Water Supply and Distribution

Building Plumbing Systems

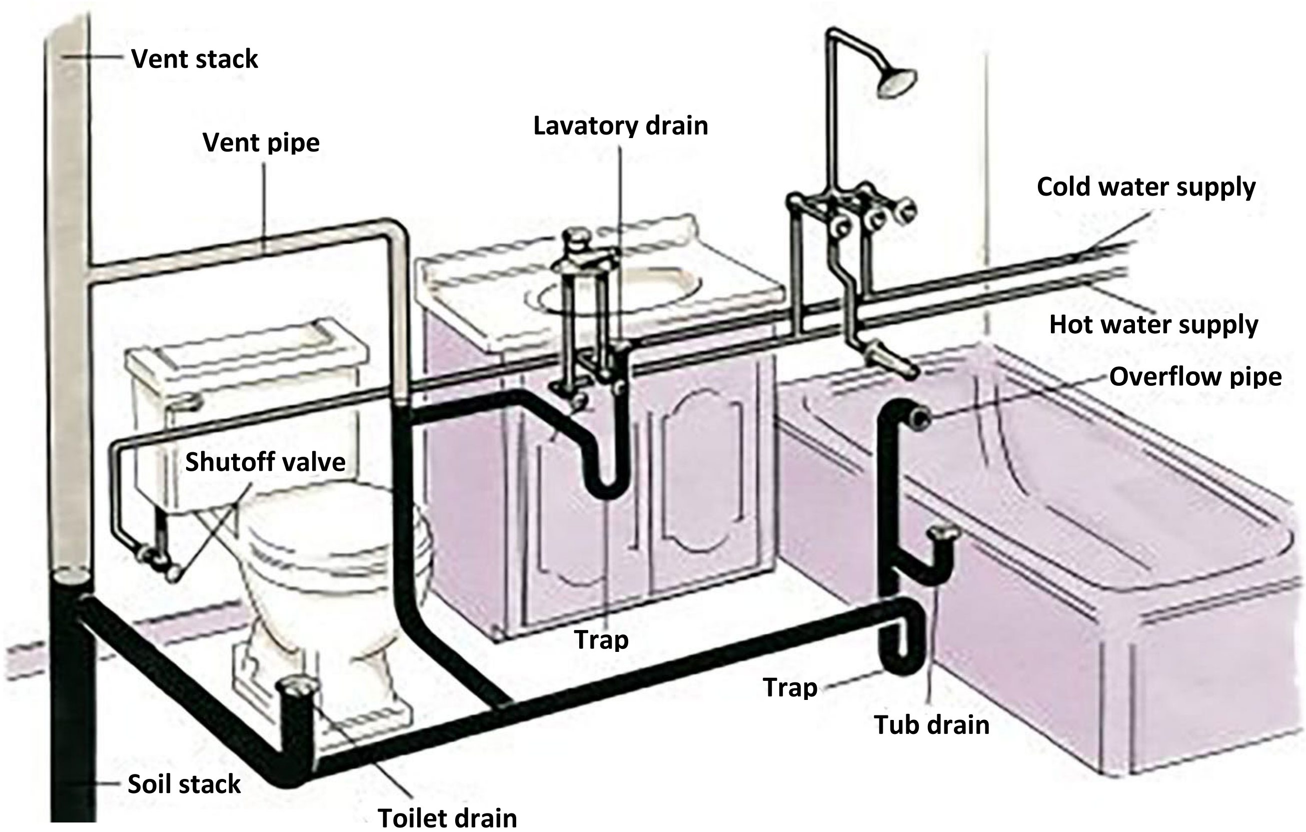
There are three main components of a building's plumbing system:

1. Water Supply System

Public system with water main
Private well
Harvesting rainwater

2. Sanitary Drain, Waste, Vent (DWV) System

Public sewer system
Private septic tank



Your home's supply and drainage system must always be two distinct subsystems, with no overlapping. At the fixtures (bridges between the two systems), the air admitted by the vent stack and vent pipes keeps the traps sealed and prevents sewer gases from backing up through the drains.

3. Stormwater Drainage System

The stormwater drainage system conveys rainwater and other precipatation to the storm sewer or other places of retention.

Rainwater is relatively clean and can be discharged into a natural drainage terminal, such as a drainage basin, without negatively affecting the ecology.

In most municipalities private buildings are required to have drainage systems that connect to the municipality storm sewer.

Water Supply and Distribution

Types of Water

Potable water is water which is fit for consumption by humans and other animals. Drinking water.

Gray water is untreated household waste water that has not come into contact with toilet waste. Gray water includes used water from bathtubs, showers, and bathroom wash basins, and water from clothes- washers and laundry tubs. It shall not include wastewater from kitchen sinks or dishwashers.

Blackwater is not fit for human consumption. Water that comes into contact with human waste and food is blackwater.

Water is often a scarce resource; nevertheless, almost 3/4 of potable water in the United States is used for irrigation and flushing toilets—where potable water is not generally required.

Water Supply and Distribution System in Commercial and Residential Applications is Comprised of:

Cold Water System

Supplies water at the standard water inlet temperature. Water supply lines are typically run underground outside a building, and the water in these lines will be at or near the underground temperature (approximately 55°F in most locations).

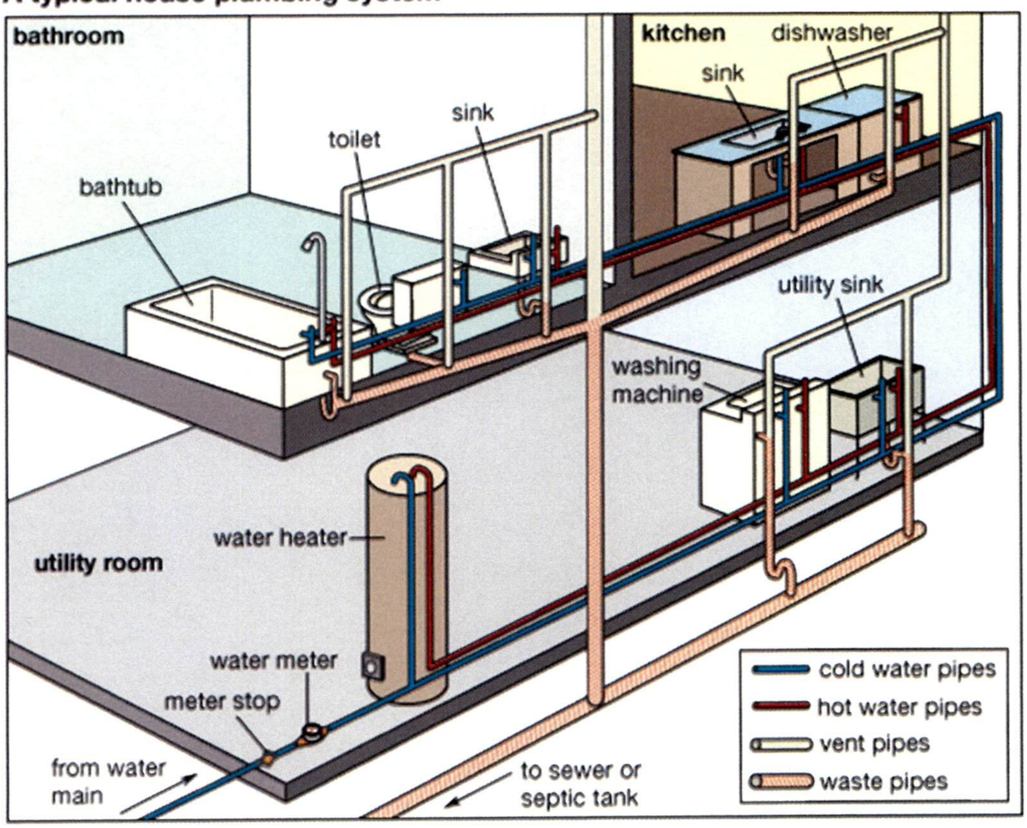
Hot Water System

Supplies fixtures (lavatory faucets, kitchen faucets, showerheads) and appliances (dishwasher, washing machine) with hot water.

A hot water heater, supplied with water from the cold water system, is used to heat the water to the desired temperature.

Standard outlet temperature of a hot water heater is 110°F to 120°F. Hospital, scouring, and other applications may require hotter water (140°F - 160°F).

A typical house plumbing system



Hot Water Recirculation

Hot water delivered over a great distance (100 feet or more), may require a recirculation system.

The hot water may either periodically or constantly circulate through the hot water supply system, keeping the water temperature at the desired level throughout the system.

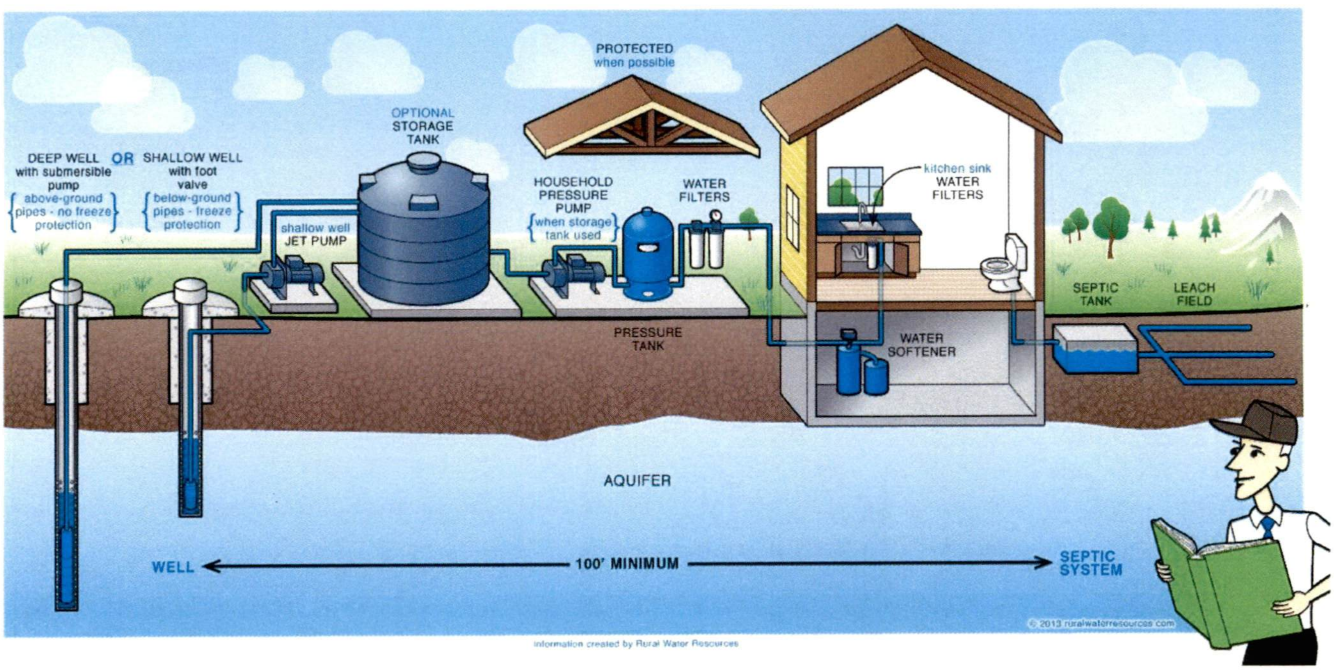
Building Water Service Line

- District Water System (utility main) - provided by the local water utility company

Plumbing Fixtures must be supplied with water at the flow rate and pressure required for proper operation.

- Private Well

Shallow Well – less than 25 feet
Deep Well – best source, little or no treatment



Processes building water supply may have to include before it is delivered to various building locations:
Pressure Regulation – reducing, increasing, balancing
Pressurization – booster pump and pressure tank
Filtration - strainers
Purification and Treatment – softening, reverse osmosis
Heating – boiler, domestic hot water
Cooling – chilling, chiller

Hydraulics

Hydraulics is the study of the physical principles that govern the behavior of liquids at rest and in motion.

Pressure

Static pressure, is measured when no water is flowing.
Dynamic pressure, is measured when water is flowing.

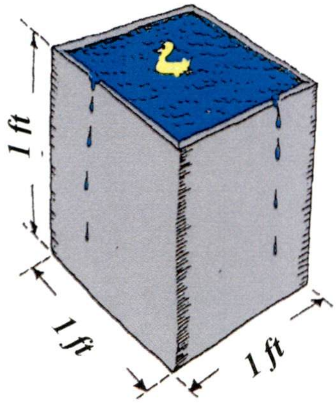
Static Pressure

Static pressure is caused by the weight of water above any point in the system.

Weight = Volume x Density   Density of Water (ρ) = 62.4 lb/ft^3

$$\text{Pressure} = \frac{\text{Weight}}{\text{Area}}$$

Determine the static pressure of each of the columns of water below. Forget the duck.



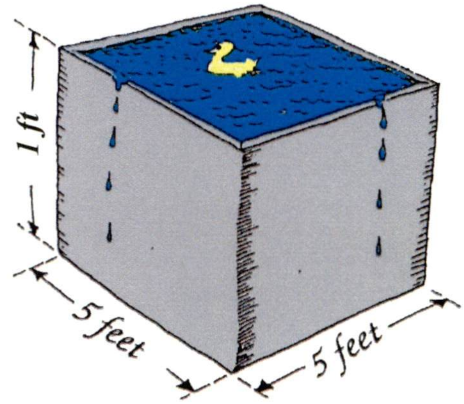
$$V = 1\,ft \times 1\,ft \times 1\,ft = 1\,ft^3$$

$$W = 1\,ft^3 \times \frac{62.4\,lb}{ft^3} = 62.4\,lb$$

$$P = \frac{62.4\,lb}{1\,ft^2} = 62.4\,\frac{lb}{ft^2}$$

$$= 62.4\,\frac{lb}{ft^2} \times \frac{1\,ft^2}{144\,in^2}$$

$$= 0.433\,psi$$



$$V = 5\,ft \times 5\,ft \times 1\,ft = 25\,ft^3$$

$$W = 25\,ft^3 \times \frac{62.4\,lb}{ft^3} = 1{,}560\,lb$$

$$P = \frac{1{,}560\,lb}{25\,ft^2} = 62.4\,\frac{lb}{ft^2}$$

$$= 62.4\,\frac{lb}{ft^2} \times \frac{1\,ft^2}{144\,in^2}$$

$$= 0.433\,psi$$

Static pressure is independent of the surface area or total volume of liquid and depends only on the depth, the height of liquid (water) "column" above the point in question.

Static pressure can be expressed in feet of water using the conversion of 1 ft of water equals 0.433 psi. Conversely, 1 psi = 1/0.433 = 2.31 ft of water

To convert psi to feet of water, multiply by 2.31 or divide by 0.433
To convert feet of water to psi, multiply by 0.433 or divide by 2.31

Since static pressure in a water system is caused by the weight of water, it is also referred to as hydrostatic pressure.

Municipal mains normally have a pressure between 40-80 psi.

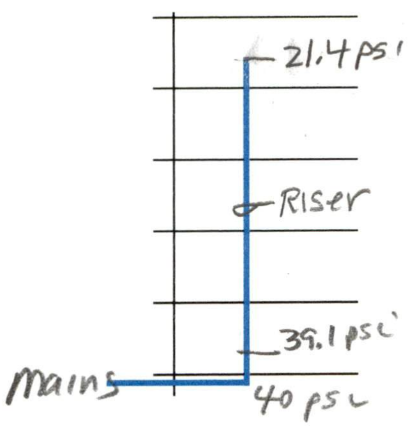
Line pressure above 80 psi cannot be used directly, it requires installation of a pressure reducing valve (PRV) as a code requirement, see 608.0 below.

Under no-flow conditions, the street mains pressure is reduced throughout the system vertically, by height.

Example 1.

a) What is the total hydrostatic pressure under no-flow conditions at the bottom of a water riser in a five-story building with 10 ft between floors and the highest fixture is 3 ft above the fifth floor?

Solution.



[4(10 ft) + 3 ft] x 0.433 psi/ft of water = 43 ft x 0.433 = 18.6 psi

If the mains pressure were at 40 psi, then under no-flow conditions the static pressure at the top fixture would be:

40 psi – 18.6 psi = 21.4 psi

Which is well below the permissible maximum fixture pressure of 80 psi.

b) Determine the pressure at a similar fixture 2 ft above the first floor, under no-flow conditions.

$$40 \text{ psi} - 2\text{ft}\left(0.433 \frac{\text{psi}}{\text{ft}}\right) = 39.1 \text{ psi}$$

608.0 Water Pressure, Pressure Regulators, Pressure Relief Valves, and Vacuum Relief Valves.

608.1 Inadequate Water Pressure. Where the water pressure in the main or other source of supply will not provide a residual water pressure of not less than 15 pounds force per square inch (psi) (103 kPa), after allowing for friction and other pressure losses, a tank and a pump or other means that will provide said 15 psi (103 kPa) pressure shall be installed. Where fixtures, fixture fittings, or both are installed that require residual pressure exceeding 15 psi (103 kPa), that minimum residual pressure shall be provided.

608.2 Excessive Water Pressure. Where static water pressure in the water supply piping is exceeding 80 psi (552 kPa), an approved-type pressure regulator preceded by an adequate strainer shall be installed and the static pressure reduced to 80 psi (552 kPa) or less. Pressure regulator(s) equal to or exceeding 1½ inches (40 mm) shall not require a strainer. Such regulator(s) shall control the pressure to water outlets in the building unless otherwise approved by the Authority Having Jurisdiction. Each such regulator and strainer shall be accessibly located aboveground or in a

Table 9.1 Minimum Pressure Required by Typical Plumbing Fixtures

Fixture Type	*Minimum Pressure, psi*
Sink and tub faucets	8
Shower	8
Water closet—tank flush	8
Flush valve—urinal	15
Flush valve—siphon jet bowl	
floor-mounted	15
wall-mounted	20
Flush valve—blowout bowl	
floor-mounted	20
wall-mounted	25
Garden hose	
5/8-in. sill cock	15
3/4-in. sill cock	30
Drinking fountain	15

Source. EPA Manual of Individual Water Supply System, 1975 and manufacturers' data.

When a fixture operates and water flows, the pressure equation changes completely.
Under flow conditions:
Total (mains) pressure = Static head + Friction head (loss) + Flow pressure

Static head – used to overcome height
Friction head – used to overcome the friction between the moving water and the piping
Flow pressure – used to impart kinetic energy (motion) to the water

Flow pressure – pressure available at the fixture when the outlet is wide open
It must equal or exceed the minimum pressure required for proper operation (Table 9.1) in order for the fixture flow to be adequate.

Example 2.
For the same five-story building in Example 1, assume the highest fixture is a sink faucet and that the total friction head loss from the mains to the fixture, including the water meter, piping and all fittings, is 10 psi. Would the fixture flow pressure be sufficient?

Solution.

Mains pressure	40 psi
Static head to top fixture	18.6 psi (43 ft high)
Friction head	10 psi
Flow pressure	?

Total (mains) pressure = Static head + Friction head (loss) + Flow pressure
Flow pressure = 40 psi – 18.6 psi – 10 psi = 11.4 psi

From Table 9.1 we see that this is sufficient for a faucet or a water closet tank but insufficient for a flush valve, which requires a minimum pressure of 15 psi.

The Design procedure reverses the order of the calculation.

Step 1. Determine the minimum flow pressure needed, from Table 9.1

Step 2. Calculate the maximum permissible system friction, and with that number size the piping

Example 3

Using the same building, assume a flush valve as the higher fixture:

Mains pressure	40 psi
Static head to top fixture	18.6 psi
Minimum flow pressure	15 psi
Maximum Friction head	?

Total (mains) pressure = Static head + Friction head (loss) + Flow pressure

40 psi = 18.6 psi + 15 psi + Maximum friction head

Maximum friction head = 40 psi – 18.6 psi – 15 psi = 6.4 psi

The piping would then need to be designed to give a maximum overall friction loss of 6.4 psi,

The piping design would provide this fixture, and all other, with sufficient pressure to deliver the minimum flow as listed in by code.

407.0 Lavatories.

407.1 Application. Lavatories shall comply with ASME A112.19.1/CSA B45.2, ASME A112.19.2/CSA B45.1, ASME A112.19.3/CSA B45.4, ASME A112.19.12, CSA B45.5/IAPMO Z124, or CSA B45.11/IAPMO Z401.

407.2 Water Consumption. The maximum water flow rate of faucets shall comply with Section 407.2.1 through Section 407.2.2.1.

407.2.1 Maximum Flow Rate. The maximum flow rate for public lavatory faucets shall not exceed 0.5 gpm at 60 psi (1.9 L/m at 414 kPa).

407.2.1.1 Kitchen Faucets. [HCD 1] *The maximum flow rate of kitchen faucets shall not exceed 1.8 gallons (6.81 L) per minute at 60 psi. Kitchen faucets may temporarily increase the flow above the maximum rate, but not to exceed 2.2 gallons (8.32 L) per minute at 60 psi, and must default to a maximum flow rate of 1.8 gallons (6.81 L) per minute at 60 psi.*

Note: *Where faucets meeting the maximum flow rate of 1.8 gpm (6.81 L) are unavailable, aerators or other means may be used to achieve reduction.*

407.2.1.2 Residential Lavatory Faucets. [HCD 1] *The maximum flow rate of residential lavatory faucets shall not exceed 1.2 gallons (4.54 L) per minute at 60 psi. The minimum flow rate of residential lavatory faucets shall not be less than 0.8 gallons (3.03 L) per minute at 20 psi.*

407.2.1.3 Lavatory Faucets in Common and Public Use Areas. [HCD 1 & HCD 2] *The maximum flow rate of lavatory faucets, installed in common and public use areas (outside of dwellings or sleeping units) in residential buildings, shall not exceed 0.5 gallons (1.89 L) per minute at 60 psi.*

407.2.2 Metering Faucets. Metered faucets shall deliver a maximum of 0.25 gallons (1.0 L) per metering cycle in accordance with ASME A112.18.1/CSA B125.1.

407.2.2.1 Metering Faucets. [BSC-CG] [DSA-SS & DSA-SS/CC] *Metering Faucets shall not deliver more than 0.20 gallons (0.76 L) per cycle in com-*

408.0 Showers.

408.1 Application. Manufactured shower receptors and shower bases shall comply with ASME A112.19.1/CSA B45.2, ASME A112.19.2/CSA B45.1, ASME A112.19.3/CSA B45.4, or CSA B45.5/IAPMO Z124.

408.2 Water Consumption. ***[HCD 1]*** *Showerheads shall have a maximum flow rate of 2.0 gallons (7.57 L) per minute measured at 80 psi and must comply with Division 4.3 of the California Green Building Standards Code (CALGreen).*

408.2.1 Single Showerhead. [BSC-CG] [DSA-SS & DSA-SS/CC] *Showerheads shall have a maximum flow rate of not more than 2.0 gallons (7.57 L) per minute at 80 psi. Showerheads shall be certified to the performance criteria of the U.S. EPA WaterSense Specification for Showerheads in compliance with Chapter 5, Division 5.3. of the California Green Building Standards Code (CALGreen).*

408.2.2 Multiple Showerheads Serving One Shower. [BSC-CG] [DSA-SS & DSA-SS/CC] *When a shower is served by more than one showerhead, the combined flow rate of all showerheads and/or other shower outlets controlled by a single valve shall not exceed 2.0 gallons (7.57 L) per minute at 80 psi, or the shower shall be designed to allow only one shower outlet to be in operation at a time in compliance with Chapter 5, Division 5.3. of the California Green Building Standards Code (CALGreen).*

Note: *A hand-held shower shall be considered a showerhead.*

Water Supply System

Upfeed system

When the pressure from the city mains is sufficient to overcome all friction in the system with the calculated flow and still maintain the minimum pressure needed at the highest outlet, the system used is called an upfeed system.

Will 40 psi minimum maintained city mains pressure be sufficient for the structure shown?

Assumptions

5 psi friction loss on the water meter
9 psi / 100 ft pressure loss in piping
Fittings add 50% to effective pipe length

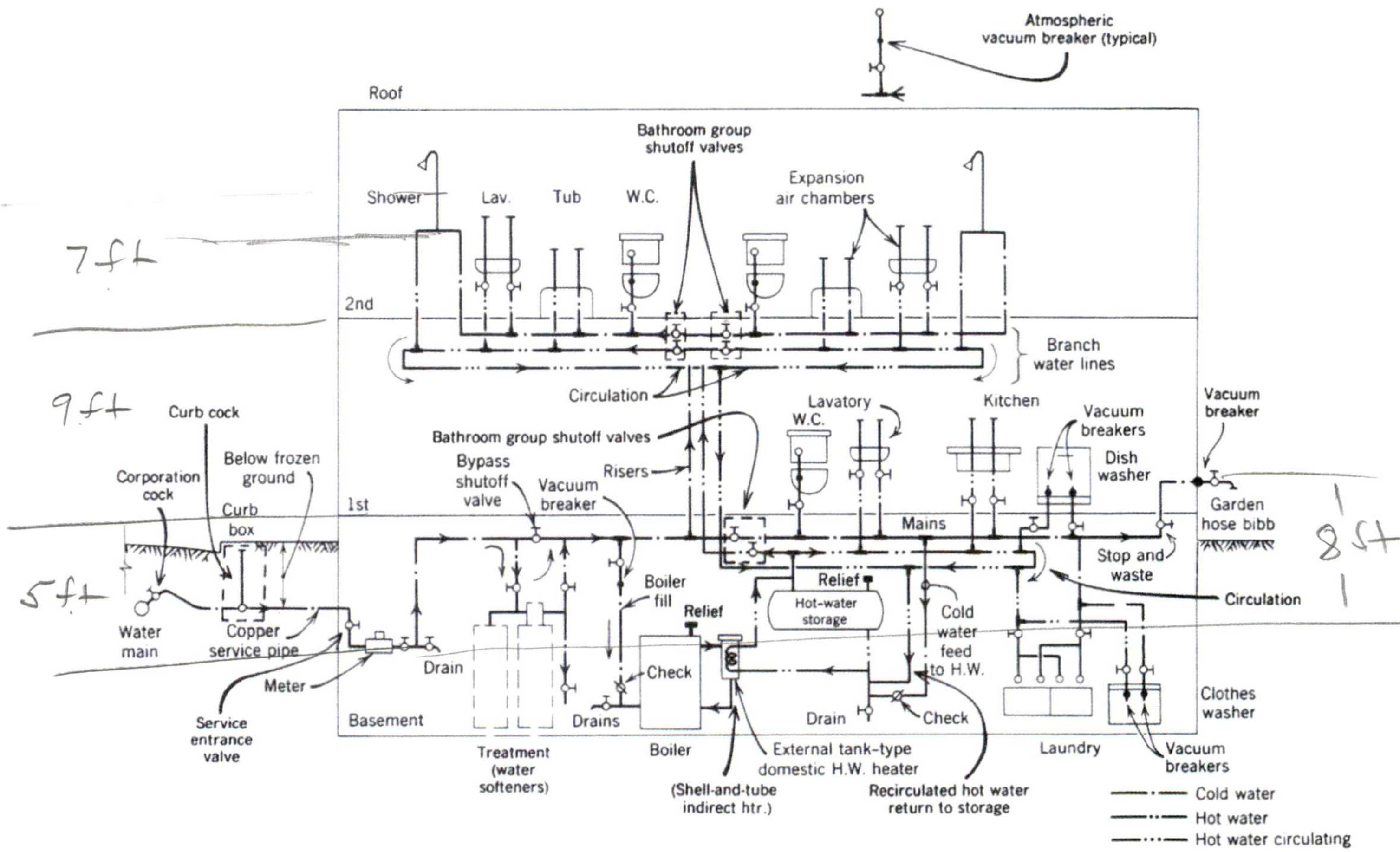
Distance from water main to the farthest fixtures:
Second-floor shower head = 90 ft
Garden hose bibb = 60 ft

9 ft floor height
5 ft from mains to first-floor

From Table 9.1:
Required minimum flow pressures are:
8 psi – showerhead
15 psi – 5/8-in sillcock

Highest fixture is the shower head:
Shower head – 7 ft above the second floor
Total height = 5 ft + 9 ft + 7 ft = 21 ft

Garden hose bibb is 8 ft above the water main



Schematic plumbing section of an upfeed water distribution system using city mains pressure. The building is a two-story residence.

Shower

Fixture pressure = Mains pressure – Static head – Total friction

meter Friction loss

$$= 40\,psi - 21\,ft\left(\frac{0.433\,psi}{ft}\right) - 5\,psi - (150\%\text{ of }90ft)\left(\frac{9\,psi}{100\,ft\text{ pipe}}\right)$$

$$= 40\,psi - 9.1\,psi - 5\,psi - 12.2\,psi$$

$= 13.7$ psi; adequate for a shower

Hose bibb

Fixture pressure = Mains pressure – Static head – Total friction

$$= 40\,psi - 8\,ft\left(\frac{0.433\,psi}{ft}\right) - 5\,psi - (1.5 \times 60\,ft)\left(\frac{9\,psi}{100\,ft}\right)$$

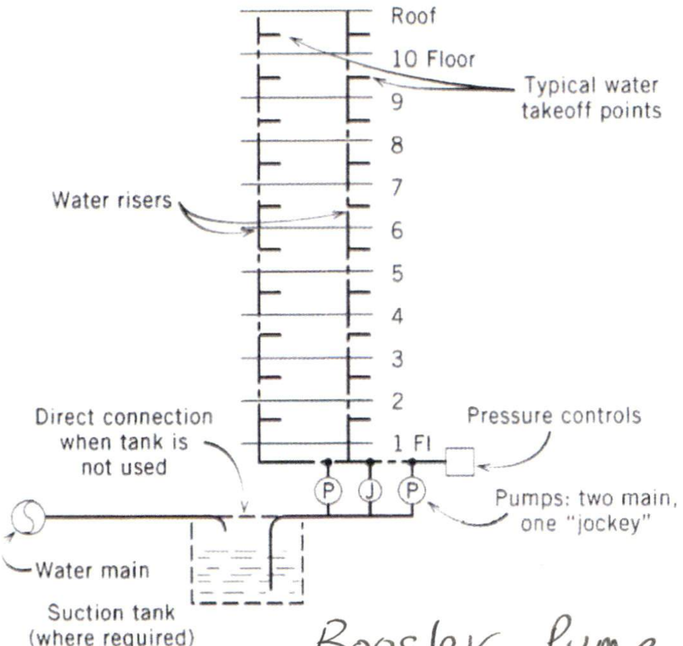
$$= 40\,psi - 3.5\,psi - 5\,psi - 8.1$$

$= 23.4$ psi, adequate for a hose bibb (15 psi req)

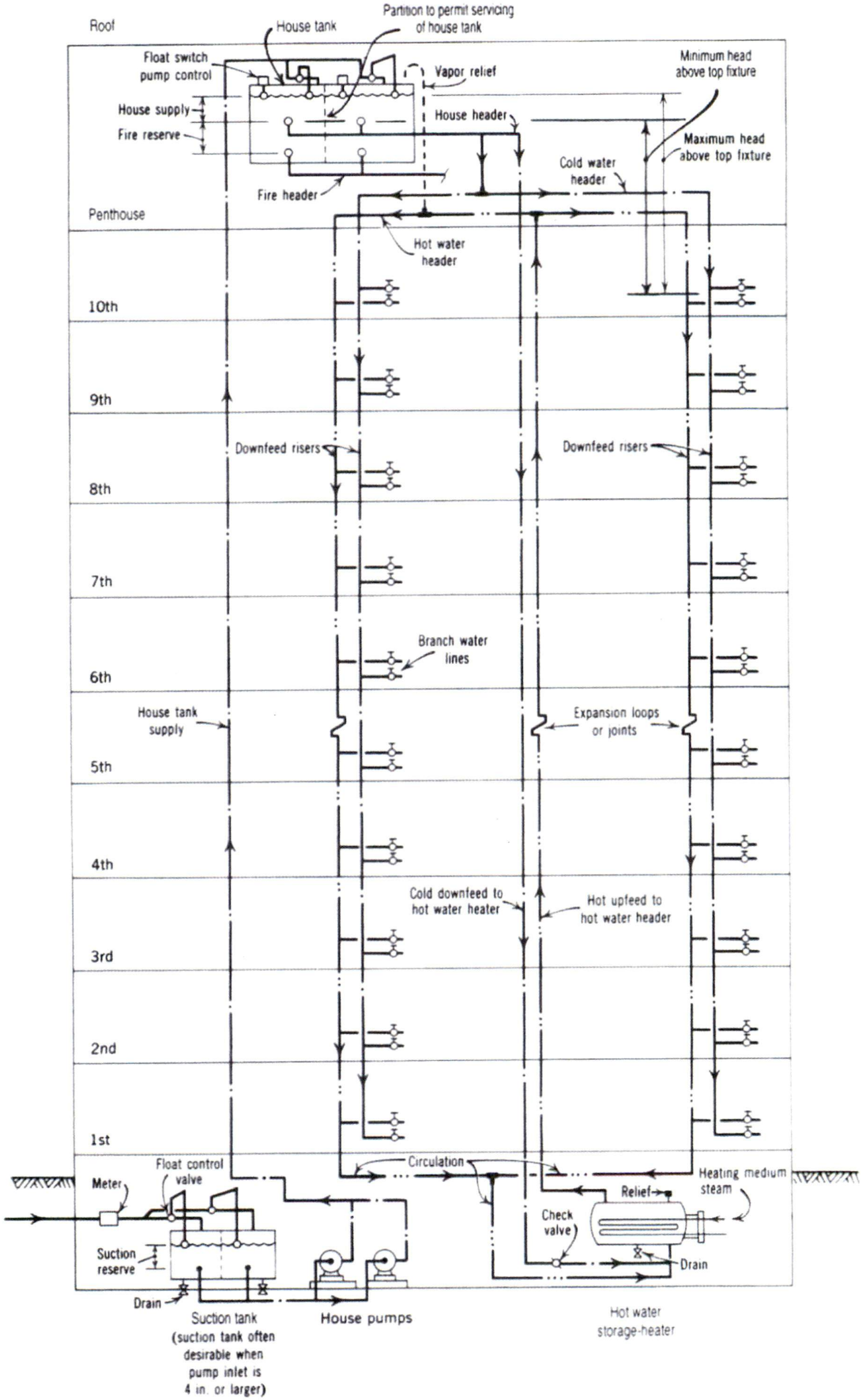
If the hose bibb was a ¾-in, requiring 30 psi, would the mains pressure be adequate? NO

Downfeed System

When the street main pressure is insufficient, the design can either use a *roof tank* and *downfeed system* or *booster pump upfeed system*.



Booster Pump, Upfeed



Roof
House tank
Partition to permit servicing of house tank
Float switch pump control
Vapor relief
Minimum head above top fixture
House supply
Fire reserve
House header
Maximum head above top fixture
Cold water header
Fire header
Penthouse
Hot water header
10th
9th
Downfeed risers
Downfeed risers
8th
7th
Branch water lines
6th
House tank supply
Expansion loops or joints
5th
4th
Cold downfeed to hot water heater
Hot upfeed to hot water header
3rd
2nd
1st
Float control valve
Circulation
Meter
Heating medium steam
Relief
Check valve
Suction reserve
Drain
Drain
Suction tank (suction tank often desirable when pump inlet is 4 in. or larger)
House pumps
Hot water storage-heater