COLD-HOT WATER SUPPLY FOR BUILDINGS

1. Water in Cities

Throughout history, in nearly all climates and cultures, the designer's major concern about water was **how to keep it *out* of a building**.

Only since the end of 19th century has a water supply *within* a building become common place in industrialized countries.

In the rest of the world today, running water is still not available within most buildings.

Water's Contribution to Human Life

Food The amount of pure (potable) water that we need for drinking and cooking is very small – only about 11.4 L/capita.day in most developed countries.

Cleansing and Hygiene Water is a ideal medium for the dissolution and transport of organic waste.
Much larger quantities of water are used for cleaning than for food; in developed countries, about 53 L/ capita.day is used for clothes washing and dishwashing, and another 79.5 L/ capita.day is used for bathing and personal hygiene.

Historic Review on Public Water Supply

The city of Rome had the largest concentration of aqueducts, with water being supplied by eleven aqueducts constructed over a period of about 500 years.

Roman aqueduct in Segovia, Spain

Satelite view of Segovia, Spain

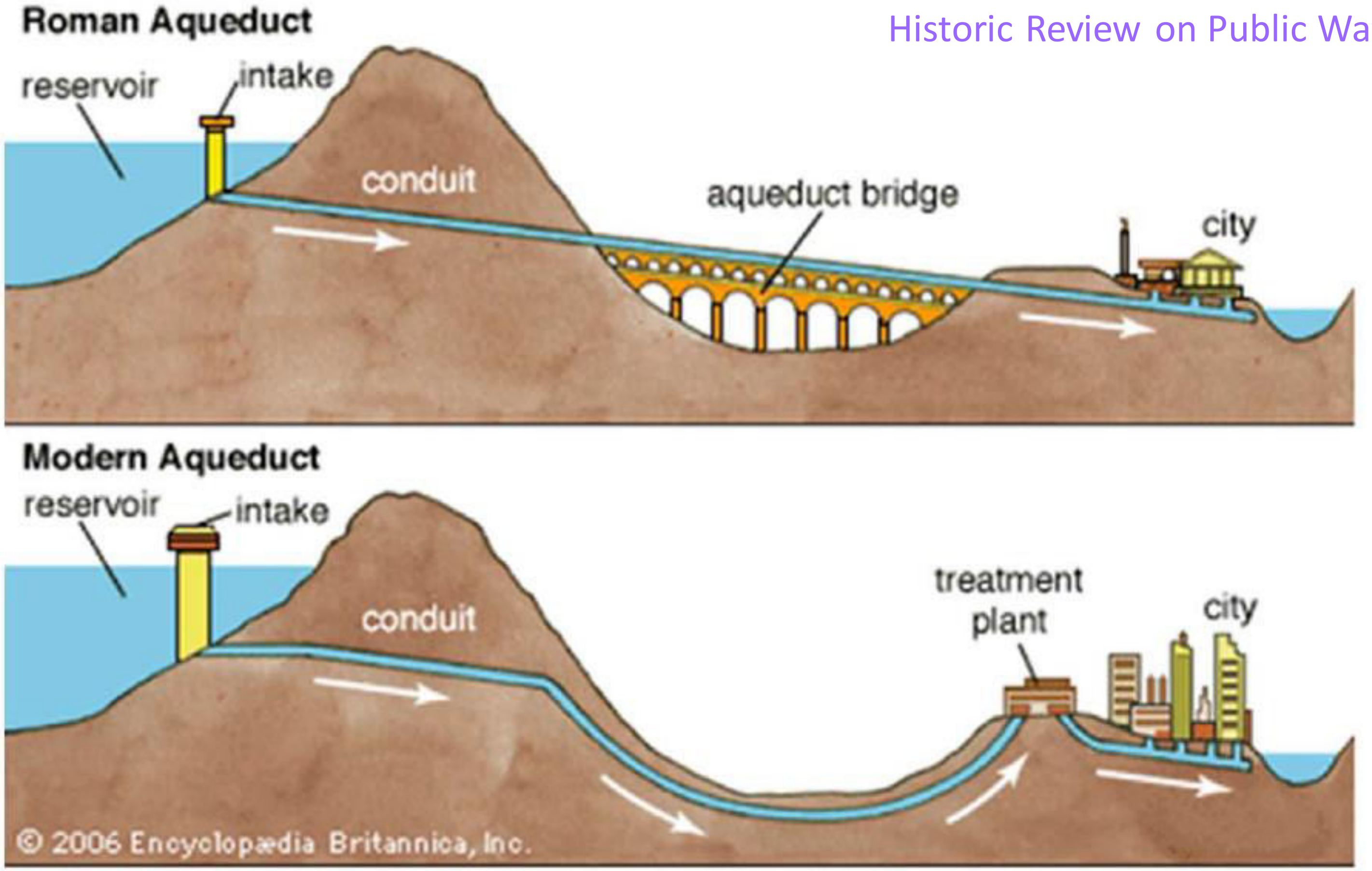
Historic Review on Public Water Supply

They served potable water and supplied the numerous baths and fountains in the city, as well as finally being emptied into the sewers, where the once-used gray water performed their last function in removing waste matter.

In addition to aqueducts, the Romans built many more channels excavated in the ground, usually with a clay lining (leats). They could serve industrial sites such as gold mines, lead and tin mines, forges, water-mills and thermae (public baths).

1. Water in Cities

Historic Review on Public Water Supply



2. Domestic water distribution systems

Water distribution systems provide ways to supply water throughout buildings at pressure sufficient to **operate plumbing fixtures**.

Smaller buildings may be served simply by the pressure available in water mains (or pressure tanks fed by pumped wells). This is called ***upfeed distribution***.

For taller buildings, several other options are available:

- ***Downfeed.*** Pumps raise the water to storage tanks at the top of a building, and water then drops down to the plumbing fixtures.
- ***Pumped upfeed.*** Pumps supply the additional pressure needed.
- ***Hydropneumatic feed.*** Pumps force water into sealed tanks, compressing the air within the tanks to maintain the needed water pressure.

Determination of domestic water system load

The required water capacity of a building depends on the **coincidental peak load demand** (**CPLD**) of all load categories, based on **an assumed time of day in the heavy demand season**.

For example, the highest CPLD for an office building is when it is fully occupied, plumbing facilities are in heavy use, and air conditioning is near its peak.

The highest CPLD for an apartment building would be around dinner time in the summer, when most people are home taking showers, washing, and preparing meals.

Domestic water system loads may be grouped into the following categories:

- Plumbing facilities
- Food service – preparation, refrigeration, washing, dining, etc.
- Research and process – laboratory equipment, commercial or industrial processes, computer equipment
- Heating and cooling systems
- Laundry
- Exterior – lawn and plant irrigation, fountains, etc.
- Pools – swimming pools, whirlpools, therapeutic pools
- Fire protection (if combined with the domestic system)

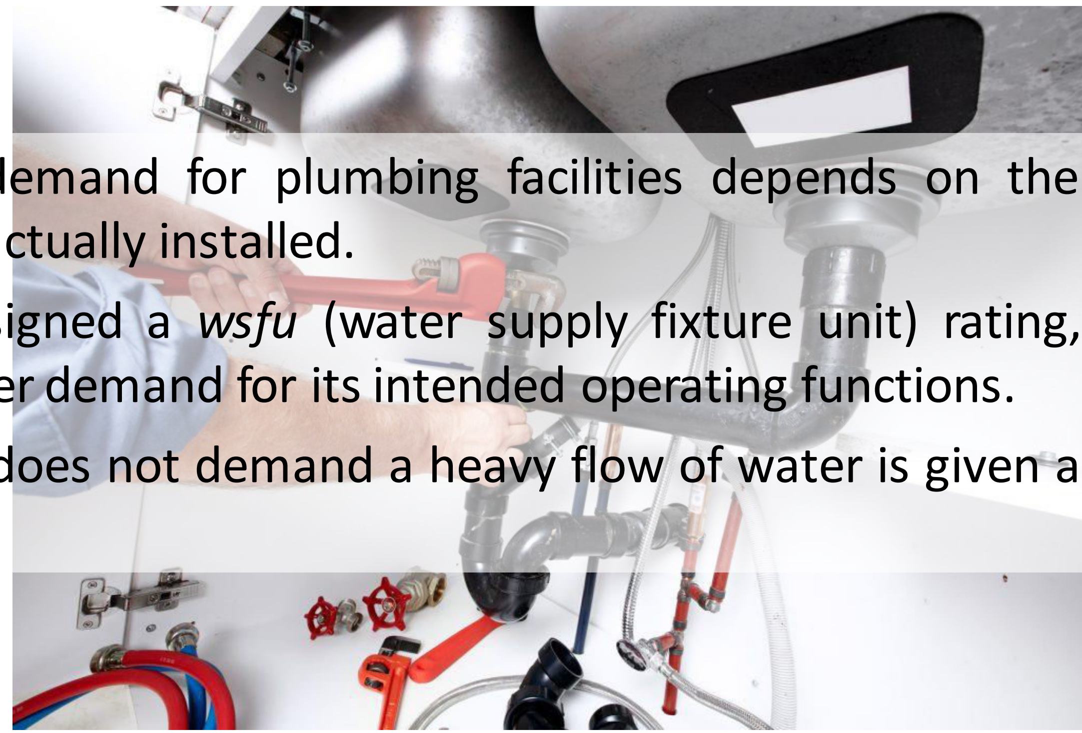
Determination of domestic water system load

1 wsfu (water supply fixture unit) = 3.8 to 5.7 L/min

- ***Plumbing facilities***. Water demand for plumbing facilities depends on the number and type of fixtures actually installed.

  Each plumbing fixture is assigned a *wsfu* (water supply fixture unit) rating, representing the relative water demand for its intended operating functions.

  For example, a lavatory that does not demand a heavy flow of water is given a wsfu of 1.



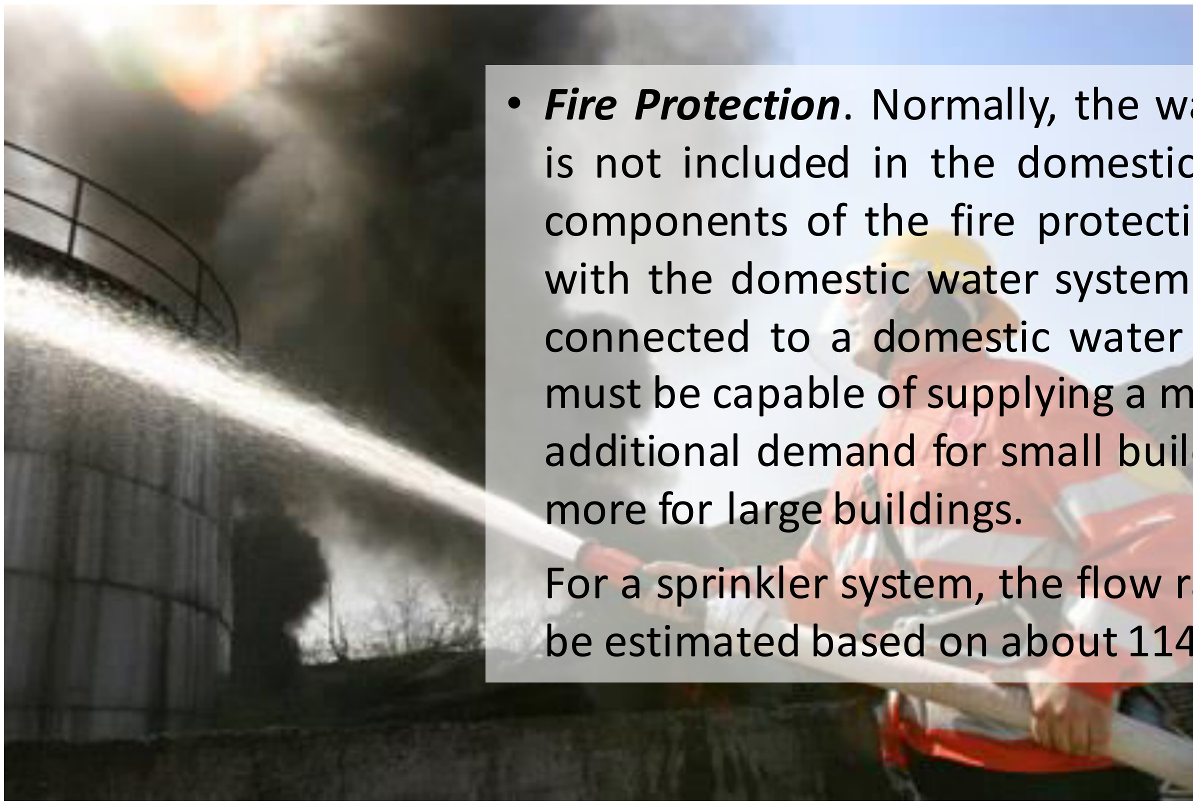
Determination of domestic water system load

- ***Exteriors***. Water demand load for exteriors depends on the size of the lot and the portion that is landscaped. No generalization can be made and the demand load must be determined on a project-by-project basis.
  - Manual watering of plants and lawns: 18.9 to 56.8 L/min
  - Landscape sprinkler system: 3.8 to 38 L/min
  - Fountain: usually designed for recirculation

Determination of domestic water system load

- ***Swimming Pools***. Normally, the flow rate of the circulation pump is designed to turn over (circulate) the entire volume of water in the pool in 6-8 hs or 3-4 times in 24 hs.

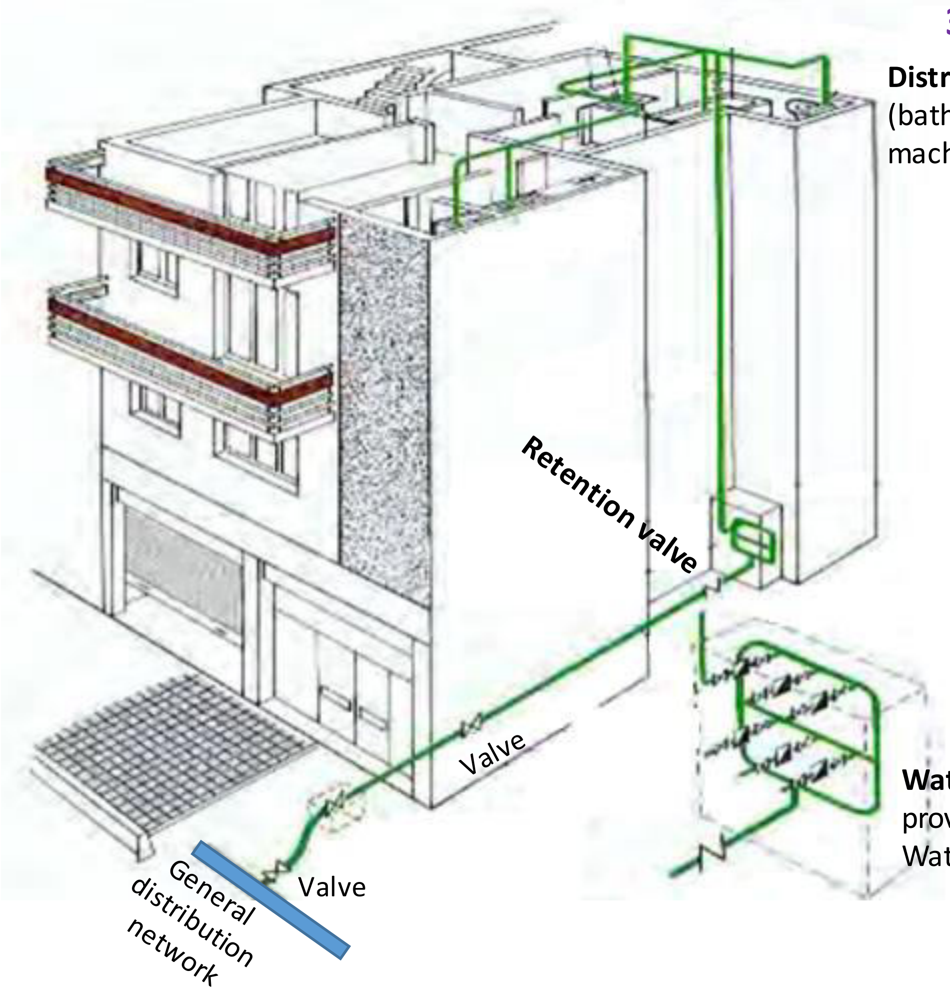
Determination of domestic water system load



- ***Fire Protection***. Normally, the water supply for fire protection is not included in the domestic water system; however, the components of the fire protection system may be combined with the domestic water system. When a standpipe system is connected to a domestic water system, the domestic system must be capable of supplying a minimum of about 379 L/min of additional demand for small buildings, to about 1893 L/min or more for large buildings.

  For a sprinkler system, the flow rate of each sprinkler head can be estimated based on about 114 L/min

3. Domestic water distribution systems



Determination of domestic water system load

Water Supply Fixture Units (WSFU)

Fixture	Occupancy	Type of Supply Control	Load Values in WSFU Cold	Hot	Total
Bathroom group	Private	Flush tank	2.7	1.5	**3.6**
Bathroom group	Private	Flush valve	6	3	**8**
Bathtub	Private	Faucet	1	1	**1.4**
Bathtub	Public	Faucet	3	3	**4**
Bidet	Private	Faucet	1.5	1.5	**2**
Combination fixture	Private	Faucet	2.25	2.25	**3**
Dishwashing machine	Private	Automatic		1.4	**1.4**
Drinking fountain	Offices, etc.	⅜" (9.5 mm) valve	0.25		**0.25**
Kitchen sink	Private	Faucet	1	1	**1.4**
Kitchen sink	Hotel, restaurant	Faucet	3	3	**4**
Laundry trays (1 to 3)	Private	Faucet	1	1	**1.4**
Lavatory	Private	Faucet	0.5	0.5	**0.7**
Lavatory	Public	Faucet	1.5	1.5	**2**
Service sink	Offices, etc.	Faucet	2.25	2.25	**3**
Shower head	Public	Mixing valve	3	3	**4**
Shower head	Private	Mixing valve	1	1	**1.4**
Urinal	Public	1" (25 mm) flush valve	10		**10**
Urinal	Public	¾" (19 mm) flush valve	5		**5**
Urinal	Public	Flush tank	3		**3**
Washing machine (8 lbs) (3.6 kg)	Private	Automatic	1	1	**1.4**
Washing machine (8 lbs) (3.6 kg)	Public	Automatic	2.25	2.25	**3**
Washing machine (15 lbs) (6.8 kg)	Public	Automatic	3	3	**4**
Water closet	Private	Flush valve	6		**6**
Water closet	Private	Flush tank	2.2		**2.2**
Water closet	Public	Flush valve	10		**10**
Water closet	Public	Flush tank	5		**5**
Water closet	Public or private	Flushometer tank	2		**2**

Source: International Plumbing Code. © 1997, International Code Council, Falls Church, VA. Reprinted with permission.

Sizing of Water Pipes

A water system must be maintained with positive pressure to establish a flow in the distribution system and through the plumbing fixtures or equipment.

Furthermore, positive water pressure prevents water from being contaminated by external sources, since at a positive pressure, water tends to leak out of the pipe.

Water pressure should be sufficient to overcome any pressure loss due to friction, differences in elevation, and flow pressure at outlets or equipment.

Minimum Flow Pressure for Fixture or Equipment

- Every plumbing fixture or connection that uses water must have the proper pressure to maintain the required flow.
- Minimum fixture pressures vary from 28 to 138 kPa for fixtures.
- Because the pressure in street main is usually about 345 kPa, it is possible to assure the minimum fixture pressure, provided that the water does not have to be lifted to too great a height and not too much pressure is lost by friction in distribution piping.

Sizing of Water Pipes

Flow and Pressure to Typical Plumbing Fixtures

Fixture Served	Minimum Flow Rate (gpm)	Minimum Flow Rate (L/s)	Minimum Pressure (psi)	Minimum Pressure (kPa)	Maximum Flow Rate or Quantity	
Bathtub	4	0.252	8	55.158		
Bidet	2	0.126	4	27.579		
Combination fixture	4	0.252	8	55.158		
Dishwasher, residential	2.75	0.173	8	55.158		
Drinking fountain	0.75	0.047	8	55.158		
Laundry tray	4	0.252	8	55.158		
Lavatory, private	2	0.126	8	55.158	2.5 gpm @ 80 psi	0.158 L/s @ 551.50 kPa
Lavatory, public	2	0.126	8	55.158	2.5 gpm @ 80 psi	0.158 L/s @ 551.50 kPa
Lavatory, public, metering or self-closing	2	0.126	8	55.158	0.25 gallon (0.946 L) per metering cycle	
Shower head	3	0.189	8	55.158	2.5 gpm @ 80 psi	0.158 L/s @ 551.50 kPa
Shower head, temperature controlled	3	0.189	20	137.895	2.5 gpm @ 80 psi	0.158 L/s @ 551.50 kPa
Sink, residential	2.5	0.158	8	55.158	2.5 gpm @ 60 psi	0.158 L/s @ 413.685 kPa
Sink, service	3	0.189	8	55.158	2.5 gpm @ 60 psi	0.158 L/s @ 413.685 kPa
Urinal, valve	15	0.946	15	103.421	1.5 gal (5.7 L) per flushing cycle	
Water closet, blow out, flushometer valve	35	2.208	25	172.369	4 gal (15 L) or 1.6 gal (6 L) per flushing cycle	
Water closet, siphonic, flushometer valve	25	1.577	15	103.421	4 gal (15 L) or 1.6 gal (6 L) per flushing cycle	
Water closet, tank, close coupled	3	0.189	8	55.158	1.6 gal (6 L) per flushing cycle	
Water closet, tank, one piece	6	0.379	20	137.895	1.6 gal (6 L) per flushing cycle	

For SI: 1 psi = 6.895 kPa, 1 gpm = 0.063 L/s (3.785 L/min)

Sizing of Water Pipes

Excessive friction results from piping that:

- Is too long in developed length (actual distance of water flow)
- That interposes too many fittings (such as elbows and tees),
- Is too small in diameter

The pressure losses in an upfeed system served by street main pressure are as follows:

Minimum fixture flow pressure (for the highest, most remote fixture from street)	A
Pressure loss due to height	B
Pressure loss due to friction in piping	C
Pressure loss by flow through water meter	D

Total required street main pressure: E = A + B + C + D

Sizing of Water Pipes

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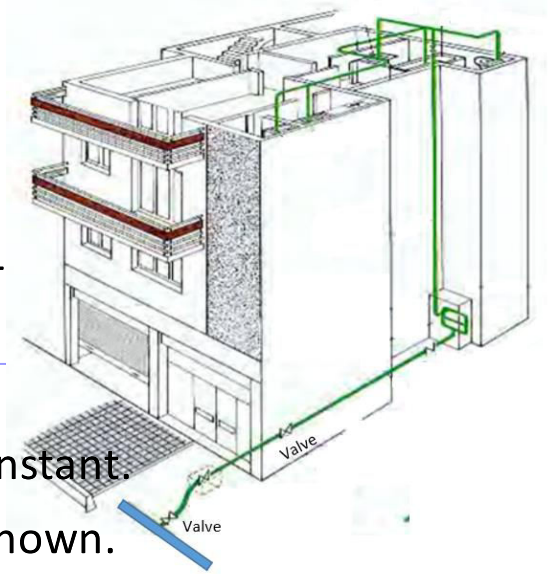


During design, items A, B, and E are known and are reasonably constant.

Item D depends upon flow and pipe size, neither of which is yet known.

Item D is estimated. For residences and small commercial building, the meter size rarely exceeds 50 mm.

This leaves one unknown, the value of $\boxed{C = E - (A + B + D)}$

Sizing of Water Pipes

Example

Using the following data, find the proper size for a water supply pipe.

Street main pressure (minimum) = 345 kPa

Height of topmost fixture above main = 9 m (1)

Topmost fixture type = Water closet
with *flush valve* using 6 L water per flush

Fixture units in the system = 85 wsfu (2)

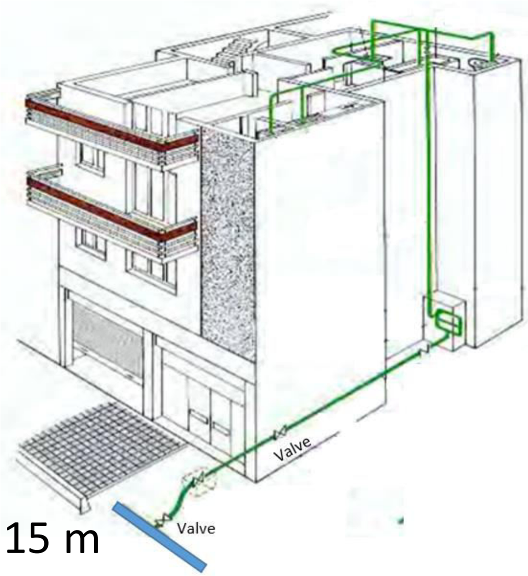
Total length of the piping

(to the highest and most remote fixture) = 30 m

Equivalent pipe length of fittings (elbows, tees and valves) = 15 m

(commonly estimated at 50% of the developed length)

System uses predominantly = *Flush valves*



Sizing of Water Pipes

Example

Notes:

(1) Height of topmost fixture above main = 9 m —— (9.8 kPa/m) → 88.2 kPa

(2) Fixture units in the system = 85 wsfu

—— (1 wsfu = 3.8 – 5.7 L/min = 0.0633 – 0.095 L/seg) → $\boxed{5.5}$ – 8.0 L/seg

Sizing of Water Pipes

Solution

From the **minimum street main pressure**, subtract the sum of the fixture pressure, the static head, and the pressure lost in the meter. This sum is:

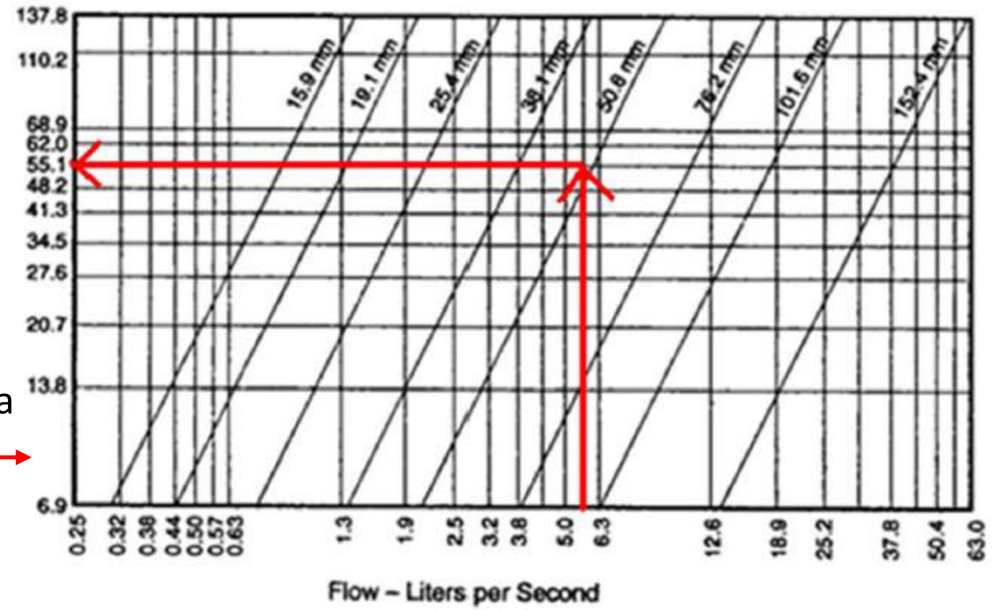
A: fixture pressure = 103.421 kPa

Flow and Pressure to Typical Plumbing Fixtures				
Fixture Served	Minimum Flow Rate (gpm)	(L/s)	Minimum Pressure (psi)	(kPa)
Water closet, siphonic, flushometer valve	25	**1.577**	15	**103.421**

B: static head 9 m x 9.8 kPa/m = 88.2 kPa

D: pressure losses in meter (85 wsfu) = 55.1 kPa

Subtotal (A+B+D) = **246.721 kPa**



Pressure losses in disk-type water meters

C: max. pressure loss due to friction

C = E-(A+B+D) = 345 – 246.721 = 98.279 kPa

Sizing of Water Pipes

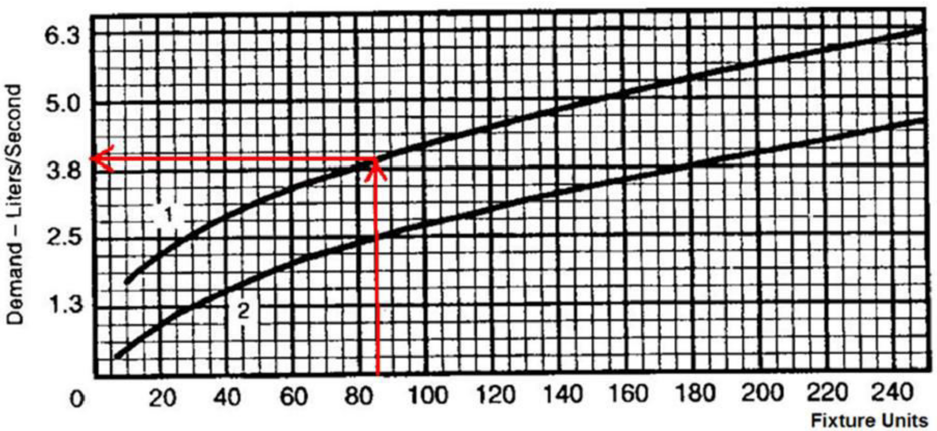
Solution

The pressure lost in 30 m (total length) of piping plus 15 m of piping equivalent to the pressure lost by friction **in the fittings** became **98.279 kPa**.

The friction loss in the pipe (30 m) will be [98.279 kPa / (30 + 15)] x 30 = 65.52 kPa in 30m

Then, the **friction loss per unit meter of pipe** will be: 65.519 kPa ÷ 30 m = **2.184 kPa/m** (218.4 Pa/m)

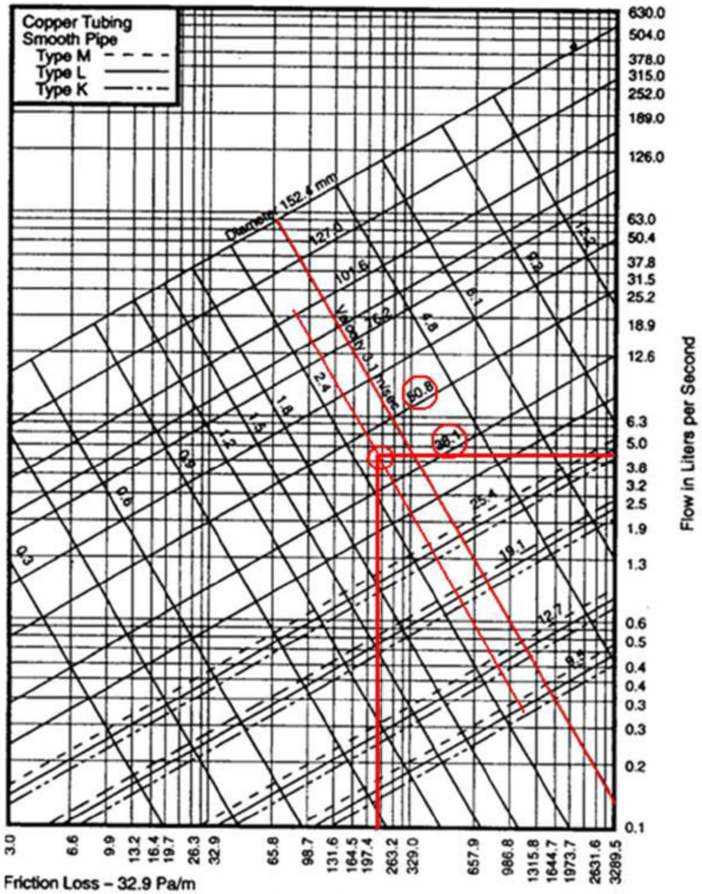
From below figure, curve 1, a flush-valve system with 85 wsfu will have a probable flow of about 4.0 L/s.



Estimate curve for flow (L/s) based upon total WSFU

Curve 1 is for a system of predominantly flush valves.
Curve 2 is for a system of predominantly flush tanks.

Sizing of Water Pipes



Recommended max. velocity - not to exceed 3.1 m/s (10 ft/s)

Solution

Given this information, enter 4 L/s and 218.4 Pa/m.

At the intersection of these lines, the **pipe diameter** and **velocity** are determined.

Pipe diameter: between 38.1 to 50.8 mm

Water velocity: about 2.75 m/s

Therefore, 50.8 mm supply pipe will be chosen with a 50.8 mm water meter.

Next

HOT-WATER SYSTEM

Design considerations for water distribution systems

- ***Piping Material***
- ***Thermal Insulation***
- ***Preventing Backflow***
- ***Vacuum breaker***
- ***Shock Absorption***

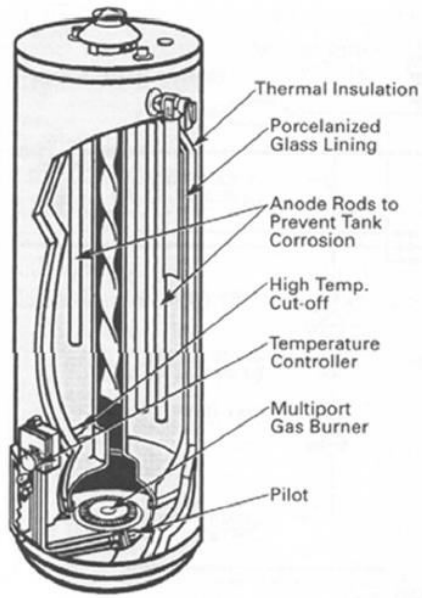
Plumbing Fixtures

Fixture units

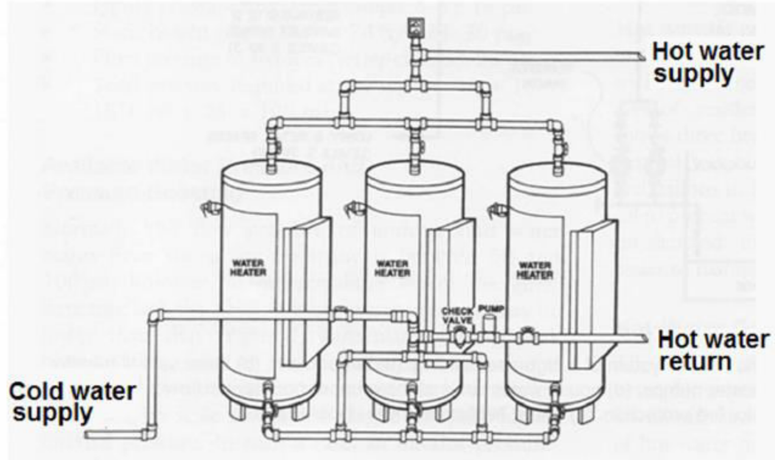
Bibliography

HOT-WATER SYSTEM

Source of energy: oil, gas, steam, or electricity

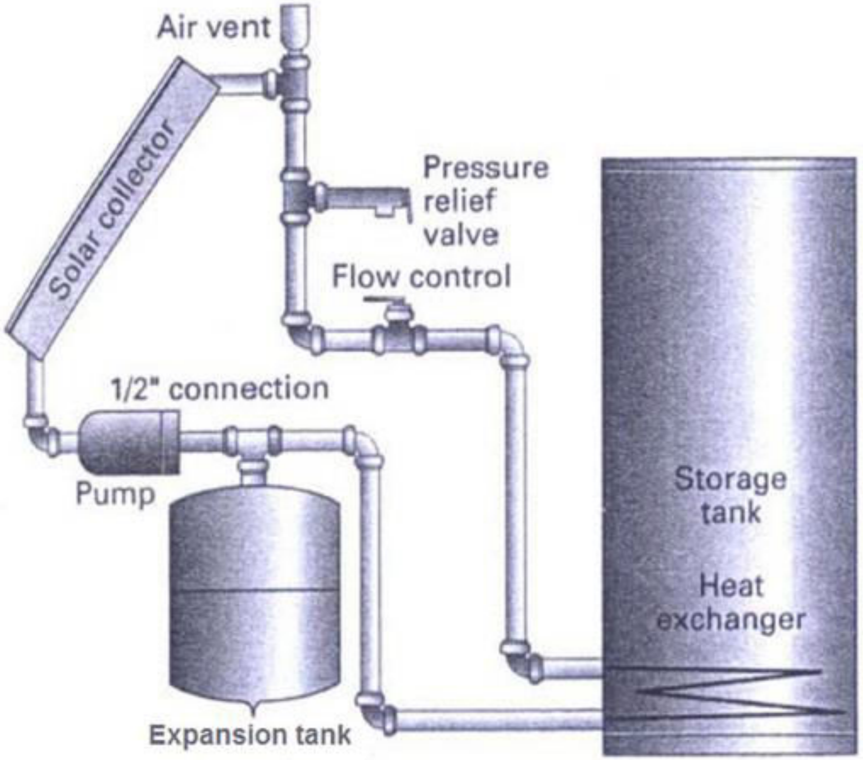


Cutaway view of a typical gas-fired residential water heater. (Courtesy: State Industries, Inc., Ashland, TN.)



Manifold piping connection of three water heaters in parallel. (Courtesy: State Industries, Inc., Ashland, TN.)

HOT-WATER SYSTEM



Solar-energy-heated water heating system

HOT-WATER SYSTEM. Hot-water demand (Quantity)

Domestic Hot Water, Commercial/Institutional

Type of Building	Maximum Hour	Maximum Day	Average Day
Mens dormitories	3.8 gal (14.4 L)/student	22.0 gal (83.4 L)/student	13.1 gal (49.7 L)/student
Women's dormitories	5.0 gal (19 L)/student	26.5 gal (100 L)/student	12.3 gal (46.6 L)/student
Motels: no. of units			
20 or less	6.0 gal (23 L)/unit	35.0 gal (132.6 L)/unit	20.0 gal (75.8 L)/unit
60	5.0 gal (20 L)/unit	25.0 gal (94.8 L)/unit	14.0 gal (53.1 L)/unit
100 or more	4.0 gal (15 L)/unit	15.0 gal (56.8 L)/unit	10.0 gal (37.9 L)/unit
Nursing homes	4.5 gal (17 L)/bed	30.0 (114 L)/bed	18.4 gal (69.7 L)/bed
Office buildings	0.4 gal (1.5 L)/person	2.0 gal (7.6 L)/person	1.0 gal (3.8 L)/person
Food service facilities:			
Type A - full meal restaurants and cafeterias	1.5 gal (5.7 L)/max meals/h	11.0 gal (41.7 L)/max meals/h	2.4 gal (9.1 L)/avg meals/day[b]
Type B - drive-ins, grills, sandwitch and snack shops	0.7 gal (2.6 L)/max meals/h	6.0 gal (22.7 L)/max meals/h	0.7 gal (2.6 L)/avg meals/day[b]
Apartment houses: no. of apartments			
20 or less	12.0 gal (45.5 L)/apt.	80.0 gal (303.2 L)/apt.	42.0 gal (159.2 L)/apt.
50	10.0 gal (37.9 L)/apt.	73.0 gal (276.7 L)/apt.	40.0 gal (151.6 L)/apt.
75	8.5 gal (32.2 L)/apt.	66.0 gal (250 L)/apt.	38.0 gal (144 L)/apt.
100	7.0 gal (26.5 L)/apt.	60.0 gal (227.4 L)/apt.	37.0 gal (140.2 L)/apt.
200 or more	5.0 gal (19 L)	50.0 gal (195 L)/apt.	35.0 gal (132.7 L)/apt.
Elementary schools	0.6 gal (2.3 L)/student	1.5 gal (5.7 L)/student	0.6 gal (2.3 L)/student[b]
Junior and senior high schools	1.0 gal (3.8 L)/student	3.6 gal (13.6 L)/student	1.8 gal (6.8 L)/student[b]

HOT-WATER SYSTEM. Hot-water demand (Temperature)

Representative Hot Water Temperatures

Use	°C
Lavatory	
Hand washing	40
Shaving	45
Showers and tubs	43
Therapeutic baths	35
Commercial and institutional laundry (based on fabric)	Up to 82
Residential dish washing and laundry	60
Surgical scrubbing	43
Commercial spray-type dishwashing	
Wash	65 minimum
Final rinse	82 to 90

Design considerations for water distribution systems.

Piping Material

Copper: most commonly used water-piping material because of its strength, durability, and resistance to corrosion.

Stainless steel: sometimes used in lieu of copper when the sulfur content in the water or air is high, as in the area of hot springs.

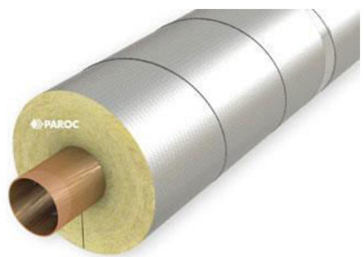
Hot-dipped galvanized steel: economical to use for larger pipes.

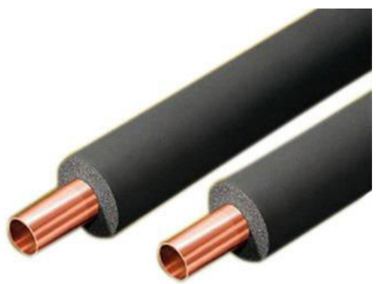
Plastic: used for water distribution because of its lower cost, corrosion resistance, and low potential for scaling.

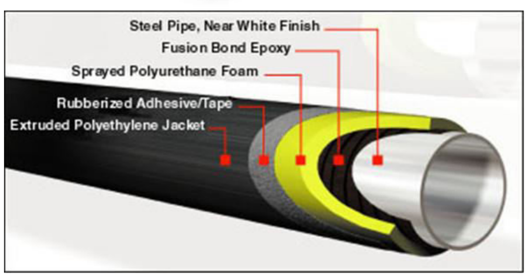
Design considerations for water distribution systems.

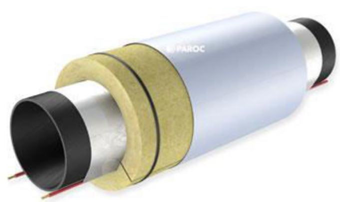
Thermal Insulation

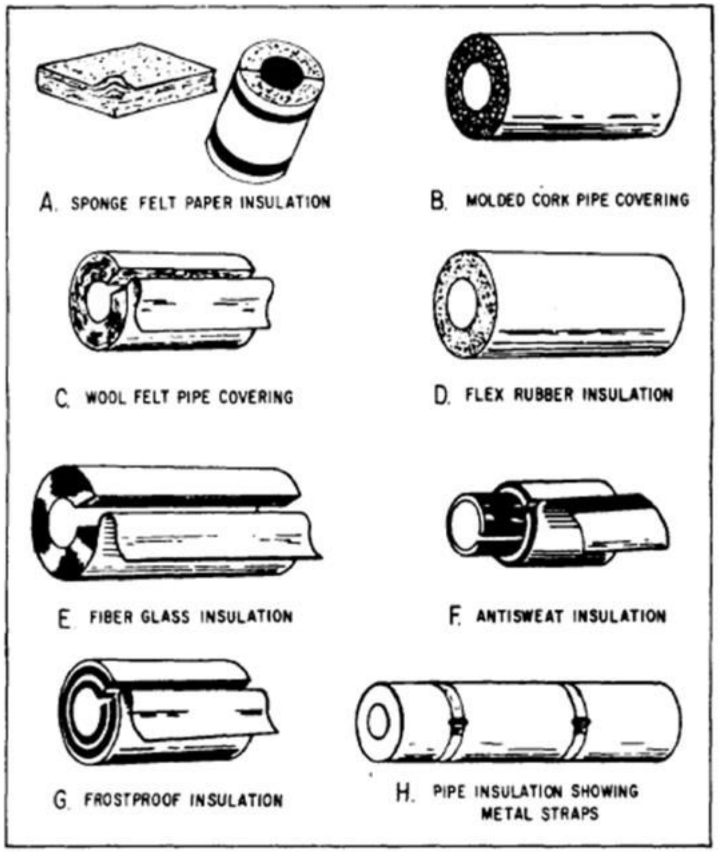
Pipes are insulated with thermal material, such as fiberglass, mineral wool, or foam plastic, to maintain the temperature of water for either chilled or hot water.







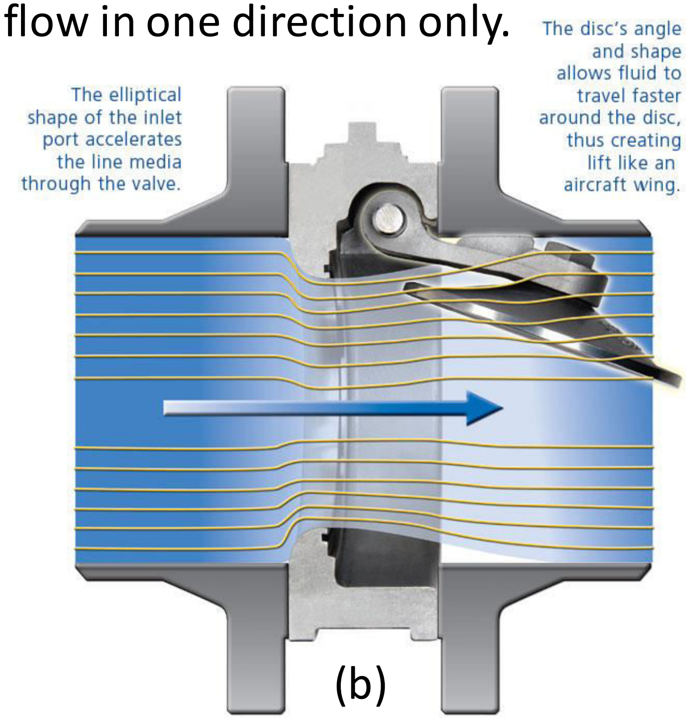




Design considerations for water distribution systems.

Preventing Backflow. A check valve allows water to flow in one direction only.

(a)



(b)

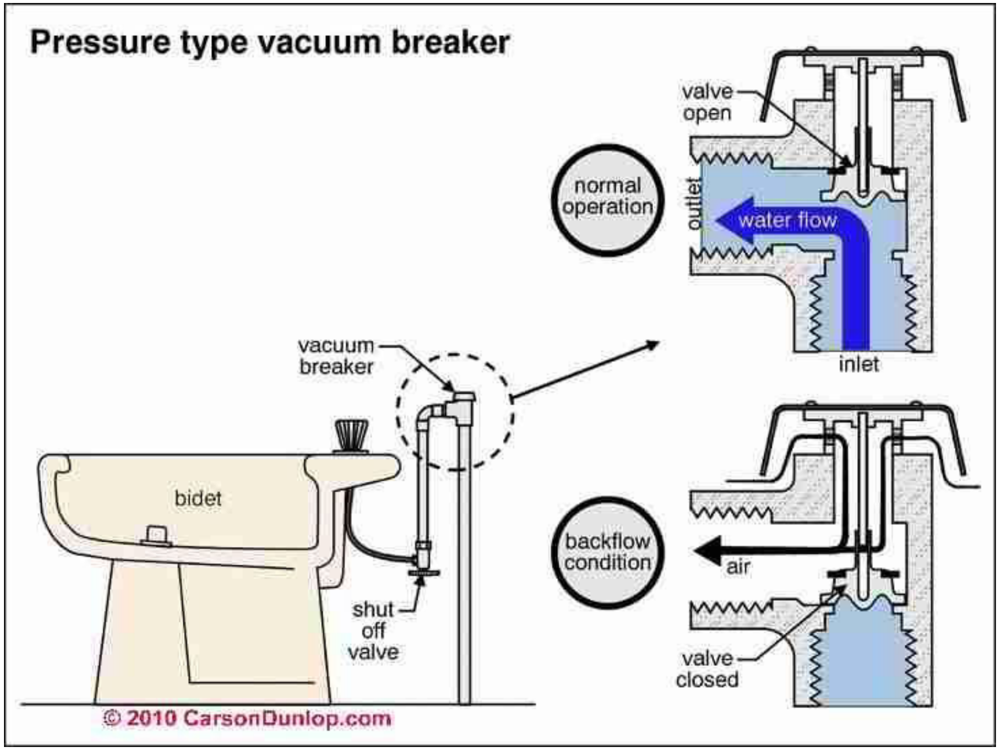
(a) Center-pivoted design with reduced pressure drop

(b)Wing-type check valve showing the check in closed and open positions

Design considerations for water distribution systems.

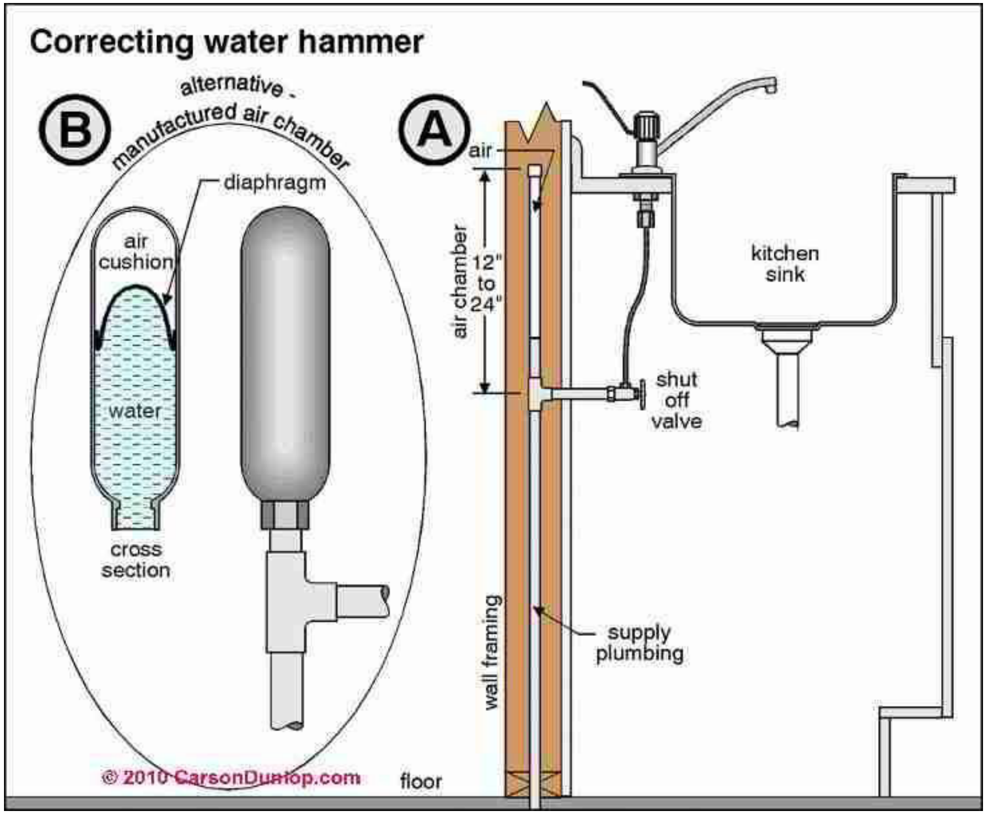
Vacuum breaker is installed at the branch connection to an equipment item or plumbing fixture, such as a sink, dishwasher, boiler, water closet, or urinal.

A vacuum breaker will automatically open the piping system to atmospheric pressure when pressure in piping drops below the atmospheric pressure level, to prevent foreign material or foul water in the equipment or fixture from being siphoned into the piping system.



Design considerations for water distribution systems.

Shock Absorption When the flow of water in a pipe is abruptly stopped, as by the closing of a faucet, the dynamic (kinetic) energy in the water must be absorbed. If it is not, the energy will be converted into a loud noise and vibration known as water hammer.



Plumbing Fixtures Plumbing fixtures are receptacles, devices, or appliances that are supplied with water or that receive liquid-borne wastes and then discharge waters into the drainage system.


Showers

Water closets


Lavatories


Sinks


Bathtubs (BT)


Drinking fountains


Bidets


Urinals

Fixture units

The water supply fixture unit (wsfu):

The wsfu is a measure of the probable hydraulic demand on the water supply by various types of plumbing fixtures.

The wsfu depends on the rate of supply, the duration of a single operation, and the frequency of operation of the fixture.

1 wsfu: A 1/2 in. (12.7 mm) residential type lavatory faucet is rated for 1 wsfu which is equivalent to about 1 to 1.5 GPM (5.7 L/min) flow rate.

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