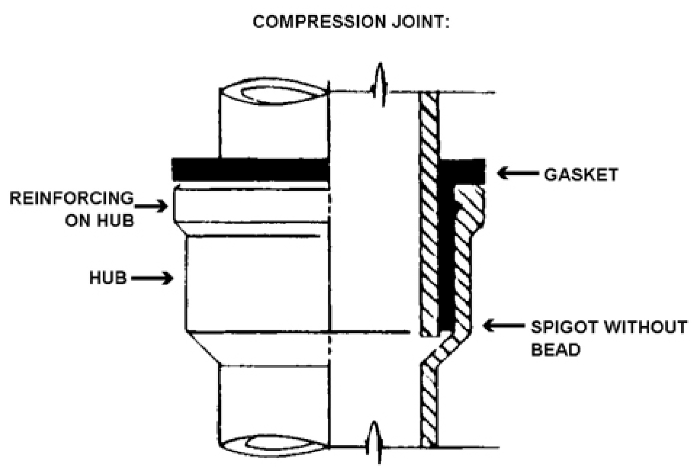
The compression joint (fig. 1–75, middle), uses a bell-and-spigot pipe ends with a *neoprene* rubber gasket. The gasket is inserted into a clean hub. Then the spigot end of the pipe or fitting is lubricated and pushed or drawn into the gasket hub. The joint is sealed by displacement and compression of the rubber gasket. The resultant joint is leak-proof, root-proof, and pressure-proof. It absorbs vibrations and can be deflected up to 5° without leakage or failure

No-hub joint

This system uses a no-hub clamp composed of a one-piece neoprene gasket and a stainless steel shield with retaining clamps, as shown in figure 1–75 (bottom). You insert the pipes or fitting into the gasket until they are against the separator ring, then slide the shield over the gasket and tighten the clamps. Tighten the stainless steel retaining clamps with a torque wrench. The desired amount of tightness is not less than 48 or more than 60 inch-pounds of torque.

The advantages of this system are that it permits joints to be made against a ceiling or in any limited-access area. Other advantages of this type of system are that the installation is fast and efficient and few tools are required. One disadvantage of the no-hub system is additional support may be required around the pipe joint.





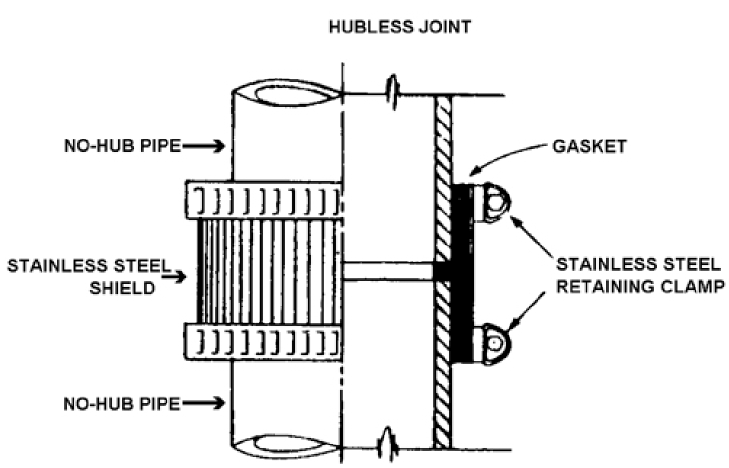


Figure 1–75. Types of cast-iron joints.

Plastic solvent welded joints

Solvent welding is used extensively in plastic pipe assembly. It makes a strong, tight, permanent connection. After you cut the plastic and remove the burr, clean the pipe with a rag to remove dirt and moisture. Put your fitting on the pipe to ensure fit. The pipe must enter at least one-third of the way into the socket without forcing. Next, remove the gloss on the end of the pipe and inside the fitting socket with a cleaner or a primer, then apply the cement.

NOTE: The type of cement used must correspond with the type of pipe used.

Using a brush, first apply a thin coat of cement to the inside of the fitting, then a thick, even coat of cement to the outside of the pipe. Quickly insert the pipe into the fitting with a one-quarter turning motion that assures an even distribution of the cement. Hold the pipe and fitting together for at least 30 seconds so the cement has time to set. If the pipe and fitting are not held until the cement sets, they pull apart.

Allow the joint to dry for a few minutes before handling it. Allow the pipe and fittings to set for about 24 hours before pressure-testing the system. Of course, this time interval varies with the type of cement used and the temperature of the air. Thus, in hot weather, joints dry faster; in cold weather, the drying process takes longer. If you have any doubts about the drying time, check the manufacturer's specifications.

Larger plastic pipe for underground use are joined using O-ring joints as shown in figure 1–76. The spigot end must have an 8° to 15° taper and must be well lubricated before assembly.

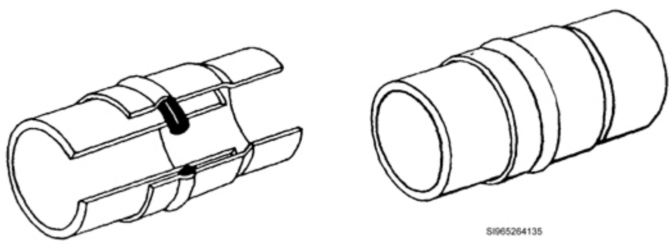


Figure 1–76. Cross section of an O-ring joint.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

408. Threading steel pipe

1. What sizes of pipe are threaded with a three-way die?

2. What should you inspect before you thread a piece of pipe?

3. What is the purpose of using cutting oil when threading pipe?

4. How do you remove the hand threader from the pipe after the threads have been manually cut?

5. What is the purpose of the taper on the threads of a pipe?

6. What determines the number of threads per inch on a correctly threaded piece of pipe?

7. What is used to clean the pipe chuck jaw teeth on a power-driven threading machine?

8. How far can you hand screw a fitting on a properly threaded pipe?

9. When using a power bench threader, how many threads do you start before allowing the threader to thread itself?

10. How does a portable power-driven vise stand operate?

11. What sizes of pipe does the chuck of a portable power-driven vise stand grip?

12. What precautions are observed when using the portable power-driven vise stand?

13. What sizes of steel pipe can be threaded with a geared-type threader?

409. Assembling threaded joints

1. How do you clean the threads of metal pipe and fittings?

2. What is applied to the male threads of metal pipe once the threads are cleaned?

3. What is the purpose of applying pipe joint compounds and/or Teflon tape?

4. To which threads should you apply pipe dope and/or Teflon tape?

5. What size pipe wrench do you use on 1” pipe?

6. How is a fitting tightened on a pipe when you are away from the shop?

7. What device does a backup wrench replace?

410. Joining copper pipe and tubing

1. What is the most common method of joining copper pipe?

2. What is the purpose of fluxing?

3. At what temperature does 95/5 solder melt?

4. How can you test your heat when making a solder joint?

5. What determines the amount of solder required for a joint?

6. How much $^{1}/_{8}$” solder would be required to solder four $^{1}/_{2}$” joints?

411. Using copper tubing for water supply connections

1. What tools can be used to bend copper tubing by hand?

2. On what surface is a bending block usually mounted?

3. What is considered the most practical way to bend copper tubing?

4. What tools are used for flaring copper tubing?

5. How is the flaring clamp face forced against a flaring block?

6. If properly formed, how should a flare fit inside a compression nut?

7. How much pressure is a properly assembled flare joint able to withstand?

8. Why should you use two wrenches when tightening a flared joint?

9. What are the three parts to a ferruled joint?

10. What types of wrenches are best to use for tightening a ferruled joint?

11. What is the purpose of swaging copper?

412. Assembling cast-iron and plastic pipe

1. What methods are used to assemble cast-iron pipe?

2. How much deflection can be tolerated without leakage in a cast-iron compression joint?

3. What components make up a no-hub clamp?

4. What is the advantage of a no-hub system?

5. What is the desired tightness for a no-hub clamp?

6. When dry assembling plastic pipe, how far should the pipe enter into the socket?

7. The type of cement you use on plastic pipe must correspond with what?

8. How is plastic pipe cement applied?

9. How is the pipe assembled after the cement is applied?

10. How long do you hold the pipe together once assembled?

11. How long should the pipe and fitting set before pressure testing?

12. How are larger plastic pipe for underground use assembled?

13. How much taper does the spigot end of plastic pipe used with an O-ring have?

Answers to Self-Test Questions

401

1. (1) e, (2) f, (3) h, (4) d, (5) a, (6) g, (7) b, (8) c.

402

1. (1) g, (2) b, (3) c, (4) i, (5) h, (6) f, (7) a, (8) e, (9) d.
2. Recessed fittings are cast with a recessed shoulder to provide a smooth interior surface and have pitched outlets (¼” per foot) for connection to horizontal drainage pipes that must be pitched or graded.

403

1. 16 times for every inch.
2. ½.
3. Call the measurement to the closest 16^{th} inch subdivision.

404

1. Find a common denominator.
2. $^{1}/_{16}$.
3. $8^{11}/_{16}$.

405

1. Offset.
2. Run.
3. Travel.

406

1. The center is that point where the lines drawn through the middle of the fitting intersect.
2. The back of the hub and the spigot end.
3. The measurement from the center point of each fitting to the bottom of the socket.

4. The small ridge in the center of the neoprene seal.
5. End-to-end, end-to-center, and center-to-center.
6. End-to-end and face-to-face.
7. The fittings.

407

1. Point the chisel toward the center of the pipe and move it around the line of cut, in overlapping steps between successive blows. Continue this procedure, rotating the pipe and striking the cold chisel with increasingly heavier blows. Repeat these steps until the pipe breaks and separates at the line of cut.
2. Raise the pipe clear of the supports and strike it lightly with a hammer.
3. A clear, bell-like ring.
4. A hacksaw and an adjustable wrench.
5. With a special cutting wheel.
6. Be certain the cutter is straight. If it is not straight the cutter will travel.
7. 70°.
8. Follow the procedures set forth by the manufacturer.
9. With a metal saw or a pipe cutter.
10. A fine-toothed file or deburring tool.
11. A tubing cutter.

408

1. ½, ¾, and 1” in diameter.
2. Ensure the dies are clean, sharp and free of nicks.
3. Cutting oil cools the pipe threads and threading dies, because overheating causes pipe thread damage.
4. Lift up and turn the knob on the ratchet to reverse direction, then turn the ratchet counterclockwise until the pipe-threading dies are free of the threads.
5. The taper makes it possible for you to make a tight, leak-proof joint when a pipe is screwed into a fitting.
6. The pipe size according to the NPT standard.
7. A stiff wire brush.
8. About half way up the threads.
9. At least two.
10. It turns the pipe to be cut or threaded while the threader is resting on the arms of the machine.
11. $^{1}/_{4}$ to 2”.
12. When you use this machine, be sure to rest the handles of the cutter, reamer, and threaders against the bars.
13. Pipe larger than 2”.

409

1. Use a wire brush.
2. Pipe joint compound (pipe dope) and/or Teflon tape.
3. Lubrication, sealing, corrosion protection, or antiseizing.
4. Male threads.
5. 14”.
6. Use two pipe wrenches, one as a backup wrench.
7. A vise.

410

1. Sweat-soldered joints.
2. To prevent oxidation.
3. 425°.

4. Occasionally touch the fitting with solder where the tubing and fitting join.
5. The diameter of the tubing to be soldered.
6. 2”.

411

1. Bare hands, bending block and bending springs
2. On a table or some other structure.
3. Using a tubing bender.
4. A flaring block and clamp kit, and a plug-type flaring tool.
5. By rotating the handle on the clamp clockwise.
6. The flare should slip freely into the compression nut.
7. 3,000 psi.
8. To prevent twisting the fitting.
9. The fitting, the nut, and the brass ferrule or compression sleeve.
10. Use either flare nut or open-end wrenches.
11. To eliminate use of one fitting.

412

1. No-hub or bell-and-spigot using a compression gasket.
2. Up to 5 degrees.
3. A one-piece neoprene gasket and a stainless steel shield with retaining clamps.
4. It permits joints to be made against a ceiling or in any limited-access area, installation is fast and efficient, and few tools are required.
5. Not less than 48 or more than 60 inch-pounds of torque.
6. The pipe must enter at least one-third of the way into the socket without forcing.
7. The type of pipe used.
8. With a brush, apply a thin coat of cement to the inside of the fitting, then a thick even coat of cement to the outside of the pipe.
9. Quickly insert the pipe into the fitting with a one-quarter turning motion.
10. For at least 30 seconds.
11. About 24 hours.
12. With O-ring joints.
13. 8 to 15°.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (401) The *benefit* galvanization provides a steel pipe is it
   a. makes the pipe easier to bend.
   b. increases pipe thickness.
   c. increases pipe strength.
   d. reduces corrosion.

2. (401) What is used to join black iron and stainless steel pipe sections with diameters of 2” within newer fuel systems?
   a. Threaded connections.
   b. Welds and welded flanges.
   c. Compression type fittings.
   d. Hub and spigot connections.

3. (402) How do street elbows differ from standard elbows?
   a. Standard elbows have male threads.
   b. Street elbows have recessed threads.
   c. Standard elbows have tapered threads.
   d. Street elbows have one female and one male end.

4. (403) Identify the *smallest* measurement increment on *most* tape measures used in our trade.
   a. Thirty-second inch.
   b. Sixty-fourth inch.
   c. Sixteenth inch.
   d. Eighth inch.

5. (404) Subtract the following fractions: $3\ {}^{8}/_{16} – 1\ {}^{5}/_{16}$ =
   a. $2\ {}^{2}/_{16}$.
   b. $2\ {}^{3}/_{16}$.
   c. $2\ {}^{12}/_{16}$.
   d. $2\ {}^{15}/_{16}$.

6. (404) Convert 7 feet to inches.
   a. 60 inches (”).
   b. 72”.
   c. 84”.
   d. 96”.

7. (405) Which kind of tape measure can you use to determine travel when the offset angle is known to be 45 degrees (°)?
   a. Angle rule.
   b. Travel rule.
   c. Standard rule.
   d. Plumber’s rule.

8. (405) You can also measure travel if you do *not* have a plumber's rule by using a standard tape measure and multiplying the distance by
   a. 1.114.
   b. 1.141.
   c. 1.414.
   d. 1.411.

9. (406) In order to make accurate measurements, how do you determine the center of a fitting?
   a. Read the branch, then the run.
   b. Determine the angle of the branch.
   c. Divide the length of the fitting by 2.
   d. Find where lines drawn through the fitting intersect.

10. (406) One method to *ensure* an accurate measurement is taken using an end-to-center measurement is to make the measurement from the
    a. middle of the pipe to the end of the fitting.
    b. end of the pipe to the center of the fitting.
    c. center of the pipe to the end of the fitting.
    d. end of the face to the center of the back.

11. (407) To remove the burr from inside of a piece of pipe, operate the handle of a reamer with
    a. short, even, counterclockwise strokes.
    b. long, even, counterclockwise strokes.
    c. long, even, clockwise strokes.
    d. short, even, clockwise strokes.

12. (408) When using a hand threader, which factor will create damaged pipe threads?
    a. Too much oil.
    b. Dull or nicked dies.
    c. Sharp and clean dies.
    d. A pipe that is not reamed.

13. (408) When threading a steel pipe with an adjustable pipe die, how do you determine when the proper number of threads have been cut on the pipe?
    a. The amount of threads cut will correspond to the pipe size (½-inch ["] pipe will have ½" threads).
    b. The cutter disengages and turns freely when the proper number of threads are cut.
    c. Twelve rotations of the die handle cut the proper number of threads.
    d. Two newly cut threads project beyond the end of the die teeth.

14. (409) When threading a fitting on a pipe, what happens if you overtighten a fitting?
    a. Leaks will be stopped completely.
    b. The wrench you are using might break.
    c. Overall pipe length decreases by 1 inch (").
    d. The fitting stretches and the joint leaks.

15. (410) How much solder is needed to solder a ½-inch (") connection?
    a. $^{1}/_{2}$".
    b. $^{3}/_{4}$".
    c. $^{7}/_{8}$".
    d. 1".

16. (411) When using a lever-type tubing bender, you can make angles up to how many degrees?
    a. 45.
    b. 90.
    c. 120.
    d. 180.

17. (412) When you assemble a cast-iron soil pipe, use a
    a. soldered bell and no-hub joints.
    b. welded spigot and no-hub joints.
    c. bell compression and screwed bell.
    d. no-hub joint or a bell-and-spigot compression.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Water Distribution

2−1. Components and Equipment 2–1
413. System components 2–1
414. Equipment 2–5
2−2. Exterior Water Distribution 2–8
415. Assembly and installation 2–8
416. Fire hydrants 2–10
417. Flow testing 2–12
2−3. Interior Water Distribution 2–17
418. Assembly and installation 2–18
419. Openings 2–20
420. Hangers and support 2–22
421. Causes of pressure loss 2–23
422. Inspection and testing 2–26
2−4. Maintenance and Repair 2–30
423. Winterize piping systems 2–30
424. Thaw frozen water pipe 2–31
425. Piping repairs 2–33
426. Field disinfection procedures 2–36

IN THIS UNIT, we cover the water distribution system from cradle to grave. As a WFSM journeyman, you will be involved in repairing and maintaining the distribution system in one way or another.

2−1. Components and Equipment

One of your primary jobs is to install, maintain, and repair water distribution systems. The first step in performing this job is to understand what makes up the system. In this section, you are going to study system components, operational pressure requirements, sizing water mains, materials used in constructing water mains, service line components, and construction procedures.

413. System components

As a WFSM journeyman, you must become familiar with the terms of your trade and with the different types of water wells and water devices. Also, there several types of water tanks that we will get to know a little better.

Wells

Holes dug or shafts sunk into the earth to obtain water are called *wells*. The type of well and the method of reaching the water will depend on the type of ground, the quantity of water desired, and the depth of the aquifer. Wells are generally categorized as *open* or *closed*. In this lesson we will discuss the closed wells. Wells must be carefully located and protected to keep surface water out, since surface water usually carries bacteria and impurities that contaminate the well water. For this reason, wells should be on relatively high ground so rainwater flows away from, and not toward, the well. To keep the earth from collapsing and filling the well hole, it is often necessary to line or “case” the well. In addition to strengthening the well, the casing serves to keep surface water from entering the shaft. The casing should be watertight and extend down into the last impervious layer of earth or rock overlying the underground water source, or aquifer. Only water from the aquifer should be allowed to enter the casing. The water is usually pumped from wells by electrically driven pumps. Where the casing emerges from the ground and joins the pumps, the connection must be watertight to keep out surface contamination (fig. 2–1).

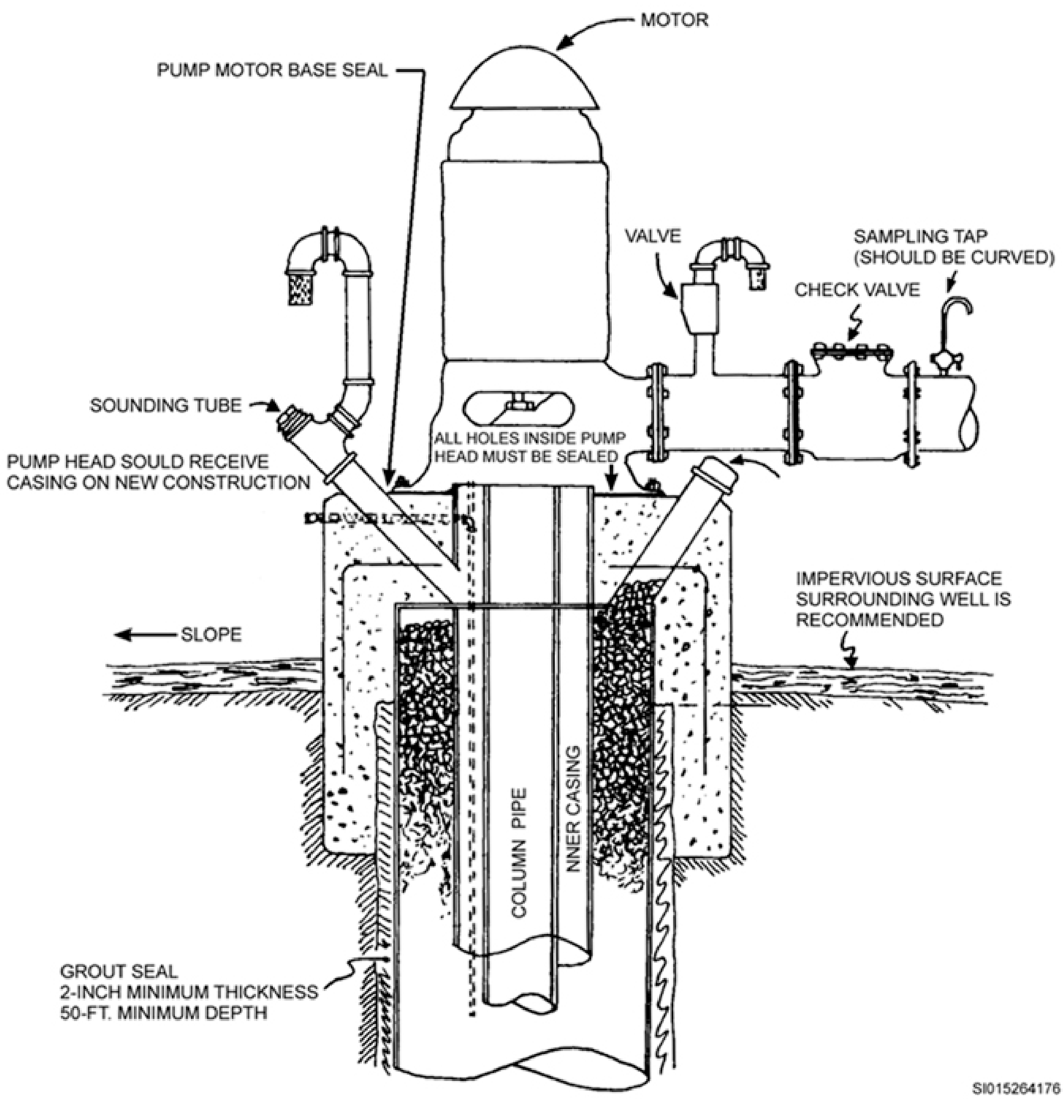


Figure 2–1. Water well.

Booster stations

Water pumping or “booster” stations, as they are commonly called, are used to draw stored water from one storage tank to another that is higher in elevation (usually an elevated storage tank). In some cases, booster stations are used to supply water to a service area at a higher elevation that does not have elevated storage.

There are various designs of booster stations in use today. Some are old—requiring manual operation of pump switches—and some are employing the latest control gadgets available to the industry—rendering completely automatic service.

Two types of pumps used in a booster station are deep-well turbine and split case. The deep-well booster pump is a turbine pump with multiple bowl assembly (fig. 2–2). Deep-well booster pumps get their name because their complete bowl assembly is lowered down into the source of water. Usually, multiples of these pumps are installed through the slab of an underground reservoir. This type of booster pump is more likely to be used when it is necessary to provide distribution pressure in areas that do not have an elevated storage tank. The portion of the reservoir in which the pumps are located, is usually covered by some type of structure to protect them from the weather. The split-case pump can be a vertical or horizontal design and used to transfer water from a source other than a well. You will commonly find split-case pumps used in fire-suppression systems to boost water pressure (fig. 2–3).

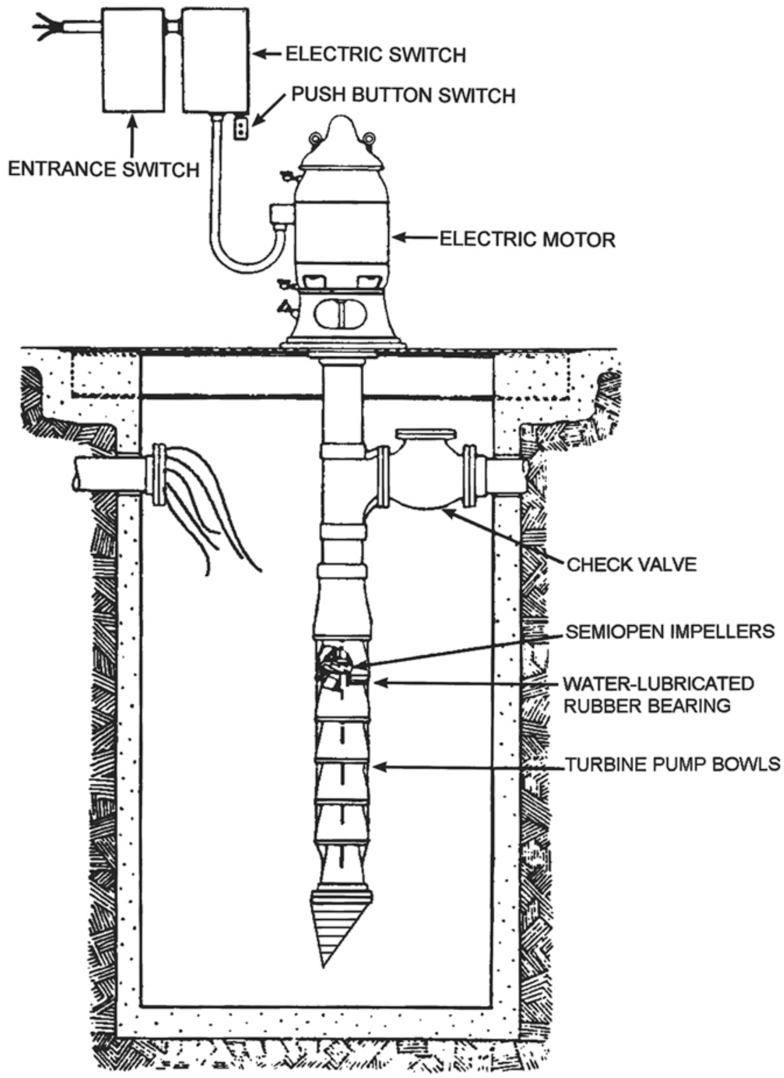


Figure 2–2. Deep-well turbine pump.

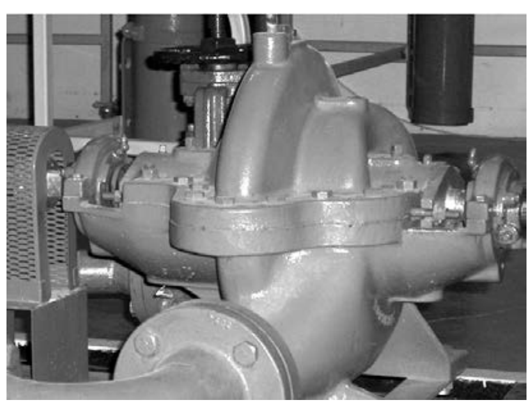


Figure 2–3. Split-case pump.

Water storage facilities

Water for consumption and fire protection is stored in two ways: elevated storage tanks and ground storage tanks. Let's take a closer look at each.

Elevated storage tanks

Elevated storage tanks are usually built in flat areas (fig. 2–4). Elevated storage tanks provide cheap water pressure by eliminating the need for booster pumps. Most importantly, elevated storage tanks provide water at a uniform pressure to a surrounding area. All elevated storage tanks in a particular area are built at the same elevation to equalize the pressure uniformly across the flat plain of the land they serve. The interior of water storage tanks should be inspected at least biannually for defects.

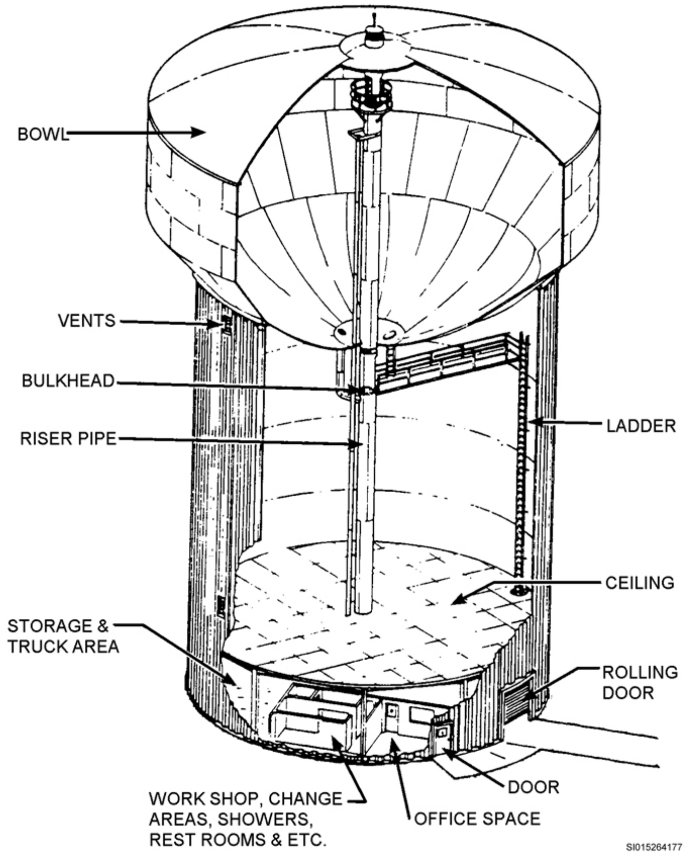


Figure 2–4. Elevated storage tank.

Ground storage tanks

Ground storage tanks may be built into the ground or above ground (fig. 2–5). They are usually made of concrete when built below ground and steel when built above ground. Ground storage tanks are used for a variety of purposes depending on the elevation level in which they are constructed. They are usually built above the service area (city) into a hill in order to provide pressure as well as for aesthetic reasons. When built into a hill, they are not readily identifiable to the public. Ground storage tanks are also built above ground at flat elevations to provide booster stations a ready reserve of water for pumping water into an elevated storage tank. An aboveground storage tank is usually the first place water is stored after it has been treated or pumped from wells.

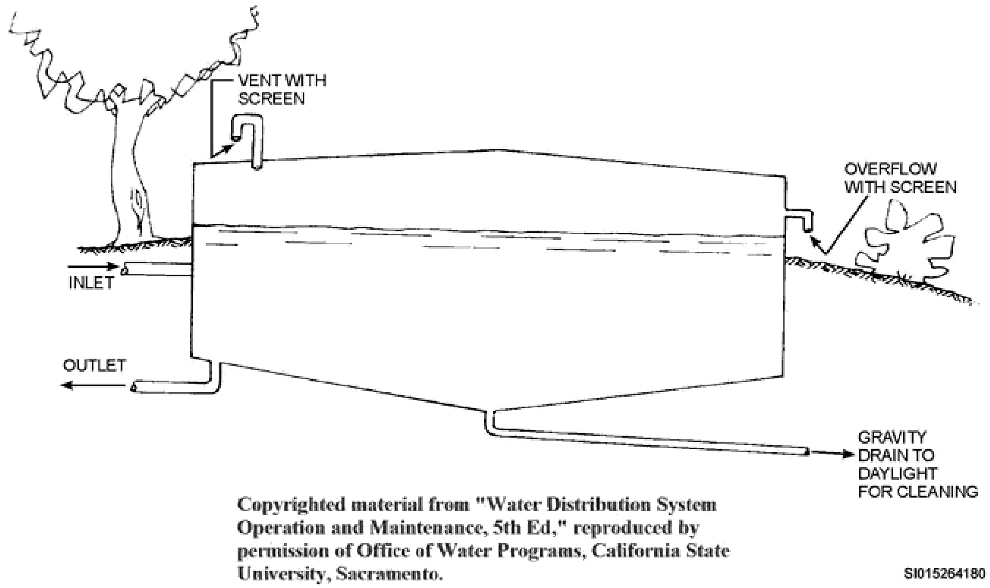


Figure 2–5. Ground storage tank.

Underground reservoirs

Underground reservoirs or clear wells (fig. 2–6) are primarily used to store prefiltered water at a water treatment plant. Another use of underground storage tanks is as a clear well for booster pumps at a "booster station." In all cases, these clear wells are usually used as a storage reservoir for some type of pumping function. Underground reservoirs are constructed of reinforced concrete and usually have a slab on top of them to prevent contamination of the stored water. A big disadvantage of underground reservoirs is that they are very susceptible to small animal infestations. Routinely check underground reservoirs to ensure that no animals have gained access to the water source.

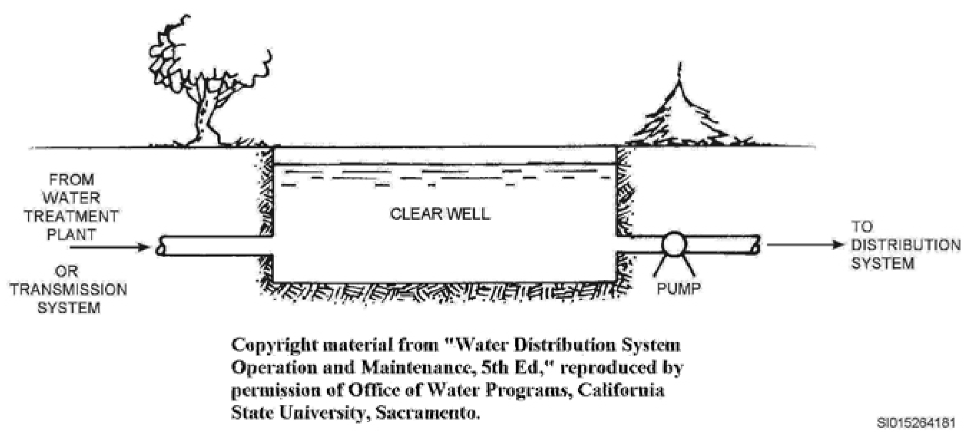


Figure 2–6. Clear well.

414. Equipment

In this lesson, we discuss the equipment used in water distribution systems. We cover the types of chemical feeders used to feed chlorine into the water system for disinfection purposes and water metering devices used to track water quantity and rate of flow.

Chemical feeders

There are three general types of chemical injection equipment used to feed chlorine gas or a hypochlorite solution. The type used depends upon the methods of control. In the manually controlled type, you must start and stop the equipment manually and adjust the rate of feed to the rate of water flow. In the semiautomatic type, equipment starts and stops automatically as the water flow starts and stops, but you must adjust the rate of feed to the rate of water flow. In the fully automatic type, the rate of feed is automatically adjusted to the rate of flow of the water being treated using the differential pressure of a metering device to do this. In all types, you must adjust the ratio of chemical feed to water treated (dosage).

Direct-feed chlorinators

Direct-feed chlorinators are used chiefly as emergency equipment and on small installations where the water pressure is too low to operate a solution-feed machine. They cannot be used where the water pressure is more than 20 psi. Since chlorine gas is always kept under pressure, direct-feed machines are highly susceptible to leakage. Escaping gas corrodes surrounding equipment and structures.

Solution-feed chlorinators

Solution-feed chlorinators feed chlorine gas into the water supply by means of a chlorine solution usually formed by drawing chlorine gas into the jet stream of water at the low-pressure point of an injector mechanism of the chlorinator. Two general types are used in water plants—the bubbling (or pulsating reduced-pressure) type and the vacuum type. Because such chlorinators keep the chlorine under a partial vacuum, they cause fewer chlorine leaks than do the direct-feed chlorinators.

Hypochlorinators

Hypochlorinators, or solution feeders, introduce chlorine or other substances into the water supply in the form of a solution. They are usually positive-displacement piston or diaphragm mechanical pumps. However, hydraulic-displacement hypochlorinators are also used. Your selection of a feeder depends on local conditions, space requirements, water pressure, and available supervision. Fully automatic types are actuated by pressure differentials produced by orifices, venturi meters, or similar devices. Portable hypochlorinators are also available for use when disinfecting water mains or for emergency chlorination applications.

Metering equipment

A water meter is a measuring device. All meters have a primary element and a secondary element. The primary element is in contact with, and actuated by, the water, while the secondary element translates the action of the water flow on the primary element in terms of water quantity or rate of flow. Water is commonly measured in terms of rate of flow (volume passing in a unit of time) or total volume. The type of primary element determines meter type.

Primary elements

The four classes of primary elements generally used in water meters are head area, velocity head, velocity, and volume as shown in the table below.

Class	Description
Head area	Includes weirs and flumes used in open channels and orifices and nozzles with free discharge to the atmosphere.
Velocity head	Includes the venturi, flow-nozzle, orifice, and pitot-tube types used in pipes carrying flow under pressure.
Velocity	Includes propeller and turbine meters used principally in larger size closed pipes. Portable propeller meters are also used to determine velocity of flow in open streams and rivers.
Volume	Principally used in the nutating or wobbling-disk meter. Determination of quantity by water level changes as water is discharged into or drawn from a tank of known size. This is also considered volume metering.

Secondary elements

The secondary element of a water meter is actuated by the movement or the pressure change of the primary element through either mechanical linkage or hydraulic, pneumatic, or electrical impulse. They are classified below in accordance with the functions they perform.

Function	Description
Indicating	Show only the momentary rate of flow. An example is a calibrated staff gauge.
Recording	Show continuous rate of flow on a clock-driven chart.
Totaling or Integrating	Show total flow that has passed through the meter, as in a disk-type house service meter.
Controlling	Control the operation of other waterworks equipment, such as valves and chemical feeders.

All measuring devices operate because of the inherent characteristics of liquids. Flow can be induced by gravity (as in a stream or from a storage tank) or by pumping through a pipe. The type of measuring device used depends on the type of flow channel of the water.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

413. Components

1. What conditions determine the kind of well used and the method by which it is sunk?

2. What prevents a well from filling up with earth (collapsing)?

3. On what type of terrain are elevated storage tanks usually built? Why?

4. What is a major sanitary disadvantage of underground reservoirs?

414. Equipment

1. What three general types of chlorinators are used in water treatment?

2. What are the two general types of solution-feed chlorinators?

3. List the four primary elements used in water meters.

2−2. Exterior Water Distribution

From the storage tank, water flows to the distribution piping. The water mains on a base are installed in a looped system. A big advantage to using this system rather than the tree system is that the loop system has no dead ends where water can become stagnant. If a branch line dead ends, it must have a blowdown capability. This means that a valve or a fire hydrant has to be installed on the end of the pipeline to allow flushing of the line.

415. Assembly and installation

Within this lesson you will learn about the steps involved with the assembly and installation of water mains. Here, we discuss water mains in general, to include tapping, testing, and disinfecting water mains.

Water mains

Water mains are located along streets to provide short fire hydrant branches and service lines to buildings. The branch line that connects a fire hydrant to a main must be at least 6” in diameter. The distance between the main and the fire hydrant must be kept as short as possible—the maximum distance is 300’. Keep branch line distances to the hydrant less than 50’, if possible.

When possible, do not lay water mains under paved streets or in locations that are subject to heavy traffic. Bury branch and main lines to protect them from damage due to collision and weather. The minimum burial depth is $2^1/_2$’ in grass areas, 3’ under roads, and 4’ under railroad tracks. Where the depth of frost requires a greater cover, increase the minimums as needed. Encase the pipe in a rigid conduit when it runs under railroad tracks. Above all else, locate water mains so that safe and adequate separation from all other underground utilities is assured.

Where water mains and sewer lines are installed parallel to roads, locate them on opposite sides of the road when possible. It is not good practice to lay sewer and water piping in the same trench; however, there are exceptions. When building sewers or drainage piping are constructed of materials that are not approved for use within a building, the *UPC* requires that they not be run or laid in the same trench with water service pipes or any underground water pipes unless *both* of the following conditions are met:

- The bottom of the water piping at all points shall be at least 12” above the top of the sewer piping.
- The water piping shall be placed on a solid shelf at one side of the common trench.

If the above conditions cannot be met, allow at least 10’ between water and sewer mains when they are constructed parallel to each other. The water service line (fig. 2–7) is the part of the water distribution system that originates at the street main and extends into the building.

Most plumbing codes do not allow the water supply line to be laid in the same trench as the sewer line except with certain precautions. If you do have to lay the water supply and sewer lines in the same trench, lay the water supply line 12” above the top of the house sewer line and on a shelf of undisturbed solid soil. This prevents the water supply line from settling to the same level as, or below, the sewer.

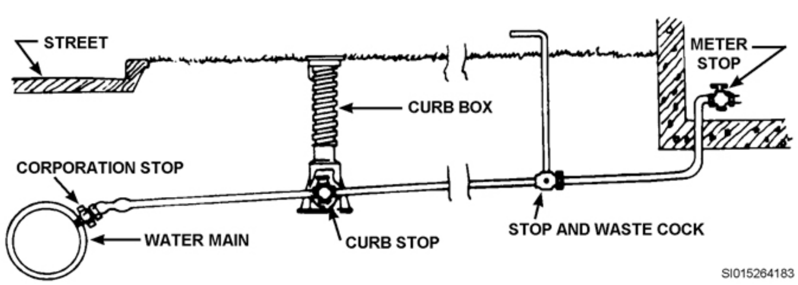


Figure 2–7. Water service line.

Tapping water mains

Many water mains are made of plastic, cast-iron, ductile-iron, or asbestos-cement pipe and usually have an 8” or larger diameter. If you have a cast-iron main that is smaller than 8” in diameter, do not make taps larger than 2”. As a rule of thumb, the tap should be no larger than one-fourth the diameter of the pipe being tapped. When you tap asbestos-cement pipe 6” in diameter or less, the largest tap you can use is $^3/_4$”. On larger diameters of asbestos-cement pipe, the tap can be up to 1”.

When you need larger taps (more volume of water), build a manifold or install a tee in the line. To build a manifold, make a series of taps in the main and connect them with a branch connection. Stagger the taps and space them at least 10” apart.

There are quite a few brands of tapping and drilling machines used by the industry. Some are for tapping water mains and some for gas mains. Others are used specifically for plastic mains. The theory of operation is the same for all these machines; the actual tapping procedure and materials used will vary from each manufacturer.

Testing water mains

You cannot put a new water main into service as soon as it is completed because it has to be tested for leaks and then disinfected to make the water in it potable. If either of these steps is omitted, a maintenance problem or a health hazard could develop. Test for leaks first, so necessary repairs can be made before the pipe is disinfected.

All new water mains must be hydrostatically tested for leaks before they are put into operation. There are several types of hydrostatic test pumps available built specifically for water main testing. The test is performed as sections of the main are completed, or after the whole main is completed. Partially backfill the trench before testing the main, leaving the pipe joints exposed to check for leaks.

Test the pipe at 1½ times its normal operating pressure. To test the water main hydrostatically, plug the ends of the pipe. If the main has valves in it, use them to isolate sections for testing. Allow all of the air to escape from the pipe as it is being filled with water.

Connect the hydrostatic testing pump to the pipe. Pump additional water or air into the pipe until the required test pressure is reached.

The test must last at least 1 hour. During this time, check for leaks at the joints and fittings and in the pipe. Make any repairs that are needed, and retest the pipe until all of the leaks are fixed. After the tests are completed, disinfect the pipe.

Disinfecting water mains

You must disinfect all water mains before they are put into service. To do this, flush the pipe to remove dirt, waste, or surface water from the pipe. After flushing, put a water-chlorine solution such as a calcium hypochlorite *solution* of chlorine into the pipe.

NOTE: Do *not* use dry calcium hypochlorite *powder* or pellets in pipe with solvent welded plastic or screwed joint steel pipe, because the reaction between the joint compounds and the calcium hypochlorite could cause a fire or explosion.

The *UPC* requires that you fill the pipe with water, allowing all of the air to escape. Then, maintain a chlorine residual reading of at least 50 parts per million (ppm) for 24 hours or 200 ppm for 3 hours. After meeting the time and chlorine residual requirement, flush the system until it reaches the chlorine residual level of the potable water being used to flush the system. After flushing is complete, conduct a bacteriological analysis of the water until the analysis shows no further disinfection is required. Repeat the procedure if bacteriological analysis by an approved agency shows that contamination persists.

416. Fire hydrants

Fire hydrants play a very important part in the mission of WFSM personnel. Within this lesson we will cover the installation factors of hydrants and the importance in regards to completing your mission.

Installation

As a WFSM journeyman, you may have to install a fire hydrant (fig. 2–8). During the installation procedures, consider the following factors:

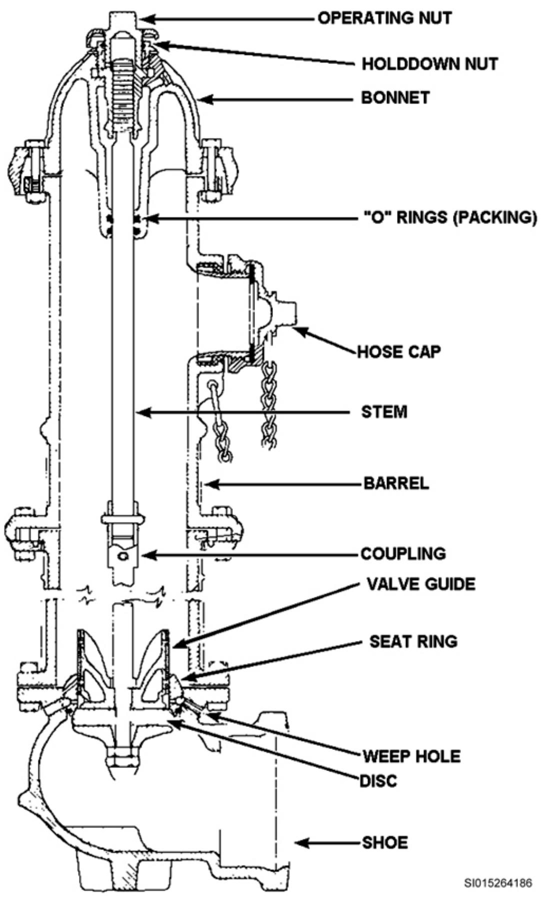


Figure 2–8. Fire hydrant components.

Installation Factors

1. Make sure the lowest outlet is at least 18” above the ground.
2. Be certain the highest operating nut is not more than 48” above the ground.
3. Be sure the water main supplying the hydrant is 6” in diameter or larger.
4. Install an isolation valve between the water main and the hydrant (fig. 2–9).
5. Bury the water line that leads to the hydrant deep enough to eliminate the possibility of freezing.
6. Open the drain hole.
7. Brace the hydrant with a kick block opposite to the water entrance. This will keep the water pressure from blowing the hydrant off the pipe. The hydrant is braced by using concrete between the hydrant and solid ground.
8. If the soil is sandy and unstable, attach the hydrant to the water main with bridle rods and clamps. The rods should be at least 3/4” in diameter and be coated with an acid-resistant paint in order to reduce corrosion.
9. After the hydrant has been connected, pack at least 7 cubic feet of crushed rocks around the base of the hydrant to ensure thorough draining of the hydrant.

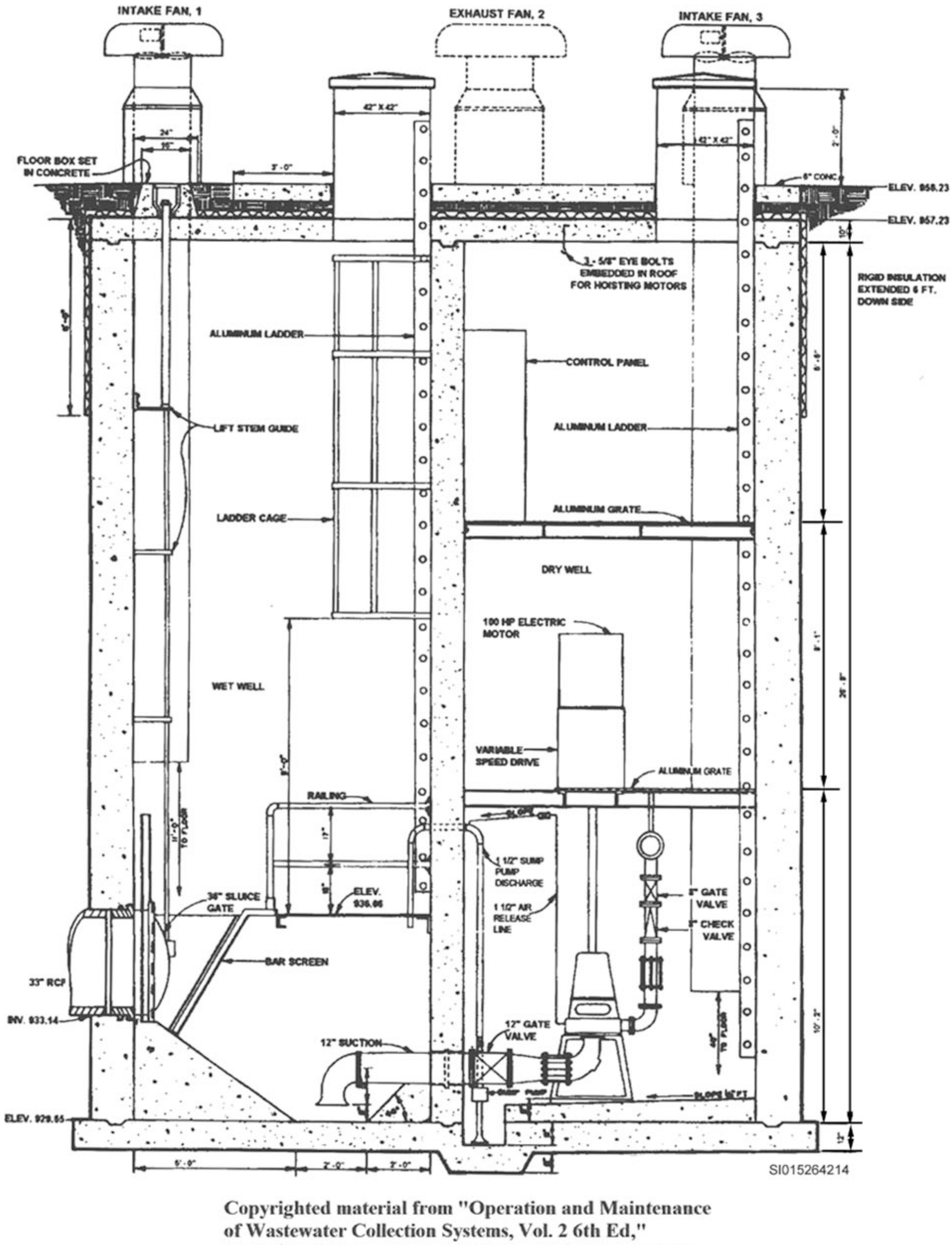


Figure 2–9. Lift station.

Maintenance

You should backfill the earth in layers that are 6” thick or less. Tamp each layer thoroughly before you add the next layer. You are also required to perform inspections and maintenance of fire hydrants on an annual basis. Obtain information pertaining to each type of hydrant from the manufacturer and maintain it in a file for ready reference. Test the hydrants in peak flow periods.

Start your inspection at the hydrant nearest the beginning of the base water supply. Maintain a record on each fire hydrant and its isolation valve on an Air Force (AF) Form 1027, Water Flow Test Record. This record states the number of the hydrant, exact location, manufacturer, past readings on the hydrant, and other pertinent information.

The isolation valve is usually installed 3–5’ from the fire hydrant. This valve allows you to turn off the water supply to the hydrant without turning off an entire block or more of the water main.

To check the hydrant, tighten the hose connection caps and turn the hydrant two turns to the open position. Doing this applies water main pressure to the hydrant so that you can check for leaks and also places the valve in the correct position for checking the operation of the weep hole. Place your ear against the barrel of the hydrant and listen for sounds of water escaping through the weep hole. If you hear a hissing sound, the water is escaping through a weep hole that is free of obstructions. Once you have determined the weep hole is open, open the main valve all the way.

Check for leaks around the operating nut. If leakage occurs, tighten the packing gland. If this does not stop the leak, replace the packing. Also, check for leaks around the nozzle caps. If you note leakage, replace the gaskets. Now, close the hydrant and remove the small hose caps. Check the main hydrant valve to see that it is not leaking by observing the water level inside the hydrant barrel at the hose outlet. The water level in the hydrant barrel should go down as the water drains out through the weep hole. If the water level in the hydrant barrel increases, the main valve is leaking and needs to be repaired.

To replace the main valve, you must first close the isolation valve isolating the hydrant from the water mains. Remove the hold-down nut by turning it in a clockwise direction because it has left-hand threads; then remove the operating nut. The bonnet can now be unbolted and removed. Insert a seat wrench into the barrel. This wrench is designed so the seat of the hydrant can be removed and replaced without digging up the hydrant. Unscrew the seat ring by turning the seat wrench counterclockwise. With the seat loose, remove the entire stem, disc, and seat from the barrel. Inspect all components and, if required, replace all worn parts. Reassemble the hydrant in reverse order and open the isolation valve to check your work.

Other maintenance required on the hydrant consists of lubricating the operating nut, replacing hose connections that have bad threads, and checking all components. If the fire hydrant is going to be out of working order for any period, notify the fire department.

417. Flow testing

The normal operating pressure in a water distribution system is 40 to 75 psi at ground elevation. If the pressure in low areas of the system exceeds 100 psi, then a two-level system may be necessary to allow both systems to be maintained in the 40 to 75 psi range. In small, low areas where the pressure exceeds 100 psi, install pressure-reducing valves in the feeder mains. The minimum pressure in high ground areas is 30 psi under peak domestic flow.

Flow testing system

Since firefighting uses a lot of water, the pressure has to be high enough to support fire-flow requirements in all parts of the water system. To fight a large fire, part of the base may have to be shut off to conserve water; this is accomplished with valves. Install valves at intervals of 1,200 to 1,500’ in main distribution loops or feeders and on all primary branches connected to these lines. Also, install valves at selected points throughout the distribution system to provide control over reasonably sized areas. Where fire hydrants are subject to damage by traffic, install a valve in the branch line to the hydrant. This allows you to shut off the hydrant for repair while keeping the water on for other services.

Flow test procedure

The flow test should be done about the same time of day on each hydrant during the periods of ordinary water consumption on the base. Select any two fire hydrants in the system. Go to the first hydrant (A) and flush it thoroughly. Close the hydrant valve and attach the hydrant gauge assembly (fig. 2–10) to the hydrant. Open the hydrant valve and measure the static pressure (when the water is not moving) (fig. 2–11) and record the static pressure. Go to the other fire hydrant (B) and perform the flow test using the pitot tube (fig. 2–12).

First, you must tightly cap all outlets on fire hydrant B, except for one 2$^1/_2$” hose outlet. Open the petcock on the pitot tube to release all the trapped air inside the gauge neck. Open fire hydrant (B) to full flow and record residual pressure on fire hydrant (A) (first hydrant).

NOTE: There must be at least a 25 percent drop in residual pressure on hydrant (A) before proceeding with the test. Additionally, system pressure should *never* drop below 20 psi. Depending on the strength of the distribution system, keep opening subsequent hydrants until you measure a 25 percent drop in hydrant (A) and record this pressure as the residual pressure (pressure in the main with water flowing though the hydrant).

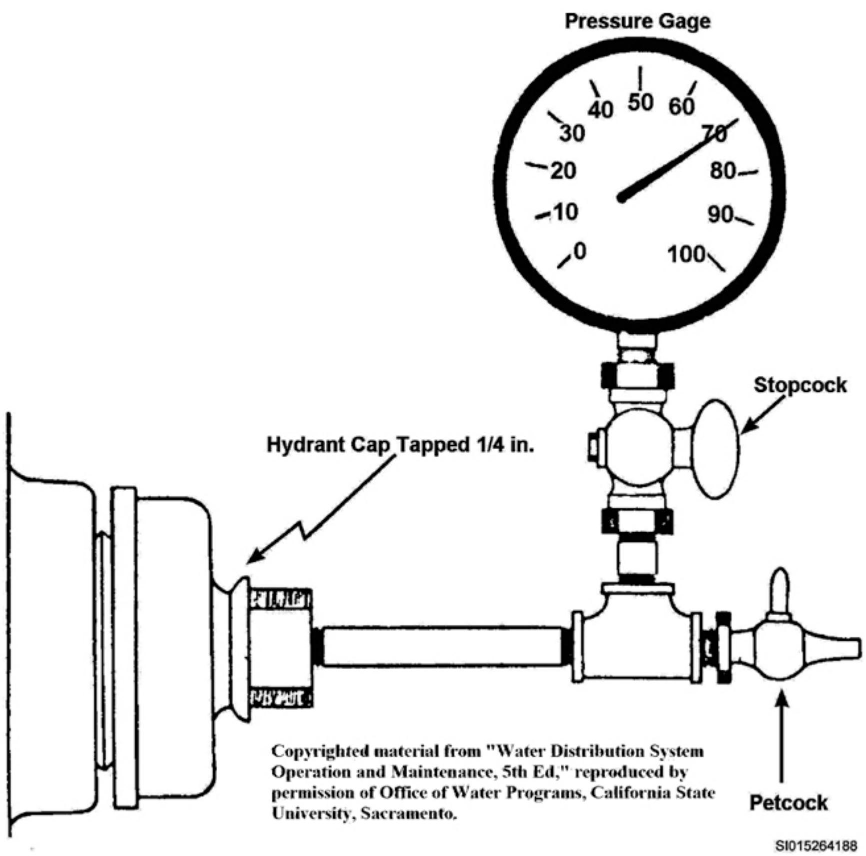


Figure 2–10. Hydrant pressure gauge assembly.

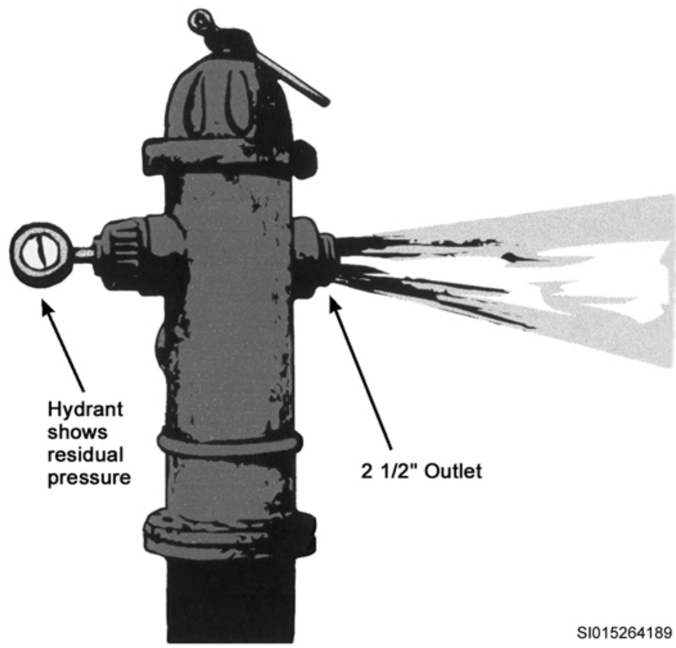


Figure 2–11. Residual pressure.

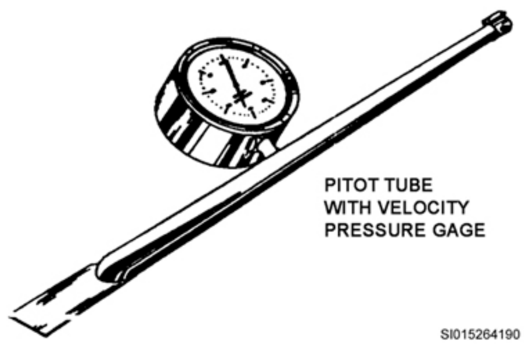


Figure 2–12. Pitot tube.

Measuring velocity flow

Use a pitot tube to measure velocity flow. Insert the flattened end of the pitot tube halfway into the center of the water flow on hydrant (B) (fig. 2–13). Close the petcock on the pitot tube when a steady stream is observed through the petcock—allowing all trapped air to be released. Record the gauge reading when the needle comes to rest. This is called the velocity pressure. Watch the gauge and write the velocity pressure reading in a log for that particular fire hydrant. After all hydrant readings have been taken, be sure to shut down each hydrant slowly to prevent surges in pressure throughout the system. If all hydrants tested are low, it is possible that the base water pressure is also low.

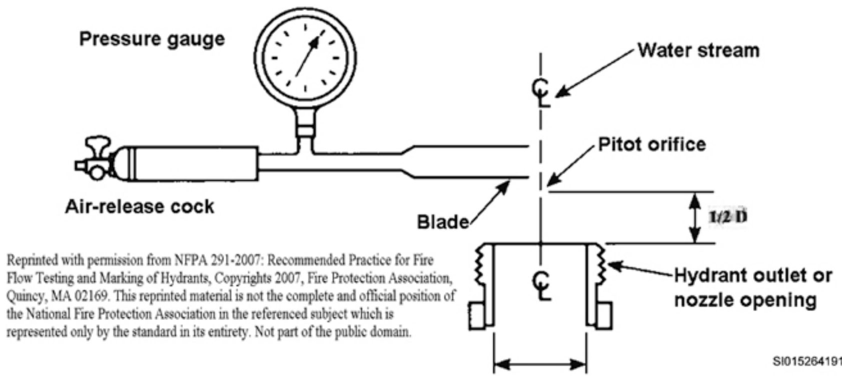


Figure 2–13. Pitot tube position in the hydrant opening.

Calculation

To calculate the flow through the hydrant, you can use a formula or a chart. The formula for determining flow is not too complicated, but most people prefer to use the chart since it is quicker. Also, most pitot tubes come with a chart for easy flow calculation. For those who like math, the formula is provide below:

$$\text{Flow (gallons per minute [gpm])} = 29.83 \times c \times d^2 \times \sqrt{p}$$

To calculate the flow rate through the hydrant using this formula, multiply 29.83 (constant) by the coefficient value for that particular hydrant times the diameter squared of the hydrant outlet times the square root of the velocity pressure obtained from the pitot tube readings. The coefficient value in the formula above is a constant value based on the inner construction of the hydrant outlet (fig. 2–14).

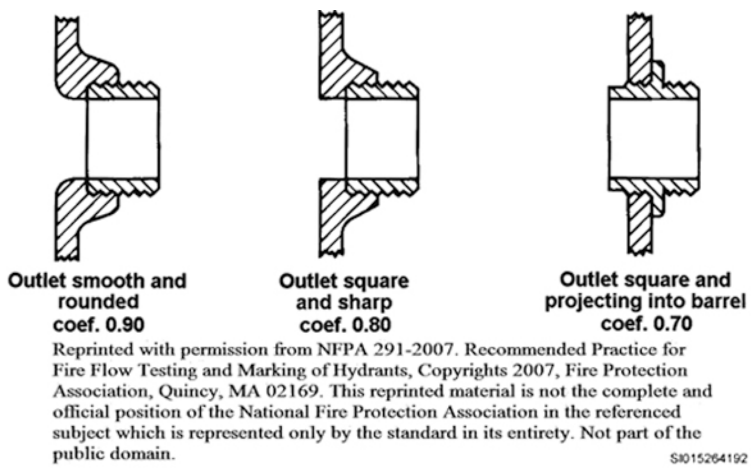


Figure 2–14. Hydrant coefficient construction and respective values.

To calculate the flow using the National Fire Protection Association (NFPA) chart (fig. 2–15), simply find your pitot tube reading in the velocity pressure column. Next, locate the diameter of orifice column applicable to your hydrant (usually 2.5”). Intersect these two values to find your gpm rating. For example, a velocity head reading of 30 psi on a 2.5” outlet gives a flow of 1,022 gpm.

Table 4,10.1(a) Theoretical Dishcarge Through Circular Orifices
(U.S. Gallons of Water per Minute

Pilot Pressure'· (psi)	Feet'(	Velocity Discharge (ft/sec)	Orifice Size Cn.)											
			2	2.25	2.375	2.5	2.625	2.75	3	3.25	3.5	3.75	4	4.5
1	2.3]	12.20	119	151	168	187	∘06	226	269	513	366	420	477	61)4
2	4.61	17.25	1611	214	238	264	291	319	380	446	517	393	675	833
3	6.92	21.:3	207	262	292	323	356	39]	465	546	633	727	827	1047
4	9.23	24.39	230	302	337	373	411	451	537	630	731	839	955	1209
5	11.54	27.21)	267	338	376	417	460	505	601	705	817	938	1068	1331
6	1'3.84	29.87	292	370	412	437	504	553	658	772	895	11125	1169	1480
7	16.13	32.26	516	400	445	493	544	597	711	834	967	1110	1263	1599
8	18.46	34.49	338	427	476	528	582	638	760	891	1034	1187	1350	1718]
0	20.76	36.58	3513	453	5115	560	617	677	806	946	1[197	1239	1432	1813
111	23.07	38.56	377	478	532	590	650	714	849	997	1156	1327	1510	191]
11	25.38	40.45	396	501	558	619	682	748	1311	11143	1212	1312	1583	21814
12	27.68	42.24	413	523	583	646	712	782	930	1092	1266	1454	1654	20113
13	29.99	43.97	430	545	607	672	741	814	968	1136	1318	1513	1721	2179
14	32.30	45.63	447	565	630	698	769	844	1003	1179	1368	1570	1786	2261
15	34.61	47.22	462	585	652	722	796	874	1040	1221	1416	1625	1849	2340
16	36.91	48.78	477	11]4	673	746	822	9113	1074	1261	1462	1679	1910	2417
17	39.22	50.28	492	623	694	769	848	930	11117	MOO	1507	1730	1969	2191
18	41.53	51.73	306	641	714	791	872	957	1119	1337	1551	1780	2026	2564
19	43.83	53.15	520	658	734	813	896	084	1171	1374	1593	1820	2081	2634
20	46.14	54.54	534	676	733	834	2211	1009	1201	1410	1533	1877	2135	271)2
22	511.75	57.19	561]	71)11	739	875	/64	11158	126)1	1478	1715	1968	2231)	2834
24	35,37	59.74	583	741)	825	914	1007	11013	1316	1344	I 791	2056	2339	2960
26	59.98	62.18	609	770	858	951	1048	1151	1360	1607	1854	2140	2434	3081
28	64.60	64.52	632	799	891	987	1088	1194	1421	11168	1034	2220	2526	3197
30	69.21	60.79	651	827	922	1022	1126	1236	1471	1726	2002	2298	2615	3510
32	73.82	68.08	1)75	855	052	1055	11013	1277	15I11	1783	2068	2374	2701	3418
:34	78.44	71.10	696	881	981	1087	1199	1316	1566	1838	2131	2447	2784	3523
36	83.05	73.16	716	906	1010	1 119	1234	135.1	1611	1891	2103	2518	2865	3526
38	87.67	75.17	736	931	1038	1150	1268	1391	1656	1943	2253	2587	2943	5725
40	92.28	77.11	735	953	1065	1180	1300	1427	161]t]	1991	2312	2654	3020	3822
42	96.89	79.03	774	11711	1011]	12(19	1333	1462	1740	21143	2360	2719	3094	51116
44	101.51	80.88	7112	111112	1116	1237	1364	1497	1781	2091	2425	2783	3167	4008
46	106.12	82.70	810	1025	1142	1265	1395	1531	1821	2138	2470	2846	3238	4098
48	110.74	84.48	827	11147	1156	1292	1425	1503	1861	2184	2533	2907	3308	4186
50	115.35	86.22	844	10118	1190	1319	1454	1596	1899	2220	2583	2967	'3376	4273

2007 Edition

Figure 2–15. NFPA discharge calculation table.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

415. Assembly and installation

1. Explain how deep water mains and branches should be buried.

2. What is the largest tap that you can make on a 4” cast-iron pipe?

3. What pressure do you use to test a new water main?

4. What is used to test a new water main before it is put in operation?

5. After flushing the water main, how long must you maintain at least 200 ppm chlorine residual to reach the required disinfection period?

416. Fire hydrants

1. What is the maximum height for a fire hydrant operating nut?

2. How often do you perform inspections and maintenance of fire hydrants?

3. What form do you use to record information about hydrant inspections?

4. How far from the hydrant do you install an isolation valve?

5. After you tighten the hose connections, how much should you open the hydrant to check it?

417. Flow testing

1. What is the normal operating pressure in a water distribution system?

2. At what intervals are valves installed in main distribution loops or feeders?

3. What is used to measure velocity pressure in a fire hydrant?

2−3. Interior Water Distribution

The water supply system for a building consists of the piping, fittings, and valves that carry water from a water main into the building and the system that supplies water to the building plumbing fixtures and equipment. When you rough in a water supply, you must know the type of fixtures to be installed. You can get this information from blueprints or specification sheets. Once you know the type of fixtures, you can refer to the manufacturer’s rough-in specifications. In this section, you will learn about water supply requirements and the building’s hot and cold water distribution systems.

418. Assembly and installation

This lesson covers the steps involved in assembling and installing a water supply system. Here we look at how to size the water supply system and install pipe appropriately.

Sizing

To determine the size of a water supply, you must consider several factors, such as the types of flush devices, pressure of the water supply in psi, length of the building service line, number of fixtures, and the probable use of these fixtures. Each fixture must have an adequate water supply. Check the diameters of the pipe involved for rough-in specifications on the blueprints (fig. 2–16).

Plumbing Fixture	Pipe Diameter (inches)
Dishwasher	1/2 or 3/4
Water Closet Tank	1/2
Water Closet Flushometer Valve	1
Urinal with Flushometer Valve	1/2
Lavatory	1/2
Shower Bath	1/2
Kitchen Sink	1/2
Slop Sink	1/2
Scullery Sink	3/4
Laundry Tray	1/2
Drinking Fountain	1/2
Hot Water Heater (domestic)	3/4
Bathtub	1/2

Figure 2–16. Minimum water supply sizes.

When a liquid flows smoothly through a pipe, particles of the liquid next to the pipe wall tend to stick to the pipe and slow down. This action retards the movement of the rest of the liquid particles in the pipe. Soon, the stream of water has a series of layers of water traveling at different speeds, with the center moving fastest. This resistance to flow caused by the particles in these layers is termed "pipe friction." In a small pipe, this problem may be overcome by supplying water at a higher pressure than normal. In a location where higher water pressure is not available, pipe friction may be reduced by increasing the size of the pipe.

When you install a water service pipe, pass the line through the foundation wall or floor into the basement, or pass the line into the crawl space of a building that does not have a basement. Next, install the distribution supply main (fig. 2–17). Finally, install the branch lines, risers to the various fixtures, and air chambers.

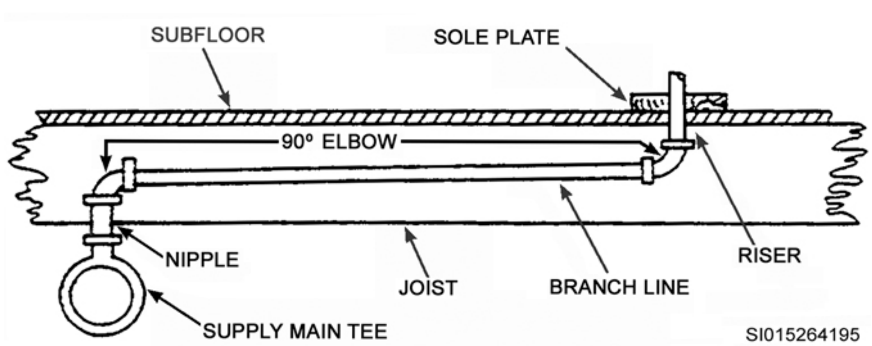


Figure 2–17. Cutaway of a building water supply.

Piping

The types of pipe used most often in hot and cold water systems are galvanized steel, plastic, copper, and PEX. The methods of assembly have already been covered for these pipe types. Still, keep in mind that pipe and fittings for pressure pipe are different from those for drainage systems. Always make sure the materials you use are designed for the system you are working on. One other difference in assembly is related to soldering copper joints. Because of the hazard of lead leaching, or being absorbed into potable water systems from soldered joints, Federal Law 99–339 bans the use of solders containing more than 0.2 percent (two-tenths of 1 percent) lead. Because of this, the solder you use must be practically lead-free. The two types of solders available are 95–5 solder (95 percent tin and 5 percent antimony) and lead-free solder, which is made up of many different alloys.

Distribution main and branches

Install a shutoff valve either just outside the foundation or just inside the building where the piping enters the building. In either case, the piping extending from this point becomes the cold water distribution main. Water is thus conveyed to various points throughout the building.

Perform most rough-in when the skeleton of the building is under construction because it is easy to run the piping to the desired points in the walls for the fixtures. In most installations, run the branch lines that serve the fixtures under the floor and between the floor joists or under the concrete slab to the point under the wall where holes have been cut through the floor and soleplate to permit the pipe to reach the fixtures. Then extend the pipe risers up through these holes between the studs to the height necessary to connect with the fixtures.

Normally, branch lines are run horizontally at a slight grade toward the shutoff valve. This permits easy drainage of the system, which is extremely important in cold climates.

Supports for the branch lines should be installed at intervals not more than 10’ apart. Supports consist of pipe straps, loops, or preformed hangers. Permanent installations require pipe support devices to be of the same material as the pipe they support, since a form of corrosion called *electrolysis* occurs when dissimilar metals are in contact with each other. In other words, corrosion occurs when a copper or brass pipe hanger supports a steel pipe. Corrosion eventually causes the pipe or hanger, or both, to fail.

Connect branch lines (fig. 2–18) to the distribution main by using a reducing tee, nipple, and 90° elbow. Run the hot and cold water branch lines at a slight grade, sloping toward the distribution main. Install a drain valve at the low end of the grade to allow easy drainage when the system is being repaired, winterized, or vacated for any period of time.

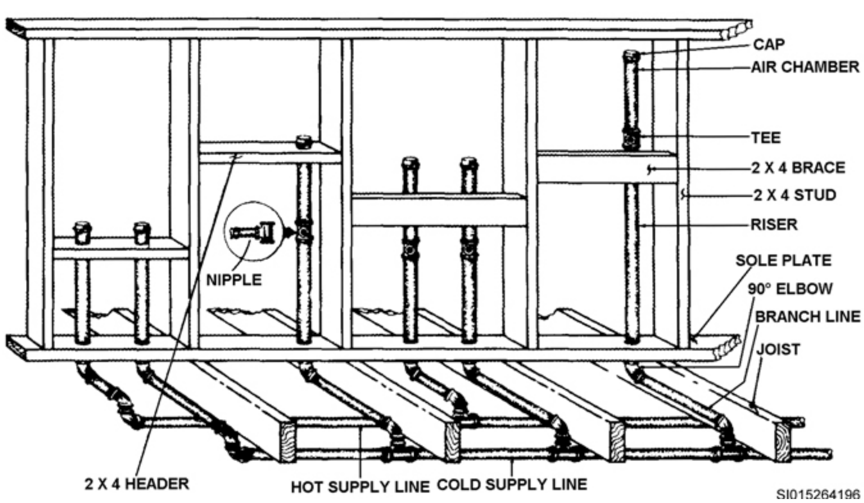


Figure 2–18. Building water distribution system.

Supply risers

The fixture supply risers are vertical pipes connected to the branch lines by means of a 90° elbow (fig. 2–18). Support the risers at each floor level and at joints. It is also a good policy to support these risers near the fixture outlets (fig. 2–19) with headers and braces to hold the pipes in position so they cannot be knocked out of alignment. Test all risers for leaks before the wall is enclosed.

Gate valves

It is good practice to 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, the water supply in any given section may be shut off without turning off the water supply to other parts of the building.

Air chambers

The sudden closing of a valve or faucet can cause the flow of water to stop suddenly and rebound against the sides of the pipe. This rebounding causes a vibration of the pipe that creates a banging noise. This noise is called *water hammer.* You can correct water hammer by installing a vertical air chamber (fig. 2–19). For the air chamber to be effective, you must place it near the quick-closing valve or faucet responsible for the noise. The air chamber should have at least 1 percent of the total capacity of the pipeline in which the water hammer is occurring.

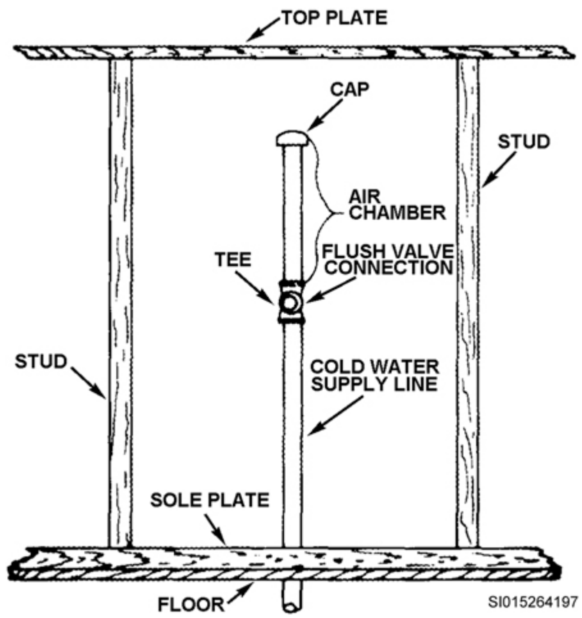


Figure 2–19. Air chamber.

The purpose of placing the air chamber in a vertical position is twofold: air in the riser is trapped in the chamber keeping the chamber full of air, and the chamber receives the full thrust of the pressure from the vertical pipeline. Since air in the air chamber eventually is absorbed by the water, the air must be replenished. To do this, the only thing that is necessary is to drain the pipe section containing the air chamber and open a valve or faucet to allow air into the line. Then, close the drain valve or faucet and turn on the water. A building's hot water distribution system *begins at the water heater* and *ends at the point of use.* The hot water distribution piping generally parallels the cold water distribution system.

419. Openings

Openings for pipe are cut in all buildings that have plumbing systems. It is your job to cut the openings for new pipe or to see that the openings are cut. You are also responsible for ensuring that the openings that are cut do not damage the structural supports of the building. On most jobs, large parts of the water and waste systems are installed under the floor. You must either properly locate the openings for pipes coming up through the floor or face a lot of unnecessary work. This is especially true where the pipes are concealed in walls.

Pipe opening

You must know the locations of the fixtures in a building before you can install the pipe, because most piping is installed to serve a fixture. The locations are shown in the building or plumbing blueprints; the exact model or type of fixture to be used is shown in the specification sheets. The rough-in dimensions for the fixture are specified by the manufacturer, and you must use these dimensions for locating the structural openings for the waste and water pipes. After checking the blueprints and specification sheets, prepare a working drawing that shows the location of the fixtures and the routing of the water and waste pipes within the structure. Also, check the construction of the buildings or inspect the plans to determine the difficulties you are likely to encounter when you install the pipes. Notice, too, the spacing and direction in which the floor joists run. It may be necessary, in some cases, to show on the working drawing the location of the floor joists or other structural members.

Using dimensions from the manufacturer's rough-in specifications, you should first locate the exact positions of the openings for the fixtures. When cutting openings in the structure, you may have to cut through other structural members to accommodate the pipes. Whenever you bore holes with a brace and bit through a line of wall studs to install a water supply pipe, you must center the holes in the studs. This practice minimizes the possibility of weakening the structural members and of damaging the pipe with nails and screws. Many times, misplaced copper water lines are punctured by nails or screws when wallboard or sheetrock has been nailed or screwed to the studs.

Since structural members of buildings are weakened when openings for pipes and fixtures are made, it is important for you to learn when and how to reinforce these openings. You should reinforce the building structure any time you think that the wooden type of construction needs additional wall studs, floor joists, or bracing for the plumbing. Some fixtures, such as wall-hung lavatories or urinals need mounting boards. Mounting boards must be built into the studding and braced before the finished wall is installed by the structural journeyman.

Center cut

Structural beams must be reinforced whenever they are cut for installing pipe. Figure 2–20 shows a pipe opening that has been cut through the center of a beam. This cut does not materially weaken the strength of the beam unless the diameter of the opening exceeds one-third of the distance across the beam. This type of opening is generally considered to cause less damage to the structural member than other types of cuts.

Figure 2–20. Center-cut opening.

Undercut

Openings for larger pipes in structural beams are usually undercut or overcut. Figures 2–21 and 2–22 show the accepted methods for reinforcing beams when they are cut in this manner. When a beam is undercut, you should place a strap iron brace across the notch and fasten it with lag screws, as shown in figure 2–21. This prevents the beam from sagging when weight is applied to it.

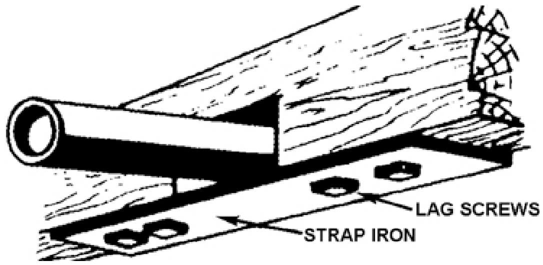


Figure 2–21. Reinforcing a beam that is undercut.

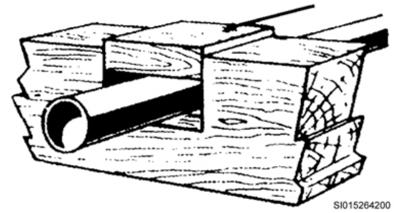


Figure 2–22. Reinforcing a beam that is overcut.

Overcut

A method used to reinforce a beam that is overcut is shown in figure 2–22. As you can see, a block of wood is wedged and nailed into the notch to prevent the beam from sagging. When there is any doubt about the strength of a member after openings for pipes are cut, always reinforce structural members.

420. Hangers and support

You must correctly hang or support plumbing lines that are installed in buildings to prevent them from breaking or sagging. Steel pipelines can be hung with hangers that are up to 12’ apart. This is because they are more durable than cast iron and, therefore, require less support. Within this lesson we discuss guidelines for hanging and supporting plumbing lines.

Support hangers

Vertical copper tubing 1½” in diameter and smaller should be supported every 4’; larger copper tubing should be supported at each floor level. Horizontal copper tubing up to 1½” in diameter should be supported at least every 6’. Copper tubing larger than 1½” in diameter should be supported at intervals not to exceed 10’.

Supports for all diameters of plastic pipe must not exceed 4’. Runs of piping installed between wooden joints or steel joists must be supported on substantial wood or pipe headers that are spiked or otherwise fastened to the building framework. Guidelines for the installation of supporting pipes are listed in the following table.

Guideline for Supporting Pipe		
Type of Pipe	**Size**	**Support Needed**
Steel	Any size	12’ apart
Vertical copper	Up to 1½”	Every 4’
Vertical copper	Larger than 1½”	Every floor level
Horizontal copper	Up to 1½”	Every 6’
Horizontal copper	Larger than 1½”	Not to exceed 10’
Plastic	All sizes	Not to exceed 4’

Materials and procedures

For a pipe support, use a material that does not cause corrosion to occur. If you use a metal hanger, make it of the same material as the pipe. For instance, if a copper line is to be supported, use a copper hanger. This hanger could be a pipe strap, reznor hook, plumber’s tape, or a vertical support, but it must be made of copper. If the line is steel, the same types of hangers could be used, but they must be made of steel.

Your first consideration when supporting or hanging pipe is its weight. Expansion and contraction due to changing temperature within the pipes must also be considered. Figure 2–23 shows some of the common methods used to support pipe.

There are several different ways to fasten the hangers to the building. Use lead anchors or expansion shields in buildings made of concrete. Use sheet-metal screws, bolts, or welding to attach hangers to metal buildings. Attach hangers to wooden structures by using nails, wood screws, and lag bolts.

The method you use depends upon the type of structure and the type of pipe you are hanging. Assume you are to hang a 4” cast-iron drain line under a wooden building. Because of the weight of the pipe, you would use lag bolts—not nails—to fasten the hangers to the building. If, however, the drain line were made of plastic, then nails would be sufficient because of the pipe’s lighter weight.

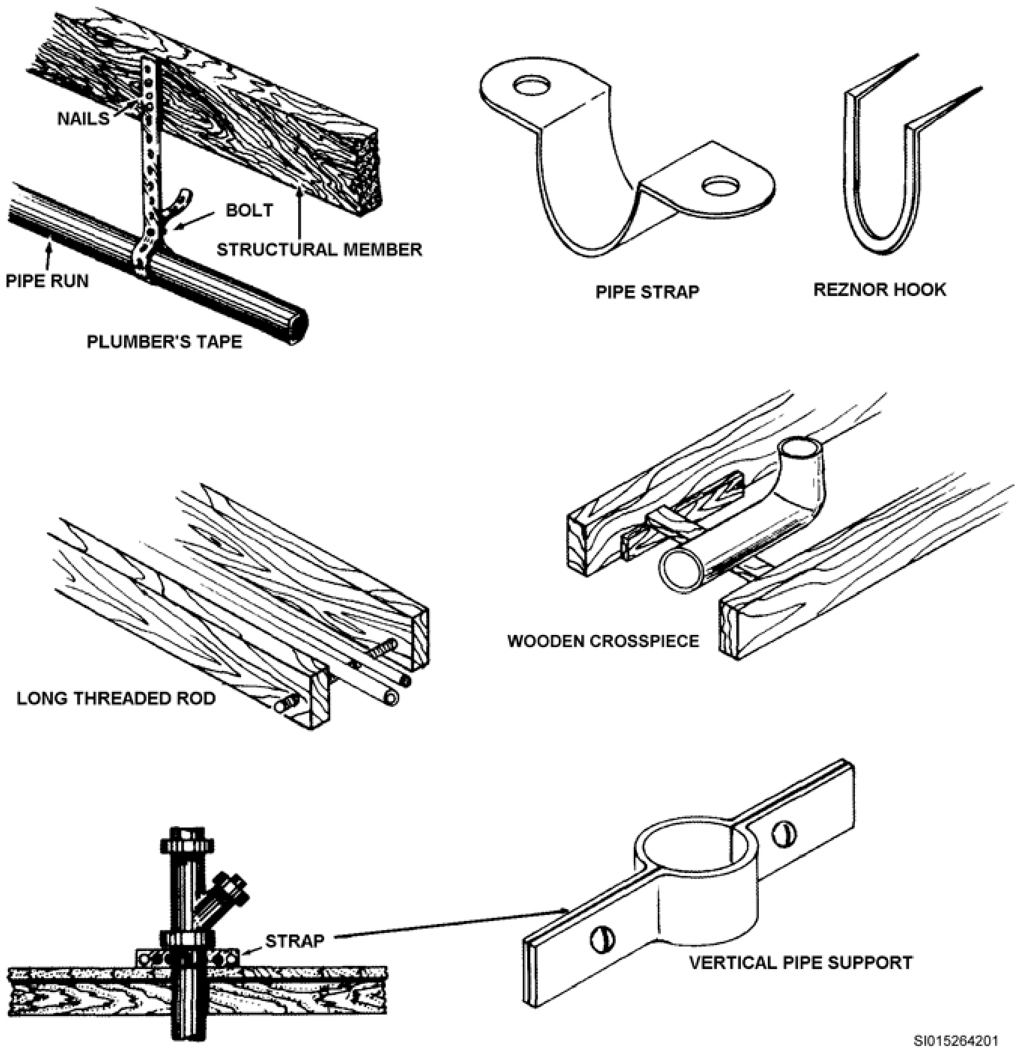


Figure 2–23. Types of pipe supports.

421. Causes of pressure loss

Capacity loss is a decrease in the carrying capacity of pipelines (over time). It is caused by increased friction in the system like a partially closed valve or buildups in the interior of the pipe, which decreases the interior diameter. The causes of increased roughness or decreased line size are corrosion, pitting, tuberculation or small “mounds” of rust inside the pipe, sediment deposits, slime growths, and air accumulation at high points in the system. A good line flushing program is the best deterrent against capacity loss problems because lines are “cleaned out.” You may also find a closed valve that is “normally open” in the process of flushing.

Procedures used to identify the conditions that cause capacity loss include fire-flow tests (already covered), loss of head tests, pressure tests, simultaneous flow and pressure tests, and leak surveys. Periodic testing of the water flow and pressure in the mains is done primarily to ensure sufficient water is available for fighting fires.

Leaks

Leaks are a major cause of pressure loss in the water distribution system. Most of the time leaks will eventually surface, and when this happens, it will be your job to repair the piping system in the most expedient manner. Sometimes, distribution system pressure loss will lead you to leaks that are not so apparent. In this case, you may have to use commercial sound-detecting instruments or other methods of locating the leaks.

When you receive a call that a water main is ruptured, speed in repairing the line is an important factor. Be familiar with water distribution maps so that you can turn off the water as quickly as possible. Keep materials to repair water mains on hand and readily accessible to repair crews. When you are making repairs on exterior piping, be sure you follow all safety practices concerning excavating.

Isolating the leak

Anytime a water main has to be turned off, notify the fire department. Remember, while water is off, some areas on the base may not have protection against fire. Fire department personnel *must* know the exact section to be out of service so that they can make alternate plans in case of a fire.

Digging up the main

After the leak has been isolated, the next step is to process an AF Form 103, Base Civil Engineering Work Clearance Request, and dig up the area around the leak. You can find buried pipes by looking at base utility maps that show the location of underground water piping. Hand dig areas where the backhoe might damage other utilities. You can use steel probes to pinpoint the exact pipe location and direction. Once you have exposed the break, follow proper shoring procedures mentioned in Volume 2, *WFSM Fundamentals, Valves, and Pumps.* After precautions to prevent cave-ins have been accomplished, expose the break and clean and inspect the pipe thoroughly.

Deciding on the repair

There are different kinds of repair procedures for water main breaks. The decision really depends on the type and condition of the pipe. This is also a technical decision that is based on cost, available repair materials, and plans for renovation of the water system. If the pipe is weak (structurally) and you have been in the same general area repairing a multitude of breaks, it may be smarter to replace the whole length of pipe. There may be occasions when the backhoe operator damages the pipe accidentally, forcing a two-clamp repair instead of one. You will cover clamp installation procedures under the maintenance and repair section.

Corrosion in water systems

Corrosion and its products eat away the metal walls of the pipe and cause leakage. Briefly stated, the theory of corrosion is the tendency for metal to return to its natural state, as graphically shown in figure 2–24. Energy was supplied during the refining of the original ores, mostly oxides, which were the source of the steel pipe. When this pipe is buried in soil, it tends to surrender the energy and return to its original state—iron oxide. The rate that metal corrodes depends upon the moisture coming into contact with it, the acidity of a solution that touches it, the motion of the metal, the change in temperature, the aeration of the water, or the presence of bacteria. In any case, metal corrodes easily in the presence of acids, salts, hydrogen sulfide, soot, ashes, and dust.

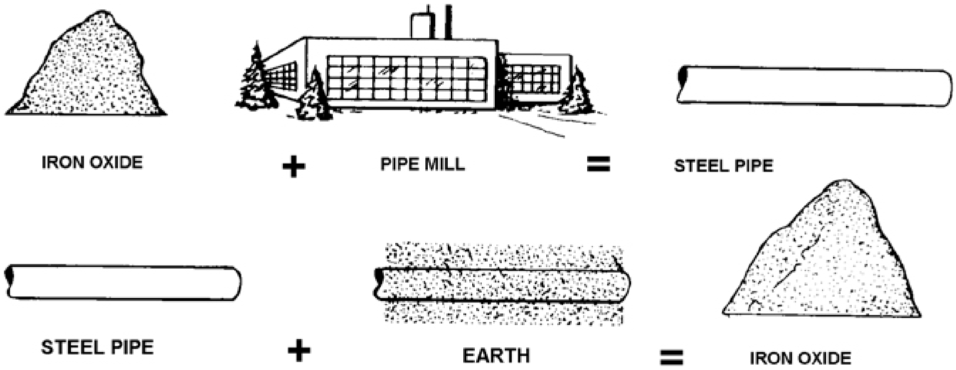


Figure 2–24. Theory of corrosion.

Corrosion is caused by an electrochemical reaction, which is (in relation to metals) an induced flow of electrons through a metallic path. The return of any formed material to complete disorganization (through corrosion or decomposition) is part of nature. Corrosion may be divided into several types, such as uniform, localized, and compositional corrosion.

Uniform corrosion

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

Localized corrosion

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

Compositional corrosion

Compositional corrosion alters the composition of metals. Some of the specific types are as follows:

- Dezincification—occurs in copper and zinc alloys.
- Graphitization—a peculiar form of disintegration that attacks cast iron.

Selection of materials

Whenever you install various types of plumbing equipment in areas where corrosion is active, try to select equipment that is made of materials least affected by corrosion. Plastic materials are not acted upon by corrosion. Glass is another material that is not affected by corrosion. This is the reason water heater tanks are lined with glass. Other materials used for the manufacture of pipe that resist corrosion are vitrified clay, cement, fiber, asbestos, and rubber. Glass fibers reinforced with epoxy or polyester resins are also resistant to corrosion.

Dielectric bushings or fittings may be installed to stop electrolytic action in plumbing systems or wherever dissimilar metals are used. These fittings usually are placed in pipe systems where two different metals are joined to insulate the metals from each other. Some of the metals least likely to be affected by corrosion are copper, brass, monel, and stainless steel.

Coatings and wrappings

Coatings and wrappings are commonly used to combat corrosion on exterior piping systems. There are many different types of coatings, such as asphalts, coal tars, plastics, mastics, greases, and cements. These coatings are considered to be insulating materials, but no one coating is effective in all environments. Each one was developed for a certain type of corrosive environment.

Cathodic protection

Cathodic protection is an electrical system for the prevention of rust, corrosion, and pitting of metal surfaces (cathodes) that are in contact with soil or water. The word “cathodic” is derived from the word “cathode.” The cathode is a negative pole of an electrolytic cell or system that attracts positively charged ions (cations). The protected structure—whether it is a pipe or water tank—is always referred to as the “cathode” in cathodic protection. The “anode” is the “sacrificial” metal in a cathodic protection system. The anode is the positive pole of an electrolytic system, and it attracts negatively charged ions (anions). Cathodic protection eliminates the corrosive current flow by applying a stronger current flow in the opposite direction. Cathodic protection uses low-voltage electricity to reverse electron flow towards a pre-designated expendable metal (anode). Cathodic protection systems provide long-term protection for pipelines and water storage tanks. Remember that a mile-long water pipeline or a 3 million-gallon water storage tank is very expensive. For this reason, you need to slow the rate of corrosion on the storage tank or pipeline to prevent untimely, expensive replacement. There are two types of cathodic protection systems: impressed current and galvanic anode.

Chemical treatment with polyphosphates

Cathodic protection is rarely used as a method by itself to reduce corrosion on pipelines and storage tanks. Chemical inhibitors (polyphosphates) such as sodium hexamatophosphate are injected into water as it leaves the plant to provide a tiny film of protection on the inside of the pipe or storage tank, thus reducing corrosion from the inside. The chemical compounds in sodium hexamatophosphate, also tie up iron and manganese ions (electrically charged atoms), preventing their formation as rust. Sodium hex is usually fed at very low dosages (lower than 5 ppm) because it is a long-term treatment and feeding high rates would cause the interior of the pipe to calcify and constrict flow prematurely. Chemical treatment of water with inhibitors is more associated with bases fed by well water rather than fully treated surface water. This is because well water contains (in most places) higher amounts of iron, manganese, and other corrosive ions, which are greatly reduced in fully treated surface waters.

422. Inspection and testing

After installing a water supply system and checking for evidence of shifting, test the system to make sure there are no leaks. This is especially important when pipes are concealed in walls or ceilings. If you conceal a leaky pipe in the building framing, water could run for a considerable length of time before it is discovered. This will result in costly damage to the building.

Test all pipes in the water system at least twice—once right after the rough-in is installed and again after the fixtures are installed. All pipes must be watertight. Two leak tests are available for use on water systems: the water test and the air test.

Water test

When the water test is used, all risers and openings must be capped or plugged to hold water in the system. Maintain the pressure for at least 15 minutes. After applying the water pressure, loosen the caps and plugs on the end of the risers one at a time to let trapped air escape. Then, retighten these openings and pressurize the system. If this is not done, the air becomes compressed and holds the water back, keeping it from reaching the extreme ends of the lines, thereby preventing a true test. If leaks develop, turn off the water and make the needed repairs.

Generally, *new* piping is tested under the operating pressure used in the main water lines of the installation. However, additional pressure of 25 to 50 psi can be added to the system by the use of a hydrostatic testing pump. If you use a pump, be sure to use a pressure gauge to check for pressure loss.

NOTE: Do not use a pump to apply additional pressure if new piping has been connected to the old pipe in the system, as it may open weak places in the old piping.

Air test

When making an air test, seal the openings as you would in the water test. Pump air into the system until the air gauge attached to the system reads 50 psi pressure. Maintain this pressure for at least 15 minutes. If the pressure gauge reading falls, there is a leak in the system. To locate this leak, you can use a soap-and-water solution and a paintbrush. Thoroughly coat each joint. When bubbles appear, you have found the leak. If the temperature is freezing, do not use water for this test. Instead, substitute linseed oil. Linseed oil maintains its liquid state and forms bubbles under much colder temperatures than water.

NOTE: Because it takes longer for the bubbles to form with linseed oil, the test requires more time.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

418. Assembly and installation

1. What must you consider when sizing a water supply?

2. How can loss of water flow from a pipe (friction loss) be overcome in a small pipe?

3. When are branch lines, risers, and air chambers installed?

4. What types of pipe are most commonly used in hot and cold water systems?

5. What type of solder is prohibited for use in water systems?

6. Why should horizontal branch lines have a slight pitch or grade?

7. How can you correct water hammer?

8. How is an air chamber sized?

9. Where does the hot water system in a building begin and end?

419. Openings

1. How do you find the locations for the fixtures in a building?

2. Who provides the rough-in dimensions for fixture water and waste pipes?

3. Which structural openings should you usually locate first?

4. How do you determine the size of an opening that can be cut through the center of a beam before additional bracing is needed?

5. How should a beam that has been undercut be reinforced?

6. How should a beam that has been overcut be reinforced?

420. Hangers and support

1. What is the required spacing to support a vertical 2” copper tubing?

2. What is the required spacing to support plastic pipe?

3. How should pipe runs between wooden floor joists be supported?

4. Why should a pipe hanger be made of the same material as the pipe?

5. What should be your first consideration when you are supporting or hanging pipe?

6. How is a pipe hanger attached to a concrete building?

421. Causes of pressure loss

1. Who must you notify if you are going to turn off a water main?

2. What is the next step after isolating a leak in the main?

3. What is the theory of corrosion?

4. What are the three types of corrosion?

5. What causes uniform corrosion?

6. What causes localized corrosion?

7. What is dezincification?

8. Which class of chemical is used to inhibit corrosion inside pipelines and storage tanks?

422. Inspection and testing

1. How many times are pipes in a water system tested?

2. When performing a water test, how much pressure do you add to the system?

3. What is used to add pressure to the system?

4. When testing the system, what should you do to allow trapped air in the pipes to escape?

5. How long do you maintain pressure in the system when you are air testing?

6. What do you use to check for leaks if the temperature is freezing?

2−4. Maintenance and Repair

In this section, you are going to wrap up the water distribution system by covering some of your maintenance responsibilities. You will go over winterization, thawing, repair, and disinfection procedures commonly used in the field.

423. Winterize piping systems

If water and drainage systems are exposed to freezing temperatures, you must take measures to prevent the lines from freezing. Such measures may include burying the water service line below the frost line and wrapping the lines with insulation. However, if the building is not in use and the heating system is turned off, you will have to drain the plumbing systems.

Water systems

To drain the water piping, first close the main shutoff valve to the building. Then, loosen the lowest connection, such as a union, and begin drainage of the system. Next, open the faucets that are at the highest levels in the water system to let air into the system and break any vacuum. Also, open the faucets at the lowest levels in the system. This should drain your cold water lines and some of your hot water lines if the system was graded properly when it was installed.

After the system pipes are empty, you need to drain the hot water heater. Turn off the source of heat to the water heater *first.* Then, you can drain the water heater tank. You might have to crack open the cold water inlet or hot water outlet unions to let additional air into the tank.

Flush the water closet to remove most of the water from the tank. Use a sponge or rag to remove any water left in the water closet tank. Many tanks have been broken because someone failed to remove this last little bit of water.

Waste systems

All traps must be drained of water to prevent their freezing. Use a force-cup plunger on fixtures, such as a water closet bowl, and use a vacuum plunger on flat surfaces, such as a kitchen sink. When most of the water has been forced out of the traps, refill them to prevent sewer gas from entering the building. Antifreeze solution, such as that used in automobile radiators, is suitable for this purpose. Also, the glycol antifreeze preparations are highly effective as is a mixture of glycerin and water. Alcohol and water or calcium chloride (salt) and water also may be used.

If you use some of the antifreeze solutions and mixtures, you must take some precautions to protect the pipes and water supply. Use the alcohol mixture and the calcium chloride mixture *only for temporary protection* because the alcohol eventually evaporates and the calcium chloride eventually causes corrosion. If you use automotive antifreeze, you must be especially careful not to put it in any fixture if there is a possibility the antifreeze will get into the potable water supply. For these reasons, it is better to use glycol as a first choice and glycerin as a second choice.

Insulation

Most of the problems of frozen pipes can be avoided by using insulation. However, protecting pipe from freezing is not the only reason to insulate. Insulation also prevents loss of heat from steam or hot water pipes, freezing of hot and cold water in pipes, and condensation (the forming of droplets of water on the outside of cold pipes when they are exposed to warm air). Insulation protects people from burning themselves on hot pipes. Other purposes of insulation include protection against noise and vibration of heating or air-conditioning equipment; reducing noise made by water flowing inside the pipes, such as the discharge from a water closet; and reducing expansion and contraction of the pipes.

Insulation is manufactured in two general types: rigid preformed sections and the blanket type. Newly installed insulation should be asbestos free. Although many actions have been taken to eliminate insulation containing asbestos, you may still encounter it in some locations. Asbestos is the largest hazard when working with insulation. Use adequate precautions if you suspect asbestos particles may be present.

424. Thaw frozen water pipe

When thawing a pipe, some type of heat is applied to the pipe. The pipe then transmits heat to the ice, and the ice next to the pipe melts, causing some flow of water. This flow, plus the heat, thaws the pipe. The method used to thaw pipes depends on the pipe's location and accessibility. Finding a frozen area of piping is simple.

Troubleshooting

For thawing water lines, start by opening the fixture faucets. If water does not flow when the faucet is open, the line going to the fixture is frozen. If you use the process of elimination, you can find out how much of the system is frozen. When you begin thawing a supply line, *start on the faucet or outlet side* and work toward the source. When thawing a waste or sewer pipe, work upward from the lower end to permit the water to drain away.

Heaters

In this section, we discuss the three different types of heaters—manual, electrical, and blowers—and how to use them.

Manual heating

Using hot water and rags is one method of thawing. Wrap rags or burlap around the outside of the frozen pipe and keep the wrapping saturated with boiling water. When using this method, exercise care so that you do not scald yourself, slip on the wet floor, or cause water damage to the building. Sometimes when you are using hot water, it is better to pour the water *into* a pipe to thaw it, especially if you cannot readily apply heat to the outside of the pipe. To use this method, you need a source of hot water, a rubber hose, a funnel, and a high-elevation opening to the frozen pipe. You also need to open an end fixture(s) before you begin, such as a faucet or low elevation union, to know when the frozen pipe is thawed. Begin by isolating the line and pushing the hose as far as possible into the pipe at the high-elevation opening. Then, insert the funnel into the hose, and hold it above the end of the pipe to be thawed. Slowly start to pour the hot water into the funnel. As the water flows down the hose and into the frozen pipe, it begins to melt the frozen clog. The surplus escapes through the opening where the hose is inserted into the pipe and drains to the floor or to a pan. You will know thawing is complete when the hot water comes out the end fixture.

Electrical heaters

Electrical heaters or lamps send current through a heating element, coil, or filament to produce heat. They are similar to the space heaters or bathroom heat lamps used to warm small areas in homes. They can be used to thaw frozen pipes concealed in walls.

For best results, isolate the frozen line from the water supply line and open a low-point fixture or pipe joint for water to empty from the line as it begins to melt. Then place a space heater or heat lamp near the wall with the frozen pipe. If possible, collect the water that empties from the pipe for easy clean-up or direct it toward a drain. Some of these electrical heaters are for industrial use and can generate high temperatures. Monitor these units closely to prevent thermal wall damage or the collection of water settling near the electrical cords.

Blowers

Fuel- or electric-driven heaters/blowers can be used to generate hot air to thaw interior *or* exterior piping. These units have collapsible/flexible duct sections that attach to the units.

NOTE: You must *never* position the fuel-driven heaters/blowers indoors because the motor's exhaust will produce enough carbon monoxide to cause asphyxiation in enclosed areas.

For fuel-driven units, and with the unit position outside, attach the first duct to the blower exhaust port. Then stretch out and connect additional ducts as needed to reach the frozen pipes. Finally, turn the unit on to begin your thawing job. If using an electrical unit, the set-up is the same, but keep any water away from the power cords. Always read the unit's technical order (TO) or manufacturer's instructions for proper start-up and shut-down procedures.

Torches

Using an acetylene or propane torch is another method of thawing frozen pipes. Precautions must be taken because of the danger of starting a fire. Proper training is required prior to their use. When working next to wooden structures, isolate the area with a heat shield, and be sure there is adequate ventilation to prevent asphyxiation. Of course, you must always have an approved fire extinguisher nearby. You should only use torches on metal pipes.

Adjust the torch to get a blue flame. Apply the flame to the piping, and move it slowly along the frozen part of the pipe, starting at the faucet or outlet side and working toward the supply. If the frozen pipe is behind a partition, apply the flame at the nearest exposed point. As it is heated, water in the pipe circulates and may clear the obstruction.

Electrical thawers

Thawing frozen water pipes with low-voltage electricity is by far the best way to thaw short lengths of piping that are up to 1½" in diameter. It is the most convenient method and it is faster, safer, and less costly. This method works with steel or copper pipe, even when the pipe is buried or concealed in walls (fig. 2–25).

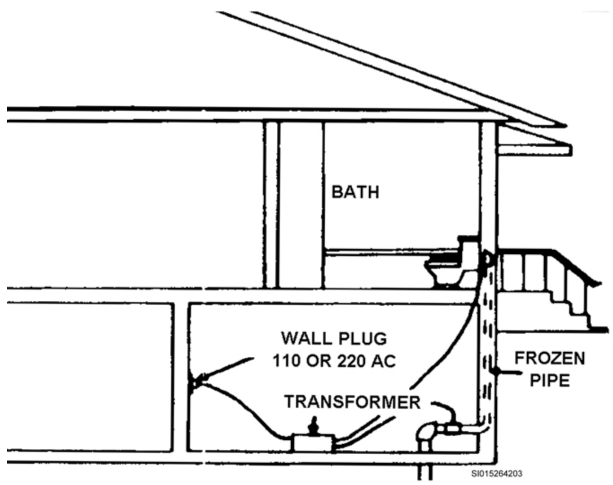


Figure 2–25. Using an electric thawer.

When you use electricity to thaw frozen pipe, of course you need good electrical connections. Plug the electrical thawer into a house receptacle. Thoroughly clean the point where the cables are to be attached to the pipe by sanding the pipe with coarse emery cloth. Either special pipe-thawing clamps or ordinary C-clamps are excellent for connecting the cables to the pipes. Make sure all connections are tight to prevent arcing and burning a hole in the pipe. When using any type of commercial equipment, always follow the manufacturer's instructions for safe operation.

Heat tape is another method that prevents pipes from freezing. Heat tape is available in different lengths and sizes to accommodate various pipe requirements. First you wrap the heat tape around the piping, and then plug it into a 110-volt Ground Fault Circuit Indicator (GFCI) receptacle for safety. Heat tape is excellent to keep exposed piping at water and wastewater treatment facilities from freezing during the winter months.

Other methods

Chemicals, such as sodium hydroxide, can also be used to thaw frozen drain lines because sodium hydroxide generates a great deal of heat, or exothermic reaction, when mixed with water. To use this method of thawing, use the rubber hose and funnel again. The chemical is conveyed through the hose down to the frozen area. When using this method, however, you must be *extremely careful* or you could burn yourself or be overcome by the chemical.

Where the freezing of the piping system is due to failure of the building heating system, the easiest way to thaw the pipes is to repair the heating plant first. Then, maintain a high temperature in the building until the pipes are thawed. If freezing has damaged the piping, shut off the water supply, repair the ruptured section, and turn the water system back on.

425. Piping repairs

A pipe's age, how it is maintained, environmental and temperature effects, and human interaction can cause pipes to leak. There are also just as many different types of breaks such as holes, splits, or full-circle breaks that will have to be temporarily or permanently repaired. The shop foreman will have to consider many factors to determine the type of repair to be done. As a WFSM journeyman, you will need to know how to accomplish these repairs.

Clamps

When making repairs to our utilities systems, your best friend on a Friday afternoon will be the repair clamp identified in figure 2–26. The repair clamp allows you to make quick repairs and keeps your customers less disgruntled. Always restock the repair clamp after use; the last thing you want is that late night call to repair a water break and find out you don't have the right size clamp on the shelf to make the repair. Also, always have an outside diameter tape on your truck so you can quickly measure the pipe to determine the size clamp required. Next, we'll discuss the different clamps and repair fittings available to make your job easier.

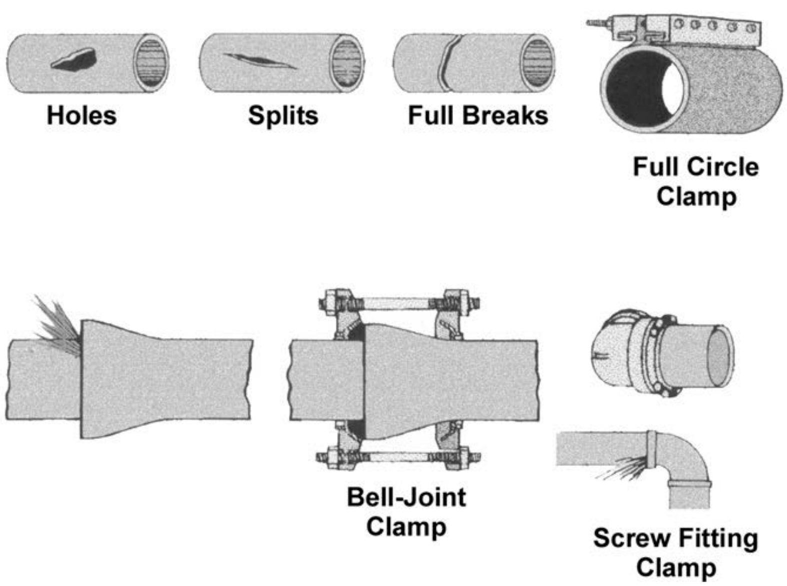


Figure 2–26. Types of breaks and the clamps to repair them.

Full-circle clamps

Also known as saddle clamps, the full-circle clamps are an excellent temporary repair clamp for holes, splits, and full breaks in piping. Water or sewer mains are usually repaired in this manner. These clamps are available in sizes of 1¼ to 24" and lengths of 6 to 36" and can be used to repair all types of piping. This type of clamp also has a specially ribbed one-piece rubber gasket that goes around the inside of the band, wrapping itself around the pipe without a "gasket break"—hence the name full circle. The ends of the gasket are oppositely tapered so that gasket thickness is uniformly maintained at the closure point of the gasket. The band or "panel" is usually made of ductile iron or stainless steel. The stainless steel band is preferred for corrosive "warm soil" applications. Pipes that have been buried for years and constructed long ago do not have a perfect outside diameter. For this reason, full-circle clamps are constructed with a variance of either 0.4" or 0.8", depending on the design. Single-panel full-circle clamps such as the one in figure 2–27 have a 0.4" variance on the OD of the pipe.

The double-panel full-circle clamp in figure 2–28 has the same gasket configuration as the single panel—the difference being the number of panels or "bands." Because of the double-panel design, this full-circle clamp has a 0.8" variance—a great advantage when ordering. The double-panel full-circle clamp is preferred because of the leverage in variance. Specially configured triple-panel full-circle clamps are used for pipe sizes larger than 24". The ends of the panel or "band" all have lugs attached. These lugs have holes in them for the bolts. Some clamps have slots in place of the holes on one of the lugs, which make installing the bolts easier.

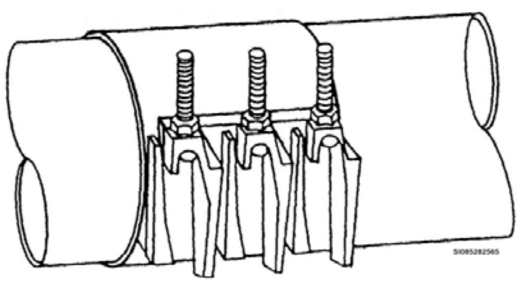


Figure 2–27. Single-panel full-circle clamp.

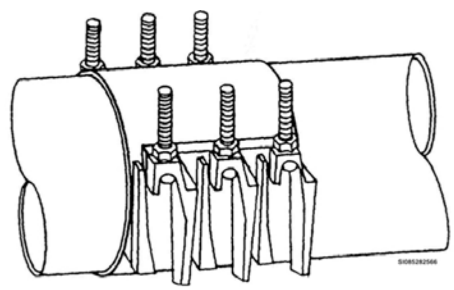


Figure 2–28. Double-panel full-circle clamp.

Installation procedure

When you have to install a full-circle clamp pay attention to the seven steps in the following table.

Circle Clamp Installation Procedures
1. Before you begin to install the clamp, thoroughly clean the pipe where the clamp will be installed, and disinfect the pipe.
2. Lubricate the full-circle gasket with a soap solution to reduce friction and evenly distribute clamping force.
3. Loosen nuts to the end of bolts and place the clamp around the pipe—centered over the break or damaged area with the gasket flap at the top.
4. Tuck the gasket flap in place, close the bolt lugs, engage the center-most bolts and nuts and finger-tighten.
5. Rotate the clamp to flatten the tapered-end of the gasket and position the bolts and nuts for convenient tightening.
6. Evenly tighten bolts working from *center outward*. Maintain an even gap between bolt lugs when installing double- and triple-panel clamps by alternating from side to side while tightening the nuts.
7. Allow gasket to fully compress and recheck bolt tightness. Finally, torque the bolts to 50 foot-pounds (ft-lb) for half-inch ($^1/_2$) bolts and 75 ft-lb for five-eighths ($^5/_8$) bolts.

When fully compressed, the gasket protrudes slightly beyond the edge of the stainless steel band, providing extra protection against galvanic corrosion. After installing the clamp, check for leaks. The emergency pipe clamp makes a dependable repair, but you should not consider it as good as replacing the problem piping.

NOTE: Before putting the repaired section back in service, disinfect it thoroughly with calcium hypochlorite. Also coordinate testing procedures with bioenvironmental.

If the hole, split, or break in a pipe is too big for the clamp, or the pipe is deformed beyond the variance to give a proper seal, then pipe replacement will be necessary.

Other repair clamps

Bell-joint, collar, and screw-fitting clamps are used to make repairs at joints and fittings (fig. 2–26). Bell-joint clamps are used to repair leaks at caulked joints and fittings. Collar clamps are used to repair leaks at couplings that leak on one end only. The collar clamp looks like a full-circle clamp except the gasket is stepped to fit over the coupling. Also, it has only one or two bolts. The screw-fitting clamp is used to repair leaks at one end of a threaded fitting. The main body of the clamp is attached to the pipe with set screws. Then, tension screws are tightened to push the gasket assembly against the end of the leaking fitting. After the leaks are repaired, notify the fire department that water service is restored.

Compression couplings

Compression or *dresser* couplings are by far one of the most common pipe repairs made as a WFSM journeyman. These couplings come in a variety of sizes and materials, but you will mainly be installing ½” to 2” couplings. The compression coupling is simple to install and makes a semi-permanent repair. The compression coupling consists of two threaded nuts, two rubber gaskets, and the threaded repair coupling that slips over the pipe. When installing the coupling, dig the area out to give you as much flexibility with the pipe allowing easy installation of the coupling. Then thoroughly clean the area of pipe to be repaired. If necessary, cut a small section of pipe out allowing enough room to slip the coupling over the area to be repaired. If the pipe is not flexible, you may need to cut a larger section of pipe out and use two couplings to make the repair. Remove the nuts and gaskets from the coupling and place the threaded nuts on first, and then slide on the gaskets. After you slip the nuts and gaskets on, slip the repair coupling onto one side of the pipe and then line the pipe ends up and center the coupling over the cut out section leaving enough on both sides of the pipe to allow the nut and gasket to grab onto. As you hand tighten the nuts onto the coupling, the gasket will compress around the pipe making a water-tight seal. Once the nuts are hand tight, tighten the nuts a little more with a strap wrench on plastic couplings or adjustable pliers on metal couplings to complete the seal. The last step is to turn the water on, check for leaks, and tighten if necessary. Once you know the coupling is holding, you can cover the exposed section of piping.

Steel pipe repairs

To make a permanent repair on steel pipe, disconnect the pipeline at a convenient point, such as a union, and remove the damaged pipe. If there is no union, remove the damaged section of pipe by cutting it with a hacksaw or a pipe cutter. Cut the pipe at least 4” from a fitting and then unscrew the ends. Cutting the pipe at least 4” from a fitting gives you working room to thread a piece of pipe this same length and use it to reassemble the pipe. The new section is made up of two lengths of pipe, one of which may be part of the old pipe, and a union. When assembled, they equal the length of the old pipe. A single length of pipe may be installed only when the old length of pipe is disconnected at a union.

A similar procedure is followed when a branch line is installed into an existing line, except that a T-fitting is required between two new lengths. This assembly must be equal to the original length of pipe that was removed.

Copper pipe repairs

When leaks occur at a soldered joint in copper tubing, drain the tubing and resolder the joint. However, if compression joints are leaking, tighten the fitting with a wrench until the leak stops. When a section of copper tubing must be replaced, use slip couplings rather than a brass union to connect the two pieces of tubing.

Plastic pipe repairs

Leaking plastic pipe and fittings are easily cut out and replaced. Normally, new pipe and fittings can be glued into place if the replacement piping is the same type as the original piping. If the original type of pipe cannot be used, you may be able to use compression couplings, as discussed earlier, if the outside diameters of the pipes are the same. You can also use a telescopic repair coupling that allows you to make simple repairs quickly. The telescopic coupling comes in a variety of sizes and lengths, but we usually use sizes of no larger than 2”. To install the coupling, simply cut out the broken section of pipe slightly larger than the coupling, then apply glue to the fittings and expand it to fill in the gaps.

Permanent repairs

Make permanent pipe repairs with pipes and fittings the same size and quality as the original installation. If you have a little extra time to make a more permanent repair, then do it. Mechanical couplings are similar to full-circle clamps, but they slip over the pipe instead of around it. They are like a compression coupling in their application, but they have bolts that compress the clamp together and they are durable enough to be considered a permanent repair. Remember, fix it fast but make it as permanent as possible the first time and you could save hours of work later.

426. Field disinfection procedures

While you are repairing a water main break or installing a new main, prevent contamination from dirt, sand, animals, and rodents. This can be accomplished by ensuring the work area is properly dewatered at all times or by installing a plug in the pipe if the main is to be left unattended.

There are four steps involved in disinfecting water mains: flushing, dosing, flushing again, and then testing. Your job is not finished until the main is deemed safe through bacteriological testing, which is performed by the bioenvironmental engineer at your medical facility.

Flushing the main

You usually flush mains using hydrants. Flush the main for at least 30 minutes at $2^1/_2$ feet per second (fps) velocity before attempting to disinfect it. The velocity must be high enough to keep dirty particles in suspension until they come out of the hydrant. Minimum flow rates in gpm are established based on pipe diameter. These flow rates are listed in the table below.

Line Size (in inches)	Flow Required (in gpm)
4	100
6	220
8	390
10	610
12	880
14	1200

Dosing the main

You use chlorine to disinfect water. Chlorine is manufactured as a gas, liquid, and solid. Each form of chlorine has a different strength and general use. The form you choose depends primarily on the size of the job or repair. Chlorine gas that is just about 100 percent pure is very dangerous to use and it requires an elaborate setup. Therefore, the size of the job must justify its use. Calcium hypochlorite, the solid form of chlorine, is manufactured in a powder or tablet at a strength of 65 percent. Contractors prefer tablets because they are small, compact, and convenient to use and they do not lose their strength when stored properly. The liquid form of chlorine, sodium hypochlorite (bleach) is available at strengths of 5–15 percent and is used when solution feeding is desired. Sodium hypochlorite is relatively unstable and it loses its strength as much as 4 percent per month. Chlorine contact time to disinfect a main is usually 24 hours at a 50 ppm chlorine residual. The higher the dose, *more* than 50 ppm, the shorter the contact time.

Flush the main again

After the 24-hour or appropriate contact time, you will need to flush the main until the residual is less than 1 ppm. Ensure that all water flushed out of the main goes into the sanitary sewer and not into a storm sewer. Chlorinated water is good for sewer mains that are a long distance from the sewer plant because it "freshens" up the collection system.

Testing the main

Coordinate with bioenvironmental engineering early enough in the process so they can test the main after it has been disinfected (super chlorinated) and flushed. Bioenvironmental engineering will collect a sample and perform a bacteriological count (total coliform). Your responsibility here is to ensure the technician sampling the main collects a sample from a *well-flushed* sample point. The total coliform test will take 24 hours to complete. It will be a full 48 hours before you can legally put the main back into service, if you add in the 24 hours it took to disinfect the main properly. If the total coliform test is unsatisfactory (i.e., too many bacteria colonies are counted), flush the main again with treated water and have the test repeated from a well-flushed sample point. If the total coliform test is still unsatisfactory, disinfect the main again using the continuous-feed method.

NOTE: Do not use calcium hypochlorite *powder* in pipes with solvent welded plastic or screwed joint steel pipe because the powder's quick reaction with the joint compound could cause an explosion. There is *rarely* a justification for putting a new or repaired main into service without some type of super chlorination (disinfection).

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

423. Winterization

1. What are the first steps in draining a building's water system?

2. When you drain a water heater tank, how can you allow air into the tank?

3. What should you use to remove most of the water from drainage system traps?

4. What should you do to drained traps once you have removed most of the water? Why?

424. Thawing

1. How can you determine how much of a water system is frozen?

2. What are some of the dangers associated with thawing frozen pipe with hot water and rags?

3. What precautions must you take when you are thawing pipes with a torch?

4. Before attaching electrical thawer cables, what should you do to prepare the pipe?

5. What could happen if electric thawer cable connections are not tight?

425. Repairs

1. What types of water main breaks would a full-circle clamp repair?

2. What sizes are full-circle clamps available in circumference and length?

3. What are the construction variances of a full-circle clamps?

4. How do you tighten the bolts on a full-circle clamp?

5. How do you make a permanent repair on steel pipe?

6. What fittings are used to connect two pieces of pipe when repairing copper?

426. Field disinfection procedures

1. What are the four steps involved in the disinfection of a main?

2. What are the three forms of chlorine?

3. What is the accepted contact time for disinfecting a main?

Answers to Self-Test Questions

413

1. Type of ground, quality of water desired, and the depth of the aquifer.
2. A well case or lining.
3. In flat areas. They are built at the same elevation to equalize the pressure uniformly across the flat plain of the land they serve.
4. They are susceptible to small animal infestations.

414

1. Manual controlled, semiautomatic, and fully automatic.
2. The bubbling or pulsating reduced pressure type and the vacuum type.
3. Head area, velocity head, velocity, and volume.

415

1. $2^1/_2$’ in grass areas, 3’ under roads, and 4’ under railroad tracks minimum.
2. Do not make taps larger than 2”.
3. Test the pipe at 1½ times its normal operating pressure.
4. A hydrostatic testing pump.
5. 3 hours.

416

1. No more than 48” above the ground.
2. On an annual basis.
3. AF Form 1027.
4. 3 to 5’ from the fire hydrant.
5. Two turns.

417

1. 40 to 75 psi at ground elevation.
2. At intervals of 1,200 to 1,500’.
3. A pitot tube.

418

1. Type of flush devices, pressure of water supply in psi, length of the building service line, number of fixtures, and probable use of these fixtures.
2. By supplying water at a higher pressure than normal.
3. After the distribution supply main has entered the building.
4. Galvanized steel, plastic, copper and PEX.
5. Solders containing more than .02 percent lead.
6. To permit easy drainage of the system; this is extremely important in cold climates.
7. Install a vertical air chamber.
8. It should have at least 1 percent of the total capacity of the pipeline in which the water hammer is occurring.
9. Begins at the water heater and ends at the point of use.

419

1. The locations are shown in the building or plumbing blueprints.
2. The manufacturer’s specification sheet.
3. The exact positions of the openings for the fixtures.
4. The opening should not exceed $^1/_3$ of the distance across the beam.

5. Place a strap iron brace across the notch and fasten it with lag screws.
6. Use a block of wood and nail it into the slot to prevent the beam from sagging.

420

1. At each floor level.
2. Must not exceed 4'.
3. Must be supported on substantial wood or pipe headers that are spiked or solidly fastened to the building framework.
4. To prevent corrosion.
5. Its weight.
6. Use lead anchors or expansion shields.

421

1. The fire department.
2. Process an AF Form 103 (digging permit) and dig up the main.
3. The tendency for metal to return to its natural state.
4. Uniform, localized, and compositional.
5. Direct chemical attack.
6. Electrolytic action of a galvanic cell.
7. A type of compositional corrosion that occurs in copper and zinc alloys.
8. Polyphosphates, such as sodium hexamatophosphate.

422

1. At least twice.
2. 25 to 50 psi or whatever the operating pressure is going to be.
3. A hydrostatic testing pump.
4. After applying the initial water pressure, loosen the caps and plugs on the end of the risers one at the time to let trapped air escape.
5. At least 15 minutes.
6. Linseed oil.

423

1. Close the main shutoff valve to the building, loosen the lowest connection, and open faucets at the highest levels to break vacuum.
2. Open pressure-relief valve.
3. Use a force-cup plunger on water closets and a vacuum plunger on flat surfaces.
4. Refill them with antifreeze solution to prevent escaping gases.

424

1. Start by opening the fixture faucets and using the process of elimination.
2. Scalding, slipping, and water damage.
3. Isolate the area with a heat shield, ensure adequate ventilation, and have a fire extinguisher nearby.
4. Thoroughly clean the contact area by sanding the pipe with emery cloth.
5. It could cause arcing, which will burn a hole into the pipe.

425

1. Holes, splits, and full breaks.
2. 1¼ to 24" and 6 to 36" long.
3. 0.4 to 0.8".
4. Evenly tighten bolts working from center outward.
5. Disconnect pipe, remove damaged pipe, and reinstall new sections with a union in between.

6. Use a slip coupling.

426

1. Flushing, dosing, flushing again, and testing.
2. Gas, liquid, and solid.
3. Usually 24 hours at 50 ppm chlorine residual.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

18. (413) When creating a closed well, what is used to keep the earth from collapsing and filling the well hole?
    a. Rock.
    b. Casing.
    c. Concrete.
    d. Steel pipes.

19. (414) Which element of a water meter translates the action of the water flow?
    a. Primary.
    b. Secondary.
    c. Tertiary.
    d. Head area.

20. (415) The diameter of the branch line that connects a fire hydrant to a main is
    a. at least 6 inches (”).
    b. at least 4”.
    c. no more than 4”.
    d. no more than 8”.

21. (415) The *minimum* burial depth for water mains under roads is
    a. 2 feet (’).
    b. 3’.
    c. 4’.
    d. 5’.

22. (416) How often is inspection and maintenance on fire hydrants performed?
    a. Monthly.
    b. Quarterly.
    c. Biannually.
    d. Annually.

23. (416) Which Air Force (AF) form is used to maintain a record of each hydrant and its isolation valve?
    a. AF Form 996.
    b. AF Form 997.
    c. AF Form 998.
    d. AF Form 1027.

24. (417) The normal operating pressure of a water distribution system is
    a. 5 to 10 pounds per square inch (psi).
    b. 10 to 20 psi.
    c. 40 to 75 psi.
    d. 100 to 200 psi.

25. (417) You should shut down the hydrants slowly after testing to
    a. decrease the flushing time.
    b. prevent surges in pressure.
    c. increase the flushing time.
    d. increase the pressure throughout the system.

26. (418) How can pipe friction be reduced in areas where higher water pressure is *not* available?
    a. Install loop system.
    b. Install dual pipes.
    c. Increase pipe size.
    d. Decrease pipe size.

27. (419) Who specifies the rough-in dimensions for a particular fixture?
    a. Craftsmen.
    b. Contractor.
    c. Manufacturer.
    d. Shop foreman.

28. (419) The *first* step in the rough-in of fixtures is to locate the
    a. main stack opening.
    b. vertical trap position.
    c. sewer and water line locations.
    d. exact position of the opening for each fixture.

29. (419) Where on the studs should you cut holes for water supply pipes?
    a. Top.
    b. Bottom.
    c. Center.
    d. Corner.

30. (419) Which type of structural opening is generally considered to cause *less* damage to the structural member?
    a. Overcut.
    b. Undercut.
    c. Flush cut.
    d. Center cut.

31. (420) When hanging a steel pipe, place the hangers *no* further apart than
    a. 4 feet (’).
    b. 6’.
    c. 10’.
    d. 12’.

32. (420) To fasten hangers to a concrete building, you should use
    a. sheet-metal anchors.
    b. any available nail or screw.
    c. braces welded to 1-inch (”) anchors.
    d. lead anchors or expansion shields.

33. (421) The *primary* purpose of periodic testing of water mains for flow and pressure is to *ensure* that
    a. sufficient water is available for firefighting.
    b. the water system can meet public demands for water.
    c. firefighters know how much water a hydrant can produce in inches of mercury.
    d. firefighters know how many pounds per square inch (psi) the system can usually provide.

34. (422) How many times are water system pipes tested?
    a. Once, after the fixtures are installed.
    b. Once, after the rough-in is completed.
    c. Twice, after rough-in and after the fixtures are installed.
    d. Twice, after the fixtures are installed and appliances are connected.

35. (422) Which ingredient can you use as a substitute for soapy water when leak-testing a pipe during freezing weather?
    a. Pine oil.
    b. Turpentine.
    c. Linseed oil.
    d. Petroleum jelly.

36. (423) When winterizing a system, what is the *first* step in draining a water system?
    a. Disconnect unions.
    b. Close main shutoff valve.
    c. Open highest level faucets.
    d. Loosen the lowest connection.

37. (423) What is the *first* thing you should do when draining a water heater?
    a. Turn off heat source.
    b. Open highest level faucets.
    c. Open pressure relief valve.
    d. Loosen the lowest connection.

38. (423) Which antifreeze solution should be your *first* choice when you are protecting fixture traps against freezing?
    a. Glycol.
    b. Alcohol.
    c. Glycerin.
    d. Calcium chloride.

39. (424) To find an area of frozen water piping, you should start by
    a. closing all faucets.
    b. opening all faucets.
    c. opening the highest union.
    d. closing the water supply valve.

40. (424) When using a torch to thaw frozen pipes near wooden structures, you *must* isolate the area with a
    a. wet rag.
    b. fire shield.
    c. heat shield.
    d. bucket of water.

41. (424) Which heat source is used to thaw frozen pipes concealed in walls?
    a. Heat tape.
    b. Electrical thawers.
    c. Motor-driven welder.
    d. Electric heating pad.

42. (425) Which is the proper way to tighten the bolts on a full-circle clamp?
    a. Working from center out.
    b. Working from outside in.
    c. Tightening every other bolt.
    d. The tightening sequence does not matter.

43. (426) In which order is a water main disinfected?
    a. Flushing, dosing, flushing, testing.
    b. Flushing, dosing, testing, flushing.
    c. Dosing, flushing, testing, flushing.
    d. Dosing, testing, flushing, testing.

44. (426) Select the proper length of time and velocity for flushing a main.
    a. 10 minutes/5.0 feet per second.
    b. 15 minutes/5.0 feet per second.
    c. 20 minutes/2.5 feet per second.
    d. 30 minutes/2.5 feet per second.

45. (426) Which disinfection method is preferred by contractors on *new* water mains because of its simplicity and ease of use?
    a. Sodium hypochlorite tablets.
    b. Calcium hypochlorite tablets.
    c. Sodium hypochlorite powder.
    d. Calcium hypochlorite powder.

Please read the unit menu for unit 3 and continue ➔

Student Notes

Unit 3. Wastewater Collection

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THE WASTEWATER COLLECTION SYSTEM collects and conveys the used (wasted) water that you generate all the way from your point of disposal (housing, office buildings, maintenance hangars, industrial shops, and other buildings) to a place of final disposal. On large military industrial complexes such as AF bases, the collection system is usually expansive because air bases are usually the size of small towns. This represents a very large investment to the infrastructure by the United States Air Force (USAF) and, as such, it must be operated and maintained properly. In this unit, you will learn about all the basic components of a wastewater collection system—from point of use to the ultimate point of disposal.

3−1. Exterior Fundamentals

WFSM journeymen and their civilian counterparts are rarely the ones responsible for the design and construction of these large and expensive infrastructure systems. However, because of your proximity to them it falls upon you to operate, repair, and recommend improvements to these systems. Because of this, it is important that you learn how a collection system is put together and how it works. Without a good understanding of its design and construction principles, you will not be able to operate and repair it effectively.

427. Components

As a WFSM journeyman, you must become familiar with the terms of your trade. Such familiarity allows you to do your job in a more proficient manner. A sanitary sewer system carries sewage from industrial and residential areas. This network includes building sewers, lateral sewers, branches, sewer mains, outlet sewers, manholes, lift stations, and a treatment plant. Figure 3–1 shows a typical wastewater collection system. Refer to figure 3–1 as you read about the components.

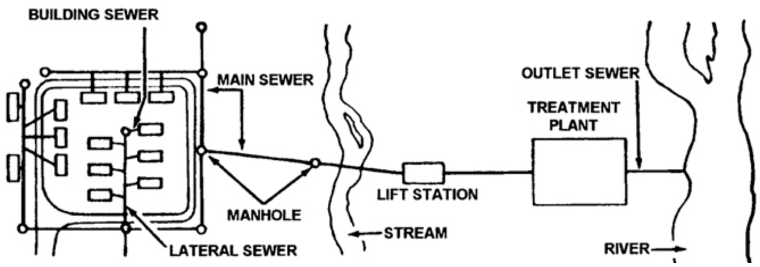

Figure 3–1. Layout of a typical wastewater collection system.

Purpose of collection system

Install a collection system at a specific fall, or grade, so that it will carry wastewater by gravity flow to a point of final disposal. When necessary, wastewater is pumped to a higher grade so that gravity flow will resume towards the wastewater plant. Each component of the collection system must be correctly located and installed to ensure that the primary means of collection is by gravity flow. Gravity flow greatly reduces energy and maintenance costs that would be incurred if hundreds of pump stations were installed for the same purpose. A sanitary sewer is used to carry liquid or waterborne waste from plumbing fixtures to the house sewer and into the main sewer lines. If this is not done efficiently, a health hazard could develop.

Building sewer

The building sewer is that part of the horizontal piping of a drainage system that extends from the end of the building drain; receives the discharge of the building drain; and conveys it to a public sewer, private sewer, individual sewage disposal system, or other point of disposal (*UPC*). As you can see in figure 3–2, a building sewer begins outside of the building (within 2–10 feet [’]), depending on local building codes, and ends at the connection into the lateral sewer. A building sewer has a minimum size requirement of 4” (3” for plastic or copper) and can never be smaller in diameter than the building drainage system.

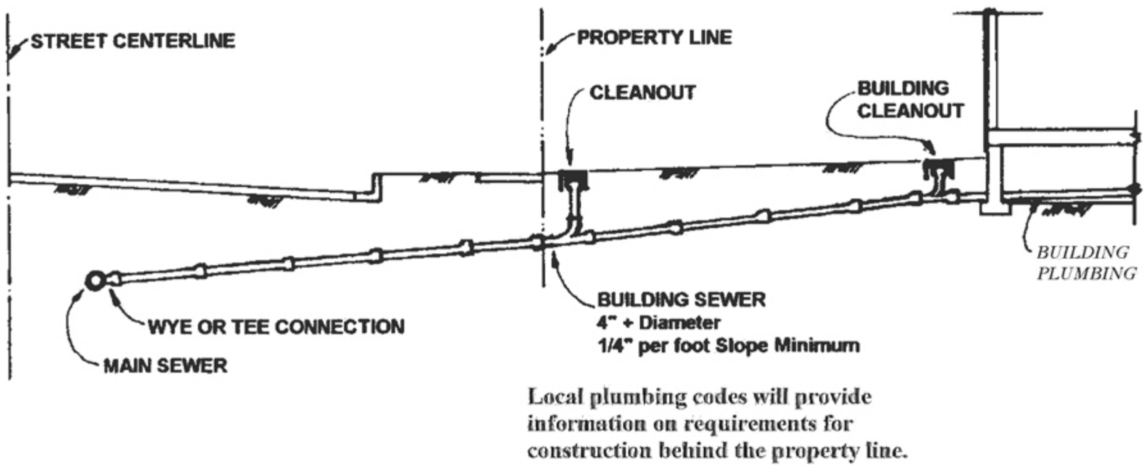

Figure 3–2. Typical building sewer.

Lateral and branch sewers

Lateral and branch sewers form the upper ends of a wastewater collection system. A lateral sewer does not receive sewage from any other common sewer except house connections. Lateral sewers receive discharge from building sewers and carry it to branch sewers. A branch sewer may receive drainage from two or more lateral sewers and carry it to the sewer main.

Main sewers

A main sewer receives discharge from several branches and lateral sewers, conveying it to trunk sewers. Main sewers are usually 8” or more in diameter and quite lengthy, because they may travel for several street blocks before being connected to trunk sewers.

Trunk sewers

Trunk sewers collect drainage from many different main sewers and are considered the main "arteries" of a gravity collection system. Trunk sewers may run for miles before discharging into either interceptor sewers or wastewater treatment plants. There are no size limitations on trunk sewers.

Interceptor sewers

Interceptor sewers are typically found just ahead of a treatment plant. These sewers "intercept" the flow from many trunk sewers and convey it to the treatment plant. These sewers are mainly used to "channel" wastewater flow into the wastewater plant.

Industrial sewer collection system

Industrial sewer systems are unique to big facilities like AF bases or large manufacturing plants. On AF bases, the "industrial sewer" is typically around flight line areas, usually parallel to the runway with perpendicular branches that serve airplane hangars. The industrial sewer is a completely separate sewer. It is not connected in any way to the sanitary collection sewer. Industrial sewers convey highly polluted wastewater to a separate "industrial treatment plant," where all harmful chemicals are removed or neutralized. The wastewater is then purified and returned to a lake, stream, or very large oil separator located in front of a sanitary wastewater plant.

Manholes

A manhole is a maintenance access point in a sewer line. Manholes are constructed into lateral, main, trunk, and interceptor sewers for the sole purpose of allowing maintenance crews and their equipment access to sewer lines. Manholes are also installed at changes in sewer line direction, elevation, slope, size, and junction. Manholes in straight runs are usually not placed farther apart than normal cleaning equipment allows. This distance is usually between 300 and 500'. Manholes are covered by round precast steel covers to prevent unauthorized access. Manhole covers and frames are specifically designed round so that the cover does not accidentally fall into the manhole. Manholes are usually equipped with galvanized wrought iron steps that are inserted into the concrete every 12".

Operating factors

Three primary factors affect the proper operation of sewer mains: (1) the correct size pipe to handle maximum flow, (2) the correct slope to ensure proper flow, and (3) the lack of obstructions to continuous flow.

Pipe sizing

Sewer piping must be large enough to handle peak periods of sewage flow. If the pipe is too small, the sewage flow during peak periods is restricted. In turn, if the pipe is too large, the wastewater has a tendency to leave the solids behind, thereby creating maintenance problems. A properly sized sewer main will be approximately half-full when it is conveying the peak dry weather designed flow and just about to the top of the pipe when it is conveying the peak wet weather design flow. Design engineers normally compute the size of sewer mains.

Fall per foot

The slope of the pipe directly affects the velocity of wastewater in a sewer line. Wastewater in a sewer line should move at a velocity that prevents the depositing of settleable solids in the line. This velocity, called the "scouring" or self-cleaning velocity, is rated at 2 fps. For this reason, you must install horizontal drainage at a uniform slope throughout the length of the sewer line in order to maintain a velocity of 2 fps. The slope of a pipe is primarily determined by the size and length of the pipe. Building sewers, which are 3" in diameter or smaller, must have a fall of not less than ¼" per foot. Sewers larger than 3" in diameter must have a fall of not less than ⅛" per foot. Laterals, branches, and main sewers must be inclined to maintain a minimum flow rate of 2 fps. Velocities greater than 10 fps or slopes greater than ¼" per foot of pipe can cause the solids to separate from the wastewater. This creates stoppages and causes excessive turbulence at manholes, which ends up eroding the sewer lines.

Obstructions

All sewer lines must be free of obstructions in order to operate efficiently. As discussed earlier, size and slope miscalculations lead to obstructions and cause maintenance headaches as the collection system ages. Obstructions create two kinds of stoppages: complete and partial. In partial stoppages, the main is restricted somewhat but is still flowing enough that complaints do not come in—yet. This is why a good sewer line preventative maintenance program is necessary. Some obstructions found in sanitary sewer systems are tree roots, cracked joints, crushed piping, sand 3–1, 427 from poor joints, excessive grease buildup, clothing articles, and excessive amounts of paper. Some obstructions are unintentional, such as when heavy equipment operators accidentally drive their equipment over manholes or soft soil areas. Other stoppages can be created by misuse of trench compaction equipment or pipe damage due to misuse of sewer cleaning equipment. In all cases, it falls upon you, the WFSM journeyman, to identify and repair all obstructions in sewer lines. We will discuss this area more thoroughly in a later lesson.

428. Trenches

The first thing that you must do when installing a building sewer is to process a "digging permit," AF Form 103, Base Civil Engineering Work Clearance Request. Next, when you know where all the existing utilities are located, dig the trench. Remember, just as in any job you perform, observe and practice safety, as many hazards are involved in digging a trench. The type of soil and the depth of the trench determine the precautions that you should take. If it is determined that shoring is needed, follow the proper procedures previously covered in career development course (CDC) 3E451A, Volume 2, *WFSM Fundamentals, Valves, and Pumps.*

Trench preparation

Study the layout of the sewer shown in the blueprint for the system. Locate and mark the centerline of the trench in the area where the trench is to be dug. Decide what precautions you should take to prevent cave-ins while digging the trench. This is normally done with some type of shoring that was discussed earlier. Remember from the previous lesson that all excavations require a competent person on site.

Grading

Proper trench grading is literally the foundation of proper installation of sewer pipe systems, whether it is a building sewer or a huge interceptor sewer. If the groundwork (grading) is not correctly done the first time, severe slope problems soon become evident and all your efforts are wasted. As you already know, the slope of a drainage system is important because an improperly graded pipe system can cause numerous maintenance headaches. Both storm and sanitary systems are installed in trenches, so let us look at the work that is involved in pipe trench preparation.

Basic theory of trench grading

Your digging job is not complete until you grade the trench to ensure that wastewater materials flow through the pipe at the correct slope. To do this, you are placing the outlet of the sewer lower than the inlet so that wastewater flows through the sewer line by gravity flow. Slanting the sewer pipe in this way is referred to as "fall." For example, the desirable fall for a 3" house sewer is $^1/_4$" per foot. In a properly graded trench, you can lay soil pipe without leveling each joint, which saves a lot of time. The proper fall is ensured by establishing a grade line and then digging the trench to exactly this line. A properly graded (sloped) trench permits proper grading of sewer pipe. If you remove too much dirt and use loose dirt to fill in, the pipe can settle and cause breakage or stoppage. Use the following three well-established methods to grade a trench:

1. Surveying using an engineer's transit or a fixed-beam laser.

2. Staking using a string level.
3. Using an ordinary carpenter’s level.

Engineer’s transit or fixed-beam laser

The best method you can use to grade a trench is surveying using an engineer’s transit or fixed-beam laser. Of these two, the fixed-beam laser is more versatile because it can be used in a variety of ways such as displayed in figure 3–3. An engineering journeyman must assist you when these methods are used. You provide the information on how much slope is required to lay the sewer line, and then the transit or fixed-beam laser is used to shoot the correct grade. When a transit or fixed-beam laser is not available, you must use other methods to grade the trench. This method is more appropriate for larger projects, such as a long sewer main installation.

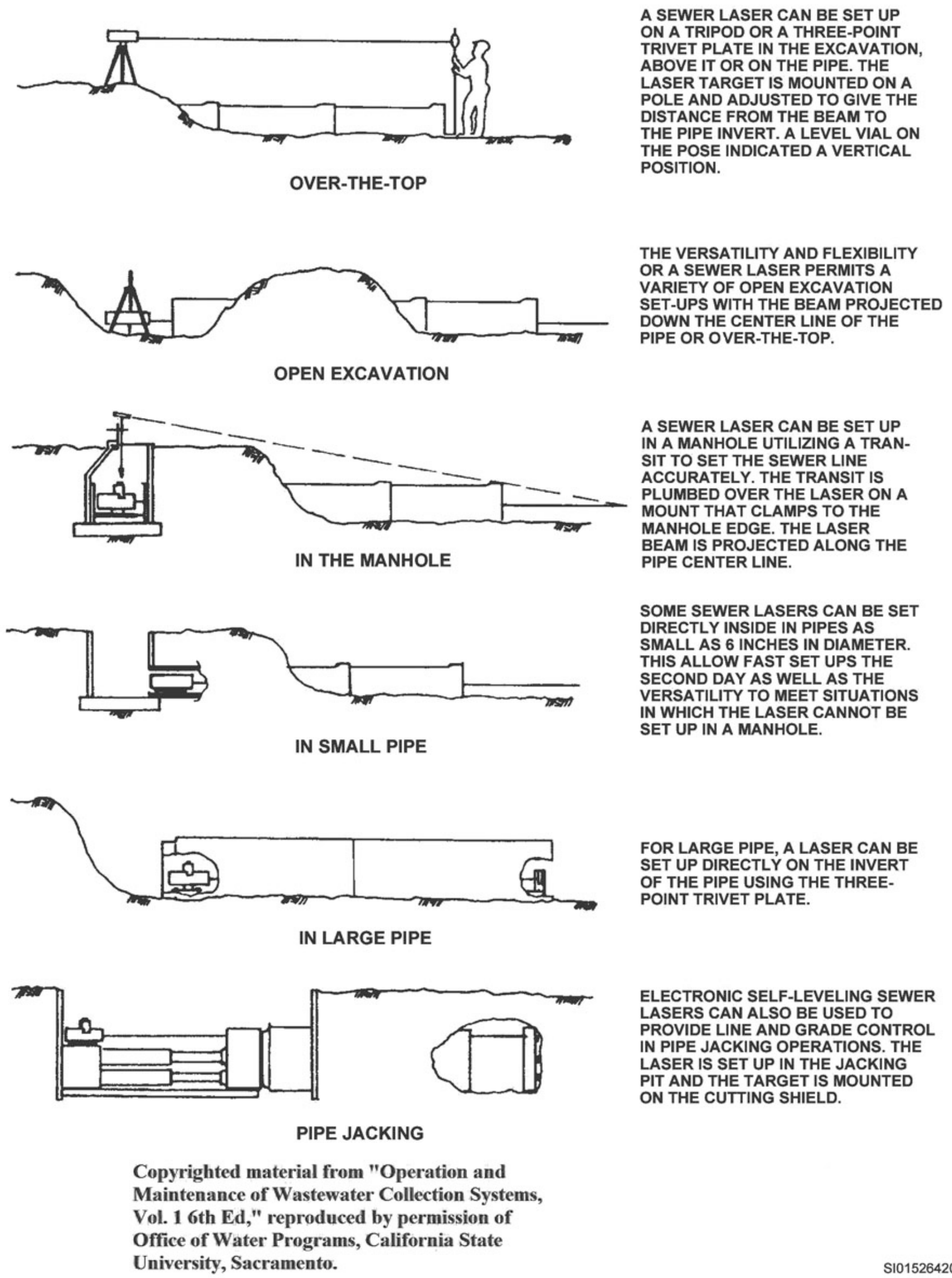

Figure 3–3. Fixed-beam laser shooting at a target.

String level

Another method of grading a trench involves the use of a string level (fig. 3–4). You stretch and level a string from stakes positioned along the trench. Then, the discharge end of the string is lowered to the amount of grade required. For instance, if the distance between the stakes is 20’, the string between is level, and the grade you want is ¼” per foot, drop the lower end of your string 5” (¼” × 20 = 5”). This would give you a grade of ¼” per foot. After the trench is dug to the desired depth, you can make a grade stick (a piece of lumber, possibly 1 by 2”) by marking the desired depth from the string to the trench bottom on the stick. You can then use the grade stick to take random depth readings of the trench from the grade string. This procedure assures you that the trench bottom has the proper slope. The string-level method is commonly used because it not only allows the equipment operator a way of checking for proper grade as the trench is dug but also allows you to check the actual closeness to grade using a grade stick. In this sense, the string line serves a dual purpose.

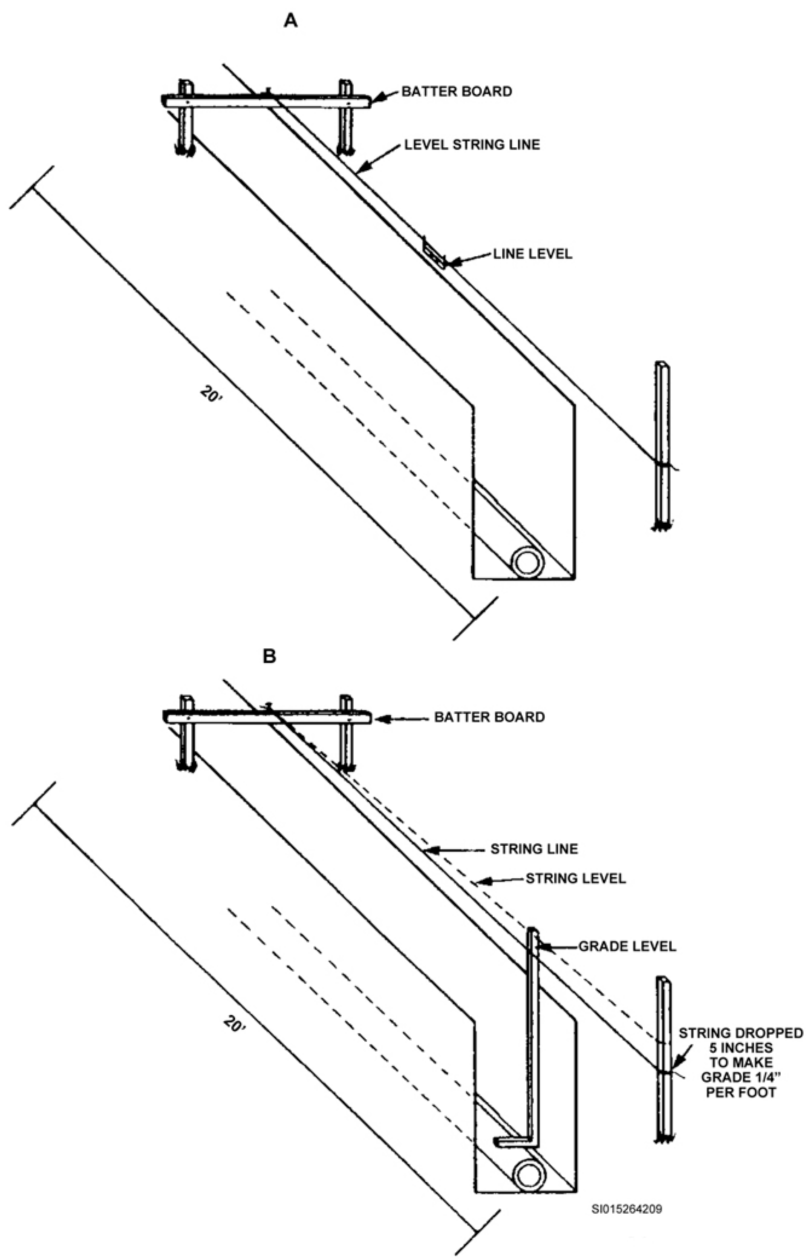

Figure 3–4. Grading a pipe using a string level.

Carpenter's level

If an engineer's transit/fixed-beam laser or string level is not available, you can use a level as a last resort. Place the level on the pipe at the high end and put a block of wood, corresponding in thickness to the grade required, under the low end of the level. When the air bubble shows level (centered between the marks of the glass), the pipe has the proper grade. You must consider the length of the level, too. Thus, if the level is 2' long and the grade is ¼" per foot, the block under the level must be ½" thick, as shown in figure 3–5. Consequently, an 18" level would require a ⅜" block, and a 1' level requires a ¼" block to maintain a ¼" fall.

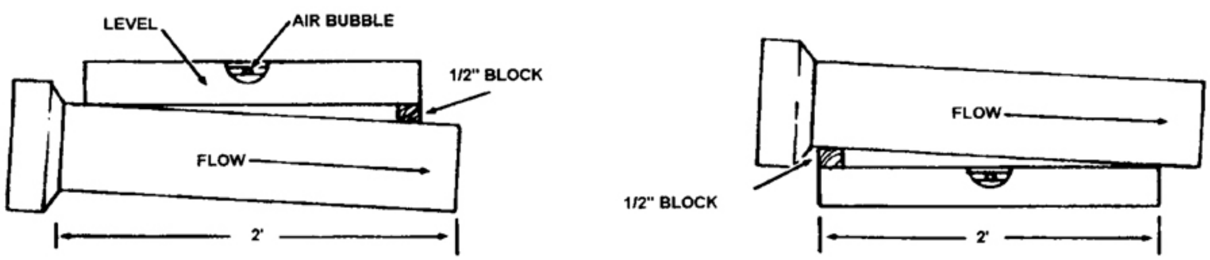

Figure 3–5. Grading a pipe with a level.

Trench bedding

Selection of the proper bedding material, class of bedding for the pipe to be laid, and how the bedding is compacted are all important factors in maintaining proper grade and slope (fig. 3–6). Remember, any pipe laid in a trench must have the proper foundation beneath it and surrounding it to maintain the designed grade after the trench is backfilled and to prevent the pipe from crushing. This is why material selection, class of bedding construction, and compacting are so important. Without the proper bedding and adequate compacting, the pipe sinks into the bedding, possibly causing the joints to leak. Pipe manufacturers will typically specify the load-supporting strength of the pipe, such as 2,500 pounds per foot. This means the pipe will support that weight per foot of length without cracking.

Draining

Sometimes surface water or rainwater enters an excavation. Before you resume digging or laying pipes, you must remove this water from the hole or trench. Remove the water by using a pail or bucket, digging a small trench to drain water away naturally, or by using some type of pump. When using a pump to remove the water, you need to dig a sump for the pump or suction line to go into. The sump will allow you to remove all the water in the excavation. If you are not using a diaphragm-type pump, then you should use a plastic bucket to set the pump into. The bucket will allow you to pump all the water out without clogging the pump with mud and rocks.

Backfilling

Backfill the trench when the inspection is completed to prevent the pipe from shifting and causing damage to the joints. The three main reasons you backfill and compact a trench are as follows:

1. To restore the natural appearance of the ground. Improper backfilling and compaction causes a depression to appear throughout the length of the trench after the backfill settles naturally due to rain.
2. Most important—never leave a trench uncovered due to safety reasons as well as local building codes, right-of-ways, and so forth.
3. Protect the pipe from movement and breakage due to the impact or crushing of the backfill load.

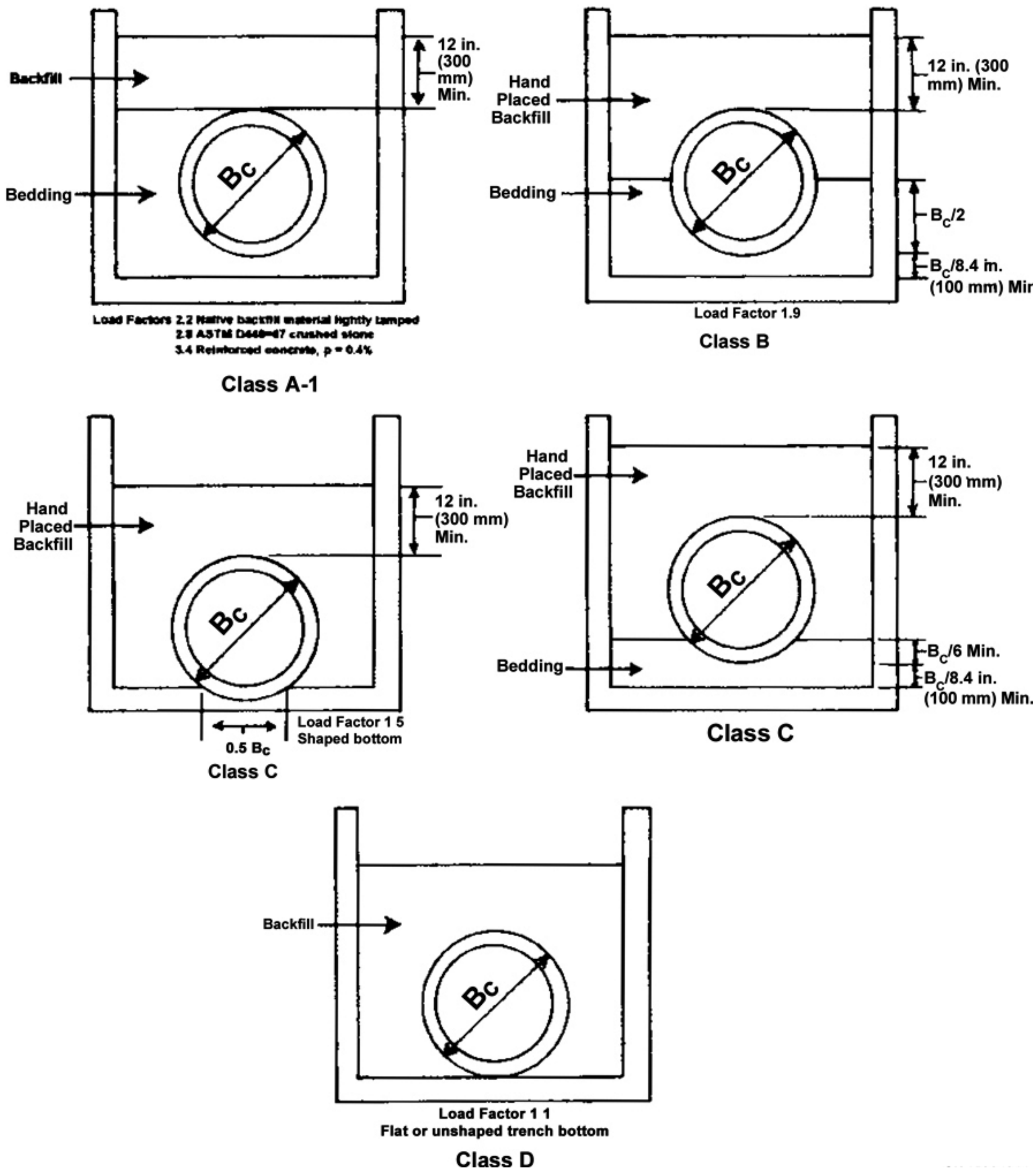

Figure 3–6. Classes of bedding.

First, backfill the sides of the trench with the required bedding using shovels until at least half of the diameter of the pipe is covered, being careful not to disturb the grade of the pipe as much as is possible. For larger, longer sewers, the bedding may be dispensed into and around the sides of the pipe by “shaking” the bucket of a front-end loader, being careful not to disturb the pipe. It is prudent to guide the loader operator while this is happening to prevent bedding or fill from falling on top of the pipe. Make sure to apply the bedding evenly to both sides of the pipe. To prevent small-diameter pipes from shifting during compacting, you should compact both sides evenly until you reach the top of the pipe.

Compacting is accomplished using a gasoline-powered tamping machine. For best results, you should backfill and compact in layers of not more than 4” and tamp with a mechanical tamper until you obtain the desired height. Be careful when compacting vitrified clay pipe because this type of pipe is brittle and may be shattered by heavier tampers. Class A, B, and C beddings require that the backfill material be tamped at least 1’ above the top of the pipe. This prevents the pipe from shifting laterally when backfilling the rest of the trench to the surface elevation.

Remove all the large rocks and pieces of pavement from all the native soil along the side of the trench. Then, carefully place the remaining soil along the trench using a front-end loader. Push the soil into the trench in 4” layers and tamp until you reach the top of the trench.

429. Piping and sewage lift stations

Sewage lift stations come in all shapes and sizes. We will cover three of them in this lesson. We will also cover the different types of piping for sewer drains.

Piping

The building (house) sewer starts 2–10’ from a building foundation and extends into a public sewer (by way of a lateral), private sewer, or individual waste disposal system. In a sense, the building sewer is an extension of the building drainage system. The building sewer is usually made of clay tile, cast-iron, asbestos-cement, or plastic pipe.

You have two alternatives when no provision for a new building sewer has been made. You can remove a section of the main sewer and install a precast fitting, or you can tap into the sewer main and make a fitting called a thimble. A thimble is a short piece of pipe with a hub (bell) on one end and a straight cut or 45° cut on the other end.

Lay the house (building) sewer pipe in the trench with the bell end facing upstream (towards the building). Begin connecting pipe at the precast fitting or the thimble in the main sewer and working toward the building drain. Use plastic, asbestos-cement, vitrified-clay tile, or cast-iron pipe. Remember that before laying the sewer pipe, the bottom of the trench must first have been prepared. After laying the sewer pipe in the trench, partially remove the bedding beneath each hub so that the pipe lies on a firm bed throughout its entire length (fig. 3–7). This evenly distributes the weight of the pipe on the bedding and not just the bell ends.

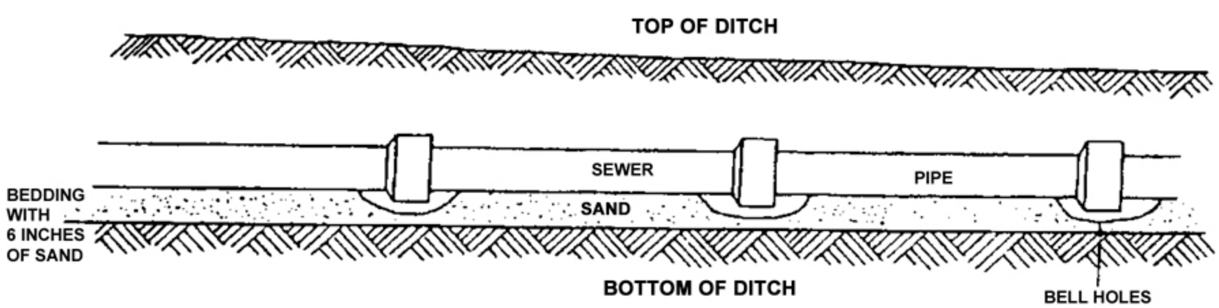

Figure 3–7. Proper pipe support.

The next step is to make the joints. We have already covered joining pipe except for resilient joints. Most resilient gaskets come in the form of an O-ring. To join pipe with resilient joints, follow these six steps:

1. Clean off the bell and spigot.
2. Lubricate the gasket and seat on the pipe as prescribed in the manufacturer’s instructions.
3. Start the joint by guiding the spigot end of the pipe into the bell end.
4. Complete the joint by pushing the pipe into place.
5. Inspect the joint for proper seating of the pipe.
6. Check the alignment and grade of the pipe.

You can also use transition connections, adapter fittings, or one-piece molded rubber couplings to join other different types of pipe. Remember that pipe joints are a critical factor in every sewer. A joint that is not centered tends to leak on the side that has the least space, creating problems caused by roots, infiltration, and exfiltration. If the grade is correct, test the pipe (procedures covered in the next section) and backfill the trench.

Lift stations

Lift stations are the part of the sewage collection system that pumps wastewater to higher elevations. They are installed at locations where a sewer main cannot continue to flow by gravity because of slope or impractical depths. When this happens, the sewer main ends and discharges directly into a pit called a *wet well*. The wet well of a lift station provides the extra reservoir of sewage needed to prevent the pumps of a lift station from turning on and off unnecessarily. When the wet well of a lift station fills to a specified height, a pump comes on and drains the wet well to within a foot of its intake. The wastewater is then *lifted* vertically and discharged from the pump into a *force main* (main under pressure). The force main conveys the wastewater to the nearest manhole or sewer main that can again continue gravity flow towards the treatment plant. There are two styles of lift stations: wet well and dry well.

Wet well

Wet well lift stations are the most common found today (fig. 3–8). They are usually small and compact. The wet well design provides for submersible sewage pumps that can easily be lifted out of the wet well for maintenance or replacement using chains and guide rails. Wet well lift stations usually have two submersible pumps installed in them. These two pumps will alternate as “primary” and “secondary” every other cycle.

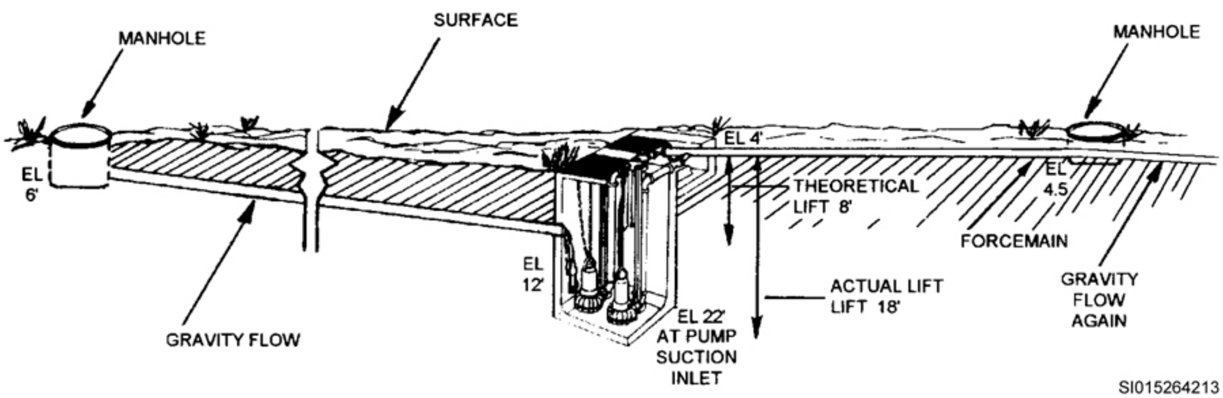

Figure 3–8. Wet well lift station.

Dry well

This is the type of lift station found in older, larger wastewater collection systems and is always characterized by a “wet” and “dry” compartment. The pumps are installed in the dry well part of the station. This type of lift station may have from two to four pumps (fig. 3–9). This design may also allow for screening and flow measurement, depending on the purpose.

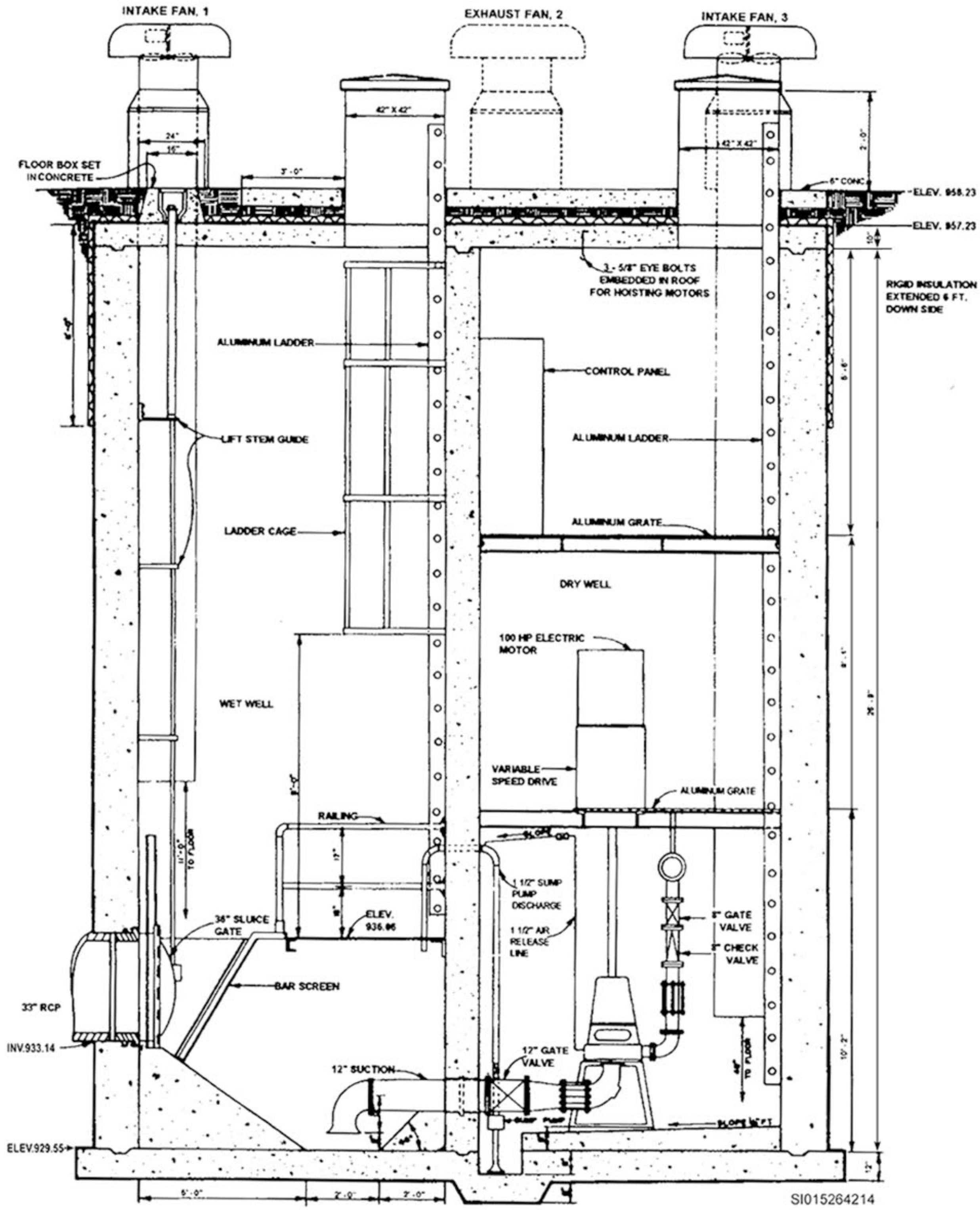

Figure 3–9. Dry well lift station.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

427. Components

1. List the components of a wastewater collection system.

2. Which part of the collection system connects the building drain to the sewer main?

3. What is the purpose of the sewer main?

4. What is the purpose of an industrial sewer?

5. Why are manholes placed in a sanitary sewer system?

6. What are the three primary factors that affect the proper operation of a sewer main?

7. What is the operational effect of oversizing a sewer main?

8. What is the fall of a 3” building sewer?

9. What is the ideal flow rate of wastewater in a sewer main?

10. What effect do obstructions have on sewer mains?

428. Trenches

1. What is the first thing you must do before installing a building sewer?

2. What is the theory of trench grading?

3. What is the proper fall for a 3” house sewer?

4. What is the best method of grading a trench?

5. Class A, B, and C beddings require that the backfill material be tamped at least every how many feet above the top of the pipe.

429. Piping and lift stations

1. Where does the building sewer start?

2. What can you do if no provision has been made for connecting a building sewer to the sewer main?

3. Where do you start laying the pipe for the house sewer?

4. Why must you remove the soil from under each hub when you lay the pipe for the house sewer?

5. What part of the collection system pumps wastewater to a higher level?

3−2. Interior Drainage Systems

Up to now, you have thoroughly covered the wastewater collection system as it applies to the outside of a dwelling. In this section, you are going to cover the interior drainage systems. Building drainage and venting systems must be installed and maintained according to specified codes. These codes are important because you must know basic terminology and principles to install building drainage systems correctly. You must also know how they are generally laid out so that you can repair them correctly. As a WFSM journeyman, you will need a thorough understanding of these principles to be able to design them accordingly.

430. Drains

Within this lesson we will go further into the discussion of drains. We will cover basic design questions, building drainage piping, drainage sizing, and installation of the building drain.

Basic design questions

A WFSM journeyman can design and install any drainage system in a building if he or she can answer the following basic questions:

- What are the piping materials to be used?
- What are the number and type of plumbing fixtures?

- What is the total drainage fixture unit value for all the fixtures involved?
- What are the locations of these fixtures?
- What is the location (space) provided to run water supply and drainage to the fixtures?
- What are the obstructions (if any) to the water supply and drainage of these fixtures?

Think about these questions as you progress along in this discussion.

Building drainage piping

You need to know that there are two classes of drainage piping in a building regardless of the type of pipe. One system is classed as the soil drainage piping and the other as the waste drainage piping. They may be the same types of pipe, but it is their intended use and size that creates a distinction between them.

Waste piping only conveys liquids that are free of fecal matter. Soil piping, on the other hand, conveys both the discharge of fecal matter by water closets (W/C) and other similar fixtures that do not discharge fecal matter. The building (house) drain is that part of the lowest horizontal piping of a drainage system that receives the discharge from soil, waste, and other drainage pipes inside the walls of the building and conveys it to the building (house) sewer, which begins from 2' outside of the building wall, as shown in figure 3–10.

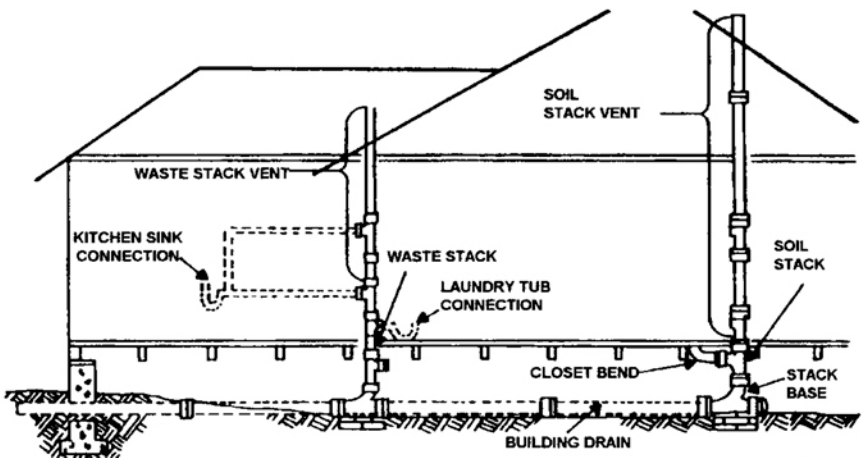

Figure 3–10. Typical building drainage system.

Drainage sizing

Before you install any sanitary drainage piping, you must first know what size piping you need. Drainage piping is sized according to the drainage fixture unit system, very much the same way that water supply to the fixture is determined. To select the proper-sized building drain, you must first calculate the maximum discharge of water and waste materials into it. Do this by calculating the total individual fixture unit values discharged into it from the various branches in the stack and waste system.

The fixture unit corresponds to 7.5 gallons or 1 cubic foot of water that an ordinary lavatory would discharge into the stack in an interval of 1 minute. All other fixtures commonly used in plumbing installations have been tested for maximum flow, and the fixture unit values have been established for each. The *UPC* has a complete listing of each fixture and its value.

Suppose that you want to know the minimum size of a building drain for a plumbing system that has two W/Cs, three lavatories, two slop sinks, a kitchen sink, a pair of laundry tubs, two floor drains, and two showers. First, determine the number of fixture units in the installation by multiplying each fixture by the fixture unit values. Next, total the fixture unit values. In this case, the total is 35.

To determine the diameter of the soil pipe to be used for the building drain, refer to figure 3–11. Continuing with the above example, which has a total fixture unit value of 35 units, and assuming a fall of ¼” per foot, you find that it would take a pipe 3” in diameter for the building drain.

Drainage Fixture Unit Calculation For The Building Drain Above

Fixture	Fixture Value	Times	Number of Fixtures		Sub-Total Value
Water Closet	6	X	2	=	12
Lavatory	1	X	3	=	3
Slop Sink	3	X	2	=	6
Kitchen Sink	2	X	1	=	2
Laundry Tub	2	X	2	=	4
Floor Drain	2	X	2	=	4
Single Shower	2	X	2	=	4
Total Drainage Fixture Units Needed				=	35

Pipe Capacities (In Drainage Fixture Units)

Pipe Size	Fall Of Pipe Per Foot	
Inches	1/8	1/4
1 1/4	---	1
1 1/2	---	2
2	---	8
3	28*	35*
4	173	216
6	216	720

*Only 3 water closets or 6 unit traps

Figure 3–11. Pipe capacities and drainage fixture units.

The following three points need to be made about building drains:

1. You cannot install more than three W/Cs on a 3” building drain.
2. A drain of less than 3” cannot have a W/C on it.
3. A W/C must drain into a building drain that is not less than 3”.

As you have probably already deduced, determining drainage fixture units and the minimum size building drain is very much like determining water supply to the same fixtures (fig. 3–11). All you need to know is the type of fixture, number of fixtures, and the drainage fixture unit value for each fixture. You should then look up all these fixture values and pipe capacities in the *UPC.*

Installation of the building drain

First, locate and install the building drain below the floor of the building and underground, on the ground, or hung from the basement ceiling. Avoid unnecessary bends; instead, take the shortest straight path to the building sewer. Provide cleanout plugs to allow access into the pipe, therefore simplifying the clearing away of obstructions when these should occur (fig. 3–12).

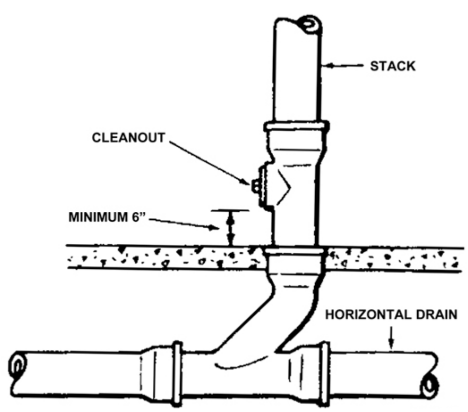

Figure 3–12. Cleanout for a building.

Locate these cleanouts at the stack base or wherever the building drain changes direction more than 135°. Provide a cleanout for every 100’ in the building drain (*UPC*). Always place a cleanout at the outside wall of a building where the building sewer and the building drain meet (fig. 3–13). Additionally, cleanouts should also be provided in the following areas:

1. The base of all vertical soil or waste stacks.
2. 90° changes in direction.
3. Upper ends of all horizontal branch lines.
4. Every 50’ for horizontal drainage pipe 3” and smaller.
5. Every 100’ for horizontal drainage pipe 4” and greater.

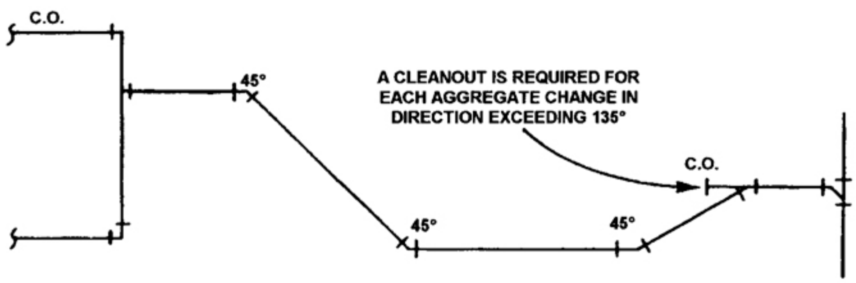

Figure 3–13. Cleanout locations.

Use long-radius fittings wherever possible in drain lines to make gradual changes of direction and to prevent stoppages. You determine the location of the building drain by the location of the main stack and the location of the house sewer. You can determine the number of stacks required and their exact locations by the location of the fixtures within the building. Position and install the fitting that serves as a stack base (and in which the stack is later constructed) when you fabricate the building drain.

Figure 3–10 shows how a combination Y and ⅛ bend are installed at the base of the stack. The blocking under the stack base is necessary to position the fitting under the floor opening, thus accommodating the stack and preventing settling when the weight of the stack is added. Lay the house drain to grade. The fall should not normally exceed ¼” per running foot for pipe that is 3” and smaller. For a 4” pipe, the fall should not exceed ⅛” per running foot.

431. Stacks and vents

A building drainage system is not complete without a venting system. A drainage vent system consists of nothing more than a piping system that lets air or gas pass through it. Without a venting system, vacuum conditions can form and cause fixture drain traps to lose their water seals. This might let sewer gas enter the building and endanger the occupants. Also, vacuum conditions could keep water from flowing properly. Vents also provide air circulation, thus reducing the highly corrosive effects of sewer gas.

Stacks

A stack is the vertical main of a system of soil, waste, or vent piping extending through one or more stories *(UPC)*.

Soil stack

The soil stack is the vertical soil pipe that carries the discharge of W/Cs, urinals, or other similar fixtures releasing human feces to the building drain (fig. 3–10). The size of the stack depends on the number and type of fixtures connected to it. The smallest size soil stack used on urinals is 2”. The smallest size used for W/Cs is 3”.

Waste stack

A waste stack is the vertical pipe (fig. 3–10) that carries waste that is free of fecal matter from fixtures. Its size depends on the number and type of fixtures connected to it.

Stack vent

A stack vent is the extension of a soil or waste stack above the highest horizontal drain connected to the stack *(UPC).* Figure 3–10 shows both a soil stack vent and a waste stack vent. The purpose of these vents and all other vents is to provide a flow of air to or from the drainage system to protect the fixture trap seals.

Vent stack

A vent stack is a vertical vent pipe installed primarily for providing circulation of air to and from any part of the drainage system (*UPC*). A vent stack is usually installed on multistory buildings to avoid emptying the discharge from upper-story fixtures into the piping that vents lower-story fixtures. It is installed for the sole purpose of venting.

Location

The location of your fixtures (the fixture group) determines where your stacks are located, and the location of your stacks determines where you run your building drain. Consider all these items in the planning stage of your job.

Sizing

The procedures for sizing the stack are similar to that of sizing a building drain. You must first calculate the maximum fixture unit values of waste discharged into the stack. After determining the total fixture unit values, convert the values to pipe diameter by using the stack table from the *UPC*. The smallest soil stack that can be used with a W/C is 3”, and no more than four W/Cs can be on it.

Layout

After you have determined the stack location and have selected the materials for the installation, you are ready to lay out the stack.

First, you must cut the structural openings for the stack. Install the stack base at the time you fabricate the building drain. If no provisions were made for testing or cleaning the drain at the stack base, install a test tee as the first fitting on the stack base. The next fitting you install on a soil stack is usually a sanitary tee—one meant to accommodate the soil branch or closet bend. Add other fittings in their proper order to complete each kind of stack. Make the measurements for cutting this pipe between the center lines of the fittings. After the pipes are cut, put the stack together for a trial assembly. Double-check the measurements for accuracy.

Assembly

Complete the assembly of the stack in a building under construction in two operations. Construct the part of the stack located below floor level first; then, complete the portion above the floor. You must determine both the portion of the work that can be done with the pipe and fittings in place and the portion that must be fabricated before piping is set in place. In any event, leave sufficient space around the fittings to make the joints. After you complete the stack, brace it with wood supports at the branch openings to prevent moving or shifting of the stack. In multistory construction, brace the stack as it passes through each floor level. Support the pipe horizontal to the stack near its connection to the pipe to lessen the stress on the stack.

Run the stack through the roof to form a vent terminal. The pipe through the roof must be of full size or larger and must project through the roof at least 6” before it is terminated. Since roof flashings are available in a number of different sizes, the size of flashing you use depends upon the size of the main and waste vents, which are the portions of the stack that project through the roof. Do not extend the terminal of a vent stack directly beneath any door, window, or other ventilating opening of a building or of an adjacent building. If the vent terminal is within 10’ of such an opening, project the vent at least 3’ above it. Never end a vent under the overhang of a roof or under any other part of a building.

Vents

There are several approved methods for venting a plumbing system. Some are designed to handle many fixtures while others take care of just one. For the waste system to work properly, you must select the correct type of vent, depending on the design of the building, the number of fixtures, the way the fixtures are grouped, and code specifications.

Main vent

The main vent (fig. 3–14), being the principal artery of the venting system to which vent branches may be connected, is used primarily in multistory buildings. This vent serves as a terminal for the vent piping from the individual fixtures. Connect the main vent full size at the base of the soil or waste stack. Make this connection below the lowest fixture branch. Extend it full size above the roofline or to a point of connection above the highest fixture branch of the stack vent.

The fitting for the connection between the main vent and the stack vent is referred to as “a main vent tee.” In most installations, the main vent is within a few feet of the soil or waste stack. Although the smallest main vent is 1¼” make sure it is at least one-half the diameter of the soil or waste stack it serves or to which it is attached (fig. 3–14).

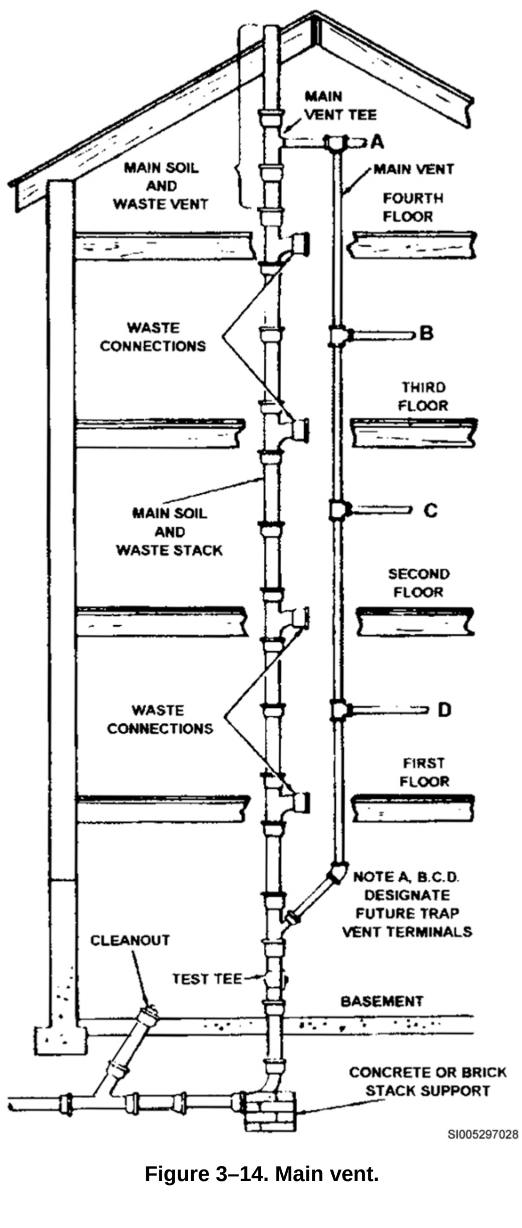

Figure 3–14. Main vent.

Individual vent

An individual vent is nothing more than the name implies. It is a pipe installed to vent a single fixture trap. It connects with the vent system above the fixture it serves or terminates in the open air. The installation of a single lavatory's individual vent attached to a main vent is shown in figure 3–15. Notice the drainage through the waste pipe to the waste stack. The individual vent pipe above the fixture trap is connected to the main vent. The vent piping must rise vertically *at least* 6" above the fixture flood rim (overflow line in fig. 3–15) before changing direction and going horizontally for connection to the main vent. The fixture is said to be dry-vented because there is no drainage flow through the vent piping in the system. The individual vent is the simplest type of vent installation used in plumbing systems. It is adaptable to all types of fixtures.

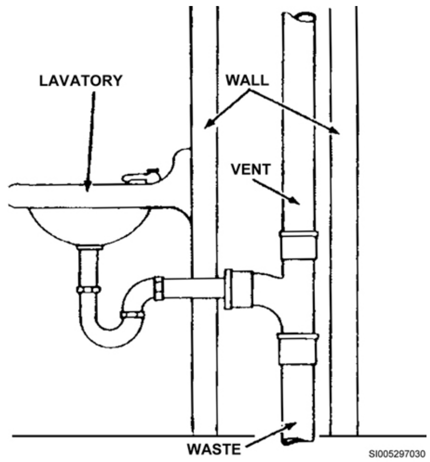

Figure 3–15. Individual vent.

Back vent

In most one-story plumbing installations where a fixture is near the soil and waste stack, the fixture drains through piping directly into the soil or waste stack. The fixture is then vented into the stack vent above the drain (fig. 3–16). The vent piping must rise vertically *at least* 6" above the fixture flood rim before changing direction and going horizontally for connection to the main vent. This is referred to as a "back vent." Back venting is desirable because it saves piping and prevents having to make additional openings in the roof.

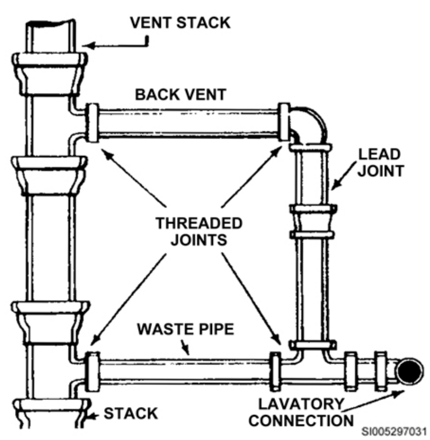

Figure 3–16. Back vent.

Unit vent

Fixtures mounted side by side or back to back on a wall at the same elevation (fig. 3–17) are unit vented. A unit vent, sometimes called a dual vent, is a vent pipe installed to protect two fixture traps. The unit vent pipe connects to the main vent when a stack is located nearby or may extend individually through the roof. Make the connection between the two fixtures according to code specifications.

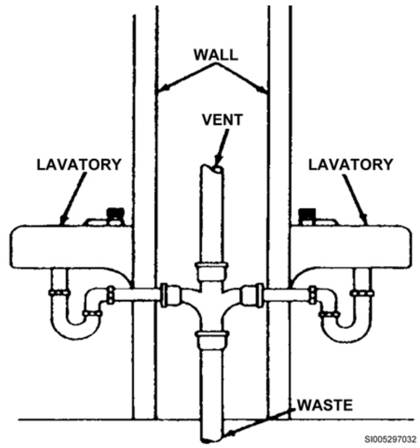

Figure 3–17. A pair of unit-vented fixtures.

Relief vent

Install a relief vent (fig. 3–18) to keep excessive turbulence that may cause negative pressure (siphoning) or back pressure from developing in the drainage system. A relief vent dissipates this *negative* pressure by introducing air into the drain that prevents siphoning of the fixture traps that are connected to the drain piping. This siphoning can create a condition that may cause a fixture to lose its trap seal. Also, negative pressure results in a vacuum condition, making the flow within the drain line sluggish. Where water flowing in a horizontal pipe changes directions quickly into a vertical pipe, there is a tendency for the water to accelerate and create negative pressure that could siphon the water out of fixture traps that are installed close to the junction of the vertical and horizontal piping. Properly located relief vents keep this from happening.

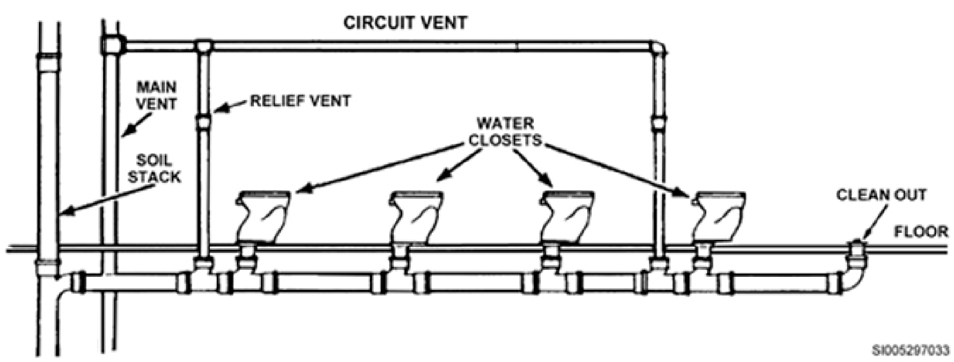

Figure 3–18. Examples of circuit and relief venting.

Circuit vent

A battery configuration is a group of fixtures in a large latrine. The most common fixtures installed in a battery configuration are W/Cs, urinals, and lavatories. A battery of fixtures usually shares a common drain and vent. It sounds simple, but to prevent vacuums and siphoning of the fixture traps, you have to use special methods of connecting the vent. One way is to use a *circuit vent* to serve two or more traps. This is a vertical relief vent pipe that rises from the drain line between the two fixtures farthest from the stack and is back-vented into a main vent (fig. 3–18). Install this vent in multistory buildings that have large numbers of plumbing fixtures and that use a main vent stack. Do not attempt to serve more than eight fixtures with a single circuit vent.

Loop vent

The loop vent is identical to the circuit vent *except* it is back-vented to the soil or waste stack vent instead of to the main vent. Use this type of vent in single-story buildings or on the top floor of multistory buildings. Figure 3–19 shows a W/C that is battery loop-vented.

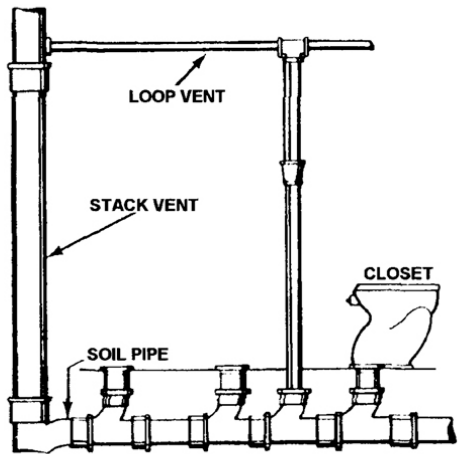

Figure 3–19. Loop vent.

Sizing

The diameter of an individual vent pipe may not be less than 1 1/4" and should not be less than half the diameter of the waste pipe to which it is connected. The diameter of a circuit or loop vent may not be less than the diameter of the soil or waste pipe for the fixture or the main vent diameter, whichever is smaller. The minimum size piping that you can use for a wet vent is 2".

Design

Build the vent pipe free of traps and connect it so any condensation or rainwater in the pipe drips back into the stack by gravity flow. The pipe that you use for vents may be cast iron, steel, copper, or plastic. Protect the seal for each fixture trap in a plumbing system from siphoning by a properly installed vent pipe. The type of vent depends on the number and location of the fixtures, the building design, and code requirements.

Locate and install fittings for vent pipe connections in the stack at the time you lay out and fabricate the stack. The fittings must have the proper-sized branch openings for connecting the vent pipe. The table in figure 3–20 shows the pipe sizes for vent lines to various types of fixtures. Plumbing codes regulate the size of pipe for a particular type of vent.

Fixture	Minimum size of vent in inches
Lavatory	1 1/4
Drinking fountain	1 1/4
Sink	1 1/2
Shower	1 1/2
Bathtub	1 1/2
Laundry tub	1 1/2
Slop sink	1 1/2
Urinal	1 1/2
Water closet	2

Figure 3–20. Individual fixture vent sizes.

432. Testing and repair

Testing and repairing a water system is very important to know when performing your duties. Within this lesson we talk about the two types of tests and the proper procedures in repairing the different types of piping and tubing.

Testing

Test soil and waste piping that are located underground before you backfill the trenches. Test portions of the system as they are constructed. Poor plumbing work is the cause of many leaks, but faulty pipe and fittings also causes trouble and must be located. These faulty parts are easily replaced if you find them before the job progresses too far. Test all waste systems with water or air. Use the water test or the air test to test new or old work that has been repaired or modified.

Water test

A water test is the simplest test to make for a drain and vent system, and it is effective in determining that the system is tight against leaks. Be careful with certain types of joints because they do not withstand as much pressure as other types. For instance, cast-iron soil pipe with hot-poured joints should not be tested for more than 10 stories. In contrast, a screwed pipe system may be tested for 15 to 20 stories at one time. Copper tubing with sweat joints can be tested up to 20 stories.

You can apply the water test to a part of a drainage system or the entire system. When you apply the water test to the entire system, close all openings in the piping tightly except for the highest stack opening. Test the system in sections. Close each opening except the highest opening of the section under test. Test no section that has less than a 10’ head of water. Keep the water in the system 12 to 24 hours to allow time for oakum joints to swell and form a watertight seal. After the soaking period has passed, refill the system with water. The system must then retain this water for 30 minutes without dropping more than 4”. Do not make water tests in parts of the country where the temperature falls below 32°F during the day. Even if you complete the tests when the temperature is above freezing, the temperature may fall later and cause the saturated oakum to freeze and crack the hub.

Air test

Some job specifications require the system to be air-tested. To perform the air test, plug all outlets, including the vents through the roof. Attach an air compressor or testing apparatus, such as the one shown in figure 3–21, to any suitable opening.

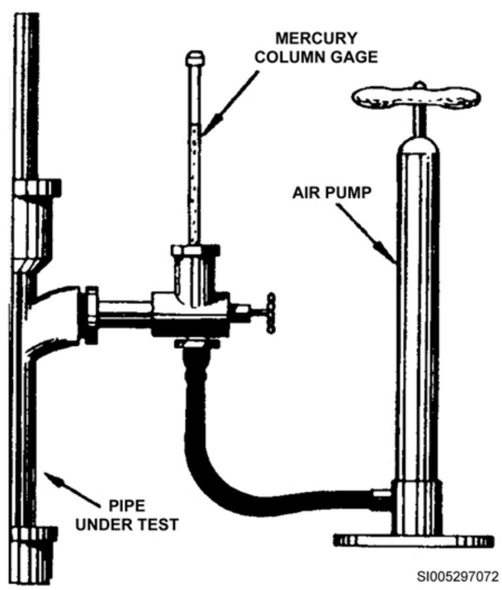

Figure 3–21. Air-testing a waste system.

Force air into the system until there is a uniform gauge pressure of 5 psi or sufficient pressure to balance a column of mercury 10” in height. This pressure should hold steady without your adding any additional air for a period of at least 15 minutes. If you find that the pressure drops, apply soapy water to the suspected leaky area. You can detect a leak by the bubbles that form where the solution has been applied.

One advantage of the air test over the water test is that the air pressure is equal over the entire system, whereas, during the water test, the pressure is greatest at the lowest point. Another advantage is that you can perform the air test in freezing weather when you cannot do the water test. An air test is somewhat more rigid than the water test. However, it is more difficult for you to find the leaks with the air test unless you use soap and water on the joints or inject some odor or scent into the pumped air.

Repairing leaks

As a WFSM journeyman, you must know not only how to test a waste system but also how to repair it if you discover a leak while making the test. Waste systems are made of different materials, all of which you cover in the following paragraphs. First, let us discuss repairing leaks in cast-iron soil pipe.

Cast-iron systems

Leaks in cast-iron systems usually occur at a joint. If the joint is caulked, try to recaulk it. Be sure to drain the water level down below the leaking joint before you make the repair. Never attempt to repair a fitting by welding, brazing, or any other such means. Instead, remove the faulty fitting and the pipe that connects to the hub end of the fitting and replace the faulty fitting with a serviceable one. Be sure you support and brace the piping, especially vertical pipe runs, before you remove a section from the system for repair. This precaution keeps the remaining pipes from moving or shifting, which could cause strain or damage to other joints. In some cases, it may be possible for you to replace leaking caulked cast-iron pipe and fittings with no-hub pipe, fittings, and couplings.

Threaded pipe joints

When you detect leaks in threaded pipe joints, it is usually necessary to remove and reinstall the piping. Rarely can you correct leaks by tightening the joint because as the thread on one end is tightened, the thread on the opposite end of the pipe is backed out and probably causes a leak on that end. Also, never attempt to close a leak in a threaded joint with pipe compound. To stop the leak, you must get the compound between the threads of the pipe and fittings and tighten the joint. You can use a pipe cutter to cut out sections of the piping so the joints can be properly tightened. Replace the piping and make the final joint with special connectors. Never use pipe unions when repairing leaks in waste or vent piping.

Copper tubing

Most of the leaks in a waste system made of copper are located at the joints. After you locate the leak, your first step in repairing it is to drain the system. Next, take the leaking joint apart by heating the joint with a torch until the solder melts. Clean the inside of the fitting and the outside of the tubing, apply flux, and re-solder the joint. Make sure you do not melt the solder in the joints that are not leaking. To prevent this from happening, apply a wet rag to the joints to keep them cool.

Plastic pipe

The leaks in a waste system made of plastic pipe and fittings are usually found at the solvent weld joints. As you know, when you locate a leak, you have to replace the fitting. You cannot fix the leak by applying plastic pipe cement to the outside of the leaking joint. Cut the pipe that leads to each connection of the fitting and remove it from the system. To install a new fitting, glue a short piece of pipe into each end of the new fitting. This piece of pipe replaces the section that was cut out when you removed the leaking fitting. Check to see if the pipe and fitting fits into the opening. If the assembly fits, glue it into the system using couplings, and then test for leaks.

Clay pipe

Only use clay pipe for underground construction. Most leaks in clay pipe occur because the pipe deteriorates and pressure causes it to crush. Leaks also occur at bad joints and in places where tree roots have infiltrated the pipe. In most cases, remove the pipe and replace it with new piping.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

430. Drains

1. Where does the building drain end?

2. Why are cleanouts provided in a building drain?

3. What determines the location of the building drain?

4. What is the smallest size building drain that can accommodate a W/C?

431. Stacks and vents

1. What is a stack?

2. What type of stack carries the discharge from urinals and W/Cs?

3. What type of stack carries no human waste?

4. What is the smallest size soil stack that can be used with a W/C?

5. What is the minimum distance a vent terminal should be located from a door or window?

6. What is the smallest size main vent that may be used?

7. What type of vent is installed to keep excessive turbulence from developing in the drainage system that may cause negative pressure (siphoning) or back pressure?

8. What type of vent is used with a battery of fixtures and ties back into the main vent?

432. Testing and repair

1. How do you complete the water test?

2. How much air pressure is required to perform an air test?

3. How can a leak at a threaded joint be repaired?

4. How would you replace a leaking plastic fitting?

3−3. Inspection and Maintenance

Inspect and maintain sewer systems on a recurring basis to avoid emergencies in the future. Checking manholes allows you to determine if there is a partial flow of sewage. A well-maintained sewer system eliminates most of the overtime work that results from main sewer stoppages. By this point in your career, you most likely have been introduced to after-duty-hours sewage stoppages, some of which can be prevented with a good maintenance program.

433. Stoppages and leak detection manholes

Manholes are the primary means of inspecting and maintaining the sewer system. Sewer mains are constructed with manholes that allow access to the sewer main. Manholes are usually located either in the center of a street or close to the sidewalk. Manholes are covered with a heavy round iron lid to prevent unauthorized entry. All of the work you do when cleaning a main sewer is done through a manhole.

Manhole conditions

Since a manhole cover may weigh anywhere from 50 to 100 pounds, use a manhole hook to help you remove it. Always use correct lifting procedures when removing covers—lift with your legs, not your back—and do not forget to get your toes out of the way, in case you accidentally drop the cover. This is one good reason you should always wear safety-toe shoes. If snow, ice, or other conditions make the ground around the manhole slippery, use a shovel, broom, or anything you need to ensure you have good, solid footing before you try to lift the cover. *Never* hit a manhole cover with a steel or iron tool. The sparks that might be created could cause a flash fire or a sewer gas explosion. *Never* use a torch or other open-flame device to remove ice from a manhole cover. Use only bronze, nonsparking tools to remove ice from the cover.

Sewer gases such as hydrogen sulfide, methane, and gasoline fumes from leaking underground gas tanks can build up in a manhole. There are also instances where an oxygen-deficiency condition can be present in a manhole. To be safe, you must either ventilate the manhole or use a self-contained breathing apparatus (SCBA). Your base has very specific procedures to follow before entering a manhole. Be sure to receive this training and certification before doing this type of work.

Methods of checking for flow

After it has been determined that the sewer is safe, begin inspection and maintenance operations. Some of the things you should look for are deposits of grease, paper, rags, tree roots, and sticks. Any of these can cause the sewer main to stop up. One way you can detect obstructions and leaks in the main sewer is by observing the flow at the manholes. You can check for obstructions and leaks between the manholes by performing the following steps:

1. Plug off a section of sewer main at the manhole with a pneumatic plug inserted in the effluent side of the manhole.
2. Fill this section of sewer line and manhole with wastewater.
3. Remove the plug and observe the rate of flow at the next downstream manhole.

A slow rate of flow at the next downstream manhole indicates that there is an obstruction or a leak in the line between the two manholes. In contrast, a fast rate of flow at the next manhole indicates that there are no obstructions or leaks in the line between the two manholes.

Another way for you to detect restrictions or leaks between manholes is to compare the level of sewage at one manhole with the level of sewage at the next manhole downstream. If the level of sewage at the upstream manhole is greater than the level of sewage at the downstream manhole, there is some restriction or leak in the line between the two manholes.

434. Interior drains

When sanitary sewers are not overtaxed and do not back up into buildings, you can interpret any rise of sewage through a floor drain as indicating a stoppage either in the house drain or in the house sewer.

Unstopping building sewers

The cleanout for the building sewer normally is located just outside the building foundation. This is your starting point for using an electric sewer auger or a flat steel snake (sometimes referred to as a “ribbon snake”) to clear the stoppage.

Flat sewer snake

The flat sewer snake, shown in figure 3–22, is one of the simplest tools that you can use to loosen obstructions in a building sewer. These snakes are made of steel ribbon that varies from ¼” to 1½” in width and $^{1}/_{16}$” to $^{1}/_{8}$” in thickness; lengths range up to 200’. The ½” width is suitable for pipes up to 3” in diameter, while the ¾” width is suitable for pipes up to 4” in diameter. The flat-type sewer snake either has a handle with an automatic grip (fig. 3–22) or one that is locked with a screw. This handle slides along the snake as it is pushed into the drain or sewer.

To use a flat sewer snake to dislodge a stoppage in a sewer line, insert it into the line through the cleanout plug or some other convenient opening. Feed the snake into the sewer, using a back-and-forth movement. When the snake will not feed any further, its head is probably up against the stoppage. Work the snake back and forth until you punch through the stoppage.

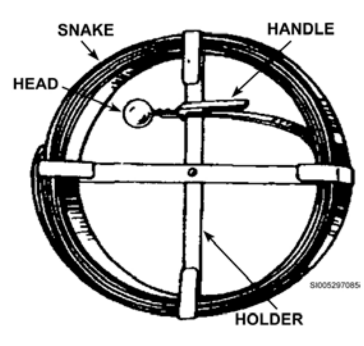

Figure 3–22. Flat sewer snake.

Power sewer auger

The electric sewer auger (fig. 3–23) is ideal for cleaning building sewers. This auger is equipped with an assortment of heads: (1) saw cutter, (2) corkscrew, (3) knife cutter, (4) drop head, and (5) pickup head. This machine is also equipped with a foot control that leaves both of the plumber's hands free to guide the auger. Again, the type of auger head you use for a particular job depends upon the obstruction to be removed.

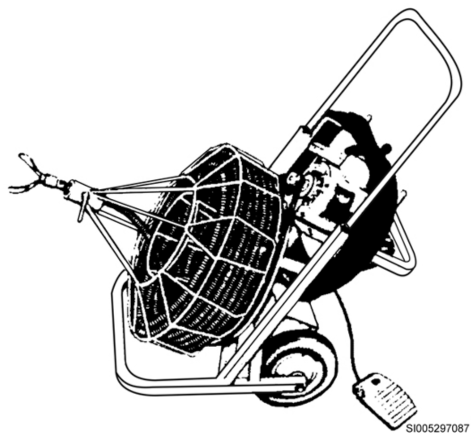

Figure 3–23. Power sewer auger for building sewer.

CAUTION: Always make sure the machine is properly grounded, and read the manufacturer's instructions before using it.

Ounce of prevention

Periodic inspection of interior piping systems prevents undesirable conditions and costly repairs. Loose, broken, or missing pipe supports permit waste pipes to sag, causing undue stress on joints. Sagging pipes alter the pipe grade, which, in turn, changes the drainage flow. Solids settle in the low area and eventually cause slow drainage or clogging. Leaks in waste systems inside a building are *definitely not* acceptable.

Clogged vents often cause fixture drains to operate slowly. Water may be siphoned from the trap due to vent stoppage. This allows sewer odors and gases to be vented through the fixture drain. Vents may be clogged by debris that was backed up from a previous line clogging. Birds attempting to nest in the vent terminal may also cause poor venting. The vent pipe itself may have been damaged, thus restricting its venting capability.

The most common problem area you may find when inspecting mess facilities' building drains is missing floor drain covers. When the floor drain covers are missing, foreign objects and debris may fall or be swept into the drain, thereby causing stoppages. Be sure to replace the floor drain covers immediately.

When waste pipes from sinks, laundry traps, bathtubs, lavatories, and urinals are correctly sized and sloped, and when standard traps are installed, drainage systems do not become readily clogged with grease, lint, hair, and other materials. Most clogging results from particles of food, lint, and hair that collect in the strainers. Thus, the rate the water discharges is reduced to a sluggish flow, which allows foreign matter to settle in the horizontal pipes rather than being swept on through the system by the stream of water. Never discard fats, greases, or oils in a sink unless the system has a grease trap and the trap is properly maintained. Collected fats, as well as hardened crusts scraped from cooking utensils and leftover bits of food in cans, should be thrown away with the garbage.

The most effective method of preventing stoppages from congealed grease that is carried into the drain of a dishwasher is to run a large amount of scalding water through the pipe for a period of at least 2 or 3 minutes after each dishwashing. Floor drains are often clogged by floor sweepings and lint from washing clothes. Normally, the strainers are not fine enough to stop floor sweepings and lint. Do not place sweepings in the trap. Clean the screens often to protect the trap from clogging.

Clogging of urinal drains is a problem because careless individuals drop chewing gum and cigarette butts in the urinal. Enough of this material can get through the screen and cause a stoppage. You can install a smaller screen to stop the chewing gum, but the cigarette butts can dissolve and go through the screen and soon cause a stoppage in the trap.

Unstopping drains

You can use several methods to open clogged drains. These methods include the use of boiling water, vacuum plungers, plumber's snakes, and chemicals. All of these methods take time, and each requires a certain procedure to do the job.

Precautions are necessary when using chemicals, because they can burn your skin. Usually, when a fixture drain clogs, it is best to try to clear it by using the simplest methods first. These may include the use of the vacuum plunger and hot water. If these methods fail, you may have to use chemicals—that is, if the waste flow is not totally restricted. If the flow is totally restricted, you may have to partially disassemble the system and use appropriate sink or sewer snakes to clear it. After the stoppage is cleared, clean the waste lines by flushing them with hot water.

Using a sink snake

If you cannot remove the stoppage from the drain with a vacuum plunger, you may have to use a sink or sewer snake to dislodge the stoppage. These snakes are constructed of coiled, tempered wire that is extremely flexible. They are generally 15–25' long and have a diameter of approximately ¼". A crank on the snake allows you to rotate it as you push it into a clogged drain. As you can see in figure 3–24, a sink snake is housed in a top-like container. This unit is also called a top sewer snake.

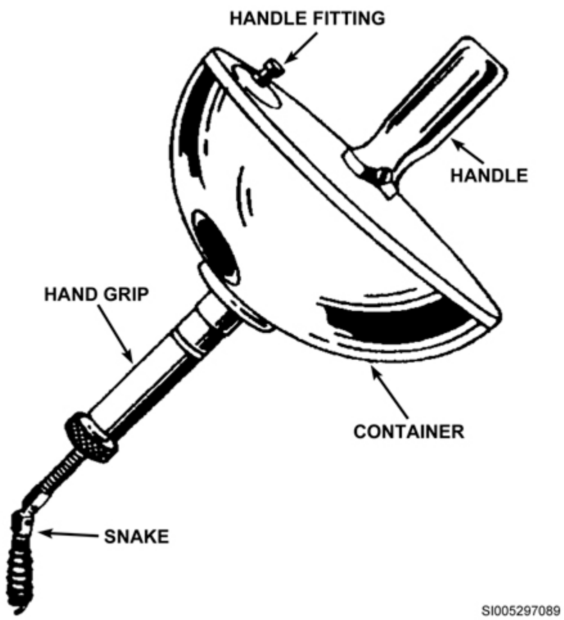

Figure 3–24. Top sink snake.

When you use this snake, rotate the top in a clockwise direction as you push the snake into the drain. In some cases, you may have to remove the trap and elbow from the drain before pushing the sewer snake into it. Push the snake down the drain and rotate it; then feed it further and rotate it again, being careful not to kink the cable. Continue this operation until you have pierced the obstruction. Usually it is impossible for you to remove an obstruction from a pipe with a snake. However, after you bore a hole through the obstacle, you can flush it down the pipe with hot water or apply the chemical treatment.

Figure 3–25 illustrates a power-driven auger used for cleaning lavatory and sink drains. In some cases, you find that plungers and sink snakes do not open a lavatory, bath, shower, or floor drain that is clogged with hair. In these cases, disassemble the drain and remove the hair from the screens, traps, or the base of pop-up stoppers on lavatories. Sometimes you can reduce the need for this disassembly by using a length of wire. Bend one end to form a small hook and fish the foreign matter from the drains. If the system has a screen, remove it and simply pull the hair from the screen.

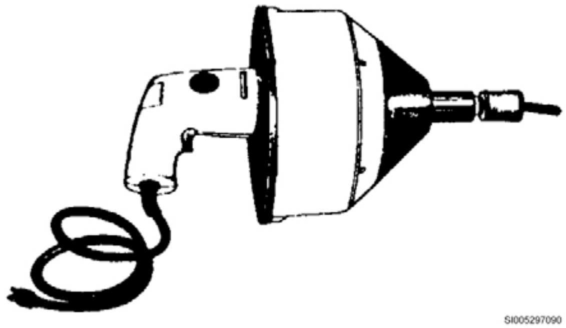

Figure 3–25. Power auger.

Using chemicals

If you find that scalding water does not open a slow drain, use a strong chemical cleaner. Most of these cleaners consist of sodium hydroxide (caustic soda). Sodium nitrate and aluminum turnings are also used, in which case ammonia gas is formed to dissolve the grease. Be aware that the use of lye (caustic soda) alone frequently adds to the grease accumulation more rapidly than can be removed by water. In such cases, the stoppage is increased because the lye and grease combination form a soapy jell. After you place the chemical in the drainpipe, it effervesces (bubble, hiss, and foam) violently and produces considerable heat. When this occurs, do *not* use a plunger to hasten the removal of the grease or other accumulation. Instead, allow the chemical sufficient time to dissolve the foreign matter.

CAUTION: Handle all drain-cleaning chemicals with great care to avoid getting the solution on your hands, arms, or face. They are extremely caustic. Also, avoid splashing the chemicals on your clothes or skin, on wood, painted surfaces, or aluminum. If the former happens, flush the affected area with water and see a physician as soon as possible. If the latter occurs, wash the material's surface with cold water, immediately apply vinegar, and, finally, rinse it with cold water.

Do not use a chemical cleaner in drainpipes that are clogged completely because a slight flow is necessary to carry the chemical down to the point of obstruction. To be effective, the chemical must be in contact with the stoppage. Consequently, by pouring the chemical into a sink drain, you are merely letting most of it settle in the trap. Your best approach is to remove the trap and insert the chemical into the pipe itself, beyond the trap.

Use about a quarter of the contents of a can of chemical at a time and, at intervals, wash it down the pipe using about a quart of hot water each time. Replace the trap each time and, after about 15 minutes, check to see whether the water drains any faster. You sometimes find that repeated chemical treatments are necessary to open the line. After you obtain good drainage, flush the pipe with scalding water for about 5 minutes.

Opening clogged traps

You can easily open traps that are fitted with clean-out plugs. To open the trap, remove the clean-out plug and pull the contents through the clean-out hole with a bent wire. Flush the trap with hot water before you replace the clean-out plug. Traps that do not have a clean-out plug are a little more difficult to open. Often chemicals, plungers, or sink snakes are required to remove the more stubborn types of stoppages.

You can clear minor stoppages of the W/C trap with a force cup. However, the more stubborn types of stoppages are removed with a tool called a closet auger, the operation of which is illustrated in figure 3–26. The cane-shaped tube, with a coiled-spring snake inside it, is equipped with a handle that is used to rotate the coiled hook on the end of the snake. To insert the closet auger into the trap of the W/C, first, retract the coiled spring all the way up into the cane-like curve of the closet auger. Hook the cane end with its projecting hook into the trap as shown in figure 3–26. Next, turn the handle clockwise to rotate the coiled spring as you push the auger down into the trap of the W/C. Rotate the handle continuously until the snake reaches the obstruction in the bowl. Then, turn the handle clockwise slowly until the obstruction is caught on the coiled hook of the closet auger. Continue rotating the handle clockwise and pull back at the same time to bring the obstruction up into the W/C. Once the obstruction is in the W/C, remove it by hand.

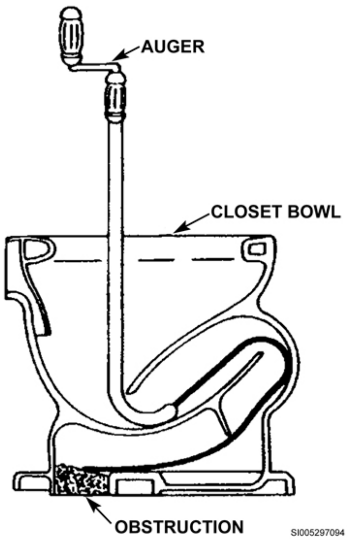

Figure 3–26. Using a closet auger to clear a W/C trap.

Never assume that the W/C is clear after one object has been removed. Instead, insert the closet auger a second time, and repeat the operation until the closet auger passes down into the closet bend and branch. Then withdraw the closet auger. Finally, put several large wads of toilet paper into the W/C and flush them through the fixture to make sure that it is completely open.

If you are not able to remove the stoppage in the W/C trap with a closet auger, remove the W/C, turn it upside down, and remove the stoppage with the closet auger through the bottom opening. If the stoppage is beyond the W/C trap, remove the W/C and run a snake down the drain. Figure 3–27 illustrates a typical power-driven auger that is used for cleaning 2–4” drains. Of course, always check the manufacturer’s instructions before using power-driven drain-cleaning equipment for the first time.

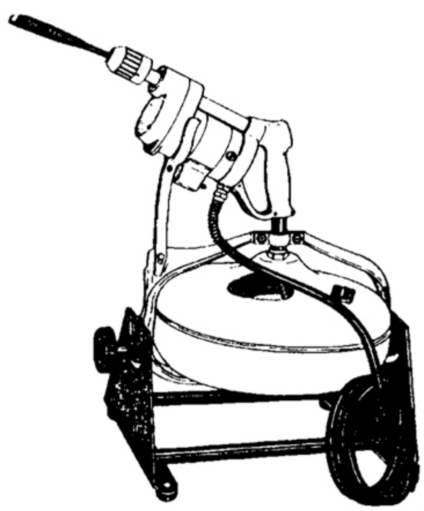

Figure 3–27. Power-driven auger for building drains.

435. Exterior sewer mains

Two types of maintenance are normal for main sewers and are of concern to you: (1) recurring and (2) emergency maintenance. Schedule recurring maintenance on an annual basis. The time of year you perform this type of maintenance depends upon the geographical location. For example, in areas where the snowfall is several feet annually, it would not be practical to perform recurring maintenance in midwinter. This is not so much because of the extreme cold weather, but because of the time it would take to locate and remove the snow from the affected manhole covers.

Process

During recurring maintenance, check for flow levels and debris in the manholes. Should you find a partial stoppage, remove it either with a power sewer auger (fig. 3–28) or with a pressure sewer-cleaning machine (fig. 3–29). Flushing sewer mains by adding additional water with a fire hose or a tanker truck, as illustrated in figure 3–30, also helps keep the sewer in better operational condition throughout the year.

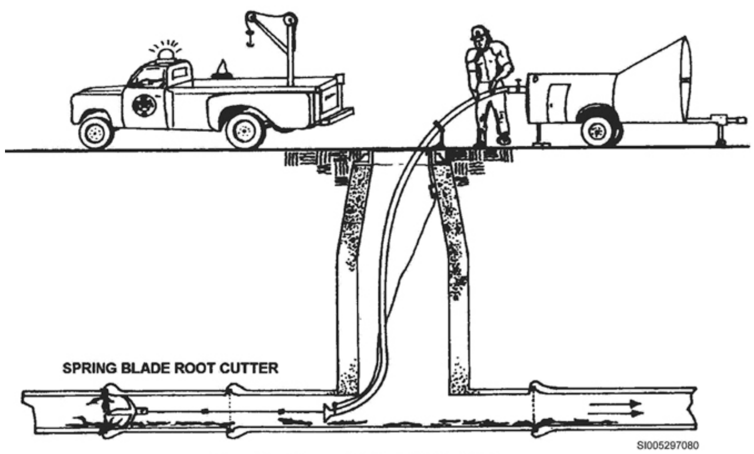

Figure 3–28. Power sewer auger with root cutter attachment.

In contrast, emergency maintenance may be required at any hour of any day. For example, sewers may be broken by equipment or by the shifting of earth at any time or during any season. Also, they may become clogged by roots, sand, grease, and wood debris. These are just a few of the problems that may confront you.

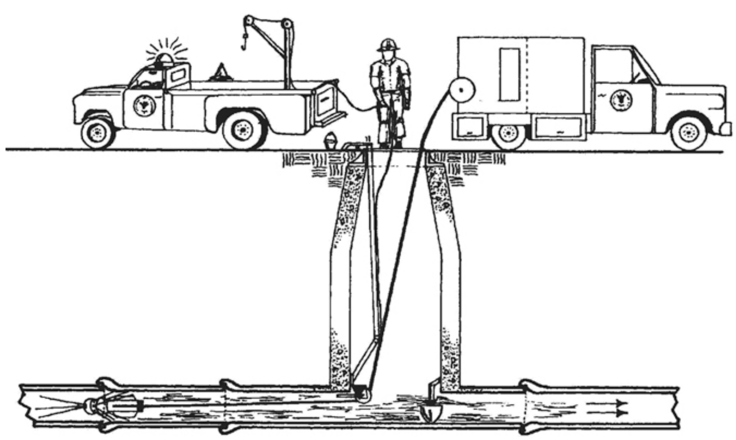

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Figure 3–29. Jet rodder machine in operation.

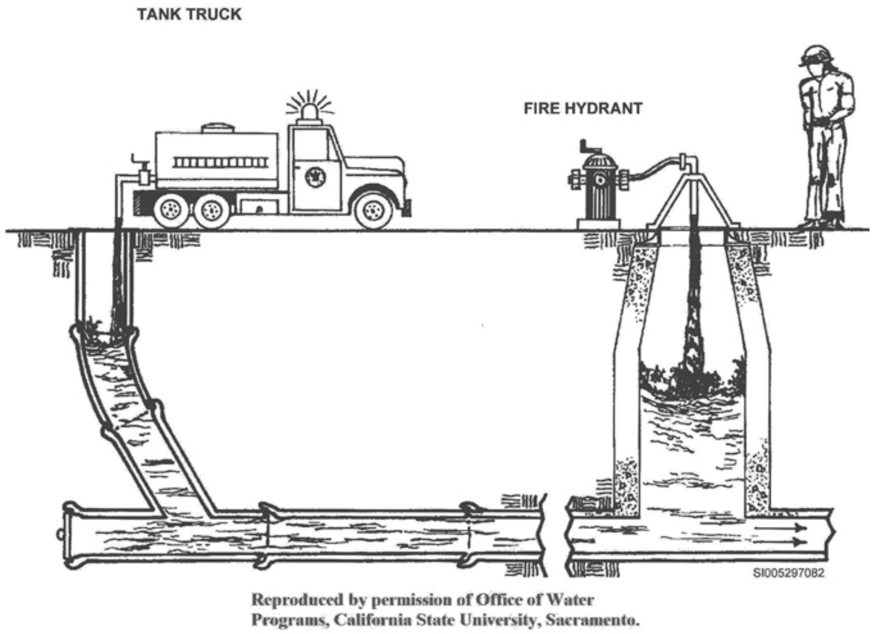

Figure 3–30. Flushing sewer mains with water.

Using a sewer auger

Once you have determined the actual trouble, make the necessary repairs. Let us say that you have found a restriction or stoppage in a main sewer. This can be removed with a sewer auger (fig. 3–28) and the proper auger attachment heads shown in figure 3–31. This machine consists of a J-tube, rod sections, an assortment of heads, a gasoline engine, and various hand tools that are used for changing heads and removing broken rod sections. The round stock corkscrew head is used for rodding where conditions in the main (cause of clogging) are unknown. The auger head is useful for cutting long, stringy roots and loosening up sedimentary deposits in the pipe. The spring blade root cutter chuck is mainly used in preventative maintenance work because the high velocity of the blades has a scouring effect on the inner walls of the pipe. The type of head you use depends upon the type of obstruction encountered. Generally, you use a hook to retrieve rags and a saw-type cutter to cut and remove roots.

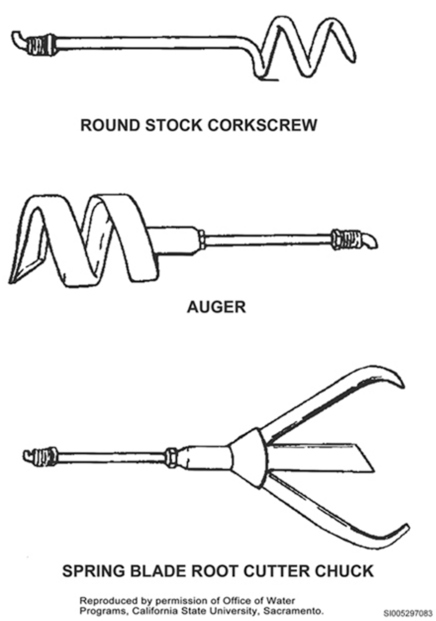

Figure 3–31. Types of power rodder heads.

The J-tube is used as a guide when you insert the rod into the main sewer. Set up the machine at a manhole downstream from the obstruction. Extend the rod using the power feed until it reaches the obstruction; meanwhile, the drum rotates clockwise. Once the head has reached the point of obstruction, slow the feed and cut through the stoppage at a slow, even speed. When retrieving an obstruction, slowly rotate the drum clockwise with the feed lever in reverse. This keeps the obstruction from slipping off the head.

Sewer augers are ideal for removing stoppages in collection systems during emergencies because they do not take long to set up. They do have some limitations and disadvantages. First, the rod tends to coil and bend if the machine is used in large-diameter mains. Second, there is always a potential for twisting a rod off and leaving it in the main. Power rodders are ideal for branches and laterals as opposed to large sewer mains.

NOTE: Always use caution when using sewer augers because the large diameter rod can cause serious injury if you are not properly trained.

Using a water-pressurized cleaning machine

These machines are called “sewer jets” because the rod (now a hose) is propelled by the jet action of pressurized water. Jet rodder machines are extremely versatile pieces of sewer line equipment. The machine is set up at the manhole downstream from the stoppage in the main. An adequate length of hose is initially reeled out to reach the pipe opening in the manhole. Next, tether the plastic J-tube over the pressure hose to a spot 3–5’ above the nozzle. The J-tube is like a 3” suction hose called a bumblebee because it is striped black and yellow. Next, grab the hose from up top and swing it into the opening of the pipe, inserting the nozzle at least 1’ into the pipe. The bumblebee is then lowered to the opening of the pipe and tethered so that it will stay fixed once the hose starts to go deeper into the pipe. The bumblebee is very important because it protects the hose from sharp edges as it travels down the sewer main.

Once the machine is started, the hose is propelled forward into the pipe by the reverse jet action of the nozzle (fig. 3–32). Once the nozzle is at least 10’ into the pipe, the pressure is increased. The object now is to let the nozzle (and hose) travel in the pipe as fast as possible so that the stainless steel nozzle has enough momentum to dislodge the obstruction. Sometimes the stoppage is not dislodged this easily. If the nozzle hits the obstruction and will not pass through it, reel the hose back 10–15’ and hit the obstruction repeatedly until the nozzle goes past it.

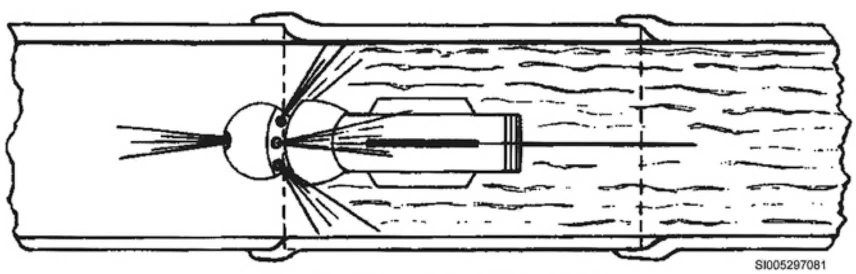

Figure 3–32. Jet action of nozzle in the pipe.

Once the obstruction is dislodged, let the hose go forward at least 15’ upstream of the obstruction and reel the hose back in under pressure. This accomplishes two things: it cleans the line backwards towards the manhole and it rolls up the hose under pressure. Do not reel the hose back up *unless* it is under high pressure, because failing to do so will cause the hose to “loop” very loosely on the reel, preventing you from rolling in all the remaining hose onto the reel assembly. It is also a very good practice to place colored tape on the hose at 10’ intervals from the nozzle backwards. Place one band at 10’, two bands at 20’, and three bands at 30’. This way, you will know just how close the nozzle is to your face when you are reeling it back in.

Some sewer jet machines are installed on a truck platform already equipped with a vacuum pump, suction hose assembly, and a 2,000-gallon recovery tank. These trucks are called “vactor” trucks. This type of equipment is rather complicated to operate and very easy to break. Since this type of equipment is *very* expensive and easy to break, it is best to have only thoroughly trained operators assigned to it. It is also a good safety practice to employ three workers while using this equipment. Of course, follow the manufacturer’s instructions any time you operate sewer-cleaning equipment.

Repair of broken sewer mains

To repair broken sewer mains, block off the pipe to be repaired with sandbags or preferably with an inflatable sewer pipe plug. Always be sure to have some means of removing the plug. Usually, you tie a rope around the plug in such a manner that it will not slip off the bag and can easily be retrieved once the air is let out. Always plug the sewer pipe on the outlet side of the manhole. Make the necessary repairs once you have blocked the flow of sewage and diverted it to another manhole. The repairs usually consist of removing and replacing one or more lengths of pipe. Remember to use good safety practices when excavating and backfilling.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

433. Stoppages and leak detection

1. What should you do before you enter a manhole?

2. How can you check for obstructions between manholes?

3. If the sewage level at the upstream manhole is higher than the level in the downstream manhole, what could this indicate?

434. Interior drains

1. What type of equipment can you use to unstop a building sewer?

2. What precautions should you observe when you use an electric sewer auger?

3. What can cause a sluggish flow of water in a horizontal waste pipe?

4. What can cause floor drains to become clogged?

5. Under what conditions would you not use a chemical cleaner to unstop a drain?

6. What tool should you use to remove a stubborn stoppage from a W/C?

435. Exterior sewer mains

1. What are the two types of sewer maintenance?

2. When you use a power sewer auger, why do you use the J-tube?

3. How far do you let the jet rodder nozzle travel after dislodging the obstruction?

4. Where should you place colored bands on the jet rodder hose and what is the reason for the bands?

5. How can you block the pipe when you have to repair a sewer main?

Answers to Self-Test Questions

427

1. Building sewer, lateral and branch sewers, main sewers, trunk sewers, interceptor sewers, manholes, lift stations, wastewater treatment plants, outlet (outfall) sewers.
2. The building sewer.
3. To convey wastes received from lateral and branch sewers to trunk sewers.
4. To convey highly polluted wastewater to a separate “industrial treatment plant,” where all harmful chemicals are removed or neutralized.
5. To allow maintenance personnel and their equipment access to the collection system.
6. Proper size, slope, and lack of obstructions.
7. The wastewater will have a tendency to leave solids behind.
8. Not less than $^{1}/_{4}$” per foot.
9. 2 fps.
10. Obstructions create two kinds of stoppages: complete and partial. In partial stoppages, the main is restricted somewhat but is still flowing enough that complaints don’t come in—yet.

428

1. Process an AF Form 103.
2. Grading a trench with a fall in slope so that a sewer pipe can be laid in a trench with the outlet of the pipe being lower than the inlet, thus allowing gravity flow.
3. ¼” per foot.
4. Using an engineer’s transit or a fixed-beam laser.
5. 1’.

429

1. 2–10’ from a building foundation.
2. Remove a section of the sewer main and install a precast fitting, or tap into the sewer main and make a fitting called a thimble.
3. At the precast fitting or the thimble, working towards the building drain.
4. So that the entire length of the pipe lays on a firm bed, not just the bell ends.
5. Sewage lift stations.

430

1. 2’ outside the building wall or foundation.
2. To simplify clearing away obstructions.
3. The location of the main stack and the location of the house sewer.
4. 3”.

431

1. The vertical main pipe in a plumbing waste system.
2. A soil stack.
3. A waste stack.
4. 3”.
5. 10’.
6. 1¼”.
7. Relief vent.
8. Circuit vent.

432

1. Close all openings in the piping tightly except for the highest stack opening. Test the system in sections. Close each opening except the highest opening of the section under test. Test no section that has less than a 10’ head of water. Keep the water in the system 12 to 24 hours to allow time for oakum joints to swell and form a watertight seal. After the soaking period has passed, refill the system with water. The system must then retain this water for 30 minutes without dropping more than 4”.
2. 5 psi.
3. Cut out sections of the piping so the joints can be properly tightened. Then replace the piping and make the final joint with special connectors.
4. Cut the pipe going to each connection of the fitting and remove it from the system. To install a new fitting, glue a short piece of pipe into each end of the new fitting. This piece of pipe replaces the section that was cut out when you removed the leaking fitting. Check to see whether or not the pipe and fitting will fit into the opening. If the assembly fits, then glue it into the system, using couplings, and test for leaks.

433

1. To be safe, you must either ventilate the manhole or use a SCBA.
2. Performing the following steps:
   (1) Plug off a section of sewer main at the manhole with sandbags or a pneumatic ball.
   (2) Fill this section of sewer line and manhole with water.
   (3) Remove the plug and observe the rate of flow at the next manhole.
3. There is some restriction in the line between the two manholes.

434

1. Electric sewer auger or a flat steel snake.
2. Always make sure the machine is properly grounded, and read the manufacturer’s instructions before using it.
3. Foreign matter settling in the pipe.

4. Foreign objects and debris may fall or be swept into the drain.
5. Drain pipes that are completely clogged.
6. Closet auger.

435

1. (1) Recurring.
   (2) Emergency maintenance.
2. As a guide when you insert the rod into the main sewer.
3. At least 15’.
4. 10’, 20’ and 30’. The colored bands tell you how close the nozzle is getting to your face when you are reeling back in the hose.
5. With sandbags or with an inflatable sewer bag.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

46. (427) For a sewer main to operate properly, its flow should be how many feet per second (fps)?
    a. 1.
    b. 2.
    c. 3.
    d. 4.

47. (428) Which measurement is the desired fall for a 3-inch (”) house sewer?
    a. ⅛” per foot.
    b. ¼” per foot.
    c. ½” per foot.
    d. 1 $^{1}/_{16}$” per foot.

48. (428) How should you backfill a trench?
    a. Manually backfill and tamp when full.
    b. Backfill with a backhoe and tamp when full.
    c. Backfill in layers of not more than 12 inches (”) and tamp by hand.
    d. Backfill in layers of not more than 4” and tamp with a mechanical tamper.

49. (429) What is the name of a short piece of pipe with a hub on one end and a straight cut or 45 degree (°) cut on the other that is used to tap into a sewer main?
    a. Elbow.
    b. Union.
    c. Thimble.
    d. Coupling.

50. (429) Which structural component of a sewage lift station carries wastewater to the nearest manhole that can continue gravity flow?
    a. Pump.
    b. Force main.
    c. Pump discharge.
    d. Wet well suction inlet.

51. (429) Which type of sewage lift station houses the pumps and motors in a different compartment than the one that receives the wastewater?
    a. Dry well.
    b. Wet well.
    c. Dry pit.
    d. Wet pit.

52. (430) What are the two *correct* classes of drainage piping?
    a. Soil and waste.
    b. Soil and plastic.
    c. Plastic and steel.
    d. Steel and waste.

53. (430) The discharge capacity for one fixture unit in a drainage pipe is
    a. 7.5 gallons per minute (gpm).
    b. 15 gpm.
    c. 30 gpm.
    d. 50 gpm.

54. (430) To know the *minimum* size of a building drain, which reference should you follow?
   a. Determine the number of fixtures and multiply by 7½.
   b. Determine the total drainage fixture units for a building; then use the *Uniform Plumping Code* (*UPC*) to determine the drain size.
   c. Multiply the fixtures values by 7½, then add them all up and look up the right size pipe in the *UPC*.
   d. Multiply the total fixture unit values in the building; then divide total by 7½ and look it up in *UPC*.

55. (430) What is the purpose of cleanout plugs?
   a. Allow cleaning of water closet (W/C) traps.
   b. Plug the drainage system and allow for cleaning downstream.
   c. Allow access into the pipe and simplify clearing away obstructions.
   d. Stop the flow in the system and allow cleaning upstream from the building sewer.

56. (431) How does a soil stack differ from a waste stack?
   a. A soil stack is horizontal piping; a waste stack is vertical piping.
   b. A soil stack is vertical piping; a waste stack is horizontal piping.
   c. A soil stack carries the human fecal discharge of water closets (W/C), urinals, or other similar fixtures to the building drain; a waste stack carries waste that is free of fecal matter from all fixtures.
   d. A waste stack carries the human fecal discharge of W/C, urinals, or other similar fixtures to the building drain; a soil stack carries waste that is free of fecal matter from all fixtures.

57. (431) The *smallest* main vent that may be used on a 4-inch (”) soil stack is
   a. 1¼”.
   b. 1½”.
   c. 2”.
   d. 3”.

58. (431) What is the *minimum* pipe size that you can use for a wet vent?
   a. 1¼ inch (”).
   b. 1½”.
   c. 2”.
   d. 3”.

59. (432) How many pounds of pressure are required on an air test?
   a. 5 pounds per square inch (psi).
   b. 10 psi.
   c. 15 psi.
   d. 20 psi.

60. (432) Identify one *advantage* of the air test over the water test.
   a. Pressure is more stable.
   b. Air pressure is easier to detect than water.
   c. Air pressure is equal over the entire system.
   d. More air pressure can be applied to the system than water pressure.

61. (433) Identify the device that is appropriate for use when removing ice from a manhole cover.
   a. Torches.
   b. Iron tools.
   c. Steel tools.
   d. Nonsparking tools.

62. (433) When the level of the upstream manhole is *greater* than the level of the downstream manhole, this indicates that
    a. this is a normal condition.
    b. there is a restriction or leak between the manholes.
    c. there is a restriction or leak below the two manholes.
    d. there is a restriction or leak above the two manholes.

63. (434) What is the *most common* problem found when inspecting mess facilities?
    a. Slow drains.
    b. Clogged vents.
    c. Main sewer stoppages.
    d. Missing floor drain covers.

64. (434) Chemical drain cleaners are appropriate when the drains are
    a. flowing sluggishly.
    b. completely stopped up.
    c. completely clogged with hair.
    d. completely clogged with grease.

65. (435) When do you perform *recurring* maintenance on a sewer main?
    a. Monthly.
    b. Quarterly.
    c. Biannually.
    d. Annually.

66. (435) Which factor determines the type of head you should use on a power rodder?
    a. Obstruction to be removed.
    b. Manufacturer's instructions.
    c. Length of the building drain.
    d. You use the one that's already attached.

67. (435) Which cause or device propels the nozzle of a jet rodder throughout the length of a sewer line?
    a. Hydraulic lever.
    b. Hose reel assembly.
    c. Clockwise action of the drum.
    d. Reverse jet action of the nozzle.

68. (435) To repair a broken sewer main, where should you block off the manhole?
    a. Inlet side.
    b. Outlet side.
    c. Gravity side.
    d. Pressure side.

Please read the unit menu for unit 4 and continue ➔

Unit 4. Plumbing Equipment and Components

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437. Water closets 4–4
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THIS UNIT deals with the practical aspects of your trade. You will probably spend most of the time installing and repairing these components of the plumbing system. The lessons in this unit are designed to teach the fundamentals, so be sure to use the manufacturer's manuals that came with a specific piece of equipment.

4−1. Fixtures

In this section, you will learn about the most common types of fixtures and their installation methods. Installing fixtures takes precise measurements and attention to detail throughout the installation process. Remember, replacing plumbing fixtures is fairly simple if the initial installation was done correctly.

436. Installing lavatories

When you install a lavatory, it will be a flat-rim or wall-hung type. Because of the different types, it is important you have the manufacturer's rough-in specifications.

Lavatory location

To find the location for a lavatory, use the plumbing blueprint or the floor plan to show where the fixtures are to be located in the building. If the job is so small that not even a floor plan is available, determine the best location of the fixture with the help of the personnel who are to use it. You must also know the type and the number of fixtures to be installed so that you can determine the drain and vent location.

Locating the drain and vent

The manufacturer's rough-in specification sheet has all the information needed to rough in a lavatory drain and vent. A sample specification sheet is shown in figure 4–1. Notice that everything you need to know about this lavatory is on the drawing. The width of this particular lavatory is 20"; the depth is

18”. The recommended height from the finished floor to the rim is 31”. All of this is important information; but at this point, you are mainly interested in the drain-opening location. The smallest drain and vent for a lavatory is 1¼”, but waste lines of 1½” are more satisfactory. After studying the drawing, you see that the waste line opening is 1¼”, and it is 16½” from the finished floor. The lavatory center has to be located somewhere on the wall so the width of the fixture is also very important. For instance, if the lavatory were to be located near an adjacent wall, this would mean the drain opening must be located far enough from this wall to allow room for setting the fixture. The minimum space from the center of the lavatory to the nearest sidewall should be 12”.

Nom. Size	L	W	O	C	A	N
20x18"	20"	18"	7-1/4"	2-7/8"	6"	3-1/2"
24x20"	24"	20"	8"	3-1/8"	7"	4"

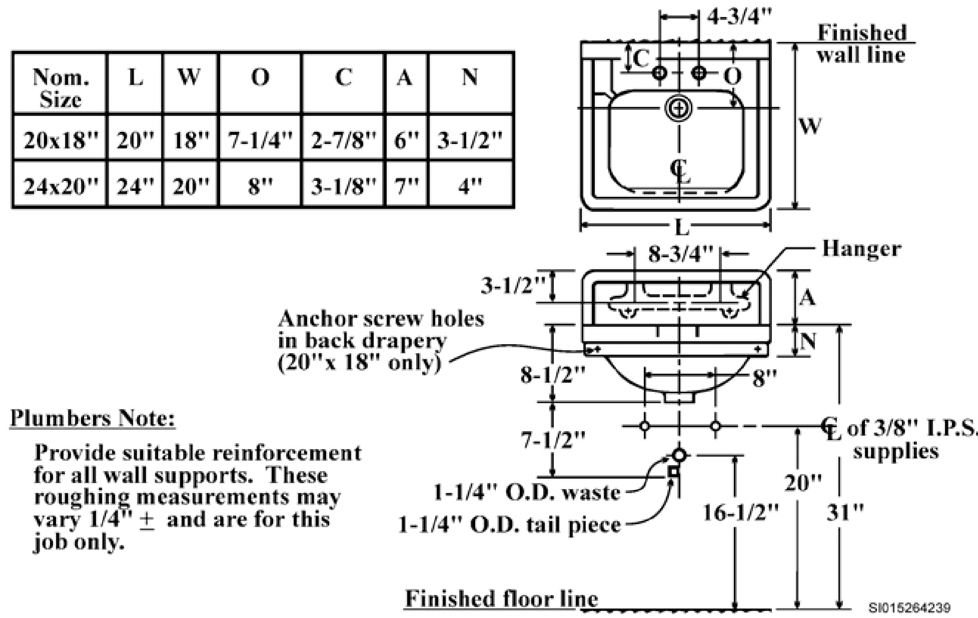

Figure 4–1. Lavatory rough-in specifications.

Once you have determined where the drain opening is to be located, you need to decide how to run the drain and vent. You may have to relocate the position of the fixture or change the routing of your drain line if an uncuttable structural member is in your way. Use the minimum number of fittings to increase efficiency of a lavatory.

Wall-hung fixtures

Secure wall-hung fixtures to the wall by means of special hanging brackets. Fasten the hangers with brass screws to a mounting board located between two studs at the height recommended by the manufacturer. (Normally, you install the mounting board when the waste outlet and water supply lines are roughed-in.) The hanger brackets must be level. If there are no manufacturer’s specifications available, install the hangers so that the lavatory rim is 31” above the finished floor (except for wheelchair units), and, if possible, center it over the waste outlet.

Drains

There are two types of drains commonly used in lavatories: the chain-on-stopper and the mechanical pop-up. When you install the drain, put a ring of plumber’s putty around the flange and insert the flange into the waste opening of the lavatory. Screw the flange locknut up against a rubber washer on the bottom side of the lavatory to form a tight seal. Then screw the tailpiece onto the strainer assembly.

When a combination faucet is used, it usually has a built-in mechanical pop-up drain. On the pop-up drain tailpiece, install a 1¼” trap. All of these exposed waste and water lines are chrome plated to present a neat appearance. Install water faucets in holes in the top of the fixture.

Faucets

Faucets may be the individual type (fig. 4–2) or the mixing type (fig. 4–3). On the spout of the mixing valve, you may find an aerator. The aerator gives a stream of revitalized water by mixing air with the water. Millions of bubbles swell the stream, increase the velocity, and prevent splashing. Aerated water tastes better, washes faster, and rinses better.

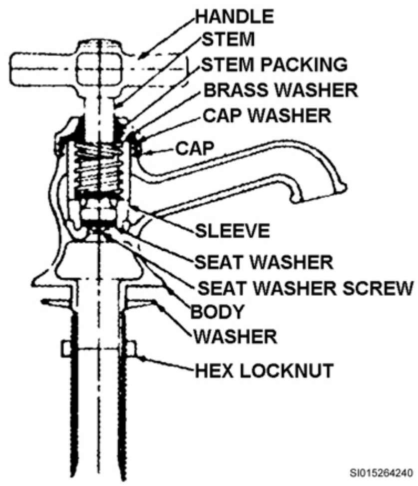

Figure 4–2. Individual faucet.

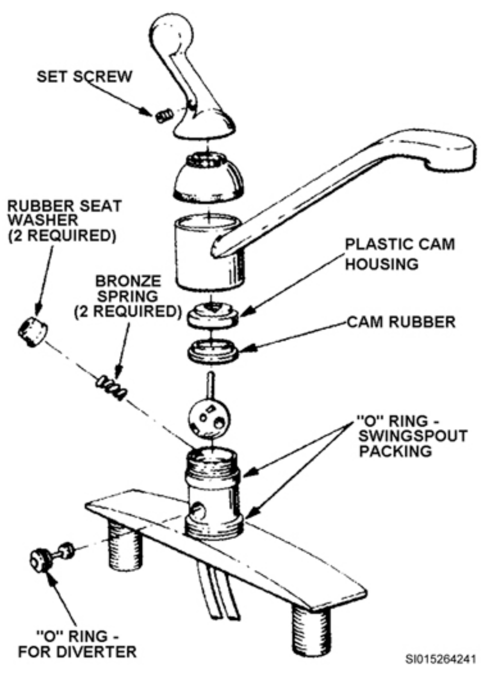

Figure 4–3. Mixing faucet.

Faucets are sealed onto the rim of the lavatory with a rubber gasket or plumber's putty, and they are held tight by a hex jamnut attached from beneath the fixture. The nut cannot be reached with an ordinary wrench, so you must use a special wrench called a *basin wrench.* The basin wrench is a right-angle pipe wrench mounted on an extension bar that extends the handle below the bottom of the lavatory bowl. Connect the faucets last, with the hot water on the left and cold water on the right. Connect faucets to the roughed-in supply lines (risers) with a jiffy connector, which is made of copper, plastic, chrome-plated copper, or braided stainless steel flex connectors. Connect the jiffy connectors to the shank of the faucet by a slip joint, which consists of a cone-shaped (or beveled) washer, a friction ring, and a coupling nut (fig. 4–4). If it is necessary to bend the chrome-plated tubing, be sure the threads on the coupling nut are in proper alignment to prevent cross threading, and be sure you do not kink the tubing.

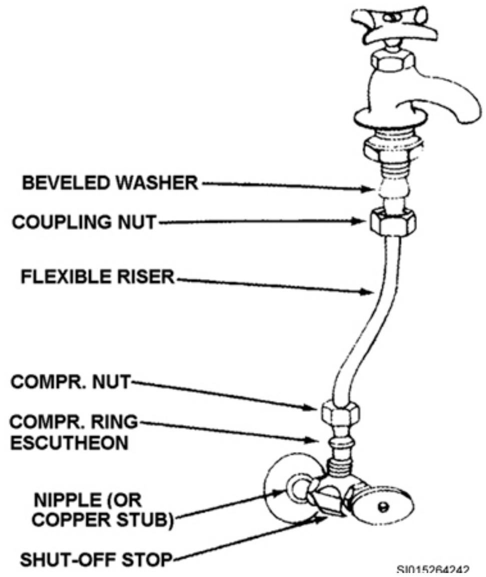

Figure 4–4. Jiffy connector.

437. Water closets

The term "water closet" (or W/C) was coined to indicate the room where the fixture is located. The W/C is the most commonly used fixture and from the standpoint of sanitation, it is probably the most efficient. It is a plumbing fixture used to convey organic body wastes to the plumbing drainage system.

The W/C is made of clay with a quality equal to that used to manufacture fine china. The quality of a closet bowl is judged by its efficiency in removing or flushing wastes deposited in it. A W/C is cast in about 13 pieces that are molded together by skilled mechanics to form the closet bowl. The closet is then treated with liquid glaze, placed in a dry kiln, and fired at 2,500°F. This process renders it impervious to moisture. To rough-in a W/C accurately, get the manufacturer's specification sheet.

Types of water closets

The two basic types of W/Cs are floor-mounted and wall-mounted. Most W/Cs used in the AF are floor mounted.

Floor-mounted

To set the floor-mounted bowl, simply put two closet bolts in the slots of the closet flange. If, however, the particular designed bowl requires four bolts, put the closet on the floor over the flange, mark the locations on the floor for the additional screws, and install these closet screws into the floor at the places marked. These screws have wood threads on one end and machine threads at the other.

Before the bowl is turned upside down, put wood or papers under the bowl to prevent scratching. When you handle the bowl, be sure not to drop it because it is made of vitreous china and will break easily. After you have turned the bowl upside down, place a roll of approved compound completely around the rim and put a prepared wax ring around the discharge opening. This forms a seal between the floor flange and the water bowl. If the floor is not level, or if the floor has been raised above the top of the closet-bend flange, use two wax rings. Lift the bowl and set it down over the flange, making sure the wax ring stays in place. Continue lowering it straight down into its final position. Press down on the top center of the bowl. Use your full weight, and twist the bowl slightly to settle the bowl wax and compound, forming a tight seal (fig. 4–5).

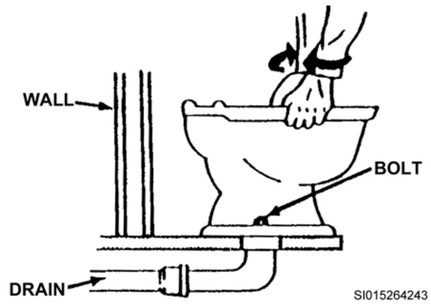

Figure 4–5. Installing a W/C.

The closet bowl should be perfectly level when set. Use a level if you are in doubt. Wedge the bowl to level it, if necessary, using wooden shim material. Be sure wedging does not lift the bowl and leave air gaps in the compound around the bowl. When the bowl is seated squarely over the seals, bolt it down to a snug fit. Do not overtighten the bolts—you could crack the bowl.

Wall-mounted

The wall-hung W/C makes cleaning of the floor much easier than the floor-mounted type. To support the wall-hung water closet, you can use either a horizontal or a vertical chair carrier. 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.

Wall-mounted W/Cs require a special fitting and mounting bracket. This bracket is called a chair carrier and it supports both the W/C and the fitting within the walls. The chair carrier for a wall-mounted W/C is positioned and bolted to the rough floor. The foot of the chair carrier supports the weight of the W/C. The bolt holes in the chair carrier are slotted so that closet bolts fit to install the closet bowl. Again, be careful when you tighten the closet bolts or you may crack the fixture.

Cold water for flushing

There are a number of different types of W/Cs, but they all flush by either a tank or a flush valve (flushometer). The tank or the flush valve requires a cold water supply. Cold water for flushing a W/C can be supplied by a closet tank or a flushometer flush valve. If you are installing a flush tank W/C, the minimum size water line is ⅜”, and if you are installing a flushometer type W/C, the minimum water line is 1”. The closet flush tank is used in residences because it is not as noisy as the flushometer and does not require as large a supply line.

Drain and vent lines

The type of W/C determines which way the drain and vent has to be installed. Find the location of a W/C on the floor plan of the building. The building plumbing plan shows exactly where the drain and vent lines are located. Allow 15” of space from the center of the bowl to the nearest sidewall.

Vent lines

Usually, the location of a W/C in a structure governs the location of the soil stack. The plumbing system is normally designed so the soil branches discharge into the soil stack with a minimum horizontal pipe run. No additional venting is required when the W/C discharges directly into a soil stack through a closet bend. Soil branch lines are constructed of cast-iron, galvanized wrought iron, copper, or plastic pipe and fittings. Use cast-iron pipes and fittings when soil and branch lines are to be installed underground or in concrete floors. You may also use threaded galvanized wrought-iron pipe for soil stacks or branch lines when the stack or branch is not to be concealed in the walls or floors. Use special cast-iron recessed fittings when you are working with threaded wrought-iron pipe. The recess of the female thread creates a smooth interior at the joint, which, in turn, lessens the probability of solids causing a stoppage in the flow. Copper and plastic are the most commonly used materials in today's new construction. By using them, you eliminate the heavy tools and equipment required for working with threaded pipe or caulked joints.

Drain line

The smallest size pipe that you can use for a W/C drain line is 3" for copper or plastic and 4" when using cast iron. Give horizontal lines a fall of ¼" per foot so they drain back to the soil pipe. Remember, the smallest size vent for a W/C is 2". When roughing-in the W/C drain below a concrete slab, make sure the vertical riser from the closet bend extends up to and possibly above the intended finished level of the concrete. This ensures that your rough-in is high enough. Wrap the riser with some material, such as building paper or cardboard, so that when the concrete is poured, a space is left between the riser and the concrete. The purpose of this procedure is to allow space for the floor flange to be inserted. After the concrete has set up, remove the paper and set the floor flange. If the riser is too long, cut it off after you have installed the floor flange.

The floor flange used in conjunction with the floor-mounted W/C is also known as a flanged collar, closet bend collar, floor flange, or closet flange. Floor flanges are usually made of plastic, cast brass, or cast iron. They may be of the solvent weld, threaded, or slip type. Threaded flanges are tapped with a 4" pipe thread. Slip-type flanges are used for caulking into the hub end of a closet bend or for caulking over a 4" soil pipe. There are a number of holes in the lip of a floor flange. Use two of these holes to insert closet bolts for attaching the flange to the closet bowl. The two holes you select, either the elongated or the round, must be an equal distance from the wall; otherwise, when you set your fixture, it may be crooked.

To install a W/C properly, refer to the manufacturer's specification sheets furnished with the fixture. The need for instructions for each separate installation is important because of the existence of so many designs and models. Although you should follow the measurements, some manufacturers allow up to a ½" variation in these types of installations.

438. Urinals

There are four basic types of urinals: wall-hung, trough, pedestal, and stall. The stall type is used extensively in public buildings. The wall-hung and pedestal types are commonly used on AF installations. The stall and trough types are not approved for use in new construction or maintenance replacement in AF buildings.

Waste pipe fitting

When you install the waste pipe for a urinal, consult the manufacturer's rough-in specifications for the exact installation measurement. Locate the waste pipe so that the lip of the urinal is from 20–25" above the finished floor.

Position the drain exactly as indicated in the rough-in specifications to ensure that the lip of the urinal is at the proper height. There is no flexibility in the measurement because the urinal has an integral trap. Some variation in measurement is allowed for urinals that have external traps attached after the fixture is hung because of the length of the tailpiece or the type of trap that is used. The *minimum* space from the center of the urinal to the sidewall should be 12". The minimum size of waste pipe you can use for draining a single urinal is a 2" pipe if the pipe is cast iron, and 1½" for copper and plastic. Increase the waste pipe for two or more urinals by one or two pipe sizes. The minimum size vent for a single urinal is 1¼", or not less than one-half the diameter of the waste pipe that it vents, whichever measurement is larger.

Urinal drain

Because of the high acid content of urine, fabricate the drain for a urinal from copper, plastic, or cast-iron pipe and fittings. You may use galvanized-steel, cast-iron, copper, or plastic pipe and fittings to construct the urinal vent system. Both the horizontal drains and vents must have a fall of ¼" per foot. Use the same methods of joining lavatory drains and vents for the urinal with the exception of the galvanized drain. Make sure the pipe or nipple that is roughed-in for the urinal trap is long enough to allow the finished wall to be installed.

The minimum water supply is ¾” in diameter. Use brass bolts or screws to hang urinals because they resist corrosion. Urinals, like most other fixtures, are usually available in a variety of shapes and sizes. Despite the similar appearances of urinals, they are not all secured the same way. All wall-hung urinals must have a support called a mounting board. Take care not to overtighten the bolts or screws, as the urinal may crack or break.

Flushometer connection

Regardless of the method used to mount the urinal, it should be level and mounted at the proper specified height. Once the urinal is mounted, you can install the flushometer and trap. Use an *angle valve* (angle stop) to connect the flushometer to the water supply line. The flushometer outlet is connected to a tailpiece, which, in turn, is connected to a *spud.* This spud, sometimes called the *supply spud,* is installed in the *top* of the urinal. Figure 4–6 shows the complete assembly from angle stop to the supply spud. After installation, turn on the water, and then check the flushometer and drain for proper operation and for leaks.

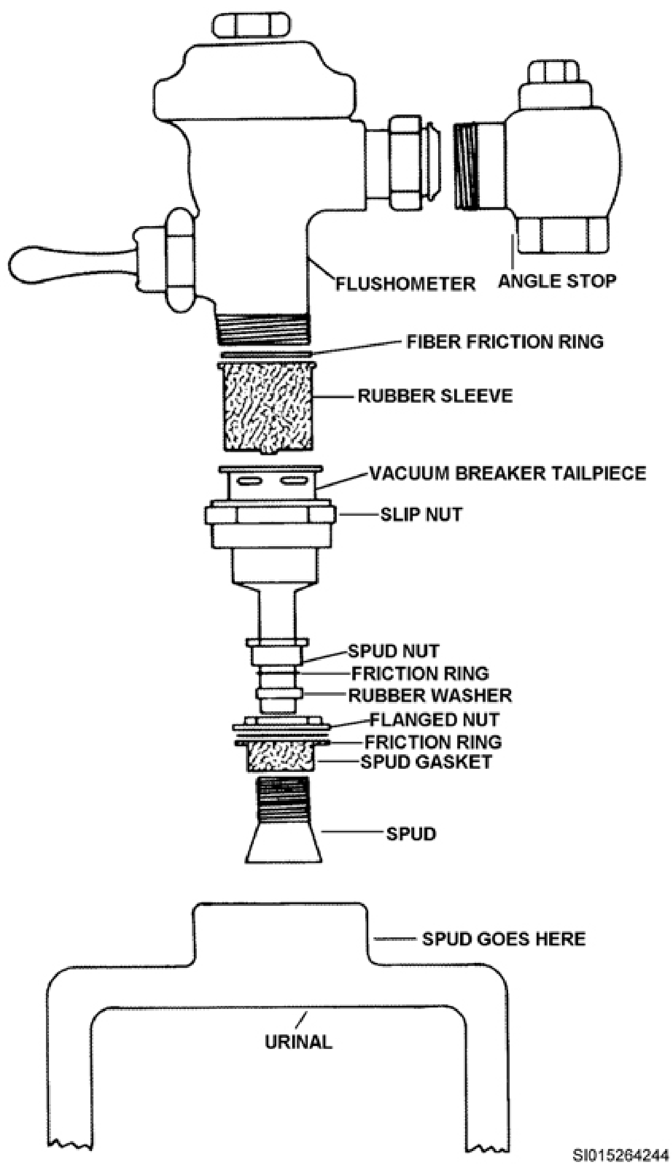

Figure 4–6. Flushometer installation breakdown.

439. Bathtubs and showers

Always refer to the manufacturer's rough-in specification for the rough-in piping measurements. Use the floor plan to find the location of bathtubs and showers in new buildings. If no floor plan is available, you must determine their location, calculate the size of the waste lines, and figure out the needs of the users. In most cases, locate the drain for a shower in the center of the shower area.

Waste lines for bathtubs

Waste lines for draining bathtubs are also located below the floor level. The main problem you face installing these waste lines are there are varieties of built-in bathtubs. For example, consider (1) those recessed on all sides except the one facing into the room; (2) those with an apron on two sides to be installed in a corner space; (3) those that are square, rectangular, or angular; (4) those with one or more ledge seats; and (5) those with right- or left-hand drain openings. Therefore, it is important that you know the type of tub you are installing before you "rough-in."

You will find that in small residential bathrooms, the tub is normally positioned so that the waste and vent pipes that serve it also serve other fixtures in the bathroom. The tub overflow and drain assembly is not included in the rough-in piping because it is attached directly to the tub at the time the tub is set. Two types of traps are used for bathtub and shower installations: (1) the drum trap and (2) the "P" trap. When you use the "P" trap, you must vent the waste pipe on the outlet side of the trap. If the trap cannot be vented or if it is wet-vented through another fixture, use the drum trap instead. When drum traps are used, route the waste line in such a manner that the top of the drum trap is flush with the floor surface.

Waste lines for showers

When you install an individual shower, the waste pipe must be a minimum of 2" in diameter. In contrast, a gang shower requires a waste pipe 3 or 4" in diameter to handle the high volume of flow during peak periods of use. A tub and shower combination requires a 1½" drain. You need a fall of at least ¼" per foot for horizontal waste lines that are 3" or smaller in diameter, and waste lines larger than 3" require a fall of at least ⅛" per foot.

The venting procedures for a shower and floor drain are similar to those for other fixtures. The size of the horizontal line and the distance from fixture trap to the vent are the critical factors. The drain's slope should be no more than one pipe diameter. A slope of more than one pipe diameter can cause the trap seal to self-siphon.

Type of showers

The two general types of individual showers are the custom-made tile shower and the prefabricated stall type. Of these, the tiled shower has tile or marble walls on three sides with a waterproof shower curtain or door for closing. The tiled floor slopes toward the center (or rear), where a drain is placed. Waterproofing the floors and walls is important. The floor is generally laid upon either a lead or a copper shower pan, which forms a waterproof base on which to lay the tile. Before installing a pan for the tiled shower, the carpenter must rough-in the general outline of the shower stall and provide a solid base of subflooring or plywood on which the shower pan rests. This is necessary because the shower pan is soft and flexible and tends to sag under the weight of the concrete and tile.

The prefabricated shower stall is a unit with three sides and a base fitted together. The sides are made of thin sheets of steel, fiberglass, or plastic, which are grooved so that they fit together with a watertight joint. The base is made of plastic, metal, or precast concrete.

The shower head is connected to a piece of 45° chrome-plated pipe called a *shower arm*. The two general types of showerheads are circular and economy. The circular showerhead has notches or grooves around the outer edge of the face that allows regulation of the spray. The economy head has a restricted nozzle that provides a fine spray and uses less water than other types of heads.

440. Sinks

There are many types and designs of sinks. Some have a single or double drain board; some have none. The material used for their construction may vary from galvanized iron, stainless steel, and enameled cast iron to enameled steel. The type faucets used with the fixture also may vary. Some of the more common types of sinks are discussed in this lesson, but other sinks can be installed and maintained in the same way.

Scullery sinks

Scullery sinks (fig. 4–7) are large deep sinks used to wash vegetables and pots and pans. They are usually built of galvanized sheet iron or stainless steel. These sinks may have one, two, or three compartments. Since these sinks are used to wash greasy pots and pans, the waste must drain through a grease trap. A scullery sink does not need a fixture trap; the grease trap acts as a trap for the fixture.

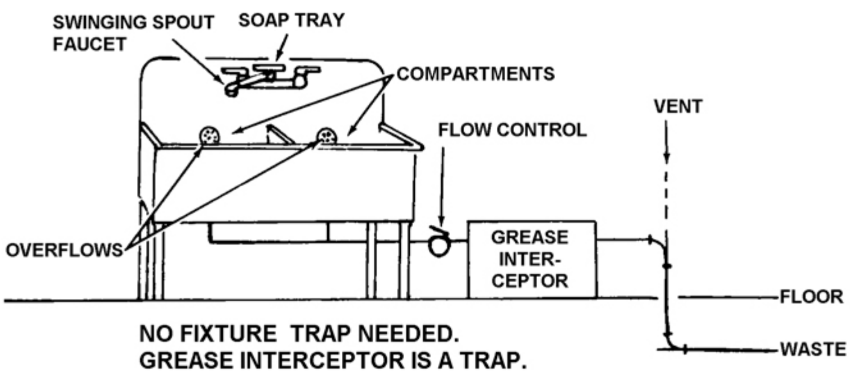

Figure 4–7. Scullery sink.

Scullery sinks are not commonly found in residences. They are installed in large kitchens, such as clubs, cafeterias, and military mess halls. If a food grinder is installed on a scullery sink (fig. 4–8), it must discharge directly into the building drain through a "P" trap. Food grinders should not discharge into a grease trap. Maintenance on a scullery sink consists mainly of cleaning the grease trap, repairing the food grinder, unclogging the drain, and repairing the faucets.

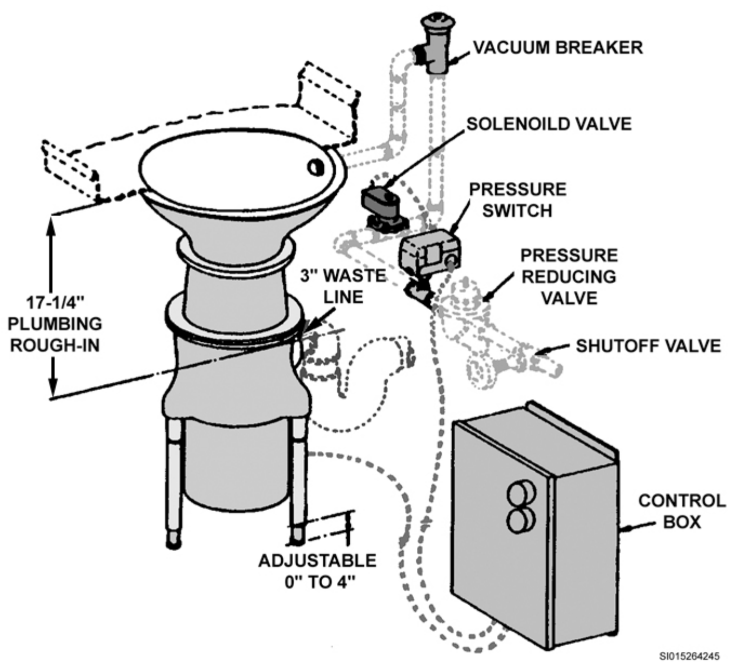

Figure 4–8. Industrial food grinder.

Kitchen sinks

Kitchen sinks are manufactured in a number of different patterns, and are designed to be used for a specific purpose. They are made of enameled steel, enameled cast iron, or stainless steel and are available in a number of different patterns and sizes. They may have either a single or a double basin. Although you may have installed other types of sinks, follow the specifications listed by the manufacturer for the type of sink that you are installing.

Most kitchen sinks are installed in a flat countertop. The sink rim sits on the countertop and is secured underneath with clips. Other countertop sinks have a separate rim set in the counter-top opening. The sink is then raised into place from below the countertop and secured to the rim with clips. The last method used to install a kitchen sink is to hang the sink on the wall using a mounting board. The distance between the floor and the top of the drainboard should be 36”.

After you screw the bracket into place, lower the sink into position on the bracket so that the lugs that are cast on the back of the sink fit down into the corresponding notches in the bracket.

Modern sinks are designed to be used with either a strainer basket or a waste grinder (fig. 4–9). The strainer and tailpiece are screwed into the sink bowl, and the trap is connected to the rough-in waste. The waste line for both types of sink connections must be at least 1½” in diameter. Food-waste grinders may be trapped separately or with the other compartment of a double sink. If the food-waste grinder is trapped separately, it must be connected to the waste line by means of a double Y (fig. 4–10). Install a cleanout (CO) plug in the drain line between the two traps.

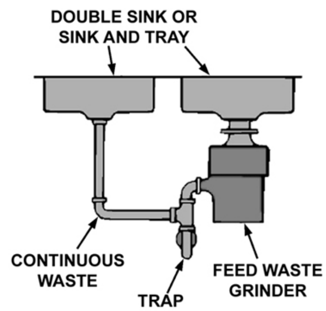

Figure 4–9. Single-trap waste-grinder installation.

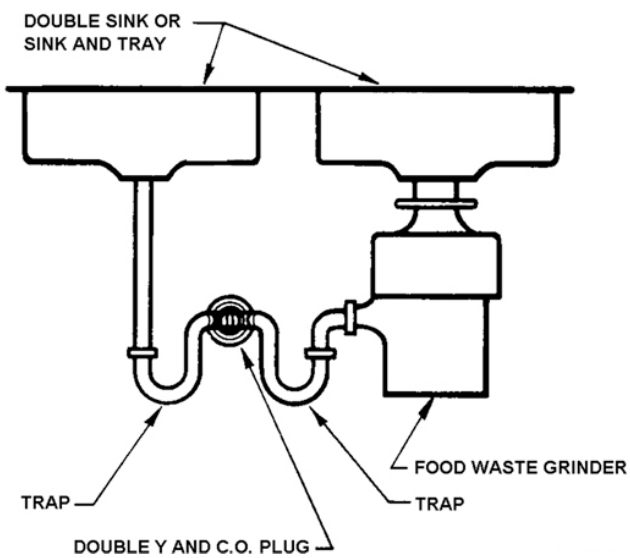

Figure 4–10. Double-trap waste-grinder installation.

The last step in the installation of the kitchen sink is to select a suitable faucet, install it on the sink, and connect the water supply to it. The procedures for installing the faucet are similar to those we used earlier to install a lavatory faucet.

The maintenance of kitchen sinks is usually confined to the removal of stoppages and the repair of water supply faucets. Minor stoppages in the trap may be removed with a vacuum plunger. If this procedure is not effective, remove the stoppage through the trap cleanout. If the stoppage is beyond the trap, you may have to remove the trap and run a sink snake down the waste pipe to dislodge the stoppage.

Utility sinks

The utility sink, sometimes called a slop or service sink, is used especially for dumping mop buckets and washing mops (fig. 4–11). It has a deep bowl and is generally constructed of cast iron and finished in enamel.

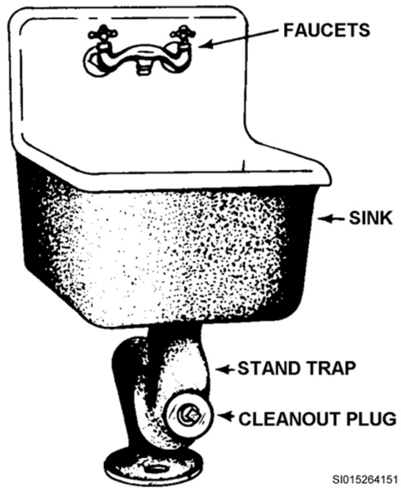

Figure 4–11. Utility (slop) sink.

The utility sink is mounted on a bracket and mounting board. In addition to the hanger, the utility sink also has a built-in adjustable stand trap that bolts to the floor and provides a pedestal support. Adjust the stand trap to take most of the weight off the hanger and prevent the sink from sagging. The maintenance of utility sinks is the same as for kitchen sinks. You will be called often to clear clogged drains or fix leaky faucets.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

436. Installing lavatories

1. How should a lavatory be located in relation to the nearest sidewall?

2. What size pipe is best for a lavatory drain?

3. When installing lavatories, what do you use to secure the hanger to the mounting board?

4. What is the recommended height for a wall-hung lavatory?

5. What type of drain is used on a lavatory with a combination faucet?

6. What is the location of the hot and cold water lines on a faucet?

7. What is used to connect faucets to the roughed-in supply lines?

437. Water closets

1. Where can you find the location of a W/C?

2. What may happen if you overtighten the bolts on a W/C?

3. What size supply is required for a W/C flushometer?

4. Where is a W/C located in relation to the nearest sidewall?

5. What is the smallest size pipe you can use for a W/C drain line?

6. What is the smallest size pipe that can be roughed-in for a W/C vent?

7. What size water supply is required for a W/C tank?

438. Urinals

1. How far above the finished floor should the lip of a urinal be located?

2. How should a urinal be installed in relation to a sidewall?

3. What is the minimum size waste pipe used for draining a single urinal?

4. What is the minimum size vent for a single urinal?

5. What is the minimum size water supply for a urinal?

6. What are used to hang urinals so that they are not affected by corrosion?

7. What is used to connect the urinal flushometer to the water supply?

8. How is a urinal flushometer tailpiece connected to the top of the urinal?

439. Draining bathtubs and showers

1. What do you use to find the location of bathtubs and showers in new buildings?

2. What part of tub installation is not considered in the rough-in piping?

3. What is the minimum size waste pipe for a bathtub?

4. What determines the size of the waste line you install for a shower?

5. What do we call the 45° angle piping that is used to install a showerhead?

440. Sinks

1. What type trap drain is connected to a scullery sink?

2. What types of maintenance are done on scullery sinks?

3. How should you install a kitchen sink?

4. How should the drain be installed to a kitchen sink if the food-waste grinder is trapped separately?

5. What type of maintenance is done on kitchen sinks?

6. What is another name for a utility sink?

4−2. Components

The job of installing fixtures is not complete until these components are installed and operating correctly. For the most part, after a fixture is roughed in and installed, the last step is to affix a trap, connecting the drainage system and a faucet or valve to regulate the flow of water.

441. Traps

One basic principle of plumbing is that every fixture must have a trap. A fixture trap is not designed to catch anything as the name implies. Traps are installed on fixtures to keep sewer gases from entering the building by way of the fixture. Sewer gases can be toxic in high concentrations and have been known to be explosive because of the methane content. In addition, the smell of sewer gas in a building can be quite a nuisance to the occupants.

There are two kinds of trap seal construction: integral and external. Integral means “internal.” The basic difference between the two is that integral traps are built into the fixture—such as a W/C. An external trap on the other hand, is not part of the fixture—such as a “P” trap.

Atmospheric conditions

All traps are designed to withstand the pressure and vacuum conditions exerted by wastes traveling down a stack. These wastes are literally “pushing” air and gases in the stack. Remember that in a multistory building, there may be several fixtures tied into a stack. Depending on the fixture’s location, it may be subject to pressure immediately before being subject to a vacuum (fig. 4–12). Let’s examine these kinds of traps more closely.

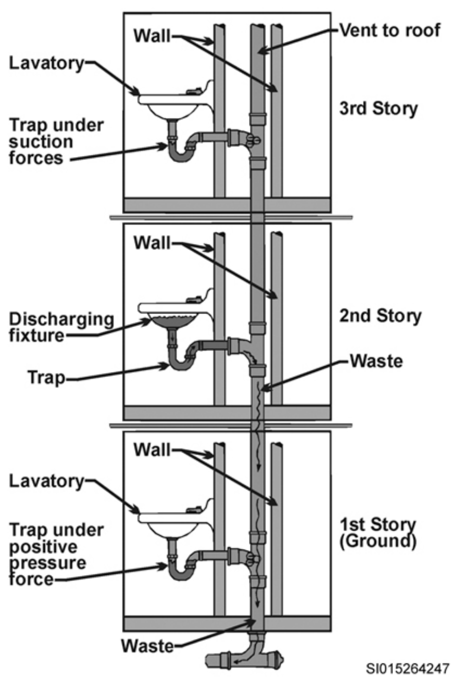

Figure 4–12. Atmospheric forces exerted on a “P” trap.

Integral

Fixture traps are designed to have a water seal inside that serves to keep gas from escaping. They are also designed so the flow of sewage is unrestricted when the trap is operating properly. Traps are normally installed at the outlet of the fixture, but some fixtures are designed with the trap built or molded into the fixture itself. These traps are called integral traps. The best example of a fixture having an integral trap is the W/C (fig. 4–13).

External

When the trap is installed outside of the fixture, it is referred to as an "external trap." An example of a lavatory with an external trap is shown in figure 4–14. The methods of selecting and installing various traps are rigidly governed by plumbing codes.

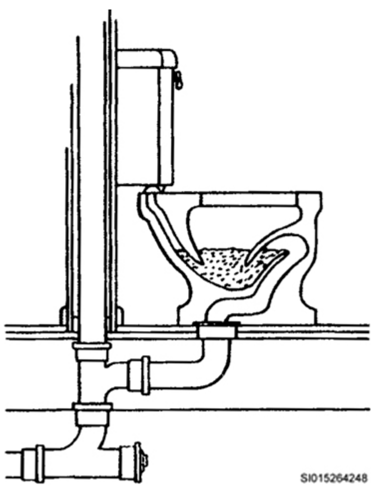

Figure 4–13. Integral trap.

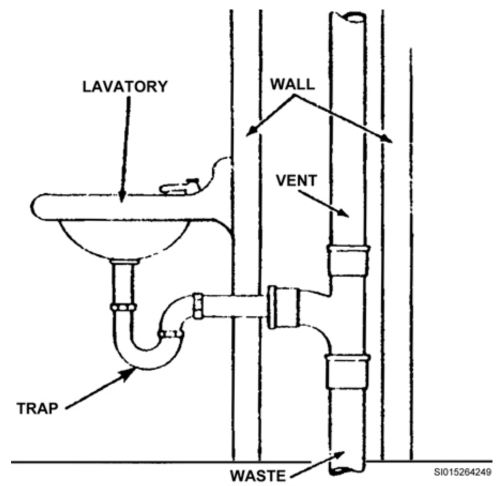

Figure 4–14. External trap.

The most widely used trap installed today is the "P" trap which is available in a variety of sizes and finishes, such as plastic, copper, rough brass, and chrome-plated brass. The size trap that is required for a specific fixture is also restricted. The trap size should be the same size as the outlet or tailpiece of the fixture it serves. You should install a "P" trap as close as possible to the fixture it serves, being especially sure that the vertical drop from the fixture outlet to the trap overflow is never greater than 24". Doing this will eliminate high velocities and prevent trap seal loss (of water) caused by direct siphonage. The section of piping that connects a trap to the soil or waste stack is called a *trap arm.* Install a trap on each trap arm. The minimum size and length of trap arms for specific fixtures is governed by plumbing codes.

Traps can be classified as "common seal" or "deep seal." A common seal trap has a water seal depth of 2", while a deep seal trap has a depth of over 4". Remember that the water seal serves as a barrier for the sewer gas. Install a deep seal trap in places where evaporation of the water seal is abnormal, such as extreme heat exposure or when complete venting cannot be obtained. There are two disadvantages to the deep seal trap. First, because more water is contained in the trap, there is an increased resistance of wastewater flow through the trap. Secondly, because the trap seal is about 2" deeper, more space must be allocated during the rough-in for their installation.

Typical problems associated with the "P" trap are corrosion or leaks around the gaskets. The only repairs that can be made to a trap are to tighten loose nuts, replace leaking gaskets, or replace corroded trap pieces.

442. Faucets

There are many styles of single and combination faucets. Those that have a common spout are called *mixing faucets*. Most faucets in use today are compression types—turning the stem tightens or loosens a disc on its seat, which closes and opens the hole through which water passes from the inlet to the outlet end of the faucet.

Types of faucets

Figure 4–15 shows a basic type of faucet in which the seat and the threads for the stem are machined in the faucet body itself. The stem packing is held in place by the packing (cap) nut.

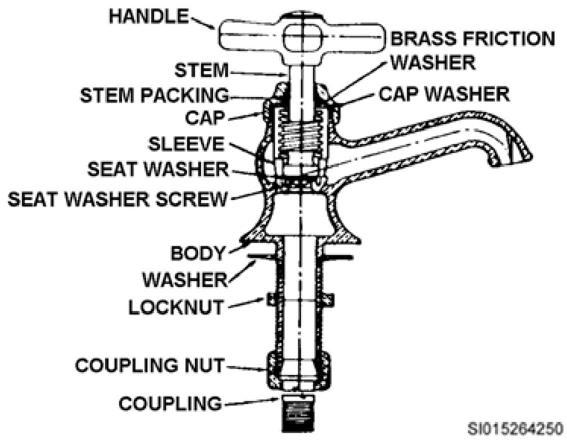

Figure 4–15. Cross-sectional view of a faucet.

Some faucets have a stem assembly (fig. 4–16) in which the stem turns inside a threaded sleeve that can be removed from the faucet and replaced. By using this type of faucet, you eliminate stem wear on the body of the valve.

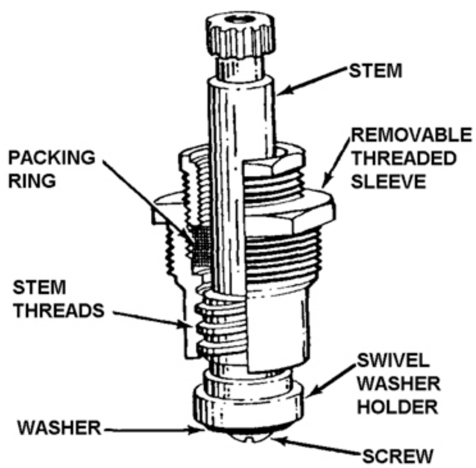

Figure 4–16. Cutaway view of a faucet stem and sleeve assembly.

Another type of faucet (fig. 4–17) closes *with* water pressure, not *against* water pressure. Closing with pressure makes the operation of the faucet a little easier and, at the same time, makes a tighter seal. The lower end of the stem-enclosing sleeve has holes in the side where water passes between the sleeve and the stem to the outlet. The seat at the end of the sleeve is rubber, and the cone-shaped end of the stem is brass.

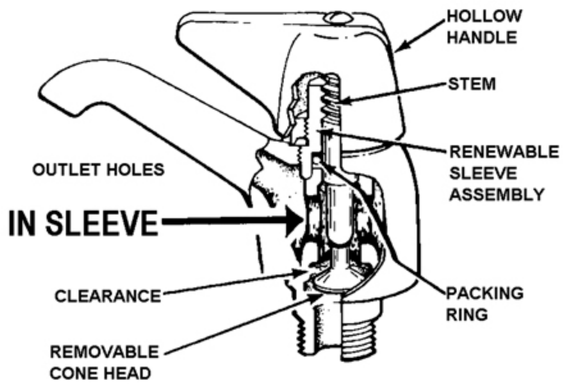

Figure 4–17. Cutaway of faucet that closes with water pressure.

Manual mixing valves

Single-handle mixing faucets are used on kitchen sinks, lavatories, laundry tubs, bathtubs, showers, and other fixtures used where variations in temperature are desired. This type of mixing valve discharges hot and cold water into a common outlet. Figure 4–18 shows a body unit faucet style used on lavatories. The body unit faucet uses state-of-the-art ceramic control components, instead of washers that wear out, in order to eliminate maintenance under normal operating conditions and to provide long service life. For heavy use applications, these faucets are easily maintained by replacing the body unit of the faucet (fig. 4–18).

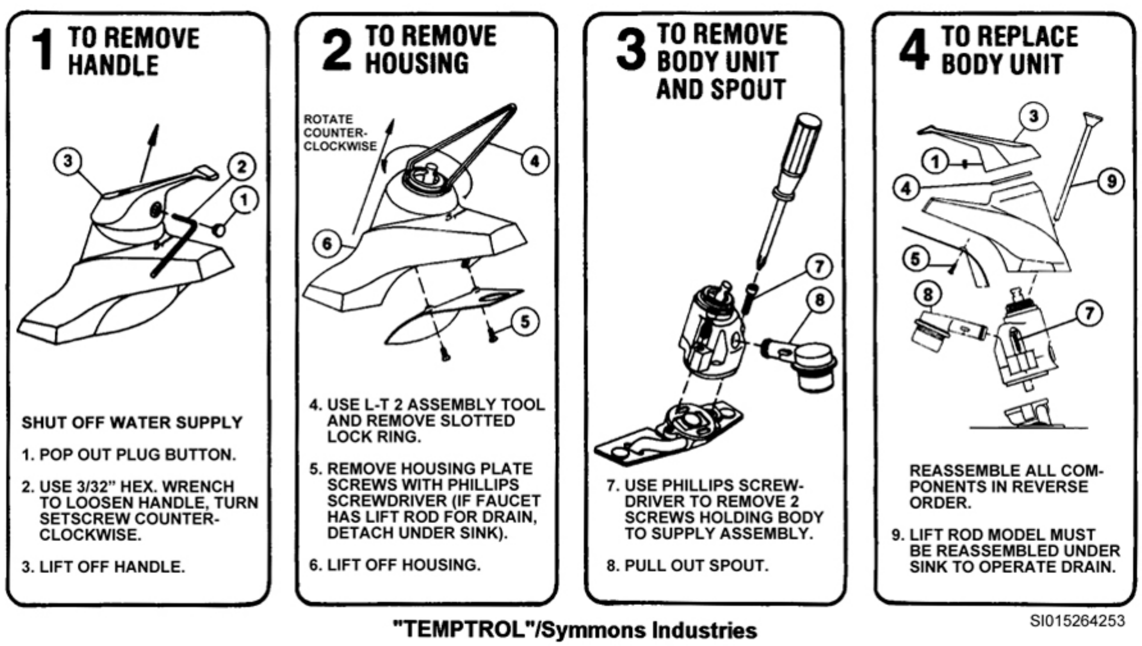

Figure 4–18. Body unit lavatory faucet.

Figure 4–19 shows a body unit kitchen faucet that has the regular swing spout. To turn this valve on, you move the handle vertically; to control temperature, you move the handle horizontally. Construction technology and maintenance procedures for the body unit kitchen faucet are identical to those for the body unit lavatory faucet.

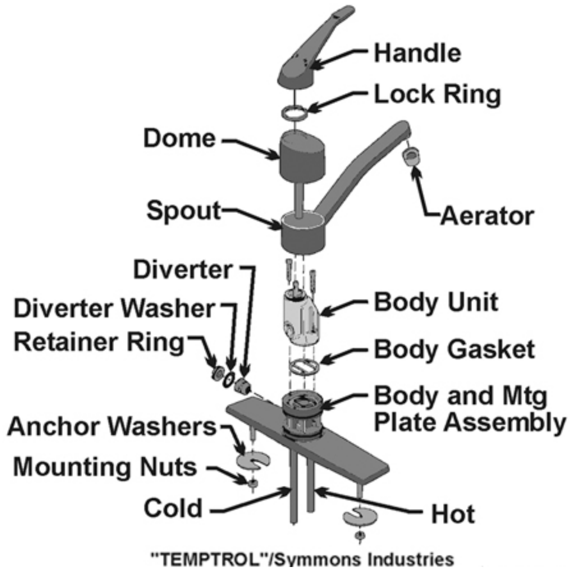

Figure 4–19. Body unit kitchen faucet.

Pressure-balancing mixing valve

The principle behind the pressure-balancing valve (fig. 4–20) is that a preselected shower temperature is maintained. The pressure-balancing valve does this by instantly and continually equalizing (or balancing) the hot and cold water pressures when pressure demands are made by other fixtures in the building. The pressure-balancing mixing valve is a brass mixing chamber that contains a sliding piston. This sliding piston has jets that allow hot and cold water to pass through them and mix when the valve handle 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 thus increasing the flow from the low-pressure supply to maintain a nearly constant temperature.

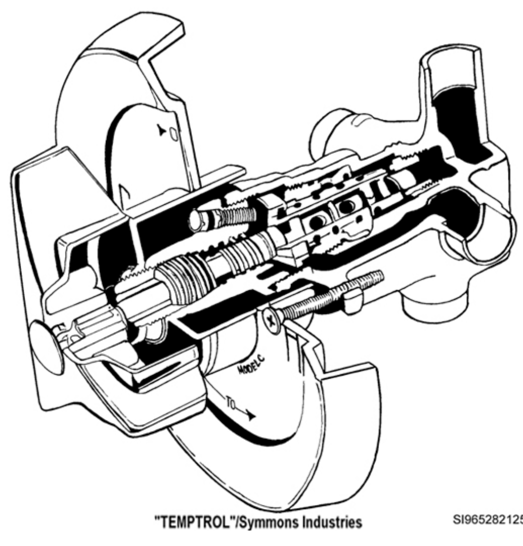

Figure 4–20. Cutaway view of a pressure-balancing shower valve.

Maintenance of single or mixing faucets

Continuous dripping of single or mixing faucets indicates a bad washer, seat, or stem packing—any of which is easy to remedy. Manufacturers sell repair kits that literally renew faucets internally. All single and mixing faucets are disassembled and repaired the same way—remove the handle and lift out the stem assembly to expose the seat and the washer for replacement. Let's use the illustrated breakdown of a pressure-balancing mixing faucet as an example and work through a repair job. Look at figure 4–21 as you read and study this discussion. After shutting off the water supply, you can disassemble and repair the valve. Your first step is to remove the handle from the stem (part T3–31). In some cases, the screw for the handle is located under a snap-in or threaded cap. After removing the handle, remove the dial (part T3–29D) by prying it up from the slot with a flat screwdriver. Remove all remaining chrome trim to expose the cap assembly (part T–12A). Open the valve to approximately the *warm* position, and remove the cap assembly using a smooth-jaw adjustable wrench. Pull out the valve stem or fluid control spindle (part TA–10). To eliminate dripping, replace all wearable components on the spindle with parts supplied in repair kit TA–9: hot washer screw (part T–5), hot washer (part T–6), cold water retainer (part T–7), cold washer (part T–8), and the cap gasket (part T–11).

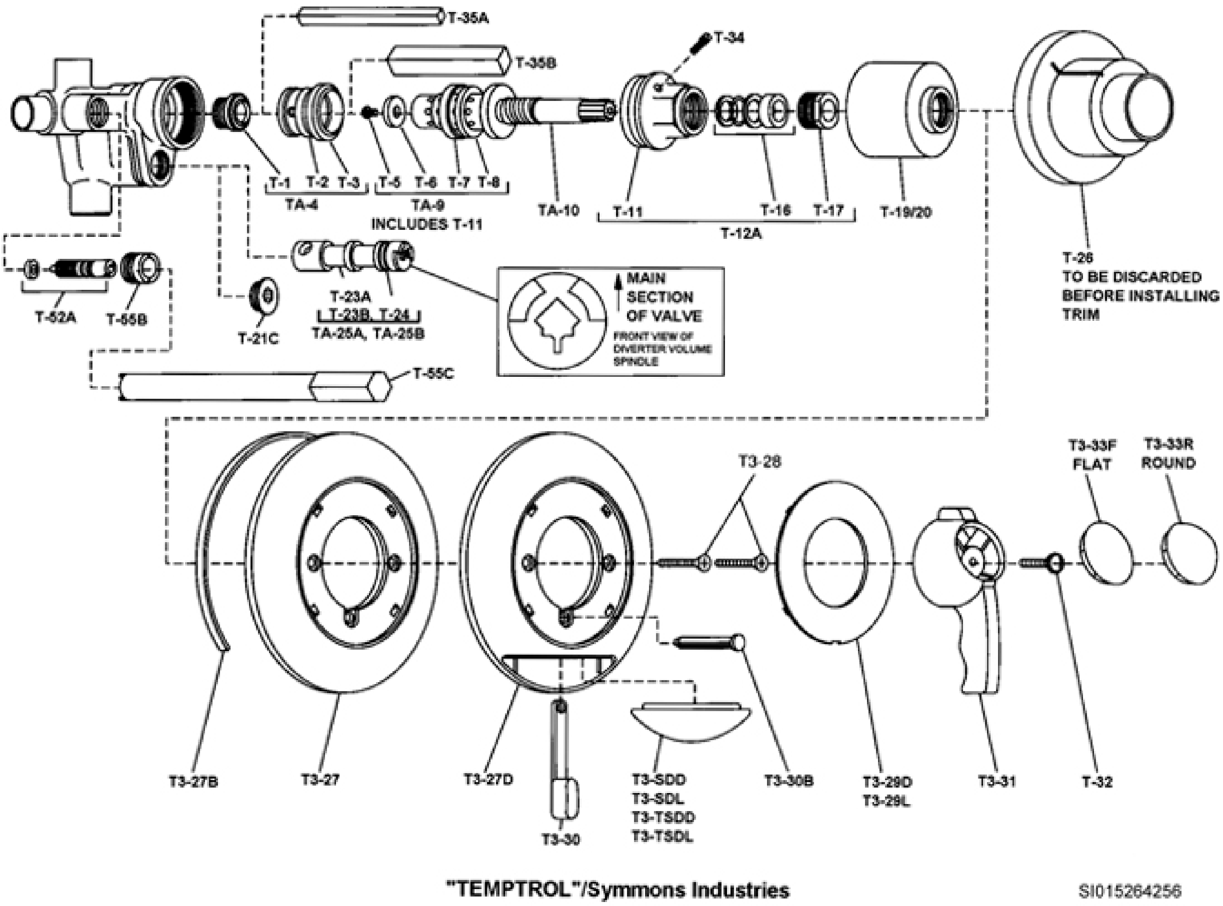

Figure 4–21. Breakdown of a pressure-balancing shower faucet.

While you have this valve apart, it is a good idea to replace both the cold and hot water seats, whether or not they are pitted. Remove the faucet by inserting the specialized seat removal tools (parts T–35A and B) into the seat openings and turning the tools counterclockwise with an adjustable wrench. Install both of the seats, as illustrated in figure 4–21, using repair kit TA–4, which provides a hot seat (part T–1), a cold seat (part T–2), and the cold seat O-ring (part T–3).

NOTE: With many other faucet seats, an Allen wrench may also be used the same way. Some seat removal tools are universal in that many Allen sizes are incorporated into one tool in a step-like fashion.

There are many faucet manufacturers, but all faucets are repaired in a similar manner. The important thing to remember is to use the correct replacement part. If you don't, the valve may not work properly, or it may malfunction again within a short time.

443. Shower valves

Showers and bathtubs use three kinds of valves to control the flow of hot and cold water—(1) manual, (2) pressure-controlled, and (3) thermostatic.

Types of mixing values

The *manual* mixing valve in the shower assembly (fig. 4–22, left side) consists of two hand-operated valves in one body, with an outlet for both valves feeding a showerhead or a bathtub. This arrangement does not give protection against sudden changes in temperature caused by varying pressure or water temperature in the supply lines.

The *pressure-controlled* mixing valve (fig. 4–22, right side) is one handle that protrudes through the wall to control both the hot and cold water. This valve compensates for a change in pressures in the system, but it does not control water temperature.

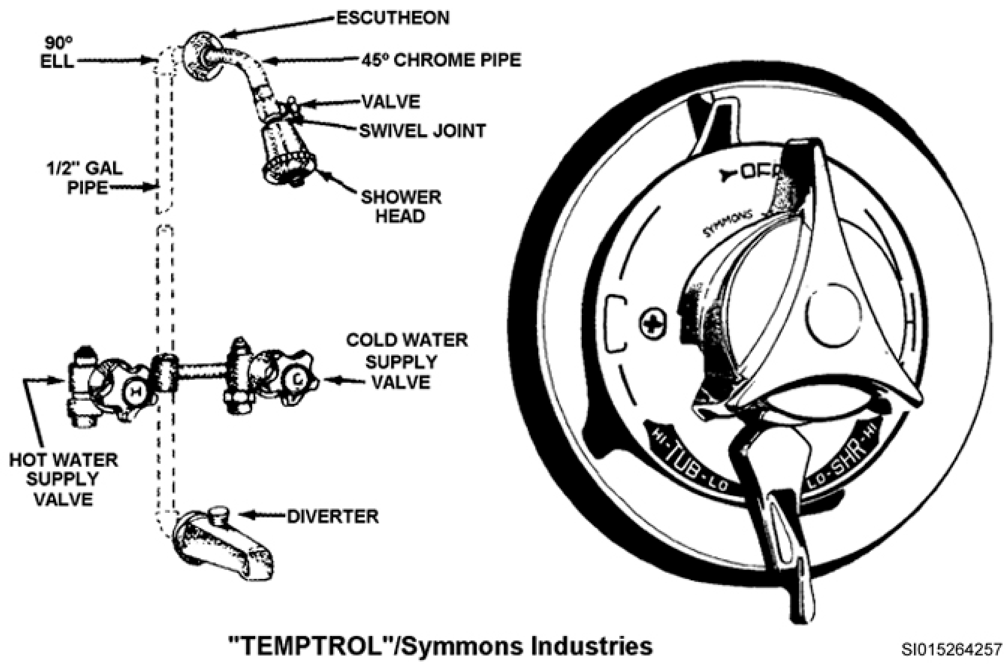

Figure 4–22. Manual and pressure-controlled mixing valves.

The *thermostatic* mixing valve is similar to the pressure-controlled valve, but it is sensitive to both temperature and pressure (T&P). This valve maintains a constant temperature, regardless of T&P changes in the system. The thermostatic mixing valve is mainly used on showers. It's important to note that, as the complexity of the valve goes up, so does the price.

Because of the variety of types and models, these valves must be installed and replaced according to manufacturer's specifications. These valves are repaired and maintained in the same manner as faucets.

444. Flushometer flushing valves

Flushometers are used in both urinals and W/Cs. Urinal flushometers are the same as W/Cs except that they only require a ¾" water supply line whereas the W/C requires a 1" supply line. Flushometer flushing valves are more advantageous in installations where noise and economy are not particularly important. The *UPC* requires that W/C flushometers be installed with a minimum 1" water supply. A flushometer valve is a compact and efficient mechanism for delivering water under pressure directly into the W/C. This type of valve delivers an adjustable amount of water in a quick, automatic flushing action. The two types of flushometer valves that we cover are the diaphragm and piston valves. The key to keeping both of these types of valves operating properly is cleanliness.

Diaphragm valve

The diaphragm flushometer valve (fig. 4–23) contains two chambers separated by a relief valve mounted on a rubber diaphragm. Equal pressure on both sides of the diaphragm keeps the valve closed. The upper chamber is connected directly to the main water supply by a bypass opening. The lower chamber is connected to a large-diameter supply pipe, usually 1” or more in diameter. Movements of the flush handle in any direction forces the plunger to trip the relief valve (upper chamber). This allows the pressure on top of the diaphragm to become lower, creating an inequality in pressure and enabling water to force its way through by raising the diaphragm. Within a preset interval, sufficient water forces itself through the bypass into the upper chamber through the bypass port in the diaphragm, moving the diaphragm down onto the seat and closing the flow of water to the bowl. Sometimes though, the bypass port becomes clogged with sand particles, preventing the upper chamber from filling (closing the valve). For this reason, install a piston-type flushometer if you believe sand particles are going to be a problem for a diaphragm flushometer valve.

The correct operation of a diaphragm valve depends on its cleanliness. Dirt or scale in the water may cause the valve to leak or become inoperative. Repair kits that include the diaphragm and other minor units are available for this valve. Be sure you get the proper repair kit for the specific valve you are repairing.

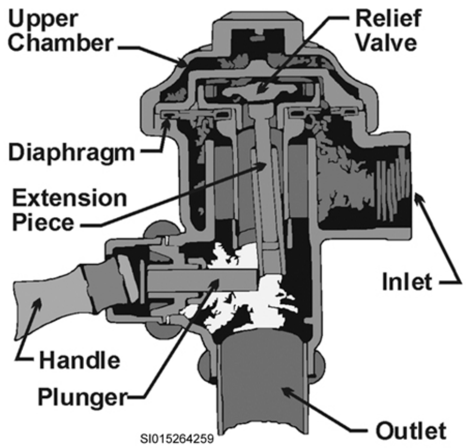

Figure 4–23. Diaphragm flushometer valve.

Piston flushometer valve

The piston flushometer valve (fig. 4–24) is operated by a lever that discharges the water from the upper chamber. The differential pressure then forces the piston assembly upward, allowing the water to enter the closet bowl. The upper chamber is filled through a bypass that is connected to the supply. When the pressure is equal on both sides of the piston, the piston drops down to its seat, closing off the water supply. The piston flushometer valve is regulated by a screw on top of the flushometer body that allows the valve to be opened no longer than the time required for flushing the bowl. Turning the screw clockwise shortens the flush, and turning the screw counterclockwise lengthens the flush. Adjust this screw so that the valve flushes for 7 to 10 seconds.

Since particles can block the bypass strainer and destroy the seal at the disc and seat; maintenance of the piston flushometer valve is mainly cleaning. The valve may also leak around the flush handle and you may have to replace the packing. The handle stem may become worn where it pushes against the stem of the trip valve plunger. Repair kits that contain all the materials needed for a complete renewal of all washers and parts in this type of valve are available. You must know what type and model of valve you are reconditioning to obtain the proper kit.

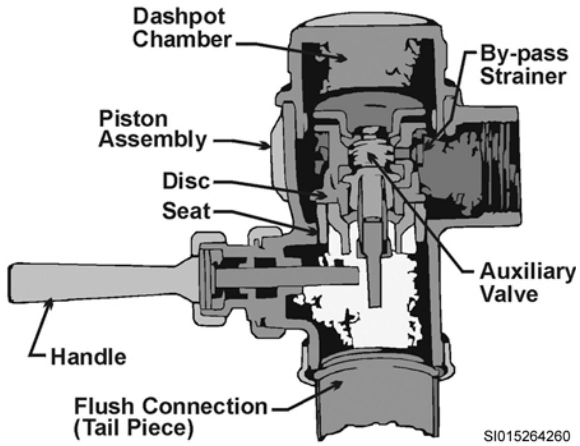

Figure 4–24. Piston flushometer valve.

Vacuum breakers

One way to stop water from back flowing is with a vacuum breaker (fig. 4–25). A vacuum breaker is used where it is not possible to have an air gap between the outlet of the water supply and the flood level of the fixture. The vacuum breaker prevents cross-connections between systems.

Equip all W/Cs and urinals actuated by a flush valve with a vacuum breaker. When the flush valve is actuated, the water expands the rubber insert, shutting off the air gap. This prevents the water from squirting outside of the vented tailpiece. When the flushometer completes the flush cycle and reverts back to the closed position, water pressure will diminish and the water can flow freely to the fixture. If water is discharged through the air gap during the flushing cycle, the rubber insert is defective and has to be replaced.

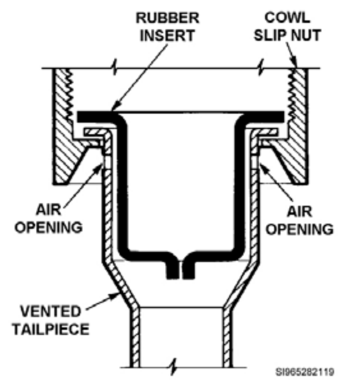

Figure 4–25. Cut-away view of a vacuum breaker.

445. Water closet float-controlled and flushing valves

There are many types of float-controlled valves, but most of them work on the same principle as the one used in a W/C tank to control the water level.

Float-controlled

Float-controlled valves (fig. 4–26) are used as control valves in water tanks and sedimentation basins and, occasionally, as altitude valves in water distribution systems. The float-controlled valves (sometimes called *float valves* or *ballcocks)* are made of copper and brass, or plastics, and they are opened and closed by a float ball and rod that are attached by levers to the valve plunger. When the water tank is full, the buoyancy exerted by the floating ball pushes the washer against the seat, thus closing the valve. As the tank empties, the ball goes down, allowing water to run into the tank. While water is entering the tank, some water flows through the refill tube to the overflow pipe and into the W/C bowl. This water fills the bowl to the proper level after a flush. A hush tube carries the incoming water to the bottom of the tank to reduce the noise of the water running into the tank. Some toilets do not use a float ball but instead have a float cup that slides up and down a tube as the water level rises and falls. This setup combines the float and ballcock into one unit. It achieves the same result as the float and lever but is a bit more precise.

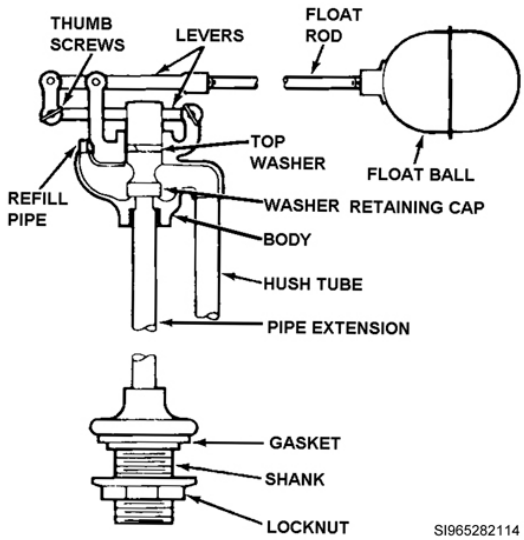

Figure 4–26. Float-controlled valve.

Repair

Repair and maintenance of float valves will vary, depending on the type of valve and its application. Worn washers are the primary cause of a float valve malfunction. If the washers are worn, it is usually best to replace the entire assembly. If the float ball fills with water, the valve will not shut-off. When this happens, the water runs down the overflow tube to the bowl. Replace the float ball to correct the problem.

The water level in the tank should be about 1” below the top of the overflow tube, or to the water-level mark on the inside back of the tank. If it is lower than this, there may not be enough water in the tank to flush the fixture properly. If the water level is higher, the ball cock will not shut off because the water is running into the overflow tube. To adjust the level in the tank, you can raise or lower the float by bending the float rod or by using an adjusting screw located at the top of some ballcock assemblies. Sand usually appears in a water system after repairs are made to a water main. If sand gets in the water system, it can lodge in the float valve and prevent the washers from seating properly. You may be able to flush the sand from the ballcock assembly for an easy repair.

Flushing valves

There are many types of flush-ball valves (fig. 4–27), but the type we discuss in this lesson is one of the most complicated. This valve is commonly referred to as a Douglas valve, which is a common manufacturer’s name.

The W/C flush-ball valve is used in a closet tank to release water from the closet tank into the closet bowl for flushing. A trip lever that lifts the ball off the valve seat usually operates this valve. The ball is buoyant and, when lifted, is drawn onto the valve seat by suction. The ball is held on the valve seat by the water pressure above it.

A flush-ball valve consists of a machined seat, a flush ball, and an overflow tube. The machined seat is not subject to wear because the ball that closes the opening in the seat is softer than the seat. The flush ball is a small rubber or plastic ball that is open on the bottom. It seats into and closes the flush-ball valve, except during the flushing cycle, and it is connected to the operating handle by a trip lever and a system of rods. The flush ball, worn by constant reseating of the flush-ball valve, becomes soft, rotten, or deformed through normal operation. Replace faulty flush balls, because they cause leakage of water into the W/C. This condition produces noise and wastes water. Also, be sure the rods holding the flush ball are kept clean and properly aligned so the ball slides back into position. Replace the rods if they are worn or corroded.

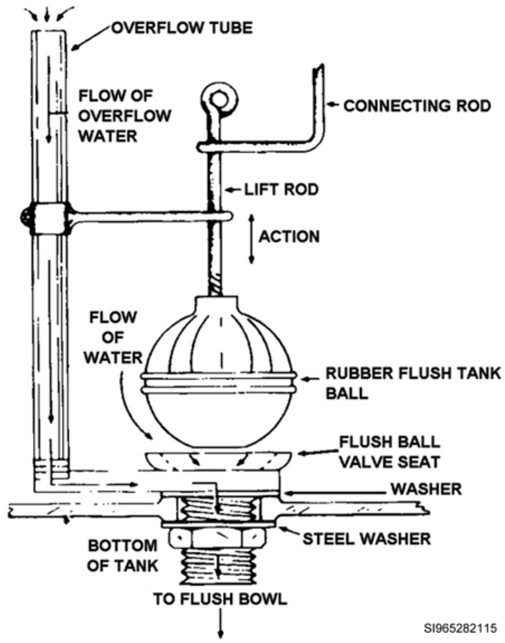

Figure 4–27. Flush-ball valve.

Some W/C flush-ball valves have a flapper in place of the flush ball and rods, as shown in figure 4–28. The flapper is attached to two lugs located at the bottom of the overflow tube. It works on the same principle as the flush ball. When a flapper starts to leak, it has to be replaced.

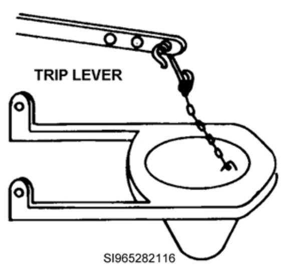

Figure 4–28. Flapper valve.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

441. Traps

1. What type of trap is built or molded into the fixture?

2. What type of trap is installed outside of the fixture?

3. What type trap is most commonly used?

4. What would be classified as a “common seal trap”?

5. What type of trap has a seal over 4”?

6. What type of repairs are made to traps?

442. Faucets

1. What parts of a single or mixing faucet could be faulty if it drips?

2. What is the first step for repairing pressure-balancing mixing valves?

3. What should you do if the faucet seat is pitted?

443. Shower valves

1. What type of shower valve consists of two hand-operated valves in one body?

2. What type of shower valve compensates for a change in pressures in the system, but it does not control water temperature?

3. What type of shower valve maintains a constant temperature, regardless of T&P changes in the system?

444. Flushometer flushing valves

1. How can you adjust the flushing cycle on a piston flushometer?

2. How can you shorten the flushing cycle on a piston flushometer?

3. What one substance most significantly affects the operation of a diaphragm flushometer?

4. What must you do if water is discharged from the vacuum breaker air gap during the flushing cycle?

445. Water closet float-controlled and flush valves

1. What is the purpose of the W/C flush ball valve?

2. What are the major components of a flush ball valve?

3. What should you do when a flush ball valve becomes worn?

4. What should you do to adjust the level in the tank?

4−3. Equipment

WFSM journeymen are always called on to repair utility accessories such as food grinders, ice machines, and drinking fountains—just to name a few. You have already found out from the previous lessons that there are many varied plumbing accessories installed in AF facilities. This section is designed to familiarize you with all of these plumbing systems and their principles.

446. Drinking fountains

Drinking fountains are installed to provide a quick and efficient supply of drinking water without the use of cups.

Drinking fountains

Sanitation is the most important factor when selecting a drinking fountain. The drinking fountain must contain a bubbler head that is located so that the user cannot touch it with their mouth. Additionally, the opening should project at least 1" above the rim of the drinking fountain so that the wastewater does not touch it. Direct the stream of water so that it does not fall back on the bubbler head.

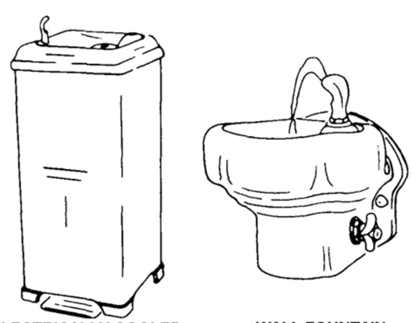

Figure 4–29. Types of drinking fountains.

Drinking fountains are constructed of vitreous china, porcelain, or stainless steel. The three different types of drinking fountains are the wall-hung, pedestal, and electrically cooled. The wall-hung fountain, as its name implies, is bolted to a mounting board on the wall. The pedestal fountain needs no support but stands on its own pedestal. The electrically cooled fountain contains a refrigerating unit. Water passes the refrigerating coils of the electronically cooled fountain and is cooled before it is supplied through the orifice of the bubbler head. The wall-hung and electrically cooled drinking fountains (fig. 4–29) are commonly used on AF installations.

Installation

The wall-hung, pedestal, and electrically cooled drinking fountains are connected to a water supply and drainage system. The only difference in these fountains is that the wall-hung type must be supported in a manner similar to that of a wall-hung lavatory, and the electrically cooled type must be connected to a source of electricity. The electrical and pedestal types sit on the floor and may or may not be bolted down. The wall-hung drinking fountain is mounted as shown in figure 4–29. As you can see in the illustration, a mounting board, hanger bracket, and mounting screws are required to support this fountain on the wall.

The minimum waste pipe size of 1¼” in diameter is used for drinking fountains, because they only carry clear water. The bubbler should be located 30 to 40” above the floor, depending on the general height of the people who are to use it. Additionally, a ⅜” water supply line is required for drinking fountains. Most fountains are equipped with a self-closing water valve to eliminate the wasting of water when they are accidentally left running. Underfeeding or overshooting fountain streams are annoying to the user and cause damage to the walls and floors; therefore, most fountains are equipped with an automatic stream regulator valve (fig. 4–30) that provides a uniform, balanced water supply in spite of fluctuating pressure. This valve has a setscrew under the cap nut that can be adjusted to obtain the desired stream of water through the orifice.

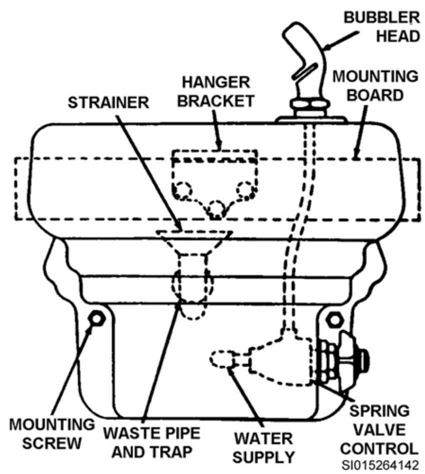

Figure 4–30. Automatic stream regulator.

Chewing gum is often left in drinking fountains by thoughtless users. For this reason, make sure your drinking fountains are equipped with good quality strainers to prevent the passage of chewing gum into the waste pipe.

Maintenance and repair

The repair of drinking fountains is generally confined to cleaning strainers, replacing valve parts, and adjusting valves. The drain line does not need clearing with a plunger very often because the fountain is equipped with a strainer. When the water cooling feature on an electrically cooled drinking fountain no longer works properly, call in a job order to have the heating and air conditioning shop inspect the cooling mechanism.

447. Grease traps

Without grease traps, many more sewer stoppages would occur. Grease traps are, therefore, necessary in all kitchens other than residential. Properly installed and maintained grease traps help immeasurably with sewer operation. Removing grease from greasy wastes is essential to the proper functioning of a sewer system in large military or commercial kitchens. In such kitchens, large quantities of grease that are allowed to pass into the waste system solidify and clog the waste pipes. To prevent this, you must install grease traps to collect the grease before it enters the waste system.

Construction and operation of grease traps

Various sizes of grease traps may be constructed of concrete, brick, wood, or metal. A number of different types of grease traps are available, but they all work on the principle that grease is lighter than water and, therefore, rises to the top of the water.

In the common air-cooled grease trap (fig. 4–31), the incoming water passes through a series of baffle chambers where the grease is cooled and rises to the top of the water. Water, free from grease, is drawn from the bottom of the trap and passed into the sanitary sewer system. As you can see in figure 4–31, the unit is only as efficient as the service it receives. In a very short period, the grease trap fills and ceases to remove grease. When this happens, the unit must be cleaned.

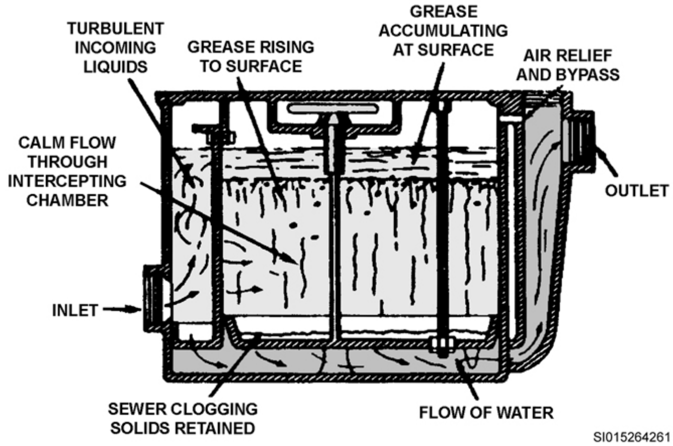

Figure 4–31. Small grease trap.

Installation of grease traps

A grease trap should be installed as close to its fixture as possible. The reason for this is that warm water helps carry greases to the trap easier. A trap located far from the kitchen might allow water flowing in the pipe to cool—increasing chances of grease particles solidifying and causing a blockage. A preferred location is outside the building so the odor does not get into the kitchen when opening the grease trap for cleaning. Since the grease trap must be cleaned periodically, it must have a removable cover. Some grease traps are connected to a hot and cold water supply so they can be flushed after the accumulated grease has been removed.

Cleaning grease traps

Typical cleaning intervals will vary with individual use. Some will need cleaning bi-monthly, while others will only need it quarterly. When you clean a grease trap, try to collect grease only. This is especially easy if you have an efficient vacuum pumper truck. Set the end of your suction pipe just above the surface of liquid and let the pump “slurp” the grease into your tank. Do not pump all the liquid from a grease trap. You want to leave enough water in the trap to prevent the grease from escaping. Pumping all the liquids from a trap will not only take up space in the tank, but also force you to fill the trap back up with water (at least half full). Previous experience best dictates cleaning intervals.

Repairing grease traps

Since a grease trap does not have any moving parts, there is very little to repair. In fact, the only parts of it that you may have to repair are the baffles, although you may also have to replace the bolts that hold the lid on the trap. On very rare occasions, the inlet and outlet tees in the trap may fall off because of corrosion. When this happens, fabricate a temporary inlet or outlet tee using plastic pipe and attach it to the remaining pipe stub until permanent repairs can be made. If the main body of the trap develops a leak, you have to patch the hole or replace the whole trap. The method you use to repair the hole depends upon the material used originally to make the trap. For example, you can repair a metal trap with epoxy or weld a patch over the hole. On the other hand, a wooden trap could be patched with roofing cement or pitch.

448. Oil/water separators

Oil/water separators (O/WS) are devices commonly used on AF installations as a method to separate oils from a variety of wastewater discharges. They are typically installed in industrial and maintenance areas, and receive oily wastewater generated during processes such as aircraft and vehicle maintenance washing. The effluent from an O/WS is typically discharged to either a sanitary or a storm sewer system. Discharges of domestic and industrial wastewater are regulated under the Clean Water Act which regulates pollutant discharges into our waterways. Properly designed, installed, and operated, O/WSs provide a treatment system for handling oily wastewater that prevents the entry of unacceptable levels of contamination to a storm sewer or sanitary sewer system. However, O/WSs are generally not designed to separate solids or high concentrations of oil from water that might occur, for example, when a drum or large quantity of oil or sludge is spilled or poured into a wash bay drain. Thus, it is important for all personnel who discharge wastewater into an O/WS to understand how they function, including their limitations, in order to prevent them from becoming sources of environmental pollution.

Operating principles of an oil water separator

O/WSs are "in-line" devices used to remove oils and greases (and sometimes solids) from industrial waste streams and storm water discharges. O/WSs operate by employing various physical or chemical separation methods, including gravity separation, filters, coagulation, flocculation, and flotation. However, the use of any separation process depends on the properties of the oil in the oil/water mixture.

The type of O/WS most frequently used by the AF is the gravity separation system. The performance of gravity separation systems is a function of the relatively low water solubility of petroleum products in water and their different specific gravities.

NOTE: The specific gravity of a petroleum product is defined as its density divided by the density of water. Since the density of petroleum products is less than that of water, they will float.

Solids, if present in the waste stream, will generally collect at the bottom of the O/WS holding tank and can be periodically removed when the tank is drained for maintenance.

A drain connected to an O/WS may be perceived as a convenient place to dispose of any type of liquid waste or sludge. This erroneous assumption can result in illegal discharges of hazardous substances to installation sewer systems (which eventually discharge to surface waters) or wastewater treatment plants. Failure to comply with regulatory guidance can result in fines and personal liability to the responsible individual. The illustration in figure 4–32 shows, in simplified form, the operation of a typical gravity O/WS system.

Occasionally, simple gravity-type O/WSs do not remove enough oil for the resulting wastewater to meet regulatory discharge requirements. In these cases, coalescing (binding together) O/WSs, which are essentially enhanced gravity-type O/WSs, are needed to achieve greater separation efficiency.

According to Stoke’s law of physics, a 100-micron diameter oil droplet will rise approximately 6” in water every 10 minutes. A 20-micron diameter oil droplet will take over two hours to rise the same distance. Because an oil droplet must rise approximately 48” to reach the water surface in a typical gravity-type O/WS, smaller droplets may pass through uncollected. Coalescing the smaller oil droplets makes them larger and more buoyant, causing them to rise faster. Coalescing O/WSs may use inclined plates placed within the separation chamber, which provide only a short vertical distance ($^1/_4$") for the small droplets to travel before they encounter a fixed surface. Here they can coalesce with other droplets and continue to rise along the plates to the water's surface. Another coalescing method uses a filter made of fine oleophilic (oil "loving") fibers such as polypropylene. The fine oil droplets attach to the fibers as the wastewater flows through. As the droplets get larger, they become buoyant enough to detach from the fibers and rise to the surface, where they can be collected.

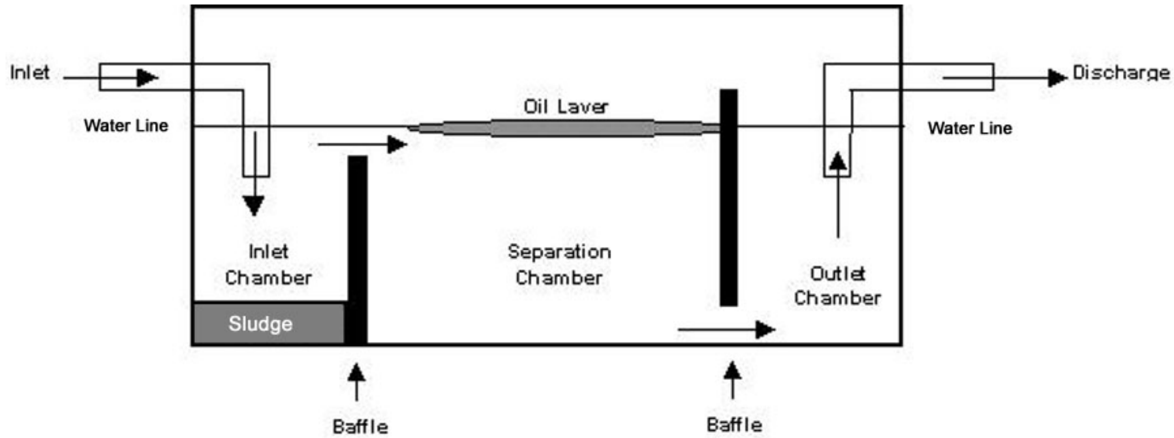

Figure 4–32. Flow of an oil water separator.

Operations and maintenance

As a WFSM journeyman, you may not have to deal with the operations and maintenance of an O/WS, but you need to be familiar with the ones on your installation and how to properly operate and maintain them if needed.

Existing oil/water separators

Follow this guidance for dealing with existing O/WSs on your installation. First, develop and implement a plan to assess the need for, and effectiveness of, existing O/WSs with the goal of consolidation or elimination of ineffective units. Second, perform a comprehensive inventory of all existing O/WSs (including on-line oil and grease/fuel traps, and small O/WSs outside of hangars, corrosion control facilities, fuels transfer/storage operations, aerospace ground equipment (AGE) maintenance shops, wash racks, etc.). Lastly, identify all separators and the mode of discharge (such as to storm sewer, sanitary sewer, septic tank, or direct discharge to the waters of the US. Locate the separator on the base utility as-built drawings and update the information as changes occur.

Quality assurance inspection of oil/water separators

Maintenance engineering will typically handle the oversight of the O/WSs on your installation, but it may fall on you to maintain these unique systems. If you find yourself responsible for your systems, follow these basic quality assurance (QA) instructions to properly maintain your base’s O/WSs. First, ensure you eliminate unpermitted pollutants and prohibit discharge of wastewater from industrial operations containing hazardous wastes and heavy metals. Second, implement dry cleanup procedures and only use floor drains to carry residual amounts of floating petroleum pollutants. Plug floor drains to separators that carry industrial wastewater from maintenance shops. Collect, treat, and dispose of industrial waste separately. Third, establish a primary office of responsibility (to include the functional organization for the management of pollutants discharged, and civil engineering for maintenance of O/WSs) which understands and has direct control over respective functions. Lastly, remove and test O/WS sludge regularly prior to disposal to ensure compliance with sludge disposal requirements. If the sludge is hazardous, take immediate actions to identify and eliminate sources of hazardous pollutants. Dispose of sludge as a hazardous waste and retest wastewater from the O/WS to assure compliance. Again, you may not be tasked to maintain the O/WSs on your installation, but this guidance gives you a starting point for maintenance if required.

449. Water heaters

A building hot water distribution system begins at the water heater and ends at the point of use. Manufacturers have developed excellent water heaters that are fully automatic. These compact units are manufactured in different shapes and sizes with a usual tank capacity of 20 to 60 gallons. New water heaters have many features to keep them operating for a long time with minimum maintenance. The major categories of domestic water heaters are gas-fired, electrically heated, and tankless heaters.

Gas water heater

The gas water heater (fig. 4–33) consists of a tank, a burner, and a flue. The tank, made of galvanized steel, is usually glass lined. All gas heaters are tested to operate at a pressure of about 300 psi, but the normal working pressure is about 125 psi. The tank is covered with an insulation that, in turn, is covered with a sheet metal casing that is painted with a baked enamel finish. The flue in the tank has a spiral-shaped deflector that baffles the burned gases to extract as much heat energy as possible. The draft hood is designed to prevent downdrafts and updrafts. It also eliminates excessive cooling drafts through the heater flue.

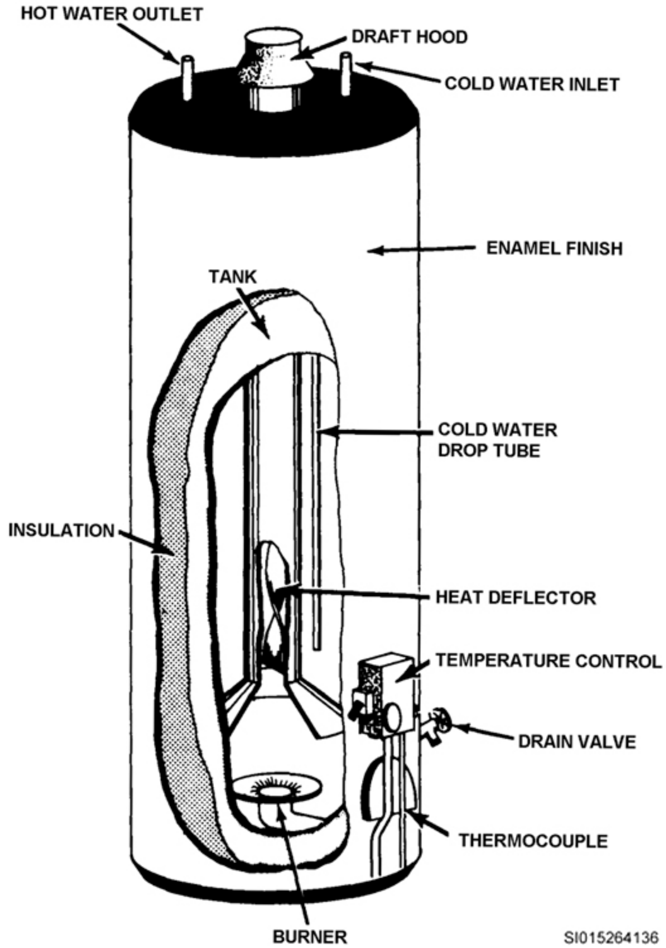

Figure 4–33. Gas water heater construction.

In the cold water inlet, there is a cold water drop tube. This tube has a beveled end and is secured in place by the cold water nipple. The tube is removable. It extends to within a few inches of the bottom of the tank. This causes the cold water that enters the tank to mix with the hot water that is present in the bottom of the tank. This is important because the discharge of hot water is from the top of the water heater. Thus, the cold water is given many opportunities to be exposed to the bottom heat source before it rises to replace the discharged hot water.

The temperature control, which is fully automatic, controls the on/off positions of the burner assembly. An arrow indicator on the temperature control dial can be set at any temperature from 80 to 180°F. This temperature control also shuts off the gas supply if the pilot light is extinguished. There is also a drain cock with a hose connection near the bottom of the tank. This is used to flush any accumulation of sediment from the heater.

Electric water heater

An electric water heater (fig. 4–34) does not require a flue; therefore, the heater can be installed anywhere in the home. A gas line is not required for the unit, but electrical wiring is required for the heating elements. The electric water heater is quieter and cleaner in operation than a gas model.

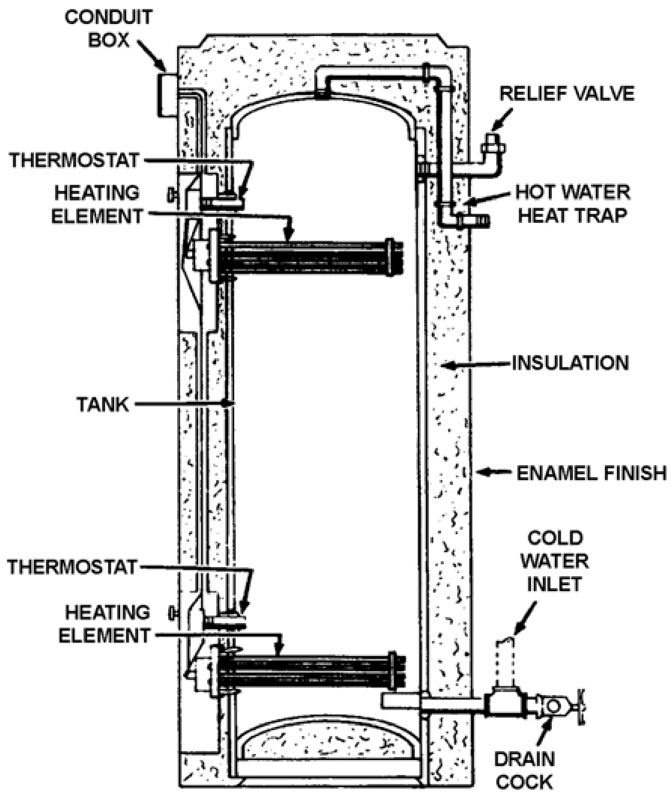

Figure 4–34. Electric water heater construction.

Tankless water heater

While tankless water heaters have been around for many years, they have only recently become popular with homeowners. The concept of producing hot water only when there is a demand for it makes a lot of sense. This approach eliminates the need for a storage tank and the energy losses associated with maintaining a reservoir of 140-degree water. However, there is also a downside to this approach. Without an available reservoir of hot water, you are restricted to the amount of hot water that can be "instantaneously" produced by the tankless unit. There is no reservoir to fall back on to help you meet increased hot water demands.

Standard electric water heaters typically require a 25–30 ampere (amp) circuit breaker, whereas tankless water heaters require 50–60 amp circuit protection. Because of this large electrical load, a tankless water heater will require that a higher capacity home wiring and breaker be installed. In some cases, wiring also must be installed at your expense between the distribution transformer in the neighborhood and your electric meter. They are also available in propane and natural gas models (fig. 4–35).

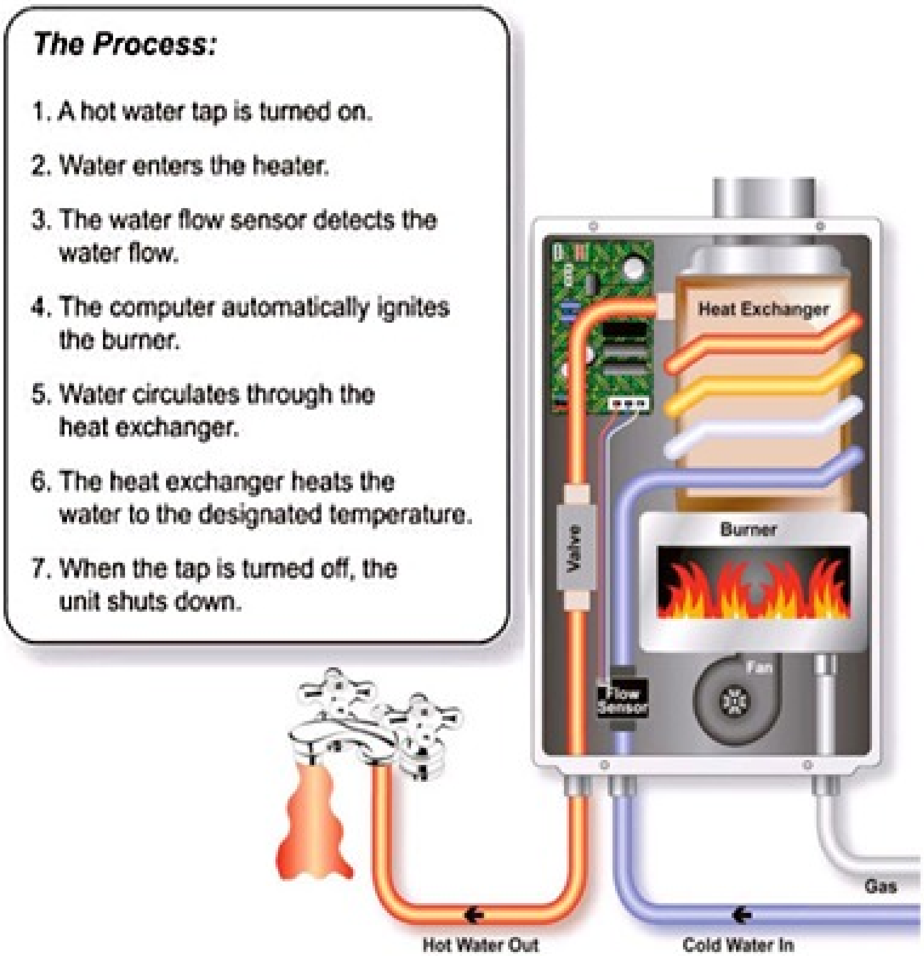

Figure 4–35. Gas tankless water heater.

Locating water heaters

When you install a water heater, first determine the location of the heater unless such location is specified in the blueprints. Also, decide on the size of pipe to be used for the cold and hot water lines. After the water heater is installed, check its operation.

In a new installation, check the blueprints or plans for the correct location of the water heater. Locate water heaters and tanks as close as possible to hot water risers to shorten the distance the water must flow to reach the fixture. When hot water is drawn, all the cold water in the pipes must flow before the hot water reaches the faucet. After the faucet is turned off, the water in the pipes cools. If the water heater cannot be placed near the riser, a great amount of savings and efficiency of the hot water system can be maintained by covering long lines of piping with insulation.

When sizing a building for hot water needs, you have to consider the number of bathrooms and bedrooms and how many and what type of appliances are to be installed. The minimum recommendation for an average hot water requirement is shown in figure 4–36. Practical tests reveal that the amount of water used by an individual range from 2–10 gallons per hour. Of course, this depends on the type of building in which the system is installed and the purpose of the water.

NUMBER OF BATHROOMS	NUMBER OF BEDROOMS	MINIMUM STORAGE CAPACITY REQUIRED
1	1	20 GALLONS
1	2 OR 3	30 GALLONS
2	2 OR 3	40 GALLONS
3	3 OR 4	50 GALLONS

Figure 4–36. Hot water requirements.

Manufacturers supply rough-in specifications for their water heaters so that pipes can be aligned accurately with heater outlets. A gas-fired heater should be located where an adequate amount of air is available for combustion. The flue of a gas-fired heater cannot be installed near combustible material. Make sure you comply with local codes before you install a gas-fired heater. Figure 4–37 illustrates a gas water heater installation.

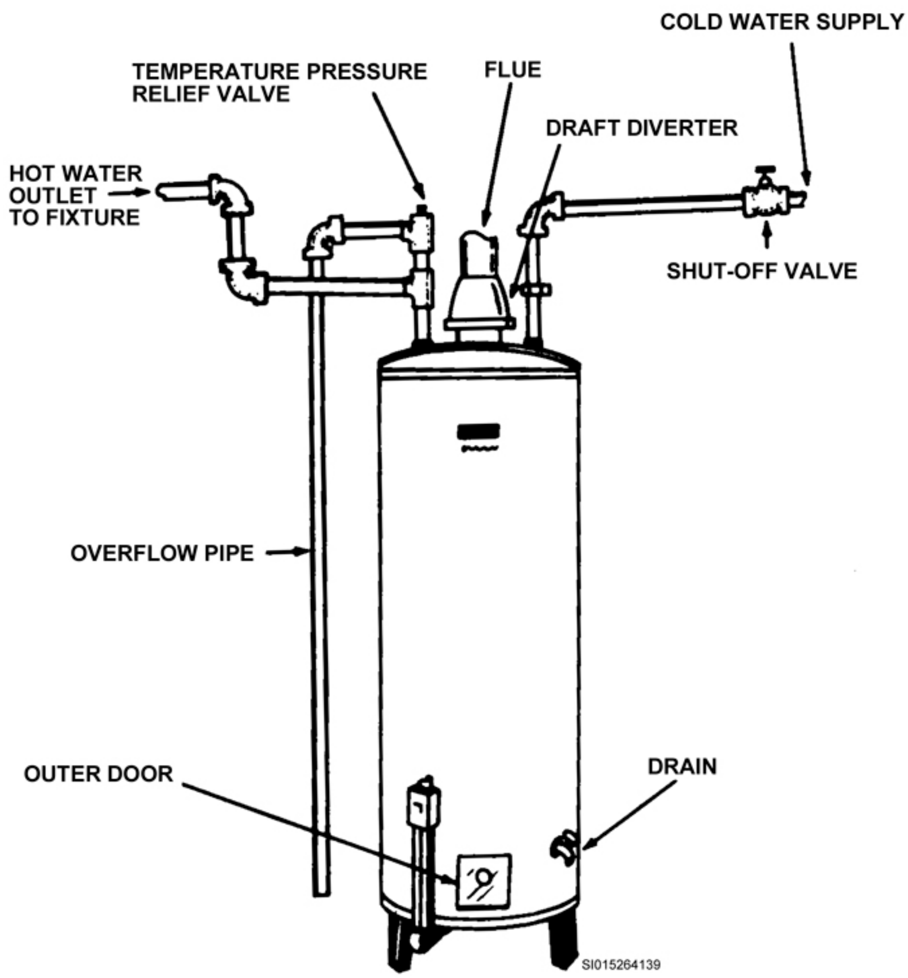

Figure 4–37. Typical water heater installation.

Each gas-fired water heater should be equipped with a suitable draft diverter or vent hood (fig. 4–38). This prevents a downdraft or updraft from affecting combustion or blowing out the pilot light. Locate a gas water heater where it can be vented through the roof or into an inner chimney. If the flue is run horizontally and connected to a chimney, the flue slope should not be less than ¼” per foot. A 3 or 4” flue is normally enough for an individual domestic gas water heater; however, always check the code requirements. Also, always check code requirements when multiple heaters are installed. Since an electric water heater doesn’t create any fumes, it does not have to be vented.

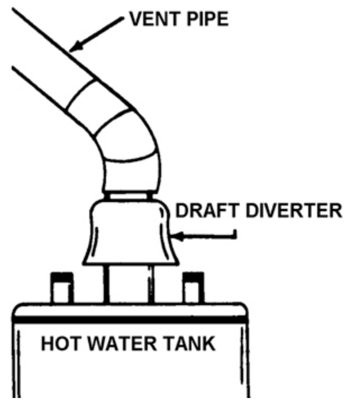

Figure 4–38. Water heater vent arrangement.

Installation procedures

The type of heater and installation method determines the type of tools you should use when you install a water heater. The rough-in measurements for a new installation are determined by the manufacturer. It remains for the craftsmen to install the risers to the height specified for proper fixture connection.

The heater outlets for connecting hot and cold water pipes are marked on top of the heater near the opening. If the heater is not marked, the hot water outlet is usually on the left as viewed from the front of the heater.

The cold water supply should not be smaller than a ¾” pipe and should be provided with a gate valve near the tank to cut off the water supply. The hot water line from the heater must be large enough to meet the demand of the fixtures connected to the distribution system.

An anode rod is factory installed at the top of the water heater. This rod prevents corrosion from occurring inside the tank. Place unions in the hot and cold water lines to disconnect the lines quickly when you must replace the heater. If the piping system is copper, install dielectric unions to prevent electrolysis. To prevent corrosion, use pipe hangers and clamps of the same material as the pipe. If galvanized steel pipe is used in the hot and cold water system, you must cut, ream, and thread all piping and apply joint compound to the threads before assembly and final connection.

Safety

Every type of hot water tank should be safeguarded against the possibility of an explosion. An explosion can be caused by water that has become superheated because of an automatic cutoff failure or because someone neglected to turn off a manually controlled heater.

Explosive force of steam

Few people realize that a single pound of water changed into steam 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. Building codes require that a safety valve is installed on the tank or the outlet side of the water heater. This type of valve is a T&P safety valve. This valve is normally set by the factory to 150 pounds working pressure and 210°F.

Installing gas service

Gas piping lines are installed within a building in the same way as water lines; that is, the black iron piping for the gas system is cut, reamed, and threaded and the joints coated with joint compound the same way as galvanized water piping. Black iron piping is used largely in gas distribution. If galvanized pipe is used, the gas causes the zinc coating to flake off and stop the flow of gas through the fixture orifice. The *minimum* size black iron gas pipe allowed to be connected to a gas water heater is ½”.

Install a union in the line so you can disconnect it easily when you must replace the heater. In place of a union, some local codes may permit a short length of copper tubing to be installed to the heater. You also should install a plug valve (called a gas cock) in the line so that the gas can be shut off if you need to remove or service the heater. When you install gas lines, be sure they are supported with proper hanger supports. Use only approved threaded pipe and fittings. You may use flared tubing if the line is above the floor level and exposed.

Testing for gas leaks

After you have installed the gas line and before the system is put into service, test it for leaks. Leakage of gas not only is wasteful but also constitutes a serious hazard. Check a gas system more closely than a water system. The simplest test for leaks at joints or valves is the application of soapsuds to the suspected joint. Bubbles appear on the pipe surface if there is a leak. You may also use electronic gas detectors.

Repair water heaters

Considering how much we depend on hot water, we are fortunate that water heaters are one of the longer-lasting appliances that we have in the household. The following are water heater components that commonly fail and need replacing.

T&P relief valves

Whenever you replace a T&P relief valve, be sure that you isolate the cold water supply line to the water heater. Open the relief valve to release pressure contained within the tank; remove by turning counter clockwise. During installation, make sure you apply anti-seize tape or pipe dope to the threads on the valve. Attach by turning the valve clockwise. Make sure the valve stem or thermal element extends into the tank. The element of the valve should be in direct contact with the hot water. The outlet of a T&P relief valve must *not* be connected to the drainage system as a direct waste. It can drain to a floor drain or to a drainpipe as long as it is not physically connected to it. If the outlet is going to discharge to the floor, put the pipe end *within 6"* of the floor.

Heating elements

More caution is demanded for replacing heating elements due to electrical hazards. Make sure you de-energize the water heater at the breaker box and lock/tag out for your safety. Remove the cover and insulation to access the heating elements. Make sure that the heater is de-energized by using a meter to check the voltage at both terminals at the top of the thermostat. Perform a continuity test on each element by using the meter. Start by removing one wire lead from the element. The testing meter should be set to ohms. Place the leads from the meter on both polls on the element. A properly operating element resistance should read between 11–14 ohms for a typical 240-volt, 4,500-watt element. Once you determine which element needs replacing, isolate the cold water supply valve to the heater. Open the T&P relief valve to exhaust pressures contained within the tank. Attach the hose to the drain valve; open and empty the heater. Make sure you leave the T&P relief valve in the open position to prevent the tank from air locking. Disconnect any remaining wires from the elements. Domestic water heater elements are usually 1½" in diameter so a socket works well for removal. Once you remove the heating element by turning counter clockwise, ensure your replacement has the same voltage and wattage as the defective element. When installing the new element do not apply anti-seize tape or pipe dope; the element comes with a rubber gasket for installation. Affix the element by turning clockwise hand tight plus a half turn with a wrench. Reinstall the wires to the elements. Open the cold water supply valve to the water heater to fill the tank. When all the air escapes and a steady stream of water discharges through the T&P relief valve, close the valve. Turn the power back on to the heater at the breaker box and test your elements with a meter to ensure you have power to your elements. Typically, it takes one half hour to heat the water in the tank.

Thermocouple

When a gas water heater will not stay lighted and the water is not heating sufficiently, a burner cleaning and thermocouple replacement is needed. Start by turning the gas cock on top of the control box to the ***OFF*** position. Make sure you wait 10 minutes to allow any gas to dissipate. Disconnect the pilot tube and the thermocouple from the bottom of the control box. Remove the outer and inner access panels covering the burner chamber. Disconnect the pilot gas tube, the burner gas tube, and thermocouple wire to free them from the control box. Tilt the burner unit slightly and remove it from the burner chamber. Unscrew the burner from the burner gas tube nipple. Clean the small opening in the nipple, using a small piece of wire. Vacuum out the burner jets and the burner chamber. Clean the pilot gas tube with a piece of wire. Vacuum out any loose particles. Screw the burner onto the gas tube nipple and pull the thermocouple from the bracket. Install a new thermocouple by pushing the tip into the bracket until it snaps into place, and insert the burner unit into the chamber. Reconnect the gas tubes and thermocouple to the control box. Turn on the gas and test for leaks with soapy water. Relight the pilot to start heating water. The following table provides some common problems with water heaters and some suggested solutions.

Problem	***Repair***
No hot water or not enough hot water	The thermostat is set too low or is defective. (Adjust/replace.) The lower heating element has burned out. (Replace.)
Water is too hot	The thermostat is set too high. (Lower temperature.) The thermostat high temperature cut off is defective. (Replace.)
Pilot flame will not stay on	Clean the gas burner and replace the thermocouple.
Noisy water heater	Sediment build up at the bottom of the tank. (Flush tank.)

450. Food grinders

These devices are installed in kitchens to provide a way to dispose of food waste. The two main types of disposals are domestic and industrial.

Domestic

These units are found in residential kitchens. They are mounted in the basin of a kitchen sink in place of a basket strainer (fig. 4–39). The domestic garbage disposal attaches to a standard sink drain, 1½” in diameter, and may have an inlet so that the drain hose from a dishwasher can attach into the disposal. An electrical switch, usually mounted near the sink, controls the activation of the unit. Place small amounts of food into the hopper with the water running and turn on the electrical switch. The flywheel inside the unit spins at about 1,700 revolutions per minute (rpm). The centrifugal force created by the high speed forces the food against the walls of the disposal. Small cutters are attached to the flywheel, and along the sides of the wall are little shredding rings. The result is that the food is pulverized and ground into a liquid that is washed down the waste line. Always follow the manufacturer’s specifications when you install a domestic disposal.

Probably the most common problem with the domestic disposal is a jammed flywheel. This is typically caused by hard objects that become jammed between the cutting rings along the sidewall and the impeller. The jam can be loosened by using a wooden plunger or broom handle to turn the flywheel. Once the impeller is free, the motor still may not operate and produce only a humming sound when the switch is turned on. Most disposals have an overload protector that shuts off the motor when the impeller jams. On the bottom of the disposal, there is a red button marked “reset.” When this button is pushed, the motor should turn freely.

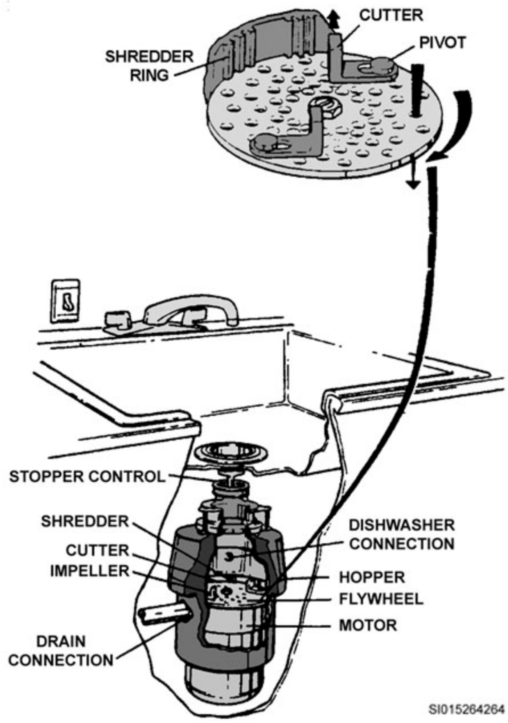

Figure 4–39. Domestic food grinder (disposal).

If water is leaking from around the disposal, you can try to tighten the ring around the bottom of the sink that holds the gasket against the sink basin. You may also have to replace the plumber's putty under the sink-mounting flange. If the disposal *itself* is leaking, check for corrosion; the disposal may need to be replaced.

Industrial

Industrial food grinders are located in commercial kitchen areas, normally near the dishwasher. They are similar to domestic units but have a few minor differences. The industrial unit is much larger and requires a constant flow of water when used. Faucets cannot supply the required amount, so normally a separate water line is installed to the unit. The size of the water supply line depends on the size of the unit. The amount of water going into the unit is controlled by a pressure-reducing valve. A solenoid valve (connected to a pressure switch and control box) actuates the flow of water going to the unit. The water supply requires a vacuum breaker to be installed to prevent the chance of back-siphonage of wastewater. The size of the drain depends on the size of the unit being installed. Check the manufacturer's specifications for the unit you are installing.

The most common problem with an industrial unit is the same as with the domestic unit—a jammed flywheel (impeller). This is usually caused by a piece of silverware or a bone. The jam can be loosened by using a wooden plunger or broom handle to turn the flywheel. When it turns free, remove the object that caused the unit to jam. If you cannot free the flywheel, follow the manufacturer's specification to disassemble the unit.

451. Emergency eyewash and shower

As we discuss the most common types of emergency showers and eyewashes, let's also examine pertinent facts about supply lines, drain lines, and locations.

Drench-type

The drench-type emergency shower design provides a rapid flow and high volume of water that quickly flushes the entire body. This shower may consist of a single large showerhead or two or more small directional heads. Install the head(s) 82–96” above the floor or above the unit’s step-on platform.

Water supply

Connect the water supply line to the potable water system. The minimum size supply line is 1¼”, but this line may need to be larger if the supply source is located a long distance from the unit or if more than one unit is connected. The pipe should be large enough to furnish at least 50 gpm of flow. The water temperature should be between 60–100°F. In some locations, a hot water source may be required.

Drain

Drench-type units may or may not require a drain. Units located in areas where toxic or contaminated substances are used cannot be directly connected to the sanitary sewer system. Either make some provision for collecting the waste and neutralizing the substances before disposal into the sanitary sewer or channel the runoff into a drain that is designed for industrial waste.

Combination-type

The combination-type units are equipped with both shower and eyewash components. The units come in a variety of styles, such as (1) open framework, (2) covered on two sides, and (3) covered on three sides. The eyewash unit may be installed in numerous ways—such as freestanding or pedestal-type, or mounted to the shower framework or sidewall.

Three types of spray heads are used in the combination units: wide-angle, jet-type (mist spray), and adjustable. The heads may be set to give full or partial body coverage. Some units are designed to flush the head area and one side of the person, while others are designed to provide flushing from all sides and top to bottom.

Water supply

The combination unit requires a water supply that is large enough to feed the shower and eyewash at the same time. The minimum water supply line depends on the manufacturer, but it can never be smaller than 1¼”. Install a strainer or filter in the line to the eyewash unit to prevent debris from clogging the small orifices of the nozzles. Make sure the eyewash control valve is a pressure-reducing valve to prevent high pressure that might cause eye injury. Be certain the pressure to the eyewash is not more than 25 psi. Equip the heads with an aerator to provide a soft flow of water. Normally, a stream 6–12” above the nozzle is adequate. Install eyewash units with the nozzles between 33 and 45” from the base of the platform or floor.

Drain

The drain requirements for this unit are the same as for the drench-type unit mentioned above.

Decontamination unit

This unit is designed to provide a complete body flushing and eyewash action at the same time. The activation of this unit is controlled by stepping onto the floor platform. It is a three-sided unit with the eyewash mounted on the back wall; this allows simultaneous body and eye flushing. The eyewash is usually a full-face, flush type.

Make sure the water line to the eyewash unit has a filter and pressure-reducer installed. The drain requirements for this unit are the same as for the other units’ requirements.

Physical location is very important to the possible users of an emergency shower or eyewash unit. Place the unit as close to the hazard as possible, and not more than 10 seconds’ travel time away from the hazard. Make sure the unit is in an open area and free from obstacles, such as stacked materials, machinery, or high-use equipment. Clearly mark the path to the unit and be certain the unit is accessible from three sides.

Maintenance

The supervisor or an authorized individual of the section where the installed shower and eyewash units are permanently located should activate the units. Do the operational tests once a month, and operate the units long enough to make sure that adequate pressure and volume are available and that all orifices are open. Remove any scale from spray heads or nozzles. If scale or rust cannot be removed, replace the heads or nozzles.

Units that are installed in unoccupied or seldom-used locations may not get tested monthly. In such cases, give the units an operational test before any work or activity begins that might expose personnel to hazardous materials.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

446. Drinking fountains

1. What is the most important factor to consider when you select a drinking fountain?

2. How should the stream of water on a bubbler head be directed?

3. How high should the bubbler be located above the floor?

4. What feature on a drinking fountain compensates for fluctuating supply pressures?

5. What are the normal maintenance items on a drinking fountain?

447. Grease traps

1. What is the principle on which grease traps operate?

2. From what location is the water that drains from a grease trap drawn and where is it directed?

3. Where is the best place for a grease trap to be installed?

4. What repairs may have to be made on a grease trap besides fixing a hole?

5. How can a hole in a metal grease trap be repaired?

448. Oil water separators

1. What is the Clean Water Act designed to do in regards to oil water separators?

2. According to Stokes Law of physics, how fast does a 100-micron diameter droplet of oil rise in water every 10 minutes?

3. After you dispose of hazardous sludge, why do you retest the effluent wastewater from the O/WS?

449. Water heaters

1. Where are the beginning and ending limits of a hot water distribution system of a building?

2. What is the usual range of sizes of water heaters?

3. What is the purpose of a spiral-shaped deflector flue inside the hot water tank?

4. What prevents downdrafts and updrafts through the heater flue?

5. What is the purpose of the cold water drop tube?

6. What are some advantages of an electric water heater over a gas water heater?

7. Where should a water heater be installed in relation to the hot water risers? Why?

8. What is the usual range of hot water used by an individual?

9. What is the minimum size water supply required for a water heater?

10. What is the normal setting (working pressure) on a T&P safety valve?

11. What is the minimum size gas supply for a gas water heater?

12. When may flared copper be used to supply gas to a gas water heater?

13. What is the simplest method to test for leaks in gas supply piping on a gas water heater?

450. Food grinders

1. What are the two types of disposals?

2. What actually cuts the food in a domestic grinder?

3. What should you check if the disposal itself is leaking?

4. What determines the size of the water supply to an industrial grinder?

451. Emergency eyewash and shower

1. What is the requirement for showerheads in a drench-type emergency shower?

2. How many gallons of flow should be delivered by the drench-type water supply?

3. When should drains not be connected to the sanitary sewer system?

4. What are the three types of heads used on the combination-type shower?

5. What is installed to prevent debris from clogging the nozzles of an eyewash unit?

6. Why should the eyewash control valve be a pressure-reducing type?

7. What should be the height of the eyewash stream?

8. How high from the floor should the eyewash nozzles be mounted?

9. How much travel time is allowed between a hazard and an emergency shower?

Answers to Self-Test Questions

436

1. The minimum space from the center of the lavatory to the nearest sidewall should be 12”.
2. The smallest drain and vent for a lavatory is 1¼”, but waste lines of 1½” are more satisfactory.
3. Brass screws.
4. Lavatory rim at 31” above the finished floor.
5. Mechanical pop-up.
6. The hot water line should go to the left side of the lavatory, and the cold line should go to the right.
7. A jiffy connector.

437

1. On the building floor plan.
2. You may crack the bowl.
3. 1”.
4. Allow 15” of space from the center of the bowl to the nearest sidewall.
5. 3”.
6. 2”.
7. $^{3}/_{8}$”.

438

1. 20 to 25” above the floor.
2. The minimum space from the center of the urinal to the wall should be 12”.
3. 2” for cast iron and 1½” for copper and plastic.
4. $1^{1}/_{4}$”, or not less than one-half the diameter of the waste pipe that it vents, whichever measurement is larger.
5. ¾”.
6. Brass bolts or screws.
7. An angle valve.
8. With a spud.

439

1. The floor plan.
2. The tub overflow and drain assembly.

3. 1½”.
4. The type of shower you install has a direct bearing on the size waste line you install.
5. A shower arm.

440

1. A grease trap takes the place of the trap.
2. Cleaning the grease trap, repairing the food grinder, unclogging the drain, and repairing the faucets.
3. Follow the manufacturer’s specifications.
4. It must be connected to the waste line by a double Y.
5. Removal of stoppages and repair of water supply faucets lines.
6. Slop sink or service sink.

441

1. Integral.
2. External.
3. “P” trap.
4. A trap with a 2” seal.
5. Deep seal trap.
6. Tighten loose nuts, replace leaking gaskets, or replace corroded trap pieces.

442

1. The problem could be a bad washer, seat, or stem packing.
2 Remove the handle from the stem.
3. Replace it.

443

1. The manual mixing valve.
2. The pressure-controlled mixing valve.
3. The thermostatic mixing valve.

444

1. By turning a screw on top of the flushometer body.
2. Turn the adjustment screw clockwise.
3. Dirt.
4. Replace the rubber insert inside the vacuum breaker.

445

1. To release water from the closet tank into the closet bowl for flushing.
2. A machined seat, flush ball, and an overflow tube.
3. Replace it.
4. Raise or lower the float by bending the float rod or by using an adjusting screw located at the top of some ballcock assemblies.

446

1. Sanitation.
2. So that it does not fall into the bubbler.
3. 30 to 40”.
4. Automatic stream regulator.
5. Cleaning strainers, replacing valve parts, and adjusting valves.

447

1. Grease is lighter than water and therefore will rise to the top of the water.
2. From the bottom of the trap and passed into the sanitary sewer system.
3. As close to the fixture as possible, preferably outside the building so that the odor will not get into the kitchen.
4. Repair the baffles and replace bolts.
5. With epoxy or by welding a patch over the hole.

448

1. Regulate the discharge of domestic and industrial pollutants into our waterways.
2. Approximately 6”.
3. To assure compliance.

449

1. Begins at the water heater and ends at the point of use.
2. Tank capacities of 20 to 60 gallons.
3. It baffles the burned gases to extract as much heat energy as possible.
4. Draft hood.
5. Keeps the cold water from diluting the hot water near the discharge pipe.
6. Does not require a flu; quieter and cleaner in operation.
7. As close as possible to hot water risers. To shorten the distance the water travels.
8. 2 to 10 gallons per individual.
9. ¾”.
10. 150 pounds.
11. ½” black iron.
12. When the line is above the floor level and exposed.
13. Apply soapsuds to the suspected joint.

450

1. Domestic and industrial.
2. Centrifugal force, small cutters attached to the flywheel, and little shredding rings attached to the sides of the wall.
3. Check for corrosion, and replace the entire disposal if needed.
4. Depends on the size of the unit.

451

1. The shower must provide a rapid flow and high volume of water that quickly flushes the entire body. This may be done with a single large head or by using two or more small directional heads.
2. At least 50 gpm of flow.
3. In areas where toxic or contaminated substances are present.
4. Wide angle, jet type (mist spray), and adjustable.
5. A strainer or filter.
6. To prevent high pressure from causing eye damage.
7. 6 to 12” above the nozzle.
8. 33 to 45” from the base of the platform or floor.
9. Not more than 10 seconds.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

69. (436) If there are *no* manufacturer specifications, how many inches from the finished floor do you install the lavatory rim?
    a. 30.
    b. 31.
    c. 32.
    d. 33.

70. (436) The special wrench designed to reach the hex jamnut beneath a fixture is the
    a. pipe wrench.
    b. box wrench.
    c. basin wrench.
    d. adjustable wrench.

71. (437) Which water supply size is required for a flushometer-type water closet (W/C)?
    a. ¼ inch (”).
    b. ½”.
    c. ¾”.
    d. 1”.

72. (437) Tank water closets (W/C) are preferred over flushometer W/Cs for residences because they
    a. are less expensive.
    b. flush more quickly.
    c. require a smaller drain.
    d. require a smaller size supply line.

73. (437) When you install a water closet (W/C), how many inches should you allow from the center of the bowl to the nearest sidewall?
    a. 12.
    b. 15.
    c. 18.
    d. 21.

74. (437) When working on a drain line, the *smallest* plastic drain that can accommodate a water closet (W/C) is
    a. 2 inches (”).
    b. 3”.
    c. 4”.
    d. 6”.

75. (438) What are the two *most common* types of urinals you would find on an Air Force (AF) installation?
    a. Trench and cradle.
    b. Wall-hung and pedestal.
    c. Integral and external.
    d. Outright and exterior.

76. (438) When you install a urinal, the *minimum* space you should allow from the center of the urinal to the nearest sidewall is how many inches?
    a. 12.
    b. 15.
    c. 18.
    d. 21.

77. (439) Which two *critical* factors will you face when installing a shower drain?
    a. Location of the shower drain and the size of the shower drain cover.
    b. Type of showerhead and the size of supply line feeding the mixing valve.
    c. Size of the horizontal line and the distance from the fixture's trap to the vent.
    d. Type of pipe used and the proper placement of the drum trap for the overflow drain.

78. (440) The distance between the floor and the drain board in a kitchen sink should be at which height after installation?
    a. 12 inches (").
    b. 24".
    c. 36".
    d. 48".

79. (440) Which component of a utility sink provides pedestal support?
    a. Catches.
    b. Stand trap.
    c. Drain basin.
    d. Brace supports.

80. (441) Identify the two types of conditions traps are designed to withstand.
    a. Pressure and gravity.
    b. Gravity and vacuum.
    c. Vacuum and pressure.
    d. Gravity and gaseous.

81. (442) Which part of the body unit faucet is replaced in heavy use applications?
    a. Body unit.
    b. Wearing washer.
    c. Stainless steel seat.
    d. Ceramic control component.

82. (442) A *continuous* dripping of a single or mixing faucet may indicate
    a. a bad washer.
    b. a damaged handle.
    c. low water pressure.
    d. angle stop leaking.

83. (443) Which three types of valves are used in showers to control the flow of hot and cold water?
    a. Manual, semi-automatic, and automatic types.
    b. Manual, automatic, and pressure-controlled types.
    c. Manual, pressure-controlled, and thermostatic types.
    d. Thermostatic, automatic, and semi-automatic types.

84. (443) Which shower/bath mixing valve is sensitive to both temperature and pressure?
    a. Pressure-controlled.
    b. Double-handled.
    c. Triple-handled.
    d. Thermostatic.

85. (444) Which factor keeps the diaphragm flushometer valve closed?
    a. Unequal water pressure.
    b. Unequal water force.
    c. Equal water pressure.
    d. Equal water force.

86. (445) When a water closet's (W/C) flapper is leaking, you should
    a. replace the chain.
    b. replace the flapper.
    c. adjust the rod guides.
    d. lightly sand it with emery cloth.

87. (446) A drinking fountain bubbler opening should be located above the drinking fountain rim at a *minimum* of how many inches?
    a. 1.
    b. 2.
    c. 3.
    d. 5.

88. (446) The device that is used to control the underfeeding and overshooting fountain stream problems is a/an
    a. splash guard.
    b. adjustable stream valve.
    c. automatic stream regulator valve.
    d. manual pressure regulator valve.

89. (447) Why *must* grease traps be installed in large military or commercial kitchens?
    a. A properly installed trap will prevent stoppages caused by grease solidification.
    b. It is easier to dispose of grease into a trap and collect it there rather than a barrel.
    c. To collect the grease and stir it up well before discharge into the sanitary system.
    d. In most states, local laws dictate that grease must be collected and dumped in a landfill.

90. (448) On which type of as-built drawings are oil/water separators (O/WS) located?
    a. Utility.
    b. Electrical.
    c. Mechanical.
    d. Environmental.

91. (449) The drain cock with a hose connection at the bottom of a water heater is *primarily* used to
    a. bypass the water heater.
    b. flush sediment out of the heater.
    c. connect cold water into the heater.
    d. provide hot water access for washing equipment.

92. (449) Where should a water heater be located?
    a. As close as possible to the hot water risers.
    b. As far as possible away from the hot water risers.
    c. In an enclosed room on the south side of any building.
    d. In an enclosed room on the north side of any building.

93. (449) Which step *must* you do *first* when replacing a heater element on a water heater?
    a. Check for voltage to the water heater.
    b. De-energize the water heater.
    c. Drain the water heater.
    d. Fill the water heater.

94. (449) If the pilot flame will *not* stay lit on a gas water heater, the
    a. thermostat is set to high.
    b. heating element has burned out.
    c. sediment build up in the tank.
    d. gas burner needs cleaning.

95. (450) A domestic food grinder is designed to attach to a drain with a diameter of how many inches?
    a. $1^1/_4$.
    b. 1½.
    c. 2.
    d. $2^1/_4$.

96. (450) Which action should you take to restore a disposal after the impeller has been freed?
    a. Check the equipment for proper voltage and amperage.
    b. Disassemble and replace the fly wheel.
    c. Disassemble and inspect for damage.
    d. Push the reset button.

97. (450) Which device is installed on the industrial food grinder water supply line to *prevent* back-siphonage of waste?
    a. Gate valve.
    b. Check valve.
    c. Vacuum breaker.
    d. Reduce pressure device.

98. (451) How high above the floor are the directional heads for a drench-type shower installed?
    a. 80 to 90 inches (”).
    b. 82 to 96”.
    c. 90 to 95”.
    d. 95 to 100”.

99. (451) The *minimum* size water supply for a drench-type *emergency* shower and eye wash is
    a. 1 inch (”) or less.
    b. 1⅛”.
    c. 1¼”.
    d. 2”.

100. (451) At which frequency should you perform an operational test on an emergency drench-type shower?
    a. Monthly.
    b. Quarterly.
    c. Semiannually.
    d. Annually.

Student Notes

Glossary of Abbreviations and Acronyms

°	degrees
’	foot/feet
”	inch/inches
ABS	acrylonitrile-butadiene-styrene
AF	Air Force
AGE	aerospace ground equipment
amp	ampere
ASTM	American Society for Testing and Materials
CDC	career development course
CE	civil engineer
CO	cleanout
CPVC	chlorinated polyvinyl chloride
CTS	copper tube size
DWV	drain, waste, and vent
fps	feet per second
ft-lb	foot-pounds
GFCI	Ground Fault Circuit Indicator
gpm	gallons per minute
HP	high pressure
LP	low pressure
MP	medium pressure
NFPA	National Fire Protection Association
NPT	National Pipe Thread
O/WS	oil/water separator
OD	outside diameter
PB	polybutylene
PE	polyethylene
PEX	cross-linked polyethylene
PP	polypropylene

ppm	parts per million
psi	pounds per square inch
PVC	polyvinyl chloride
QA	quality assurance
rpm	revolutions per minute
SCBA	self-contained breathing apparatus
T	tee
T&P	temperature and pressure
TO	technical order
UPC	*Uniform Plumbing Code*
US	United States
USAF	United States Air Force
W/C	water closet
WFSM	Water and Fuel Systems Maintenance
XLPE	cross-linked polyethylene
Y	wye

Student Notes

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