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CHAPTER 8

MECHANICAL SYSTEMS AND PLAN

To be able to prepare workable construction. drawings, EAs should have the ability to recognize and describe the materials used in mechanical systems, to understand their uses and functions, and to discuss the purpose and the development of a mechanical plan in the context of plumbing for water distribution and drainage systems.

This chapter will discuss only the plumbing and drainage portions of the mechanical systems and the various materials used. You will not be expected to design the system; however, as an EA, you may be called upon to prepare construction drawings from sketches and specifications.

MECHANICAL SYSTEMS (PLUMBING)

In general, plumbing refers to the system of pipes, fixtures, and other appurtenances used inside a building for supplying water and removing liquid and waterborne wastes. In practice, the term also includes storm water or roof drainage and exterior system components connecting to a source, such as a water main, and a point of disposal, such as a domestic septic tank or cesspool.

The purpose of plumbing systems is, basically, to bring a supply of safe water into a building for drinking, washing, and cooking, distribute the water within the building, and carry off the discharge of waste material from various receptacles on the premises to sewers, leech basins, and so forth, without causing a hazard to the health of the occupants. Codes, regulations, and trade practices define the plumbing specifications, which vary from one location or place of application to another. Although the National Plumbing Code is widely accepted as a guideline for the minimum requirements for plumbing designs, you must also be familiar with applicable local codes, especially when working with mechanical drawings and plans.

WATER DISTRIBUTION SYSTEM

The purpose of a water distribution system is to carry potable COLD and HOT WATER throughout a building for domestic or industrial use. A typical water supply system (fig. 8-1) consists of service pipe, distribution pipe, connecting pipe, fittings, and control valves. The water service pipe begins at the WATER MAIN. The water distribution pipe starts at the end of the service pipe and supplies the water throughout the building.

Piping Materials

Several types of pipe are used in water distribution systems, but only the most common types used by the SEABEEs will be discussed. These piping materials include copper, plastic, galvanized steel, and cast iron. Some of the main characteristics of pipes made from these materials are presented below.

COPPER PIPE AND TUBING.— Copper is one of the most widely used materials for tubing. This is because it does not rust and is highly resistant to any accumulation of scale particles in the pipe. This tubing is available in three different

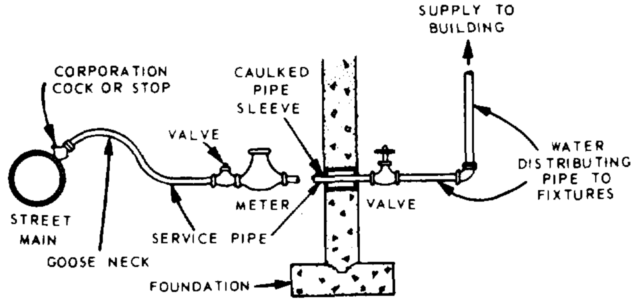


Figure 8-1.-Cross-sectional diagram of a water supply and distribution system.

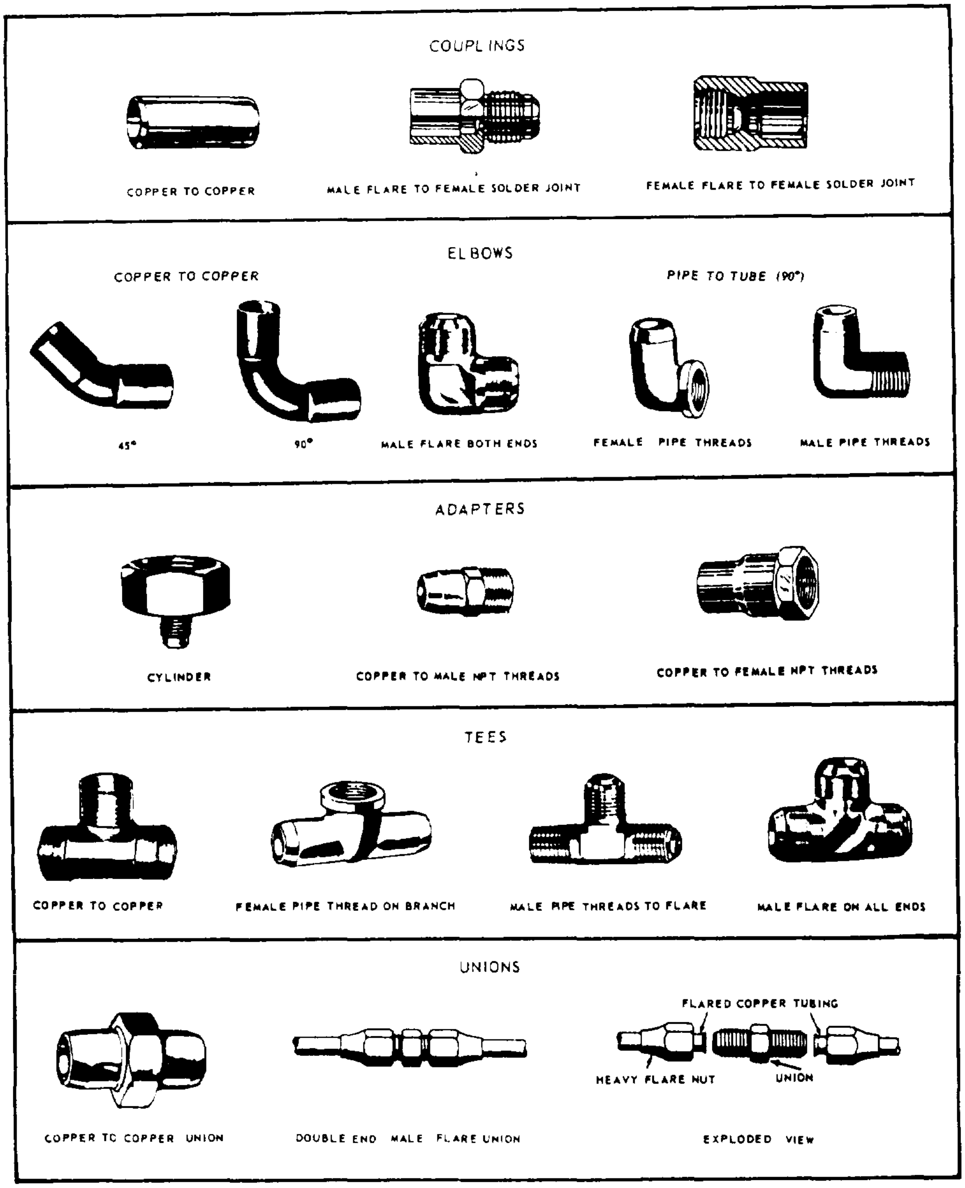


Figure 8-2.-Typical copper fittings.

types: K, L, and M. K has the thickest walls, and M, the thinnest walls, with L's thickness in between the other two. The thin walls of copper tubing are soldered to copper fittings. Soldering allows all the tubing and fittings to be set in place before the joints are finished. Generally, faster installation will be the result.

Type K copper tubing is available in either rigid (hard temper) or flexible (soft temper) and is primarily used for underground service in the water distribution systems. Soft temper tubing is available in 40- or 60-ft coils, while hard temper tubing comes in 12- and 20-ft straight lengths.

Type L copper tubing is also available in either hard or soft temper and either in coils or in straight lengths. The soft temper tubing is often used as replacement plumbing because of the tube's flexibility, which allows easier installation. Type L copper tubing is widely used in water distribution systems.

Type M copper tubing is made in hard temper only and is available in straight lengths of 12 and 20 ft. It has a thin wall and is used for branch supplies where water pressure is low, but it is NOT used for mains and risers. It is also used for chilled water systems, for exposed lines in hot-water heating systems, and for drainage piping.

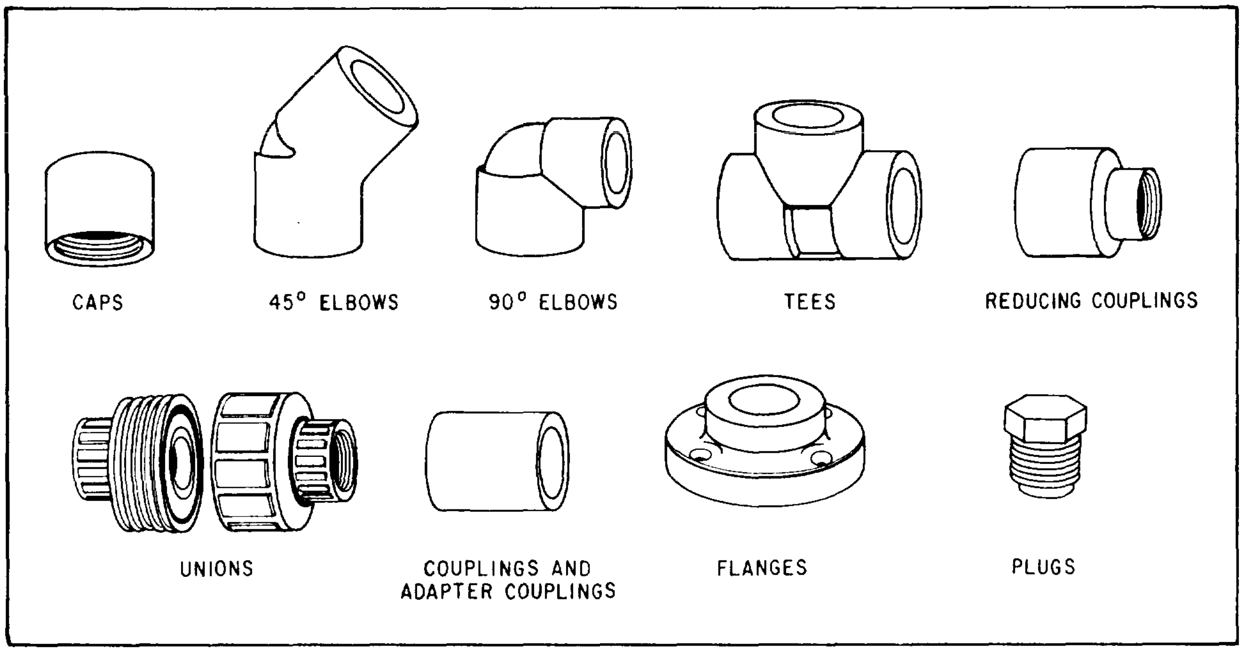


Figure 8-3.-Plastic pipe fittings.

PLASTIC PIPE.— Plastic pipe has seen extensive use in current Navy construction. Available in different lengths and sizes, it is lighter than steel or copper and requires no special tools to install. Plastic pipe has several advantages over metal pipe: it is flexible; it has superior resistance to rupture from freezing; it has complete resistance to corrosion; and, in addition, it can be installed aboveground or belowground.

One of the most versatile plastic and polyvinyl resin pipes is the polyvinyl chloride (PVC). PVC pipes are made of tough, strong thermoplastic material that has an excellent combination of physical and chemical properties. Its chemical resistance and design strength make it an excellent material for application in various mechanical systems. Sometimes polyvinyl chloride is further chlorinated to obtain a stiffer design, a higher level of impact resistance, and a greater resistance to extremes of temperature. A CPVC pipe (a chlorinated blend of PVC) can be used not only in cold-water systems, but also in hot-water systems with temperatures up to 210°F.

Economy and ease of installation make plastic pipe popular for use in either water distribution and supply systems or sewer drainage systems.

GALVANIZED PIPE.— Galvanized pipe is commonly used for the water distributing pipes inside a building to supply hot and cold water to the fixtures. This type of pipe is manufactured in 21-ft lengths. It is GALVANIZED (coated with zinc) both inside and outside at the factory to resist corrosion. Pipe sizes are based on nominal INSIDE diameters. Inside diameters vary with the thickness of the pipe. Outside diameters remain constant so that pipe can be threaded for standard fittings.

CAST-IRON WATER PIPE.— Cast-iron pipe, sometimes called cast-iron pressure pipe, is used for water mains and frequently for service pipe up to a building. Unlike cast-iron soil pipe, cast-iron water pipe is manufactured in 20-ft lengths rather than 5-ft lengths. Besides bell-and-spigot joints, cast-iron water pipes and fittings are made with either flanged, mechanical, or screwed joints. The screwed joints are used only on small-diameter pipe.

Fittings

Fittings vary according to the type of piping material used. The major types commonly used in water service include elbows, tees, unions, couplings, caps, plugs, nipples, reducers, and adapters. Some typical copper pipe fittings are shown in figure 8-2. Plastic pipe fittings (fig. 8-3) that are similar in appearance to those used with metal piping are available. Some plastic pipes can

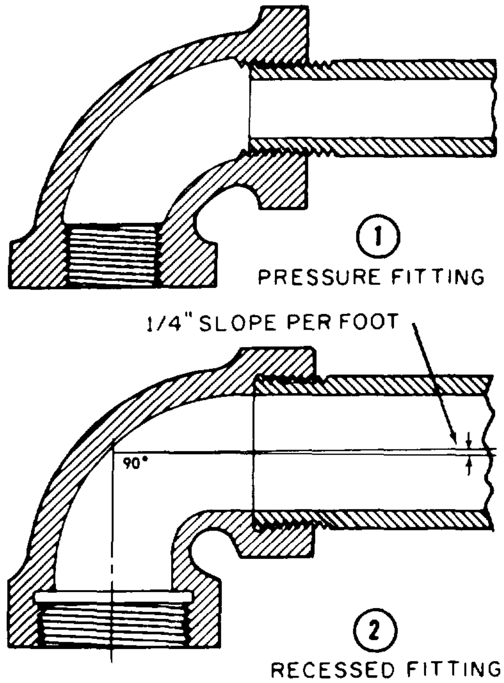


Figure 8-4.-Comparison of pressure and recessed (Durham) types of fittings.

also be adapted to metal pipe fittings. The fittings used on either steel pipe or wrought iron are generally made of malleable iron or cast iron. There are two types of iron pipe fittings used: the PRESSURE type and the RECESSED type (fig. 8-4).

The pressure type of fitting is the standard fitting used on water pipe. The recessed type of fitting, also known as a cast-iron drainage or Durham fitting, is generally required on all drainage lines. The recessed type is most suitable for a smooth joint; it reduces the probability of grease or foreign material remaining in the joint and causing a stoppage in the line. Recessed fittings are designed so that horizontal lines entering them will have a slope of one-fourth in. per foot.

ELBOWS (OR ELLS) 90° AND 45°.— These fittings (fig. 8-5, close to middle of figure) are used to change the direction of the pipe either 90 or 45 degrees. REGULAR elbows have female threads at both outlets. STREET elbows change the direction of a pipe in a close space where it would be impossible or impractical to use an elbow and nipple. Both 45- and 90-degree street elbows are available with one female and one male threaded end. The REDUCING elbow is similar to the 90-degree elbow except that one opening is smaller than the other.

TEES.— A tee is used for connecting pipes of different diameters or for changing the direction of pipe runs. A common type of pipe tee is the STRAIGHT tee, which has a straight-through portion and a 90-degree takeoff on one side. All three openings of the straight tee are of the same size. Another common type is the REDUCING tee, similar to the straight tee just described, except that one of the threaded openings is of a different size than the other.

UNIONS.— There are two types of pipe unions. The GROUND JOINT UNION consists of three pieces, and the FLANGE UNION is made in two parts. Both types are used for joining two pipes together and are designed so that they can be disconnected easily.

COUPLINGS.— The three common types of couplings are straight coupling, reducer, and eccentric reducer. The STRAIGHT COUPLING is for joining two lengths of pipe in a straight run that does not require additional fittings. A run is that portion of a pipe or fitting continuing in a straight line in the direction of flow. A REDUCER is used to join two pipes of different sizes. The ECCENTRIC REDUCER (also called a BELL REDUCER) has two female (inside) threads of different sizes with centers so designed that when they are joined, the two pieces of pipe will not be in line with each other, but they can be installed so as to provide optimum drainage of the line.

CAPS.— A pipe cap is a fitting with a female (inside) thread. It is used like a plug, except that the pipe cap screws on the male thread of a pipe or nipple.

PLUGS.— Pipe plugs are fittings with male (outside) threads. They are screwed into other fittings to close openings. Pipe plugs have various types of heads, such as square, slotted, and hexagonal sockets.

NIPPLES.— A nipple is a short length of pipe (12 in. or less) with a male thread on each end. It is used for extension from a fitting.

At times, you may use the DIELECTRIC or INSULATING TYPE of fittings. These fittings connect underground tanks or hot-water tanks. They are also used when pipes of dissimilar metals

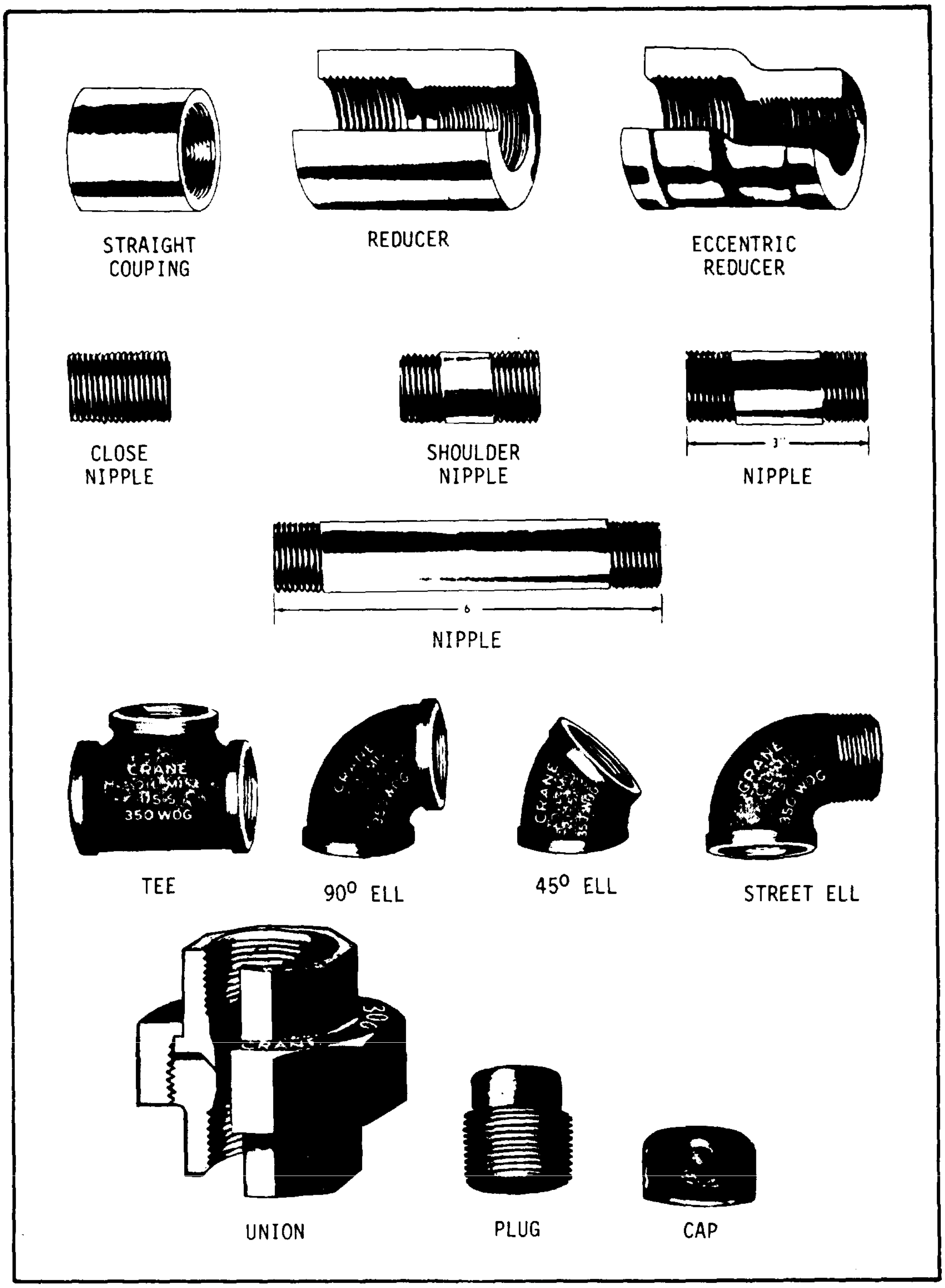


Figure 8-5.-Types of pipe fittings.

are to be joined. The purpose of dielectric fittings is to curtail galvanic or electrolytic action. The most common dielectric fittings are the union, coupling, and bushing.

Fittings are identified by the sizes of pipe that are connected to their openings. For example, a 3- by 3- by 1 1/2-in. tee is one that has two openings for a 3-in. run of pipe and a 1 1/2-in. reduced outlet. If all openings are the same size, only one nominal diameter is designated. For example, a 3-in. tee is one that has three 3-in. openings.

Joints and Connections

There are various methods of joining pipes for water distribution systems. Each method used is designed to withstand internal (hydrostatic) pressure in the pipe and normal soil loads if joints and connections are belowground. Some of these methods produce the types of joints and connections described below.

FLARED AND SWEATED JOINTS.— These joints are generally used with copper pipe and tubing. The end of a copper pipe is formed into a funnellike shape so that it can be held in a threaded fitting when a line joint is being made. This method is called FLARING, and the result is called a FLARED JOINT. A SWEATED JOINT is made with soft solder instead of threads or flares. In plumbing, copper pipe or tubing is occasionally fused by heating with a gas flame and silver-alloy filler metal called SILVER BLAZING (also called HARD SOLDERING).

SOLVENT WELDED, FUSION WELDED, FILLET WELDED, THREADED, AND FLANGED JOINTS.— These types of joints are common to plastic pipes. In the production of a SOLVENT WELDED JOINT, a solvent cement with a primer is used. Before solvent is applied, the pipe and fitting must be thermally balanced (caused to have similar temperatures). This process should not be undertaken when the temperature is below 40°F or above 90°F or when the pipes are exposed to direct sunlight.

FUSION WELDED JOINTS are produced by the use of a gas- or an electric-heated welding tool. The process consists of simultaneously heating the meeting surfaces of the pipe and fitting to a uniform plastic state, joining the components together, and then allowing the two surfaces to fuse into a homogeneous bond as the materials cool to room temperature.

FILLET WELDED JOINTS are made by the use of a uniform heat and pressure on the welding rod during application of the bead. This process can also be applied to repair leaks in thermoplastics.

In plastic pipes, THREADED JOINTS are commonly used for temporary and low-pressure piping since threading reduces the pipe wall thickness. Only certain heavy pipes can be threaded with a special strap wrench. Teflon tape is often used for pipe joint compound when this method of joining pipes is used.

FLANGED JOINTS are extensively used for process lines that are dismantled frequently. Plastic pipes are joined together by the use of plastic flanges with soft rubber gaskets.

BELL-AND-SPIGOT AND MECHANICAL JOINTS.— These types of joints are most commonly used with cast-iron pressure pipe and fittings for water mains. These service lines are joined by the use of lead, lead wool, or sometimes a sulfur compound. Mechanical joints are made with rubber sealing rings held in place by metal follower rings that are bolted to the pipe. These are designed to permit expansion and contraction of the pipe without injury to the joints.

THREADED PIPE JOINTS are commonly used on galvanized steel, galvanized wrought iron, and black-iron pipe. The process includes connecting threaded male and female ends. Nontoxic compounds are used for t bread lubricant on water pipes, while powdered graphite and oil are used for steam pipes.

Valves

Valves are devices that are used to stop, start, or regulate the flow of water into, through, or from pipes. Essentially, valves consist of a body containing an opening and a means of closing the opening with a valve disk or plug that can be tightly pressed against a seating surface around or within the opening. Many different valve designs are available; however, only the three most common types of valves will be discussed here. They are the gate, check, and globe valves.

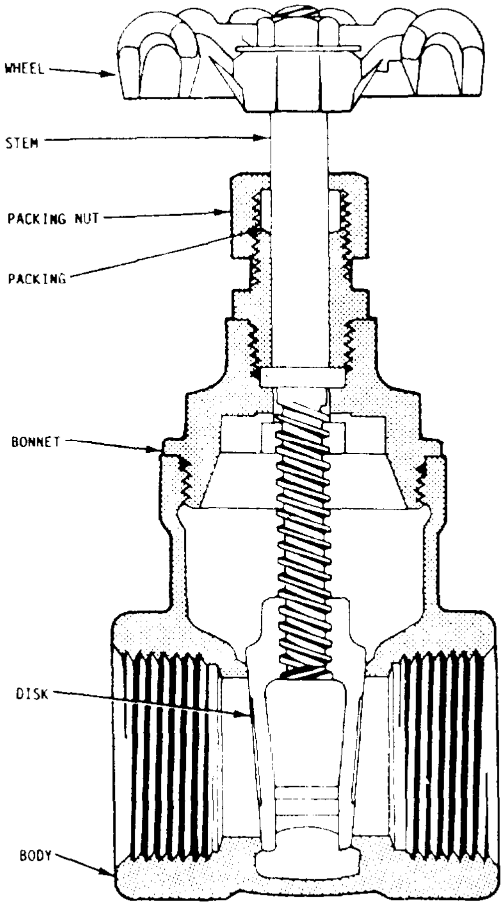


Figure 8-6.-Crow section of a gate valve.

GATE VALVE.— The gate valve (fig. 8-6) has a wedge-shaped, movable plug, called a gate, that fits tightly against the seat when the valve is closed. When the gate is opened, an unrestricted flow passage is provided. It allows fluid to flow through in a straight line with little resistance and less friction and pressure drop, provided the valve gate or disk is kept fully opened. The gate valve releases a variable amount with each turn of the gate.

Gate valves must always be operated in either their fully opened or fully closed position, never in any position to adjust the rate of flow. A partly closed gate will cause vibration and chattering, damaging the seating surfaces.

CHECK VALVE.— The check valve is used principally to prevent backflow in pipelines automatically. The valves are entirely automatic and are used where flow of liquids, vapors, or

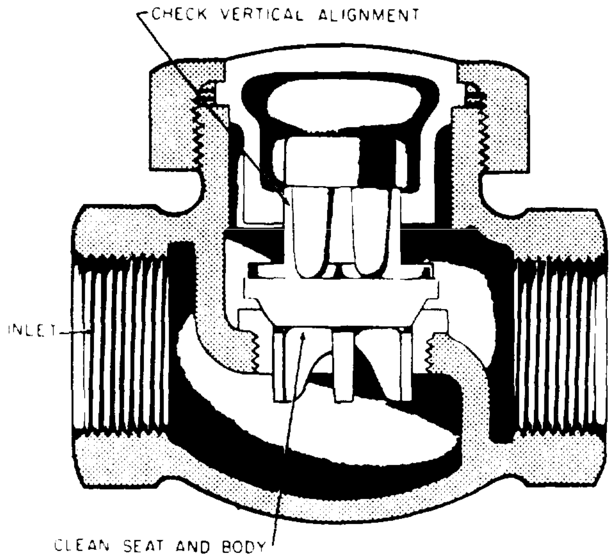


Figure 8-7.-Cross section of a swing check valve.

gases in one direction only is required. Check valves fall into two main groups: swing check valves and lift check valves. A SWING CHECK VALVE, shown in figure 8-7, is used where an unrestricted flow is desired. A LIFT CHECK VALVE is usually used for air or gases or when operation of the check valve is frequent (fig. 8-8).

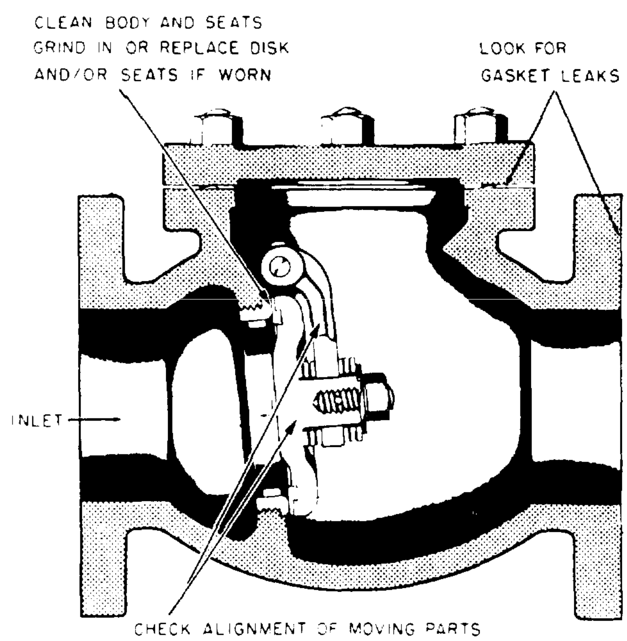


Figure 8-8.-Lift check valve.

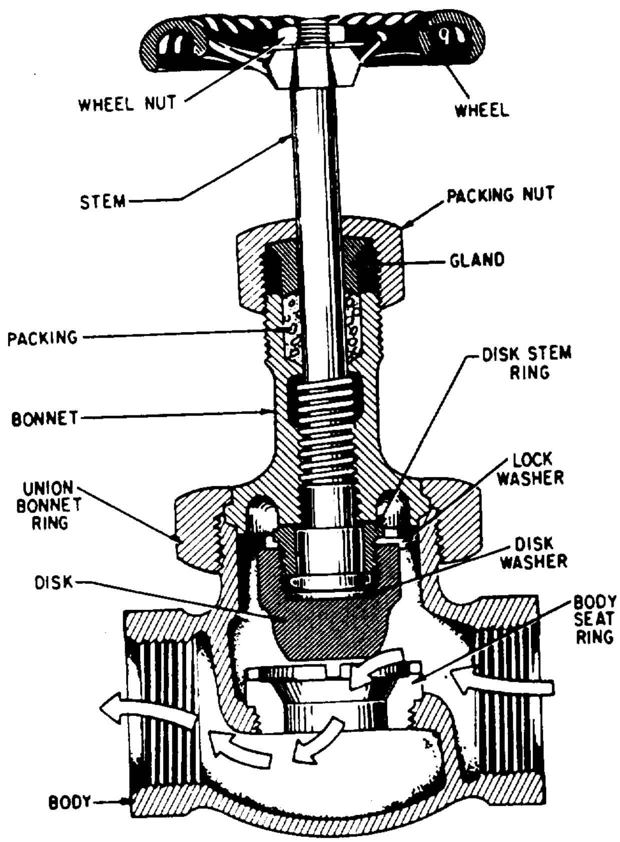


Figure 8-9.-Cross section of a globe valve.

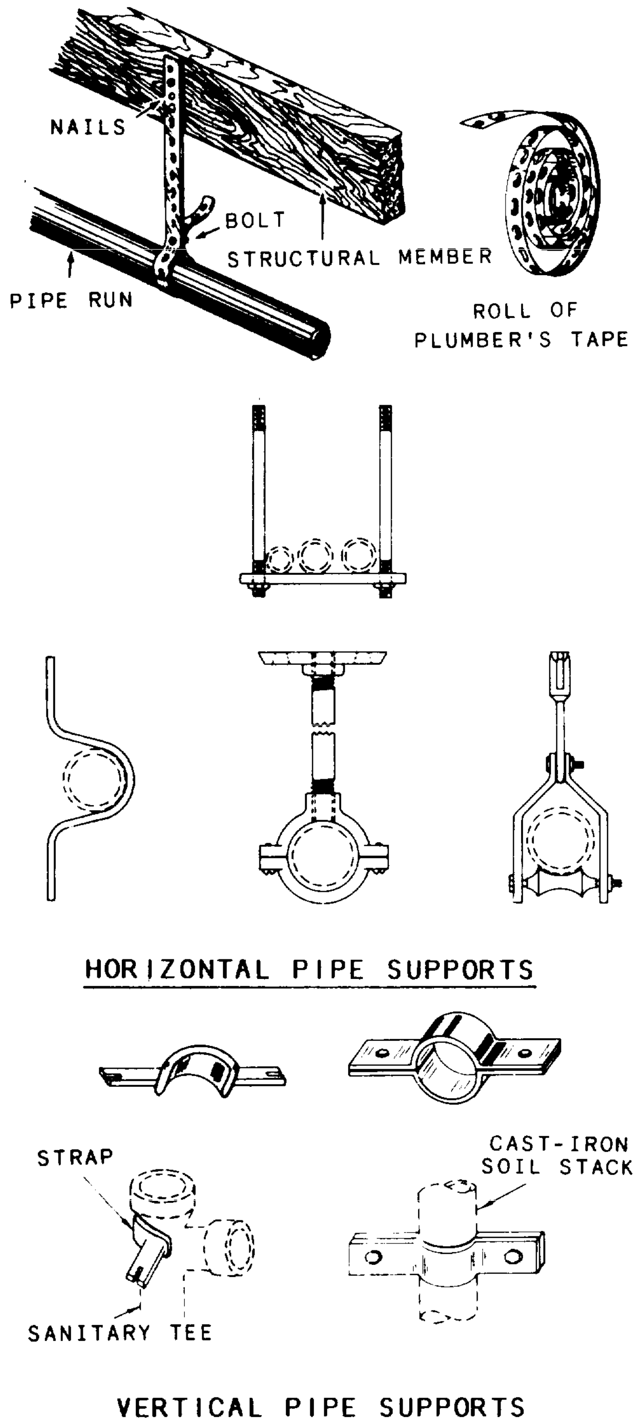


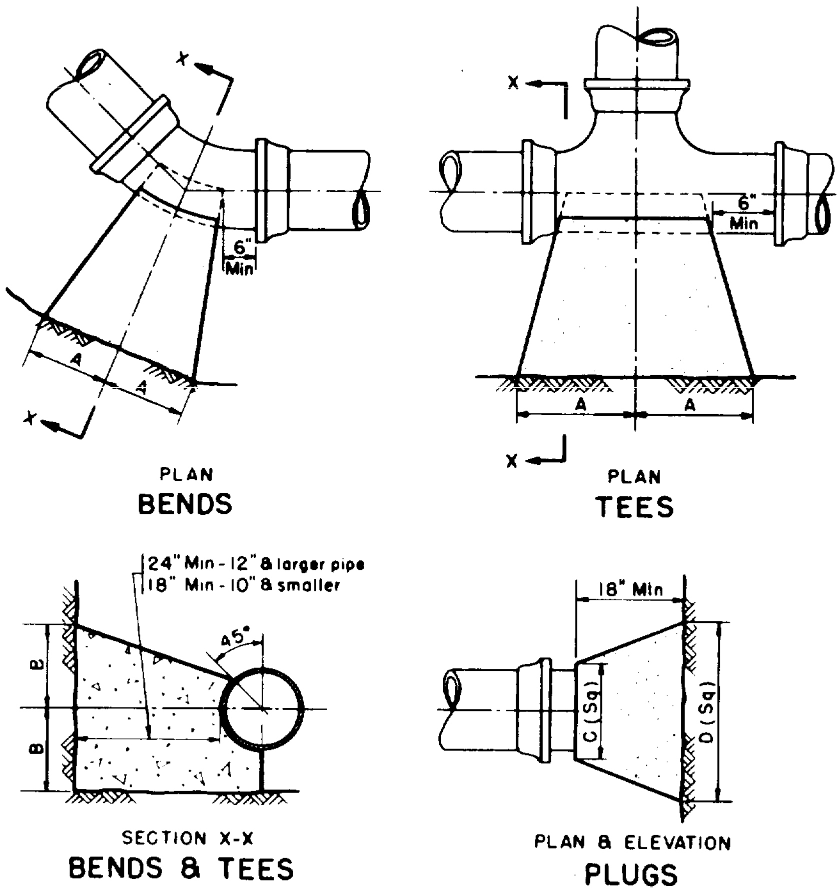
Figure 8-10.-Methods of supporting pipe.

GLOBE VALVE.— The globe valve (fig. 8-9), so-called because of its globular-shaped body, is used for regulating liquids, gases, and vapor flow by means of throttling (adjusting rate of flow). They are well suited for services requiring regulated flow and/or frequent valve settings (throttling).

Pipe Supports

Pipes are designed to be used for structural applications only to the extent of withstanding normal soil loads and internal pressures up to their hydrostatic pressure rating. Therefore, any pipe supplying air, water, or steam, when exposed aboveground and in the interior of buildings must be supported adequately to prevent sagging.

The weight of the pipes plus the weight of fluid contained in them may produce strained joints and breaks that can cause leaks in the valves. Figure 8-10 shows several methods of supporting pipe in both horizontal and vertical positions. On water mains, standard thrust blocks (fig. 8-11), made of concrete or other applicable materials, are installed at all changes of direction to prevent pipe displacement caused by high water pressure.



TYPE	SIZE	1/4 BENDS		1/8 BENDS		1/16 BENDS		TEES		PLUGS	
		A	B	A	B	A	B	A	B	C	D
TYPE I 4000 PSF SOIL	6"	8"	10"	6"	8"	3"	8"	8"	8"	10"	15"
	8"	12"	12"	8"	10"	5"	9"	9"	12"	12"	20"
	10"	16"	14"	10"	12"	6"	10"	11"	14"	14"	25"
	12"	19"	16"	12"	14"	8"	11"	14"	16"	16"	30"
	14"	23"	18"	14"	16"	10"	12"	16"	18"	18"	34"
	16"	26"	20"	16"	18"	11"	13"	18"	20"	20"	38"
TYPE II 2000 PSF SOIL	6"	16"	10"	9"	10"	6"	8"	10"	12"	10"	21"
	8"	22"	13"	12"	13"	8"	10"	13"	16"	12"	29"
	10"	26"	17"	14"	17"	10"	13"	16"	20"	14"	36"
	12"	29"	21"	16"	21"	11"	16"	18"	24"	16"	41"
	14"	35"	24"	19"	24"	12"	20"	22"	27"	18"	48"
	16"	38"	27"	21"	27"	12"	24"	24"	30"	20"	54"

NOTE: Based on 100 p.s.i. static pressure plus A.W.W.A. water hammer
All bearing surfaces to be carried to undisturbed ground

STANDARD THRUST BLOCKS FOR WATER MAINS

Figure 8-11.-Uses of thrust blocks.

Pipe Insulation

The main purpose of insulating pipelines is to prevent heat passage from steam or hot-water pipes to the surrounding air or from the surrounding air to cold-water lines. In some cold regions, insulation also prevents water from freezing in a pipe, especially when the pipe runs outside a building. Thus, hot-water lines are insulated to prevent loss of heat from the hot water, while potable waterlines are insulated to prevent absorption of heat in drinking water. Insulation also subdues noise made by the flow of water inside pipes, such as water closet discharges. Common types of pipe insulating materials are shown in figure 8-12.

SANITARY DRAINAGE SYSTEM

The purpose of a drainage system is to carry sewage, rainwater, or other liquid wastes to a point of disposal. Although there are three types of drainage systems—storm, industrial, and sanitary—only the latter, which is the most common drainage system installed by the SEABEEs, will be discussed.

The SANITARY DRAINAGE SYSTEM carries sanitary and domestic wastes from a source (or collection system) to a sewage treatment plant or facility. Surface waters and groundwaters must be excluded from this system to prevent overload of the sewage treatment facilities.

Piping Materials

The types of materials actually used will depend upon whether the installation is underground, outside buildings, underground within buildings, or aboveground within buildings. The availability of certain types of desired piping materials and fittings may also govern the type of pipe actually used.

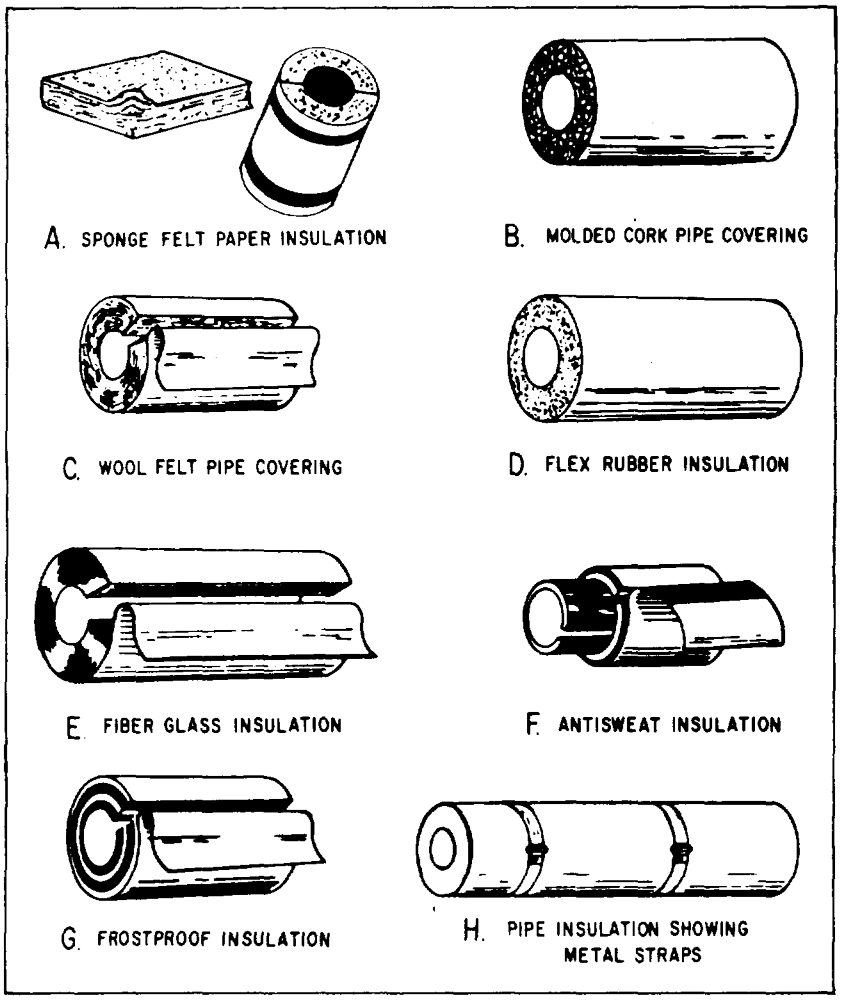


Figure 8-12.-Types of pipe insulation.

Underground piping outside of buildings may be cast-iron soil pipe, vitrified clay or concrete, or plastic polyvinyl chloride (PVC) pipe, but PVC pipes are the most common. Underground piping within buildings may also be of cast iron, galvanized steel, lead, or PVC; however, cast iron and PVC are the most popular materials used.

Aboveground sewage piping within buildings consists of either one or a combination of the following: brass or copper pipe, cast iron or galvanized wrought iron, galvanized steel or lead, and PVC pipe. Again, the reason for the growing popularity of plastic PVC piping is the unique combination of chemical and physical properties it has, ease of installation, and cost effectiveness. Descriptions and characteristics of some of the most common piping materials used in a sanitary drainage system follow.

CAST-IRON SOIL PIPE (CISP).— This type of pipe is composed of gray cast iron made of compact, close-grained pig iron; scrap iron and steel; metallurgical coke; or limestone. Cast-iron soil pipe is normally used in or under buildings, protruding at least 5 ft from the building. Here, it connects into a concrete or clay sewer line. Cast-iron soil pipe is also used under roads or other places of heavy traffic. If the soil is unstable or contains cinder and ashes, vitrified clay pipe is used instead of cast-iron soil pipe.

Cast-iron soil pipe comes in 5-ft and 10-ft lengths, with nominal inside diameters of 2, 3, 4, 5, 6, 8, 10, 12, and 15 in. It is available as single-hub or double-hub in design, as indicated in figure 8-13. Note that single-hub pipe has a hub at one end and a spigot at the other, while a double-hub pipe has a hub on each end. Hubs or bells of cast-iron soil pipe are enlarged sleevelike fittings that are cast as a part of the pipe to make watertight and pressure-tight joints with oakum and lead.

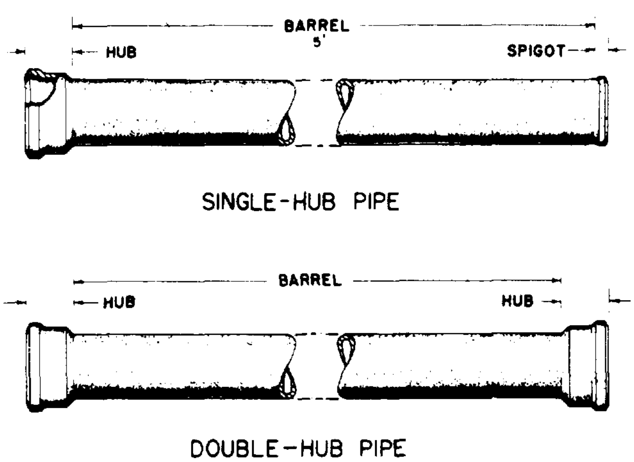


Figure 8-13.-Single-hub and double-hub cast-iron soil pipe.

VITRIFIED CLAY AND CONCRETE PIPE.— Vitrified clay pipe is made of moistened, powdered clay. It is available in laying lengths of 2, 2 1/2, and 3 ft and in diameters ranging from 4 to 42 in. Like cast-iron soil pipe, it has a bell end and a spigot end to facilitate joining. Vitrified clay pipe is used for house sewer lines, sanitary sewer mains, and storm drains.

Precast concrete pipe may be used for sewers in the smaller sizes—those less than 24 in. This pipe is not reinforced with steel. Dimensions of concrete pipe are similar to those of vitrified clay pipe.

PLASTIC PIPE.— The use of rigid plastic pipe has expanded greatly over the years. Years ago, plastic piping was used extensively for farm water systems, lawn sprinklers, and some other domestic and industrial uses. Now, plastic pipe is used for all kinds of water and drainage applications.

Plastic piping has outstanding resistance to nearly all acids, caustics, salt solutions, and other corrosive liquids and gases. It does not rust, corrode, scale, or pit inside or outside. It is also nontoxic, nonconductive, and not subject to electrolytic corrosion—a major cause of failure when metal pipe is installed underground. Another important advantage of plastic pipe is low resistance to abrasion because of its smooth inner wall, resulting in maximum flow rate and minimum buildup of sludge and slime.

Fittings

The types of fittings, joints, and connections used by water distribution are strikingly similar to those used by waste drainage systems. In sanitary or waste drainage systems, fittings also vary according to the type of piping materials used; however, special mechanical seal adapters are available for joining different types of pipes, such as cast-iron soil pipes to vitrified clay, or vice versa. Some of the fittings commonly

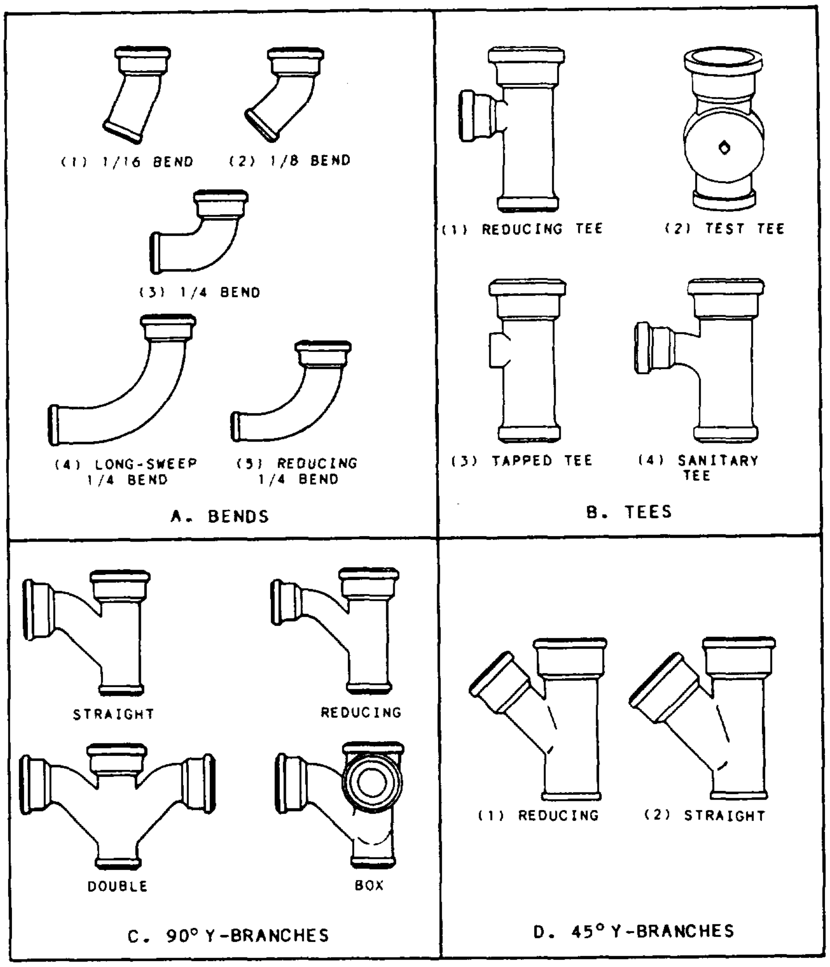


Figure 8-14.-Common cast-iron soil pipe fittings.

used are shown in figure 8-14 and described below.

BENDS.— The 1/16 bend (fig. 8-14, view A) is used to change the direction of cast-iron soil pipe 22 1/2°. A 1/8 bend changes the direction 450. The direction is changed 90° in a close space when the SHORT-SWEEP 1/4 bend is used. The LONG-SWEEP 1/4 bend is used to change the direction 90° more gradually than a quarter bend. The REDUCING 1/4 bend changes the direction of the pipe gradually 90°, and in the sweep portion, it reduces nearly one size.

TEES.— Tees (fig. 8-14, view B) are used to connect branches to continuous lines. For connecting lines of different sizes, REDUCING tees are often used. The TEST tee is used in stack and waste installations where the vertical stack joins the horizontal sanitary sewer. It is installed at this point to allow the plumber to insert a test tee and fill the system with water while testing for leakage. The TAPPED tee is frequently used in the venting system where it is called the main vent tee. The SANITARY tee is commonly used in a main stack to allow the takeoff of a cast-iron pipe branch.

NINETY-DEGREE Y-BRANCHES.— Four types of cast-iron soil pipe 90° Y-branches generally used are shown in figure 8-14, view C. These are normally referred to as COMBINATION Y AND 1/8 BENDS. The STRAIGHT type of 90° Y-branch is used in sanitary sewer systems where a branch feeds into a main, and it is desirable to have the incoming branch feeding into the main as nearly as possible in a line parallel to the main flow. The REDUCING 90° Y-branch is the same as the straight type, except that the branch coming into the main is a smaller size pipe than the main. The DOUBLE 90° Y-branch (or DOUBLE

COMBINATION Y and 1/8 BEND) is easy to recognize since there is a 450 takeoff bending into a 90° takeoff on both sides of the fitting. It is especially useful as an individual vent. The BOX type 90° Y-branch has two takeoffs. It is designed so that each takeoff forms a 90° angle with the main pipe. The two takeoffs are spaced 900 from each other.

FORTY-FIVE-DEGREE Y-BRANCHES.— The two types of 45° Y-branches (fig. 8-14, view D) are the reducing and straight types. They are used to join two sanitary sewer branches at a 45° angle. The REDUCING type is a straight section of pipe with a 45° takeoff of a smaller size branching off one side. The STRAIGHT type of 45° Y-branch, or true Y, is the same as the reducing type except that both bells are the same size.

Figure 8-15 shows some common fittings used with vitrified clay and concrete pipes. It should be noted that these types of pipes are used outside the building, which greatly reduces the number of different types of fittings. Joints on vitrified clay and concrete pipe are made of cement or bituminous compounds. Cement joints might be made of grout—a mixture of cement, sand, and water.

Plastic pipe fittings for waste drainage are shown in figure 8-16.

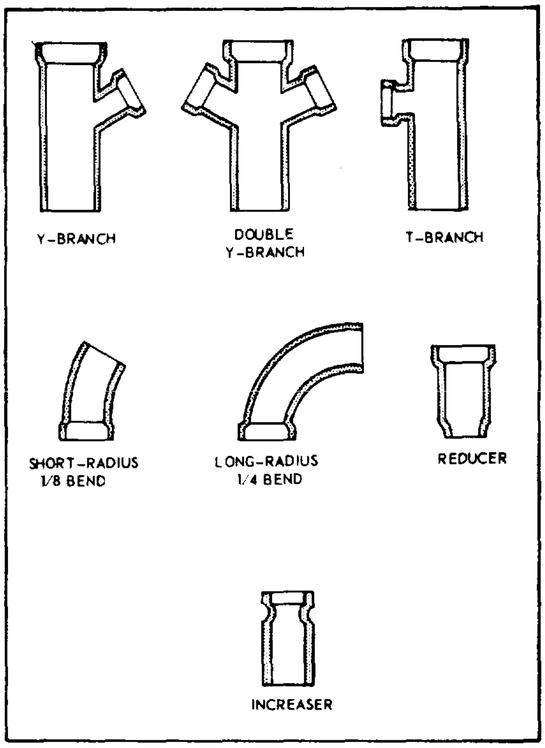


Figure 8-15.-Cross section of vitrified clay or concrete pipe fittings.

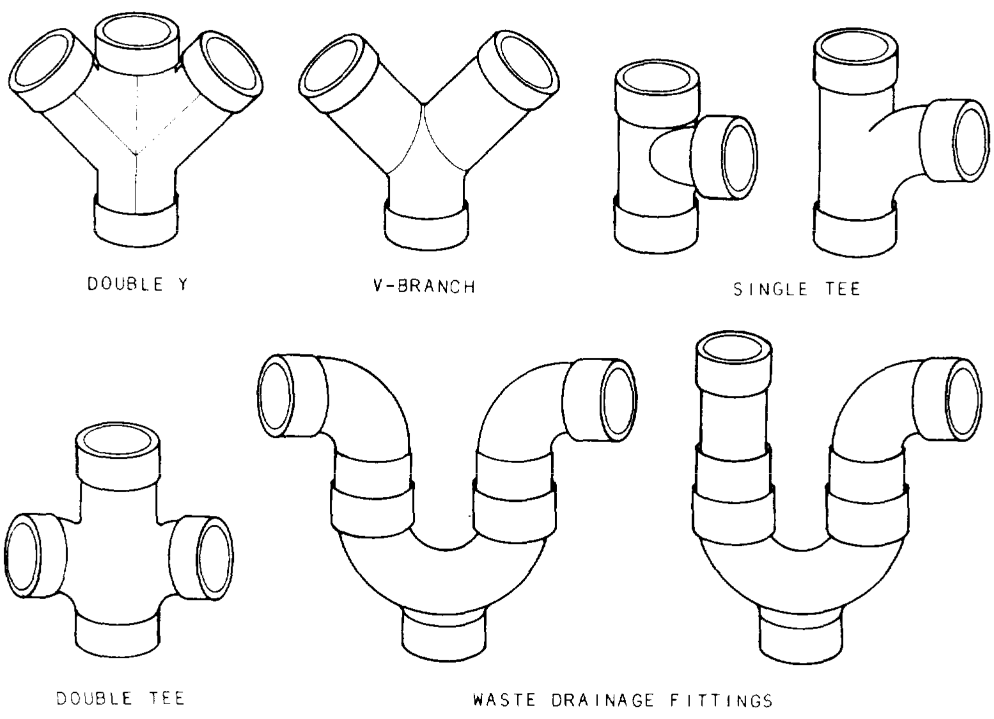


Figure 8-16.-Typical plastic pipe fittings.

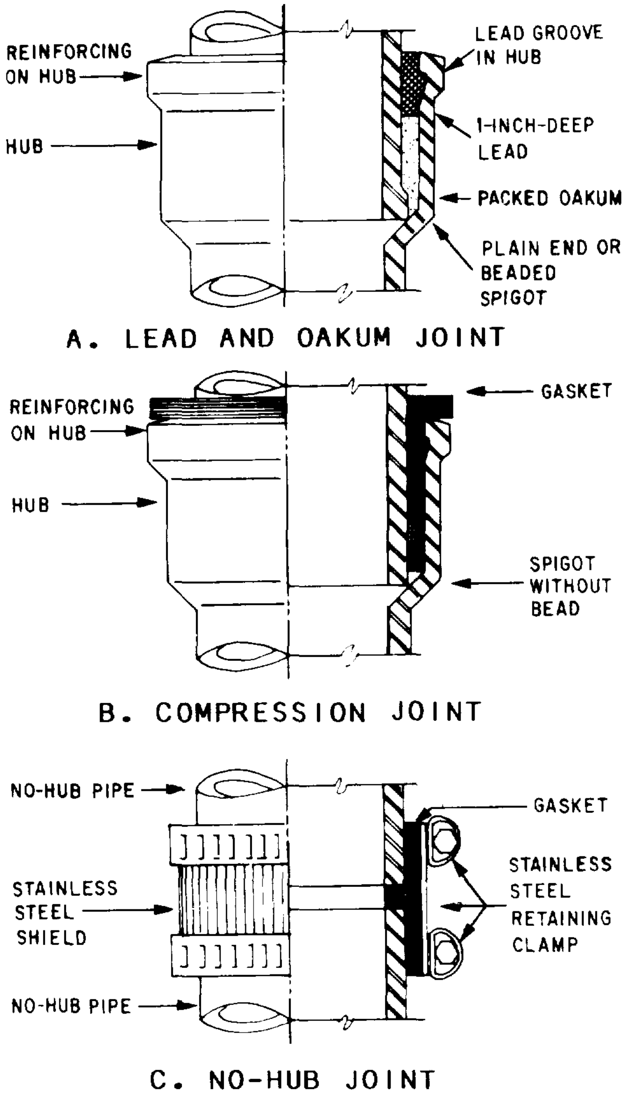


Figure 8-17.-Various joints currently used to connect CISP and fittings.

Joints and Connections

Various types of joints and connections used in waste drainage systems are described below.

LEAD AND OAKUM JOINT, COMPRESSION JOINT, AND NO-HUB JOINT.— These types of joints (fig. 8-17) are used to connect cast-iron soil pipes (CISP) and fittings. In lead and oakum joints, oakum (made of hemp impregnated with bituminous compound and loosely twisted or spun into a rope or yarn) is packed into the hub completely around the joint, and melted lead is poured over it (fig. 8-17, view A).

In compression joints, an assembly tool is used to force the spigot end of the pipe or fitting into the lubricated gasket inside the hub (fig. 8-17, view B). A no-hub joint uses a gasket on the end of one pipe and a stainless steel shield and clamp assembly on the end of the other pipe (fig. 8-17, view C).

MORTAR OR BITUMINOUS JOINTS.— This type of joint is common to vitrified clay and concrete pipes and fittings. Mortar joints may be made of grout (a mixture of cement, sand, and water).

The use of SPEED SEAL JOINTS (rubber rings) in joining vitrified clay pipe has become widespread. Speed seal joints eliminate the use of oakum and mortar joints for sewer mains. This type of seal is made a part of the vitrified pipe joint when manufactured. It is made of polyvinyl chloride and is called a plastisol joint connection.

Traps

A trap is a device that catches and holds a quantity of water, thus forming a seal that prevents the gases resulting from sewage decomposition from entering the building through the pipe. A number of different types of traps are available; however, the trap mainly used with plumbing fixtures is the P-TRAP (fig. 8-18). It comes in sizes from 1 1/4 in. to 6 in. in diameter. P-traps are usually made of nickel or chrome-plated brass, malleable galvanized or wrought iron, copper, other metal alloys, and plastic.

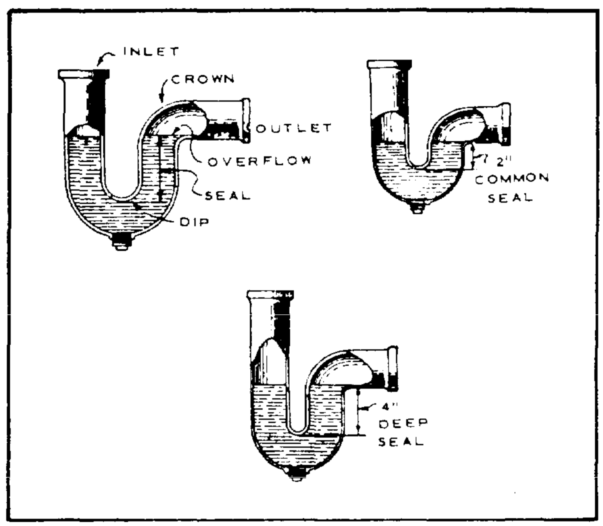


Figure 8-18.-P-traps.

Traps are commonly installed on fixtures, such as lavatories, sinks, and urinals. At times, the P-trap may also be suitable in shower baths and other installations that do not require wasting of large amounts of water.

Vents

A VENT (pipe) allows gases in the sewage drainage system to discharge to the outside. It also allows sufficient air to enter, reducing the air turbulence in the system. Without a vent, once the water is discharged from the fixture, the moving waste tends to siphon the water from the other fixture traps as it goes through the pipes. This means that the vent piping must serve the various fixtures, as well as the rest of the sewage drainage system. The vent from a fixture or group of fixtures ties in with the main vent. A MAIN VENT is the principal artery of the venting system to which vent branches maybe connected and run undiminished in size as directly as possible from the building drain to the open air above (fig. 8-19).

The MAIN SOIL AND WASTE VENT or VENT STACK, installed in a vertical position, refers to the portion of the stack that extends above the highest fixture branch, through the roof, and to the exterior of the building.

Various types of vents are used in the ventilation of fixtures. The selection of a particular type depends largely on the manner in which the plumbing fixtures are to be located and grouped.

An INDIVIDUAL VENT, also known as a BACK VENT, connects the main vent with the individual trap underneath or behind a fixture. This method of venting is shown in figure 8-19.

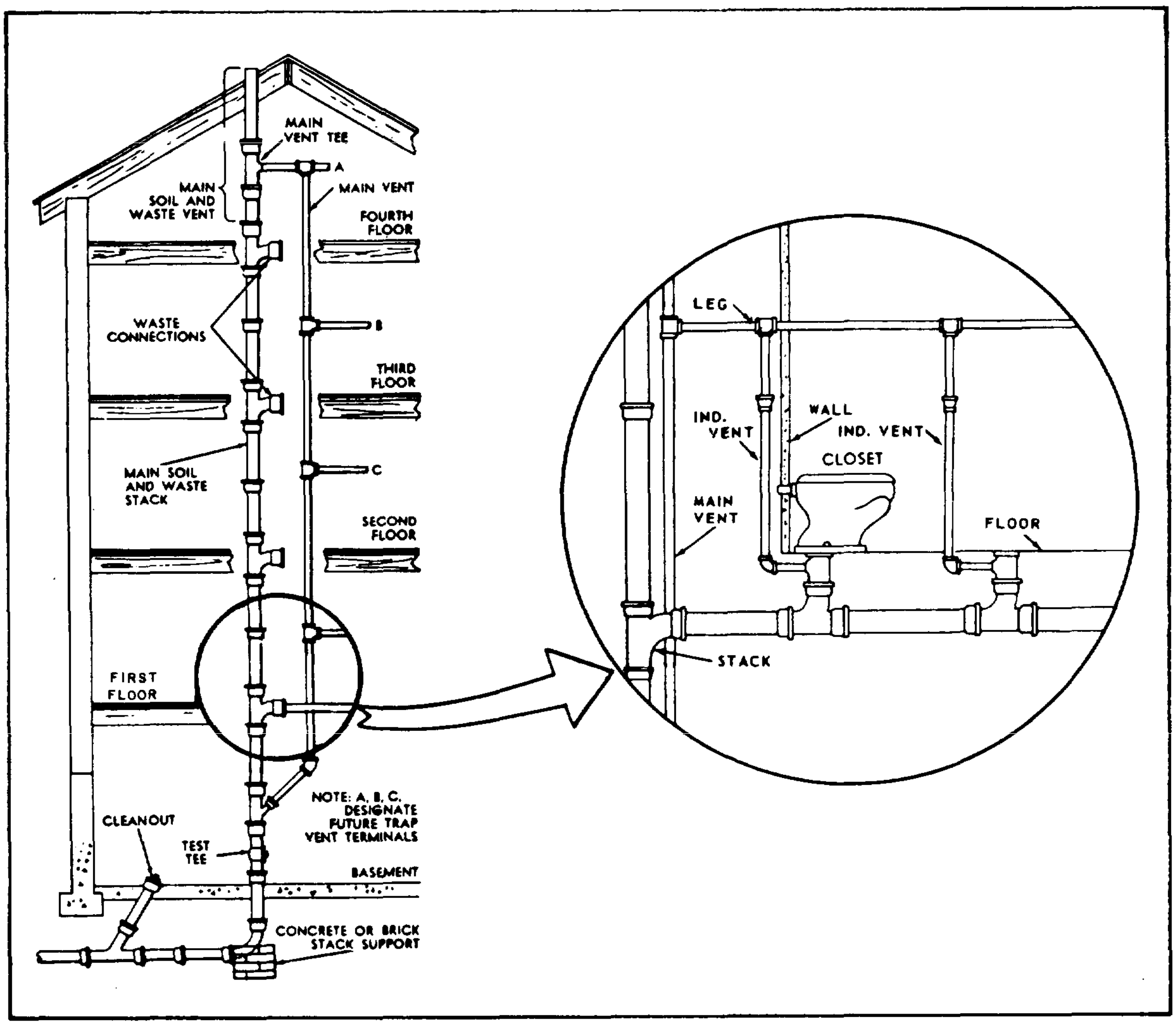


Figure 8-19.-Typical stack and vent installation.

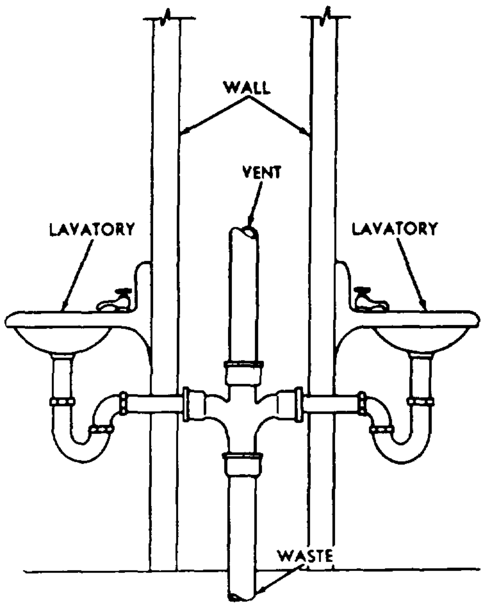


Figure 8-20.-Two fixture units sharing a common vent.

A COMMON VENT vents two traps to a single vent pipe, as shown in figure 8-20. The unit vent can be used when a pair of lavatories is installed side by side, as well as when they are hung back to back on either side of a partition (as shown in the figure). A point to note is that the waste from both fixtures discharges into a double sanitary tee.

A CIRCUIT VENT serves a group of fixtures. As shown in figure 8-21, a circuit vent extends from the main vent to a position on the horizontal branch between the last two fixture connections. If more than eight fixtures are to be vented, an additional circuit vent is to be installed. In this type of vent, water and waste discharged by the last fixture tend to scour the vents of other fixtures on the line.

When liquid wastes flow through a portion of a vent pipe, the pipe is known as a WET VENT. A LOOP VENT is the same, except that it connects into the stack unit to form a loop. This type may be used on a small group of bathroom fixtures, such as a lavatory, water closet, and shower, as shown in figure 8-22. The pipe for a wet vent installation should be sized to take care of the lavatory, water closet, and shower.

NOTE: The pipe for a wet vent installation should never be under 2 in. in diameter when it will be draining more than four fixture units. A water closet should not drain into a wet vent.

As shown in figure 8-22, the lavatory should be individually vented. This is necessary to prevent loss of the trap seal through indirect siphonage. Another point to note is that the relatively clean water discharged from the lavatory will tend to scour the wet vent, preventing an excessive buildup of waste material in the vent.

Materials used in vent piping ordinarily include galvanized pipe, cast-iron soil pipe, and, at times, brass, copper, and plastic piping.

In all phases of the venting system, it is best to use proper-sized piping. Remember that the diameter of the vent stack or main vent must be no less than 2 in. The actual diameter depends on the developed length of the vent stack and on the number of fixture units installed on the soil or waste stack. The diameter of a vent stack should be at least as large as that of the soil or waste stack.

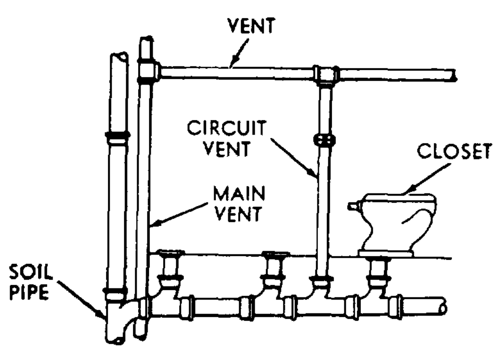


Figure 8-21.-Use of a circuit vent.

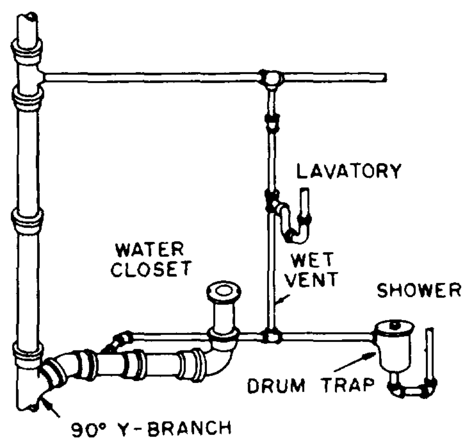


Figure 8-22.-Use of a wet vent.

Branches

Solid and waste pipe BRANCHES are horizontal branch takeoffs that connect various fixtures and the vertical stack (fig. 8-19). One method of installing a branch takeoff from the vertical stack is to use a Y-branch with a 1/8 bend caulked into it. Another method is to use a sanitary tee, which is an extra-short-pattern 900 Y-branch. Of these two methods, the sanitary tee is better because you eliminate one fitting and an extra caulked joint, both of which arc required for the 1/8 bend takeoff.

In some cases, however, the combination Y and 1/8 bend is used more often than the sanitary tee when local codes allow more fixture units to be connected to a stack of a given size.

Generally, waste pipes are graded downward to ensure complete drainage. Horizontal vents are also pitched slightly to facilitate discharge of condensation.

MECHANICAL PLAN

A mechanical plan, as used in this chapter, includes drawings, layouts, diagrams, and notes that refer only to water distribution and sanitary drainage systems. Heating and air conditioning, refrigeration, and other like systems will not be discussed in this section. In the Navy, mechanical systems vary, depending on whether these systems are aboard ship or shore-based. As an EA, you will be mainly concerned with the shore-based systems, which may be permanent installations with the most modern fixtures, equipment, and appurtenances, or temporary installations at advanced bases. For temporary installations, the most economical materials that will serve the purpose are normally used.

WATER SUPPLY AND DISTRIBUTION DIAGRAM

The water supply system for a building starts from a single source—the water main. Water is tapped from this source with a self-tapping machine (fig. 8-23, view B), and a corporation stop (fig. 8-23, view A) is installed. Cold water enters the building through a cold-water service

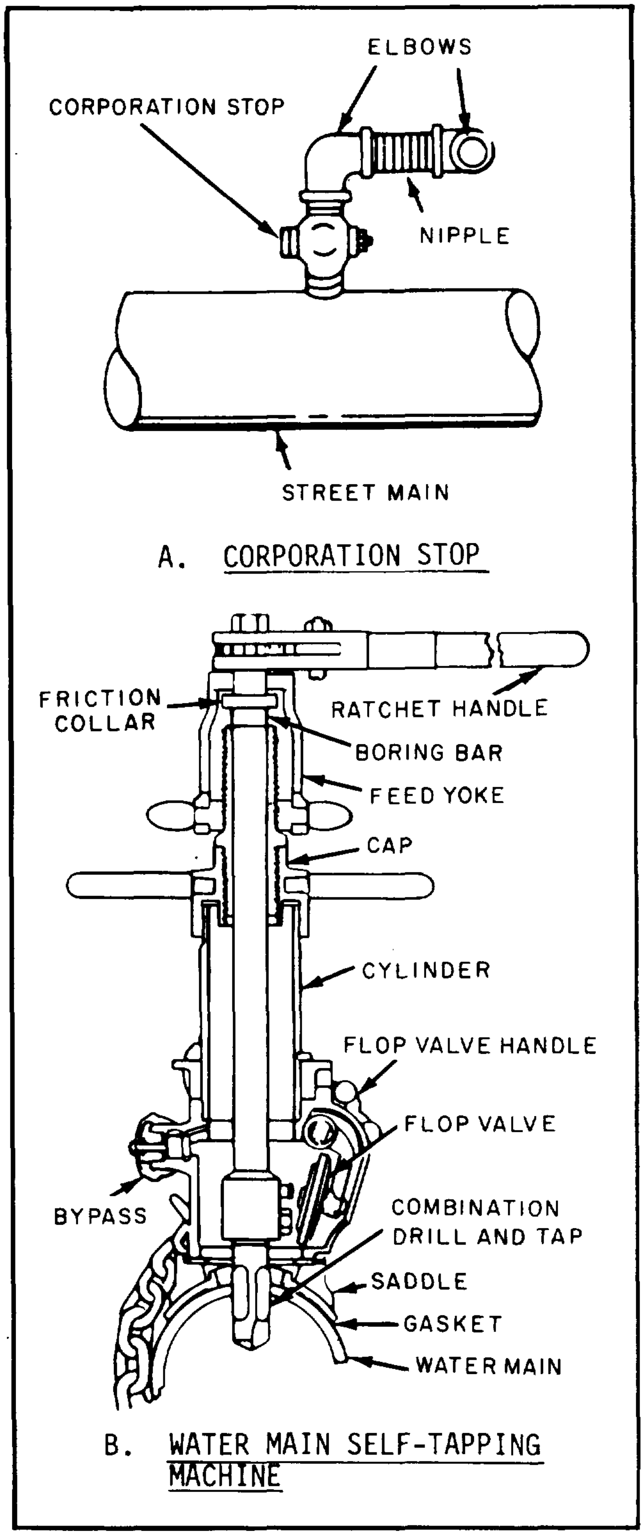


Figure 8-23.-Use of corporation stop and self-tapping machine.

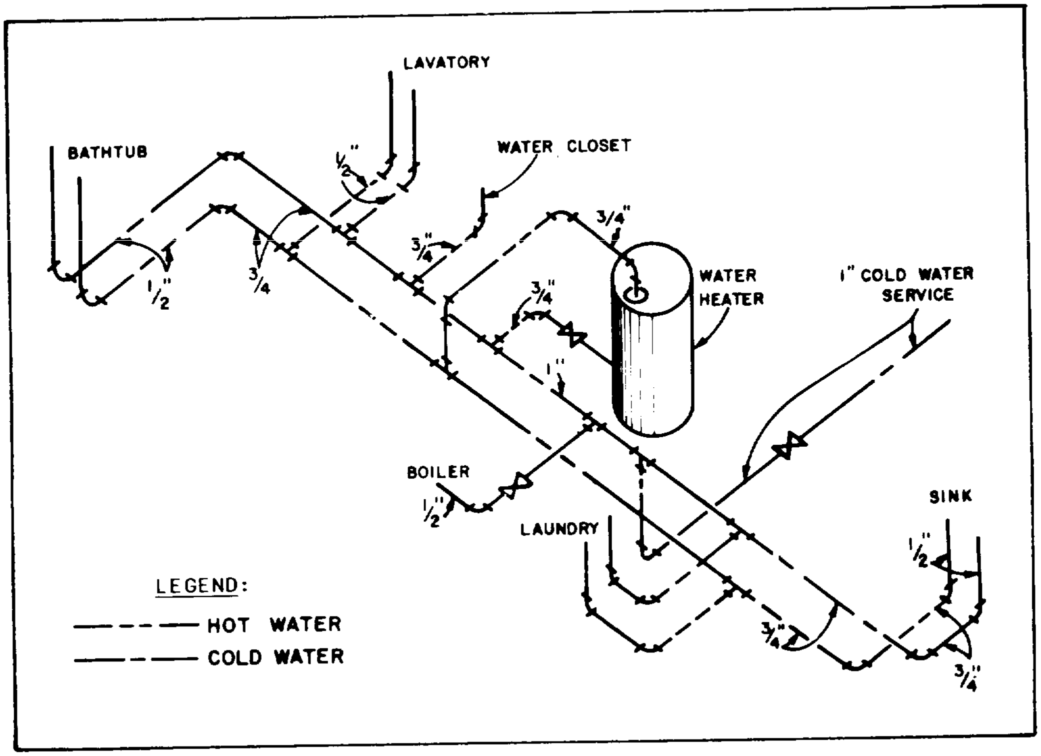


Figure 8-24.-Typical hot and cold water risers diagram.

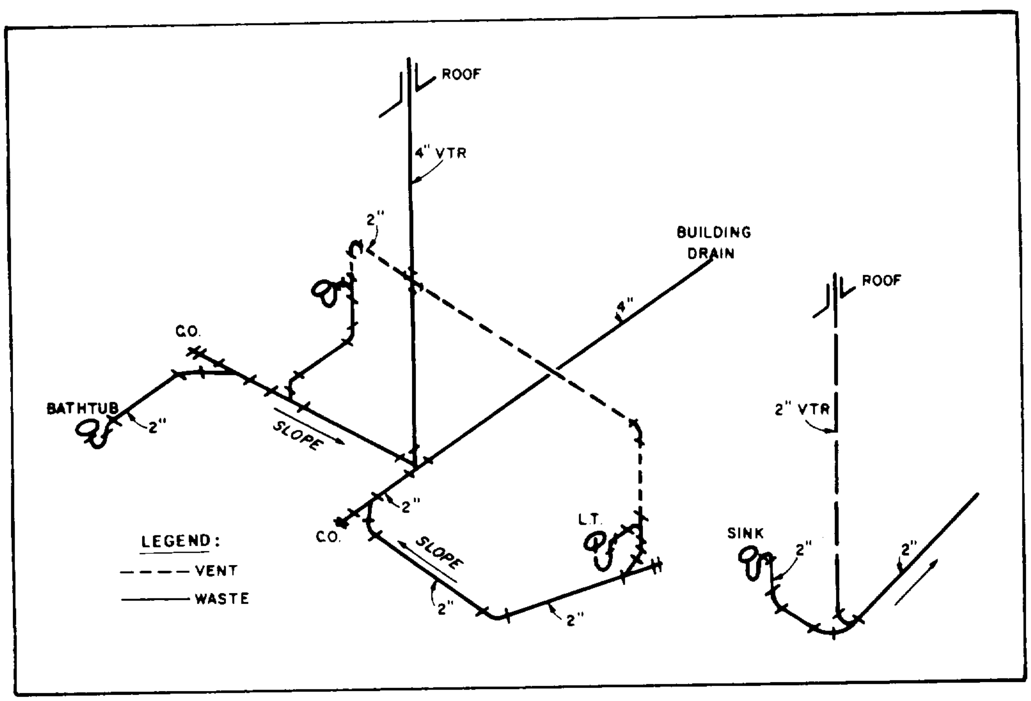


Figure 8-25.-Example of a waste and soil risers diagram.

line. Figure 8-24 shows typical hot- and cold-water service lines for a single-story residential building and how they are connected to feed the fixtures. This type of layout is often called a RISER DIAGRAM. This diagram, in isometric, is a method of visualizing or showing a three-dimensional picture of the pipes in one drawing.

WASTE AND SOIL DRAINAGE DIAGRAM

Figure 8-25 shows the waste and soil pipes and. associated fitting symbols in a riser diagram. The arrow represents the direction of flow. If you notice, all the pipes are sloping towards the building drain. Figure 8-26 further shows the basic layout of a drainage system. The function of each part is as follows:

● FIXTURE BRANCHES are horizontal drainpipes connecting several fixtures to the stack.

● A FIXTURE DRAIN extends from the P-trap of a fixture to the junction of that drain with any other drainpipe.

● SOIL AND WASTE FIXTURE BRANCHES feed into a vertical pipe, referred to as a stack. If the waste carried by the fixture branch includes human waste (coming from water closets or from a fixture with similar functions), the stack is called a SOIL STACK. If a stack carries waste that does not include human waste, it is referred to as a WASTE STACK. These stacks service all the fixture branches beginning at the top branch and go vertically to the building drain.

● A BUILDING DRAIN (also referred to as a house drain) is the lowest piping part of the drainage system. It receives the discharge from the soil, waste, and other drainage pipes inside the building and extends to a point 3 ft outside the building wall. (Most local codes require that the house drain extend at least 3 ft beyond the building wall, but a few local requirements range from 2 to 10 ft.)

● A BUILDING SEWER is that part of the horizontal piping of a drainage system that extends from the end of the building drain. It

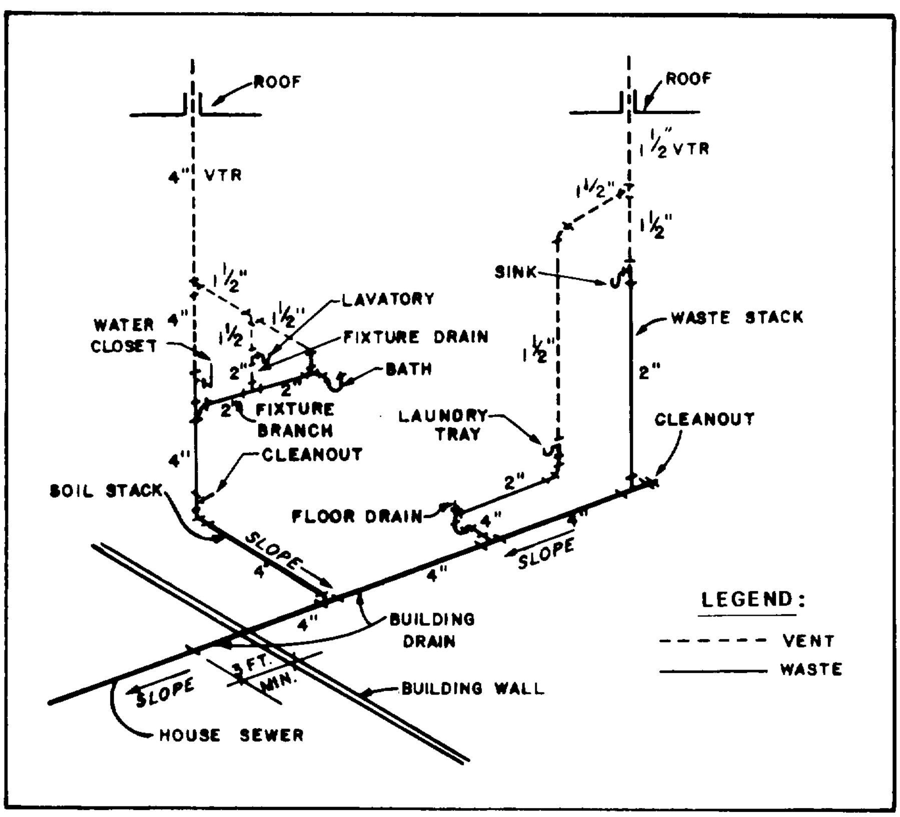


Figure 8-26.-Basic layout of a drainage system.

conveys the waste to the community sewer or an independent disposal unit.

● A FLOOR DRAIN is a receptacle used to receive water to be drained from the floors into the drainage system. Floor drains are usually located near the heating equipment and in the vicinity of the laundry equipment or any unit subject to overflow or leakage.

● A CLEANOUT is a unit with a removable plate or plug that provides access into plumbing or other drainage pipes for cleaning out extraneous material.

PLUMBING LAYOUT

In construction drafting, a mechanical (or utility) plan normally includes both water

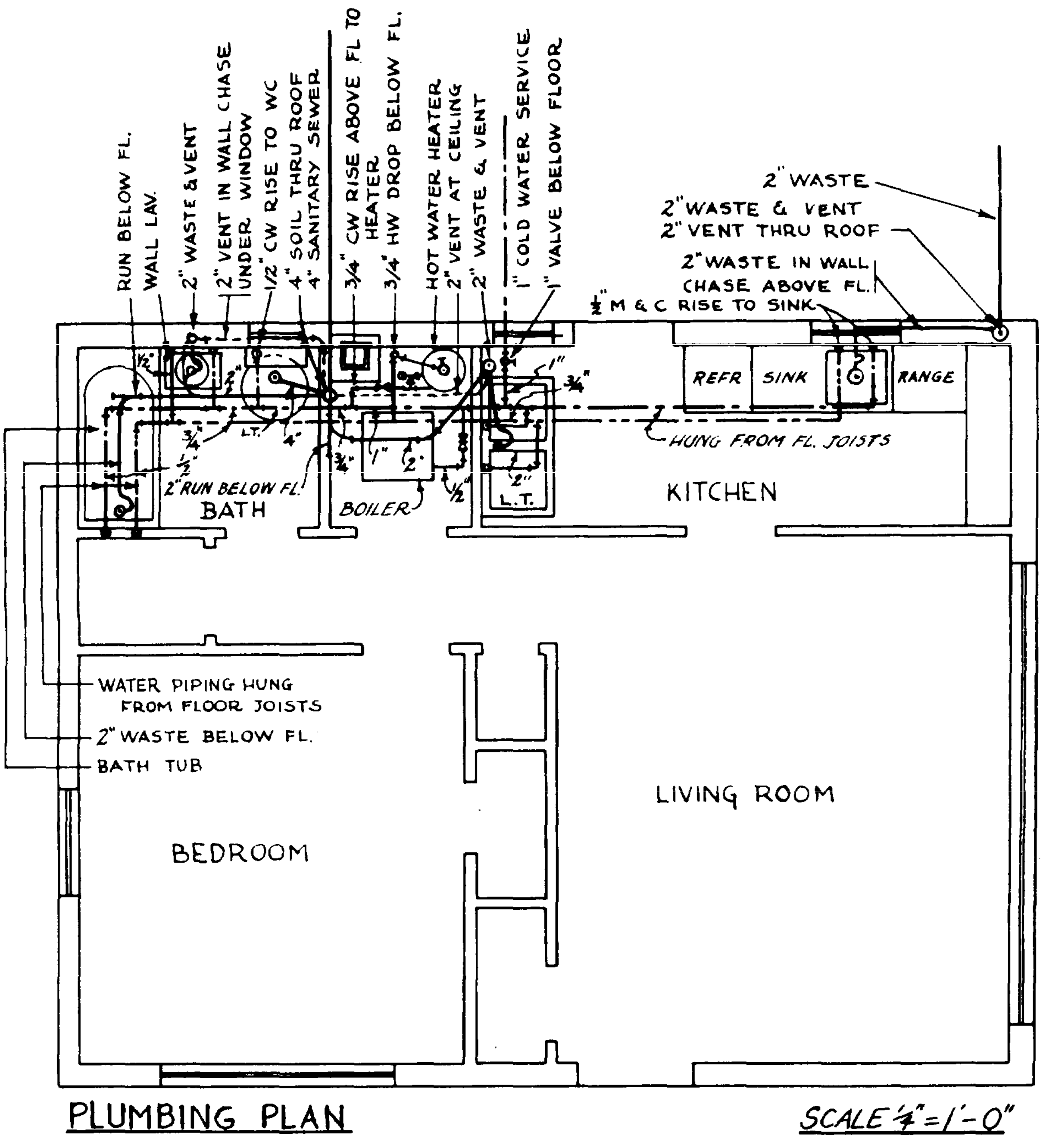


Figure 8-27.-Typical plumbing layout for a small residential building.

distribution and sanitary drainage systems combined, especially on smaller buildings or houses. The plumbing layout is usually drawn into a copy of the floor plan for proper orientation with existing plumbing fixtures, walls and partition outlines, and other utility features. Figure 8-27 shows a typical plumbing layout. The reproduction is, unfortunately, too small to be easily studied, but you can see that it uses the mechanical symbols. Refer to ANSI Y32.4-1977, *Graphic Symbols Used in Architectural and Building Construction* and MIL- STD-17-1, *Mechanical Symbols.*

As shown in figure 8-27, the cold-water service line, which enters the building near the laundry trays, is indicated by a broken dash-and-single-dot line, while the waste pipes are indicated by solid lines. If you follow the cold-water service line, you will see how it passes, first, a 1-in. main shutoff valve below the floor and just inside the building wall. From here, it proceeds to a long pipe running parallel to the building wall and hung under the floor joists, which services, beginning at the right-hand end, the cold-water spigot in the sink, the cold-water spigot in the laundry, the hot-water heater, the boiler for the house heating system, the flushing system in the water closet (W.C.), the cold-water spigot in the bathroom washbasin, and the cold-water spigot in the bathtub. The below-the-floor line is connected to the spigots by vertical RISERS. Valves at the hot-water heater and boilers are indicated by appropriate symbols.

From the hot-water heater, you can trace the hot-water line (broken dash-and-double-dot line) to the hot-water spigots in the sink, laundry, bathroom washbasin, and bathtub. This line is also hung below the floor joists and connected to the spigots by risers.

You can see the waste line (solid line) for the bathtub, washbasin, and W.C. (with traps indicated by bends) running under the floor from the bathtub by way of the washbasin and W.C. to the 4-in. sanitary sewer. Similarly, you can see the waste line from the laundry running to the same outlet. However, the kitchen sink has its own, separate waste line. The bathroom utilities waste lines vent through a 4-in. pipe running through the roof; the sink waste line vents through a 2-in. pipe running up through the roof.

MECHANICAL SYMBOLS

As stated earlier in this chapter, the Engineering Aid is not expected to design the system, but the main objective is to draw a workable plumbing plan for use by the plumbing crew or any other interested parties. In order to accomplish this, the EA must be familiar with the terms, symbols, definitions, and the basic concepts of the plumbing trade.

As a rule, plumbing plans should show the location of the fixtures and fittings to be installed and the size and the route of the piping. The basic details are left to the plumber (UT), who is responsible for installing a properly connected system according to applicable codes, specifications, and good plumbing and construction practices. Generally, plumbing plans consist of four types of symbols: piping, fittings, valves, and fixtures.

Piping Symbols

The line symbols for piping shown in figure 8-28 are composed of solid or dashed lines that indicate the type and location of that particular

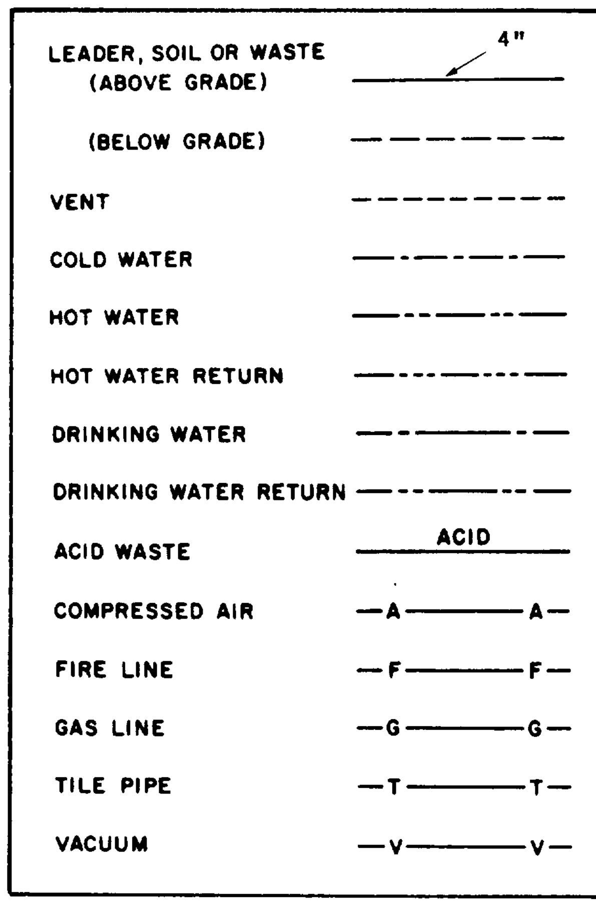


Figure 8-28.-Line symbols for piping.

pipe on the plan. Other line symbols identify the proposed use of the pipes. The size of the required piping should also be noted alongside each route of the plan. Piping up to 12 in. in diameter is referred to by its nominal size, which is approximately equal to the inside diameter (I.D.). The exact inside diameter depends on the classification of the pipe. Heavy types of piping have smaller inside diameters because their wall thickness is greater. Piping over 12 in. in diameter is referred to by its outside diameter (O.D.).

Fitting Symbols

The pipe-fitting symbols shown in figure 8-29 are the basic line symbols used for pipes, in

ITEM	SYMBOL	SAMPLE APPLICATION (S)	ILLUSTRATION
PIPE	SINGLE LINE IN SHAPE OF PIPE—USUALLY WITH NOMINAL SIZE NOTED		
JOINT—FLANGED	DOUBLE LINE		
SCREWED	SINGLE LINE		
BELL AND SPIGOT	CURVED LINE		
OUTLET TURNED UP	CIRCLE AND DOT		
OUTLET TURNED DOWN	SEMICIRCLE		
REDUCING OR ENLARGING FITTING	NOMINAL SIZE NOTED AT JOINT		
REDUCER CONCENTRIC	TRIANGLE		
ECCENTRIC	TRIANGLE		
UNION SCREWED	LINE		
FLANGED	LINE		

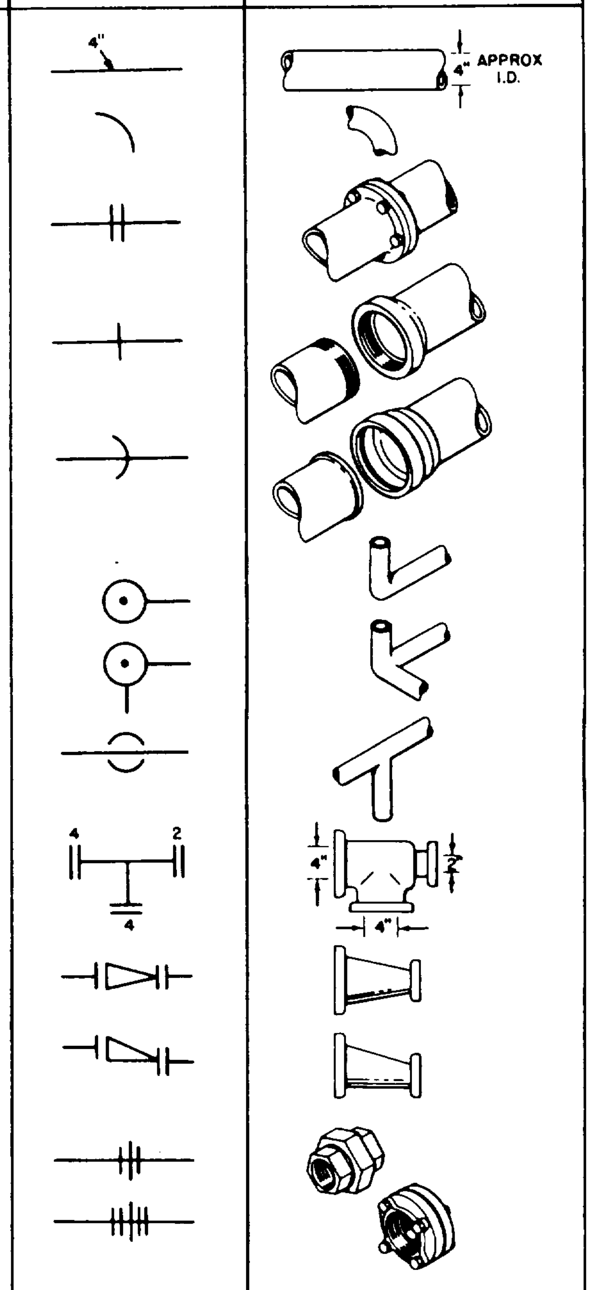


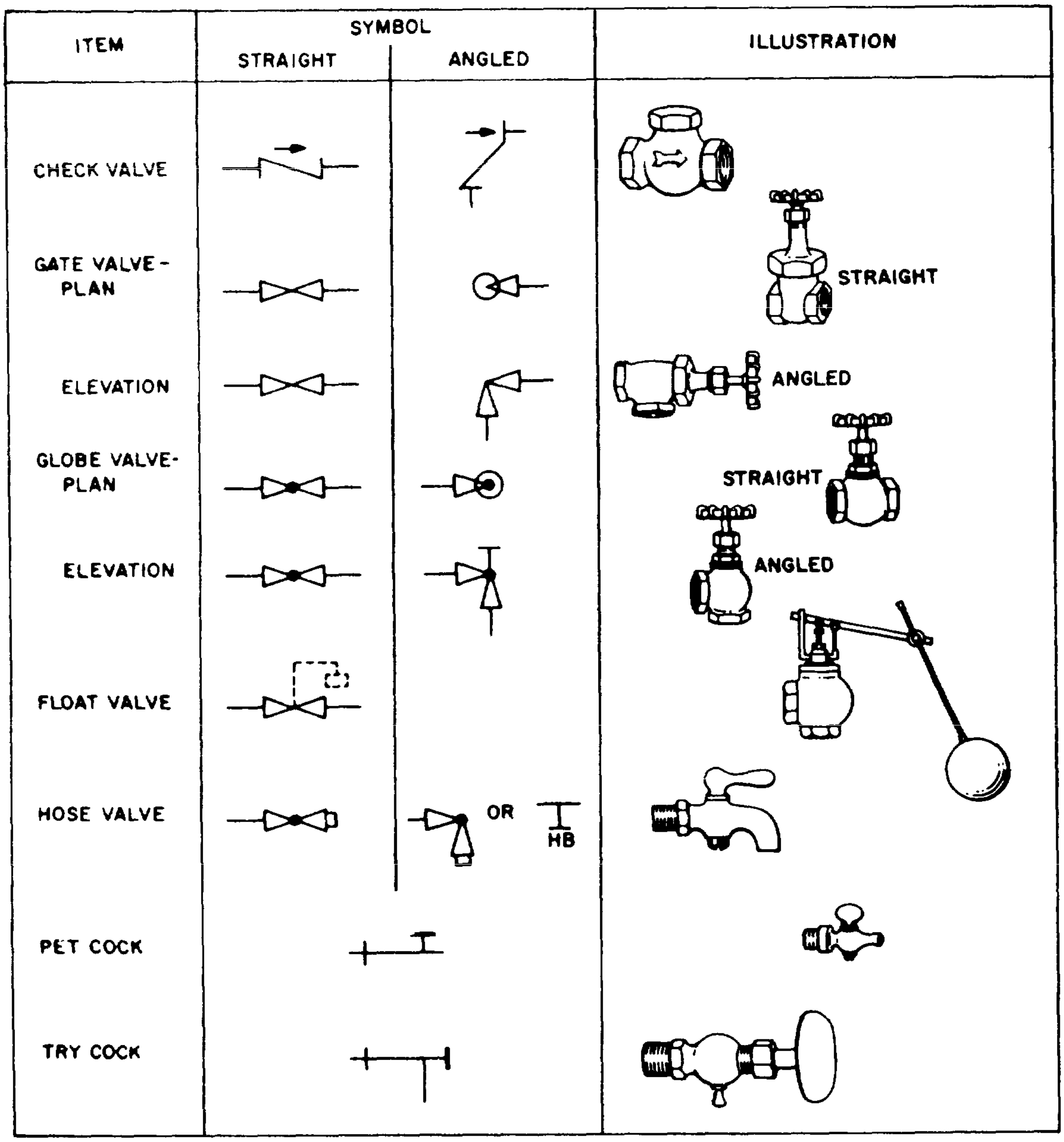
Figure 8-29.-Pipe-fitting symbols.

conjunction with the symbology of pipe fittings or valves. They define not only the size of the pipe and the method of branching and coupling, but also the purpose for which the pipe will be used. This is important because the type of material from which the pipe is made deter-mines how the pipe should be used.

Figure 8-29 covers only a few of the symbols for fittings, joints, and connections used in the plumbing system. For additional symbols on welded and soldered joints, refer to the appendices on plumbing symbols found in the back of this book .

Valve Symbols

Figure 8-30 shows the symbols used for the most frequently encountered valves. The type of material and size of valves are normally not noted on mechanical drawings but must be assumed from the size and material of the connected pipe.



NOTE: SYMBOLS ARE SHOWN FOR SCREWED FITTINGS – SYMBOLS FOR JOINTS ARE ADDED FOR OTHER TYPES

Figure 8-30.-Valve symbols.

However, when specified on the lists of materials or plumbing takeoff, valves are called out by size, type of material, and working pressure; for example, 2-in. gate valve, PVC, 175-lb working pressure.

Fixture Symbols

The symbols shown in figure 8-31 are for general appurtenances, such as drains and sumps, but other fixtures, such as sinks, water closets, and shower stalls, are shown on the plans by pictorial or block symbols. The extent to which the symbols are used depends on the nature of the drawing. In many cases, the fixtures will be specified on a bill of materials or other schedules keyed to the plumbing plan. When the fixtures are described on the schedule, the EA can use symbols that closely resemble the actual fixtures or obtain mechanical symbol templates that are available commercially.

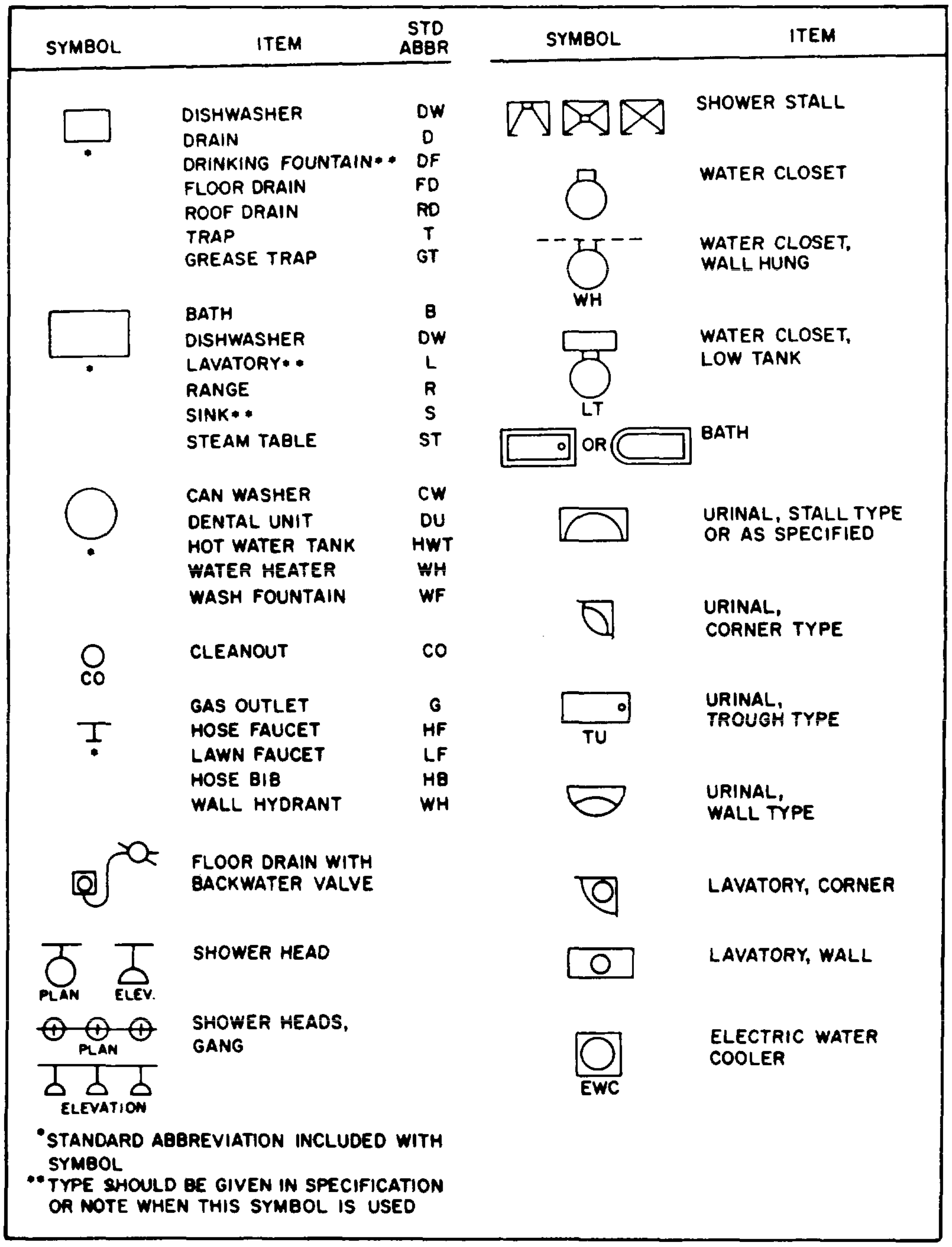


Figure 8-31.-Symbols for plumbing fixtures.

CHAPTER 9

ELECTRICAL SYSTEMS AND PLAN

It is important for an EA working on a set of drawings or plans to convey his ideas (or instructions) effectively to a skilled craftsman (CE) who is to install the electrical system. It is also equally important for you, as an EA, to understand and be thoroughly familiar with the methods and basic functions associated with the different materials and fixtures used in the installation of an electrical system.

This chapter, when used in conjunction with the previous chapters on wood, concrete and masonry, and mechanical systems and plan, will enable you to prepare construction drawings (discussed in the next chapter), revise as-built drawings in the field, and incorporate minor design changes with ease.

ELECTRICAL SYSTEM

Each building requires an electrical system to provide power for the lights and to run various appliances and equipment. At Navy bases, the electrical (or power) system consists of three main parts: the power plant that supplies the electrical power, the electrical distribution system (external) that carries the electrical current from the generating station to the various buildings, and the interior electrical wiring system that illuminates the building and feeds the interior electrical power to the appliances and equipment within the building.

In this section, we will discuss only the external power distribution and the various materials and fittings used in the installation of an electrical system. For more information, refer to the latest edition of *Construction Electrician 3 & 2*, NAVEDTRA 10636, *National Electrical Code*®(NEC®), and Army Technical Manuals (TMs).

ELECTRICAL (POWER) DISTRIBUTION SYSTEM

Electrical distribution is defined as the delivery of power to building premises, on poles or placed underground, from the power plant or substation through feeders and mains.

The power system is generally considered to be a combination of two sections: the transmission and the distribution. The difference between the two sections depends on the function of each at that particular time.

At times, in a small power system, the difference tends to disappear, and the transmission section merges with the distribution section. The delivery network, as a whole, is referred to as the distribution section and is normally used to designate the outside lines and frequently continues inside the building to include power outlets.

Most land-based power systems use alternating current (ac) rather than direct current (dc), principally because transformers can be used only with ac. An ac distribution system usually contains one or more generators (technically known as ALTERNATORS in an ac system); a wiring system of FEEDERS, which carry the generated power to a distribution center; and the DISTRIBUTION CENTER, which distributes the power to wiring systems called PRIMARY MAINS and SECONDARY MAINS. A representative transmission and distribution system is shown in figure 9-1.

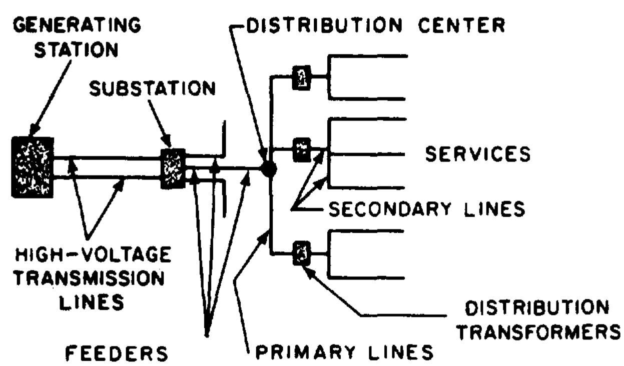


Figure 9-1.-Electrical transmission and distribution system.

Power from the generating station may be carried to the various points of consumption by overhead transmission and distribution lines, by underground cable, or by a combination of both. At most advanced bases, OVERHEAD feeder lines are commonly used because such lines are cheaper to build, simpler to inspect, and easier to maintain than UNDERGROUND cables. Obviously, the use of underground cables is preferred at airports and runways to prevent hazardous flight conditions.

Overhead Power Distribution

Figure 9-2 shows a three-phase, three-wire OVERHEAD power distribution system. Assume that the system has an alternator generating 220 V (fig. 9-3). From the generating station, three-phase, three-wire feeders carry the power overhead to the distribution points (or centers), from which two primary mains branch off. One of these mains carries power to a lighting system and a single-phase motor in a motor pool, each of which is designed to operate on 110 V, and to a three-phase motor designed to operate on 220 V. The 220-V, three-phase motor is connected directly to the 220-V, three-phase primary main. However, for the lighting system and 110-V motor, two wires in the primary main are tapped off to a transformer, which reduces the 220-V primary main voltage to 110 V. The use of two wires creates a single-phase voltage in the secondary main to the motor pool. Similarly, power to secondary mains running to the operational headquarters, living quarters, and the mess hall is reduced to 110 V and converted to single phase.

A system may be a THREE-WIRE or a FOUR-WIRE system, depending upon whether the alternators are connected DELTA (A) or WYE (Y). Figure 9-4 is a schematic diagram showing a delta connection. The coil marked

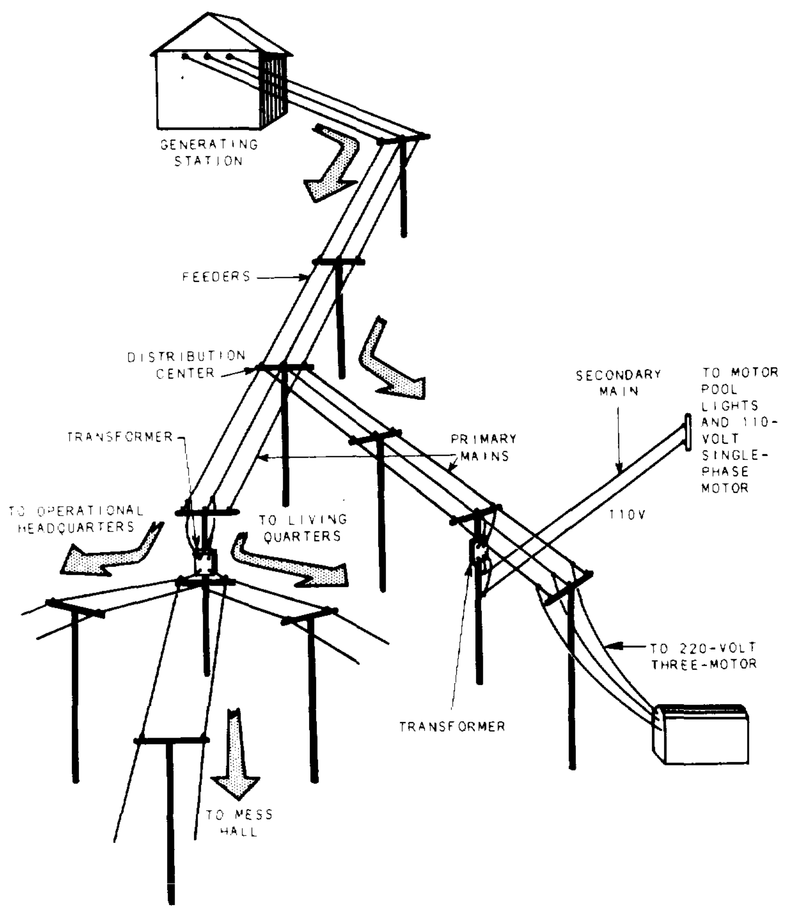


Figure 9-2.-A typical overhead power distribution system.

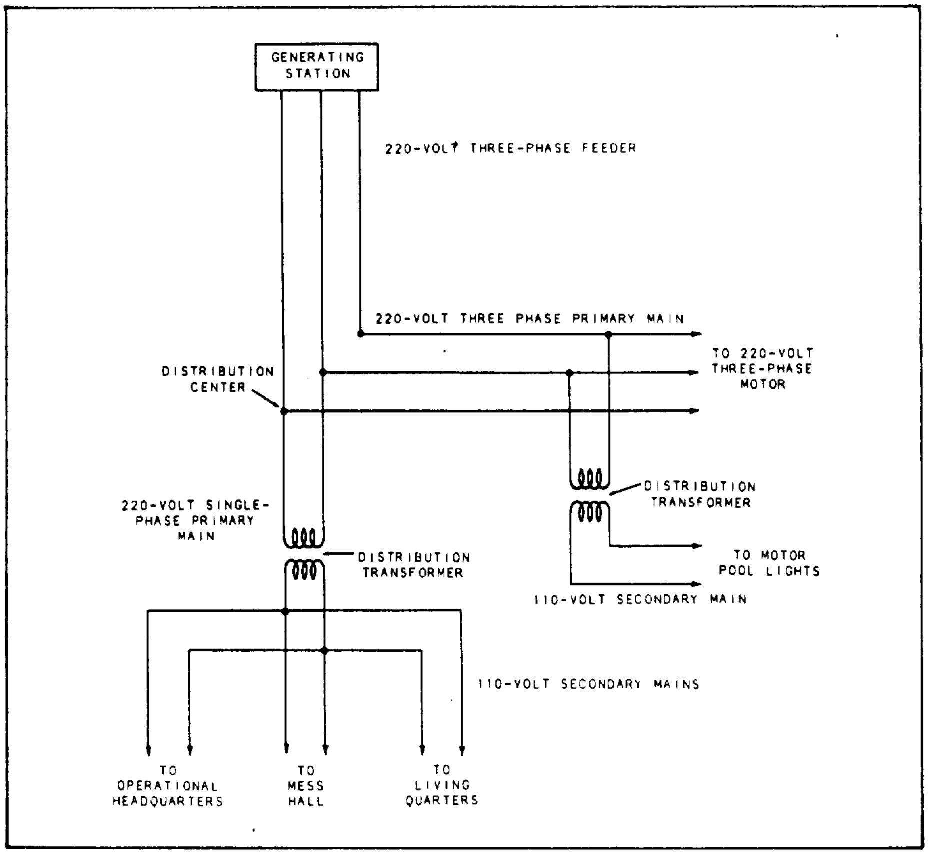


Figure 9-3.-Wiring diagram of the three-phase, three-wire distribution system in figure 9-2.

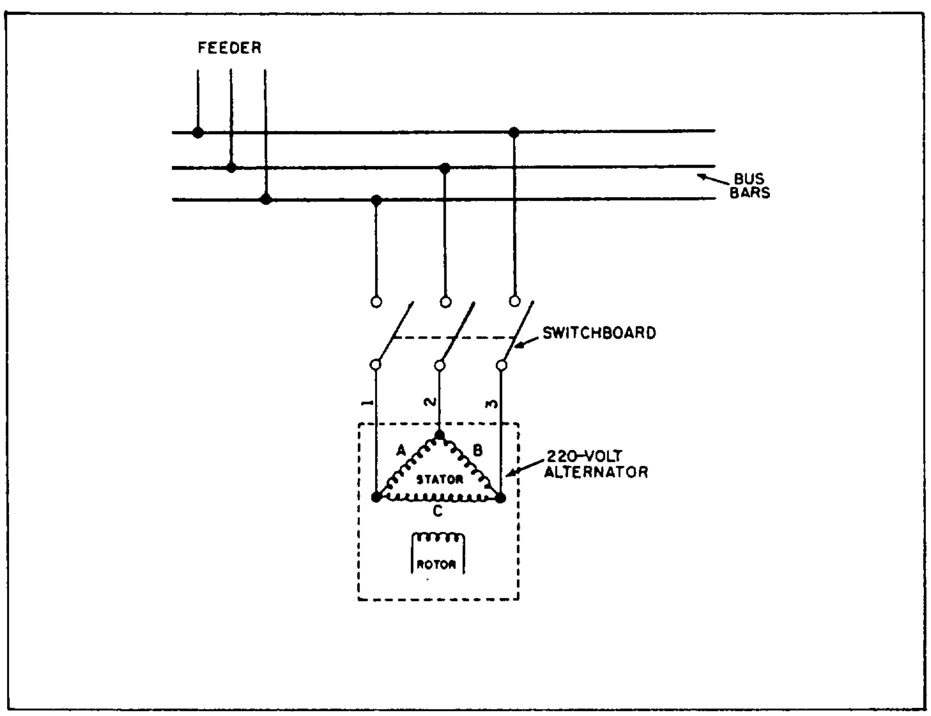


Figure 9-4.-Schematic diagram of a delta-connected alternator.

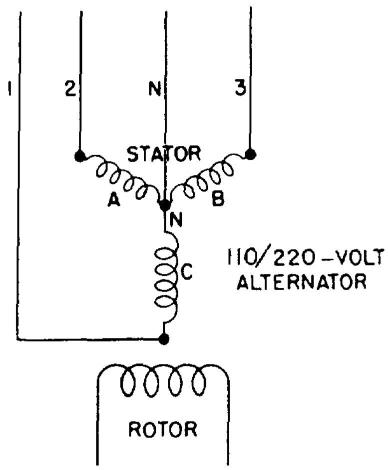


Figure 9-5.-Y-connected alternator (three-phase, four-wire).

STATOR represents the stationary coils of wire in the alternator; the one marked ROTOR represents the coils, which rotate on the armature. You can see that the power is taken off the stator from three connections, which in the drawing form a triangle or delta. All three wires are live (called HOT) wires.

Figure 9-5 shows a Y-connected alternator (three-phase, four-wire). N represents a common or NEUTRAL point to which the stator coils are all connected. The current is taken off the stator by the three lines (wires), 1, 2, and 3, connected to the stator coil ends; and also by a fourth line, N, connected to the neutral point. Lines 1, 2, and 3 are hot wires; line N is NEUTRAL.

The voltage developed in any pair of wires, or in all three wires, in a delta-connected alternator is always the same; therefore, a

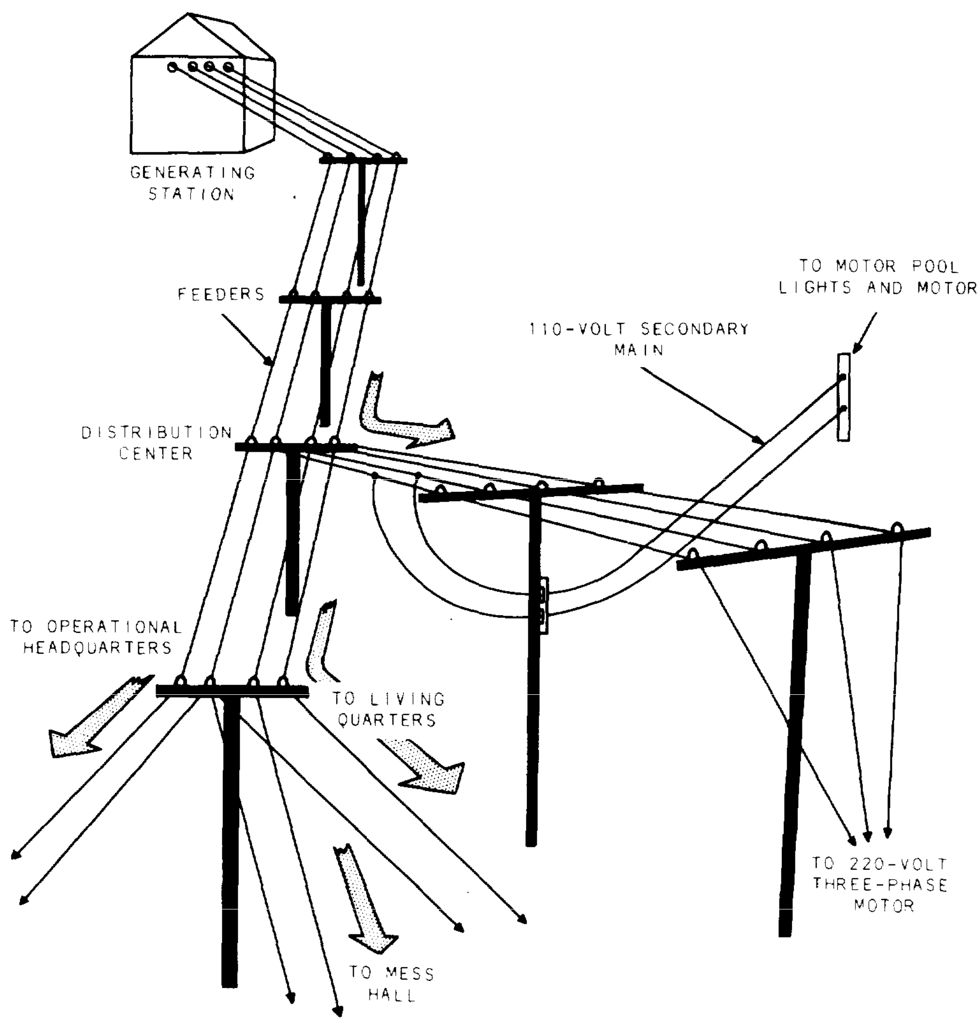


Figure 9-6.-A pictorial view of a four-wire overhead distribution system.

delta-connected system has only a single voltage rating (220 V in fig. 9-4). However, in a Y-connected system, the voltage developed in different combinations of wires is different. In figure 9-5, you can see that lines 1 and 2 take power from two stator coils (A and C). The same applies to lines 1 and 3 (power from coils C and B) and lines 2 and 3 (power from coils A and B). However, the neutral (N) and line 2 take power from coil A only; neutral (N) and line 1, from coil C only; and neutral (N) and line 3, from coil B only.

It follows from this that a Y-connected alternator can produce two different voltages: a higher voltage in any pair of hot wires, or in all three hot wires, and a lower voltage in any hot wire paired with the neutral wire.

Output taken from a pair of wires is SINGLE-PHASE voltage; output from three wires is THREE-PHASE voltage. The practical significance of this lies in the fact that some electrical equipment is designed to operate only on single-phase voltage, while other equipment is designed to operate only on three-phase voltage. This equipment includes the alternators themselves, and a system with a three-phase alternator is called a three-phase system. However, even in such a system, single-phase voltage can be obtained by tapping only two of the wires.

Figure 9-6 shows a four-wire system serving the same facilities. Here there is a Y-connected alternator rated at 110/220 V. You can see that to get 110 V single phase for the secondary mains, no transformers are necessary. These mains are simply tapped into pairs of wires, one of each pair being a hot wire and the other, the neutral wire. The 220-V, three phase motor is tapped into the three hot wires that develop 220 V, three-phase. You can see that the neutral wire in a four-wire system exists to make it possible for a lower voltage to be used in the system.

Figure 9-7 shows a wiring diagram for the system shown in figure 9-6.

Now, let's discuss the device called a DISTRIBUTION TRANSFORMER. A transformer is simply a device for increasing or reducing the voltage in an electrical circuit. It ranges in size from one that is portable (those used for appliances inside the building) to heavy ones that are mounted permanently on platforms or

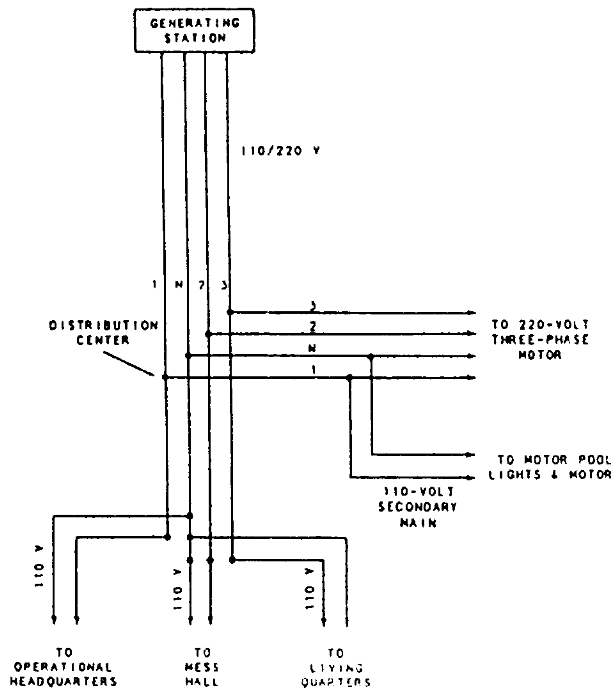


Figure 9-7.-Wiring diagram of the four-wire system in figure 9-6.

hung with crossarm brackets attached to an electric pole. Ask one of the CES to show you a transformer. It is very probable that one is nearby.

Now, for long-distance power transmission, a voltage higher than that normally generated is required. A transformer is used to step the voltage up to that required for transmission. Then at the service distribution end, the voltage must be reduced to that required for lights and equipment. Again a transformer is used; but this time it is to step down the voltage.

The reason for stepping up the voltage in a line lies in the fact that the greater the distance, the more resistance there will be to the current flow; and a much greater force will be required to push the current through the conductor. Perhaps you can best understand this reasoning if you examine Ohm's Law.

$$I = \frac{E}{R}.$$

(Refer to chapter 1 of this book.)

You can see from the formula above that the CURRENT (I) varies inversely to the RESISTANCE (R). To maintain the required current flow as the resistance increases, one must increase the VOLTAGE, or ELECTROMOTIVE FORCE (E), accordingly. The increase in voltage makes it possible to use smaller wires or cables, thus minimizing the support for aboveground transmission lines, and consequently minimizing the cost of the system.

Underground Distribution

The Navy uses UNDERGROUND power distribution systems on most shore facilities for several reasons: underground lines are secure against damage that high winds and storms inflict on overhead lines in some areas; underground lines leave clear areas and open spaces for the operations of heavy mobile equipment; and underground lines are much more secure against enemy attack than overhead lines.

There are three principal categories of underground lines: duct lines, cables buried directly, and conduits located in tunnels. The system most frequently installed by construction battalions is the underground duct system, which consists of manholes, handholes, duct lines, and cables. In general, a representation of the system layout and a list of materials needed to install the system can be found in a standard set of drawings.

INTERIOR ELECTRICAL WIRING SYSTEM

In general, the term *service* means the electrical system that brings the power from the pole or other point on the exterior power distribution line to the point on or inside the building from which it is distributed to the building circuits. Service for a building consists of two parts: the service conductors and the service equipment.

The SERVICE CONDUCTORS supply power from the pole or other point on the exterior distribution system to the building. These conductors may be SERVICE DROP conductors for overhead service, or they may be SERVICE LATERAL conductors for underground service. From the service conductors, electrical power is brought into the building through a SERVICE ENTRANCE to the SERVICE EQUIPMENT on or inside the building. The service equipment is the necessary equipment, usually consisting of a circuit breaker or switch or fuses, that is located near the entry point of the supply conductors to the building. This equipment is the main control and means of cutting off the power supply to the building.

Service Conductors

The SERIVCE DROP CONDUCTORS (fig. 9-8) run from the pole to the building. These conductors may consist of an approved multiconductor cable or individual (single) conductor. In either case, they must have thermoplastic, rubber, or other weatherproof insulation. The current-carrying capacity of the service drop conductors must be sufficient to ensure that ample current for the prospective maximum load may be conducted without a temperature rise to a point high enough to damage the insulation. The NEC® specifies the minimum size conductors that may be used for different load (amperage) requirements.

Figure 9-9 shows an UNDERGROUND SERVICE that brings power into a building. the conductors, corresponding to the service drop that

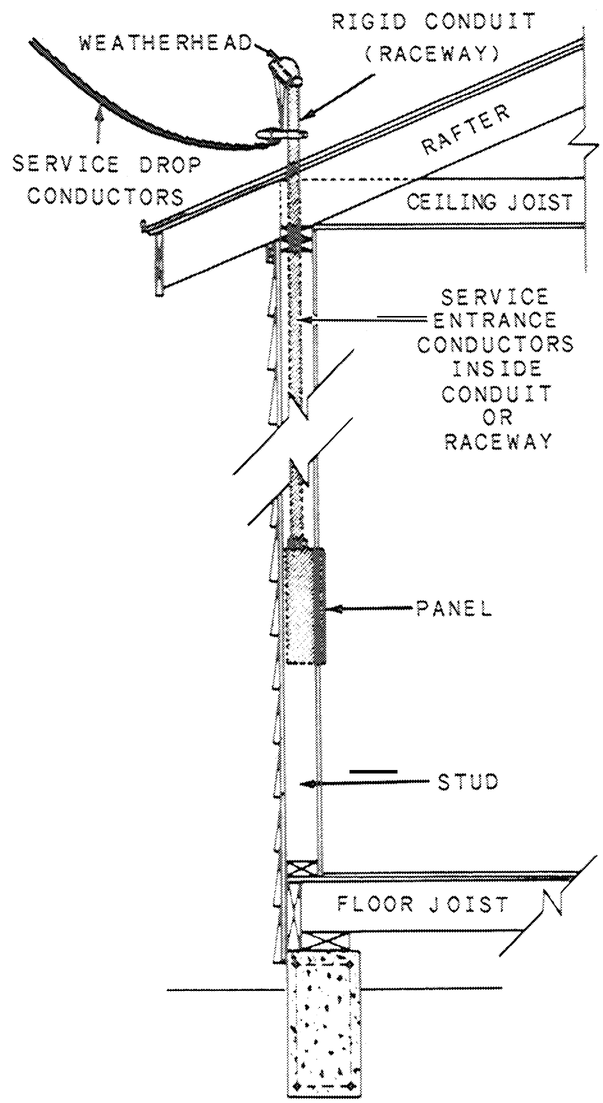


Figure 9-8.—Overhead service entrance.

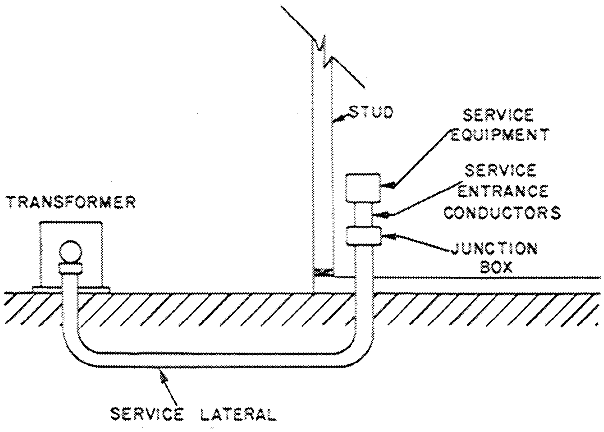


Figure 9-9.—Underground service to building.

brings the power to the building, are called the service lateral. Sometimes these conductors are tied to an overhead distribution system, and they run down the pole into the ground before they are run to the building. In other cases, the entire distribution system, except for the transformers, is underground. The service lateral may be connected to a secondary main, or, if the building is served by separate transformers, it is connected to the transformers.

The service lateral may be installed in rigid conduit, either metallic or nonmetallic, or it can be installed with underground service entrance (USE) cable. The figure shows the layout of an underground service lateral run from the transformer to the junction box and to the service equipment.

Service Entrance

The starting point for interior wiring is the SERVICE ENTRANCE, which brings power from the service conductors to the service equipment. Refer again to figure 9-8. As shown in this figure, the service entrance conductors are connected to the service drop at a point just outside the building. These conductors may be approved single conductors run through a protective raceway, such as rigid metallic or nonmetallic conduit. The service entrance conductor may also be an approved type of service entrance cable that does not need raceway protection unless it is likely to be damaged by abrasions or from being struck by passing equipment. Where single conductors are used, they must be insulated as require by the NEC®. The NEC® also specifies the size wire that may be used as service entrance cable.

Also shown in figure 9-8 is a SERVICE HEAD. A service head, frequently called a WEATHERHEAD, is used with a raceway to provide an entrance for the conductors into the building. The weatherhead is designed to prevent the entrance of rain into the raceway. It is also designed to reduce abrasion to the insulation.

A SERVICE ENTRANCE SWITCH (left-hand side of fig. 9-10) provides a means of

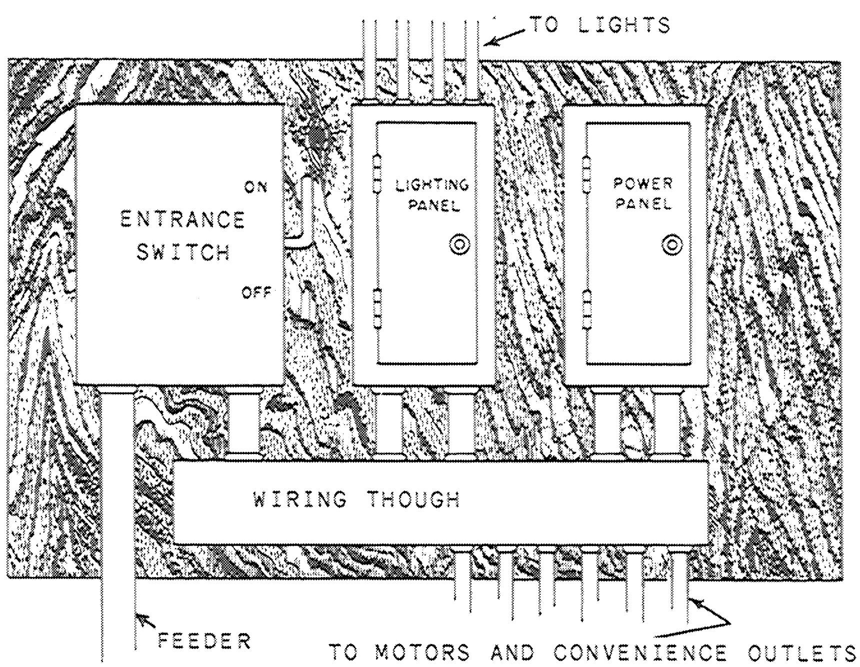


Figure 9-10.—Typical layout for entrance switch, lighting panel, and power panel.

disconnecting the service conductors from the supply source. It may consist of a single manually operated switch or a circuit breaker. The NEC® sets a minimum size for entrance switches at 60 A for the fuse type and 50A for the circuit breaker type. A CIRCUIT BREAKER is a protective device that automatically opens the circuit, rather than burning out like a fuse, when the amperage exceeds that rated for the circuit breaker. The NEC® recommends a minimum size of 100-A service for individual residences. However, when not more than two two-wire branch circuits are installed, a 30-A entrance switch may be used.

Panelboard

A PANELBOARD (fig. 9-10) is defined by the NEC® as a single panel, or a group of panel units designated for assembly in the form of a single panel, including buses. It comes with or without switches and/or automatic overcurrent protective devices for the control of light, heat, or power circuits of small individual as well as aggregate capacity; it is designed to be placed in a cabinet or a cutout box and placed in or against a wall or partition and is only accessible from the front.

A BREAKER PANEL uses a thermal unit built into the switch with the breaker being preset at the factory to open automatically at a predetermined

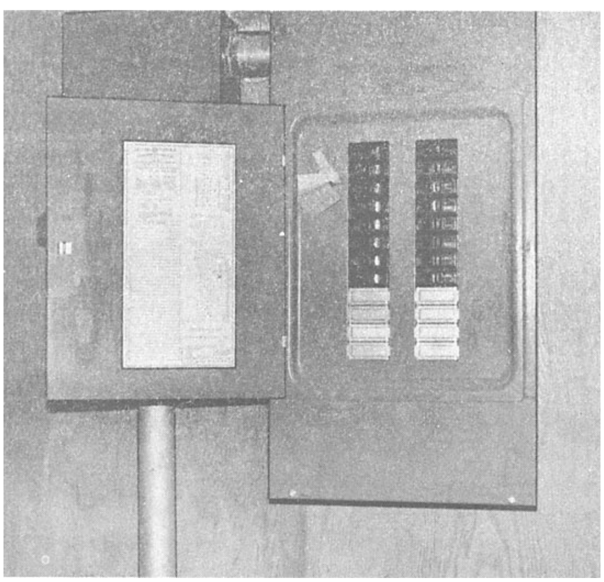


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Figure 9-11.-Lighting panel.

ampere setting. It maybe reset to the ON position after a short cooling-off period.

LIGHTING PANELS (fig. 9-11) are normally equipped with 15-A single-pole automatic circuit breakers, while the power panels may have one-, two-, or three-pole automatic circuit breakers with a capacity to handle the designated load. In most buildings, the entrance switch and panelboards can be mounted close to each other; however, they must be placed where service and maintenance can be easily performed. They should not block any passage that is supposed to be open, and they should not be in a place where exposure to corrosive fumes and dampness is imminent. Panelboards should be located as near as possible to the center of the electrical load.

Conductors

ELECTRICAL CONDUCTORS generally consist of drawn copper or aluminum formed into wire. They provide paths for the flow of electrical current. Conductors are usually covered with insulating materials (fig. 9-12) to minimize the

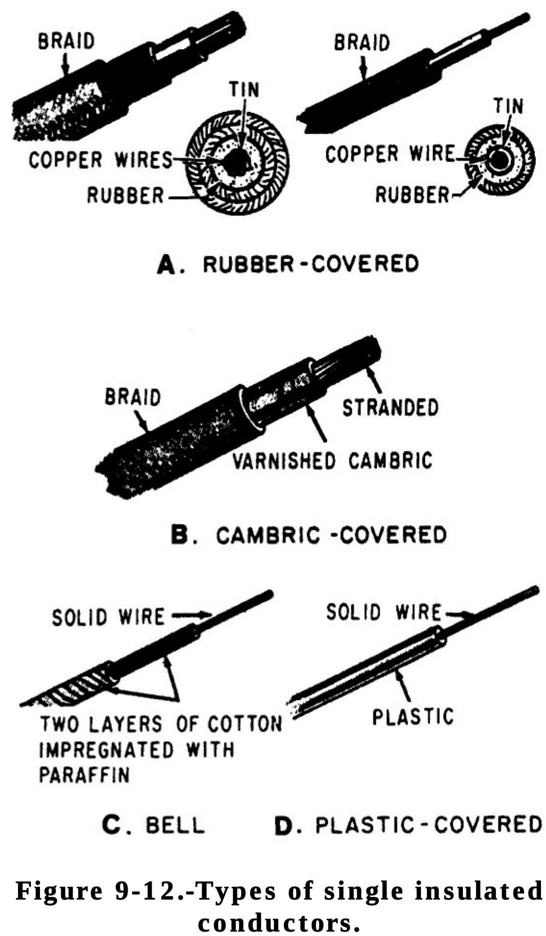

Figure 9-12.-Types of single insulated conductors.

chances for short circuits and to protect personnel. Atmospheric conditions, voltage requirements, and environmental and operating temperatures are factors to consider in selecting the type of insulating material for a particular job.

SINGLE CONDUCTORS.— A single conductor may consist of one solid wire or a number of stranded, uncovered, solid wires that share in carrying the total current. A stranded conductor has the advantage of being more flexible than a solid conductor, making it more adaptable for pulling through any bends in a conduit. Common types of single conductors are shown in figure 9-12.

Conductors vary in diameter. Wire manufacturers have established a numerical system, called the American Wire Gage (AWG) Standard, to eliminate the necessity for cumbersome circular mil or fractional-inch diameters in describing wire sizes. Figure 9-13 shows a comparison of one-half actual wire diameters to their AWG numerical designations. Notice that the wire gauge number increases as the diameter of the wire decreases.

The wire size most frequently used for interior wiring is No. 12 AWG and is a solid conductor. No. 8 and larger wires are normally used for heavy power circuits or as service entrance leads to buildings.

The type of wire used to conduct current from outlet boxes to sockets in the lighting fixtures is called "fixture wire." It is stranded for flexibility and is usually size 16 or 18 AWG.

MULTIWIRE (CABLE) CONDUCTORS.— A multiwire conductor, called a CABLE, is an assembly of two or more conductors insulated from each other with additional insulation or a protective shield formed or wound around the group of conductors. The covering or insulation for individual wires is color coded for proper identification. Figure 9-14 shows common types of multiwire conductors.

AWG NUMBER	½ ACTUAL SIZE	DIAMETER (INCHES)
18	•	.0403
16	•	.0508
14	•	.0640
12	•	.0808
10	•	.1018
8	●	.1284
6	●	.184
4	●	.232
2	●	.292
1	●	.332
1/0	●	.373
2/0	●	.419
3/0	●	.470
4/0	●	.528

Figure 9-13.—Comparison of standard wire gauge number to wire diameters.

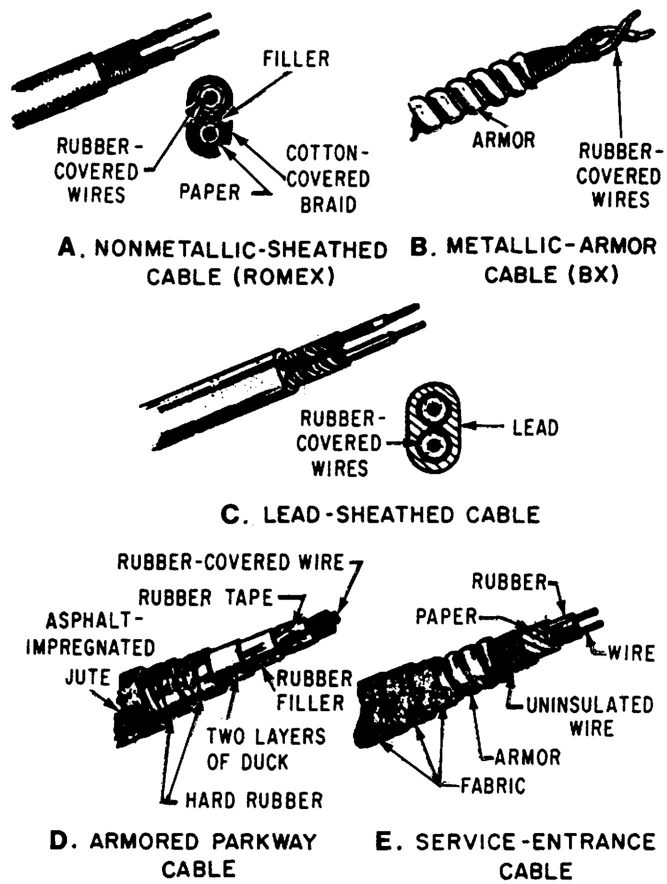

Figure 9-14.—Types of multiwire insulated conductors (cables).

Nonmetallic-sheathed cable (NMC) (fig. 9-14, view A) is more commonly called by the trade name "ROMEX," ROMEX (NMC) comes in sizes No. 14 through 2 for copper conductors and No. 12 through 2 for aluminum or copper-clad aluminum conductors. This type of cable comes with a bare (uninsulated) ground wire. The ground wire is laid in the interstices (intervals) between the circuit conductors and under the outside braid. The ground wire is used to ensure the grounding of all metal boxes in the circuit, and also to furnish the ground for the grounded type of convenience outlets that are required in Navy installations. Nonmetallic-sheathed cable is used for temporary wiring in locations where the use of conduit would be unfeasible. The use of Romex as service entrance cable, in garages, in storage battery rooms, imbedded in poured concrete, or in any hazardous area is NOT authorized.

Metallic-armored cable (fig. 9-14, view B), also called BX cable, is used in naval installations for temporary wiring, but unlike Romex, its use in commercial installation is restricted. Most city building codes restrict the use of BX cables to oil burner control circuits and the like. A difficulty with BX is the fact that it tends to ground after installation. Small metal burrs on, the armor can, because of vibration, penetrate the insulation and cause a ground.

BX cables come in sizes from No. 14 to 2 AWG, and each cable may contain one, two, three, or four conductors. The armor on the cable furnishes a continuous ground between boxes.

Insulation

As mentioned earlier, electrical conductors are available with various kinds of insulating materials. Some of these are rubber, thermoplastic, and varnished cambric. Special types of paper, glass, silk, and enamel are also used to insulate conductors, but with less frequency than those previously mentioned. The NEC® recommends insulation of certain kinds for use in dry, damp, and wet locations. Underground installations, those in concrete slabs and masonry, those in direct contact with the earth, and those subject to saturation with water or other liquids are considered wet-location installations.

Another factor to consider in the choice of insulation is temperature. Different insulations have different maximum temperature ratings. Check the NEC® and applicable LOCAL CODES to be sure you are using the appropriate insulation for the location and temperature considered in the plans. Some examples of the composition of insulation, the location that applies, and their maximum temperature rating follow:

Type RH is a heat-resistant compound, that will stand higher temperature than Type R. This type is commonly used in dry locations. The maximum temperature rating is 167°F.

Type RHW is a moisture-resistant rubber compound for use where the wire may be subject to wet conditions. This type is used in both wet and dry locations. The maximum temperature rating is 167°F.

Type RUH is a high grade rubber compound, consisting of 90-percent latex. This type is often used for direct burial in dry locations. The maximum temperature rating is 140°F.

Thermoplastic insulation has the advantage of long life, toughness, and a dielectric strength (that is, a capacity for insulating) equal to that of rubber. It requires no protective covering over the insulation. Common types of thermoplastic insulation are Types T, TW, and TA. Type T is suitable only for dry locations with a maximum temperature rating of 140°F. Type TW is moisture-resistant, and again, with a temperature rating of 140°F. Type TA is a thermoplastic-asbestos compound that combines the characteristics of Types T and TW. This type has a maximum temperature rating of 194°F. Its use is restricted to switchboard wiring.

Varnished cambric insulation has an insulating quality midway between that of rubber and paper. It is more flexible than paper; its dielectric strength is greater than that of rubber. This type is not adversely affected by ordinary oil and grease. It is manufactured in either standard type (black finish), or in the heat-resistant type with a yellow finish. Varnished insulation is restricted to dry locations in areas such as motor leads, transformer leads, and high-voltage cables.

Conduits and Fittings

An electrical conduit is a pipe, tube, or other means in which electrical wires are installed for protection from accidental damage or from the elements. If pipes or tubing is used, the fittings depend upon the pipe or tubing material. The conduit used in Navy construction is generally classified as RIGID, THIN-WALL, or FLEXIBLE conduit. The three types of conduit and their associated fittings are shown in figure 9-15.

RIGID CONDUIT.— Rigid galvanized steel or aluminum conduit is made in 10-ft lengths. It is threaded on both ends and comes with a coupling on one end. It comes in sizes from 1/2 in. to 6 in. in diameter. Various fittings used

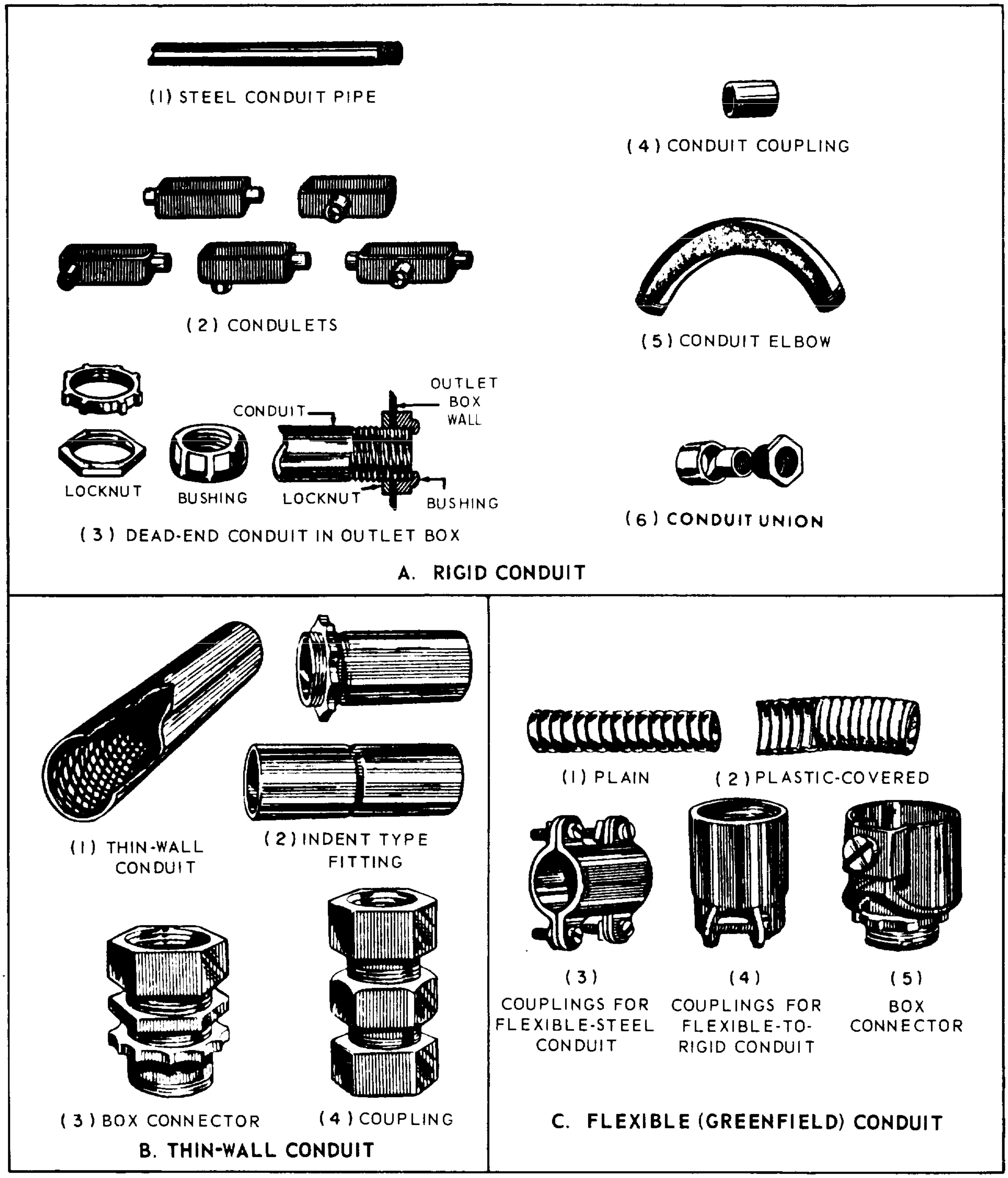

Figure 9-15.-Types of conduit and their associated fittings.

for connecting rigid metal conduit are shown in figure 9-15, view A. The use of rigid conduit involves a good deal of cutting, bending, and threading of lengths. An ordinary hacksaw or special wheel pipe cutter is used for cutting, while a ratchet type of mechanical die is used for thread-cutting conduit pipes. Bending of pipes can be undertaken both manually, using a bending tool commonly called a hickey, and hydraulically. A hydraulic bender is recommended for making smooth and accurate bends.

CONDULETS (fig. 9-15, view A (2)) are a convenient way of making bends, especially in conduit that will be exposed to the elements. They are heavily used on sharp corners and also to reduce the number of bends made in a run of conduit.

Another type of rigid conduit approved for use by NAVFAC is the polyvinyl chloride (PVC) pipe. This now popular plastic conduit is specially suitable for use in areas where corrosion of metal conduits has been a problem. Some of the advantages of PVC conduit are as follows: light handling weight, ease of installation, and leakproof joints. This conduit is primarily intended for underground wire and cable raceway use and is made in two forms. Type I is designed for concrete encasement, and Type II is designed for direct earth burial. Rigid plastic conduit and fittings are joined together by a solvent-type adhesive welding process. It also comes in sizes of 1/2 to 6 in. in diameter. PVC fittings are also available from the manufacturer. (For more information on PVC fittings, refer to Article 370 of the NEC®.)

THIN-WALL CONDUIT.— Electric metallic tubing (EMT) or thin-wall conduit, as it is better known, is a type of conduit with a wall thickness quite a bit less than the rigid conduit. It is made in sizes from 1/2 to 2 in. in diameter. Thin-wall conduit cannot be threaded; therefore, special types of fittings (fig. 9-15, view B) must be used for connecting pipe to pipe to boxes.

FLEXIBLE CONDUIT.— Flexible conduit (fig. 9-15, view C), also called Greenfield, is a spirally wrapped metal band wound upon itself and interlocking in such a manner as to provide a round cross section of high mechanical strength and flexibility. It is used where rigid conduit would not be feasible to install and requires no elbow fittings. It is made in sizes from 1/2 to 3 in. in diameter. Greenfield is available in two types: the plain or standard unfinished-metal type and a moisture-resistant type called sealtite, which has a plastic or latex jacket. The moisture-resistant type is not intended for general use but only for connecting motors or portable equipment in damp or wet locations and where flexibility of connections is desired.

Wire Connectors

Figure 9-16 shows various types of connectors that are used to join or splice conductors. The type used will depend on the type of installation and the wire size. Most connectors operate on the same principle, that of gripping or pressing the conductors together. WIRE NUTS are used extensively for connecting insulated single conductors installed inside of buildings.

Outlet Boxes

OUTLET BOXES bind together the elements of a conduit or cable system in a continuous

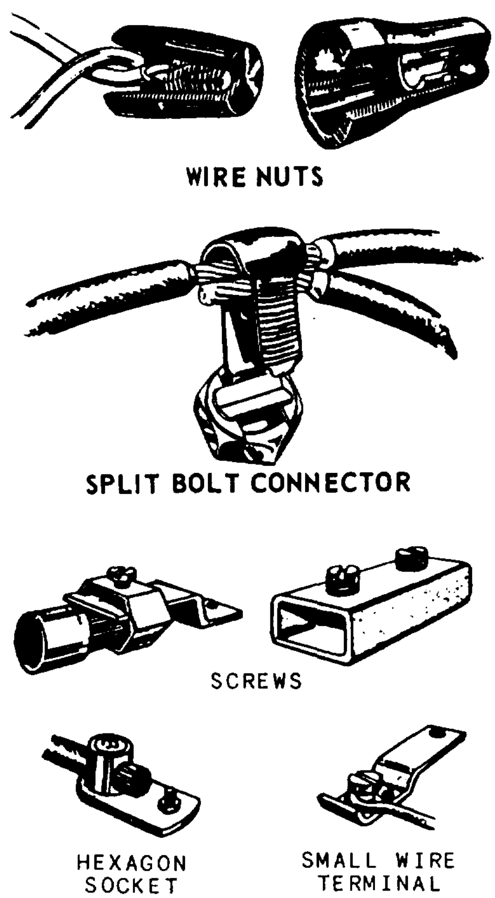

Figure 9-16.-Types of cable and wire connectors.

grounded system. They provide a means of holding the conduit in position, space for mounting such devices as switches and receptacles, protection for these devices, and space for making splices and connections. Outlet boxes used in Navy construction are usually made of galvanized steel; however, nonmetallic boxes, such as rigid plastic compounds, are being used for approved installation. Boxes are either round, octagonal, square, or rectangular in shape. Commonly used outlet boxes are shown in figure 9-17.

An outlet box is simply a metal container, set flush or nearly flush with the wall, floor, or ceiling, into which the outlet receptacle or switch will be inserted and fastened. Figure 9-17, view A, is a 4-in. octagon box used for ceiling outlets. This box is made with 1/2- or 3/4-in. KNOCKOUTS—indentations that can be knocked out to make holes for the admission of conductors and connectors. Figure 9-17, view B, shows a 4 11/16-in. square box used for heavy duty, such as for a range or dryer receptacle. It is made with knockouts up to 1 in. in diameter. Figure 9-17, view C, is a sectional or GEM BOX used for switches or receptacles. By loosening a screw, you can remove the side panel on the gem box so that two or more boxes can be GANGED (combined) to install more than one switch or receptacle at a location. Figure 9-17, view D, is a UTILITY BOX, called a handy box, made with 1/2- or 3/4-in. knockouts and used principally for open-type work. Figure 9-17, view E, is a 4-in. square box with 1/2- or 3/4-in. knockouts, used quite often for switch or receptacle installation. It is equipped with plastic rings having flanges of various depths so that the box may be set in plaster walls of various thicknesses.

Besides the boxes shown, there are special boxes for switches when more than two switches at one location are required. These are called CONDUIT GANG BOXES, and they are made to accommodate three, four, five, or six switches. Each size box has a cover to fit.

The NEC® requires that outlet boxes be 1 1/2 in. deep except when the use of a box of this depth will result in injury to the building structure or is impractical, in which case a box not less than 1/2 in. deep may be used. For switch boxes, the 2 1/2-in. depth is the most widely

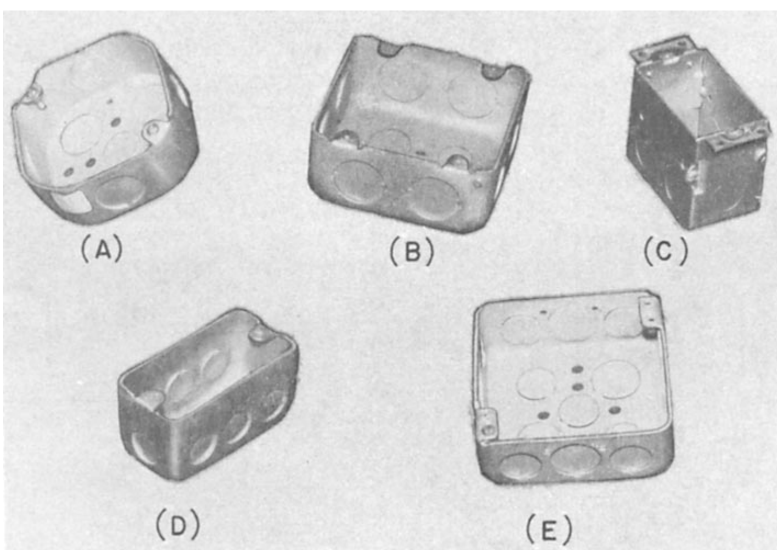

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Figure 9-17.-Types of outlet boxes.

used. The NEC® also requires that the outside edges of outlet and switch boxes without flush plates NOT be recessed more than 1/4 in. below the surface of the finished wall.

Receptacles

RECEPTACLES are used to plug in lights and appliances around the building. Some of the types of receptacle commonly used in interior wiring are discussed in the following paragraphs in the order of their frequency of use.

A CONVENIENCE OUTLET (fig. 9-18) is a duplex receptacle with two vertical or T-slots and a round contact for the ground. This ground is connected to the frame of the receptacle and is grounded to the box by way of screws that secure the receptacle to the box.

A RANGE RECEPTACLE (fig. 9-19) maybe either a surface type or a flush type. It has two slanted contacts and one vertical contact and is rated at 50 A. Receptacles for clothes dryers are similar but are rated at 30 A. Range and dryer receptacles are rated at 250 V and are used with three-wire, 115/230 V, two hot wires and a neutral. A receptacle for use with an air-conditioner taking 230 V is made with two horizontal slots and one round contact for the ground.

Also used in the Navy are strips that allow movement of the receptacle to any desired location. These strips are available in 3-ft and 6-ft lengths and may even be used around the entire room. This type of outlet is particularly desirable in rooms where portable equipment or fixtures,

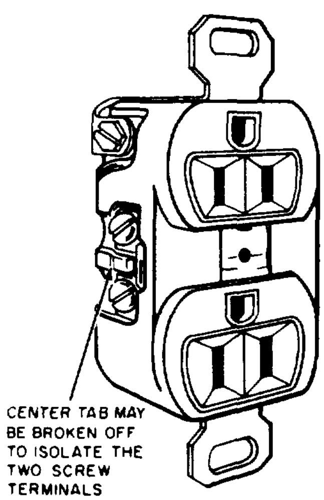

Figure 9-18.-A typical duplex convenience outlet.

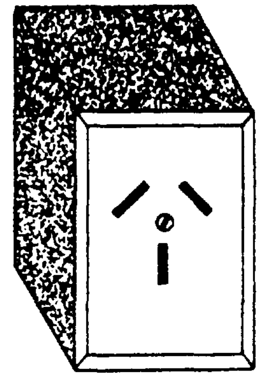

Figure 9-19.-Range receptacle.

such as drafting tables and audio-visual equipments, are used. Specialty outlets (weather-proof are used in all exterior locations because they resist weather damage.

Switches

For interior wiring, single-pole, three- or four-way toggle switches are used. Most of the switches will be single-pole, but occasionally a three-way system is installed, and on rare occasions, a four-way system.

A single-pole switch (fig. 9-20) is a one-blade, on-and-off switch that may be installed singly or in multiples of two or more in the same metal box.

In a three-way switch circuit (fig. 9-21), there are two positions, either of which may be used to turn a light ON or OFF. The typical situation is one in which one switch is at the head of a stairway and the other at the foot.

A four-way switch (fig. 9-22) is an extension of a three-way circuit by the addition of a four-way switch series.

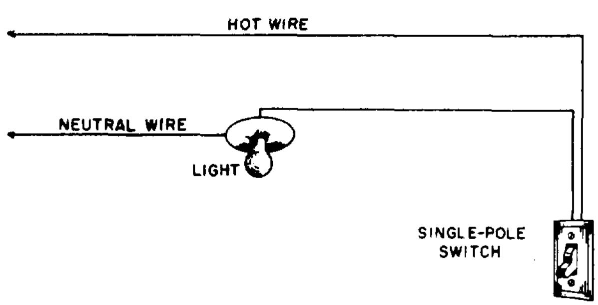

Figure 9-20.-Single-pole switch circuit.

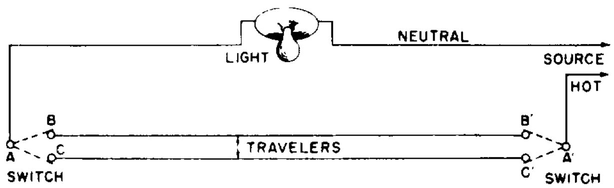

Figure 9-21.-Three-way switch circuit.

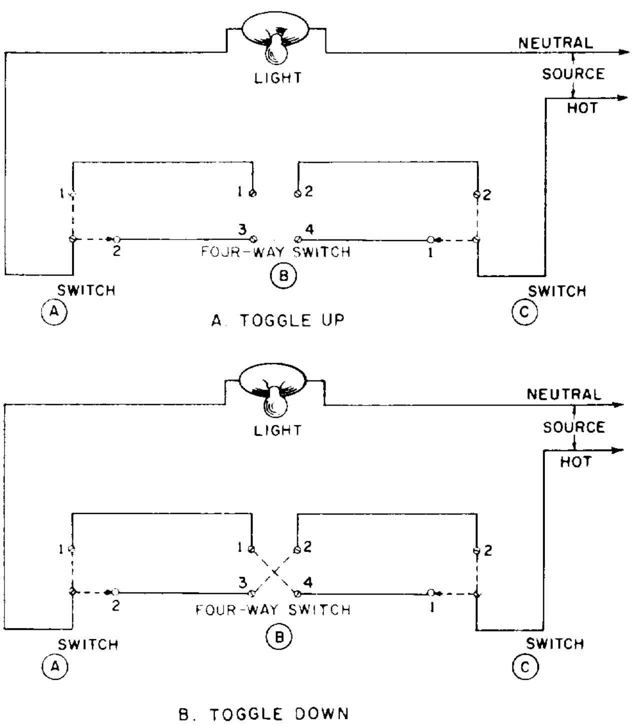

Figure 9-22.-Four-way switch circuit.

Note that three- and four-way switches can be used as single-pole switches, and four-way switches can be used as three-way switches. Some activities may install all small-wattage, four-way switches for all lighting circuits to reduce their inventories. However, three- and four-way switches are usually larger than single-pole switches and take up more box room. The size of a switch depends on its ampacity (related maximum amperage). The ampacity and maximum allowable voltage are stamped on the switch.

ELECTRICAL PLAN

The electrical information and layouts in construction drawings, just as the mechanical plan, are generally superimposed on the building plan and the plot plan.

In this chapter, we will address electrical plans as those drawings that pertain to the ELECTRICAL (POWER) DISTRIBUTION SYSTEM, which indicate outside power lines and appurtenances for multibuilding installations, and the INTERIOR ELECTRICAL WIRING SYSTEM.

As an EA3, the electrical layout for both light and power is your main concern. You will be required to draw electrical drawings and layouts from notes, sketches, and specifications provided by the designing engineer. Although you are not required to design the electrical wiring system, you must be familiar with the methods, the symbols, and the nomenclature, as well as the basic functions of the components associated with the electrical systems, its transmission and distribution, and the circuits hookup. In addition, you must also be familiar with the codes (both NEC® and local) and standards and specifications, and be able to apply that knowledge in drawing electrical plans.

STANDARDS AND SPECIFICATIONS REQUIREMENTS

Because the safety of the electrical system is of prime importance, it is imperative that all Navy electrical installations ashore conform to rigid standards and specifications. When preparing construction drawings, the EAs, like the CES, are required to follow the specifications issued by the Naval Facilities Engineering Command (NAVFACENGCOM). In particular, an EA working on electrical wiring and layout diagrams for electrical plans should refer to the latest edition of ANSI Y32.9 and ANSI Y14.15.

Codes

Code requirements and installation procedures offer protection for the consumer against unskilled electrical labor. Among other functions, the NEC® serves as a basis for limiting the type and wiring to be used, the circuit size, the outlet spacings, the conduit requirements, and the like. In addition, local codes are also used when separate electrical sections are applicable to the locale in which the building will be built. Be certain that you always have a copy of the latest edition of the NEC® available for your use.

Similarly, all of the types of electrical devices and fixtures included in the materials list prepared for electrical plans are to meet certain specifications and minimum requirements. An independent organization called Underwriters

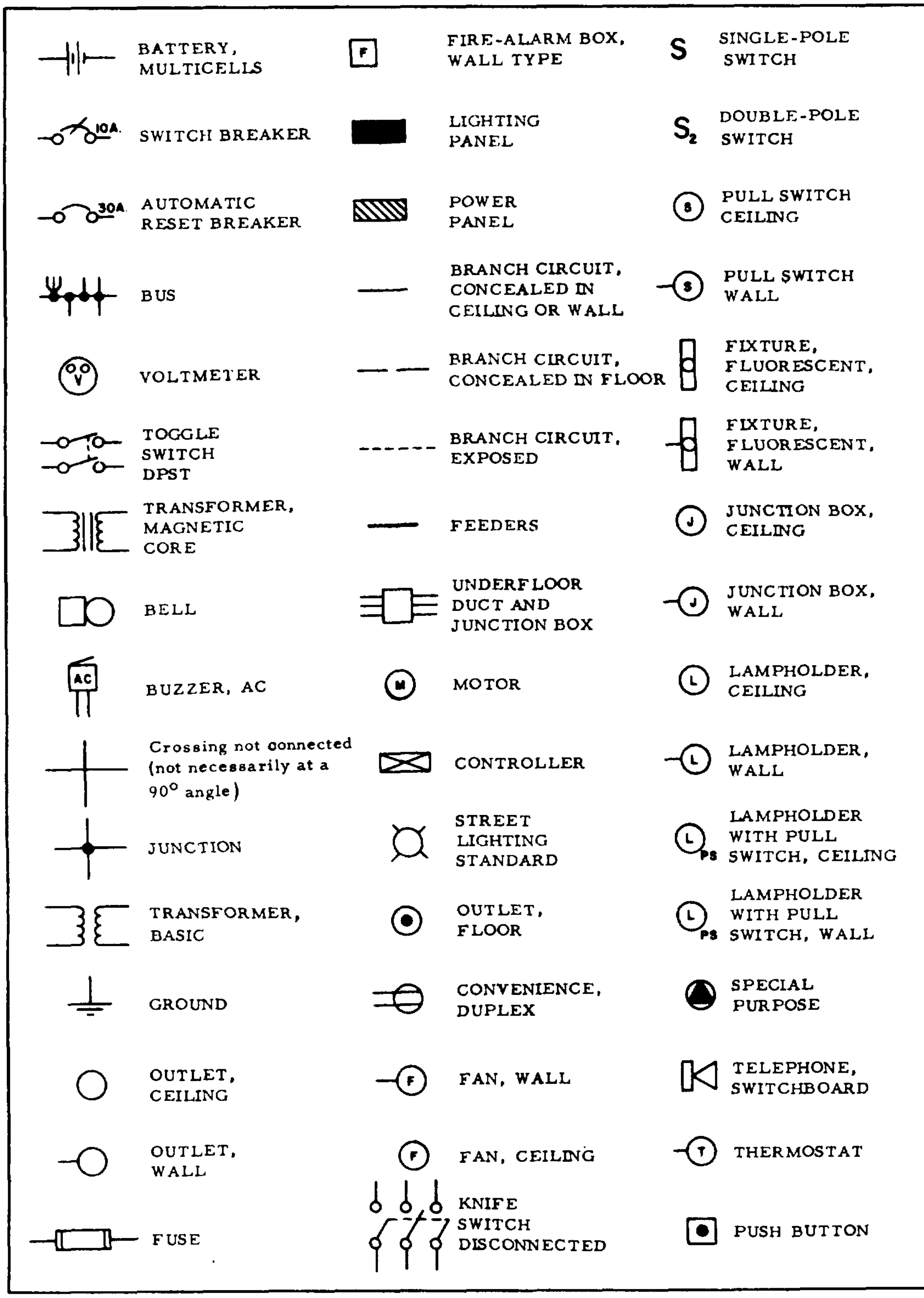

Figure 9-23.-Common types of electrical symbols.

Laboratories (UL) tests various electrical fixtures and devices to determine if they meet minimum specification and safety requirements as set up by UL. Those fixtures and devices that are approved may then bear UL labels.

Permit

In the SEABEEs, utility drawings (both mechanical and electrical) are thoroughly reviewed before an excavation (or digging) permit is granted and issued to the project subcontractor. Such action minimizes the hazards to personnel and underground structures during the construction process. All of the minor design changes and field adjustments must be noted and reflected on as-built and working drawings. Therefore, close coordination and cooperation must develop within and among all of the parties involved in the project to maintain periodic checks on red-lined prints so that information can be compared and verified as up to date.

ELECTRICAL SYMBOLS

The conventions used on the electrical plan are SYMBOLS that indicate the general layout, units, related equipment, fixtures and fittings, and routing and interconnection of various electrical wiring. The most common types of symbols used in electrical drawings are shown in figure 9-23. To see additional or special symbols, refer to the appendix section of this book and/or to ANSI Y32.9.

To draw in electrical symbols in an electrical drawing, as in drawing a mechanical plan, it is best to use templates. For example, a wiring symbol is generally drawn as a single line but with slanting "tick marks" to indicate the number of wires in an electrical circuit.

EXTERIOR ELECTRICAL LAYOUT (PLAN)

Exterior distribution lines (or network) deliver electrical power from the source (generating station or transmission substation) to various points of use. Figure 9-24 shows a typical layout, extracted from NAVFAC P-437, *Facilities Harming Guide,* of an exterior electrical network of buildings for a 100-man camp. This layout, in condensed form, shows a site plan of the camp area with facilities and the location of the electrical component system. Included in the electrical plan is a list of facilities (upper right-hand corner of fig. 9-24) that describes the corresponding item symbol, facility number, and quantity. An electrical load data table is also included in the drawing.

As an EA, you will be called upon to trace, modify, revise, and even review the workability of the drawing. It is therefore to your advantage not only to study and become familiar with the electrical plans, but also to gain a working knowledge of how the system works. NAVFAC P-437 offers a wide variety of plans, drawings, and applications for the Advanced Base Functional Component (ABFC) System for use in SEABEE construction.

INTERIOR ELECTRICAL LAYOUT (PLAN)

As we mentioned earlier, the electrical information on exterior electrical distribution is generally shown in the regular site or plot plan. The INTERIOR ELECTRICAL LAYOUT, however, is, for small buildings, drawn into a print made from the floor plan. On larger projects, additional separate drawing sheets are necessary to accommodate detailed information needed to meet construction requirements.

Figure 9-25 shows an electrical layout of a typical public works shop. Once again, note that the electrical information is superimposed on an outline taken from an architectural floor plan. In addition to the list of assemblies and electrical load table, a wiring diagram and panel schedule of a 225-A, three-phase circuit breaker is drawn. The underground service entrance (item 10 on the list of assemblies) delivers a four-wire, 120/208-V power into the building. Lighting circuits use a three-wire, No. 12 AWG (TW).

The following basic steps are suggested to guide you in the development of an interior electrical plan:

1. Show the location of the service panel and its rating in amps.
2. Show all of the wall and ceiling outlets.
3. Show all of the special-purpose outlets, such as telephones, communications, doorbells, and so forth.
4. Show all of the switches and their outlet connections.
5. Show convenience outlets.
6. If required, complete a schedule of electrical fixtures, symbols, legends, and notes necessary to clarify any special requirements in the drawing that are not stipulated in the specifications.

The steps suggested above can be put to practice in the next chapter following mastery of civil and architectural drawings.

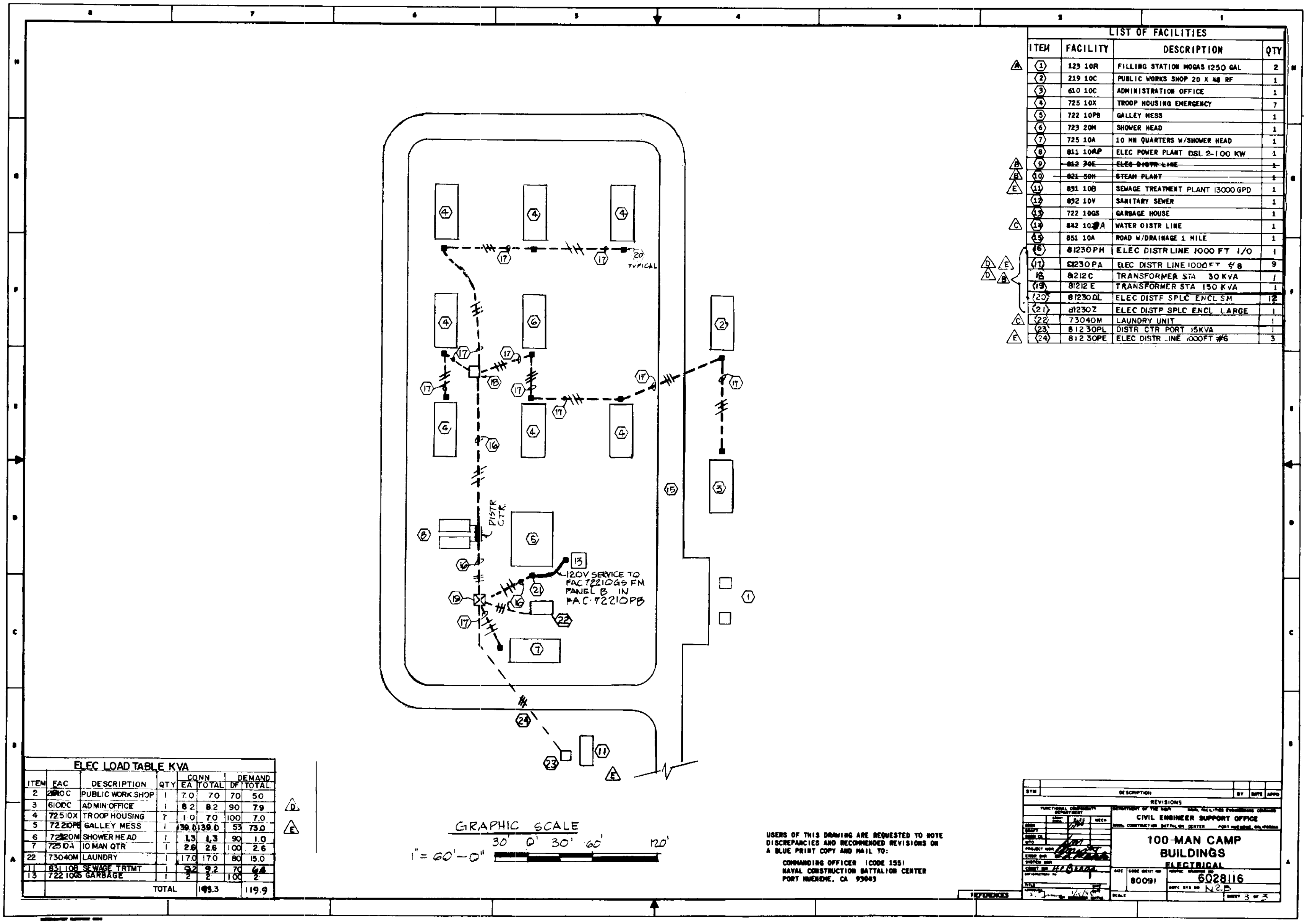

Figure 9-24.—Example of an exterior electrical plan.

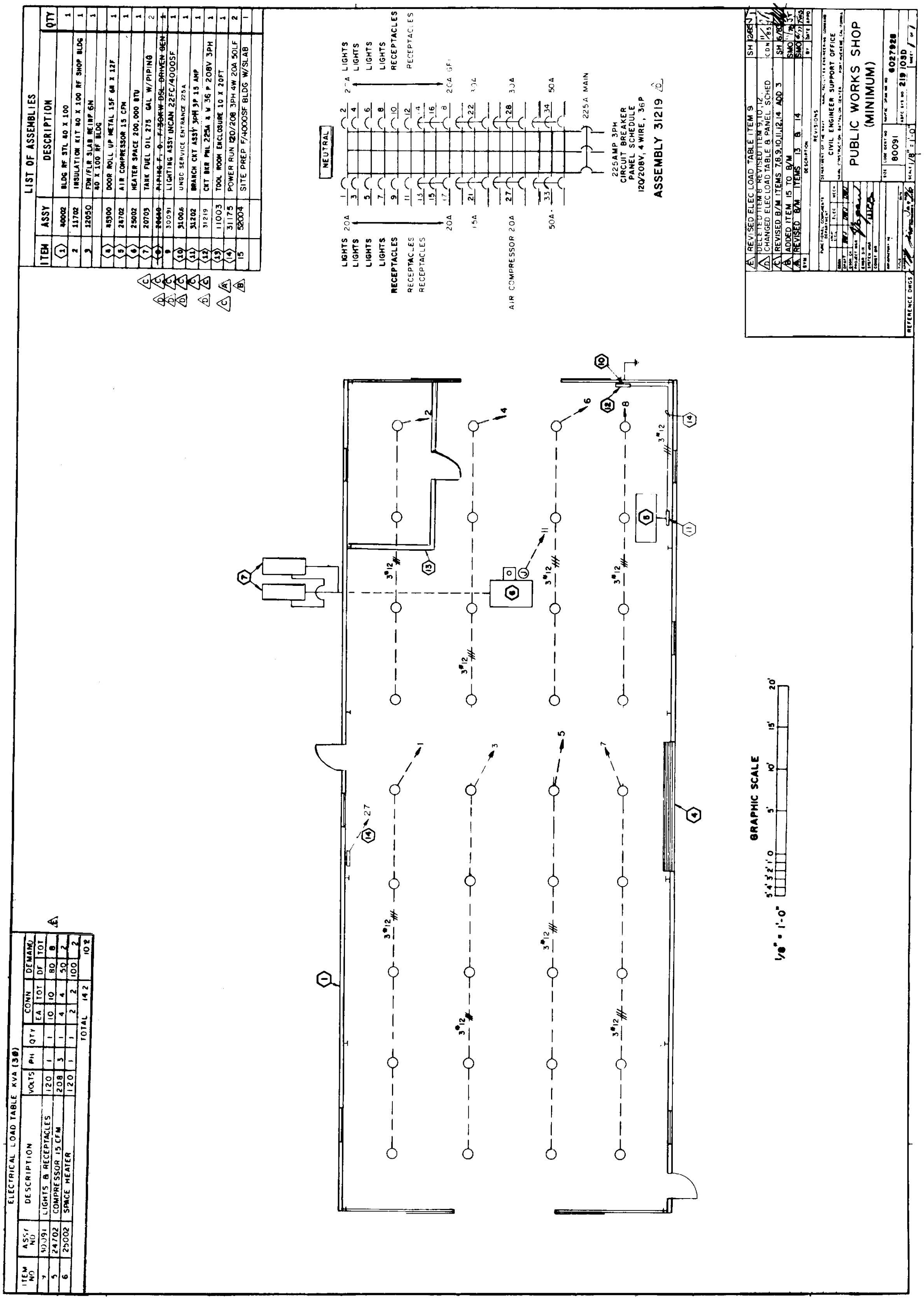

Figure 9-25.—Example of an interior electrical plan.