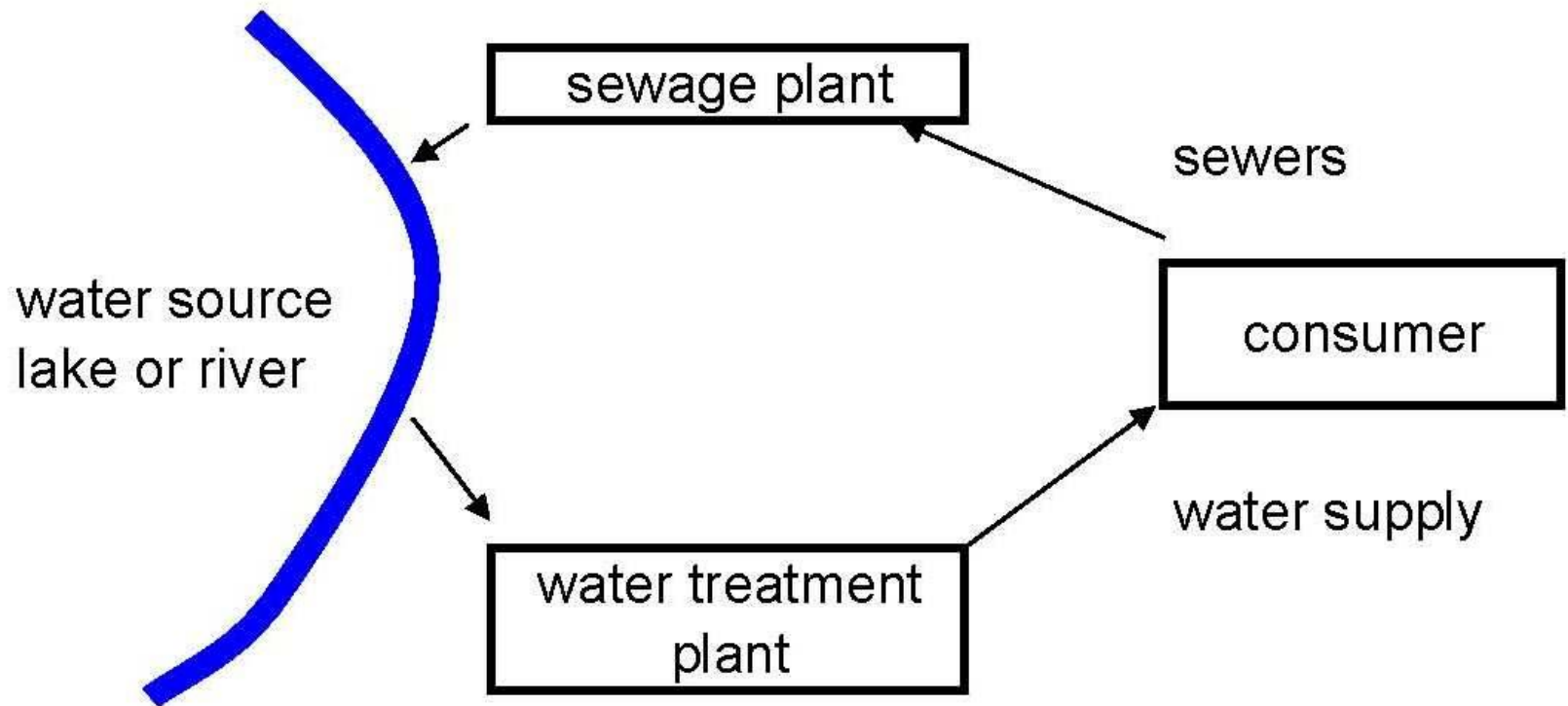


# Domestic Water Bernoulli, and Hazen-Williams

# Urban Hydrologic Cycle



# Municipal Water Systems

1. Collection works (reservoirs, dams, conduit)
2. Purification works (filters and chemicals)
3. Transmission works (pumping stations)
4. Distribution works (pipe networks )

# Municipal Water Systems

1. Collection works
  - a. tap a source that is capable of producing a continuously adequate volumes to meet present and reasonable future demands, or
  - b. convert a source that may be intermittently sufficient into a continuously adequate supply. This requires large storage works be provided for continuity.
2. Purification - When quality of water is unsatisfactory, purification works are introduced to make it suitable for the different purposes it must serve.
  - a. contaminated water is disinfected
  - b. aesthetically displeasing water (brown, blackish) is made attractive & palatable.
  - c. iron or manganese rich water is deferized or demanganized
  - d. corrosive water is deactivated (acid, chlorine). We want neutral water (ph 7)
  - e. hard water softened
3. Transmission works convey the purified supply to the community.
4. Distribution works dispense water to the consumers in required volume and pressure - meters are installed at all points of use so that an equable charge can be made for its supply and disposal after use.

# Quantity Requirements Depend On:

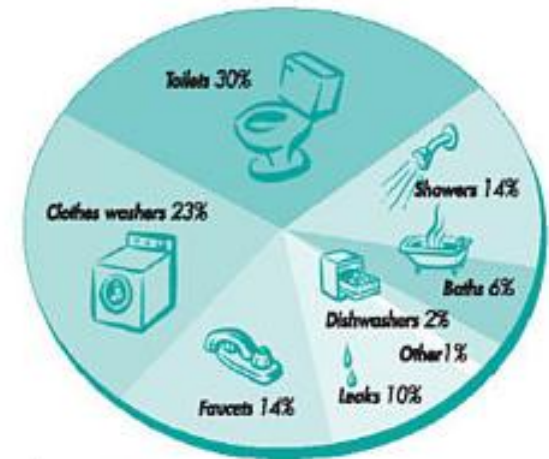
- industrial use, climate, economic considerations
- approximately 66% of water is for non-consumptive use
- > 90% of this is cooling water returned to source. Auto manufacturing needs approximately 100 m<sup>3</sup> per car supplied by municipality (approx. 60%)
- typical city dweller - 340 L/d
- new houses - more water fixtures, clothes washers, dishwashers, lawns consume much water
- many cities charge sewer use by industry
- max. daily demand approximately 200% of average daily
- flows for waterworks design depends on magnitude and variations in municipal consumptions and reserve needed for firefighting govern size of piping, pumping, and storage etc.
- intakes, wells, treatment plant, pumping and transmission lines are sized for peak demand ( = max. daily use where hourly variations handled by storage) variations in consumption litres per day

# Water Supply

- The basic unit of capacity used for design criteria is litres per capita per day (l/c/d)
- Size and design period depends on:
  - a. water mains are sized to meet peak demands
  - b. sized to achieve a balance between hydraulic requirements and water quality maintenance. (excessive retention = deterioration of water)
  - c. water mains should be looped with no dead ends if possible (deadends require regular flushing)
  - d. probable life of the system
  - e. method by which construction is financed If projected to have a long life than finance over a longer period so taxpayer is not carrying a burden now for future
- Design for future use - 10 to 30 years in the future
- Capacity required at the end of design period based on future population and per capita consumption at that time

# Consumption Factors

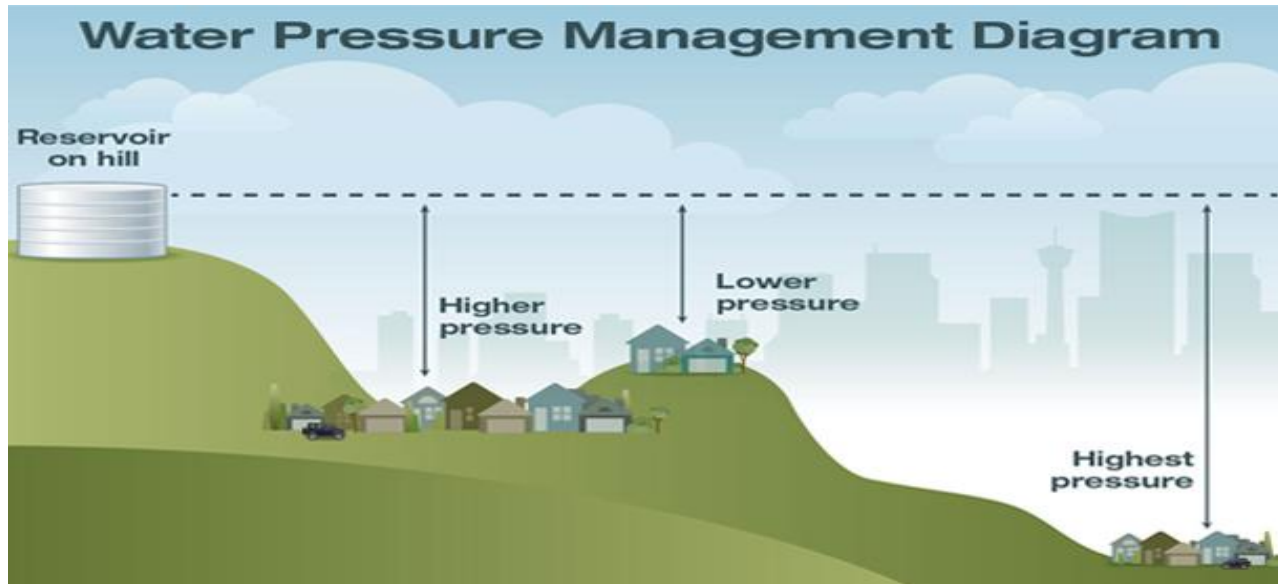
- a. Size of city (both present and future growth)
  - b. Make up of community (residential / commercial / industrial)
  - c. Type of industry
  - d. Climate - higher average temperature means higher the water consumption
  - e. cost of water: Higher rates = lower consumption
  - f. Miscellaneous Factor: Quality of water (higher quality = higher consumption)
- For design, we use L/s or m<sup>3</sup>/s (1000 L = 1 m<sup>3</sup> )



\* Source GVRD

# Pressures

- Fundamental unit for pressure is Pascal (Pa)
- 1 Pascal =  $1\text{N/m}^2$
- 1 pascal is very minimal therefore, use kPa  
Pressure Requirements
- Normal operating pressures range from 350 to 550 kPa (50 to 80 psi)



# Water Main Systems

1. Transmission Main - treatment plant to storage reservoirs (towers / tanks)
2. Arterial system - convey water from treatment plant to areas of major use (rare)
3. Distribution pipes - going along streets to feed a street
4. Locals - feeding local residences off of distribution lines

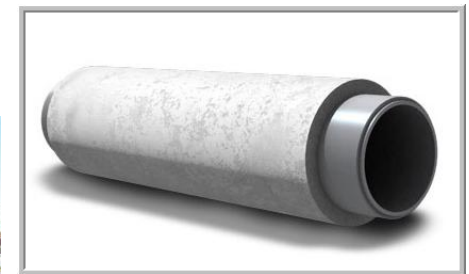




# Pipe Materials



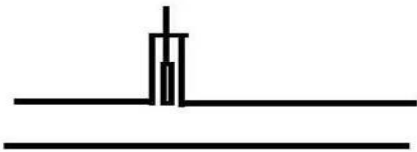
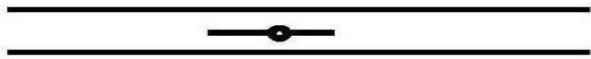
- Rigid
  - C.I.P. cast iron (heavy, brittle)
  - D.I.P. ductile iron (more versatile, more forgiving)
  - C.P. concrete pressure pipe (mostly mains)
  - A.C.P. asbestos cement (miles of it in ground)
  - concrete encased welded steel
- Flexible
  - Plastics
    - PE (polyethelene)
    - PVC (polyvinylchloride)



# Common Valves

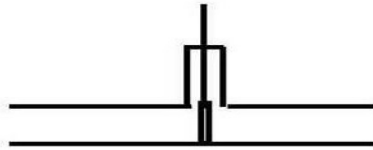
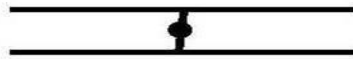
## BUTTERFLY VALVE

(lots of friction)



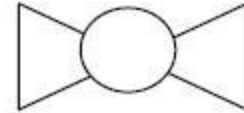
## GATE VALVE

(Common)



## BALL VALVE

(Mechanical Uses)

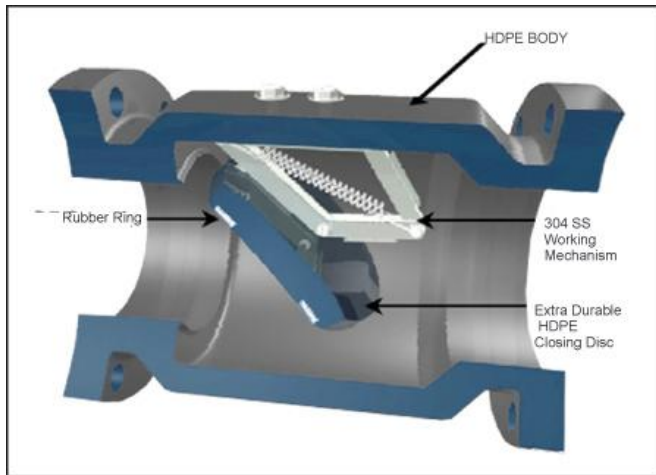
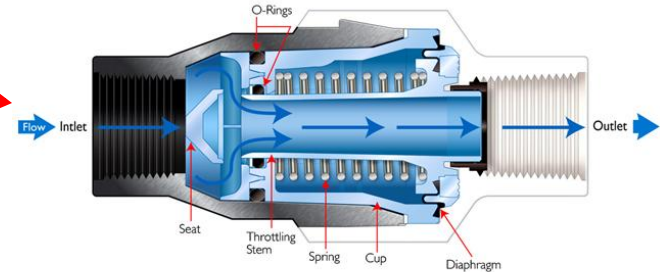


# Other Types of Valves

1. Pressure Reducing Valves

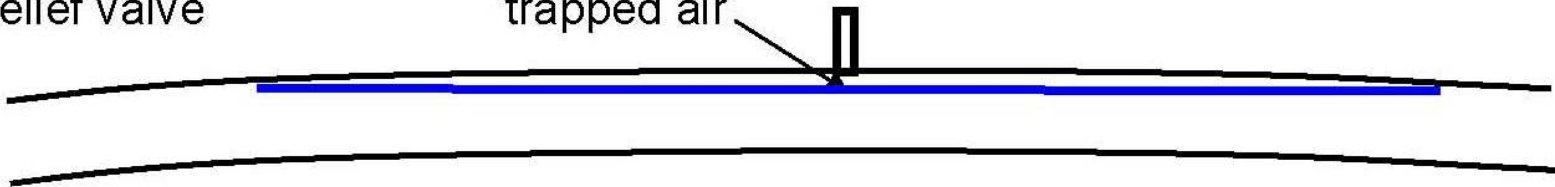
2. Air Relief Valves

3. Check Valves



air relief valve

trapped air



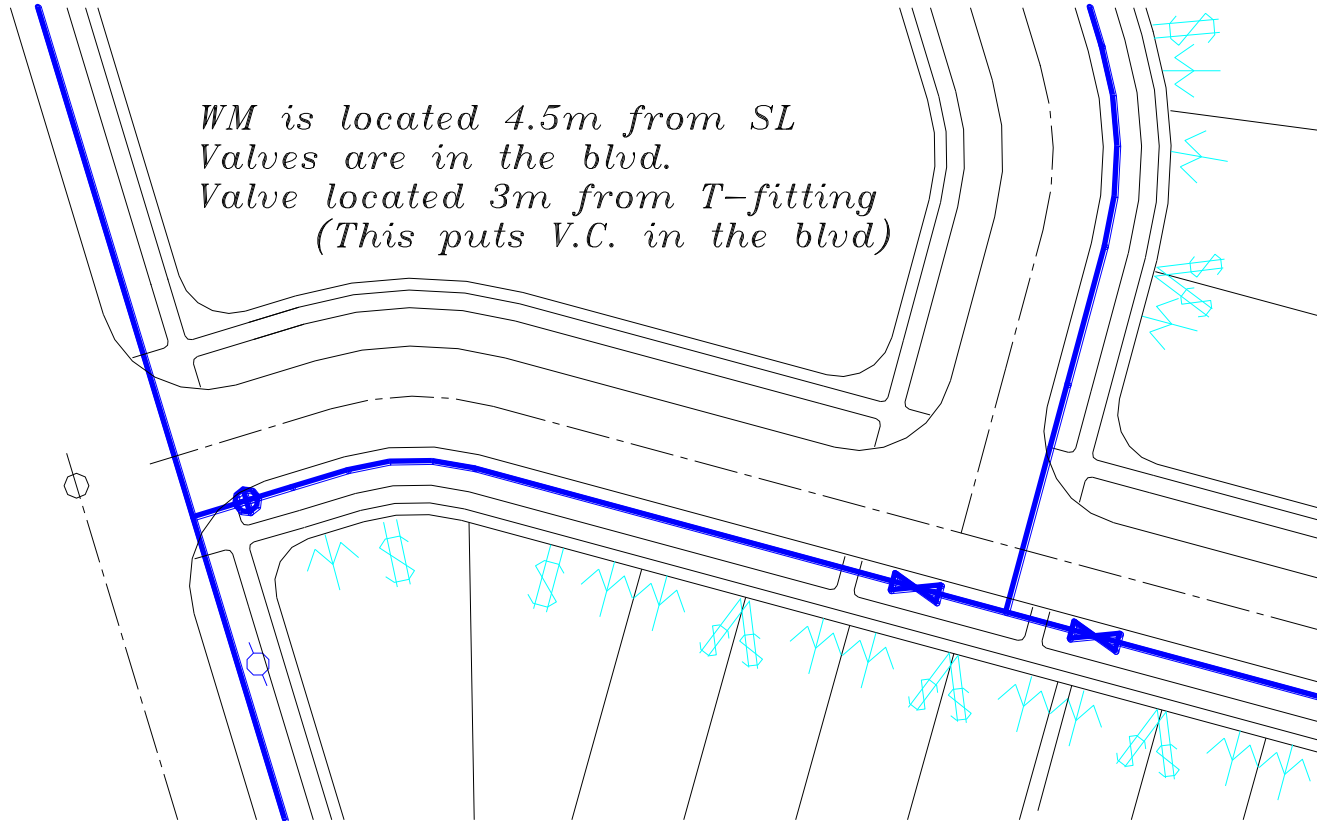
# Valves Locations

1. Near Junctions (max 3 valves to shut down any section of pipe)
  2. Mid-line
    - a. at 'T' intersections 2 of 3 legs are valved
    - b. midline valves are typically placed 200 m between valves for 150 to 250mm diameter pipe
    - c. maximum distance of 250 metres between valves on 250 to 300mm diameter pipe
    - d. typical wm location is 4.5m off street line
    - e. symbol for valve & box
    - f. symbol for valve chamber
- Ask Yourself: Can I shut off the portion of system required with only 3 valves and minimize the number of customers impacted?

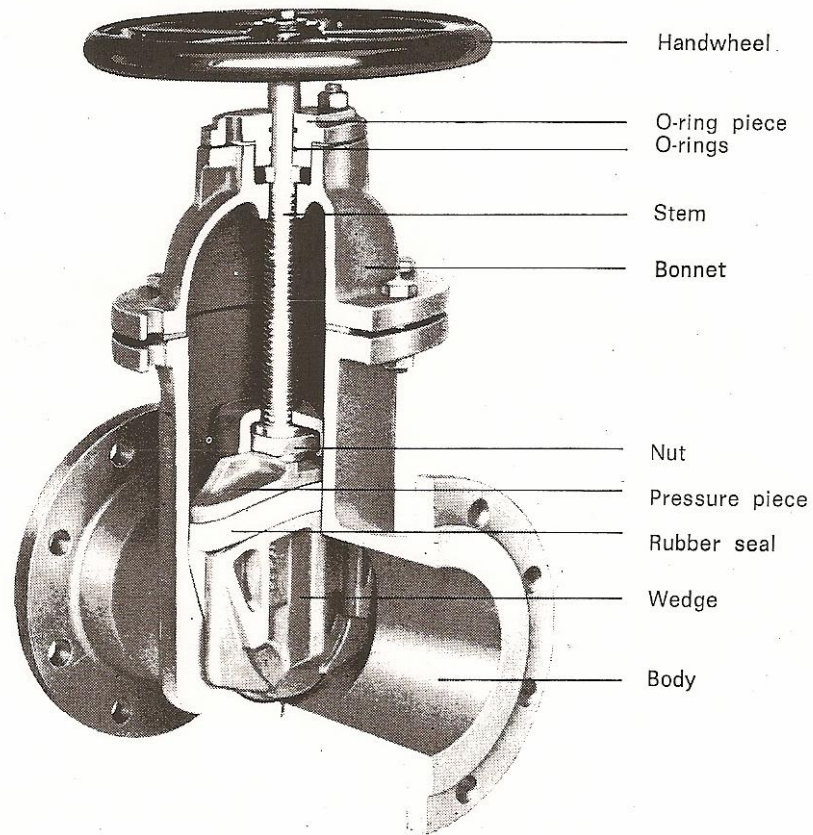
# Testing and Disinfection

1. After construction is completed all new water pipe and appurtenances are pressure tested
2. After construction is completed all new water pipe and appurtenances are disinfected and flushed
3. After pressure testing and disinfection are completed, the water is tested check for Coliform bacteria, colour, turbidity, odor, pH and if satisfactory then place into active service

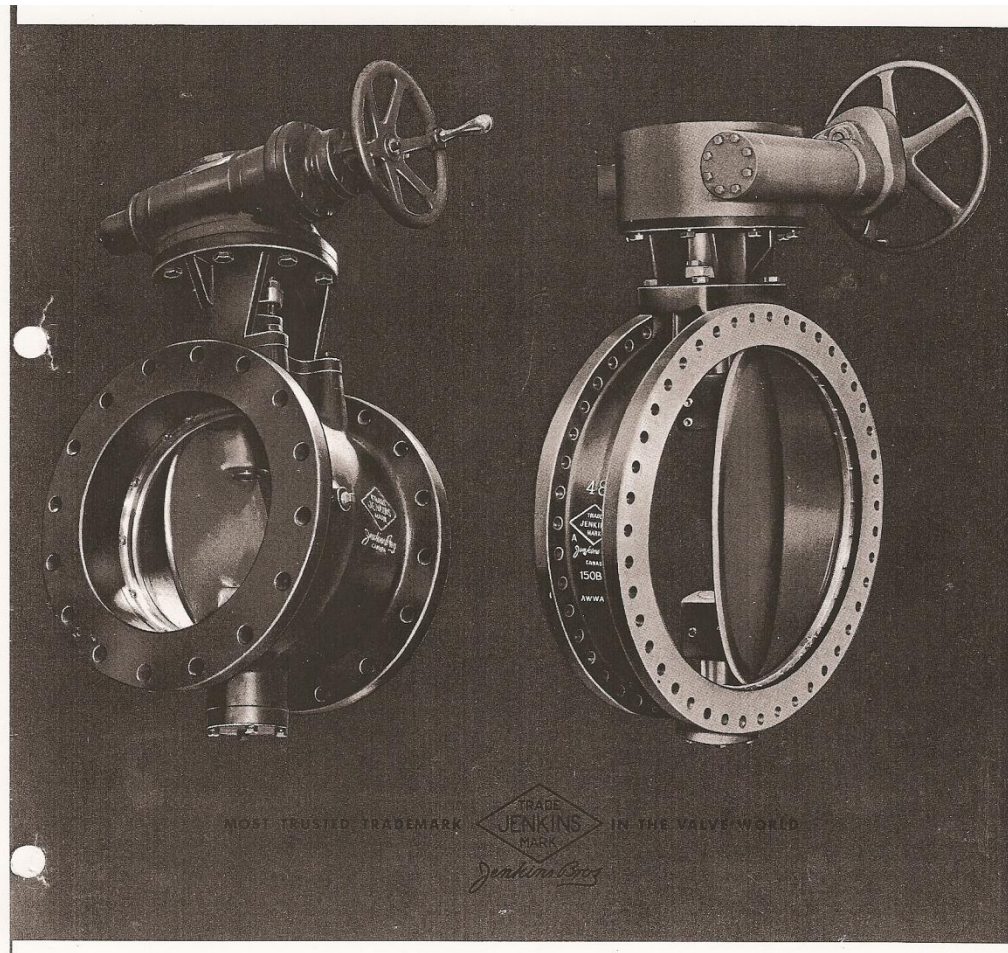
# Example Layout



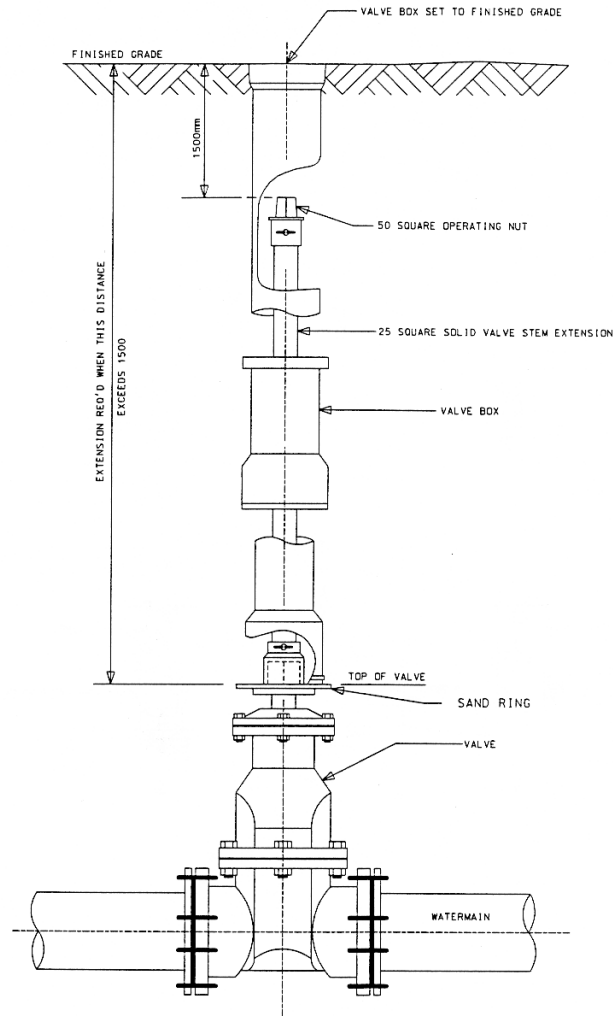
# Gate valve



# Butterfly Valve

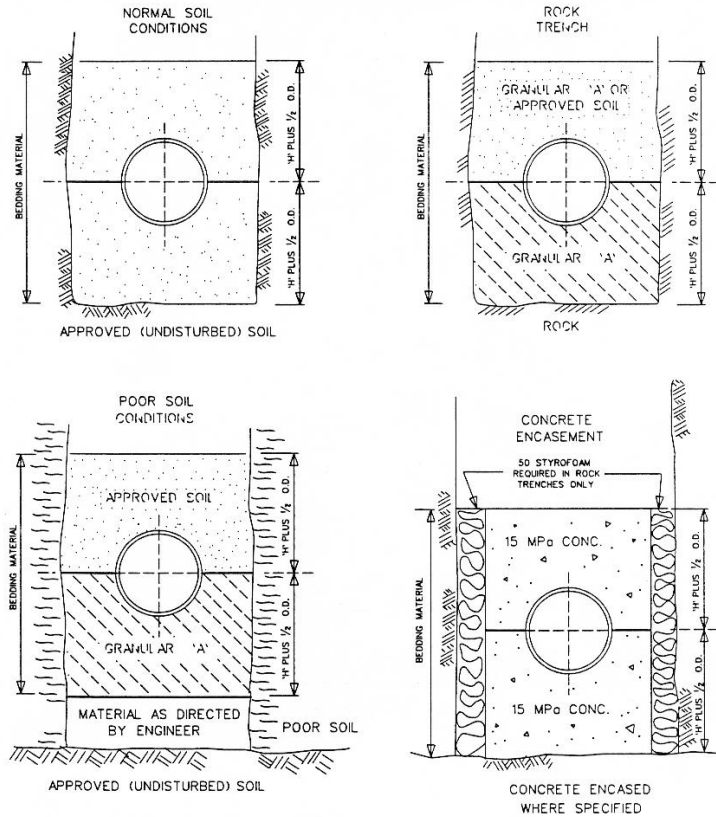


# Valve Box



NOTE:  
VALVE TO BE RESTRAINED AS SHOWN IN STD. 1-3-3A

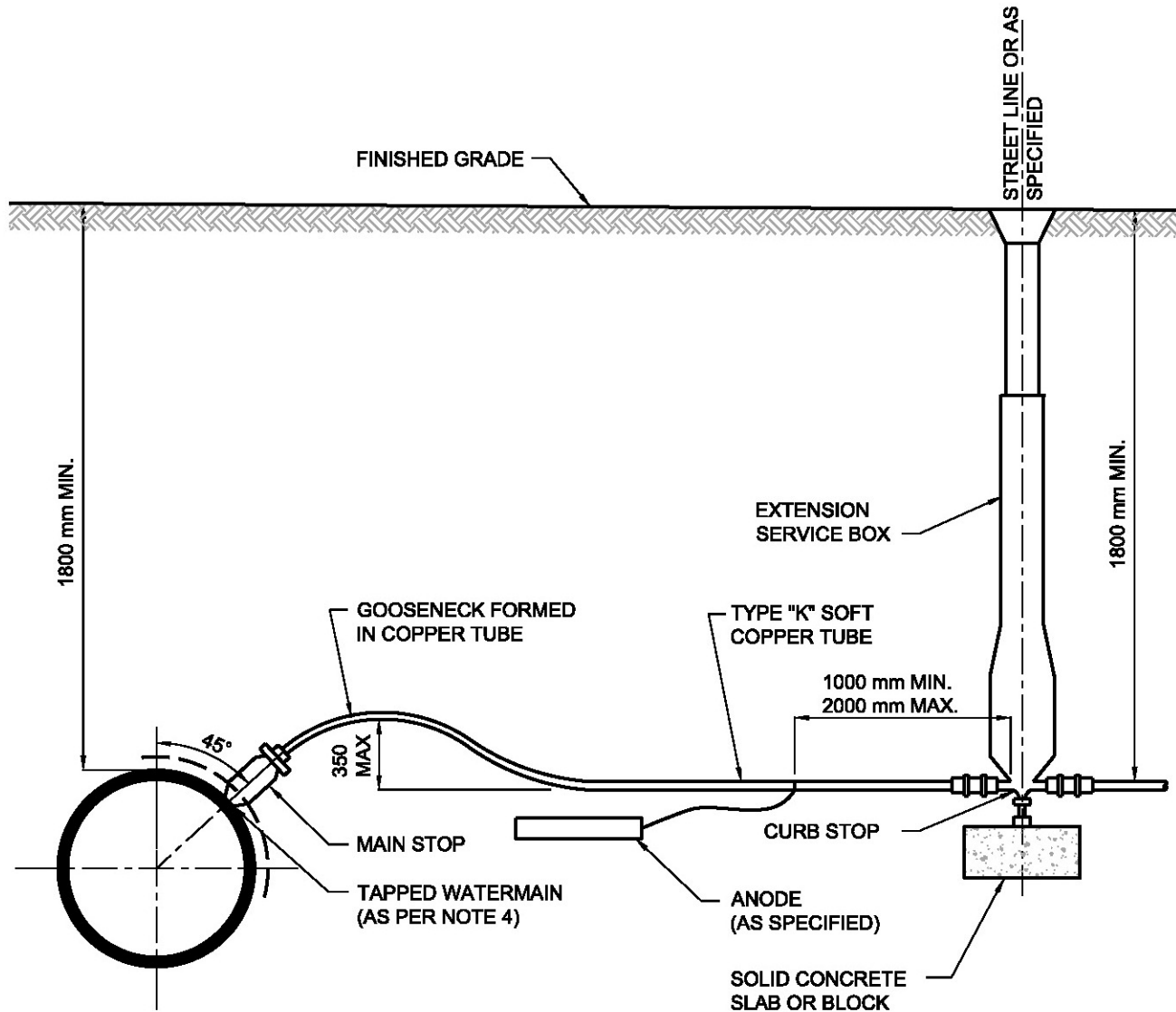
# Bedding



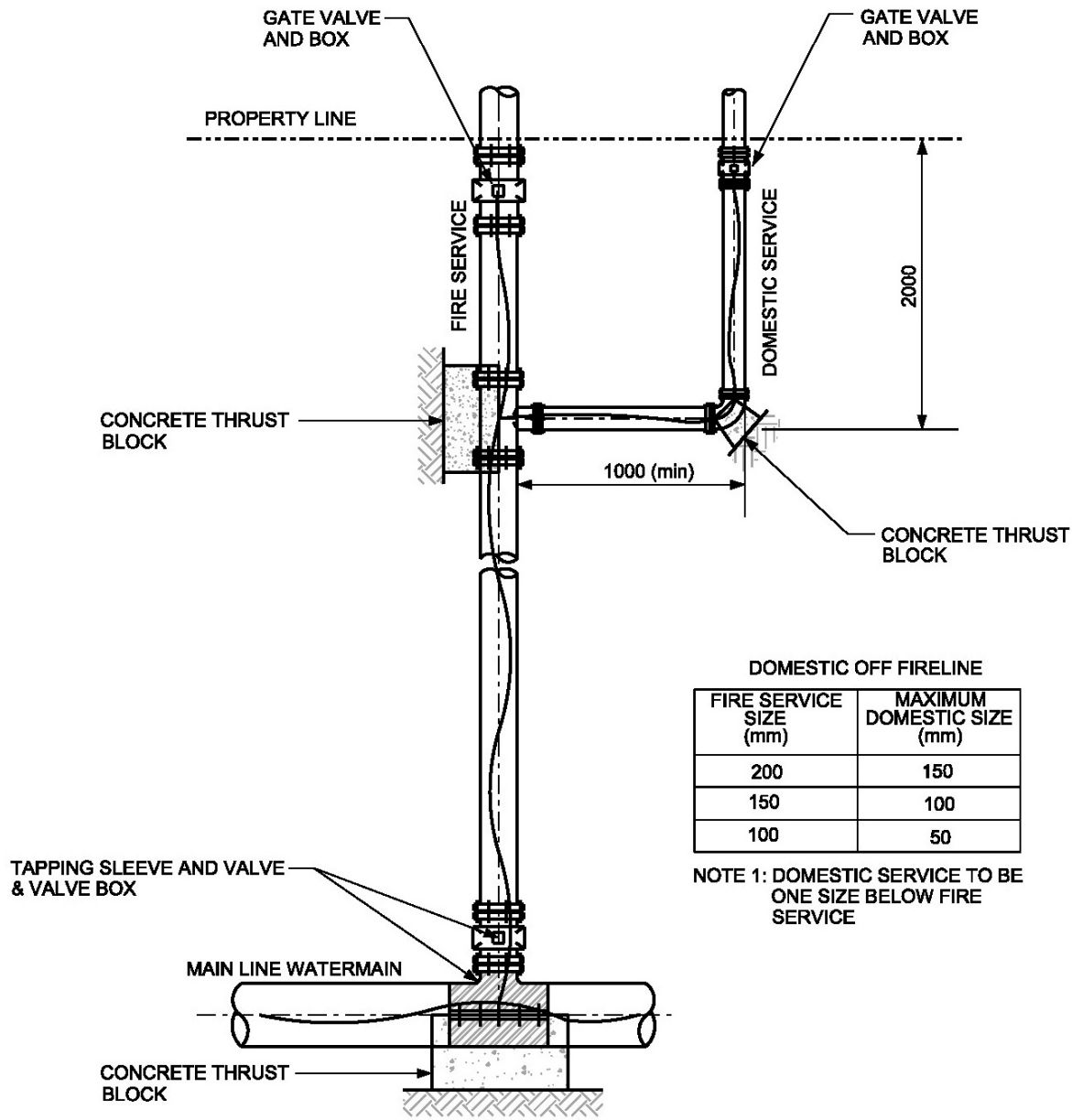
## NOTE

1. FOR P.V.C. PIPE BEDDING MATERIAL TO BE GRANULAR D ( LIMESTONE SCREENING ) 150mm ABOVE THE TOP OF PIPE.
2. MATERIAL TO BE PLACED IN TRENCH IN 150mm LAYERS AND COMPACTED TO 100% STANDARD PROCTOR DENSITY.
3. IN CASE OF OVER-EXCAVATION TRENCH TO BE FILLED TO BOTTOM OF PIPE WITH APPROVED MATERIALS IN 150 LAYERS AND COMPACTED TO 100% STANDARD PROCTOR DENSITY.
4. IN POOR SOILS ENGINEER MAY VARY PIPE FOUNDATION TO SUIT.
5. BACKFILL ABOVE BEDDING AS APPROVED BY PROJECT MANAGER.
6. GRANULAR MATERIAL AS PER M.E.A. SPECIFICATIONS.
7.  $H = 150$  OR DIA./4 OF WATERMAN WHICH EVER IS GREATER.
8. MIN. TRENCH WIDTH TO BE O. D. PLUS 600mm MAX. TRENCH WIDTH TO BE O. D. PLUS 750mm.
9. COVER MATERIAL, NO STONES GREATER THAN 25mm WILL BE PERMITTED.

# Water Connection (Residential)



# Water Connection (Commercial)



DOMESTIC OFF FIRELINE

FIRE SERVICE SIZE (mm)	MAXIMUM DOMESTIC SIZE (mm)
200	150
150	100
100	50

NOTE 1: DOMESTIC SERVICE TO BE ONE SIZE BELOW FIRE SERVICE

# Bernoulli and Hazen-Williams

# Units

## Unit Volumes and Unit Weights:

- 1 ft<sup>3</sup> of water = 62.4 lbs
- 1 ft<sup>3</sup> of water = 7.5 gallons
- 1 gallon of water = 8.34 lbs

Unit Pressure: Pressures are usually expressed in pounds per square foot (psf) or pounds per square inch (psi). This is known as unit pressure.

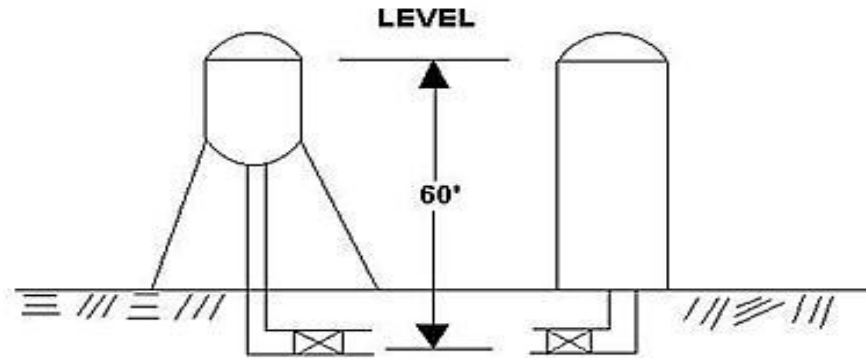
A container which has dimensions of 1' x 1' x 1' (the same as 12" x 12" x 12") and is filled with water, weighs 62.4 pounds.

The total pressure on the bottom is therefore 62.4 lbs., and the unit pressure is 62.4 psf OR 0.43 psi (62.4 lbs / 144 inchs).

How high must a column of water stand to cause a pressure of 1 psi?  
It would be (2.33 ft).

# Pressure Example

- If pressure can be measured as 0.43psi for every foot, find the pressure at the bottom of a standpipe in which water stands 60 ft deep. In the following diagram the unit pressure at each valve will be the same. Answer: (26 psi)



# Pressures Cont'd

Pressures are sometimes measured in terms of feet of head which means the same thing as height to the water level. For example, the head on the pipes from either of the tanks is 60 feet.

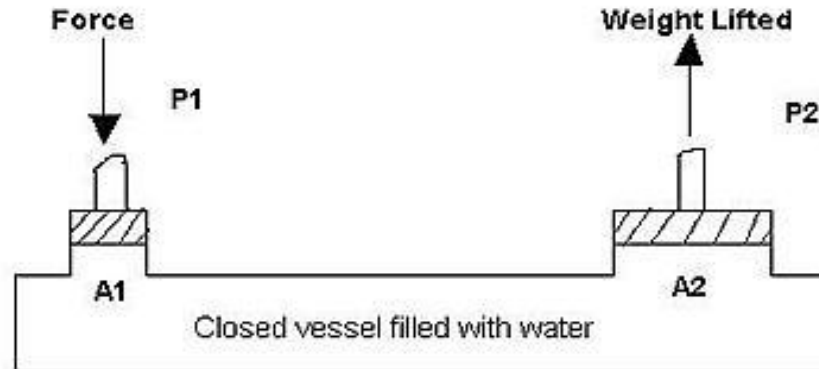
Gauge and Absolute Pressure: The dials of gages are designed so that the readings indicate pressures caused by the head of water.

Air has weight and therefore exerts a pressure. This pressure is usually taken to be 14.7 psi (atmospheric pressures).

The absolute pressure at the bottom of the tank is actually:

$$\begin{aligned} \text{Absolute pressure} &= \text{gauge} + \text{atmospheric} = 26 \text{ psi} + 14.7 \text{ psi} \\ &= 40.7 \text{ psi} \end{aligned}$$

# Transmission of Pressure



The principle of transmission of pressure illustrated above is that the unit pressure at any point in a fluid at rest is transmitted equally in all directions.

- If  $P_1 = 100$  lbs. and  $A_1 = 10$  sq. Inches
- Let  $(p)$  = pressure in pounds per square inch (psi)
- So an exerted pressure,  $P_1$ , of 100 lbs. at  $A_1$  results in a pressure,  $P_2$ , of 1,000 lbs. All unit pressures are 10 psi.
- The pressure at any point in the vessel can be figured in the same manner.
- The hydraulic gage valve operates on the principle outlined above.

# Water in Motion

- Pressure and head in relation to bodies of water at rest have been considered. This is called **static pressure** and static head. When water is in motion, such as from the mechanical force exerted by a pump in producing motion, the pressure created is called **dynamic pressure**.
- There are factors other than elevation which affect pressures when water is in motion. Suppose a pump at a source of supply will pump water to a storage tank with an overflow elevation **100 feet** above the centerline of the pump. A pressure gauge placed at the outlet of the pump would show a pressure reading of 43 psi (Recall: 1 ft of water = **0.43 psi**).
- This would represent a back-pressure against the pump. To pump water, the pump would have to exert a force greater than the pressure exerted by this 100 foot column of water. We would say this pump would operate against a static head of 100 feet.

# Water in Motion (cont'd)

- If the source of water for this pump came from a reservoir ten feet above the centerline of the pump, there would be a positive pressure on the suction side of the pump of ten feet (or 4.3 psi). This is called suction head and would serve to relieve some of the work of the pump, and it would only have to exert a force against a net static head of 90 feet. (100 ft. - 10 ft.).
- If the source of water came from a well where the ground water stood at an elevation ten feet below the centerline of the pump, this would require an increased force to be exerted as a result of the need to lift the water ten feet to the pump. This is called suction lift and the head against which the pump must operate would be increased to 110 feet.
- It takes just as much energy for a pump to lift water 10 feet by suction as it does to force water 10 feet in elevation by pressure.

# Water in Motion (cont'd)

- The amount of water passing a given section of a pipe line in a unit time is called the discharge, Q
- We can use the CONTINUITY EQUATION:

$$Q = V \times A$$

Where:

- Q = discharge (ft<sup>3</sup>/s)
  - V = velocity of water in pipe (ft/s)
  - A = cross sectional area of pipe (ft<sup>2</sup>)
- 
- In water works practice it is customary to express discharge in gallons per minute (gpm) or even in million gallons per day (mgd).
  - The effect of reducing a pipe diameter is to increase the velocity. For example, if a 6" pipe connects into a 4" pipe, the velocity in the 4" pipe will be greater.

# Loss of Pressure

If only static head was involved in pumping operations, any force exerted by the pump which was greater than the static head (or back pressure), would result in water being pumped. But as soon as water is in motion, there are other factors to be considered. Most important of these factors is friction loss.

- There is always friction in any moving body of water. In pressure pipe lines, friction is caused by the water rubbing on the inside surface of the pipe.
- Friction results in loss of pressure. Friction loss is usually measured in "feet per 1,000 feet of pipe" and may be easily converted to pressure loss in pounds per square inch.
- Pumps are designed to operate under specific head conditions. In addition to the static head, all friction losses and minor losses should be computed in order to determine the total head against which the pump will operate.
- The pump will then be specifically designed or selected from a standard design to provide the desired capacity for the conditions under which it will operate.
- The total pressure provided at the discharge side of the pump represents the discharge pressure of the discharge head.

# Loss of Pressure (cont'd)

- When water flows through a pipe, the water molecules rub against each other and against the wall of the pipe. This is called friction and it requires pressure to overcome it. The amount of pressure required (or feet of head) to overcome the friction cannot be used for any other purpose and it is therefore called lost pressure or lost head.
- Factors Influencing Head Loss in Pipes :
  - Friction loss in a pipe depends on the length of the line since the head loss varies directly to the pipe length. The rate of flow and the condition of the interior surface of the pipe also influence head loss.
  - Type of pipe, pipe coating (if any), age of pipe, and the smoothness or roughness of the interior surface of the pipe affects the friction loss. A smooth interior surface would result in very little friction loss at a reasonable velocity, whereas a very rough surface would develop a considerable loss through friction, at the same velocity.
  - The rate of flow is referred to as velocity, which is the speed of the water. Velocity is measured in feet per second. Friction loss increases as the velocity through the pipe increases. If the flow through a pipe is doubled, the friction loss in the pipe will be increased by almost four times.
  - The diameter of the pipe also affects the head loss, as the diameter determines the area of wall in contact with flowing water. Also, for a given discharge the diameter determines the velocity of the water.

# Causes of Friction Losses

Increased friction may also be due to any of the following factors:

1. Sedimentation: mud/silt/sand.
2. Obstruction of the pipe due to debris: sticks, boards, stones, tools and other things that may have gotten into the pipe during construction.
3. Partly closed valves.
4. Accumulation of air at summits.
5. Mineral deposits and slime growths on walls of pipe.
6. Tuberculation.



*Tuberculation is the development of small mounds of corrosion products on the inside of iron pipes.*

*This phenomenon generally happens in domestic water distribution systems where iron pipes are used for water supply. Tuberculation makes pipes rough inside, which can increase pumping costs and reduce the pressure in the distribution system. In severe cases, it can cause pipelines to leak.*

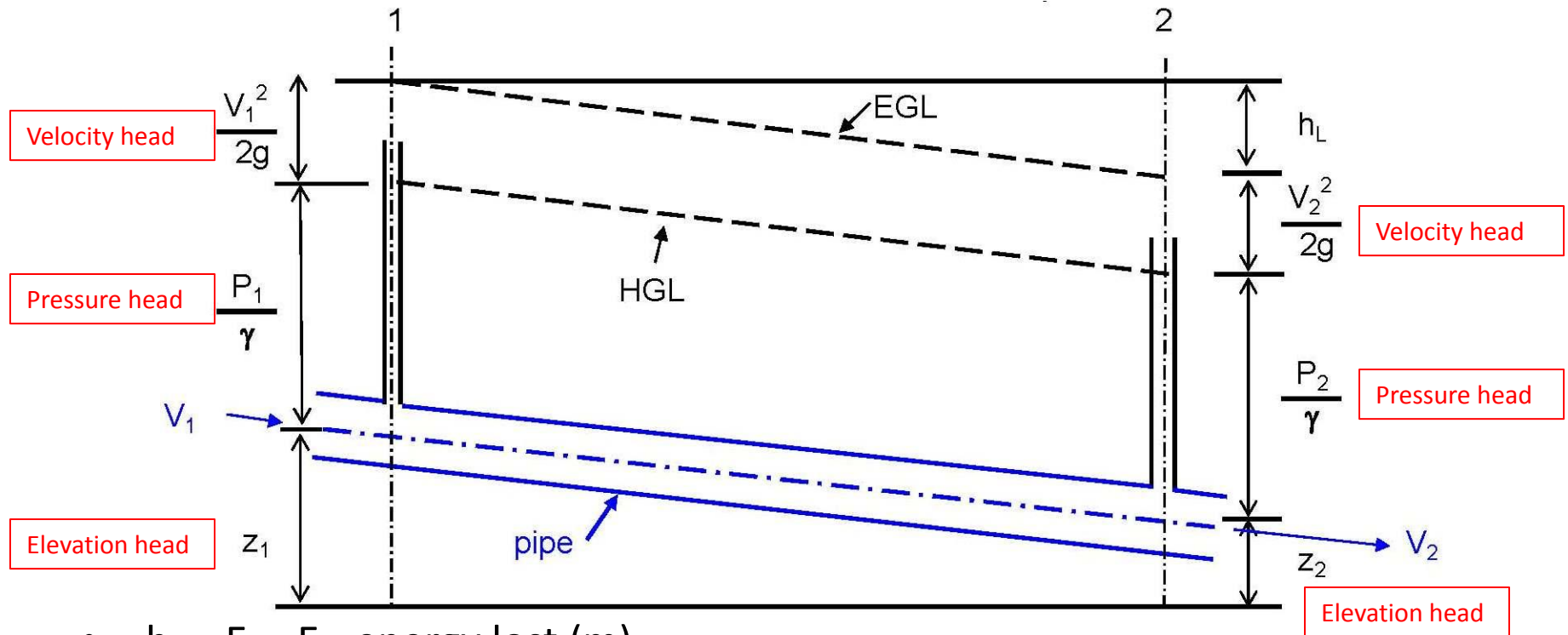
# Causes of Friction Losses (Cont'd)

- There are other minor losses such as losses resulting from changes in size of pipe or direction of flow, meter losses, losses through check valves or undersize gate valves, pump friction, etc.
- The amount of friction developed is the criterion by which the size of pipe and the amount of power required for pumping are determined.
- When a given amount of water is to be transported, the total amount of friction developed depends on the diameter and length of pipe and the condition of its interior.

# Minimum Size and Pressures

- Hydrant leads = 6" diameter
- An 8 inch main costs little more than a 6 inch main to install, since trenching and other costs remain the same. Yet an 8 inch main has more than twice the capacity of a 6 inch main, under the same head. It is much more desirable to oversize, rather than to undersize, when installing new mains.
- When mains are not of sufficient size to meet peak demands in an area, pressures drop rapidly and inadequate service results. Conditions of this nature have been rather prevalent in many cities during the past few years because of increasing demands resulting from improved standards of living, rapid population growth, new appliances, air conditioning and other factors.
- The American Water Works Association recommends a normal static pressure of 60 to 75 psi through the system. A minimum pressure of 45 psi is desirable in a residential area and 75 psi would be desirable in a commercial or industrial area.

# Energy or Bernoulli Equation



- $h_L = E_1 - E_2$  energy lost (m)
- $z$  = static head or elevation head at centre line of pipe
- $P$  = pressure kPa = kN/m<sup>2</sup>
- $\Upsilon$  = specific weight kN/m<sup>3</sup>
- $P/\Upsilon$  = pressure head kN/m<sup>2</sup> divided by kN/m<sup>3</sup> (ENDS UP IN METRES)
- NOTE:  $V_1^2 = V_2^2$  (same because pipe size has not changed)  $2g$   $2g$

# Energy or Bernoulli Equation

- The algebraic sum of the kinetic head, the pressure head, and the elevation heads accounts for nearly all the energy contained in a unit weight of water flowing through a particular section of pipe. It is commonly assumed that where water is flowing in a pipe the energy at any point in the flowing stream is equal to the energy at any other point downstream plus the loss of energy due to friction is flowing between the points. This principle, generally known as Bernoulli's theorem, can be expressed as (energy equation).

Elevation head

Pressure head

Velocity head

$$z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} = z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + h_L$$

$P$  = pressure (lb/ft<sup>2</sup>) or (kPa)

$\gamma$  = specific weight of fluid (lb/ft<sup>3</sup>) or (kN/m<sup>3</sup>)

$V$  = velocity (ft/s) or (m/s)

$z$  = head (ft) or (m)

$h_L$  = head losses (ft) or (m)

*NOTE:*

*Gravity is a conversion factor and is not required if using metric units*

Note:  $\gamma_{\text{water}} = 9.81 \text{ kN/m}^3$

# Hazen-Williams Equation

We calculate the frictional losses within a given pipe using the H-W Equation:

$$Q = 0.278 \cdot C \cdot D^{2.63} \cdot \left(\frac{H_f}{L}\right)^{0.54}$$

Or re-arranged and solving for frictional head loss:

$$h_f = \frac{10.675 \cdot L \cdot Q^{1.85}}{C^{1.85} \cdot D^{4.8655}}$$

Where:  $H_f$  = head loss over length of pipe (m)

L = Length of Pipe (m)

D = inside dia. (m)

Q = flow rate (m<sup>3</sup>/s)

C = pipe roughness coeff.