Plumbing

Inlet

Slip Joint

Outlet

Water Seal 2"—4"

Cleanout

Council Note G5.0
Building Research Council
School of Architecture
University of Illinois at Urbana-Champaign
How does water get to your fixtures and where does the waste go? This circular will explain the water supply and drainage/waste/vent systems.

**BASIC SYSTEM**

Residential plumbing installations usually consist of three systems: 1) a water supply system; 2) fixtures at which water is used; and 3) a drainage and vent system to carry away the wastes.

The **water supply system** is always filled with water at greater-than-atmospheric pressure. Once inside the building from the water main, the supply system branches into a cold water supply tree and another part which goes through the water heater and becomes a hot water supply tree.

**Fixtures** fulfill the basic purpose of plumbing systems—to provide clean water and dispose of wastes. They also ensure that the water supply remains clean by providing a physical separation between the supply and drainage piping.

The **drainage system** consists of waste, soil, and vent piping. **Waste pipes** carry water-diluted waste products; **soil pipes** carry fecal matter and wastes; **vent pipes** connect the drainage system to the atmosphere and allow gases to escape.

Movement of liquids and solids through the drainage system is by gravity. In addition to the occasional waste flow, the drainage system contains air and sewer gases. To prevent these foul-smelling gases from entering the building, a **trap** is installed at each fixture. A trap is a length of drain pipe which is shaped in such a way that it does not drain completely. After each use of the fixture, the trap retains enough water to fill the drain pipe at that point. The trapped water serves as a seal to contain the gases within the drainage system.

Occasionally, the pressure developed in front of a column of water falling through a drain pipe may be enough to blow the water seal (and the sewer gases) through the trap and into the building. Likewise, the pressure behind a falling column of water can be low enough to suck the water from a trap into the drainage system.

To prevent either of these things from happening, a second set of openings is added to the drainage system. These openings form the venting system, which connects the drainage system to the outdoors. The venting system maintains atmospheric pressure in the drainage system, which helps the wastes to flow properly and protects the water seal in the traps.

**PLUMBING CODES**

The design of plumbing systems is generally governed by a local or statewide plumbing code. Most of these have been based on one of the model plumbing codes published by the major model code associations.

*These are:*

- **Basic Plumbing Code**, by the Building Officials and Code Administrators International (BOCA);
- **Uniform Plumbing Code**, by the International Conference of Building Officials (ICBO); and

Other privately published plumbing codes include the National Plumbing Code of the American Society of Mechanical Engineers and the **National Standard Plumbing Code of the National Association of Plumbing-Heating-Cooling Contractors**.
SUPPLY SYSTEM

The water supply system should be designed for efficient use of materials, ease of construction, protection from freezing, and ease of maintenance and repair. A basic principle is that all piping runs be short, straight, and direct, with as few fittings as possible.

In planning the house, an effort should be made to locate rooms that will contain plumbing fixtures as close as possible to the point where the water service enters the house and where the sewer line leaves the house. If possible, rooms that contain plumbing fixtures should be grouped so that the fixtures in more than one room can share the same wall containing piping. This can be done by arranging rooms so that the fixtures in two or more rooms are placed back-to-back against the same wall or are located above one another on different floors.

Walls containing vertical piping are known as chase walls, wet walls, or plumbing walls. They are usually thicker than typical interior walls. In most houses, the plumbing wall will be built with 2 x 6 studs rather than the typical 2 x 4s. In some cases, a double wall, each side framed with 2 x 4s, will be used.

Jogs and offsets in plumbing walls containing horizontal lines should be avoided. Fixtures in any one room should be arranged so that all of their supply, drain, and vent lines fall within one wall.

This makes installation easier, uses less material, and simplifies the framing of the house. The water heater should be located as near to the fixtures using hot water as possible.

To reduce the possibility of problems with pipes freezing, water supply lines should not be located in exterior walls of the house. If this location is unavoidable, the pipes should be run against the inside face of the wall with as much insulation as possible separating them from the cold side of the wall. No insulation should be installed on the warm side of the pipes.

Freezeproof valves should be provided for outdoor sill cocks. Drain valves should be used to provide seasonal drainage of outdoor piping, and the pipes must be carefully sloped so that they will drain properly.

The location of the drainage and vent systems must also be considered when planning the supply piping and fixture locations. The plumbing wall should not fall in the same plane as a roof truss or floor joist. If it does, the plumbing systems will have to be elbowed around the structural members, or the structural members will have to be cut and consequently weakened.

If major framing elements run perpendicular to the plumbing wall, care should be taken that the fixtures requiring below-floor drains are located so that the
drains do not conflict with the floor framing. Joists should not be notched in the middle third of the span, and holes in them should not be larger than one third the depth of the joist.

Accessibility for installation and repairs should also be considered. A crawl space must be at least 24" and preferably 36" deep. An access panel into the bathroom plumbing wall just behind the tub greatly simplifies typical repairs to the drain plug mechanism, faucet, and shower diverter.

Placement of the bathroom fixtures within the room should consider easy access for use and for cleaning. For suggested clearances, see Council Note C5.7, Bathroom Planning Standards.

Supply Pipe Sizing

The pipes should be sized to provide adequate pressure and flow at each fixture. For one- and two-family houses of average size, experience has shown that a 1" house main, 3/4" house service and supply riser, and 1/2" pipes to individual fixtures will provide adequate service. Larger sizes may be needed for special uses, such as swimming pools.

<table>
<thead>
<tr>
<th>Fixture</th>
<th>Supply Size, in. 1</th>
<th>Drain/Trap Size, in.</th>
<th>Vent Size, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>House Main</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>House Service</td>
<td>3/4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Supply Riser</td>
<td>3/4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>House Sewer</td>
<td>-</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>House Drain</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Soil Stack</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Branch Drain/Vent</td>
<td>-</td>
<td>1-1/2</td>
<td>1-1/4</td>
</tr>
<tr>
<td>Water Closet</td>
<td>1/2</td>
<td>3-1/2</td>
<td>2</td>
</tr>
<tr>
<td>Bathtub</td>
<td>1/2</td>
<td>1-1/2</td>
<td>1-1/4</td>
</tr>
<tr>
<td>Lavatory</td>
<td>1/2</td>
<td>1-1/4</td>
<td>2-1/4</td>
</tr>
<tr>
<td>Kitchen Sink</td>
<td>1/2</td>
<td>1-1/2</td>
<td>1-1/4</td>
</tr>
<tr>
<td>Laundry Tray</td>
<td>1/2</td>
<td>1-1/2</td>
<td>1-1/4</td>
</tr>
<tr>
<td>Clothes Washer</td>
<td>1/2</td>
<td>2</td>
<td>1-1/4</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>1/2</td>
<td>1-1/2</td>
<td>1-1/4</td>
</tr>
<tr>
<td>Shower Stall</td>
<td>1/2</td>
<td>2</td>
<td>1-1/4</td>
</tr>
</tbody>
</table>

1. For one- and two-family dwellings of average size.
2. All supply pipe sizes except main and service are for either hot or cold.

Supply Pipe Materials

Two major factors are used to make the choice of piping material for a specific job: 1) the characteristics of the local water supply—its acidity and its air, carbon dioxide, and mineral content; and 2) original cost and ease of installation and repair.

Galvanized Steel. The galvanizing process deposits a thin coating of zinc on the surface of a steel pipe, which protects it against corrosion. The advantage of galvanized steel pipe is its low cost and high strength. It is resistant to high pressures and water hammer. The major disadvantage is that the joints are typically threaded. The threads are coated with pipe joint compound or wound with plastic joint tape before assembly to prevent leaks. The initial installation is laborious, and the need to thread new joints in place makes later connections to existing systems difficult.

Another disadvantage is its tendency to corrode or form scale on the pipe interior. Galvanized pipes are best where the water is moderately hard and alkaline. Water that is naturally soft should be treated with a silicate corrosion inhibitor and with caustic soda or lime to make it alkaline. Very hard water should be softened to control scaling. Corrosion or scaling can effectively reduce the inside diameter of the pipe, greatly reducing its carrying capacity and decreasing the water pressure. Galvanized steel pipe should not be in contact with concrete.

Copper. Although it is more costly than galvanized steel, copper pipe is easy to work and join. It is sufficiently corrosion-resistant for use with most water supplies. Water that is very soft, very hard, or very high in carbon dioxide should be treated before entering a copper plumbing system. While the piping is durable, the joints are weaker than the pipe and are subject to damage from water hammer. Air chambers should be installed at the ends of supply lines to cushion sudden flow stoppages.

Rigid copper pipe is hard-tempered and is generally connected using copper fittings sealed with tin-lead solder. Rigid copper pipe comes in three wall thicknesses: type K (thick); type L (medium); and type M (thin). All have the same outside diameter and the same nominal size. Rigid copper comes in 10' and 20' lengths.

Flexible copper tubing has several advantages over rigid copper pipe. It is easier to install, especially in cramped areas. It can be bent into smooth turns, which reduces both friction in the system
and the number of fittings required. It can withstand several freezing cycles without cracking, although with each freeze the pipe expands and the pipe wall becomes thinner.

Flexible copper tubing offers more types of connection. In addition to soldered fittings, which require heat, flared and compression fittings can be used. A flared fitting is made by slipping a flare nut over the end of the tube, reforming the tube so that it has a flared tip, then screwing the flare nut onto a tapered threaded fitting. A compression fitting is similar except the nut bears against a brass ferrule as it is screwed onto the fitting instead of against the flared end of the tube. A push-in connector is now available, consisting of stainless steel retainers and a neoprene sealing ring mounted in a nylon body.

Flexible tubing is available in 30', 60' and 100' coils of type K or type L. Type K is usually used underground, and type L indoors.

**Plastics.** Plastic piping is relatively new and is accepted by most plumbing codes. Plastic pipe weighs only about 1/20th as much as steel pipe, is easily joined, is non-corroding, and has low internal friction. Joints are typically made using solvent and plastic fittings. Although these joints are easy to make, the solvent acts quickly, and the joint is permanent. The only way to correct mistakes is to saw the joint out and start over. The corrosion resistance of plastic allows it to remain smooth inside, which maintains the carrying capacity of the pipe as the system ages.

Plastic is a much better insulator than metal pipe. Therefore, hot water lines do not cool as fast, and condensation is less likely to form on cold water lines. Plastic expands and contracts much more with temperature changes, so it is necessary to support it at closer intervals than metal pipe to prevent sagging. For the same reason, plastic pipe is snaked when it is laid underground. The maximum operating temperature for plastic pipe ranges from 120 to 300°F, depending on the type of plastic.

Plastic piping generally should be kept away from high temperature areas, such as heat ducts. Unlike metal piping, it is not an electrical conductor. This prevents corrosion, but means the cold water pipe cannot be used as a ground for the building electrical system or equipment requiring a ground connection.

Depending on type, plastic pipe varies in its degree of flammability. Plastics weather differently than metal; instead of corroding or oxidizing, they chemically degrade when exposed to ultraviolet radiation and become brittle. This can be avoided by using plastics made with ultraviolet stabilizers.

**There are four types of plastic supply piping commonly used in houses:**

- polyethylene (PE);
- polyvinyl chloride (PVC);
- chlorinated polyvinyl chloride (CPVC); and
- polybutylene (PB).

All four can be used for cold water, but only the latter two should be used for hot water.

Polyethylene pipe (PE) is commonly used for the cold water supply from the main or well to the house. It has a lower working temperature than most plastics, from -67° to 112°F. It comes in Types I, II, and III, in order of increasing density. Joints are made using tapered, serrated inserts of polystyrene or galvanized steel that slip into the ends of the pipe, which is compressed against the insert by a metal hose clamp.

Polyvinyl chloride (PVC) is the most common plastic used for cold water supply lines within the house. Joints in PVC pipe can be either solvent welded or made with threaded fittings, which are commonly available in heavier weights of pipe. PVC pipe is made in two types. Type I is unplasticized and has a maximum working temperature of 150°F. Type II is plasticized by the addition of rubber, which makes it less brittle than Type I but reduces its strength and working temperature.

Chlorinated polyvinyl chloride (CPVC) is the most common plastic pipe for hot water lines. It can be used with water temperatures up to 212°F, although the water heater relief valve should be set no higher than 180°F. Support clamps should be provided on horizontal runs.
Plumbing

An air gap prevents the back-siphoning of waste water if the pressure drops in the supply.

Polybutylene (PB) pipe is suitable for either hot or cold water. It is so flexible that most bends can be made without fittings. It can be obtained in a high-temperature grade for use up to 221°F. PB pipe is similar to Type III PE, but is stronger. Freezing will not burst it, and it is flexible enough to absorb water hammer. As with PE, joints are made using a tapered insert and an external clamp, usually a copper ring clinched with a special tool.

DRAIN/WASTE/VENT SYSTEM

The drainage system is often referred to as the drain, waste, and vent (DWV) system. It is larger and more complex than the water supply system. Its installation is more critical because the pipes are larger and must be installed at a slope sufficient to allow gravity drainage.

System Layout

The three major parts of the DWV system are the drain lines (waste and soil pipes), traps, and vents. All are interconnected. In fact, a given pipe may serve as a drain in part of its length and as a vent in the remainder, or as both a drain and a vent at the same time at the same location.

At the center of the DWV system is one or more vertical drain/vent pipes. They are usually near the water closets, since they require the largest drains and shortest horizontal runs. A typical drain/vent pipe will have one or more connections to water closet drains, plus branch drains serving several fixtures each. Branch vents serving those same water closets and other fixtures also connect to the drain/vent pipe at points higher than the branch drain connections. Thus, the lower portion of this vertical pipe serves as a main drain (soil stack), which leads to the building drain and eventually to the sewer. The upper portion serves as the main vent (stack vent), which leads through the roof to the outdoors, providing a source of atmospheric pressure.

The branch vents and branch drains are in turn fed by fixture drains. These include the traps, which prevent sewer gases from entering the building through the fixture drains.

Drain Piping. The routing of drain pipes can cause serious problems during...
construction unless it is carefully considered during the design process. Because the system drains by gravity, all horizontal pipe runs must be sloped downward in order for water to flow. This restricts the length of horizontal runs which can be used before the sloping pipe crosses a structural member or exceeds the depth of the space in which it is concealed.

A horizontal pipe should slope at least 1/4" per foot of run if it is 3" or less in diameter, or at least 1/8" per foot of run for larger pipes. The pipe must be properly supported to maintain the slope. Drains laid underground should be on undisturbed earth or concrete to avoid settlement.

Turns and fittings should be minimized. Ideally, the flow should move in one direction. If turns are necessary, sweeping bends are preferred to sharp turns. Fittings for drain systems are different from those for supply systems. Therefore, the fitting name is preceded by the name “drain,” as in drain bend and drain wye.

**Traps**. Each fixture requires its own trap. Most fixture traps are shaped like the letter “P” and are called P-traps. These are used on kitchen sinks, lavatories, and laundry trays. A drum trap is usually used for the bathtub because it is easier to clean, and bathtub drains are frequently clogged with dirt and hair. Drum traps are generally 3" to 4" in diameter and have a removable top for easy access. The drain line from the tub enters the lower portion of the drum, and the drain line to the rest of the system leaves it 2" to 4" higher maintaining a water seal. Water closets have a trap built into their internal structure.

There are five ways in which a trap can lose the water seal:

- by suction (back-siphonage) in the drain system;
- back-pressure from a slug of sewage passing through the system may force the water seal up into the fixture;
- in rarely used drains, such as floor drains, the seal may be lost by evaporation of the water;
- the seal can be lost by capillary action of an object stuck in the trap, such as a piece of cloth; and
- outdoor wind conditions can create positive or negative pressures within the DWV system that can either push or suck the water out of the trap (the latter is more likely to occur).

While freezing is a greater problem in the supply system, the water seal in a trap can also freeze, causing cracks in the pipes or joints, and later leaks. If a building is to be left unheated during freezing weather, each trap must be individually drained or antifreeze added to the water in the trap.

Cleanouts are fittings that provide access to the drainage system for the removal of blockages caused by hair, grease, lint, or other solids. They usually consist of a 45° drain wye fitting, the same diameter as the drain pipe, with a removable plug. When the plug is removed, a cleaning tool can be inserted to remove the blockage. Cleanouts should be located at the base of each soil stack and where the drain leaves the building. A cleanout also should be provided at each change of direction of more than 45°, and every 50' in pipes 4" or smaller or every 100' in larger pipes.

**Vent Piping**. The vent piping consists of the upper half of the fixture branches, a vent stack where these join, and the upper portion (stack vent) of the soil stack. It usually is the same size and material as the lower components, which serve as drains. The larger the diameter of the drain pipe, the farther the vent can be located from the trap and still protect the water seal.

In one-story buildings, or the top floor of multistory structures, where the fixtures are located close to a soil stack, stack venting may be permitted by some codes. In this case, the drain pipe is sized large enough and is short enough that it is never entirely filled with water. Therefore, there is always an air space above the water flow, which acts as a vent.

In those situations where it is inconvenient to run a vent from a fixture, such as a kitchen sink in an island, wet venting can be used. In wet venting, the fixture drain is oversized and used as a vent as well as a drain. Wet venting should not be used for water closets.
DWV Pipe Sizing

Adequate pipe sizes are needed for the drainage system to work properly. The recommended drain and vent sizes for different parts of the system are given in the table on page four. Reducing the size or slope of the drainage pipes to fit the space available may result in inefficient and noisy systems.

DWV Pipe Materials

The most common materials for drainage systems are plastic, cast iron, and galvanized wrought iron or steel. Brass and lead are sometimes used, but they are usually too costly for residential construction.

Plastics. Two types of plastic pipe suitable for drainage systems are polyvinyl chloride (PVC) and acrylonitrile-butadiene-styrene (ABS). PVC pipe used in drainage systems is of the same formulation as that used in water supply systems, but has thicker walls.

ABS pipe has an operating temperature range of -40°F to 180°F. It can be obtained with solid walls or with foam-cored walls, the latter being cheaper. ABS pipe can be solvent welded with or without a primer, or it can be obtained with threaded fittings.

Plastic drain piping has several advantages. Some manufacturers produce a 3" drain pipe with joints compact enough to fit within a standard 2 x 4 stud wall. This may eliminate the need for special framing for plumbing walls. The light weight of plastic pipe means less load on the structure. Since plastic is a better thermal insulator than metal, hot liquids with suspended grease (dishwater) are less likely to be cooled to the point of depositing the grease, which clogs the pipes.

Disadvantages include its vulnerability to puncture, to damage by rodents, and to some industrial chemicals.

Building and plumbing codes vary in their attitude toward plastic drain piping, but it is accepted by most. Local codes should always be consulted during the early stages of the design of the plumbing system.

Cast Iron. This is the traditional material for drain piping. It is heavy, durable, and serviceable underground or in concrete. Older installations have bell-and-spigot or hub-and-spigot joints. Pipe sections are cast so that one end flares out into a hub or bell, which fits over the straight end, or spigot, of the next section. The gap between the bell and spigot is packed with oakum or tow hemp and caulked with molten lead. The flow should always be from spigot to bell.

The introduction of hubless joints and fittings for cast iron pipe has made it possible to run a 3' cast iron drain line within a 2 x 4 stud wall. Hubless joints consist of a neoprene rubber sleeve gasket that fits over the joint, a stainless steel jacket that fits over the gasket, and worm-drive clamps that compress the jacket and gasket against the pipe. Support must be provided at the joints and at 4' intervals along the pipe.

Galvanized Steel or Wrought Iron. This pipe is used in DWV systems essentially the same way it is used in water supply systems. Threaded joints and fittings are typical but must be of the drain type. Where galvanized pipe connects to cast iron, it is generally fitted into a bell and leaded.