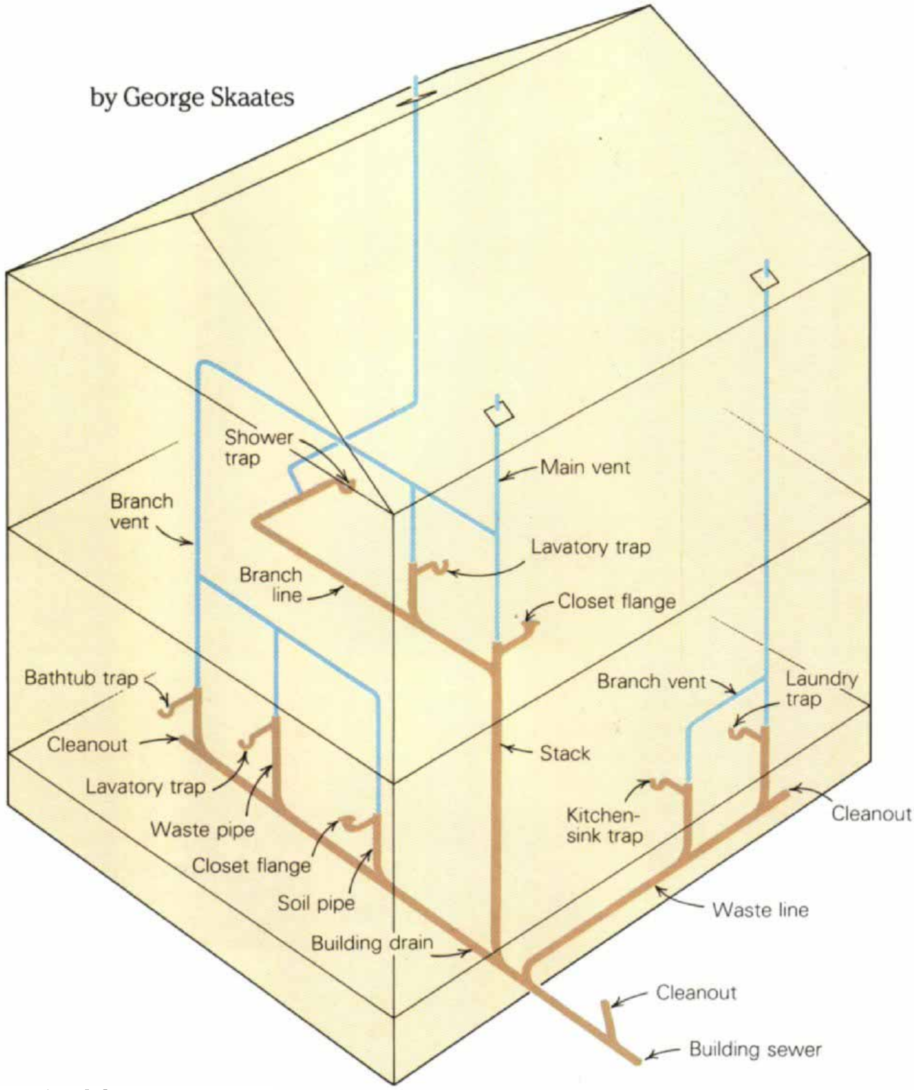
Drainage Systems

On sizing, laying out and choosing the right fittings for a residential waste system

by George Skaates



A residential waste system

The typical residential drainage system is a network of pipes that convey waterborne household wastes from fixtures such as sinks and toilets to the building drain and out to the building sewer. Each fixture is connected to a vent pipe, which equalizes the pressure in a drain line as water passes through it. In the drawings, vent pipes are blue; waste and soil lines are brown.

A residential drainage system is analogous to a watershed. Each fixture in the house, whether it's a lavatory, laundry sink or shower, is like a small creek that drains into a larger stream. These larger tributaries eventually merge with the building's drain, which conveys the household waste to the site's septic system or to the city sewer lines.

This article is about the procedures I use to size and lay out a residential drainage system. In the San Francisco Bay Area, where I do most of my work, plumbers and inspectors follow the guidelines set forth in the 1982 edition of the Uniform Plumbing Code ($28.95 from the International Association of Plumbing and Mechanical Officials, 5032 Alhambra Ave, Los Angeles, Calif. 90032). This code is widely respected within the plumbing industry, and the principles and definitions it lists are reflected in this article.

Drainage-system components—Any discussion of a drainage system has to start with a few definitions so we all know what we're talking about. Let's begin just outside the building's foundation, at the building sewer (drawing, right). The building sewer is a horizontal drain line that connects the ***building drain*** (photo right) with the sewage-disposal system—usually a public sewer line or a private septic tank. The code book defines ***horizontal*** as a piece of pipe that makes an angle of not more than 45° with the horizon.

The building drain extends 2 ft. outside the building's foundation. It is the lowest drainpipe in the building, and it receives the discharge from all the ***soil pipes*** and ***waste pipes*** within the structure. A waste pipe carries wastes that are free of fecal matter, while a soil pipe carries the discharge from toilets and urinals. A soil pipe may also carry waste from other fixtures.

A ***branch line*** is any drainpipe other than a stack feeding into the building drain—a ***stack*** is a primary ***vertical*** drain line. Vertical means that the pipe makes an angle less than 45° with the vertical, but a vertical pipe is usually as plumb as possible. An ***offset stack*** has to be bent to get around some obstacle. If you can bend it at 45° or less, the unit sizing is not affected.

Every fixture in a building has a ***trap***. The trap is the U-shaped pipe that separates the fixture drain from the ***trap arm***. The trap is always filled with water, which keeps sewer gases from in-

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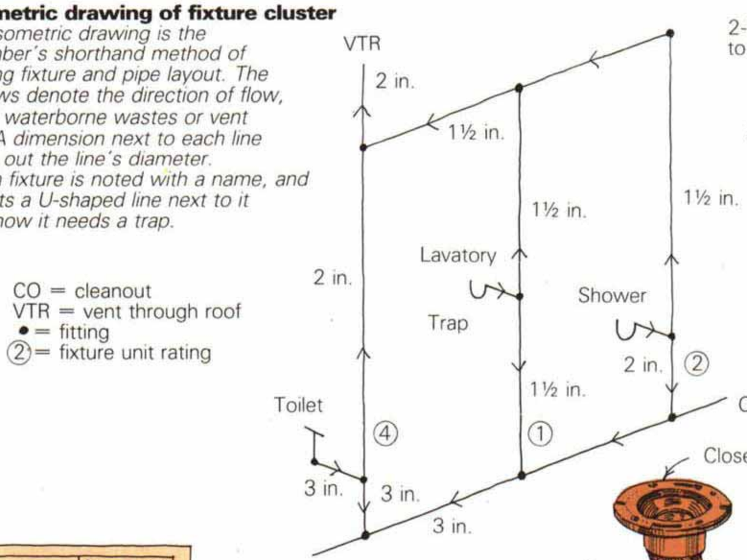
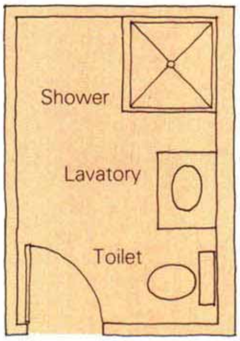
Right, a 4-in. building drain dives under a perimeter foundation on its way to link up with the building sewer. Just before the line descends into the earth, a 4-in. soil pipe rises above floor level, where it will be capped with a closet flange once the subfloor is in place. Just in front of the soil pipe, a 2-in. vent rises and then angles toward the wall that will eventually enclose it. At the bottom of the photo, a 1½-in. lavatory waste line is joined to the building drain by a combination tee and Y fitting.

Drawings: Gary Williamson

Isometric drawing of fixture cluster

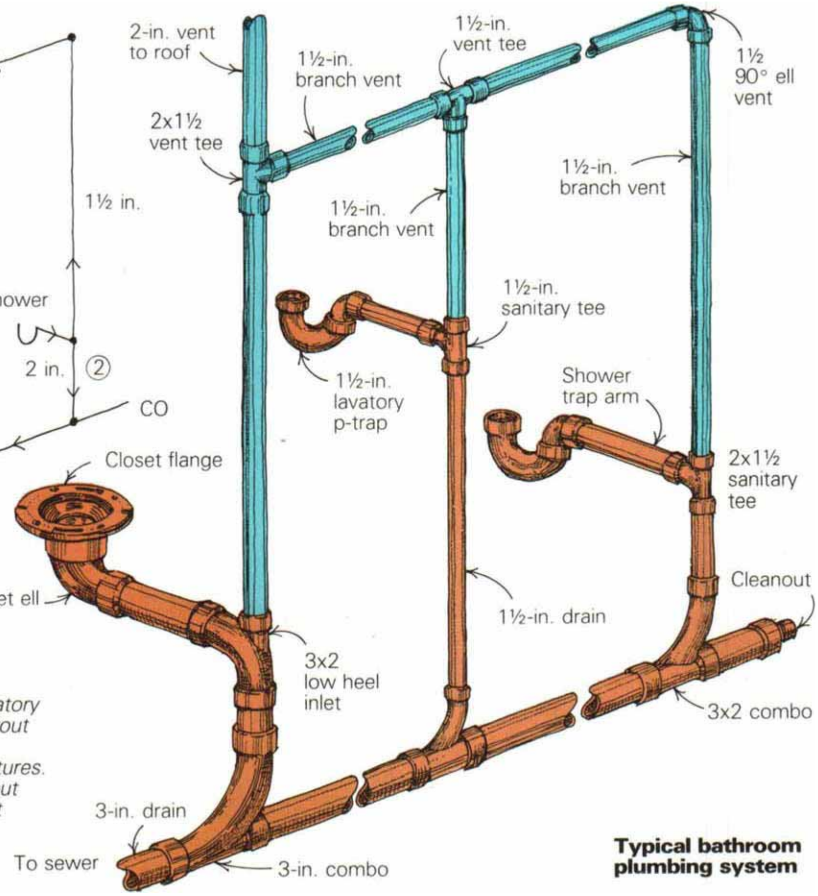
An isometric drawing is the plumber's shorthand method of noting fixture and pipe layout. The arrows denote the direction of flow, be it waterborne wastes or vent air. A dimension next to each line calls out the line's diameter. Each fixture is noted with a name, and it gets a U-shaped line next to it to show it needs a trap.





Typical bathroom plan

A typical bathroom has a toilet, a lavatory and a tub or shower. Its plumbing layout may look something like this. A 3-in. drain carries wastes from all three fixtures. At the end of its run there is a cleanout to allow servicing the line in the event of a blockage.



Typical bathroom plumbing system

vading the house. The trap arm extends from the trap to the vent, and its maximum length is dependent upon its diameter.

A *main vent* (sometimes called a stack vent, or a vent stack} is the principal artery of the venting system. Its purpose is to provide an air supply to all parts of the drainage system. Without an air supply, waste water traveling to the building sewer could create a suction strong enough to pull the water out of the traps, A main vent extends upward through the building, eventually terminating above the roof. A house will occasionally have several main vents, but it's best to avoid penetrating the roof more often than necessary. Consequently, many fixtures are connected to main vents by *branch vents.* More on vents later in the article.

Pipes and fittings—The common materials for drainage systems are ABS plastic, PVC plastic, copper and cast iron. Pipes that are suitable for drains and vents are stamped with the letters DWV, which stands for drain, waste and vent. Typical pipe diameters for residential applications are 1½ in., 2 in., 3 in. and 4 in. Larger pipes are available, but are used primarily in commercial buildings.

ABS systems are less expensive to buy and less trouble to work with than copper or cast iron. ABS is easily cut and assembled, and its light weight enables one person to handle long sections of pipe. But there are some disadvantages to it. ABS expands and contracts a lot with changes in temperature, and it has to be supported with twice as many hangers as cast iron to keep it from bending. It gives off poisonous gases in a fire, and readily transmits the sound of water running through it when the system is in use. Cast iron, on the other hand, dampens the sound of running water. It is quite durable, and less sensitive to temperature changes. I prefer to use 3-in. no-hub cast-iron. drain lines in conjunction with 1½-in. and 2-in. copper branch drains and vents. The copper pipes are soldered together, while the no-hub cast-iron pipes are joined by stainless-steel bands over neoprene gaskets. But this sort of system costs my customers about 30% more than a plastic one. Most of my clients specify ABS to keep costs down.

Regardless of what material I'm using, I need a wide variety of fittings to join pipes and to make the changes of direction required in any plumbing system. No matter what the material, the shapes, functions and names of the fittings remain the same (see p. 55).

Layout preparation—Though most regions voluntarily follow one of the model codes, each town and county can institute additional code requirements. Before I begin a new job, I check with the district's chief plumbing inspector to find out what materials are approved for use in the area, and what code book is enforced.

Once I know what to expect from the building department, I visit the site to study any irregularities that may occur in the system. I locate the sewer hookup, and I check with the client to find out about any special fixtures that are to be included in the job. If a set of the building plans is available, I check them to make sure that the placement of the fixtures complies with code clearances. For instance, a toilet has to be centered in a space at least 30 in. wide, with 30 in. in front of the bowl. Does the location on the blueprint take this into account? Then I find out what kind of toilet is to be installed, and I check the manufacturer's specs to find out where the center of the outlet is. This determines the placement of the closet flange. Typically, the centerline of a closet flange will be positioned 12 in. from the rough wall—11½ in. from the finished wall.

A lavatory drain line is typically 19 in. to 21 in. above the floor, while a kitchen-sink drain is usually 16 in. above the floor. This difference accounts for the depth of a garbage disposal. A bathtub drain is centered on the axis of the tub—usually 15 in. from the side wall. The placement of a washing-machine trap is between 6 in. and 18 in. above the floor—the stand pipe brings it up to the level of the machine's drain hose.

I also study the framing plans and consider the parts of the building that will affect the shape of the plumbing system. These are features such as windows, headers, medicine cabinets, offset walls and joists that want to run in contrary directions. All these factors affect the design of the system, and it's best to start thinking about them early on. I want the drains to run parallel to the joists wherever possible, and I need to know where the obstacles are so I can calculate the number of fittings that it will take to route the pipes around them.

The isometric drawing—This layout drawing is an isometric schematic of all the drains, vents and plumbing fixtures in a building. The plumbing for a small, one-story house can be shown on one drawing. But if the house is large or complex, I make detail drawings of fixture clusters, noting the drain connections with a heavy dot. The middle drawing on the facing page shows a typical isometric of a fixture cluster.

If there is an upstairs bathroom, I try to line the stack up so that it will fall in the same bay as the toilet drain. If it doesn't line up, I'll have to cut some large holes somewhere in order to install the drain line.

I begin my drawing at the approximate location of the sewer tie-in—about 2 ft. from the exterior of the house. As I work my way into the house I make a heavy dot at the intersections of the drain and vent lines to represent the fittings that I'll need, and I also mark arrows on the drains to show which way the waste goes, "CO" wherever a cleanout goes, and the note "VTR" to indicate where a vent goes through the roof. Although the isometric appears simple, it contains a lot of information. An expanded version of the same layout would look like the right-hand drawing on the facing page.

I don't make my isometric drawings to scale. Instead, I use the plan and section drawings of the building to take off the lengths of my plumbing runs and rises from floor to floor. I add these up and tack on 20% to get my pipe totals.

Sizing the drain and vent lines—Each plumbing fixture requires a minimum-diameter drain. These dimensions are listed as "minimum trap and trap-arm sizes" in table 4-1 in the code book. For example, a toilet drain should be at least 3 in. in diameter, while showers should have a 2-in. trap arm and a 2-in. waste line. Lavatories, on the other hand, have a 1½-in. trap arm and a 1½-in. waste line. A toilet vent is 2 in., and vents to all other fixtures are 1½ in. for a typical house.

When I size the layout, I like to start at the end of the system—usually the bathroom farthest from the sewer hookup. I write a number next to the fixture's drain representing the pipe's diameter, and another one noting the diameter of its vent. Then I mark the unit rating for each fixture alongside its pipe diameter, as shown in the isometric drawing on the facing page.

To find the number of units assigned to each fixture, turn to the section in your code book on sizing drain lines (table 4-1). Notice that each fixture has a unit rating. These units represent the fixture's discharge in gallons per minute. One unit equals O to 7½ gallons, two units equal 8 to 15 gallons and so forth. Each fixture has a discharge rate based on this. For example, a kitchen sink has a unit rating of two units, a toilet is assigned four units and a lavatory is rated at one unit.

After I have completed the sizing for the bathroom, I make a note next to the branch line on the drawing that lists the total unit demand at that point. This tells me about how much more can be added to the drain line before its dimension needs to be increased. Table 4-3 in the code book lists maximum allowable units for any diameter pipe. For instance, a 2-in. pipe can handle up to eight units of flow if it's installed horizontally—sixteen units if it's vertical.

Now I go on to the fixtures that are the next farthest from the sewer hookup, and I repeat the same sequence, noting the diameter of each line and the unit load for each fixture. I continue this process until the entire plumbing system is designed. My finished drawing includes all cleanouts, changes of direction, vents, the unit total for each branch line, the diameters of the lines and a dot for every fitting that it will take to make the necessary directional changes.

Once I know the number of fixtures and their assigned units, I make a list of them and add them up to get the total number of units for all the fixtures in the building. Now I turn to the table on drainage systems in the code book (table 4-3), and I look for the section on pipe sizes. The table lists units on one scale, and pipe diameters on the other scale. Once I locate my unit number on the chart, it tells me what diameter building drain and sewer that the house will require. A 3-in. horizontal line can handle up to 35 units of flow, so it's usually plenty for a small house. On the other hand, if you're planning a big house with many bathrooms, a big kitchen, laundry and a spa, you'll need a 4-in. building drain. It can accommodate a whopping 216 units on a horizontal run.

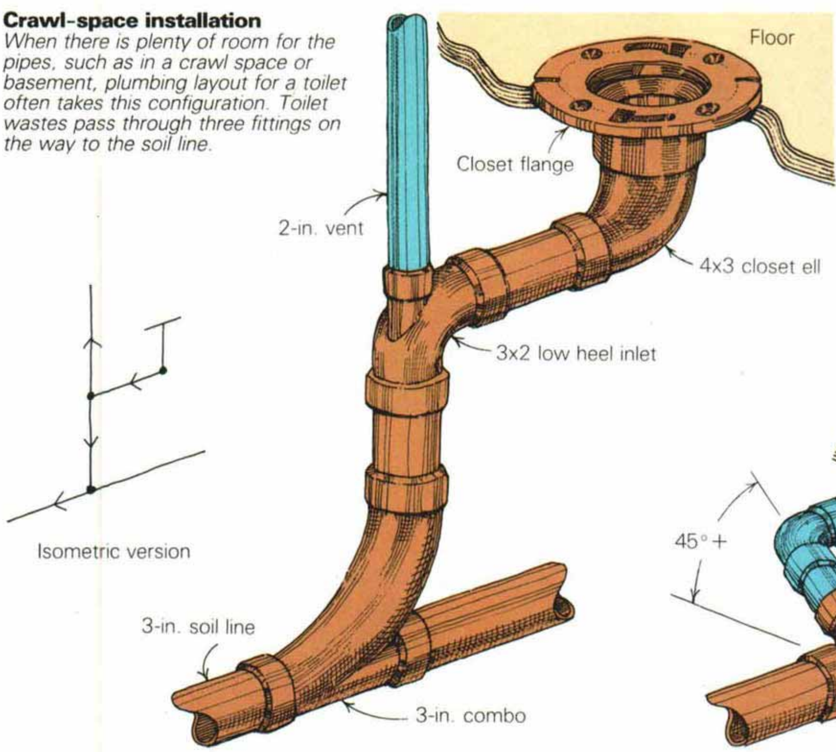
While I'm sizing the building drain, I decide on how big my main vents have to be. Even though the vents to individual fixtures are either 1½ in. or 2 in. in diameter, the stacks to which they connect must be at least equal in cross section to the cross section of the building drain. For example, a 3-in. building drain would require a minimum of two 2-in. vents and one 1½-in. vent through the roof.

There are many ways to build a plumbing system that will work, but usually there is one way that will be easier than others. The alternatives you must weigh depend on types of construction, fixtures, proximity to vent stacks, crawl-space clearances, and clearances between floors.

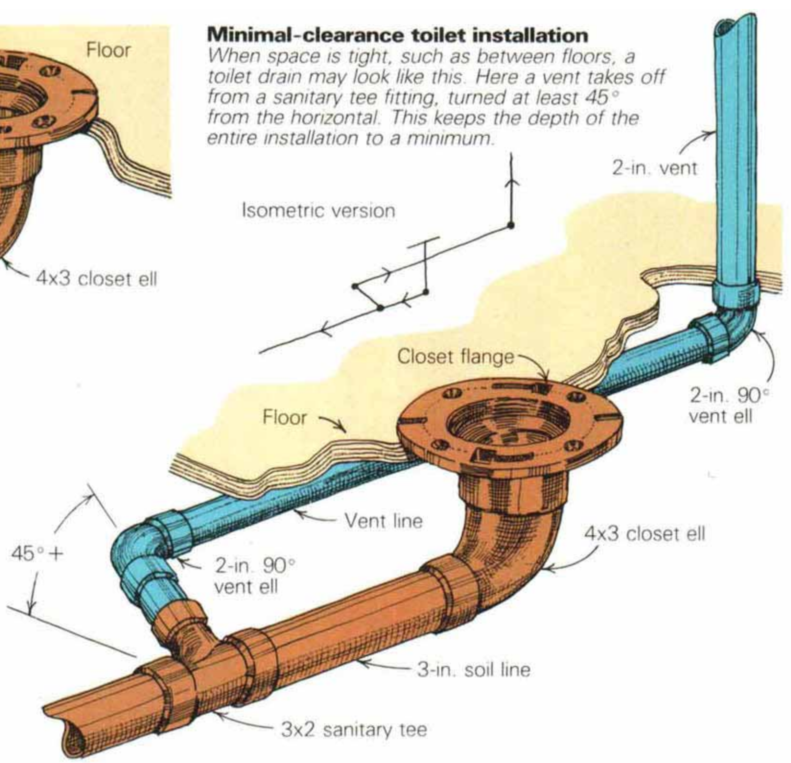
Toilet layout—With a large crawl space and plenty of fall in your drainage system, a typical toilet layout might look like the drawing below left. The two key fittings here are a combo and a 3x2 low heel inlet. The combo is turned on its back, and the tee goes on top with the 2-in. outlet pointed vertically. The other fitting is a 4x3 closet ell. The 4-in. outlet goes through the floor and connects to the closet flange.

If the clearance is minimal—between floors is a good example—the toilet layout might look like the drawing below right. In this diagram, the 3x2 sanitary tee is turned so that the vent outlet is directed at an angle. This satisfies a code requirement that says that vents off a horizontal drain line must be directed at an angle that falls between 45° and 90°. The vent continues on

Crawl-space installation
When there is plenty of room for the pipes, such as in a crawl space or basement, plumbing layout for a toilet often takes this configuration. Toilet wastes pass through three fittings on the way to the soil line.

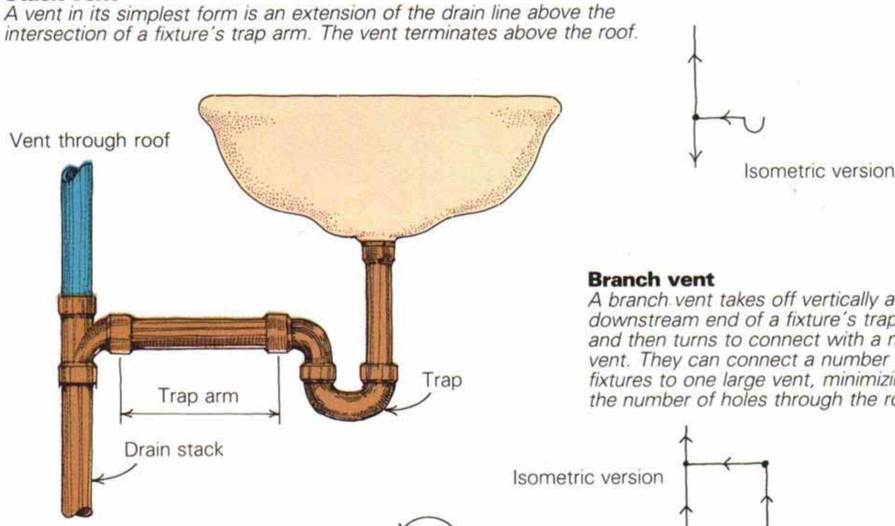


Minimal-clearance toilet installation
When space is tight, such as between floors, a toilet drain may look like this. Here a vent takes off from a sanitary tee fitting, turned at least 45° from the horizontal. This keeps the depth of the entire installation to a minimum.



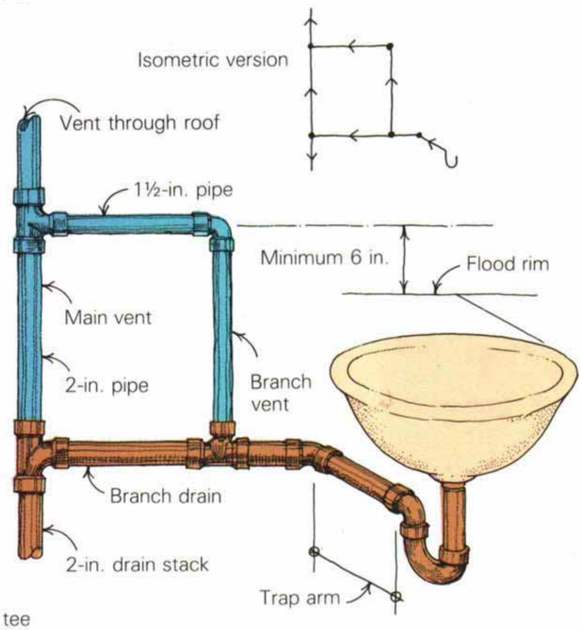
Stack vent

A vent in its simplest form is an extension of the drain line above the intersection of a fixture's trap arm. The vent terminates above the roof.



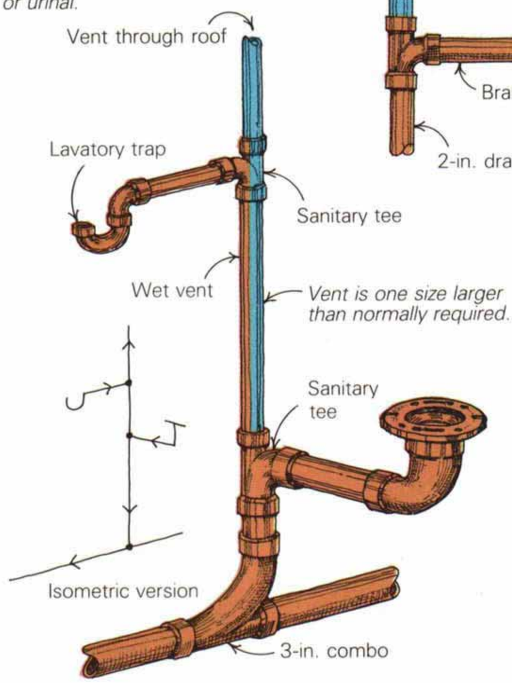
Branch vent

A branch vent takes off vertically at the downstream end of a fixture's trap arm and then turns to connect with a main vent. They can connect a number of fixtures to one large vent, minimizing the number of holes through the roof.



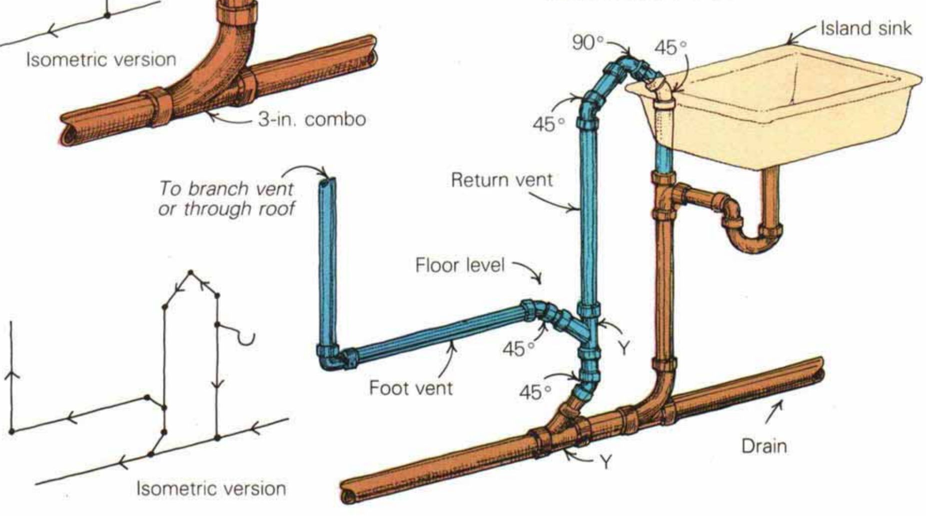
Wet vent

A wet-vent installation is one in which the vent for one fixture does double duty as a drain for a fixture upstream. A wet vent must be one size larger than normally required, and it cannot be used to carry wastes from a toilet or urinal.



Loop vent

A loop vent, or return vent, is used to vent an island fixture—usually a kitchen or bar sink. The return vent is an extension of the vertical drain. It extends as high as possible under the countertop, then makes a 180° turn using a 45° fitting, a 90° fitting, and another 45° fitting. Below the floor, a foot vent takes off the vertical leg of the return vent, then extends to a partition, where it rises vertically past the roof or to another vent.



through the roof or ties into a branch vent at least 6 in. above the flood rim of the highest fixture on the line.

Vents–Every fixture needs a vent, but sometimes it's not immediately apparent how to tie the fixture's trap arm to a vent. The easiest solution is the stack vent (drawing, top left). This vent is an extension of the vertical drain, or stack, that carries waste to the building drain.

The stack vent is fine if your fixture is close to the drain stack, but if it isn't, you might want to tie into it with a branch vent. The branch vent takes off vertically from the trap arm, then makes a 90° turn toward the vent stack when it's at least 6 in. above the fixture's flood rim (drawing, second from top). The flood rim is the level at which the fixture begins to overflow.

The code allows wet vents in certain conditions–they can be especially handy in remodeling situations. A wet vent is a vertical vent that also serves as waste line–never a soil line. Each wet-vented section must be at least one pipe size larger than the required pipe under normal circumstances. The connection between the fixture's trap arm and the vent stack must be made with a sanitary tee (drawing, third from top).

If you want to vent an island sink, you'll need a loop vent (also known as a return vent). This system takes the vent as high as possible above the waste connection, and then back under the floor where it is tied by a pair of Y fittings to the branch line that carries the sink's discharge (bottom drawing). The vent then rises above the floor to connect with a vent stack. The connection between the drain and the foot vent makes it impossible for the low part of the vent to fill with condensation.

Trap-arm dimensions–Recall that the trap arm is that portion of a fixture drain between the trap and the vent. Table 7-1 in the code book lists the maximum lengths for trap arms of a given diameter. For instance, you can have a 3½-ft. trap arm with 1½-in. pipe, a 5-ft. trap arm with 2-in. pipe, and a 6-ft. trap arm with 3-in. pipe. In some cases you can save yourself some trouble by applying this rule. For example, I once had to tie a kitchen sink, centered beneath a large window, into a drain line about 5 ft. away. If I'd used the standard 1½-in. trap arm, I wouldn't have had enough length to get to my branch vent. So I went to 2-in. pipe, and gained the 1½ ft. needed to make a legal connection.

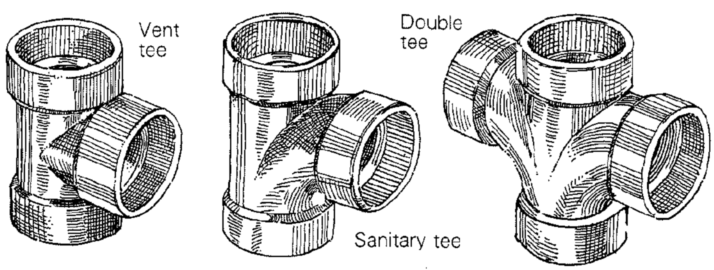
Cleanouts–A cleanout gives you access to the drainage system when something clogs one of the lines. You unscrew the threaded cap, insert a cable snake of some sort, and gnaw away at the blockage. A cleanout is required just outside the foundation, where the building drain meets the building sewer. Cleanouts are also required at the upper terminal of horizontal drain lines below the first floor, and there has to be plenty of clearance around each one so that you'll have room to maneuver maintenance equipment. There is a separate section in the code book that lists all the rules that apply to cleanouts–be sure to study this section carefully. Plumbing inspectors seem to like a lot of cleanouts. □

Common pipe fittings

Even though materials differ, the names and functions of the various pipe fittings used to join sections of drainpipe remain the same. The fittings in this list are the ones I use most often to assemble a residential drainage system. There are many more, but they are slight variations on the basic ones listed here.

Fittings are identified by numbers that designate the diameter of their outlets in inches, and an abbreviation of their shape. The size of the largest outlet is listed first. For instance, a reducing elbow with a 3-in. outlet and a 2-in. outlet is called a 3x2 ell. For a three-outlet fitting, such as a tee, Y and combo, the side-outlet diameter is the last number listed. For example, a tee with a 3-in. run and a 1½-in. side outlet is called a 3x1½ tee. If it's a reducing tee, three numbers describe the fitting and the side outlet is still listed last, such as a 3x2x1½ tee.

Most fittings have a socket at each outlet that accepts a piece of the nominal pipe. Fittings designed for cleanout plugs have a threaded female outlet. Adaptors can be either male or female, and nipples have threaded male ends. Street fittings have an outlet that's the same OD as the nominal pipe size.

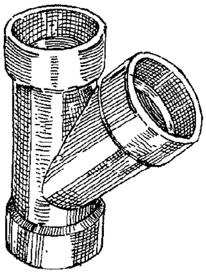


Tees

Vent tee: A tee fitting used strictly for joining sections of vent pipe. It lacks the sweep of a sanitary tee, and shouldn't be used for waste or soil lines.

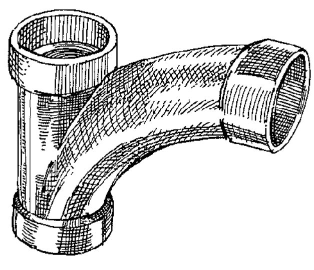
Sanitary tee: Unlike the vent tee, the sanitary tee has a sweep built into the intersecting line. This sweep has to be installed so the curve follows the direction taken by the waste. These fittings are used to connect trap arms to waste stacks, and to connect branch lines to waste stacks. They can be used in venting, and in horizontal to vertical drain applications.

Double tee; If you have two lavatories with the same flood rim on opposite sides of the same wall, you may connect them to the same stack and vent with this fitting. The vent stack continues upward from the top outlet.



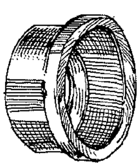
Ys

These fittings are used to join lines at a 45° angle, or to make a 45° change in direction while providing a cleanout outlet at the same time. The codebook requires this fitting for horizontal changes of direction. In a stud wall they can be difficult to use if a lot of angled holes have to be drilled in the framing to accommodate the angled line.



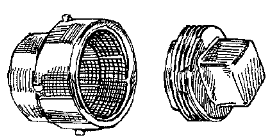
Combination tee and Y

Known as combos, this fitting is most often used for a 90° change in direction in the waste or soil lines where a cleanout is needed. It can be used in vertical or horizontal applications.



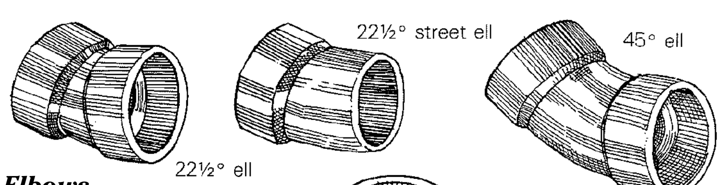
Bushings

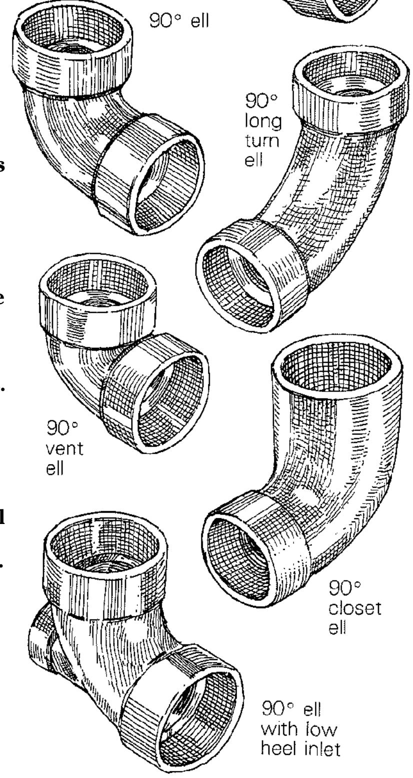
For joining pipes of different diameters.



Cleanouts

These are watertight fittings with removable plugs. They consist of a threaded adaptor that inserts into a fitting or over a pipe. The adaptor accepts a threaded plug.





Elbows

22½° ell: Also known as a 1/16 bend, this ell is the standard fitting used to make slight changes in direction in soil, vent or waste lines.

22½° street ell: Same as the standard ell, but the street ell has a male and female end, which allows it to make a directional change in a bit less space than the standard ell.

45° ell: Also known as the ⅛ bend, the 45° ell is used to change directions in DWV lines. It also has a street version.

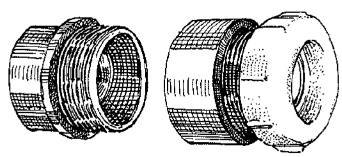
90° ell: This ell is used primarily to change directions in vent lines. It may also be used to connect a horizontal drain line to a stack, but not a stack or a horizontal line to another horizontal line.

90° long turn ell: Used for changes in direction from vertical to horizontal, or horizontal to horizontal in soil and waste lines.

90° vent ell: For directional changes in vent lines only.

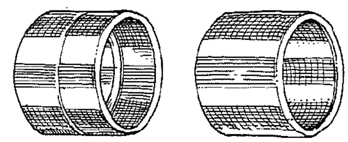
90° closet ell: This fitting is used to connect a 4-in. closet flange to a 3-in. soil line.

90° ell with low heel inlet: A handy fitting for changing directions in a soil line where a vent outlet is needed.



Trap adaptors

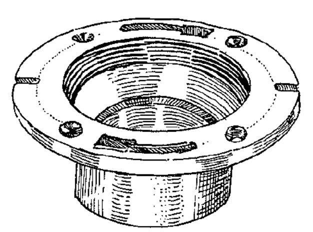
The trap adaptor is the transition fitting that connects the trap arm to the drain. There are two kinds: One is an adaptor that inserts into the side opening in a sanitary tee (left). The other fits over a pipe (center). Both have a slip-joint nut with a plastic washer that seals the trap arm (right). This links the fixture and the plumbing system. Trap adaptors are also used to connect a tub waste and overflow line to a p-trap.



Couplings

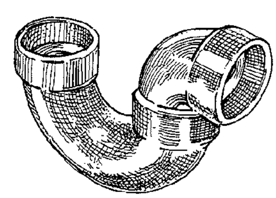
Coupling: A link between sections of waste, soil and vent lines.

Repair coupling: Same as the regular coupling, but It lacks the interior stop flanges, allowing it to slide onto a section of pipe while another pipe segment is brought alongside. Then the repair coupling is slid back to encompass the ends of both pipes. These are good for connecting pipes in tight spots.



Closet flange

This is the transition coupling between a toilet and its soil line. The circular flange is screwed to the bathroom subfloor.



P-trap

The p-trap is the fitting that contains the water seal that keeps the sewer gases in the sewer. Toilets have built-in traps, but every other fixture requires some kind of p-trap. They are installed below the fixture drain.

—G. S.