Plumbing Systems

This part of your program begins with a look at plumbing-system design. The design process starts with the most visible part of the system, the living spaces to which water must be delivered and from which wastewater must be carried. Much of the reading focuses on the bathroom, where most water consumption occurs. Fixture size and placement determine not only the appeal of the space but also its level of efficiency. You'll study minimum requirements for locating fixtures in typical installations as well as for those serving persons with physical disabilities.

The lesson next concentrates on the most challenging part of the plumbing design, the *drain, waste,* and *vent (DWV) system.* You'll learn to calculate the proper size for the drain piping serving various fixtures and decide where to locate the main stack(s) that connect fixture drains to the building's main drain. Equal attention goes into planning the vent system. Next, you'll learn how to ensure each fixture receives the required supply of water at an acceptable pressure. This includes a review of the effects of friction and height on supply pressure. You'll ultimately learn to size portions of the supply system to meet each fixture's expected usage level.

The second assignment describes the work schedule on a typical construction site by grouping a plumber's responsibilities into stages. You'll learn the significant effect fixture dimensions and specifications have on the early stages of plumbing installation. Similarly, your early work relies on knowing the thickness of the eventual wall and floor finishes. That's because the thickness of these surfaces affects fixture positions and, ultimately, the resulting pipe positioning.

Finally, the DWV-piping installation process is detailed in Assignment 3. This includes a description of pipe measuring and cutting methods. The textbook explains, with great detail, a typical bath installation from the building drain connection in the basement or crawl space to the stack penetration in the roof. You'll study main stack installation as well as horizontal branch plumbing. In addition to DWV piping, you'll learn how certain fixtures are installed at this stage of construction.

When you complete this lesson, you'll be able to

- Design plumbing systems that are easily serviced
- Plan plumbing systems to save materials
- Understand design modifications that accommodate the disabled
- Explain the steps involved in bringing water and sewer service into a building
- Contrast and compare three methods of pipe measurement between fittings
- Demonstrate techniques for working with plastic, copper, galvanized-iron, and cast-iron materials

ASSIGNMENT 1

Read this introduction to Assignment 1. Then, study Chapter 17, "Designing Plumbing Systems," in your textbook.

When building a new home or renovating an existing one, a homeowner often meets with a kitchen/bath designer to plan a new design. During this process, you can be reasonably sure they won't study piping diagrams along with tile samples and color chips. That's because the plumber's involvement in the design process usually begins after the homeowner, designer, or architect finalizes the layout. It's then the plumber's responsibility to carefully study the resulting plans for the bathroom, kitchen, or laundry room while designing a practical piping system. Your textbook explains this design process.

When it comes to plumbing systems, there's an important difference between what's possible and what's practical. For instance, assume a bathroom designer suggests moving a toilet to an opposing wall as a way to create a more appealing space in a remodeled bathroom. In his design, this change seems minimal as the homeowner also intends to replace the flooring and subflooring. However, after exposing the existing drain system, the plumber learns that extending the drain line to the new location means installing a drainage pipe running perpendicular to the floor joists. This hidden detail means that several floor joists must be significantly altered and that the toilet's new location requires an additional dedicated vent pipe running through the wall, attic space, and roof. The design initially appeared as a relatively small, practical modification to a bathroom. The designer and homeowner assumed it required the addition of a few extra feet of pipe joined to the existing drain system. After the plumber is involved, it's now clear that the change also requires the cost of cutting and reinforcing several floor joists and other framing members, installing the new vent along with an additional roof flange, and repairing the many wall surfaces that must be removed to install the vent pipe. While this proposed modification is *possible,* unless cost is of no importance to the homeowner, it's not a very *practical* design.

Starting the System Design

Designing the plumbing system for a newly constructed building typically offers the plumber more practical options than he or she encounters during renovation work. While designing the building, the architect considers the location of plumbing fixtures in relation to other rooms that require plumbing. Where possible, practical designs include positioning bathrooms over each other or back-to-back. Predicting and correcting DWV routing problems is relatively easy when designing the plumbing system for a structure that's not yet complete. However, don't be tricked into thinking that new-construction plumbing-system design offers no challenges. You should put the same effort into studying plans for a new home, for instance, as you would when approaching a remodeling job. Catching potential problems in the design phase eliminates cost overruns and project delays. Remember, even though several very skilled people are typically involved in the design phase of a particular project, it's the plumber who will ultimately transform their ideas into a properly working plumbing system.

Approach each plumbing system design by first considering the DWV piping. First, the material cost of this larger-diameter pipe (compared to supply pipe) is greater. The labor consumed while installing larger pipes is greater as well. Second, since water moves through the drain system only as a result of gravity, these pipes must be carefully sloped. This limits acceptable positions in a way that doesn't factor into the routing of the pressurized water-supply part of the system. Ultimately, your goal is to plan a drainage route incorporating the proper slope with the least number of turns. You'll then plan the supply-piping runs taking into account the DWV system's intended path.

Drain Design

Designing the DWV system begins with locating the stack. The *stack* is the vertical connection between the fixtures and the main building drain. An efficient design includes locating as many fixtures as possible around a single stack. Toilets require the largest branch piping. Therefore, locate toilets as close to a stack as possible. When it's impractical to locate all of the plumbing fixtures in the proximity of one drain stack, you'll need to plan for two or more stacks throughout the structure.

The potential drain-water volume produced by the fixtures it serves, determines the correct stack diameter. In fact, this sizing technique applies to all drain piping. You'll easily determine the proper diameter pipe needed to carry the wastewater by first assigning a *load factor* to each fixture the horizontal drain branch serves. Then add the load factors for all branches that connect to the stack and consult a codebook to determine the required stack pipe size. Horizontal drain branches and building drains are also sized by identifying and combining load factors for the fixtures they serve.

A plumbing fixture is typically manufactured with an outlet drain connection sized to a diameter that's suitable for the drain-flow volume it produces. For example, a shower base is manufactured with an outlet that accepts a 2-inch drain fitting, a toilet flange includes (at least) a 3-inch connection, and a kitchen sink basket strainer is sized to accept a $1^1/_2$-inch tailpiece. Fixture manufacturers developed this standardization after years of experience. It results in easy-to-follow guidelines for the minimum acceptable drainage-pipe diameter that can connect to most common plumbing fixtures.

Vent Design

With the drain and waste system planned, your design should next focus on the vent system. Often, the vent-system plan proves the most challenging part of plumbing design. It's best to begin your study of vent-system design by remembering the role played by the vent system and how a poor vent design affects the performance of both the drainage system and fixtures. Vents help eliminate the buildup of unhealthy gases in the drain system by providing an escape path outside the building and into the atmosphere. Vents also help drains to move water efficiently by allowing air to enter the drain system and replace the water moving out of it.

The vent-system component closest to each fixture is the *trap.* To the nonplumber, a fixture trap is an effective way to capture jewelry (and, less desirably, hair) that falls into the drain. In reality, fixture traps seal out unhealthy sewer gases present in the drain system. They do this by retaining a small amount of water in the trap's curved pipe. This part of the trap is always filled with water. When a fixture is used, the wastewater's pressure is more than sufficient to force its way through the trap. However, the last bit of wastewater remains in the trap, thus maintaining the seal.

A problem known as *siphonage* can draw the gas-sealing water out of the trap. Siphonage occurs when water moves through a full pipe, creates a vacuum, and pulls air behind it. To better understand this phenomenon, consider that a toilet actually operates based on a *controlled siphonage.* A toilet's trap is part of its design. On some traditional tank-type toilet models you can even see the familiar shape of a trap molded behind the bowl and under the tank. The siphon action begins by releasing enough water from the tank into the bowl. Provided the water enters the bowl quickly enough, it fills the diameter of the trap. The volume of water moving through the trap creates a vacuum, which empties the bowl of wastewater. The wastewater then moves through the toilet's trap and drain. As the bowl is emptied, the rush of water from the tank is stopped and a small amount of water slowly passes into the bowl to refill the trap.

You should now understand that when uncontrolled siphonage occurs in the drain system, water that's drawn from one or more traps isn't replaced. The design of DWV systems prevents uncontrolled siphonage by designating a minimum drainage-pipe diameter that's sufficiently large to prevent the pipe from completely filling with wastewater. By maintaining an air space in drainage pipes, a vacuum won't form and siphonage is unlikely to occur. However, this airspace alone won't completely ensure that all traps remain sealed since a vacuum forms even when a very short section of pipe fills completely with moving water. To ensure that traps remain sealed, the waste system also incorporates vents. Since a vent is open to the atmosphere, it allows air to move into the drain line anytime a vacuum is briefly created in the plumbing system. Therefore, when movement of wastewater generates a vacuum, air drawn through the drain system (rather than water) relieves it. This occurs because, as you learned in a previous lesson on hydraulics and pneumatics, air is easier to move than water.

Vent-system design is complex because there are so many acceptable design options. The actual vent-pipe installation is nearly identical to the process followed for drainage pipes. Keep in mind that each fixture that's served by a drain must also be served by a vent. Both drain and vent pipes slope. However, drains slope down while vent pipes must slope up.

A plumber could produce a perfectly functioning vented system by installing a separate vertical pipe through the roof for each fixture installed in the building. However, that would result in unnecessary protrusions in the roofing system and a waste of pipe. By extending the vertical waste stack pipe through the roof, this central feature of the drain system becomes a key part of the vent system. Many of the fixtures connected to the stack by branch drainage pipes can also be vented through the upper section of the main stack. However, their vent lines must connect to the main stack at a point above the point at which the building's highest drain branch connects to the stack. Some fixtures can share a branch to the main stack (known as *circuit vents* and *unit vents*) and some may even be able to use a segment of another fixture's drain route to serve as a vent route (considered a *wet vent*).

At times, when connecting a fixture's vent pipe to a main stack isn't possible or practical, it's necessary to add a separate vent through the roof for a single fixture.

Thoroughly understanding different acceptable venting methods and recognizing when each type is practical, allows you to design systems in which traps remain sealed, drains function efficiently, and installation time and materials are wisely consumed.

Water-Supply Piping Design

Compared to drain and vent piping, supply-pipe design is less complicated. Installing supply pipe of the correct diameter is the primary concern. Plan pipe routing with the least number of turns and fittings, keeping in mind that pressurized-supply systems don't rely on gravity and are therefore easier to route around obstacles. Of course, as you'll learn again in this reading assignment, some pressure loss occurs when supply water moves upward (such as to a second or third-story bathroom). You'll consider this height-dependent *head loss* and loss due to friction when designing the supply.

In this assignment, you'll learn the conventional method for sizing main supply pipes. If the plan calls for branch supplies running to several fixtures from the main supply pipe, make sure all fixtures receive the correct volume of water by increasing the diameter of the main supply. There are acceptable standard pipe diameters for common fixtures, however, there are times when plans require that a fixture function in an uncommon way. For instance, it's normal to supply a shower through a $^1/_2$-inch diameter pipe, but suppose a multihead shower is planned in a second-story bath. Following the standard sizing practice may leave the customer quite dissatisfied with the resulting low-volume water-flow experience. The same holds true with large tubs. Customers will be unhappy if required to wait 20 minutes for an oversized tub to fill each time they take a bath.

Other Design Considerations

A plumbing system may adequately supply water to all fixtures and remove wastewater through a properly functioning DWV system while still being poorly designed. Finish the design process by considering what *could* go wrong with the system.

All plumbing systems eventually need some type of service. This could stem from a clogged drain, a leaking pipe, a malfunctioning hot-water tank, or simply the customer's desire to upgrade a fixture. Locate cleanouts where problems might occur in the drain system. Install a sufficient number of supply line shutoff valves to simplify the service and replacement of fixtures. Eliminate the chances of cross contamination of the potable system by installing vacuum breakers and check valves. Fortunately, most modern fixtures are manufactured with built-in safeguards. Toilet fill valves and hose bibs include a vacuum break. Boiler fill valves include check valves. You would have a hard time buying a water heater today without a factory-installed pressure relief valve. Still, you need to adopt a "what if?" attitude with all of your plumbing designs. What if someone is walking past when that relief valve discharges in its current direction? What if the customer chooses a 12-inch rain head instead of using a standard showerhead? What if that one-piece shower enclosure won't fit through the hallway after the building is framed? What if the customer repeatedly wastes five gallons of water before it gets hot enough in the upstairs shower? What if someone in a wheelchair needs to use this bathroom?

The person who plans out and installs a well-working plumbing system accomplishes a great deal. Approach design work to accomplish more than simply haphazardly moving water into fixtures and wastewater out. While most of your efforts will be hidden inside wall and floor cavities, someday your work will be altered, repaired, or even replaced. Another plumber will see and judge your work. Plan your design so that it would be pleasing to uncover if you were that future person. Who knows, you might be.

After you've read Chapter 17 in the textbook carefully and completed the "Test Your Knowledge" on page 277 check your answers against those provided in the back of this study guide. When you're sure you completely understand the material from Assignment 1, move on to Assignment 2.

ASSIGNMENT 2

Read this introduction to Assignment 2. Then, study Chapter 18, "Preparing for Plumbing System Installation," in your textbook.

The completion of a new structure's plumbing system involves a lengthy process. Unlike most of the contractors who participate in the construction process, the plumber will be involved in the project from the excavation phase to the final finish. Plumbing installation is completed in phases and is carefully coordinated with the work of other tradespeople as construction progresses. City workers, utility companies, or specialized contractors normally install main water lines, wells, sewer mains, septic systems, and gas mains. Your work as a plumber usually begins with joining a structure to one or more of these already-installed utilities. This initial work is referred to as the *first rough.*

The plumbing phase known as the first rough includes installing the water supply's main branch and the building drain from the municipal supply and waste lines (often referred to as the *municipal mains*) or in the case of a private system, the well and septic locations. These connecting lines are installed underground and in compliance with local codes governing their depth and proximity to other underground utilities. Often, at this time the plumber prepares drain locations that will eventually be located below grade in the lowest floor of the structure. Stack connections and floor drains are also carefully located prior to pouring a structure's concrete slab or basement floor.

The second phase of plumbing installation occurs after the structure is framed and before any wall surfaces are installed. The *second rough* is the longest and most important part of the plumber's work. Now the plumber refers to the construction plans to determine fixture *rough-in dimensions* and precisely install the required piping to each location. Most of the fixtures won't be installed until the finish stage so finished wall and floor thickness must be taken into consideration when dimensioning the fixture locations. Exceptions include tubs and shower bases, two fixtures commonly installed during the second rough. The rough-in dimensions for tubs and shower bases are commonly specified from the framing members rather than finished wall surface. The reason is that finished wall surfaces are usually overlapped onto the flange of these already-installed fixtures.

Some fixtures that won't be installed until the finish stage demand extra attention during the rough-in phase. This attention includes adding *blocking,* extra wall-stud material that provides a strong mounting support into which fasteners can later be driven. Wall-hung lavatories, toilets, and urinals require blocking or brackets where they'll mount. Paper holders, towel bars, shower curtain rods, and especially grab bars also require the installation of blocking at the locations where they'll eventually be installed.

After locating and marking the locations to which the rough plumbing will be brought, you'll need to determine the structural alterations needed to make room for the piping. It's almost guaranteed that framing members will interfere with the intended piping path. Building codes dictate where and how much framing members can be drilled or notched without adding structural reinforcement. When reinforcement is required, the code identifies acceptable procedures. If you must alter a framing member to make room for a section of pipe, it's your responsibility to retain the integrity of the structure. You're also responsible to protect any piping that may later (especially during the wall-finishing stage) be pierced by fasteners. Building codes require that metal plates be installed in front of pipe locations positioned close enough to the framing edge to be punctured by standard-length drywall fasteners. This includes not only locations where plumbing passes through wall studs and floor joists, but also where it's routed through top and bottom plates. The main drain stack, for instance, would certainly require metal-plate protection at each floor's top and bottom plates.

As a final note regarding preparation, before you *fur out* (add furring strips to wall studs, making the wall thick enough to hide an enclosed drain pipe) an entire wall to make room for a stack, rethink all options. Will the cost of changing the stack material to copper (which may fit in a cavity that's too small for PVC) be less than the cost of altering the wall thickness? If you move a lavatory drain one inch to clear a stud, how will it affect the installed position of the fixture? Would using an offset toilet flange avoid a required (and time-consuming) modification to floor framing? In this final stage of planning, be sure your design makes the best possible use of your time and materials.

After you've read Chapter 18 in the textbook carefully and completed the "Test Your Knowledge" on page 295, check your answers against those provided in the back of this study guide. When you're sure you completely understand the material from Assignment 2, move on to Assignment 3.

ASSIGNMENT 3

Read this introduction to Assignment 3. Then, study Chapter 19, "DWV Pipe and Fitting Installation," in your textbook.

With the fixtures accurately located and proper pipe diameters chosen, you'll begin installing the DWV system. Pay careful attention to the part of your assignment describing the techniques employed in measuring, cutting, fitting, and supporting DWV piping. Some of this assignment is a review of previous lessons, and some will add more detailed information to what you've already learned. The majority of DWV piping installed today is plastic, so your textbook concentrates on installation methods used for plastic pipe. Most of what you'll learn about plastic-pipe installation also pertains to other pipe materials. The main differences are the methods used to cut and join different types of pipes.

Recall that your study of plumbing math stressed the need for precise measurements. Some plumbers might consider the precision required for DWV rough plumbing to be just that—rough. This line of reasoning would say that cutting a length of pipe one-half-inch short will still allow it to protrude far enough into the fitting sockets at each end to make a watertight joint. This might be true and (initially) the installation probably won't leak. However, one problem with lazy measuring is that the result leads to a reduction in long-term joint strength, as the pipe isn't inserted all the way into the mating sockets. A fully inserted glue joint is as strong or stronger than the pipe itself. Therefore, producing something less than a fully inserted joint leaves room for a major failure if the pipe is subjected to high physical loads. Also, fitting sockets are designed to make a smooth interior transition when the pipe is fully inserted. If a pipe isn't inserted all the way into the socket, a ledge is created inside the pipe. This ledge can cause debris to build up and may, over time, result in clogging. The same problems can occur if the plumber carelessly cuts plastic pipe at an angle (rather than square). Use a plastic-pipe cutter or miter box to produce squarely cut pipe ends that fully insert into fittings.

Plumbers employ one of three methods when measuring pipe length. In each case, the end goal is to determine the length of a pipe that will fill the space between two fittings so that the pipe is fully inserted into their sockets. The first method, known as *face-to-face,* requires measuring the distance between two in-place fittings and then adding a known distance representing the amount of pipe to be inserted into the fittings. You'll refer to that known insertion distance as *depth of engagement* or *fitting allowance.*

The second measurement method is called *center-to-center.* As the name implies, you measure from the centerline of one pipe run to the centerline of another, parallel run. The amount of room required by the installed fittings (excluding the socket depth), defined as a fittings' *laying length,* is then subtracted from the center-to-center measurement. The resulting distance represents the length of pipe you'll need to cut to join the two parallel pipe runs. Keep in mind that laying length is also a known dimension that differs not only by pipe diameter but also from one fitting type to another.

The third method of measuring is *shoulder-to-shoulder.* This method only applies to DWV fittings since fittings for pressure piping have no shoulders. The *shoulder* of a fitting is the interior (closest to the center of the fitting) line of the socket. This part of the fitting represents the internal limit against which the pipe can be pressed after it's inserted through the fitting's opening. As with face-to-face measuring, fittings must be in place prior to measuring a shoulder-to-shoulder distance. This method produces accurate pipe lengths without additional math.

You'll most often determine that DWV pipe length can be based on shoulder-to-shoulder measurements. However, there'll be times when the other methods are more handy. Consider a situation requiring the addition of a tee fitting to an existing pipe. In this case, you'll make room for the tee fitting by cutting the branch pipe twice. Knowing the laying length of the tee and removing a corresponding amount of branch pipe takes the guesswork out of this procedure. Perhaps you'll find a tight spot where the shoulder of one fitting isn't visibly accessible but your measuring rule will easily touch the fitting face. Adding the fitting allowance to this measurement is the most accurate way to find the required pipe length. The key to efficient measuring is to use what works. Don't restrict yourself to one method just because it seems easiest; that won't always be the case.

As you've already learned, an installed drain piping run must be sloped by a very specific amount. This makes its installation all the more challenging. Supply plumbing generally runs level and plumb, making it fairly easy to install. Remember that slope can be measured as an angle from the horizontal. Plumbers always position DWV piping relative to a horizontal position. A laser level is handy for the long runs of drainage pipe, passing through a building's basement, and connecting various stacks to the building drain. You might rig your bubble level with a block of wood on one end to represent the desired slope of a short pipe. In this case, you'll be using a level reference to produce a desired slope. There are level references all over a construction site. Mortar lines on a foundation wall and floor joists (the bottom edge of which are at the same height for all joists on the same floor) serve as great references when attempting to slope a pipe relative to horizontal.

When level or sloped piping runs perpendicular to framing, the framing members must be drilled or notched. Laying out a series of holes or notches in a straight, sloping line through several members is a challenging task requiring special attention. The diameter hole that normally suits a particular horizontal-running pipe won't work for the same pipe if it's sloped. Consider drilling a hole on an angle that approximately matches the downward slope of a drainage pipe. This produces a hole on the framing member's front side that's higher than the hole as it exits the same member. Of course hole saws and self-feeding auger bits are safely used when squarely positioned against the work surface. You may be able to angle the tool enough to produce a mildly sloping hole, but most plumbers elect to drill a hole that's one size larger than normal to provide additional room for the sloping pipe. Notching for a sloped pipe presents the same problems as drilling. However, angling the saw to cut the member on a line that's parallel to the sloping pipe is easier than using a hole saw at an angle.

Installing a stack though the roof creates the same problem as drilling framing members for a sloped pipe. While the problem is nonexistent or minimal with flat or low-sloped roofs, it's much more serious when working with steeper slopes. That's because increasing the diameter of a round hole enough to install the pipe can result in a grossly oversized hole that may affect the ability of the roof flashing to seal out leaks. Instead of drilling an oversized round hole, consider holding a short piece of pipe (the same diameter as the stack) in a vertical (plumb) position against the roof where the stack will emerge. Now trace a slightly larger hole around its outside circumference. You'll notice that the tracing is actually an *elliptical shape*. Use a reciprocating saw to remove the elliptical-shaped piece of roof surface. This is just one example of how plumbers should look for methods that accomplish the task at hand while minimizing the amount of structural alteration.

DWV pipe-support requirements have changed over the years. When cast iron was the material of choice for DWV plumbing, there was clearly a strong need for sturdy support. Plastic pipe, by contrast, is very lightweight. However, when planning and installing drainage pipe supports, don't forget to consider the weight of the water the pipe can hold. While the amount of contained water might be minimal in a normally functioning system, consider how much water the pipe could contain if something goes wrong. A clogged or frozen drain causes the pipe to quickly fill, adding a surprising amount of weight. Be sure to follow pipe-support requirements (which are defined in codes as well as your textbook) when installing all types of piping.

You should recognize a minor error in your textbook. The equation under Figure 19-25 indicates an “Engagement” of 2 $^{3}/_{4}$ inches. However, both the drawing *and* the final resulting pipe length reflect the correct total engagement of 1 $^{1}/_{2}$ inches.

After you’ve read pages 297–315 in the textbook carefully and completed the “Test Your Knowledge” on page 322 check your answers against those provided in the back of this study guide. When you’re sure that you understand the material from this lesson, complete the Lesson 1 Examination.