Sizing Domestic Water Pipes

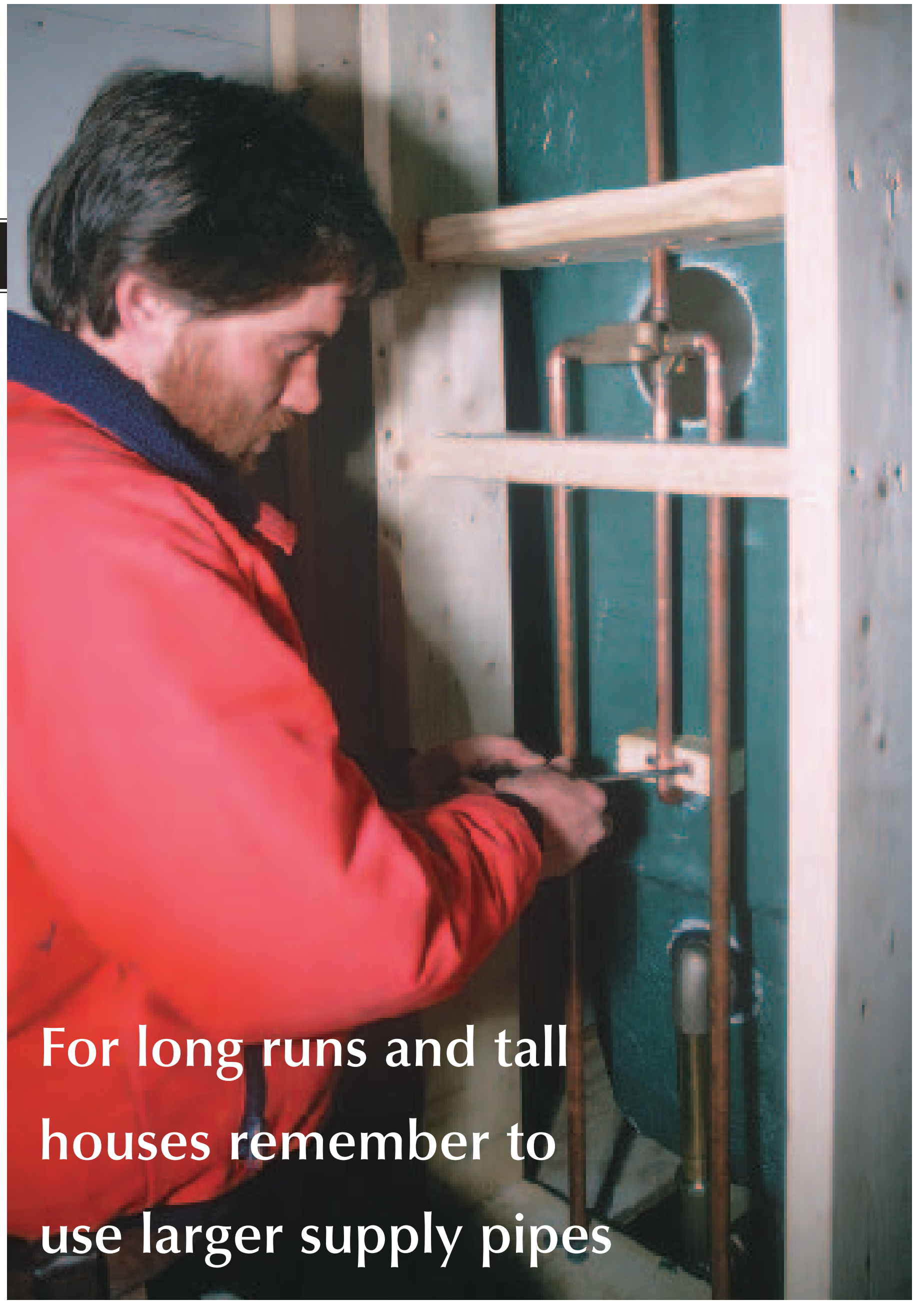
by Richard Zannini

Some plumbers successfully size residential supply pipes based on long experience or rules of thumb. But in unusual circumstances — when a house has low pressure, long pipe runs, an extensive irrigation system, or a large whirlpool tub — rules of thumb may result in undersized pipes that perform poorly or don't meet code (see Figure 1, next page).

To accurately size residential water supply pipes, you need to have information on six important variables:

- code requirements
- available minimum static pressure at the water meter or pressure tank
- the pressure-reducing effect of any water meter, backflow preventer, water softener, and/or whole-house filter
- length of pipe to the most remote fixture in the building
- height of the building
- water demand, expressed in supply fixture units or gallons per minute

Once these six factors are known, pipe sizes can be determined by simple tables. In creating these tables, engineers have considered several factors, including the need to limit water velocity. (When water velocity exceeds about 8 feet per second, it can be noisy



CAROLYN BATES

and can cause erosion of the pipe.) Using the tables ensures that even at the end of a long pipe run, a minimum pressure of 8 or 10 psi will be available at each fixture. (Flushometer valves, which are typically found only in commercial buildings, require between 15 and 25 psi at the fixture for proper operation.)

Know Your Local Code

Regardless of the method used to size your pipes, local codes must be followed. Some codes have specific requirements that overrule engineering calculations — for example, the requirement that a water service pipe must be no smaller than 3/4 inch, or that a 1/2-inch pipe can serve no more than four fixtures.

Most codes stipulate a minimum pipe diameter for each type of fixture; in almost all cases, that minimum is 1/2 inch. There are a few exceptions, however: Some codes permit the use of 3/8-inch pipe for lavatories, bidets, and toilets; and others permit the use of 3/8-inch PEX in a manifold system. A flushometer valve will always require a pipe size greater than 1/2 inch.

Virtually every code, including the BOCA *National Plumbing Code*, the SBCCI *Standard Plumbing Code*, the UBC *Uniform Plumbing Code*, the *California Plumbing Code*, and the IBC *International Residential Code*, has a section specifying the method to be used for sizing supply pipes, and the codes do not always agree. Your local code, as interpreted by your inspector, trumps all other opinions and sizing methods.

Pressure

There are two kinds of pressure: static pressure, which is measured when no water is flowing, and dynamic pressure, which is measured when water is flowing. When measured at a fixture, both the dynamic and the static pressure are likely to be less than the static pressure measured at the meter or pressure tank. The drop in pressure is due to friction as water flows through equipment, pipe, and fittings, and to the static loss in pressure from raising the water to a higher elevation.

Minimum and maximum pressures. Most codes require residential static water pressure to be between 40 and 80 psi. The pressure provided by a municipal water system may be either too low or too high. Where I work, in Manchester, N.H., the municipal water pressure varies from neighborhood to neighborhood, from a low of about 45 psi to a high of 130 psi. If the municipal pressure is higher than 80 psi, most codes require the installation of a pressure-reducing valve to knock the pressure down to 80 psi.

Although the 1993 BOCA *National Plumbing Code* permits residential static pressure to be as low as 30 psi, the 2000 *International Residential Code* (*IRC*) requires a minimum of 40 psi. In areas where the municipal pressure is too low, the solution is to install a booster pump and pressure tank.

To size the pipes, you can measure the static pressure directly with a pressure gauge (after the meter and pressure-reducing valve), or you can contact the local utility to ask what pressure is typical in the neighborhood. In areas where the water pressure varies from season to season, use the lowest value provided.

When it comes to sizing water pipes, codes do not make any distinction between systems supplied by municipal water and systems supplied by private wells. On a rural system, the static pressure will vary between the cut-in and cut-out settings on the pressure switch controlling the pump — typically 45 to 60 psi. To size the pipe, use the minimum pressure (45 psi).

Pressure losses from equipment. Some types of equipment, including water meters, backflow preventers, water filters, and water softeners, introduce friction that results in dynamic pressure loss. It's your responsibility to contact the manufacturer of any such equipment to obtain pressure loss information. For example, a 3/4-inch Watts #7 backflow preventer creates a friction loss of 4 psi at 12 gpm (7.5 feet per second). Water softener and whole-house filter manufacturers rate their equipment at different flow rates (typically between 5 gpm and 7.5 gpm), with pressure loss ratings in the range of 5 to 15 psi, depending on the specific piece of equipment. Use this information to adjust the available water pressure downward.

Pressure loss from elevation. The pressure used to size the supply pipes

REX CAULDWELL

Figure 1. It's no surprise that this homeowner had water supply problems. The builder had installed a reducing coupling on the pressure-tank tee, so he could supply the entire house with a 3/8-inch soft copper line.

also needs to be reduced to account for the elevation difference between the source and the highest fixture in the building. This type of pressure loss is called the static pressure loss; even when no water is flowing, the pressure on the top floor of a multistory building will be less than the pressure in the basement. Many codes (including the *Uniform Plumbing Code*) specify that for every foot increase in elevation, the assumed pressure should be reduced by 0.43 psi, which is very close to the actual value. Other codes, including the *IRC*, round this number up a little, and require that the assumed pressure be reduced 0.5 psi per foot increase in elevation.

This calculation is made for the highest fixture or outlet in the building, and the result is the pressure used to size the water pipes. For example, if the pressure is 60 psi in the basement, and the highest fixture is located 20 feet higher than the water meter, the reduction in pressure will be 10 psi (20 feet x 0.5 psi reduction per foot elevation), dropping the effective pressure down to 50 psi. If the pressure is 50 psi on the top floor, then you must use 50 psi to size the pipes for the entire building.

Developed Length

Since it takes more pressure to push water through long narrow pipes than short fat pipes, you need to know the length of the longest pipe in the house before you can choose a diameter. The "developed length" of a home's supply pipe is usually defined as the length of the supply pipe from the water source (the water meter or pressure tank) to the most remote fixture. However, the codes are not consistent on this point. BOCA requires that the actual measurement of the supply pipe be used, while the *IRC* requires that the pipe length measurement be multiplied by 1.2 to account for pressure loss due to fittings.

Since most supply fittings are 90-degree elbows or tees, the length of the pipe can be calculated from the plans by measuring the distance along the length of the house, plus the offset along the width of the house, plus the elevation difference.

Fixture Units

For many decades, plumbers have calculated a home's water supply demand in terms of "supply fixture units." Fixture-unit numbers don't measure anything; the scale is arbitrary and is used to compare the relative water requirements of different fixtures. The fixture-unit system is based on decades-old research conducted by the National Institute of Standards.

Unfortunately, the different plumbing codes do not agree on fixture-unit values. The recent trend toward the use of water-saving fixtures has led some plumbing codes to lower the traditional unit values for some fixtures. Moreover, in some codes, supply fixture units differ from drainage fixture units.

Most plumbing codes include a chart that provides supply fixture-unit values for each fixture (Figure 2). These charts can be confusing; it's important to note, for example, whether the fixture-unit value refers to only the cold or hot supply, or to both. Supply fixture-unit values for the hot and cold supplies to a bathtub vary from 1.4 (*IRC*) to 2 (BOCA) to 4 (*Uniform Plumbing Code*), while the fixture-unit values for the hot and cold supplies to a clothes washer range from 2 (BOCA)

Water Supply Fixture-Unit Values

	Fixture-Unit Value		
Type of Fixtures	Hot	Cold	Combined
Bathtub (with/without overhead shower head)	1.0	1.0	1.4
Clothes washer	1.0	1.0	1.4
Dishwasher	1.4	-	1.4
Hose bibb (sillcock)	-	2.5	2.5
Kitchen sink	1.0	1.0	1.4
Lavatory	0.5	0.5	0.7
Laundry tub	1.0	1.0	1.4
Shower stall	1.0	1.0	1.4
Water closet (tank type)	–	2.2	2.2
Full-bath group with bathtub (with/without shower head) or shower stall	1.5	2.7	3.6
Half-bath group (water closet and lavatory)	0.5	2.5	2.6
Kitchen group (dishwasher and sink with/without garbage grinder)	1.9	1.0	2.5
Laundry group (clothes washer standpipe and laundry tub)	1.8	1.8	2.5

Figure 2. Fixture-unit values provide an indication of relative levels of water supply demand. These fixture-unit values come from the *International Residential Code*; the values provided under other codes may vary.

Minimum Size of Water Meters, Mains, and Distribution Piping Based on Water Supply Fixture-Unit Values

Meter and Service Pipe (inches)	Distribution Pipe (inches)	Maximum Developed Length (feet)									
		40	60	80	100	150	200	250	300	400	500
Pressure Range — 30 to 39 psi											
3/4	1/2*	2.5	2	1.5	1.5	1	1	0.5	0.5	0	0
3/4	3/4	9.5	7.5	6	5.5	4	3.5	3	2.5	2	1.5
3/4	1	32	25	20	16.5	11	9	7.5	6.5	5.5	4.5
1	1	32	32	27	21	13.5	10	8	7	5.5	5
3/4	1 1/4	32	32	32	32	30	24	20	17	13	10.5
1	1 1/4	80	80	70	61	45	34	27	22	16	12
1 1/2	1 1/4	80	80	80	75	54	40	31	25	17.5	13
1	1 1/2	87	87	87	87	84	73	74	56	45	36
1 1/2	1 1/2	151	151	151	151	117	92	79	69	54	43
Pressure Range — 40 to 49 psi											
3/4	1/2*	3	2.5	2	1.5	1.5	1	1	0.5	0.5	0.5
3/4	3/4	9.5	9.5	8.5	7	5.5	4.5	3.5	3	2.5	2
3/4	1	32	32	32	26	18	13.5	10.5	9	7.5	6
1	1	32	32	32	32	21	15	11.5	9.5	7.5	6.5
3/4	1 1/4	32	32	32	32	32	32	32	27	21	16.5
1	1 1/4	80	80	80	80	65	52	42	35	26	20
1 1/2	1 1/4	80	80	80	80	75	59	48	39	28	21
1	1 1/2	87	87	87	87	87	87	87	78	65	55
1 1/2	1 1/2	151	151	151	151	151	130	109	93	75	63
Pressure Range — 50 to 60 psi											
3/4	1/2*	3	3	2.5	2	1.5	1	1	1	0.5	0.5
3/4	3/4	9.5	9.5	9.5	8.5	6.5	5	4.5	4	3	2.5
3/4	1	32	32	32	32	25	18.5	14.5	12	9.5	8
1	1	32	32	32	32	30	22	16.5	13	10	8
3/4	1 1/4	32	32	32	32	32	32	32	32	29	24
1	1 1/4	80	80	80	80	80	68	57	48	35	28
1 1/2	1 1/4	80	80	80	80	80	75	63	53	39	29
1	1 1/2	87	87	87	87	87	87	87	87	82	70
1 1/2	1 1/2	151	151	151	151	151	151	139	120	94	79
Pressure Range — over 60 psi											
3/4	1/2*	3	3	3	2.5	2	1.5	1.5	1	1	0.5
3/4	3/4	9.5	9.5	9.5	9.5	7.5	6	5	4.5	3.5	3
3/4	1	32	32	32	32	32	24	19.5	15.5	11.5	9.5
1	1	32	32	32	32	32	28	22	17	12	9.5
3/4	1 1/4	32	32	32	32	32	32	32	32	32	30
1	1 1/4	80	80	80	80	80	80	69	60	46	36
1 1/2	1 1/4	80	80	80	80	80	80	76	65	50	38
1	1 1/2	87	87	87	87	87	87	87	87	87	84
1 1/2	1 1/2	151	151	151	151	151	151	151	144	114	94

* Minimum size for building supply is 3/4-inch pipe.

Figure 3. Once values have been determined for the design pressure, developed length of pipe, and fixture units, these four tables from the *IRC* can be used to size residential water supply pipes, depending on the pressure range. Choose the column with a "length" value that is equal to or greater than the longest supply pipe in the house, and choose a fixture-value number that is equal to or greater than the fixture units being supplied. The minimum pipe size can be found in the "Distribution Pipe" column.

Sizing Water Supply Pipes

To size the main water distribution pipe:

1. Find the pressure loss:

Municipal water service pressure		70 psi
minus pressure loss from equipment (water softener)	–	5 psi
minus pressure loss from elevation (22' x 0.5)	–	11 psi
Adjusted pressure		**54 psi**

2. Find the developed length of pipe:

Length of pipe to farthest fixture times 1.2
(to account for pressure loss due to fittings)

37' x 1.2 = 45'-0"

3. Find the fixture-unit values:

Full-bath group w/ bathtub	3.6	(hot and cold)
Half-bath group	2.6	(hot and cold)
Kitchen group	2.5	(hot and cold)
Laundry group	2.5	(hot and cold)
Hose bibb	2.5	(cold only)
Total fixture-unit value	**13.7**	

4. Use code tables (figure 3) to determine pipe size

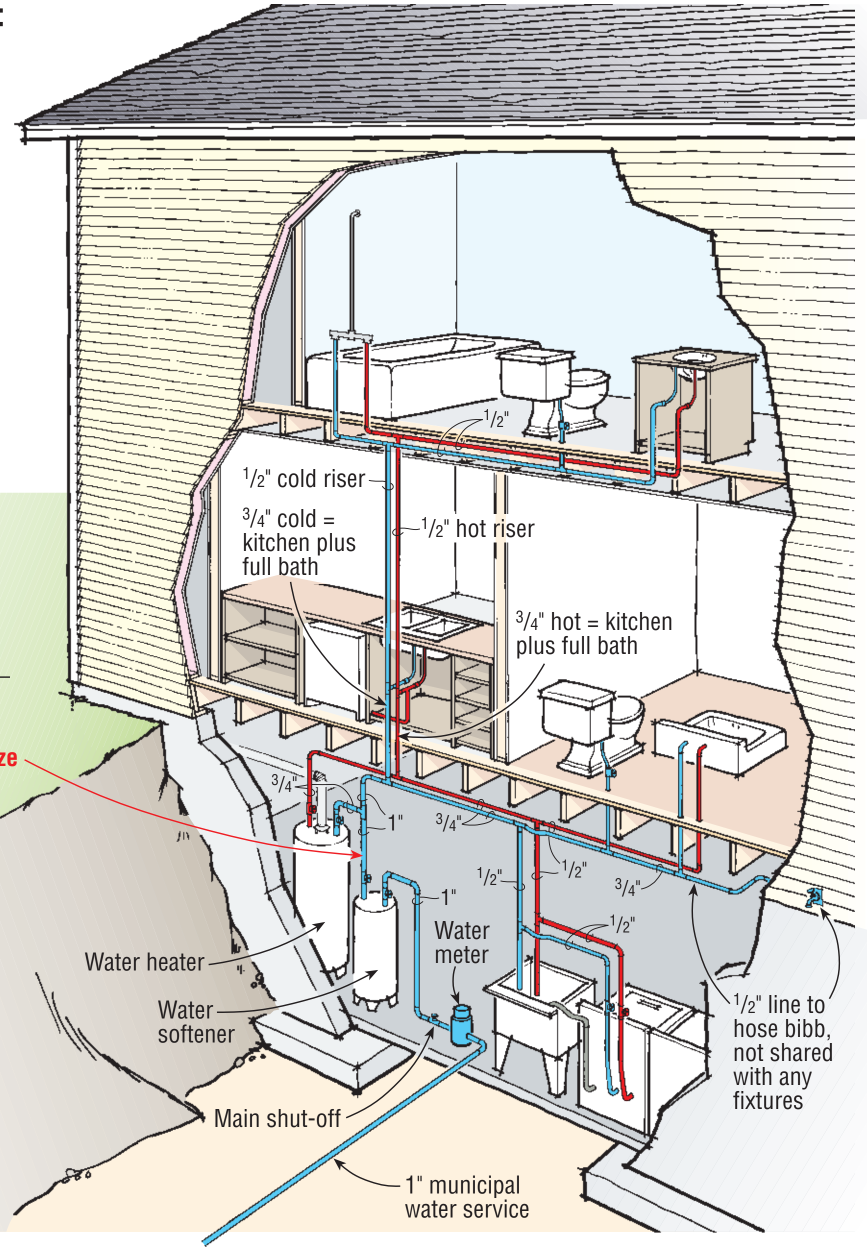


Figure 4. When sizing the main distribution pipe, add up all the fixture groupings in the whole house (see table in Figure 2). After the cold and hot lines divide, use separate hot and cold fixture groupings to size branch lines.

to 4 (*California Plumbing Code* and *Uniform Plumbing Code*).

Some codes do not provide a fixture-unit value for a bidet; usually, a bidet is considered to have a value equivalent to a lavatory. Moreover, most codes do not distinguish between a standard 5-foot tub and a monster whirlpool tub.

To size the main water supply pipe for a house, add up all of the supply fixture units in the building, including hose bibbs and the lawn sprinkler system. To size a branch line to a group of fixtures, add up the total fixture units being served by that branch line. Some codes, including the *IRC*, provide fixture-unit values for clusters of fixtures; for example, a full-bath group (defined as a toilet, lavatory, and bathtub with or without a shower) has a combined hot-and-cold value of 3.6.

Sizing the Pipes

If you know the pressure (adjusted for the height of the building and any equipment), the developed length of the supply pipe, and the fixture-unit values, you have gathered all the information you need to begin sizing the pipes.

Consult the tables. Most code books provide a series of tables for sizing supply pipes. These tables are broken down into several pressure ranges; in the *IRC*, there are four tables corresponding to four pressure ranges (Figure 3). Other codes break down the tables differently.

Select the table with a pressure

range that corresponds to your design pressure (the available pressure adjusted for the height of the building and any equipment). Choose a "Length" column that is equal to or longer than the developed length of the longest pipe in the house. Then find a fixture-unit value equal to or greater than the fixture-unit value for the house, and, on the left of the chart, you'll find the smallest pipe diameter that will serve that number of fixture units.

Sizing a branch. Sizing a branch pipe is done in the same manner as sizing the building supply pipe, except with a different fixture-unit value. The size of hot water pipes is calculated by the same method as cold water pipes. Since location of the water heater can affect supply pipe sizing, it's always a good idea, if possible, to keep the water tank near the meter or pressure tank.

An example. Let's suppose we want to size the main water distribution pipe for a bath-and-a-half, two-story house in a town governed by the *IRC* (Figure 4, previous page). The house has municipal water service providing 70 psi after the water meter. The house has a water softener, and the equipment manufacturer informs us that the water softener reduces the dynamic pressure by 5 psi; so we're down to 65 psi. The highest fixture is located 22 feet higher than the service pipe, so we deduct 11 psi (0.5 x 22) from the available pressure, bringing the pressure down to 54 psi.

The length of the pipe to the farthest fixture is 37 feet; we multiply this by 1.2 to account for fittings, which gives us a developed length of pipe equivalent to 45 feet.

The fixture-unit values for the entire house total 13.7. This number was obtained by adding up the following values: full-bath group with bathtub, 3.6 (hot and cold); half-bath group, 2.6 (hot and cold); kitchen group, 2.5 (hot and cold); laundry group, 2.5 (hot and cold); hose bibb, 2.5 (cold).

Now we go to the *IRC* tables, where we choose the table with a pressure range of 50 to 60 psi. We use the "Maximum Developed Length" column of 60 feet and find that we need at least a 1-inch distribution pipe. Branch lines serving a limited number of fixtures on the hot or cold side can be smaller (Figure 5).

Home-Run Manifold Systems

When it comes to sizing supply pipes, most codes make no distinction between different pipe materials; copper, CPVC, and PEX are usually sized the same way. In some codes, however, there is an exception: When a home-run manifold system is installed, plastic pipes are sized differently than metal pipes (Figure 6).

For example, the *IRC* requires "parallel water-distribution system manifolds" to be sized according to gallons per minute of flow rather than fixture-unit values. To calculate the water supply demand for a manifold system, consult Table P2903.1 in the *IRC*, "Required Capacities at Point of Outlet Discharge." In that table, the "Flow Rate" column provides the minimum number of gallons per minute for each fixture. Once the total flow rate is known, consult the "Manifold Sizing" table (Table P2903.8.1) to determine the size of the pipe supplying the manifold. That table shows, for example, that 1-inch plastic pipe can handle a maximum flow of 29 gpm. (Note that, according to the *IRC*, a 1-inch metal pipe has a lesser flow capacity of only 20 gpm.)

Most manifold systems have individual tubing runs between the manifold and each fixture. These pipes are often sized according to the minimum pipe size permitted by the local code authority — typically 1/2 inch. Some codes allow the use of 3/8-inch tubing for lavatories, bidets, and toilets. If the plumbing design has been stamped by an engineer and approved by the local inspector, some residential manifold systems can use 3/8-inch tubing for most or all fixtures. As a rule of

COPPER DEVELOPMENT ASSOC.

Figure 5. In this home, 3/4-inch copper lines tee off from the 1-inch mains on the left.

thumb, some PEX manufacturers advise that 3/8-inch tubing works for any fixture requiring 2 1/2 gallons per minute or less, including most sinks and lavatories and some showers. Other manufacturers suggest that 3/8-inch tubing is adequate for pipe runs up to 80 feet long to any fixture except a large whirlpool tub.

Smaller tubing, as long as it is adequate, has one advantage: Since it holds a smaller volume of water, the homeowner won't have to wait as long for hot water to arrive at the sink.

Unusual Situations

Sizing pipes according to code mandates will provide service that meets minimum requirements. There are a few circumstances, however, that may not be fully covered in the code tables — circumstances in which it may be prudent to size pipes beyond the minimum requirements.

Whirlpool tubs. The fixture-unit tables in most code books do not provide a separate value for a whirlpool tub. Plumbers have learned from experience that if a large whirlpool tub with a single fill spout has a pipe sized according to the requirements for a standard 5-foot tub, it may take a long time to fill.

To solve the whirlpool problem, one or all of the following strategies can be used:

- provide two or three fill spouts
- install a dedicated pipe from the water heater straight to the whirlpool tub
- increase the size of all pipes supplying the whirlpool to a minimum of 3/4 inch

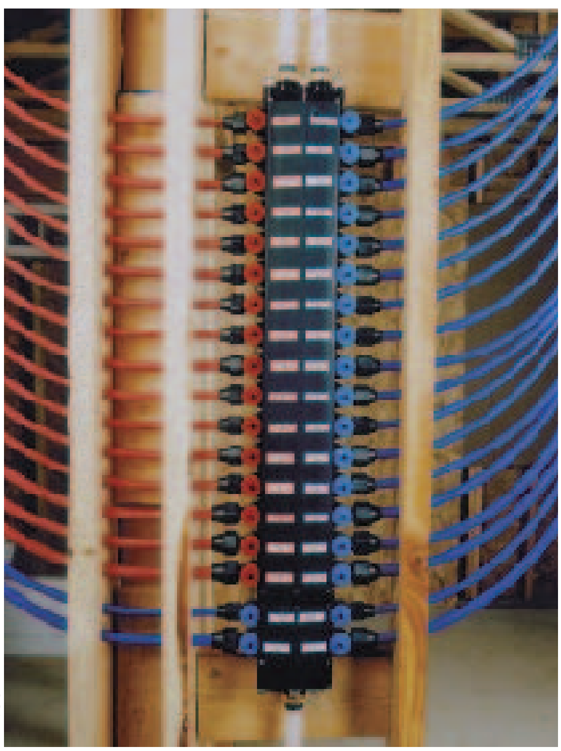
Irrigation systems. Since an irrigation system can require a lot of water, it's usually best for the branch pipe for the irrigation system to tee off near the meter.

A Final Note

Residential supply pipes need to be sized with two important goals in mind: satisfying your customer and satisfying your plumbing inspector. Regardless of the sizing method you use, it's important to remember that your local inspector will never cite you for choosing a pipe that is one size too large.

Richard Zannini is a master plumber and a city plumbing inspector in Manchester, N.H., and serves on the Plumbing Code Review Committee for the Plumbing-Heating-Cooling Contractors Association (800/533-7694; www.phccweb.org).

WATTS HEATWAY



VANGUARD

Figure 6. Home-run piping systems use a copper manifold (above) or a plastic manifold (right). Under some codes, the pipe sizing method for home-run manifold systems is different than that used for standard branch systems.