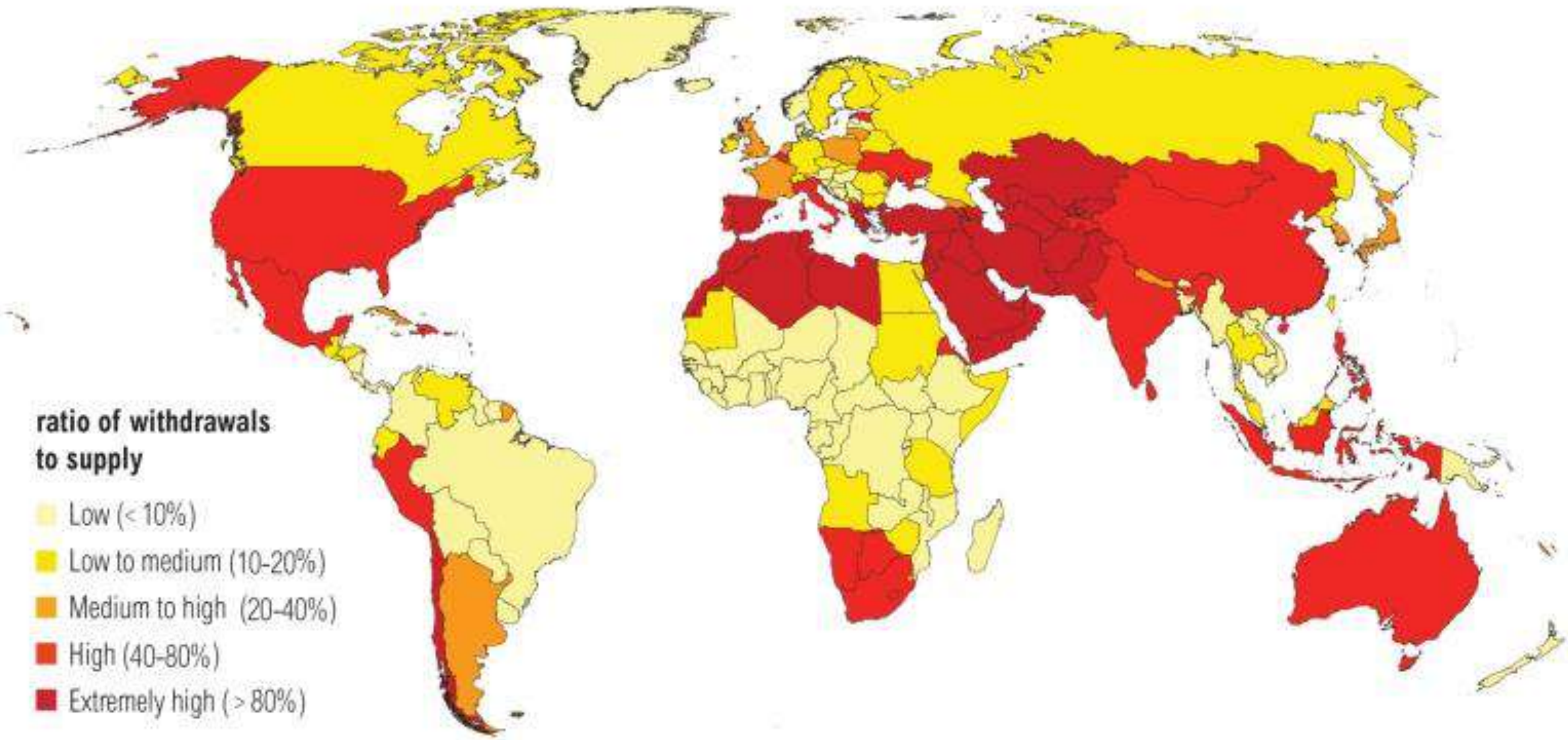
Unit 4

WATER DISTRIBUTION SYSTEM

Water Stress by Country: 2040



NOTE: Projections are based on a business-as-usual scenario using SSP2 and RCP8.5.

For more: ow.ly/RiWop

WORLD RESOURCES INSTITUTE

Top 33 Water-Stressed Countries: 2040

Rank	Name	All Sectors
1	Bahrain	5.00
1	Kuwait	5.00
1	Qatar	5.00
1	San Marino	5.00
1	Singapore	5.00
1	United Arab Emirates	5.00
1	Palestine	5.00
8	Israel	5.00
9	Saudi Arabia	4.99
10	Oman	4.97
11	Lebanon	4.97
12	Kyrgyzstan	4.93
13	Iran	4.91
14	Jordan	4.86
15	Libya	4.77
16	Yemen	4.74
17	Macedonia	4.70
18	Azerbaijan	4.69
19	Morocco	4.68
20	Kazakhstan	4.66

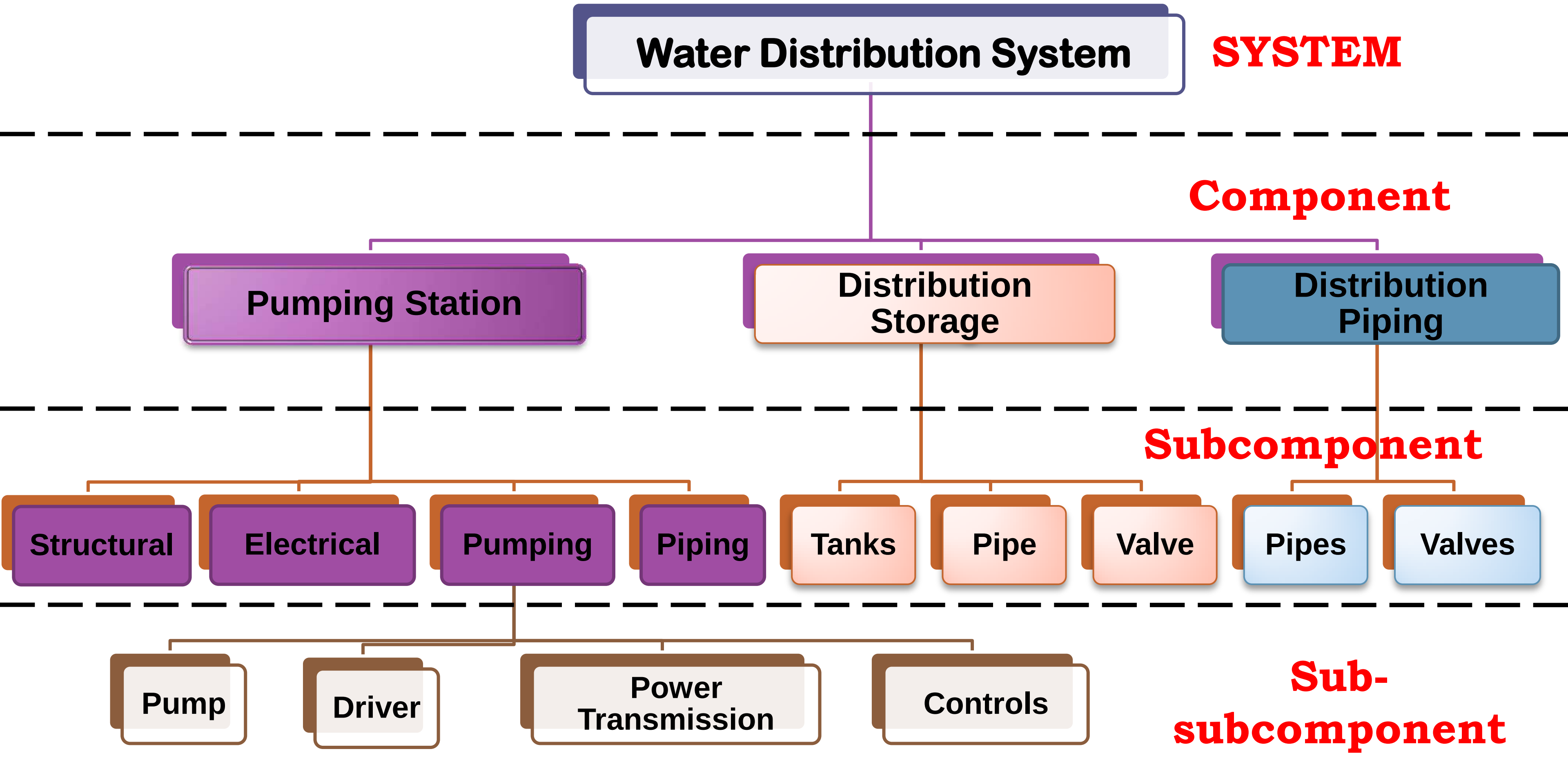
Top 33 Water-Stressed Countries: 2040

Rank	Name	All Sectors
21	Iraq	4.66
22	Armenia	4.60
23	Pakistan	4.48
24	Chile	4.45
25	Syria	4.44
26	Turkmenistan	4.30
27	Turkey	4.27
28	Greece	4.23
29	Uzbekistan	4.19
30	Algeria	4.17
31	Afghanistan	4.12
32	Spain	4.07
33	Tunisia	4.06

Tentative costs of Components of a water supply scheme

Sl. No	Component Item	Cost of the item expressed as percentage of the total
1.	Pumping Stations	18%
2.	Reservoirs	6%
3.	Treatment Plant	10%
4.	Supply Penstocks	9%
5.	Distribution System	50%
6.	Buildings for housing operational staff, etc.	2%
7.	Meters and other contingencies	5%

Hierarchical Relationship of Components, Subcomponents and Sub-subcomponents for a water distribution system

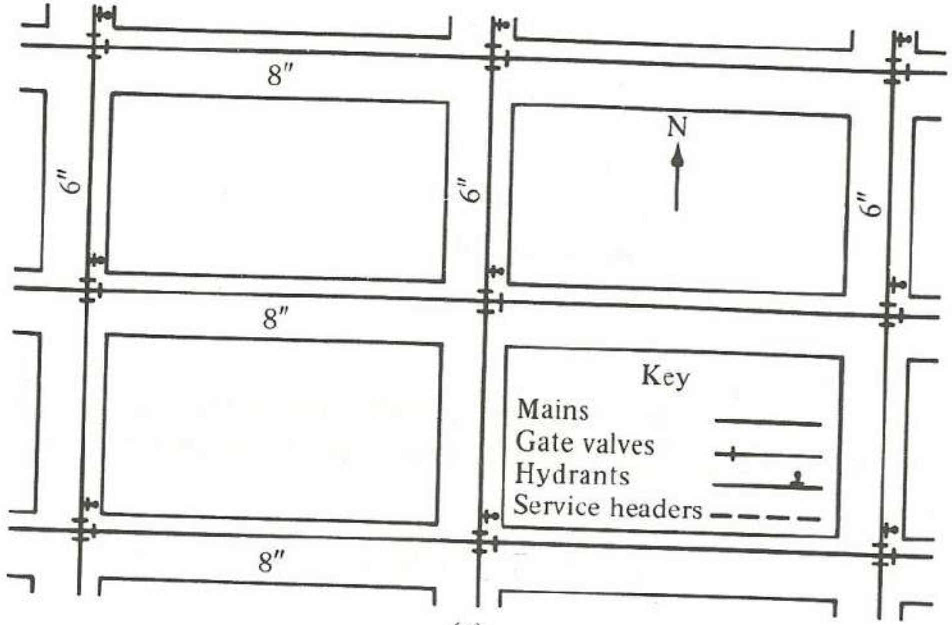


Water Distribution System Consists of:

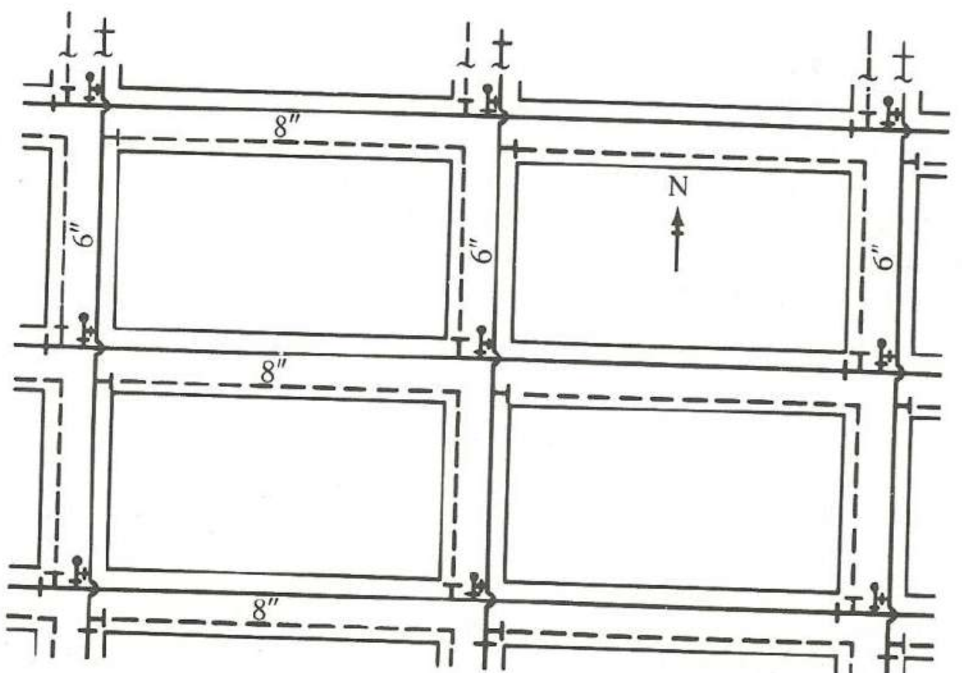
- Pipe Lines (Mains, Sub-mains, Branches, Laterals (also called feeders)) of various sizes
- Valves for controlling the flow in pipes
- Hydrants for releasing water during Fires
- Meters for measuring discharges
- Service Connections
- Pumps
- Distribution or Service Reservoirs

Requirements of a Good Distribution System

- Capable of supplying water at all intended places within a city at reasonably sufficient pressure
- Capable of supplying requisite amount for fire fighting
- Cheap with least construction cost
- Simple and easy to operate and repair
- Safe against future pollution
- Safe as not to cause damage against bursting
- Fairly water-tight to minimize losses due to leakage

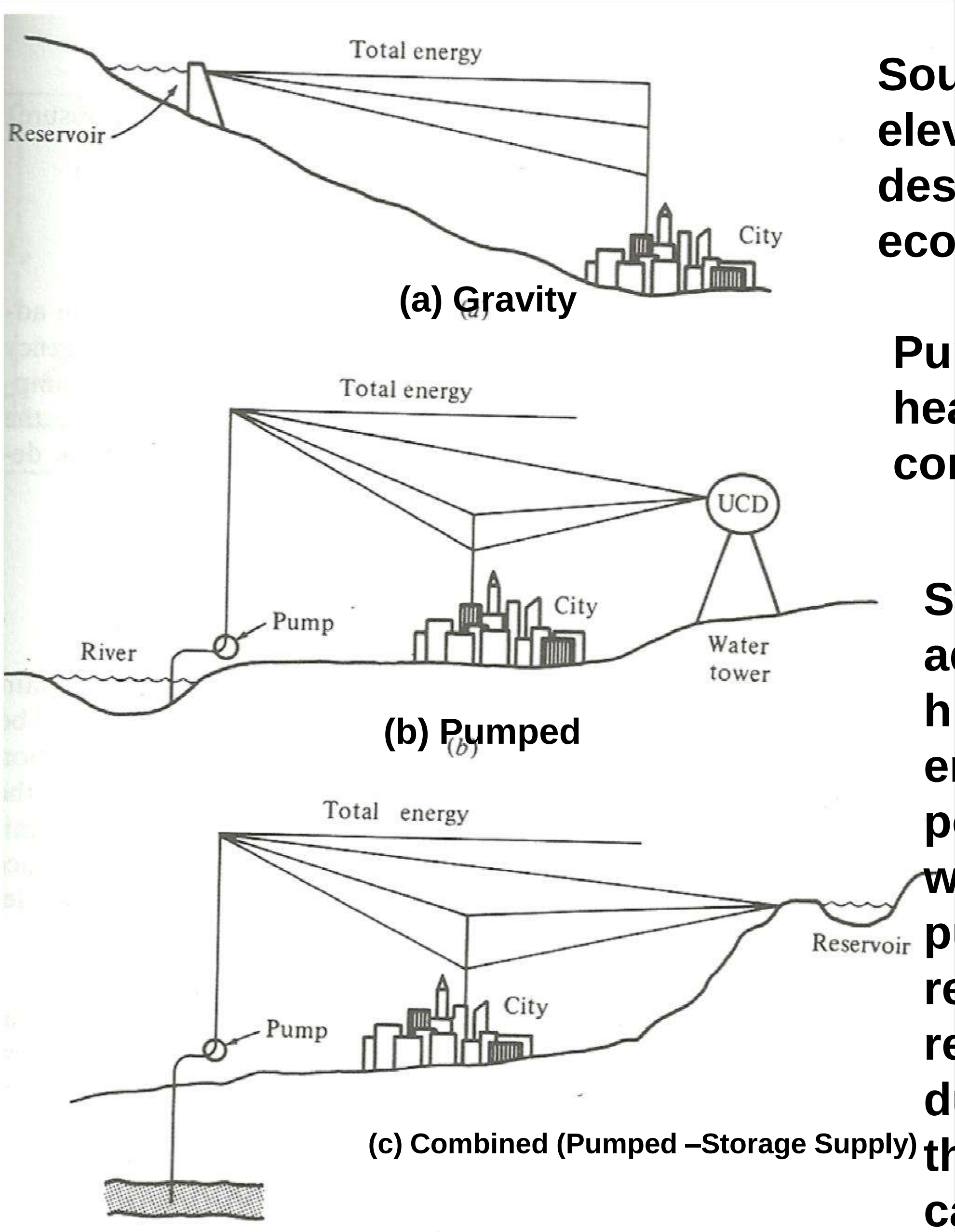

8″
6″
6″
N
6″
8″
Key
Mains
Gate valves
Hydrants
Service headers
8″

(*a*)


8″
6″
6″
N
6″
8″
8″

(*b*)

Methods of Distributing Water



(a) Gravity

(b) Pumped

(c) Combined (Pumped –Storage Supply)

Source of supply is at sufficient elevation above the consumer so that desired pressure can be maintained. It is economical

Pumps are used to develop necessary head (Pressure) to distribute water to consumers and distribution reservoir

Storage reservoirs are used to maintain adequate pressure during periods of high consumer demand and under emergency conditions such as fires or power failures. During periods of low water consumption, excess water is pumped and stored in the storage reservoirs. Because the storage reservoirs are used to provide water during periods of high or peak demand, the pumps can be operated at their rated capacity

Dead End System:

It is suitable for old towns and cities which have developed in a haphazard manner having no definite pattern of roads. This system consists of a main pipe laid along the main road. A number of sub-mains originate (generally at right angles) from main pipe. Each sub-main, then divides into several branch pipes, called laterals. From the laterals, service connections are given to the consumers.

Dead End System ..contd

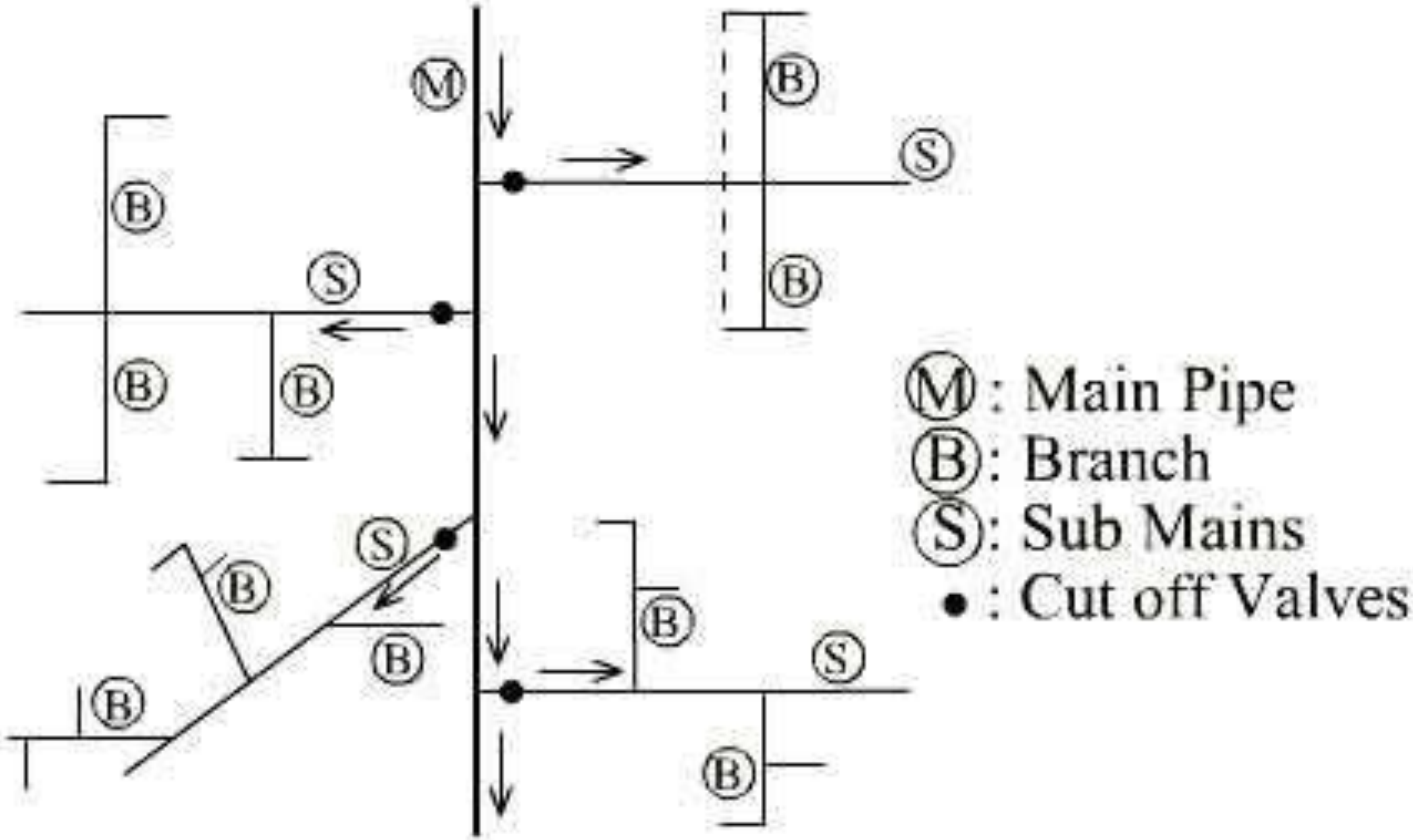
Advantages:

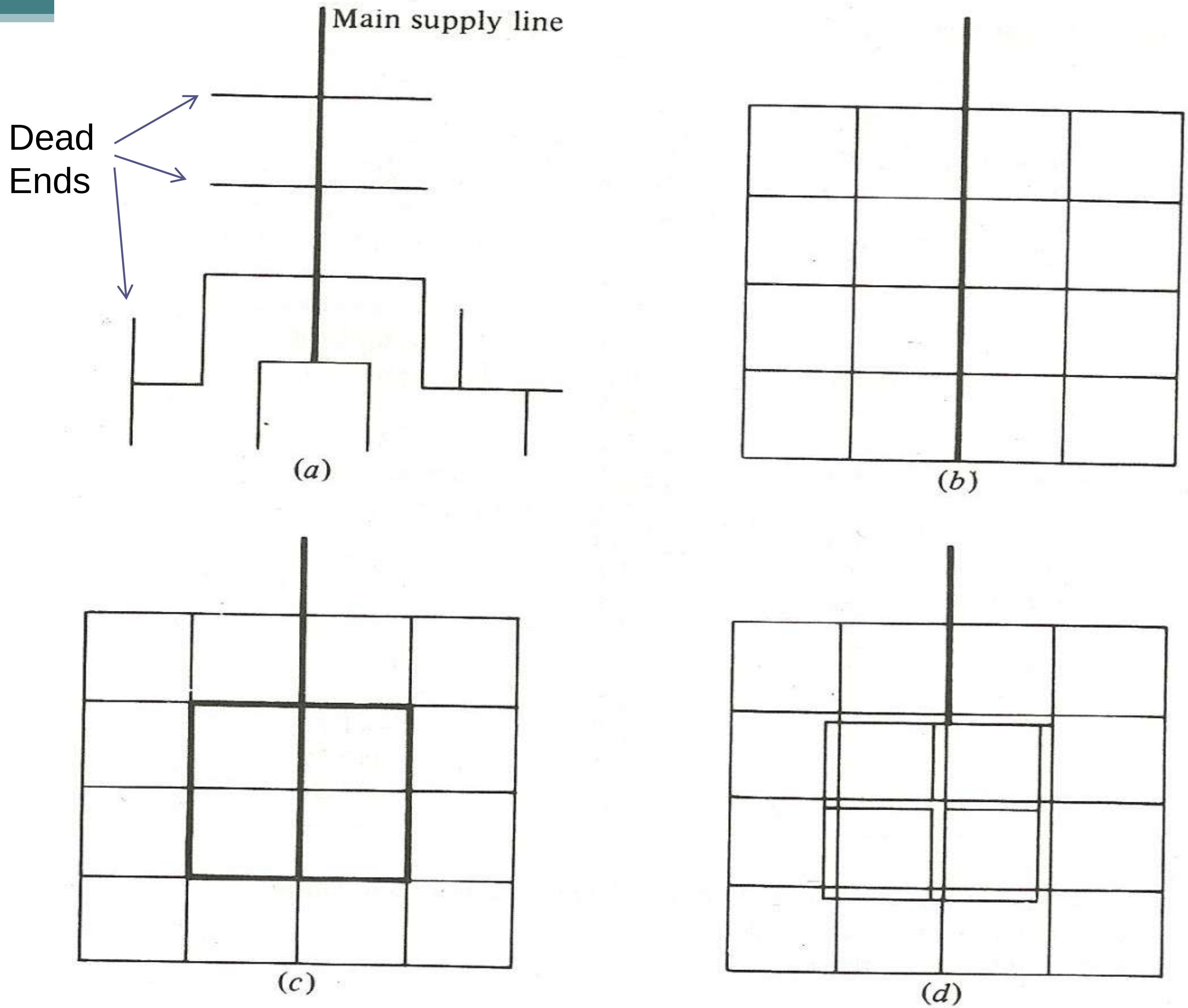
- Distribution network can be easily solved
- Discharges and pressures can be accurately calculated at different points in the system
- Lesser number of valves required
- Shorter pipe lengths needed
- Relatively cheap and can be extended or expanded easily
- Determination of discharges and pressure easier due to less number of valves

Disadvantages

- Due to many dead ends, stagnation of water occurs in pipes. Bacterial growths and sedimentation may occur in branch ends
- Difficult to maintain chlorine residual at the dead ends of the pipe
- During repairs to individual line, service connections beyond the point of repair will be without water until the repairs are made
- Pressure at the end of the line may become undesirably low as additional extensions are made

Dead End or Tree System





Main supply line
Dead
Ends
(a)
(b)
(c)
(d)

Grid Iron System:

Also known as Reticulation or Interlaced system. It is suitable for cities with rectangular layout, where the water mains and branches are laid in rectangles. Example : Chandigarh

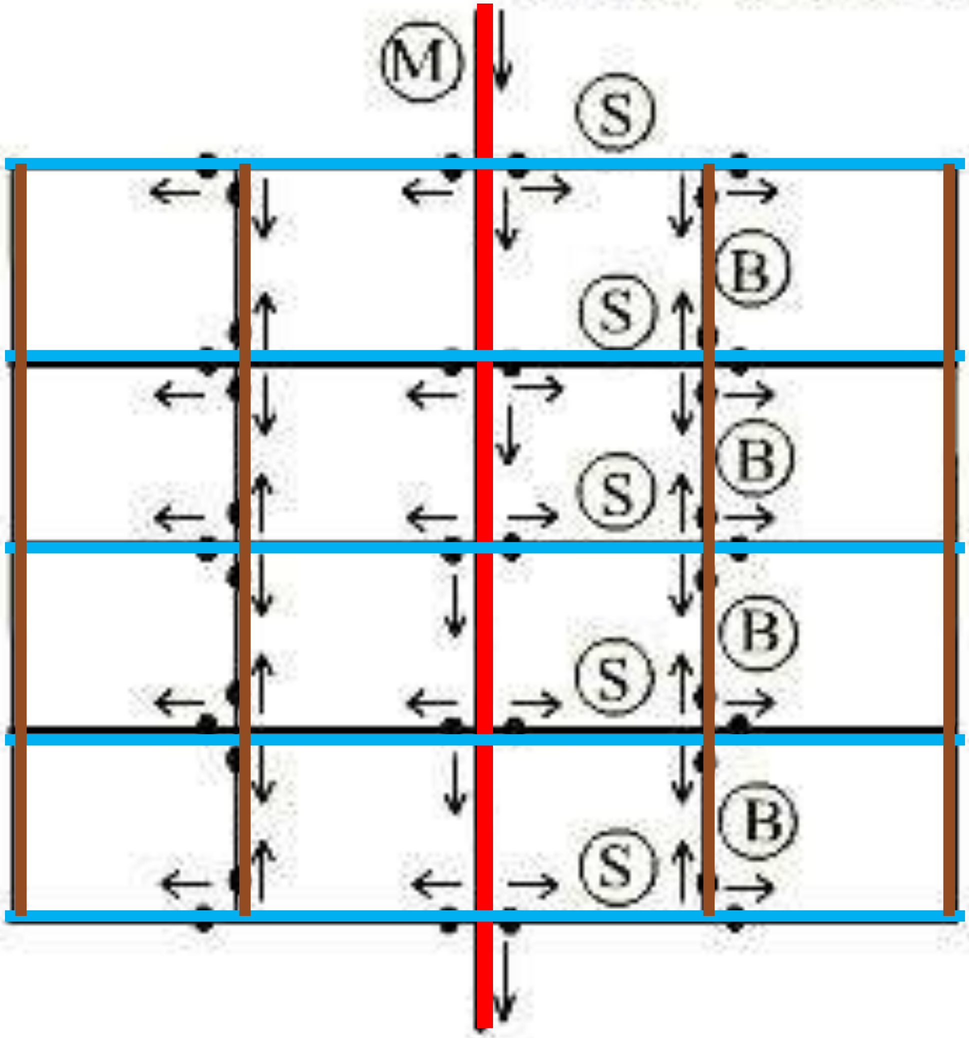
Advantages:

- ❖ Water is kept in good circulation due to the absence of dead ends.
- ❖ In the cases of a breakdown in some section, water is available from some other direction.

Disadvantages

- ❖ Requires more length of pipe lines and a larger number of sluice valves (i.e. cut-valves)
- ❖ Construction is costlier
- ❖ Design is difficult and costlier.
- ❖ Exact calculation of sizes of pipes is not possible due to provision of valves on all branches.

Grid-iron System



Ⓜ : Main Pipe
Ⓑ : Branch
Ⓢ : Sub Mains
• : Cut off Valves

Radial System:

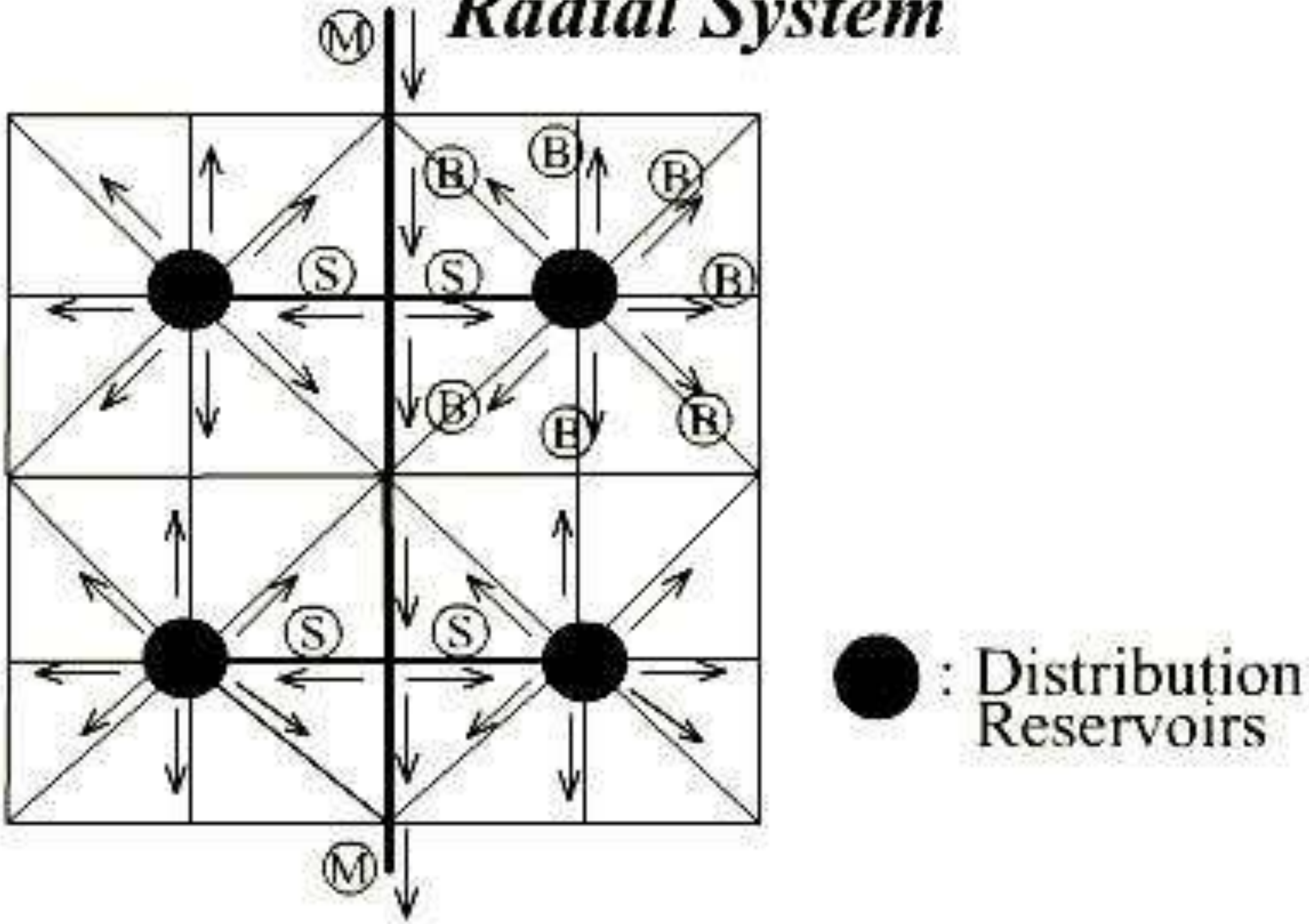
The area is divided into different zones. The water is pumped into the distribution reservoir kept in the middle of each zone and the supply pipes are laid radially ending towards the periphery.

Advantages:

It gives quick service.

Calculation of pipe sizes is easy.

Radial System



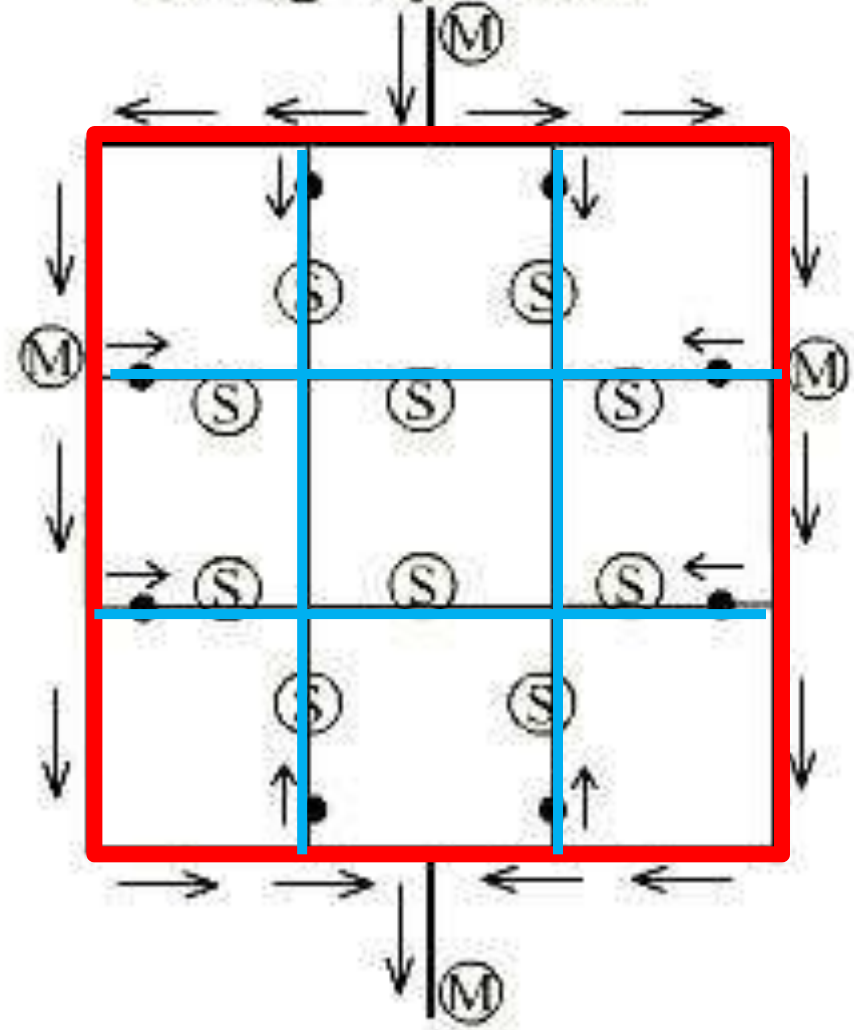
Ring System:

This system is also sometimes called *Circular System*. The supply main is laid all along the peripheral roads and sub mains branch out from the mains. Thus, this system also follows the grid iron system with the flow pattern similar in character to that of dead end system. So, determination of the size of pipes is easy.

Advantages:

Water can be supplied to any point from at least two directions.

Ring System



Ⓜ : Main Pipe
Ⓑ : Branch
Ⓢ : Sub Mains
● : Cut off Valves

Hydraulic Analysis of Water Distribution System: Methods

- ✓ Hardy-Cross Method
- Method of Sections
- Circle Method
- Relaxation Method
- Pipe Equivalence Method
- Digital Computer Analysis
- Electrical Analogy

In any pipe network, the following two conditions must be satisfied:

1. The algebraic sum of the pressure drops around a closed loop must be zero, i.e. there can be no discontinuity in pressure
2. The flow entering a junction must be equal to the flow leaving the same junction; i.e. the law of continuity must be satisfied

Hardy Cross Method

1. Assume any internally consistent distribution of flow. The sum of the flows entering any junction must equal the sum of the flows leaving that junction
2. Compute the head loss in each pipe by means of an equation or diagram. Conventionally, clockwise flows are positive and produce positive head loss and, *vice versa*.
3. With due attention to sign, compute the total head loss around each circuit, i.e. $\sum K.Q_a^2$
4. Compute without regard to sign, for the same circuit, the sum of $\sum x.K.Qa^{x-1}$
5. Apply the corrections obtained from the equations below to the flow in each pipe. Pipes common to two loops will receive both corrections with due regard to sign.

$$\Delta = -\frac{\sum K.Q_a^x}{\sum \left| x.KQ_a^{x-1} \right|}$$

$$\Delta = \frac{-\sum H_L}{x.\sum \left| \frac{H_L}{Q_a} \right|}$$

Where H_L = head loss for the assumed flow Q_a

K - Value

- Fittings such as elbows, tees, valves and reducers represent a significant component of the pressure loss in most pipe systems. Calculation of pressure losses through pipe fittings and some minor equipment are done using the K-value method, also known as the Resistance Coefficient, Velocity Head, Excess Head or Crane method.

- The K-value, Resistance Coefficient, Velocity Head, Excess Head or Crane method allows the user to characterise the pressure loss through fittings in a a pipe. The K-value represents the multiple of velocity heads that will be lost by fluid passing through the fitting.
- It is more accurate than the Equivalent Length method, as it can be characterised against varying flow conditions (i.e. Reynold Number). However it is less accurate than other methods as it does not take into account the varying geometries of fittings at different sizes. For example a DN 50 (2") long radius 90° elbow is not geometrically similar to a DN 150 (6") long radius 90° elbow, thus the K-value is inaccurate at sizes other than that of the fitting used to determine the K-value. These K-values also generally assume fully developed turbulent flow, and thus are inaccurate at low Reynolds Numbers.

- There are several other methods for calculating pressure loss from fittings, such as:
  - Equivalent Length
  - 2K Method
  - 3K Method
- K-VALUE METHOD AND TYPICAL VALUES
  - The Velocity head method is named as such because it represents the pressure loss through a fitting as the equivalent number of 'velocity heads'. It is in some ways similar to the equivalent length method, and the two may be equated by the formula below:

Formula for Calculating Head Loss from K Values

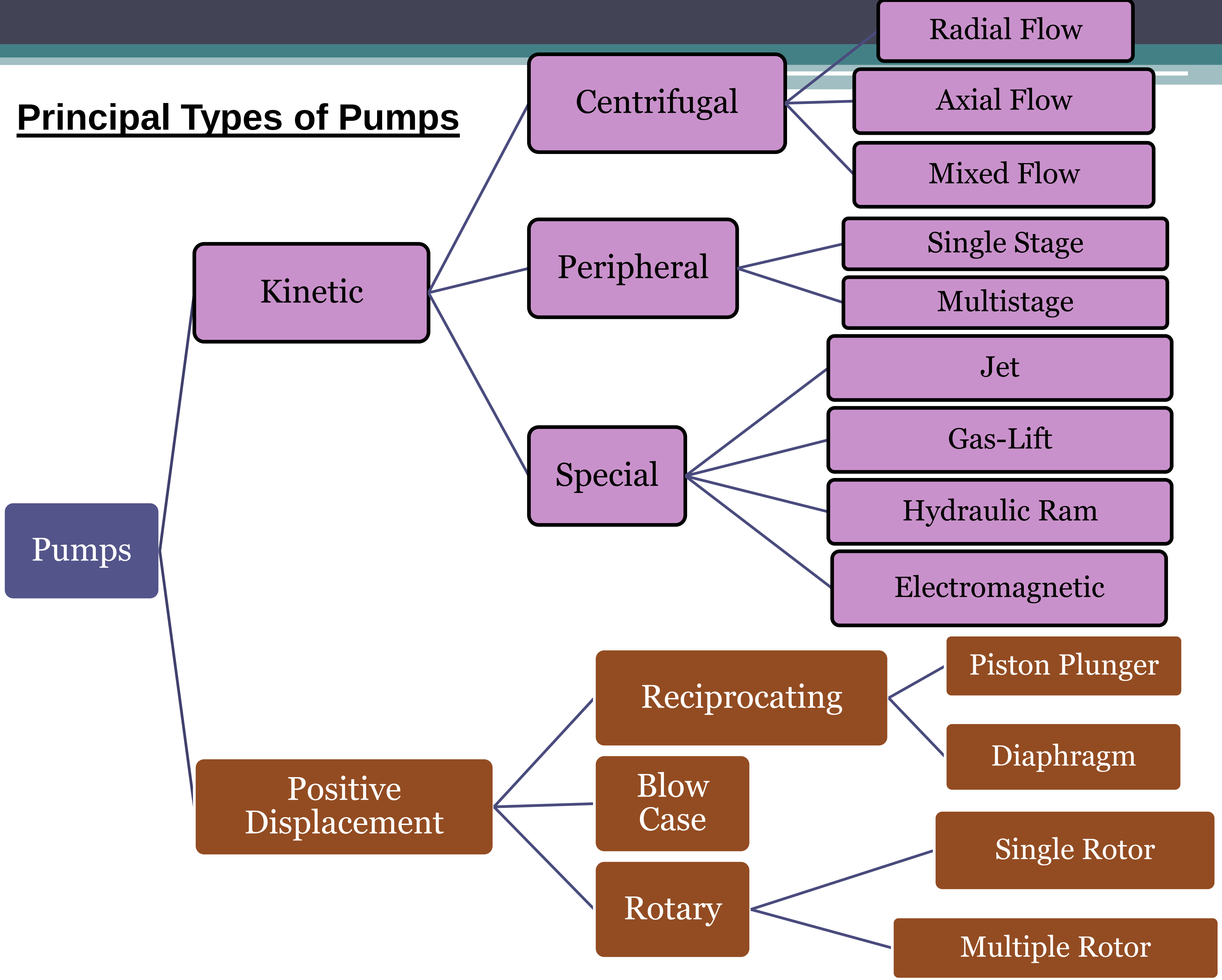
- *K=f*L/D*

Where L/D is the equivalent length

$$h_L = K\frac{V^2}{2g}$$

Pumps

Principal Types of Pumps



Classification of Pumps

- According to
- Principle of Operation
  - Kinetic-Energy Pumps
  - Positive Displacement Pumps
- Field of Application (i.e. liquids handled)
- Operational Duty (i.e. Head and Capacity)
- Type of Construction
- Method of Drive

Principal Components of Kinetic Energy Pumps

- Impeller – Rotating element. Imparts energy to the liquid being pumped
- Shaft – on which impeller is mounted
- Pump Casing – includes inlet and outlet passages
- Frame – supports pump casing

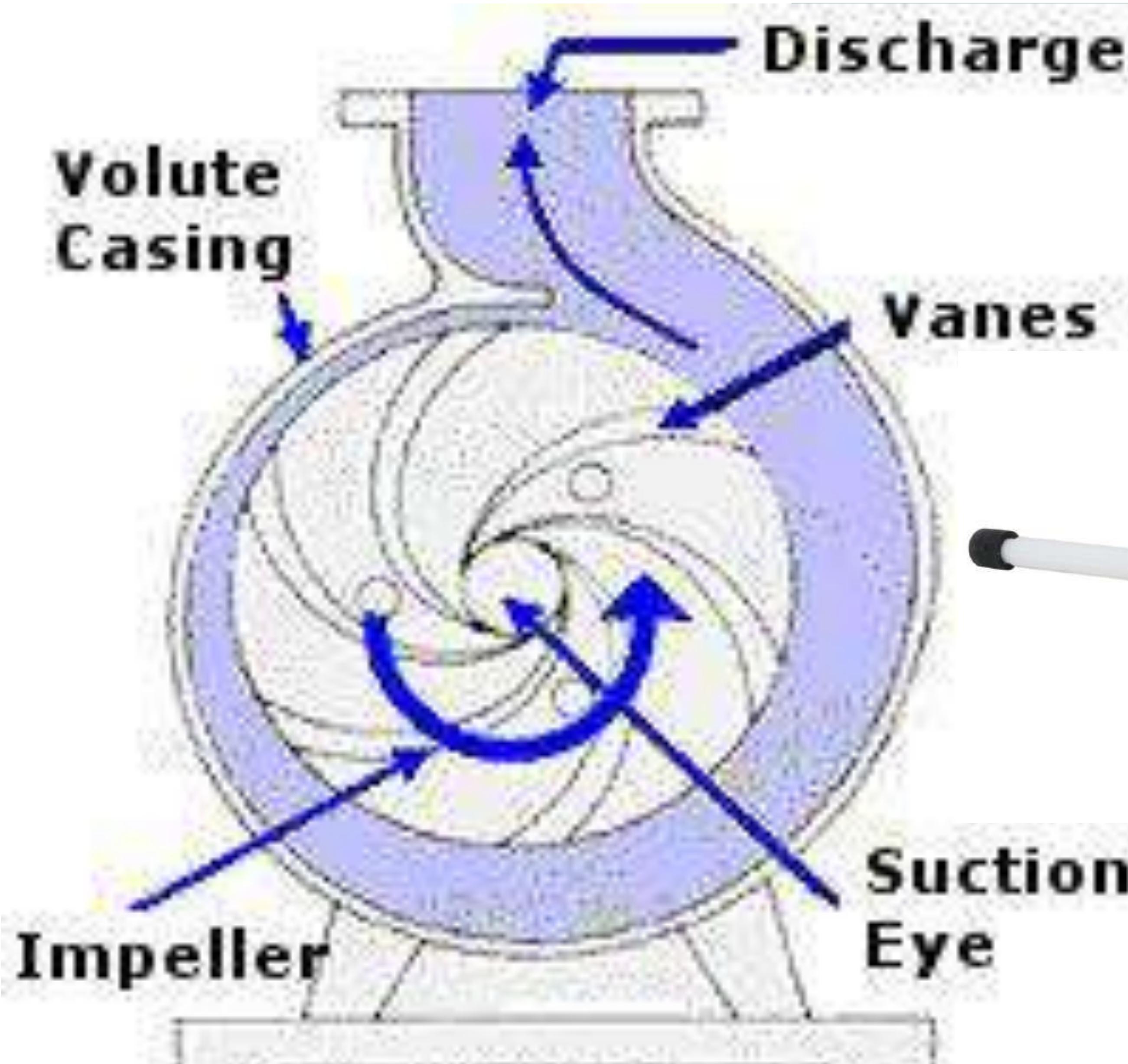


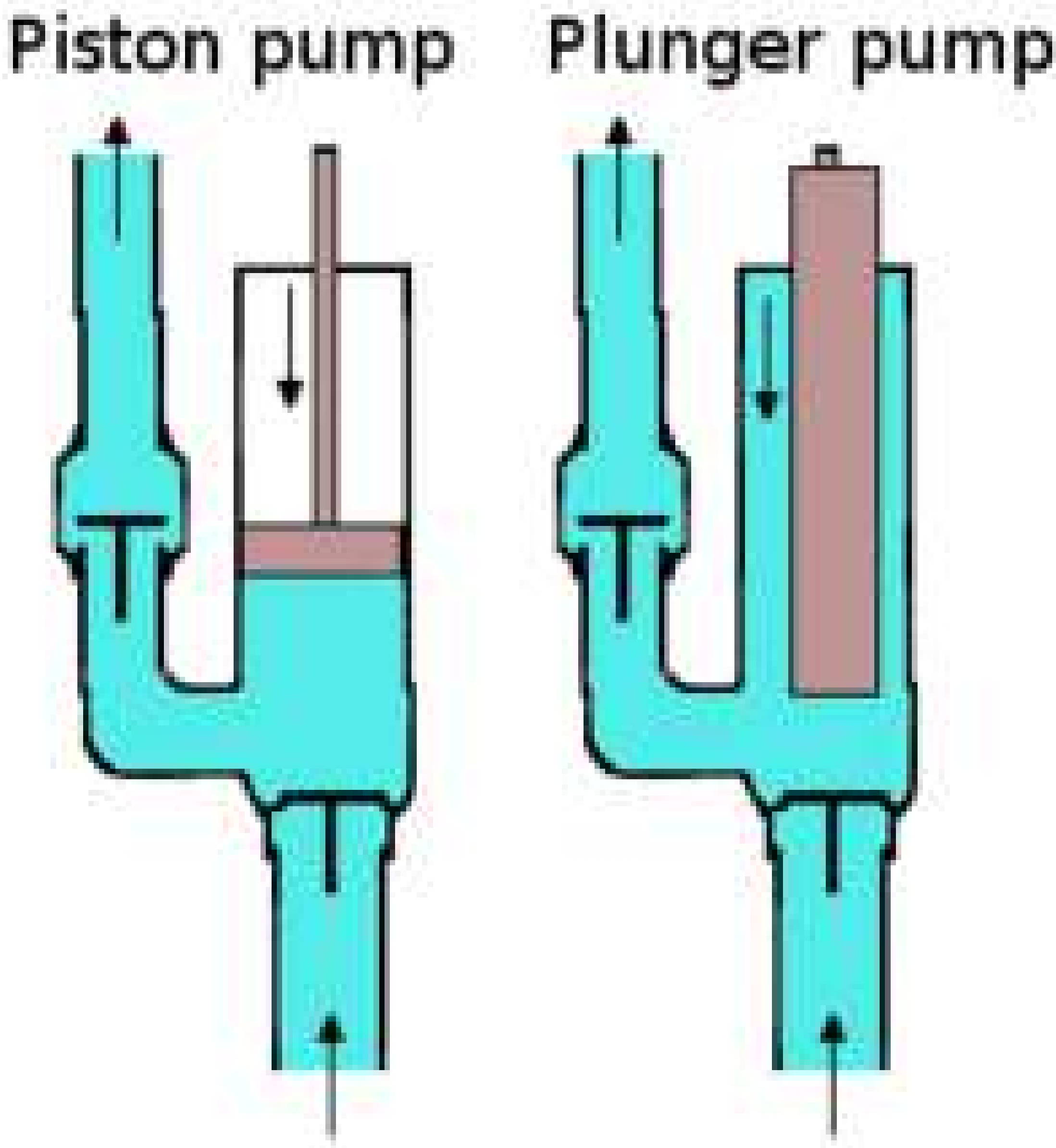
FIG 1

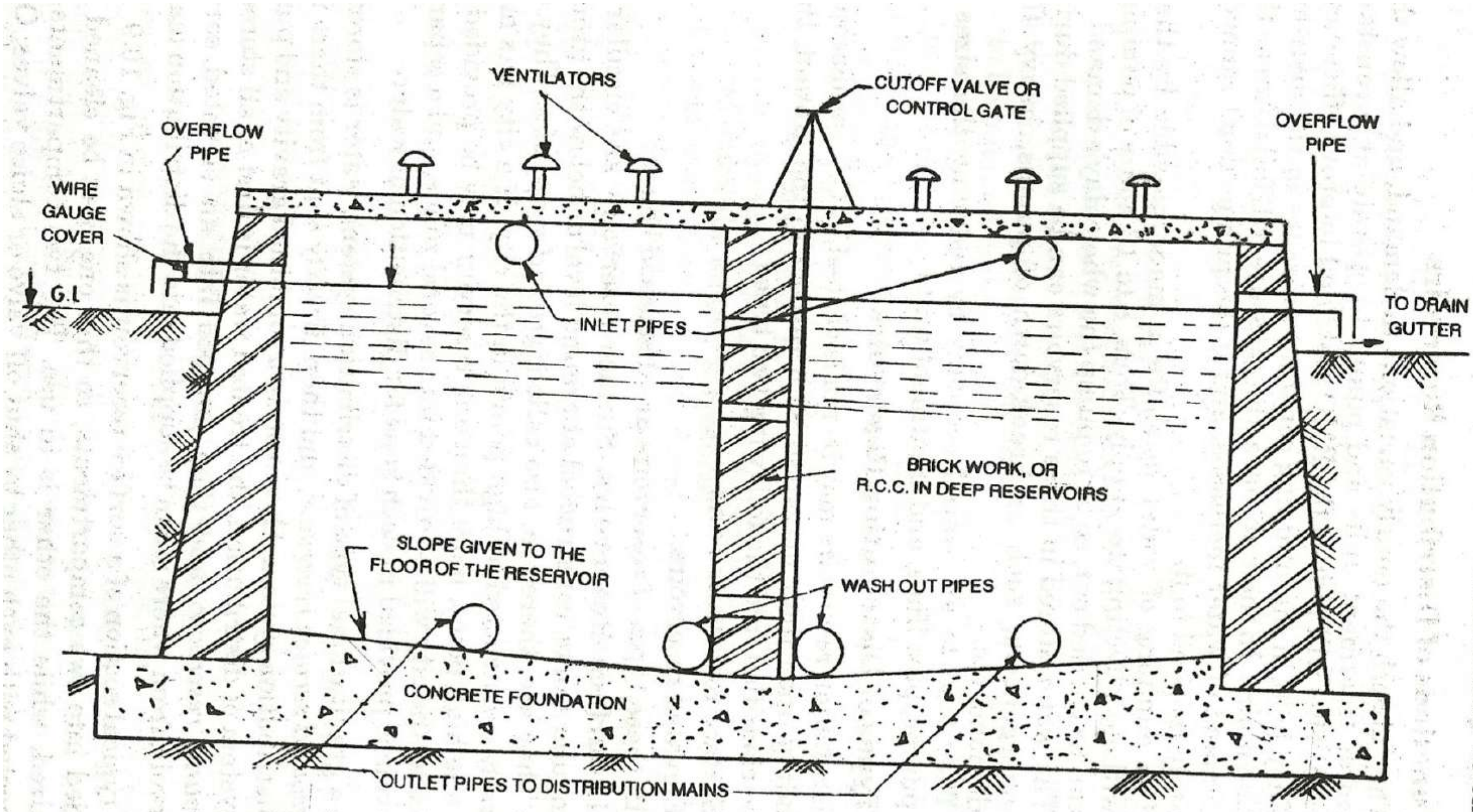
Pump Drive Units

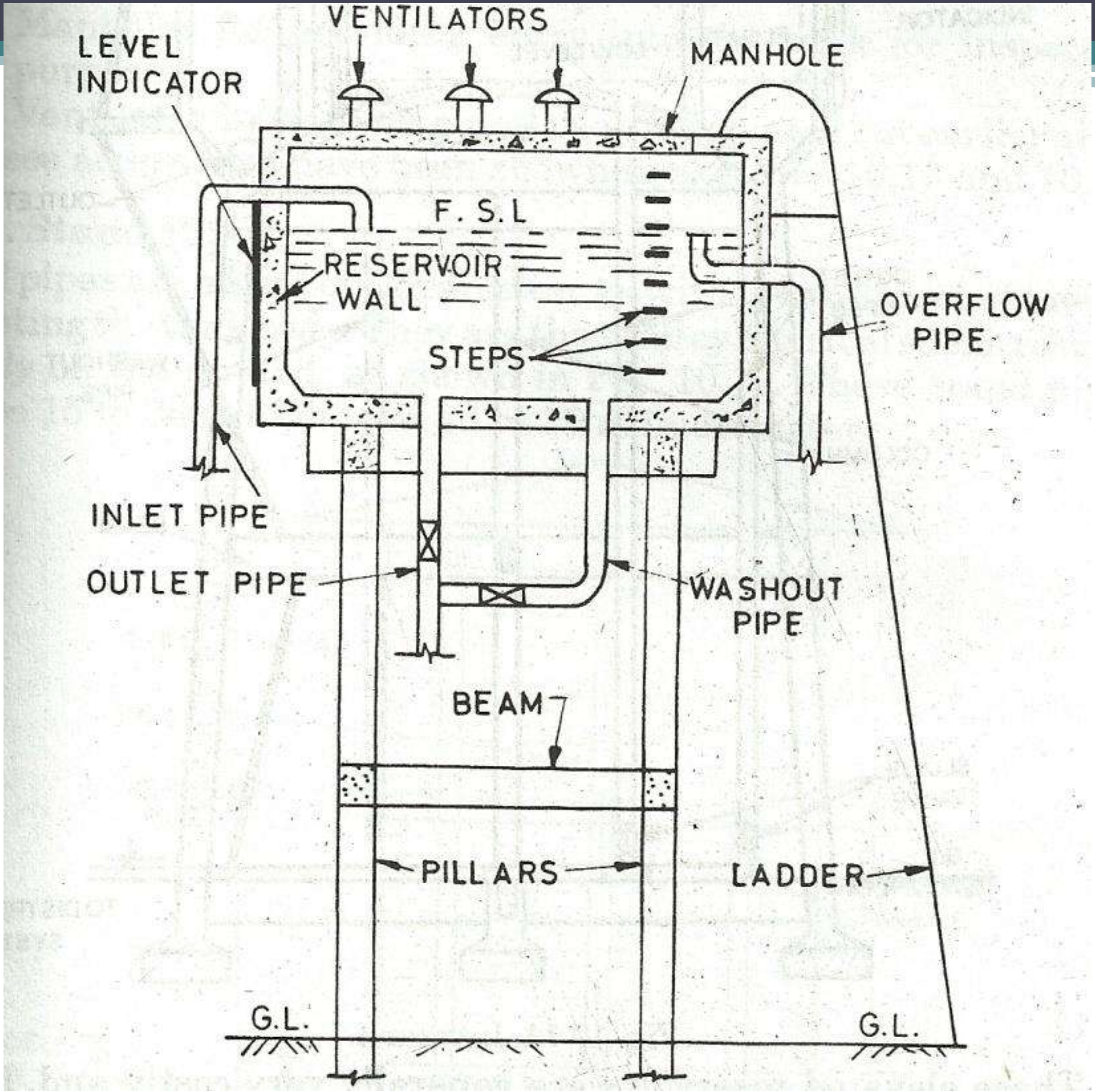
- Electric Motors – Direct Connected
- Electric Constant-Speed Motors Coupled to Variable-Speed Devices
- Internal-Combustion Engines and Gas Turbines
- Fluid-Driven Pumps

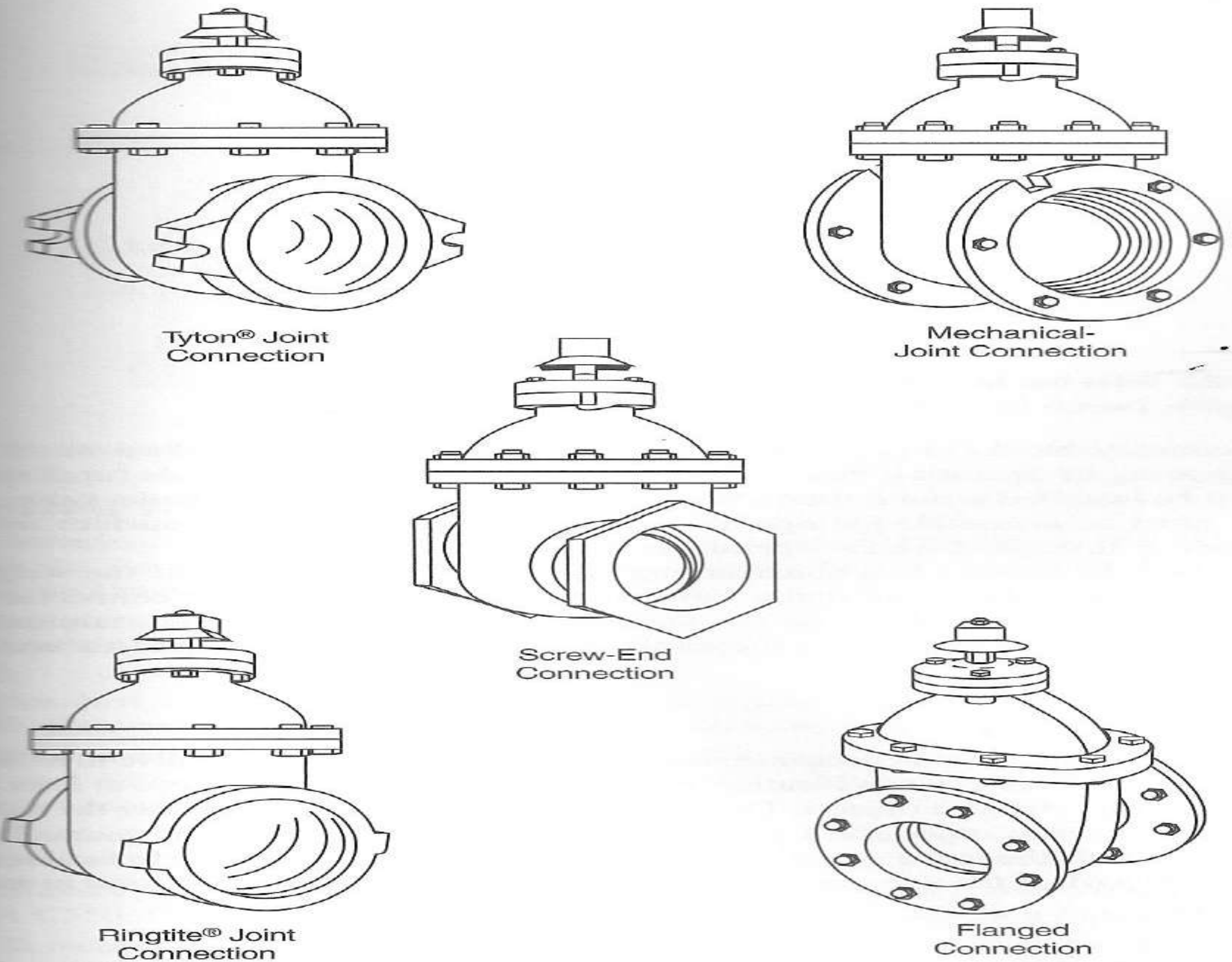
Pump Application Terminology and Usage

- Capacity
- Head
- Pump Efficiency
- Power Input


Piston pump
Plunger pump


VENTILATORS
CUTOFF VALVE OR CONTROL GATE
OVERFLOW PIPE
OVERFLOW PIPE
WIRE GAUGE COVER
G.L
TO DRAIN GUTTER
INLET PIPES
BRICK WORK, OR R.C.C. IN DEEP RESERVOIRS
SLOPE GIVEN TO THE FLOOR OF THE RESERVOIR
WASH OUT PIPES
CONCRETE FOUNDATION
OUTLET PIPES TO DISTRIBUTION MAINS


VENTILATORS
LEVEL INDICATOR
MANHOLE
F. S. L
RESERVOIR WALL
OVERFLOW PIPE
STEPS
INLET PIPE
OUTLET PIPE
WASHOUT PIPE
BEAM
PILLARS
LADDER
G.L.
G.L.



6-21 Common types of valve couplings

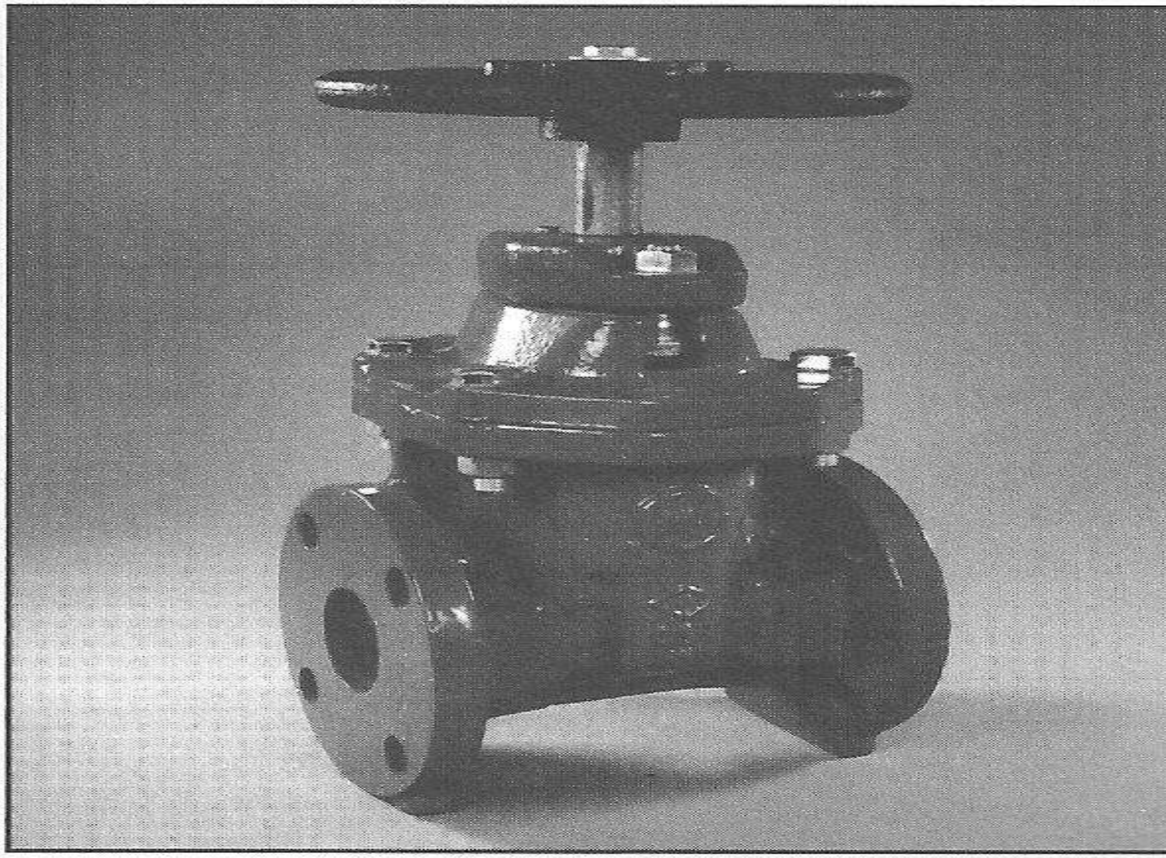


FIGURE 6-19 Handwheel operator
Courtesy of M&H Valve and Fire Hydrant

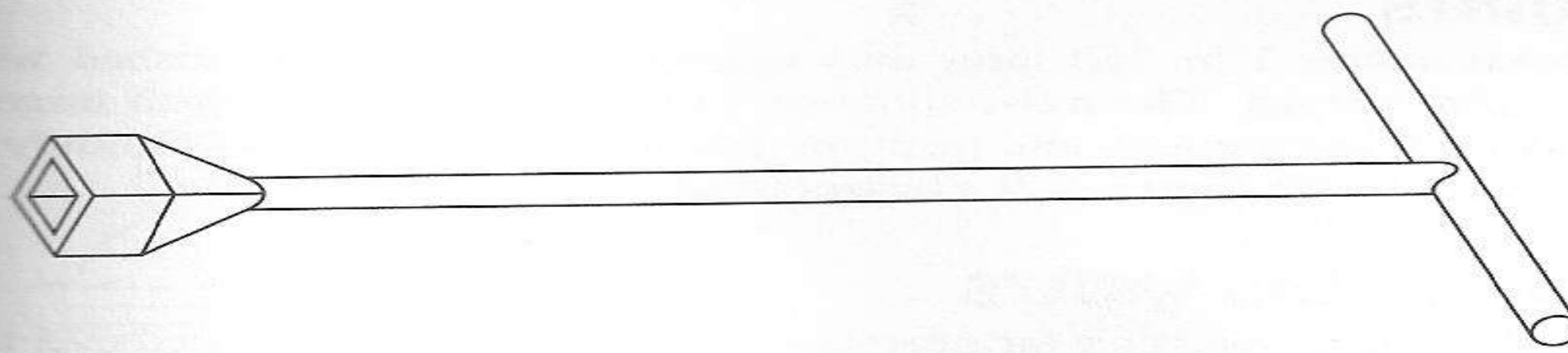


FIGURE 6-20 Valve key for water main valves

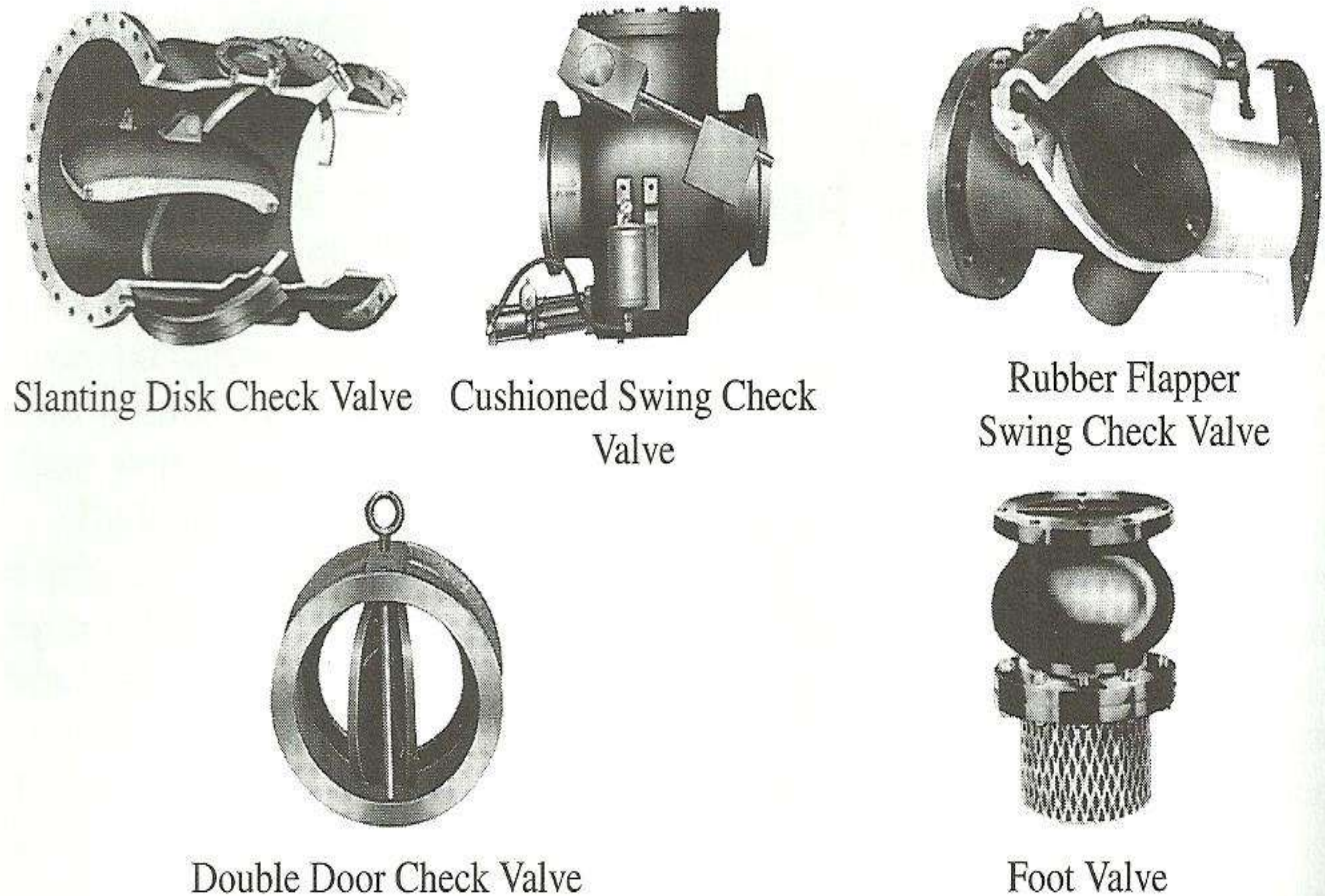
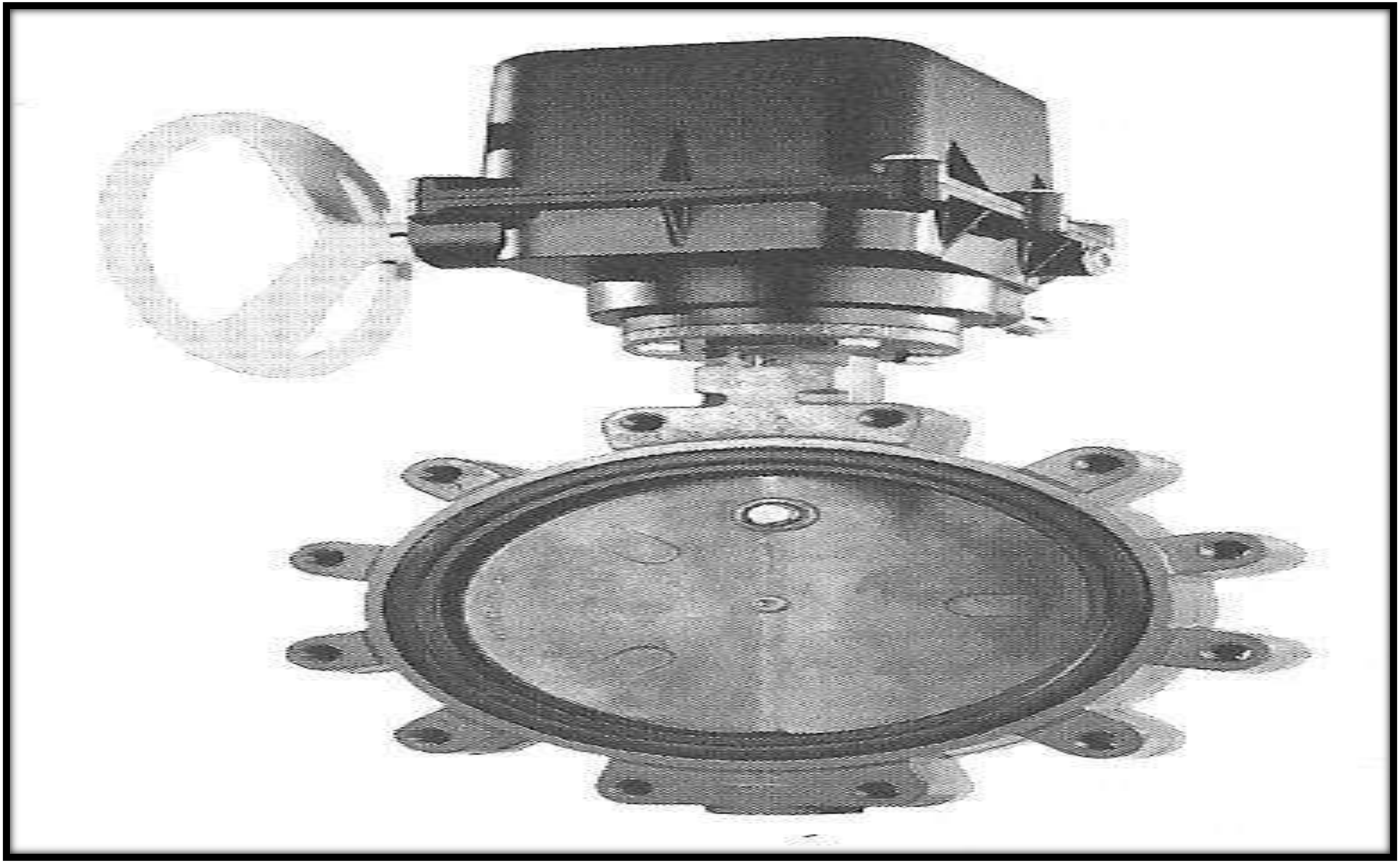
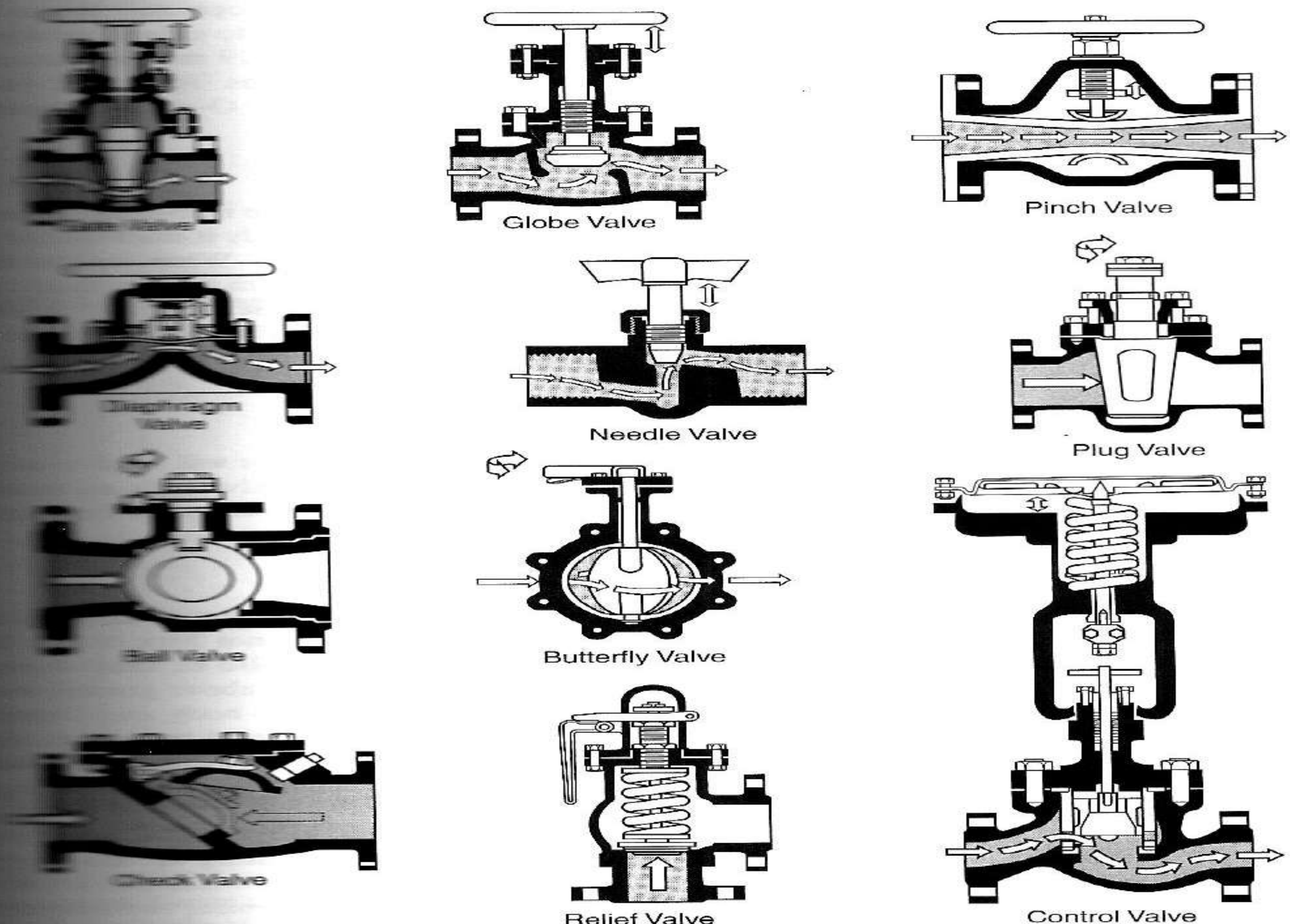


FIGURE 6-18 Five types of check valves

Reprinted with permission of APCO/Valve & Primer Corp.

Butterfly Valve with Electric Actuator





Types of water utility valves

Valve Manufacturers Association of America, Washington, D.C.

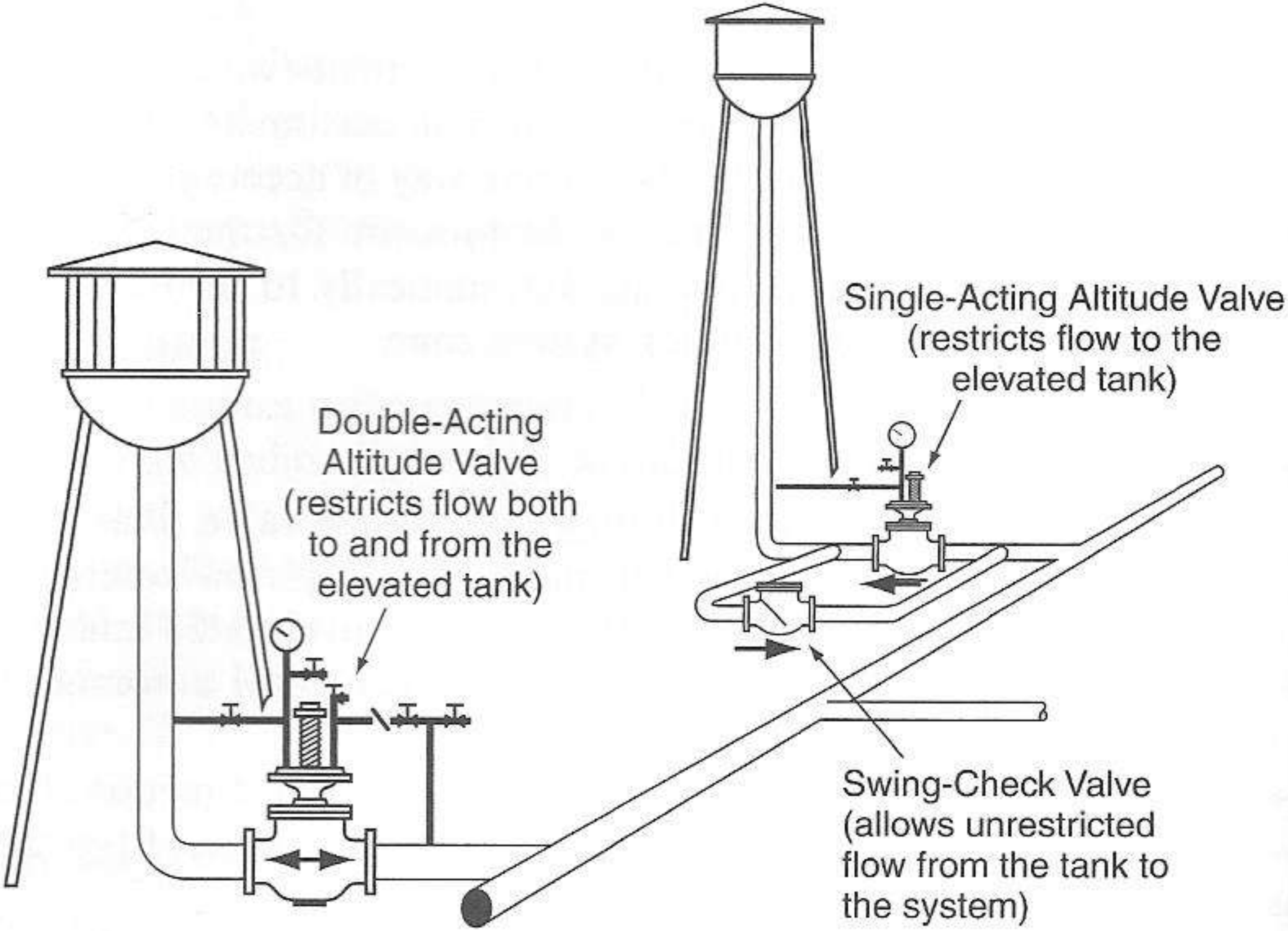


FIGURE 6-3 Altitude valves

Courtesy of GA Industries, Inc.

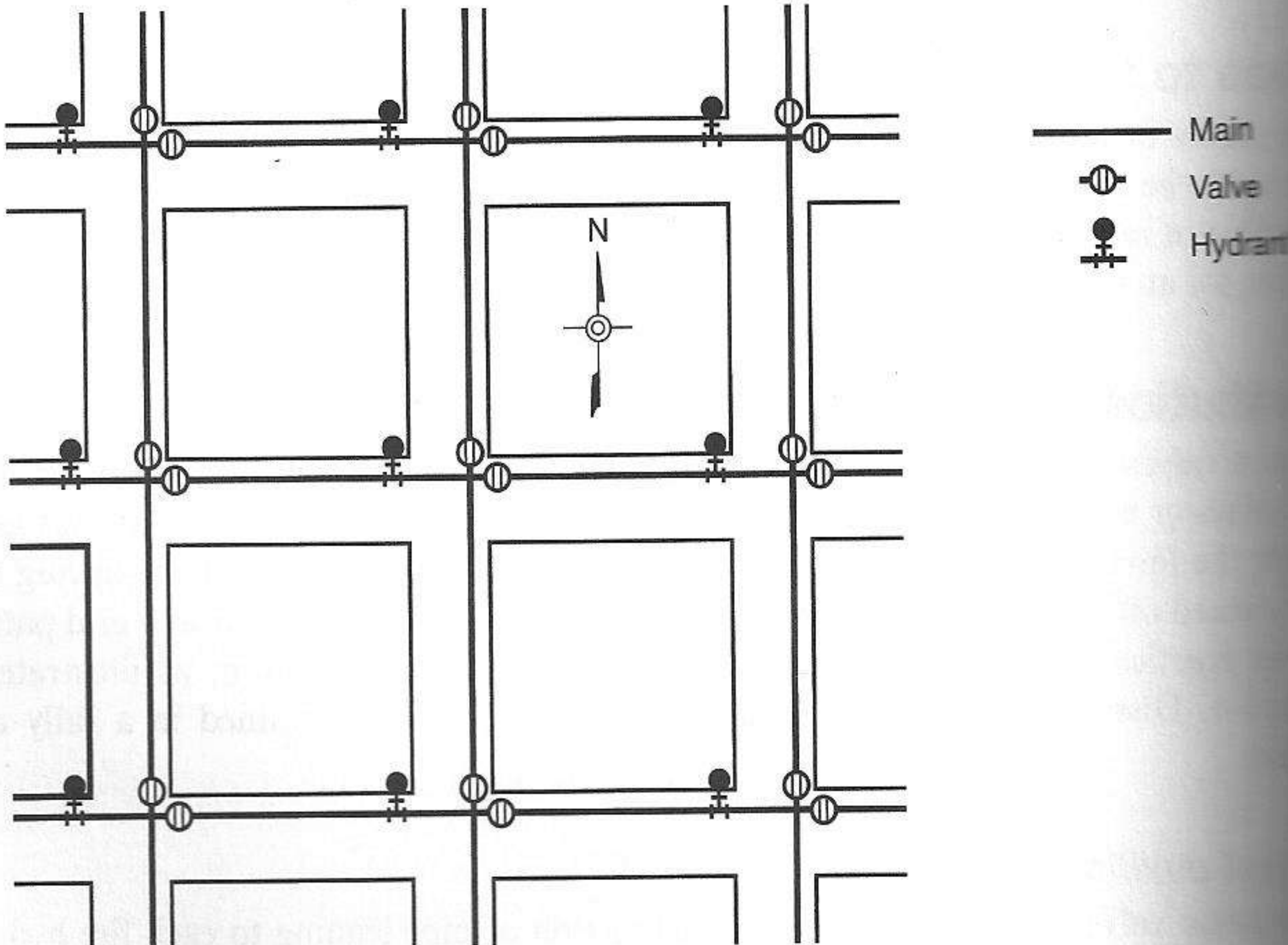


FIGURE 6-1 Valves installed at intersection of mains in a grid pattern

FIGURE 3-3 A 1,000,000-gal single-pedestal spheroidal elevated tank painted to look like a hot air balloon

Courtesy of CB&I

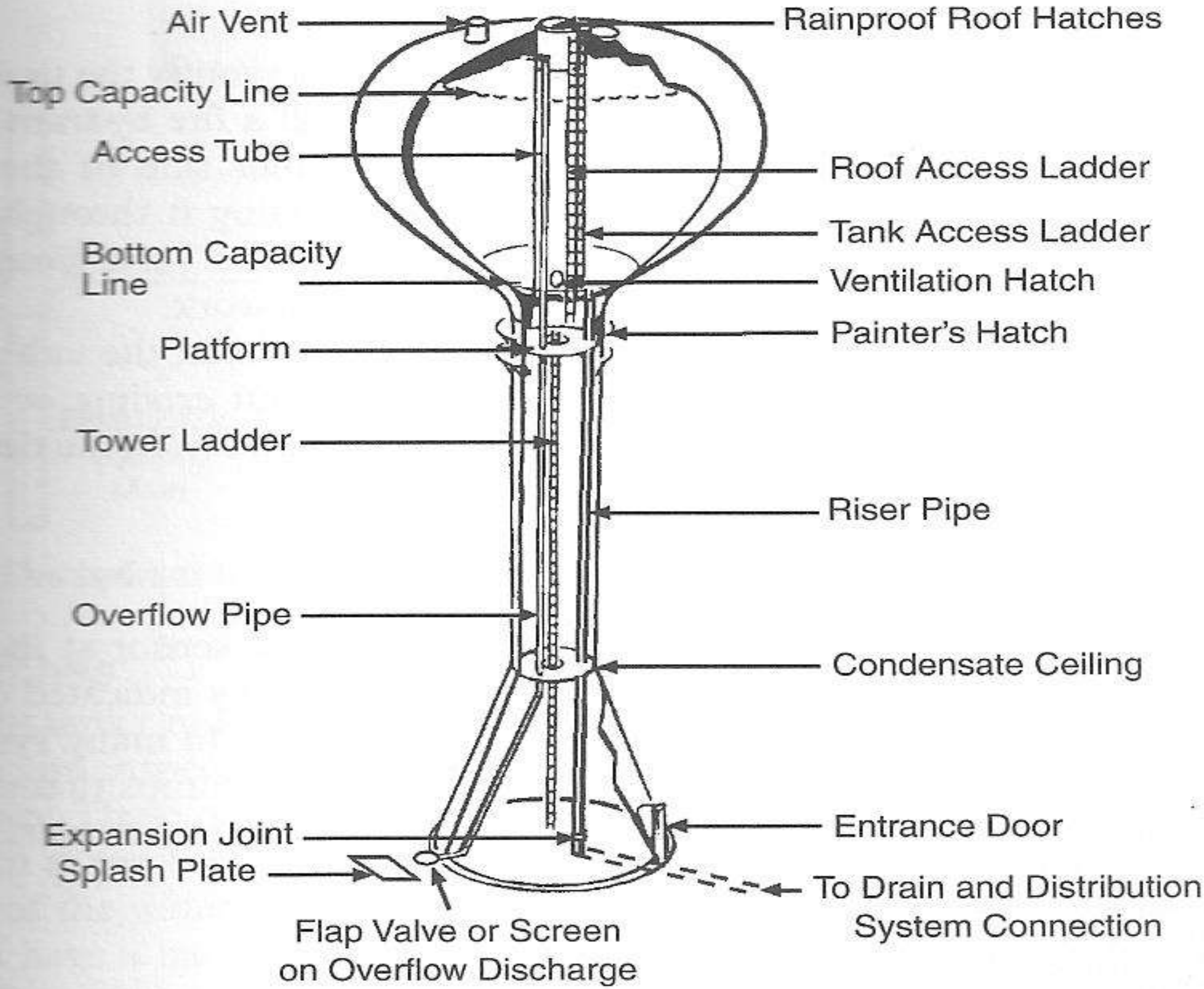


FIGURE 3-9 Principal accessories for an elevated storage tank

Courtesy of CB&I

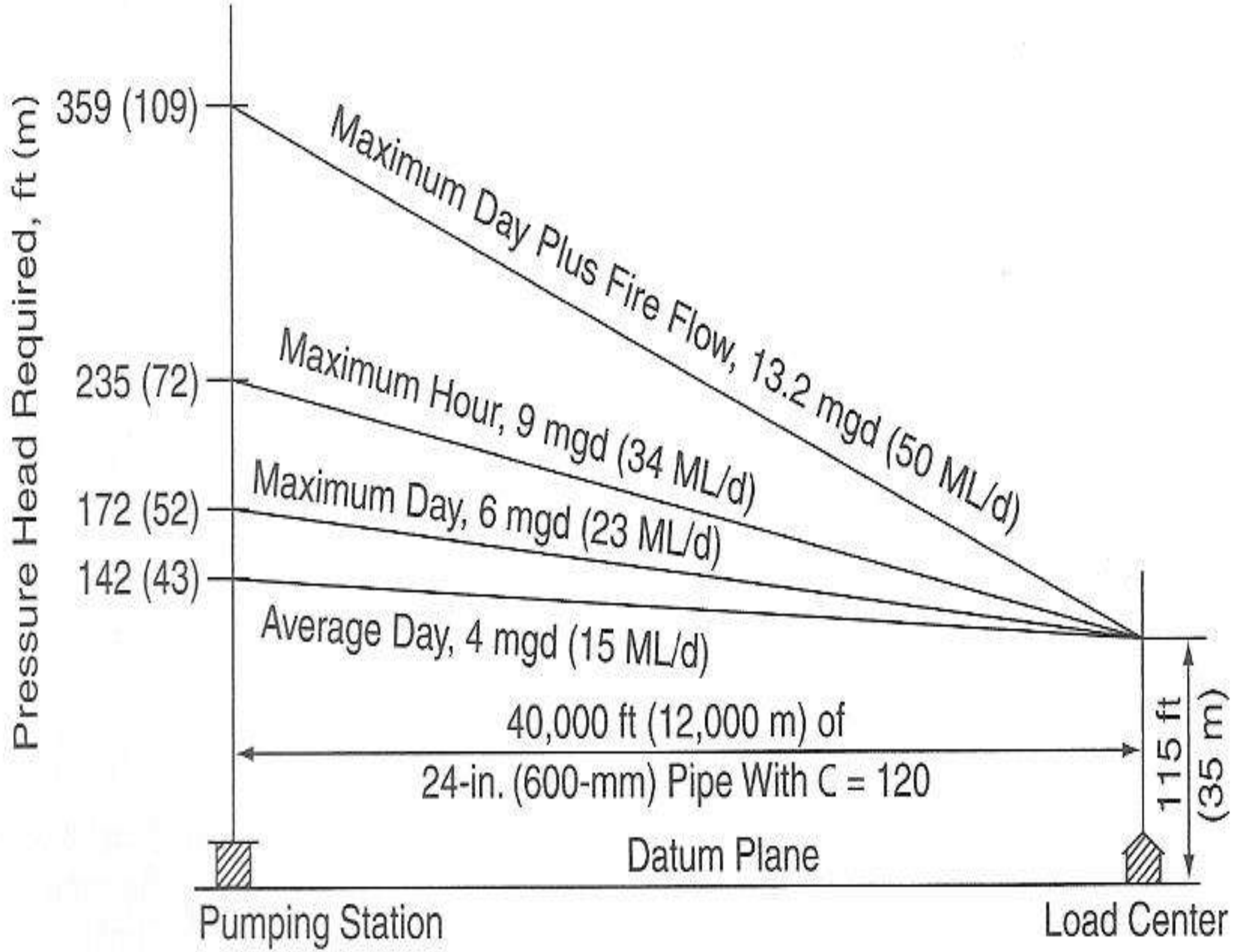


FIGURE 3-8 Sufficient pumping head must be provided when there is no storage

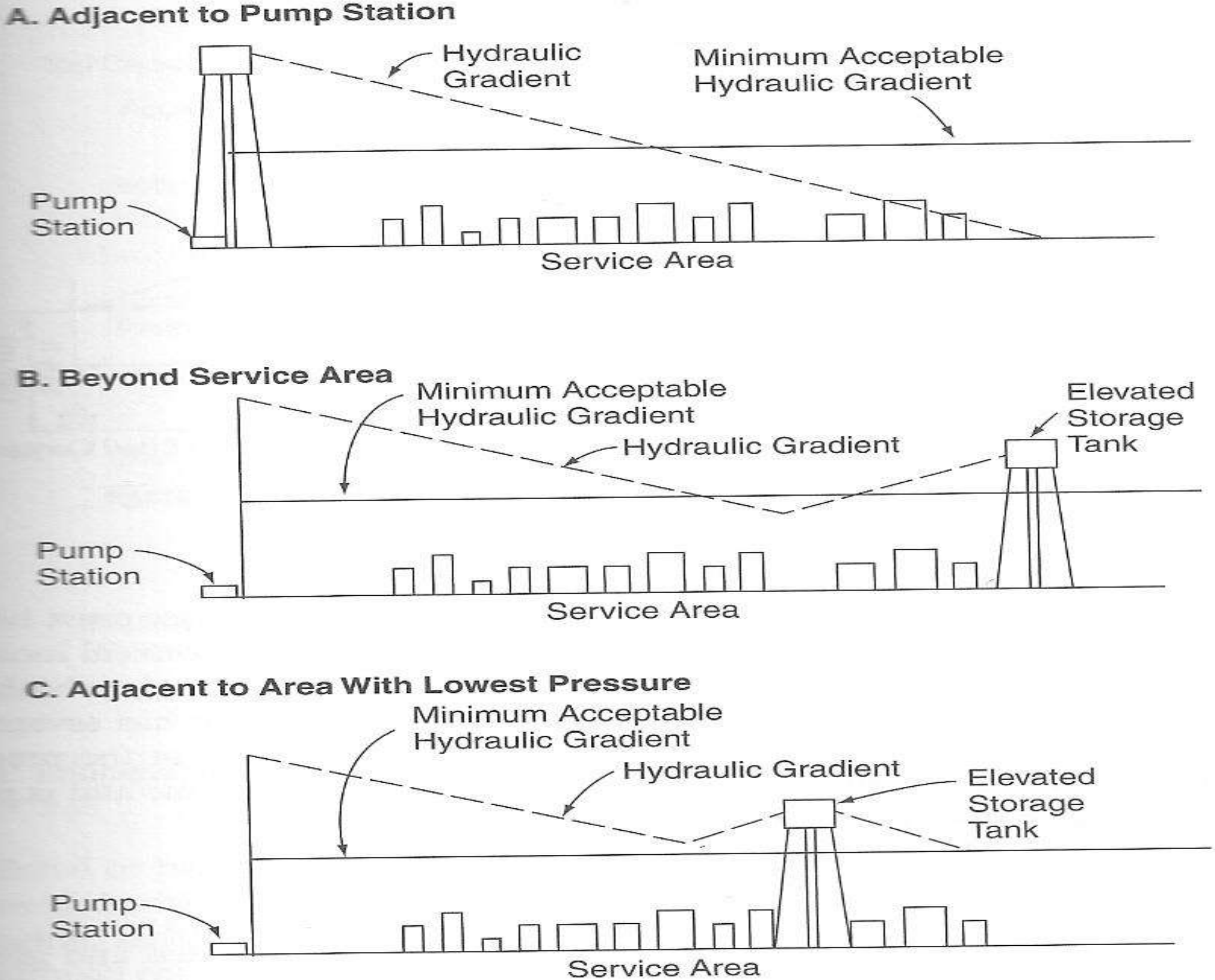


FIGURE 3-7 Different locations of elevated storage

Courtesy of Public Works Magazine

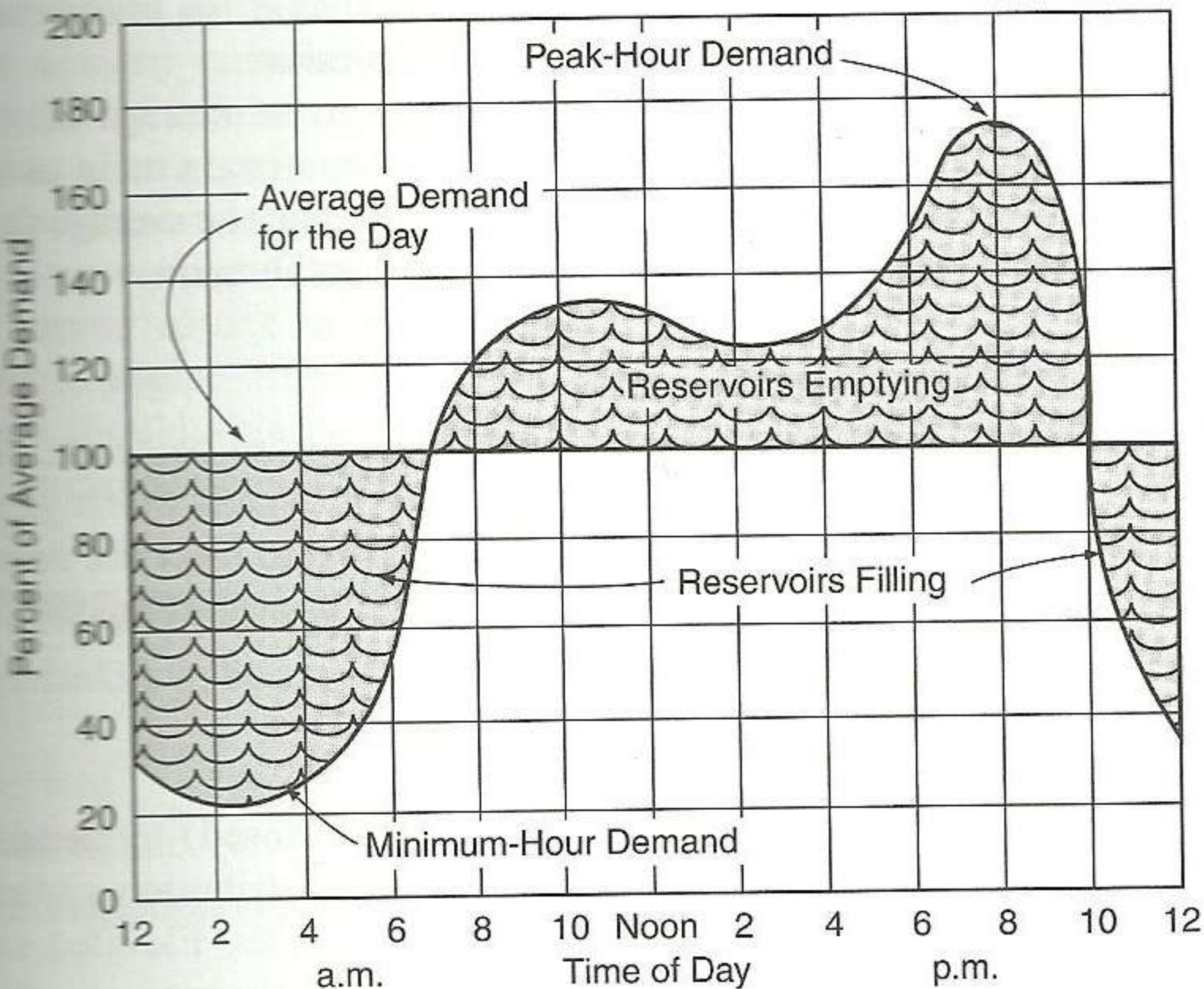


FIGURE 3-1 Daily variation of system demand

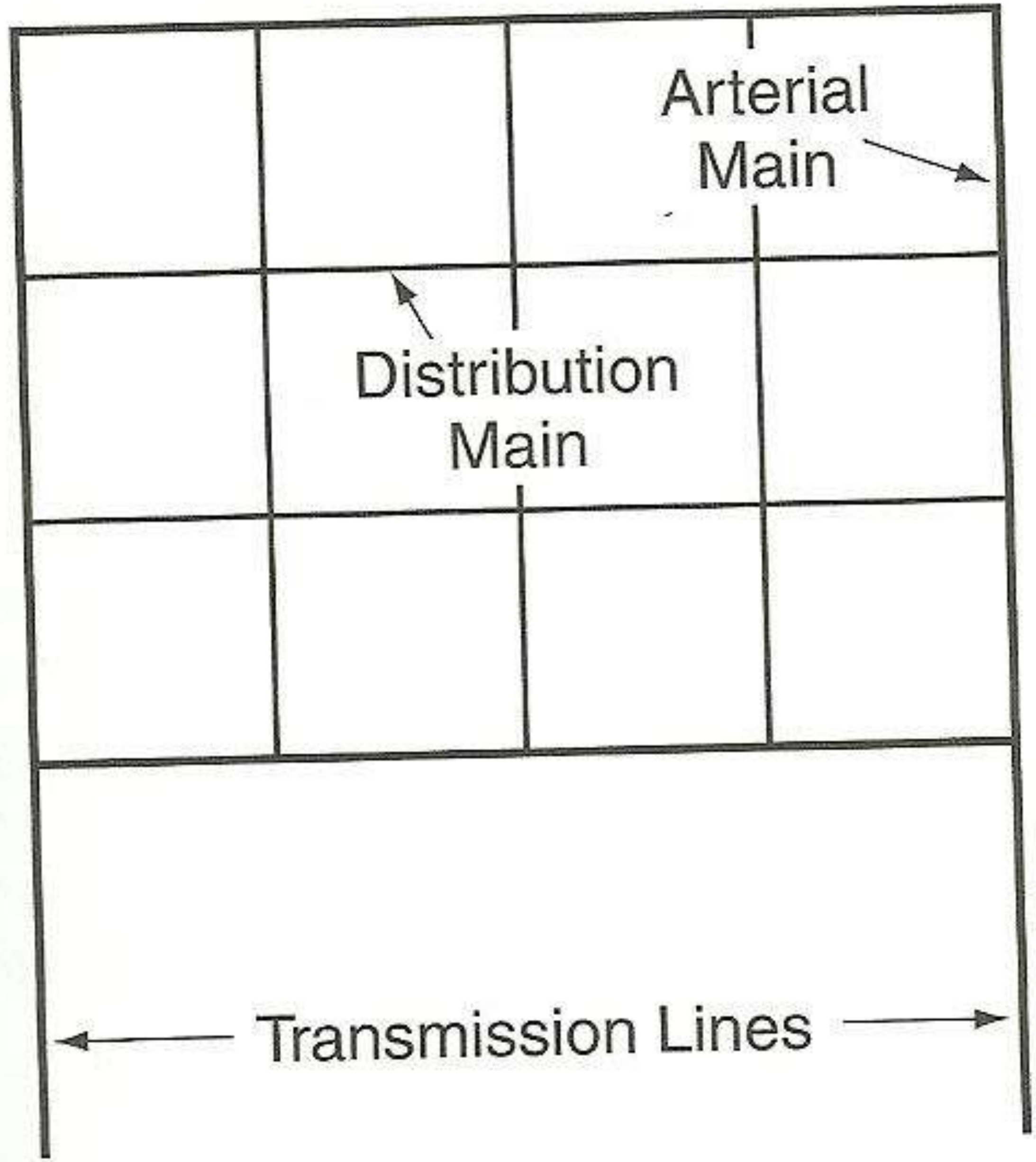


FIGURE 2-1 Arterial-loop system

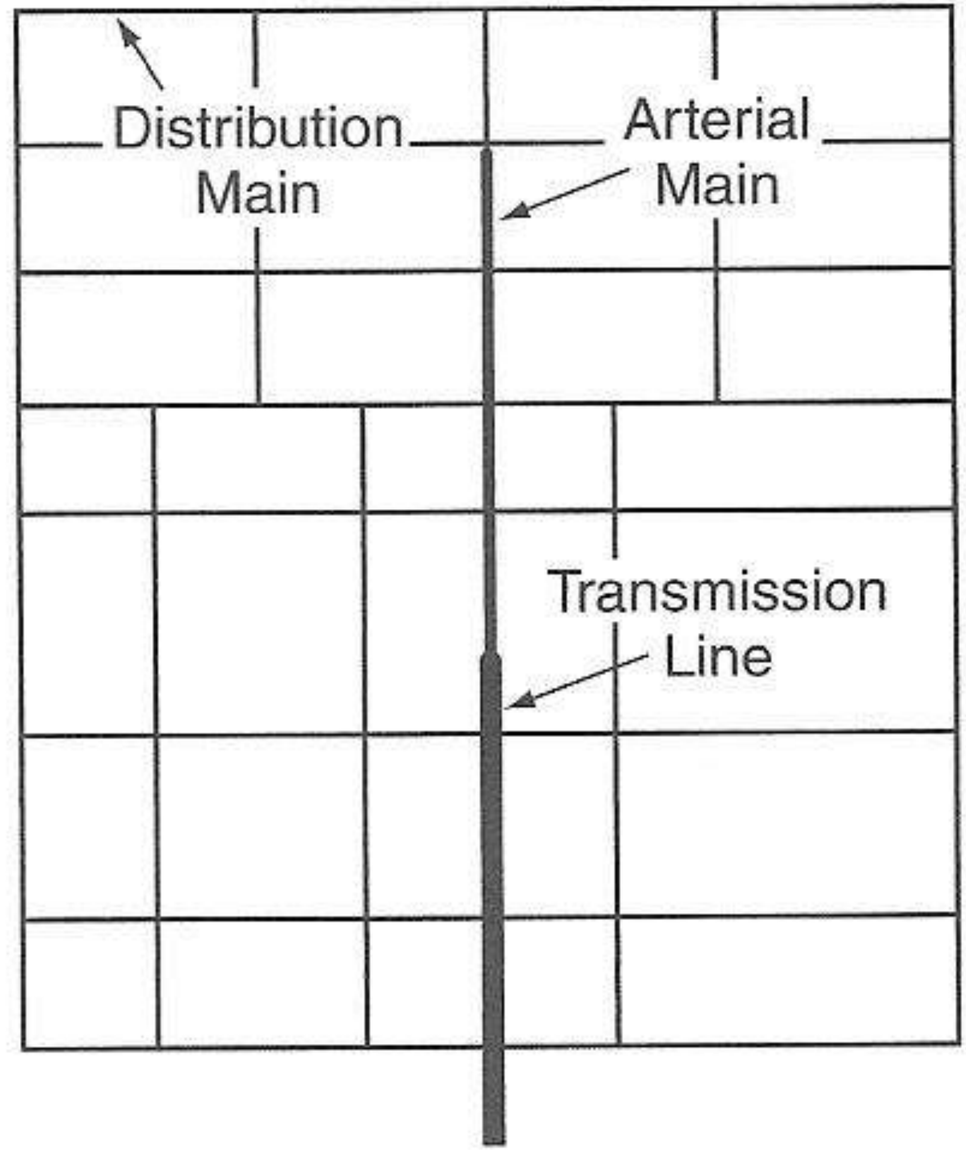


FIGURE 2-2 Grid system

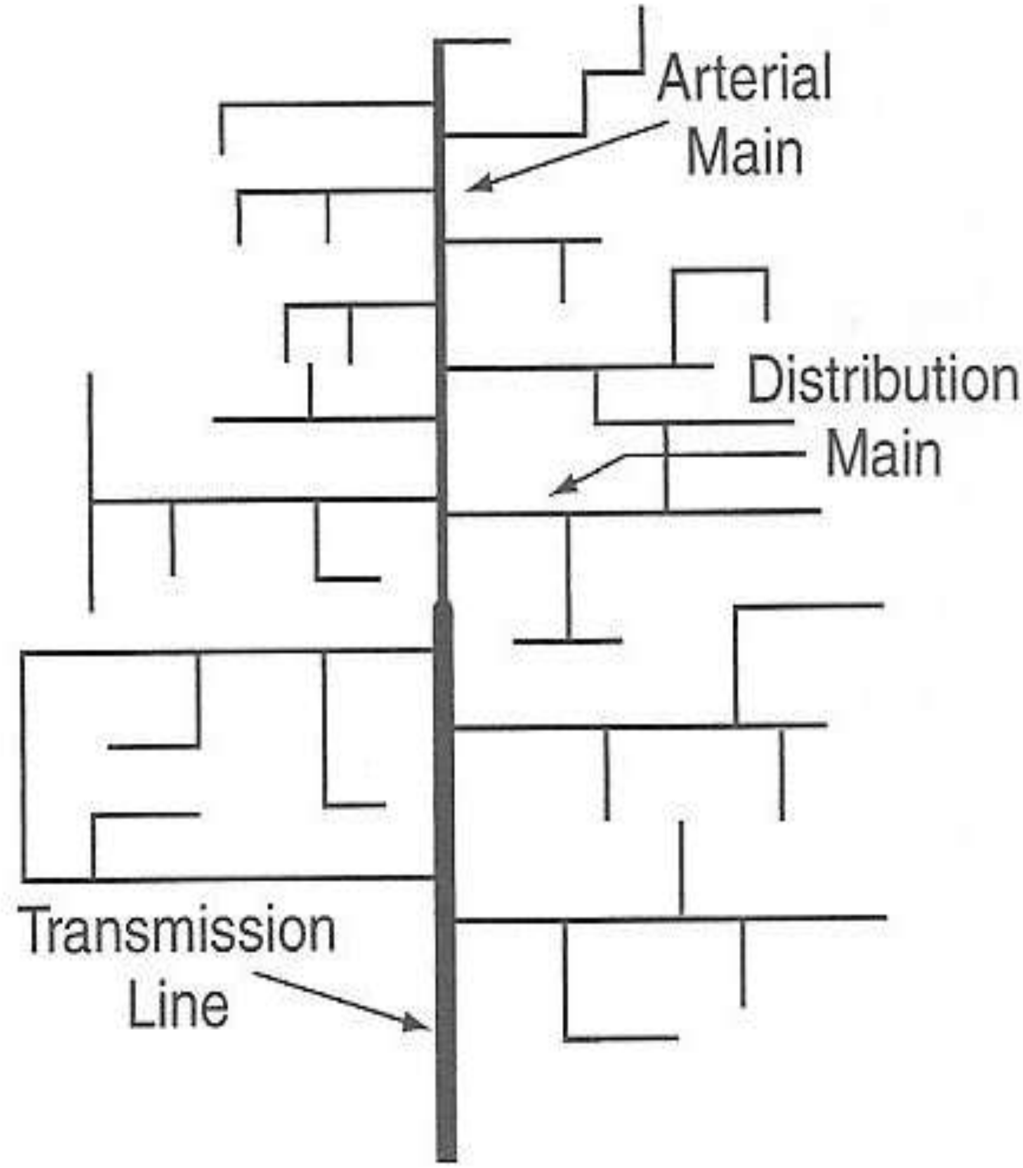


FIGURE 2-3 Tree system

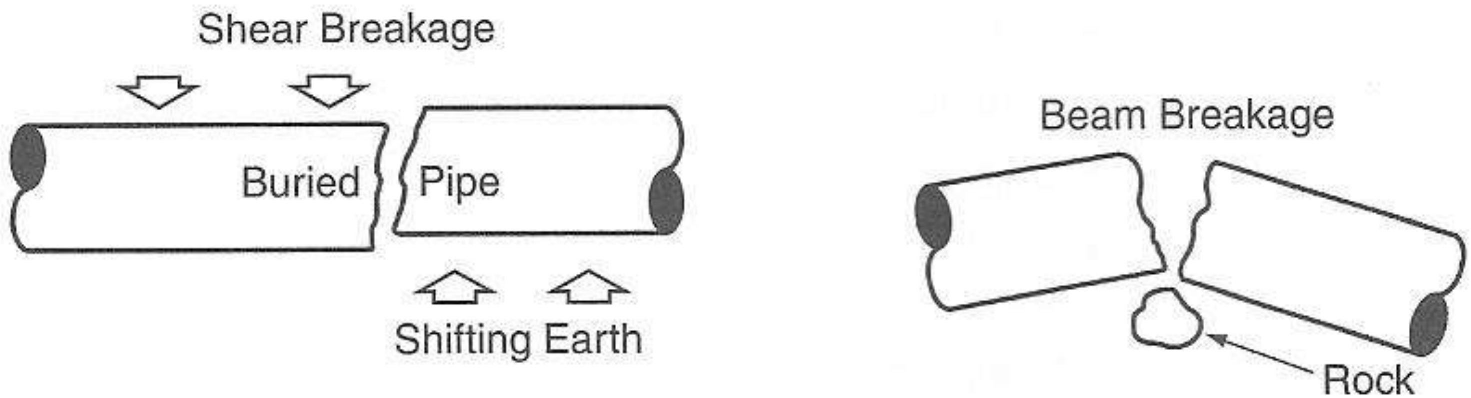


FIGURE 2-5 Shear and beam breakage

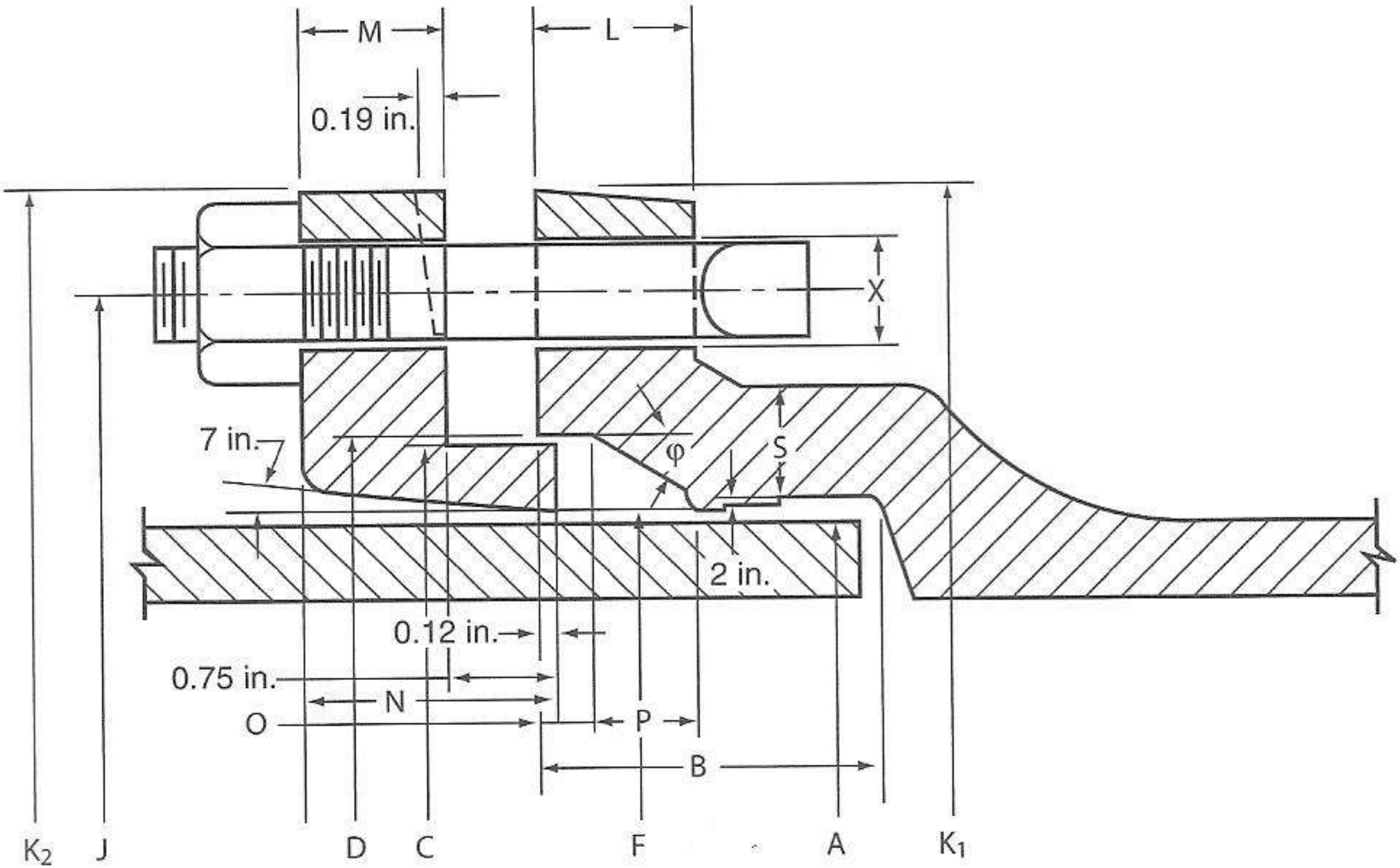


FIGURE 2-12 Mechanical-joint example for sizes 3–48 in.

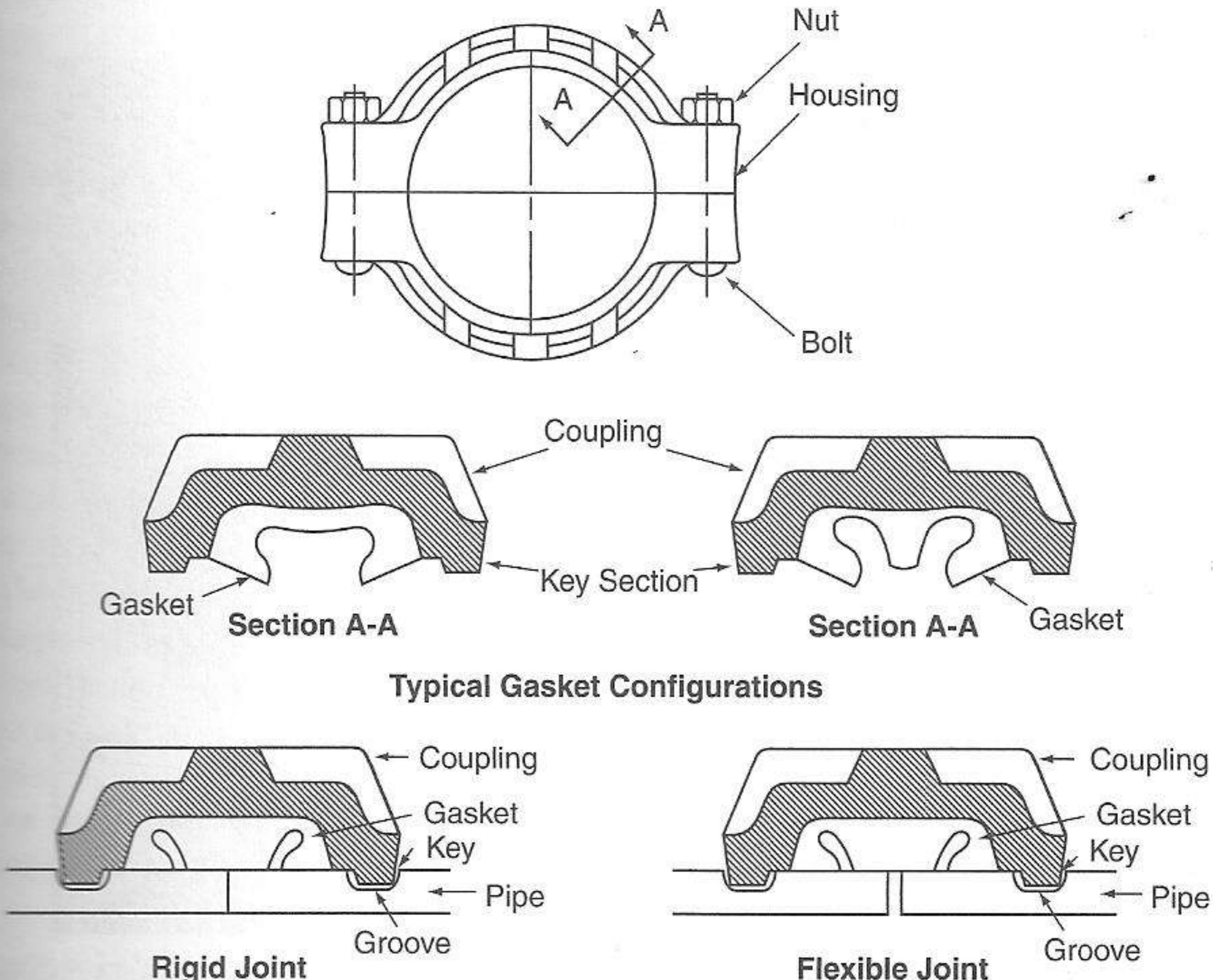


FIGURE 2-13 General coupling and joint configurations

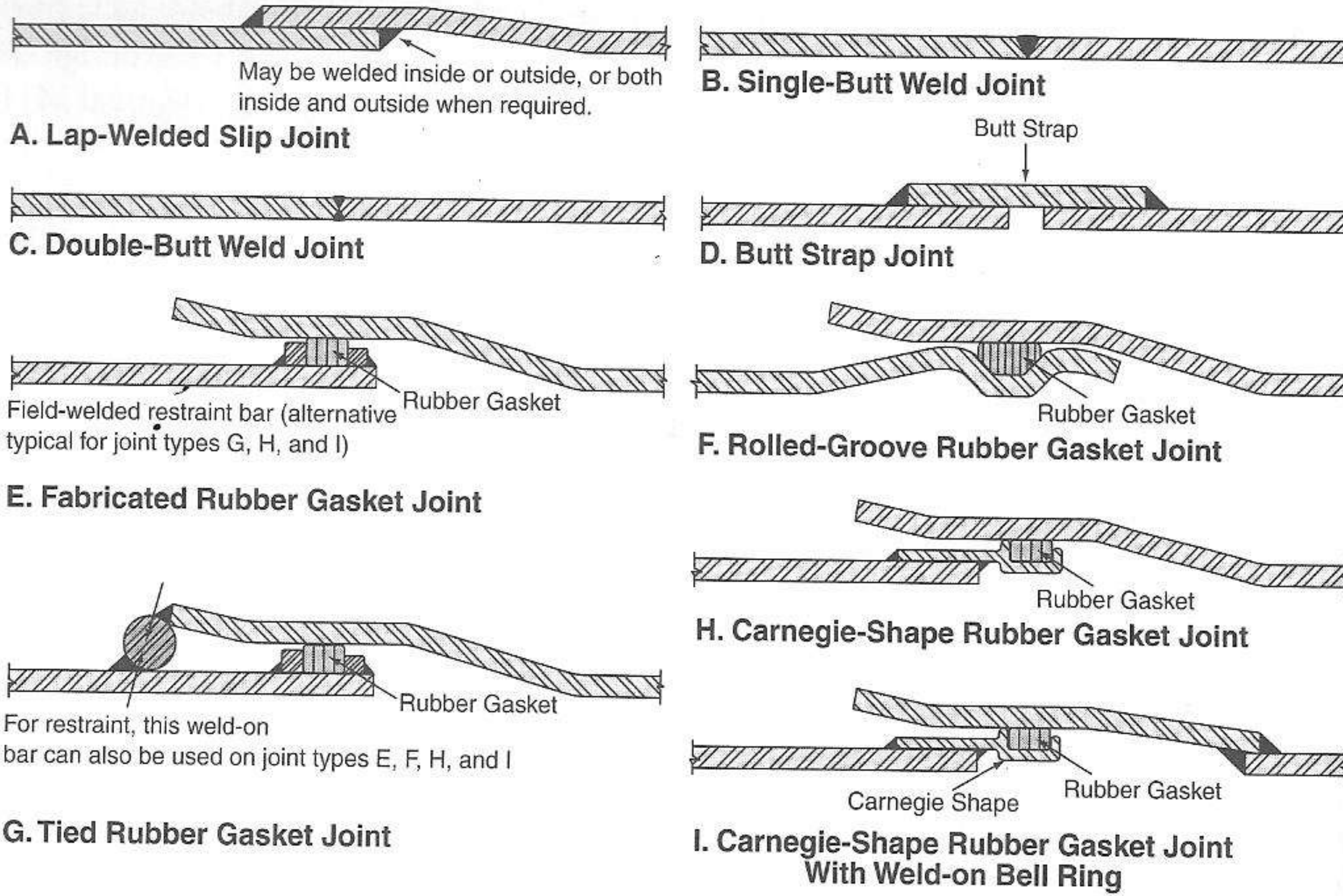


FIGURE 2-17 Welded and rubber-gasketed field joints used for connecting steel pipe

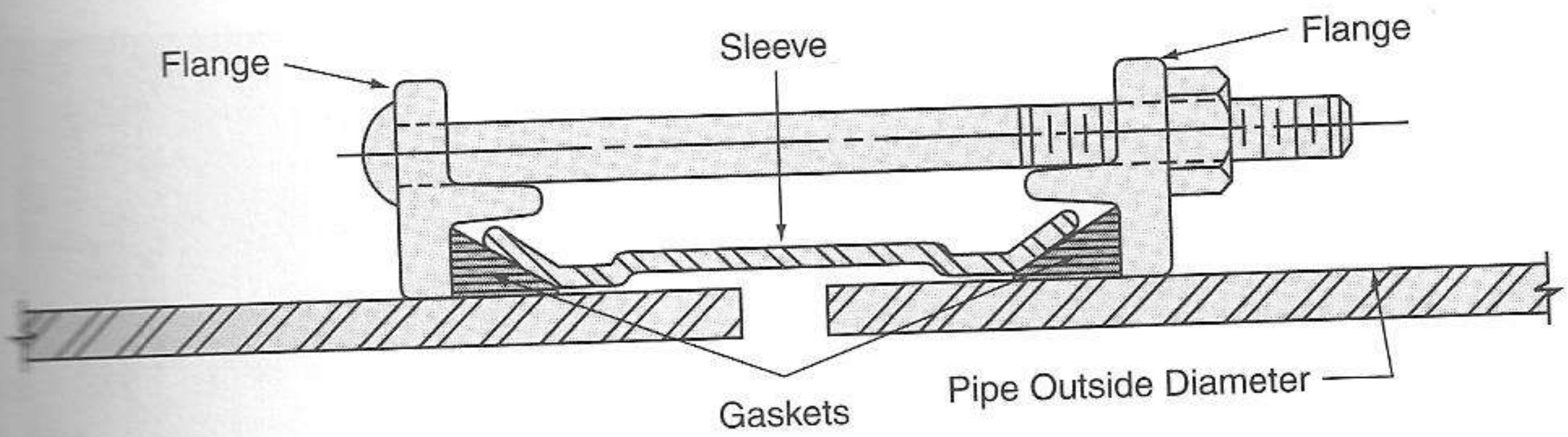


FIGURE 2-18 Detail of a sleeve coupling used for connecting steel pipe sections

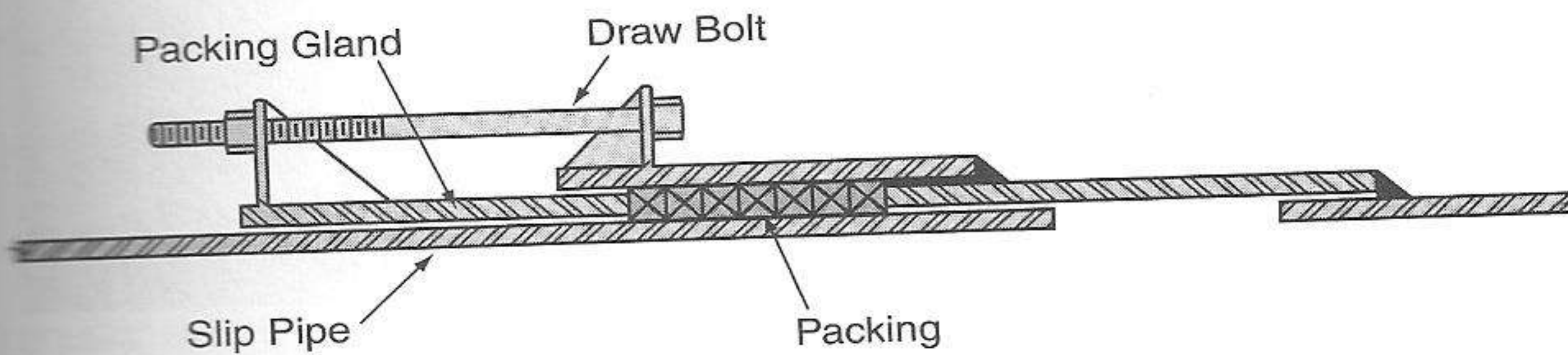


FIGURE 2-19 Detail of one type of expansion joint for steel pipe

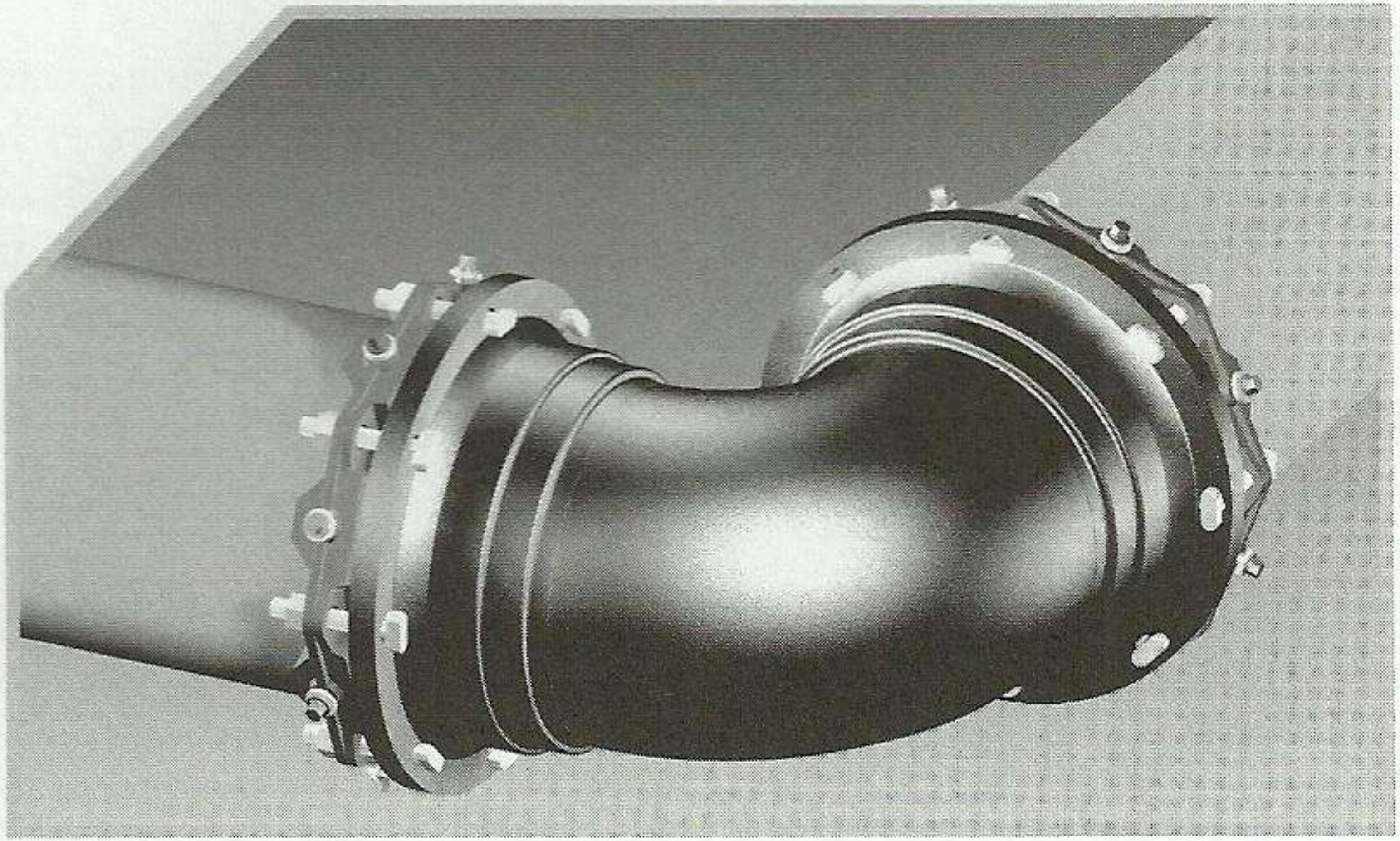


FIGURE 2-21 Restrained fitting
Courtesy of EBAA Iron, Inc.

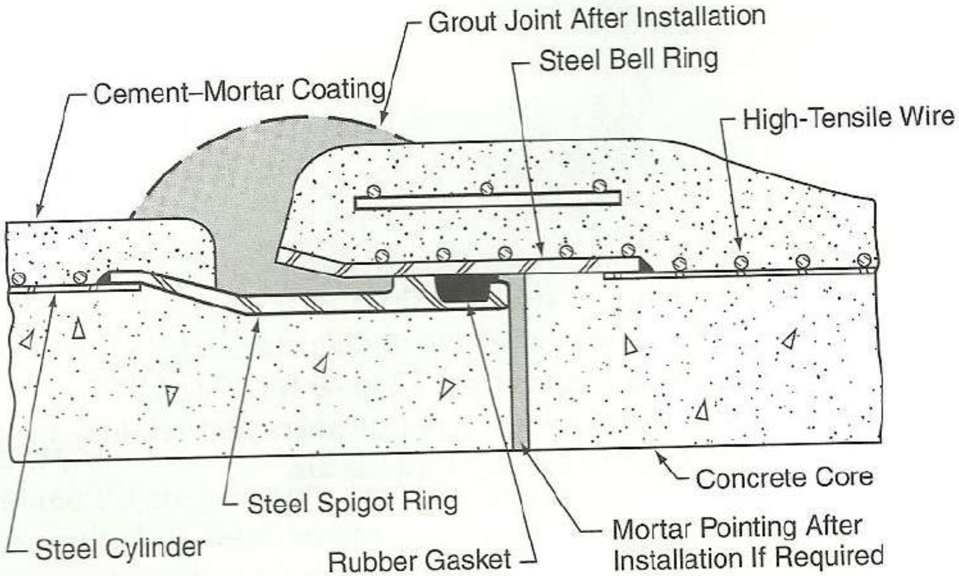


FIGURE 2-22 Prestressed concrete lined-cylinder pipe

Drawing furnished by American Concrete Pressure Pipe Association

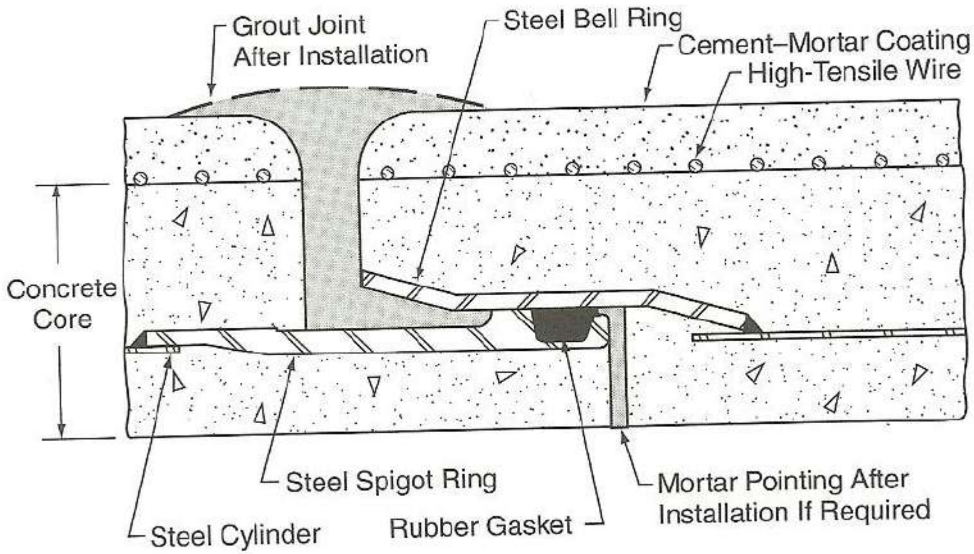


FIGURE 2-23 Prestressed concrete embedded-cylinder pipe

Drawing furnished by American Concrete Pressure Pipe Association

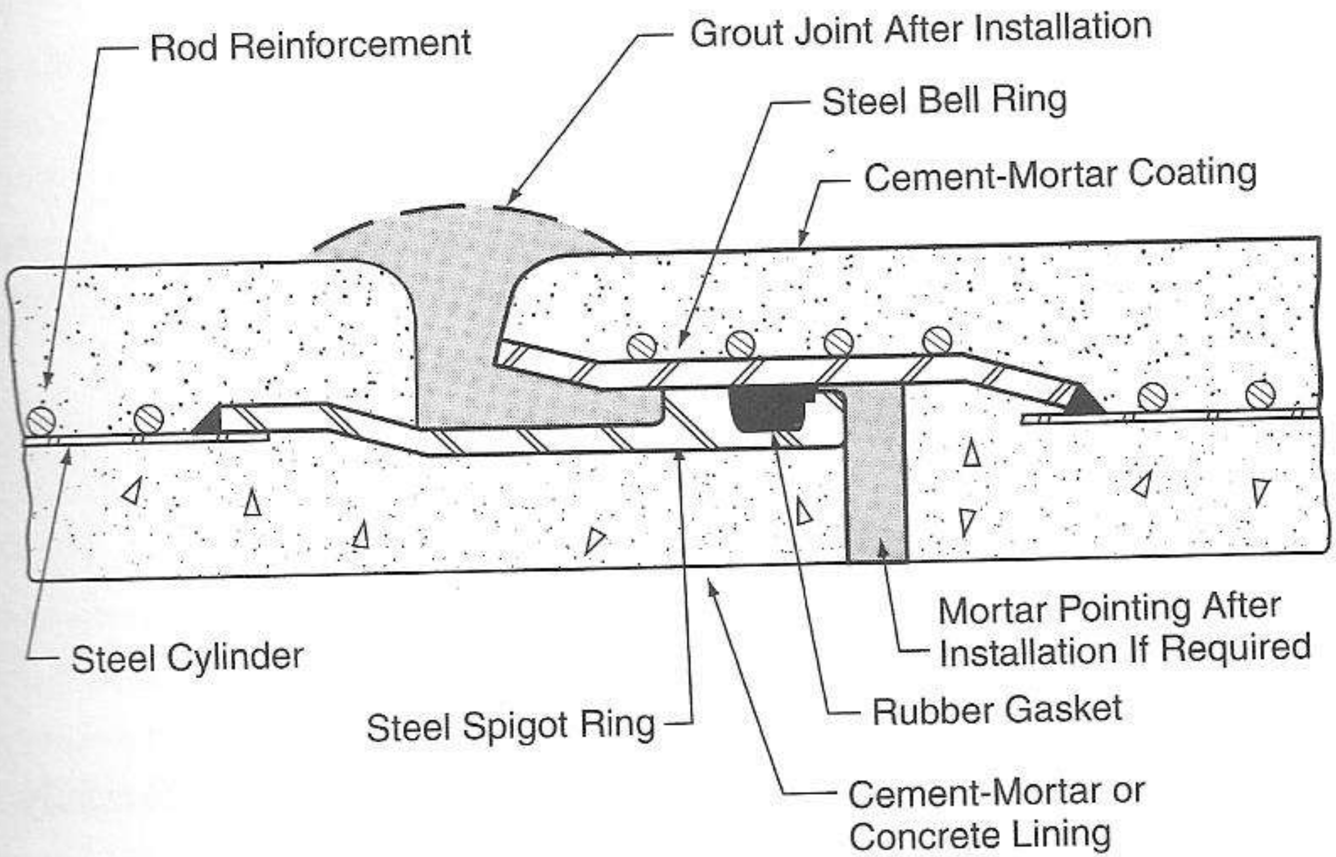


FIGURE 2-24 Pretensioned concrete cylinder pipe

Drawing furnished by American Concrete Pressure Pipe Association

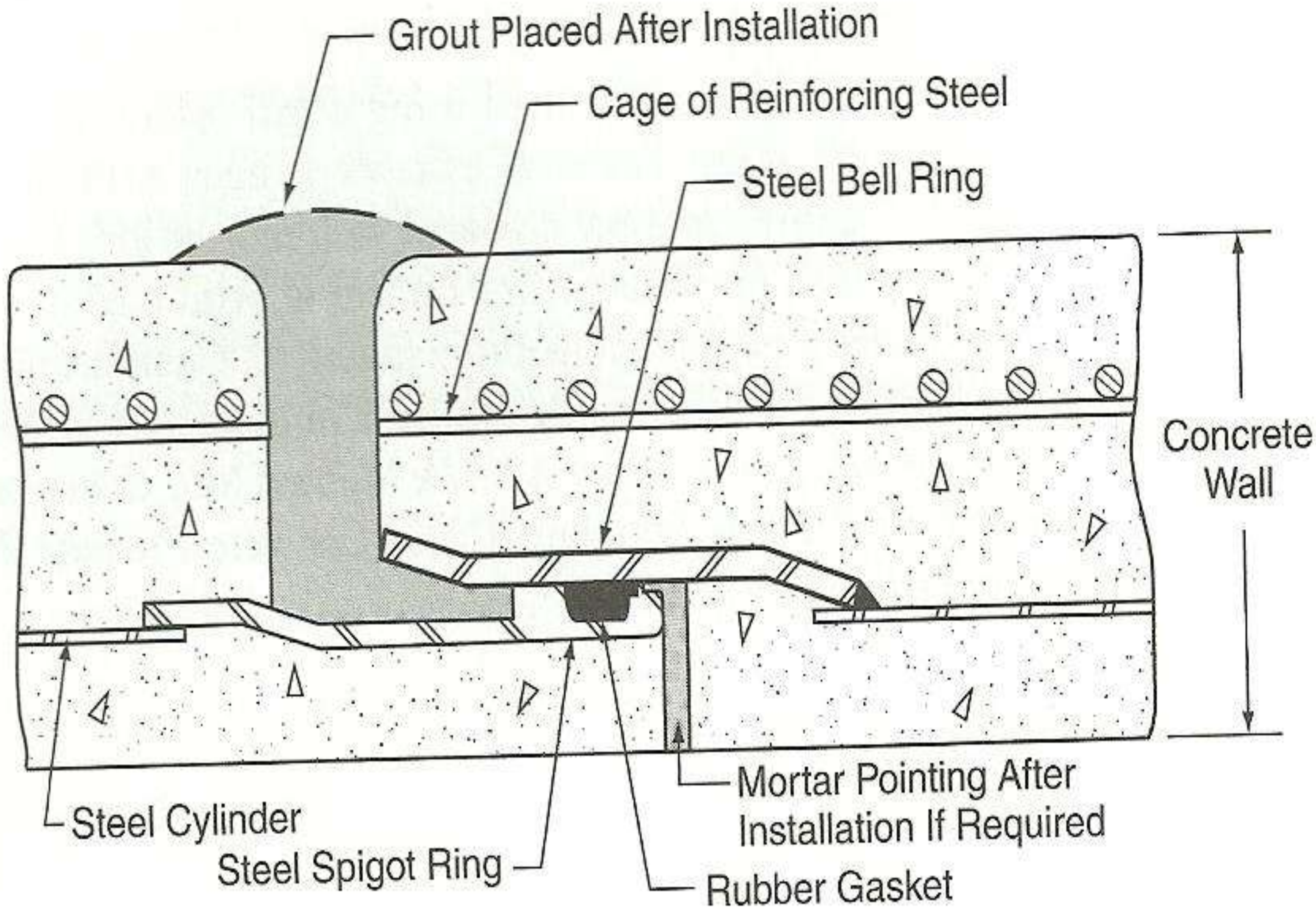


FIGURE 2-25 Reinforced concrete cylinder pipe

Drawing furnished by American Concrete Pressure Pipe Association

Reservoirs

Storage or Conservation Reservoirs

- Irrigation
- Hydroelectricity
- Domestic and

Industrial Supplies

Flood Protection Reservoirs

- Store water during flood and release it gradually at safe rate

Distribution Reservoirs

- Small Reservoir
- Water Supply in a city or industrial area
- Varying demand rate, exceeding the constant pumping rate is met from the distribution reservoir

Multipurpose Reservoirs

- serves more than one purpose

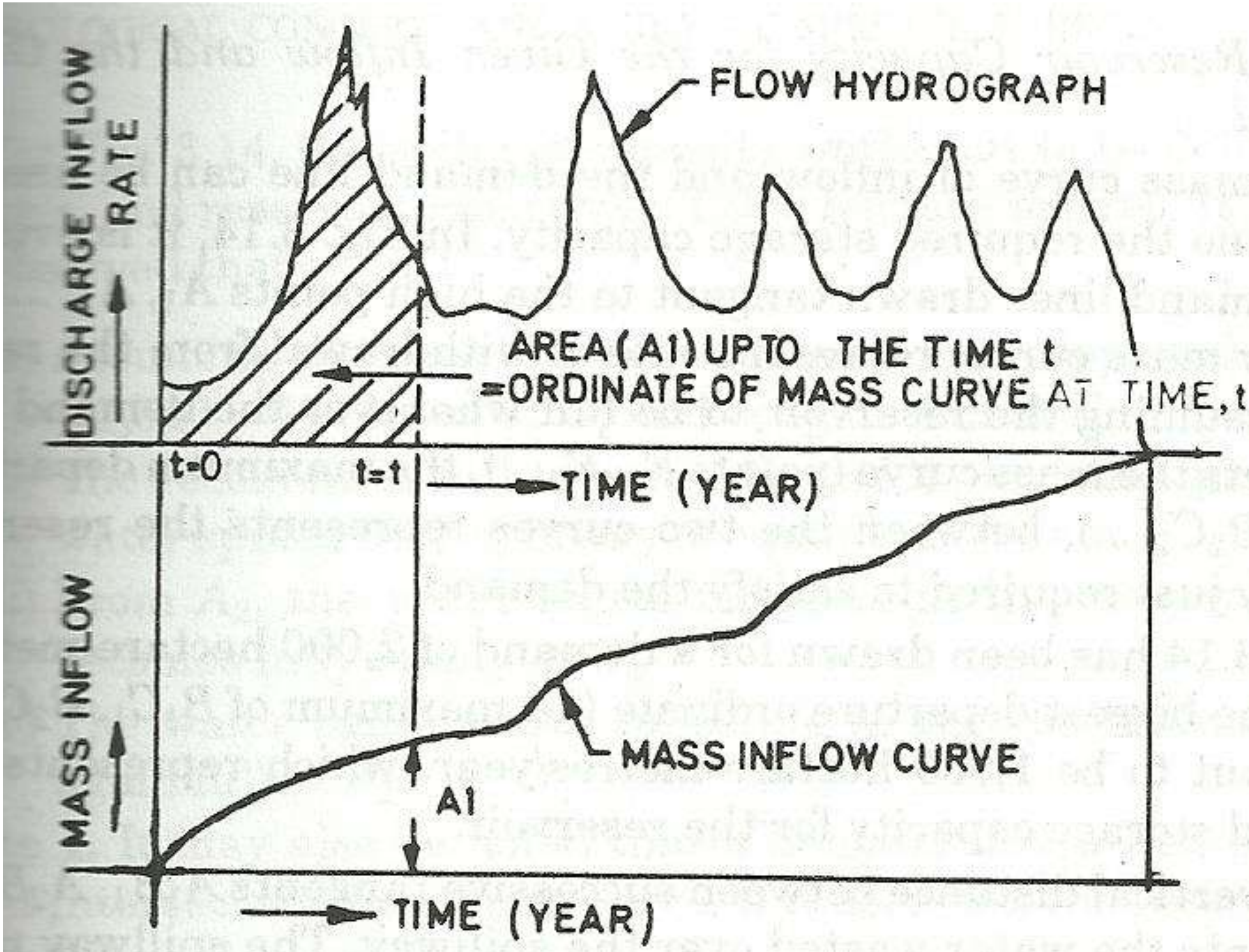
- Reservoir Yield – Amount of water that can be supplied from the reservoir in a specified interval of time
  - Represented by Mass Curve of Outflow (or) Mass Demand Line
- Safe Yield or Firm Yield – Maximum quantity of water guaranteed during a critical dry period
- Secondary Yield – Quantity of water available in excess of safe yield during periods of high flood
- Average Yield – Arithmetic average of firm and secondary yield over a long period of time

Reservoir Yield depends upon Inflows +Reservoir Losses + Reservoir Evaporation

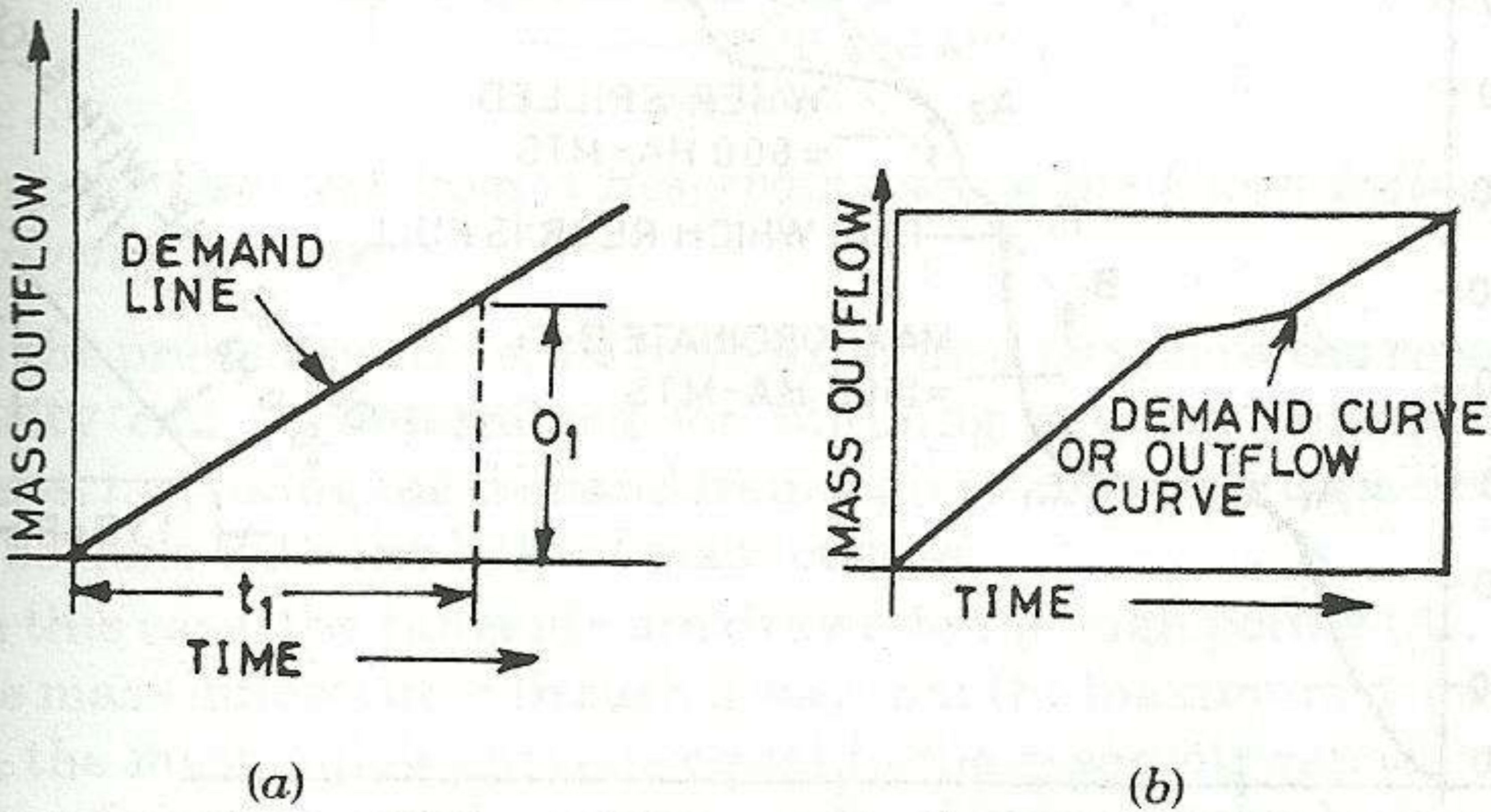
- Catchment Yield – Total yearly runoff, expressed as volume of water entering/passing the outlet point of the catchment, expressed as Mm3 or M.ha.m
  - Represented as Mass Curve of Inflow

Reservoir Capacity is determined with the help of Mass Inflow Curve and Demand Curve

Flood Hydrograph and Mass Inflow Curve



Demand Line or Demand Curve



(a) (b)

$$\frac{O_1}{t_1} = \text{Slope of the line}$$
$$= \text{Demand rate.}$$

Fig. 3.13

Estimation of Reservoir Capacity

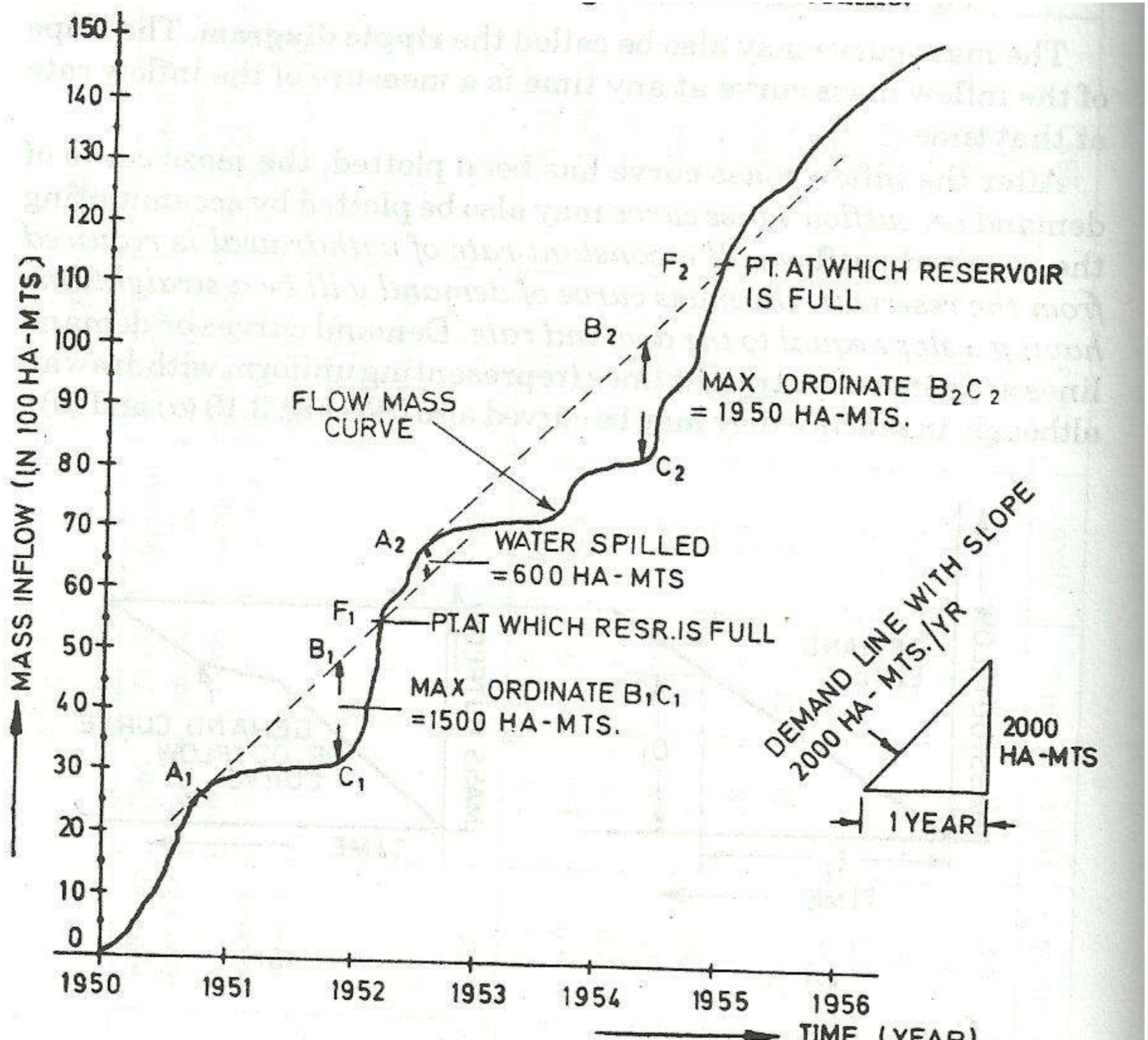
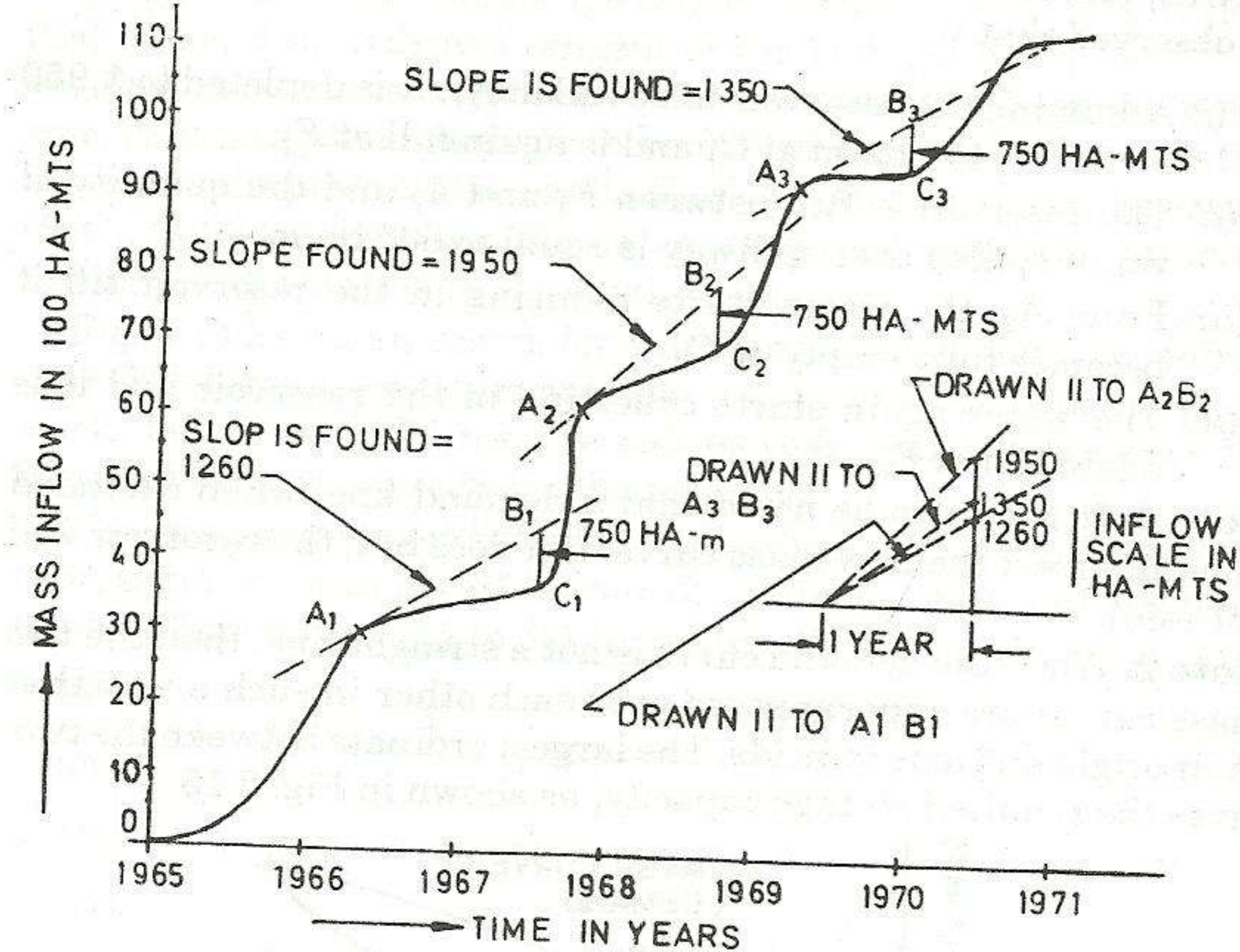
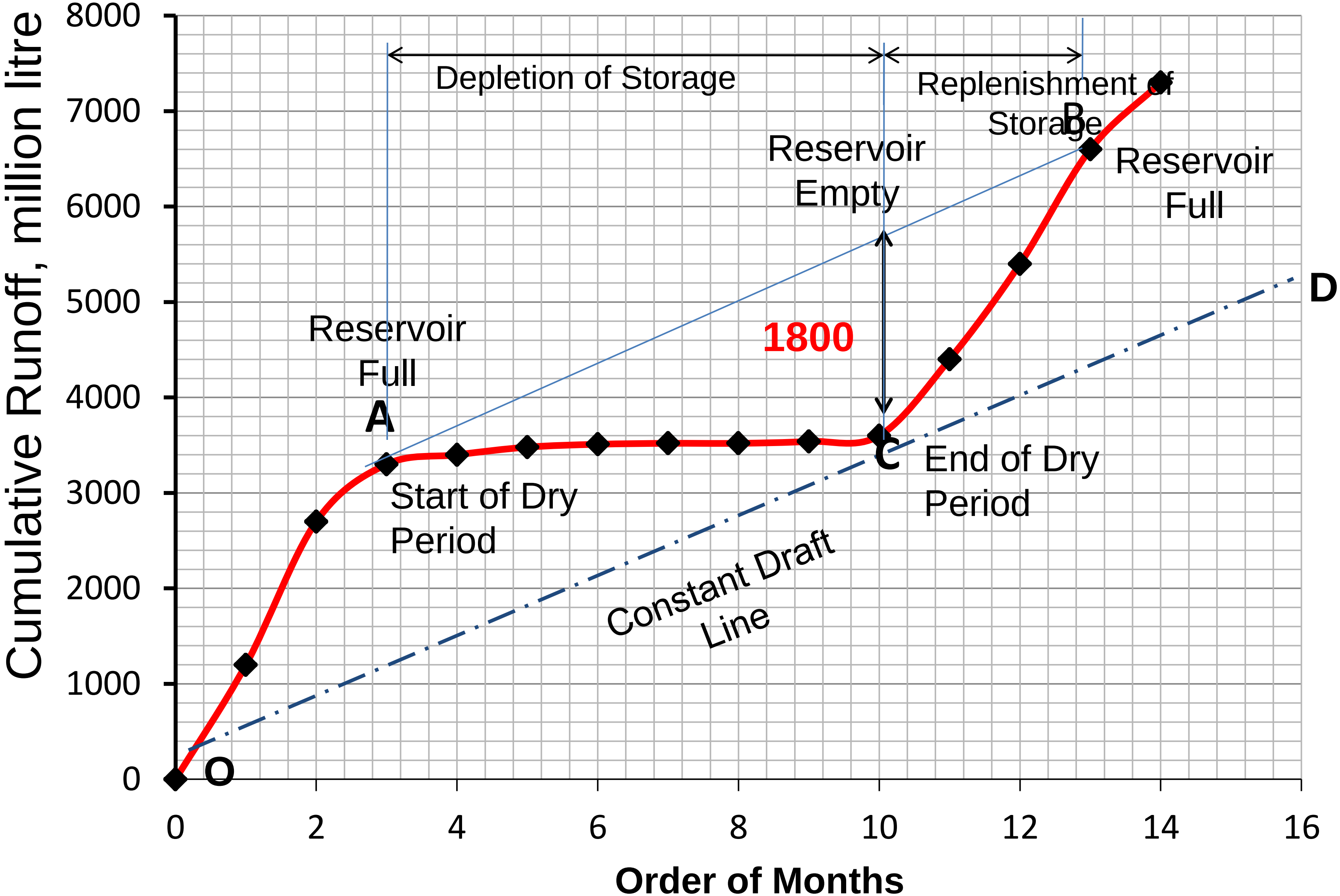


Fig. 3.14



SLOPE IS FOUND = 1350
B3
750 HA-MTS
A3
C3
SLOPE FOUND = 1950
B2
750 HA-MTS
C2
DRAWN II TO A2B2
A2
SLOP IS FOUND = 1260
1950
DRAWN II TO A3 B3
1350
1260
INFLOW SCALE IN HA-MTS
B1
750 HA-m
C1
A1
1 YEAR
DRAWN II TO A1 B1
MASS INFLOW IN 100 HA-MTS
TIME IN YEARS
110
100
90
80
70
60
50
40
30
20
10
0
1965
1966
1967
1968
1969
1970
1971

Order of Month (1)	Runoff, Q (2)	Draft, D (3)	Cumulative Runoff ∑Q (4) = ∑ (2)	Deficiency (D-Q) (5) = (3) - (2)	Cumulative Deficiency ∑(D-Q) (6) = ∑ (5)	Reservoir State (7)
1	1200	300	1200	-900	0 (2400)	
2	1500	300	2700	-1200	0 (1500)	
3	600	300	3300	-300	0 (300)	Reservoir Full at the beginning of dry period
4	100	300	3400	200	200	
5	80	300	3480	220	420	
6	30	300	3510	270	690	
7	10	300	3520	290	980	
8	0	300	3520	300	1280	
9	20	300	3540	280	1560	
10	60	300	3600	240	1800*	Max. deficiency
11	800	300	4400	-500	1300	
12	1000	300	5400	-700	600	
13	1200	300	6600	-900	0 (300)	Reservoir Full
14	700	300	7300	-400	0 (700)	



Cumulative Runoff, million litre
8000
7000
6000
5000
4000
3000
2000
1000
0
0
2
4
6
8
10
12
14
16
Order of Months
Depletion of Storage
Replenishment of Storage
Reservoir Empty
Reservoir Full
Reservoir Full
1800
A
B
C
D
O
Start of Dry Period
End of Dry Period
Constant Draft Line

Confusing terms… ?

Reservoir	Dam	Barrage	lake
It is a store house to store the water. These may be created in river valleys by the construction of dam.	Dams are artificial barriers across a flowing river or any other natural water body that are meant to obstruct, direct, or slow down the flow of water, thus creating a reservoir or a lake.	A barrage is an artificial obstructio n at the mouth of a river that is used divert the flow of river and to increase its depth to assist in navigation or for irrigation purpo ses	Lake is usually shallow reserve of water similar to reservoir but it is naturally formed.

Types of Reservoirs

Reservoirs are of two main categories:

- Storage reservoirs into which a river flows naturally
- Distribution or Service reservoirs receiving supplies that are pumped or channeled into them artificially also called balancing reservoirs.

Types of Reservoirs Contd...

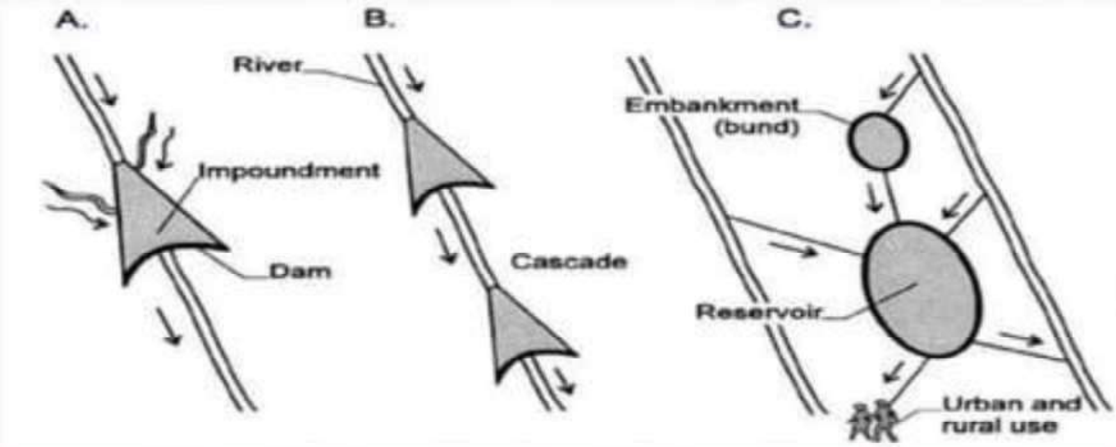
- ***Storage Reservoir:*** A reservoir with gate-controlled outlets wherein surface water may be retained for a considerable period of time and released for use at a time when the normal flow of the stream is in sufficient to satisfy requirements.

- Impounding
- Embankment reservoir
- cascade

Forms of Storage Reservoir

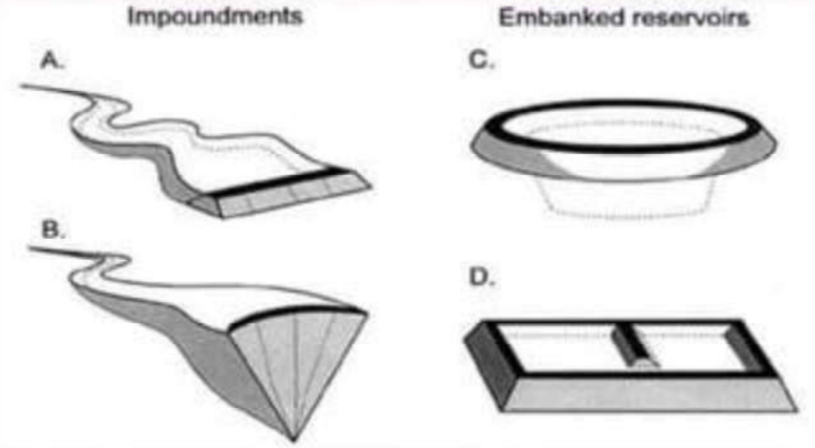
- Reservoirs formed by a dam across the course of a river, with subsequent inundation of the upstream land surface are often called impoundments.
- Water bodies not constructed within the course of the river and formed by partially or completely enclosed water-proof banks (and usually filled by diverted river flows or pipes) are often referred to as off-river, or bonded, reservoirs.
- Reservoirs created by dams or weirs serially along a river course form a cascade

Forms of reservoir formation



Impoundments and Embankment Reservoirs

- A. Shallow U shaped
- B. Deep V shaped
- C. Deep regular
- D. Shallow regular



Storage reservoirs

- An impounding or storage reservoir is a basin constructed in the valley of a stream or river for the purpose of holding stream flow so that the stored water may be used when supply is insufficient.

They have the following two functions :

- To impound water for beneficial use.
- To retard flood.
- These two functions may be combined to some extent by careful operations.

Storage reservoirs design factors

Since storage of reservoir is the essential principle on which an impounding reservoir is based, the general factors to be considered in its design are: –

- The run-off or the quantity of water flowing from the drainage area for successive intervals of time. This, as we have seen, would be determined from the long-term records of the rainfall and run-off for the catchments area considered.
- The total demand of water for all purposes including the consumption requirements, loss of water due to evaporation from the surface of reservoir, leakage and percolation losses and the necessary withdrawals to satisfy the demands of the riparian owners own stream, for like intervals of time.

Storage reservoirs location selection

Considerations affecting the location impounding reservoirs are:

- Existence of suitable dam site. The shortest dam to pond the requisite volume of storage is the best. This would possible if the river flows through a narrow gorge and the rapidly widens upstream from the site.
- The quantity of water available. It should be sufficient to meet all the demands throughout the year. This would depend the rainfall, run-off and the catchment area. The catchment should be such as to drain off waters from all points in the catchment.
- Distance and elevation of the reservoir with reference the point of distribution. A longer distance means greater cost of conduits while proper elevation of the reservoir ensures adequate supplies through gravity flow.

Storage reservoirs location selection

- Density and distribution of population over the catchment area. From the point of view of stream-pollution, it would be able to have a small density of population per sq. kilometer on catchment area above the reservoir.
- Existence of towns, highways, rail yards and other cultivation areas. These should be excluded from the submerged area of reservoir.
- Geological conditions of the storage basin. The exist of bed rocks of calcareous stone is likely to impart quality of hard to water. Also, if the rocks are deeply fissured, there will considerable loss o water due to percolation.

Principle uses of storage reservoir

- Their main uses include:
  - drinking and municipal water supply
  - industrial and cooling water supply
  - power generation
  - agricultural irrigation
  - river regulation and flood control
  - commercial and recreational fisheries
  - body contact recreation, boating, and other aesthetic recreational uses
  - navigation
  - canalization and
  - waste disposal (in some situations).

Types of Reservoirs Contd...

- ***Distribution Reservoir:***

A reservoir also called service reservoirs connected with distribution system or a water supply project and stores the treated water for supplying water during emergencies (such as during fires, repairs, a break in a main supply line failure of a pumping plant etc.) and also to help in absorbing the hourly fluctuations in the normal water demand.

Distribution Reservoir

- **Distribution Reservoirs**

This reservoir is requirement of Good Distribution System.

Functions of Distribution Reservoirs:

- To equalize and absorb the variation in hourly demand of water by the consumers to a uniform rate of supply from the source either by gravity or pumping,
- To maintain the desired minimum residual pressure in the distribution system,
- Water stored can be supplied during emergencies.
- To provide the required contact time for the disinfectant added in order to achieve effective disinfection, and
- To facilitate carrying out repairs either to the pumping main or to pump-set without interruption to the supply of water.

Distribution Reservoir

Location and Height of Distribution Reservoirs:

- should be located as close as possible to the center of demand.
- water level in the reservoir must be at a sufficient elevation to permit gravity flow at an adequate pressure.

Types of distribution Reservoirs

- Underground reservoirs.
- Small ground level reservoirs.
- Large ground level reservoirs.
- Overhead tanks.

Underground reservoirs.

Natasha Wiseman, Water & Wastewater Treatment

Small ground level reservoirs.

Taken in: Pennsylvania American

Taken on: September 3, 2012

Large ground level reservoirs.

- **Taken in:** United States / Colorado / Boulder

Overhead tanks

- Ratnawali , India

Storage Capacity of Distribution Reservoirs

The total storage capacity of a distribution reservoir is the summation of:

- ***Balancing Storage:*** The quantity of water required to be stored in the reservoir for equalizing or balancing fluctuating demand against constant supply is known as the balancing storage (or equalizing or operating storage). The balance storage can be worked out by *mass curve method*.

Storage Capacity of Distribution Reservoirs

- ***Breakdown Storage:*** The breakdown storage or often called emergency storage is the storage preserved in order to tide over the emergencies posed by the failure of pumps, electricity, or any other mechanism driving the pumps. A value of about 25% of the total storage capacity of reservoirs, or 1.5 to 2 times of the average hourly supply, may be considered as enough provision for accounting this storage.

- ***Fire Storage:*** The third component of the total reservoir storage is the fire storage. This provision takes care of the requirements of water for extinguishing fires. A provision of 1 to 4 per person per day is sufficient to meet the requirement.

Basic Comparison

Storage reservoir	Distribution reservoir
1. The storage reservoirs hold untreated water. 2. The water held by a Storage reservoir may be used for other purposes such as irrigation. 3. Basic component of water storage and flood control systems.	1. The distribution reservoir holds treated water. 2. Distribution water is used for domestic and industrial purposes. 3. Basic requirement for good water distribution system.

References

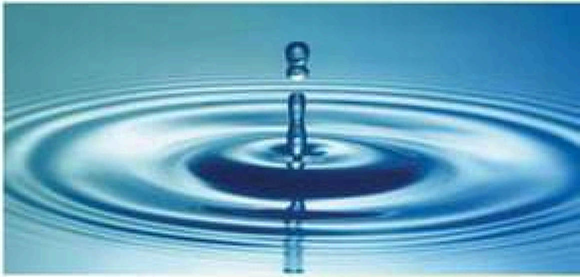
- Environmental engineering by Arcadio P. Sincero.
- Balon, E.K. and Coche, A.G. 1974 Lake Kariba: A Man-made Tropical Ecosystem in Central Africa, Monographiae Biologicae 24, Dr W. Junk, The Hague
- Reservoirs by J. Thornton, A. Steel and W. Rast May. 2011


"Any question…??"
Thank you for your time.

WATER METER

INTRODUCTION

- Our homes are becoming smarter each day. The amount of connected devices increases everyday. We can easily know and control the temperature of our home. We can also switch on and off any light with Switch mate, control all our devices and keep an eye at home when we are away with Flare. But we needed something to learn and know more about how to control on water.



WATER METER

- A water meter is a device that measures how much water you use. It is similar to your gas or electricity meter. Your supplier uses readings from the meter to calculate how much to charge you for your water and sewerage services. If you have ameter, the amount you pay will depend on how much water you have used.

- Several types of water meters are currently being used. However, the choice depends on the accuracy requirements, the required flow rates, the end user and flow measurement method.

Why are meters important ?

- Water meters are important to a utility for several reasons:

  - 1. They make it possible to charge customers in proportion to the amount of water they use.
  - 2. They allow the system to demonstrate accountability.

"SAVE WATER SAVE LIFE"

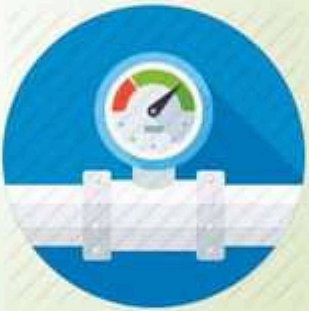
  - 3. They are fair for all customers because they record specific usage.
  - 4. They encourage customers to conserve water (especially as compared to flat rates).
  - 5. They allow a utility system to monitor the volume of finished water it puts out.
  - 6. They aid in the detection of leaks and waterline breaks in the distribution system. A system without meters is like a taxi without a fare counter. Without a meter.

Flow meters and Water Utilities

- Water utilities are one of the major users of flow meters, using the technology every day to ensure that their customers are billed properly based on their actual usage. These flow meters, commonly referred to as water meters, are placed at points along the water utility infrastructure where the lines branch out to provide services to residential and business customers.
- Water meters can also be used at other points in the utility system. For example, flow meters can be used in the larger part of the infrastructure to ensure that the rate of flow is as expected. This helps identify issues in the utility owned lines such as leaks or breaks. They can also be used to monitor the rate of flow from a well or other water source.

WATER METERING

Water metering is the process of measuring water use. In many developed countries water meters are used to measure the volume of water used by and commercial buildings that are supplied with water by a public water supply system. Water meters can also be used at the water source, well, or throughout a water system to determine flow through a particular portion of the system. In most of the world water meters measure flow in cubic metres (m3) or litres



Types of metering devices

- There are two common approaches to flow measurement and displacement and velocity, each making use of a variety of technologies. Common displacement designs include oscillating piston and nutating disc meters. Velocity-based designs include single- and multi-jet meters and turbine meters.

Displacement Water Meter

Velocity measurement Water Meter

Displacement water meters

- With this type of meter, a known quantity of liquid within a small unit moves with the flow of water. They operate by repeatedly filling and emptying the unit. The flow rate of water is calculated based on the number of times the unit is filled and emptied. The meter also includes a piston or disc that triggers the motion of gears for recording the volume of liquid exiting the meter.
- These meters exhibit high accuracy over a wide range of flow rates, and they are sensitive to low flow rates.
- PD meters are generally very accurate at the low-to-moderate flow rates typical of residential and small commercial users, and commonly range in size from 5/8" to 2". Because displacement meters require that all water flows through the meter to "push" the measuring element,

Velocity water meters

- A velocity-type meter measures the velocity of flow through a meter of a known internal capacity. The speed of the flow can then be converted into volume of flow to determine the usage. There are several types of meters that measure water flow velocity, including jet meters (single-jet and multi-jet), turbine meters, propeller meters and mag meters. Most velocity-based meters have an adjustment vane for calibrating the meter to the required accuracy.

Types of Velocity Meters

1- Multi-jet meters

2- Turbine meters

3- Compound meters

4- Electromagnetic meters

5- Ultrasonic meters

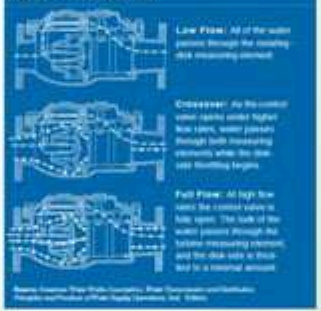


Figure 2 - Compound Meter

- Multi-jet meters

Multi-jet meters are very accurate in small sizes and are commonly used in ⅝" to 2" sizes for residential and small commercial users. Multi-jet meters use multiple ports surrounding an internal chamber to create multiple jets of water against an impeller, whose rotation speed depends on the velocity of water flow.

- Turbine meters

Turbine meters are less accurate than displacement and jet meters at low flow rates, but the measuring element does not occupy or severely restrict the entire path of flow. The flow direction is generally straight through the meter, allowing for higher flow rates and less pressure loss than displacement-type meters.

- compound meter

A compound meter is used where high flow rates are necessary, but where at times there are also smaller rates of flow that need to be accurately measured. Compound meters have two measuring elements and a check valve to regulate flow between them. At high flow rates, water is normally diverted primarily or completely to the high flow element.

- Magnetic flow meters

Magnetic flow meters, commonly referred to as "mag meters", are technically a velocity-type water meter, except that they use electromagnetic properties to determine the water flow velocity, rather than the mechanical means used by jet and turbine meters.

- Ultrasonic water meters

Ultrasonic water meters use one or more ultrasonic transducer to send ultrasonic sound waves through the fluid to determine the velocity of the water. Since the cross-sectional area of the meter body is a fixed and known value, when the velocity of water is detected, the volume of water passing through the meter can be calculated with very high accuracy. Because water density changes with temperature, most ultrasonic water meters also measure the water temperature as a component of the volume calculation.

Selecting a Meter

- Meters are selected using several factors: flow rate, size of pipe, pressure loss and safety considerations, such as fire service regulations. For sizes of one inch and smaller and low flow rates, positive displacement types of meters are common. For residential uses, 5/8" or 3/4" meters are used. For medium flows, such as in apartment buildings, businesses, and public buildings, positive displacement meters in sizes of 1", 11/2", or two inches are used. In sizes of two and three inches, either, displacement, multi-jet, or turbine types of meters can be used. In the three- to four-inch size range, the meter type depends on the average flow rate. If the flow rate is between five and 35 percent of maximum flow rate, the positive displacement type is better. If the flow rates are going to be 10 to 15 percent of the maximum capacity, a turbine type should be used. If close accuracy at low flows is important, but large flows also have to be measured, a compound meter is best.

Water Meter Reading

- A standard water meter uses two common types of registers - straight and circular - to read the flow of water in cubic feet or inches.
- The registers can be observed on the surface of the meter. The straight registers can be read like an odometer in a car. On some larger meters, a multiplier will be present on the register face, which can be noted as 10x, 100x, or 1000x based on the size of the meter. Circular registers, on the other hand, are more complex to calculate water usage. They employ a series of dials marked with divisions of ten.
- There are several ways of reading the water meter, which includes:
  - Direct reading
  - Remote reading, which is accomplished via an electronic signal using a wire where one can either directly read or touch read.
  - Touch read or plug-in reading that employs a handheld device which acquires the electronic signal by touching the remote station or plugging-in. The signal is then translated into the readings that are stored in the handheld device.
  - Automatic meter reading, in which the meter reader obtains readings through radio transmission.

Applications

Given below are some of the major uses of water meter:

1. It detects water leaks in the distribution network
2. It identifies potential well, pump or irrigation system problems
3. It determines efficiency of a water plant for supplying water.

Benefits

- The benefits of metering are that:

1. in conjunction with volumetric pricing it provides an incentive for water conservation,
2. it helps to detect water leaks in the distribution network, thus providing a basis for reducing the amount of non-revenue water;
3. it is a precondition for quantity-targeting of water subsidies to the poor.

Costs

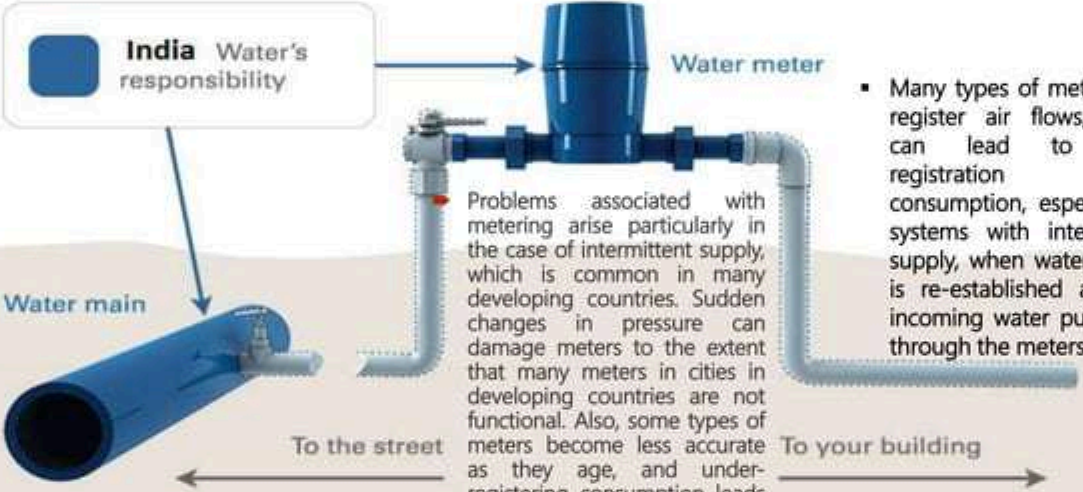
The costs of metering include:

- Investment costs to purchase, install and replace meters,

- Recurring costs to read meters and issue bills based on consumption instead of bills based on monthly flat fees.

While the cost of purchasing residential meters is low, the total life cycle costs of metering are high. For example, retrofitting flats in large buildings with meters for every flat can involve major and thus costly plumbing work.

Problems



- Problems associated with metering arise particularly in the case of intermittent supply, which is common in many developing countries. Sudden changes in pressure can damage meters to the extent that many meters in cities in developing countries are not functional. Also, some types of meters become less accurate as they age, and under-registering consumption leads to lower revenues if defective meters are not regularly replaced.

- Many types of meters also register air flows, which can lead to over-registration of consumption, especially in systems with intermittent supply, when water supply is re-established and the incoming water pushes air through the meters.

Where will the water meter be fitted?

- We normally fit the water meter inside your home free of charge (on the water supply pipe, which is the pipe which brings water into your home). If we cannot fit the meter inside your home, we will fit it outside instead (in some instances a purpose made meter box may already exist outside your home - if this is the case we would fit the meter in this box).
- We will visit your home to carry out a survey to decide on the best place to fit the meter. We will try our best to fit your meter during this visit, but we may have to come back again if this isn't possible.
- As the meter needs to be attached to your water supply pipe (which is often found under the kitchen sink), we may ask you to move certain items so that we can do this (such as any white goods that might be blocking the water supply pipe, wood panelling etc).
- We can do minor joinery work when we fit your meter, and will always make sure you are happy about this before we start any work.

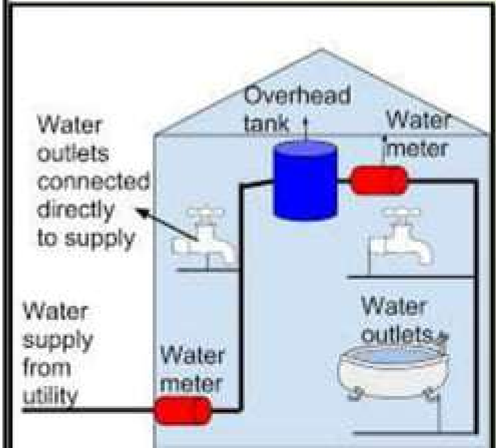
Water Meter Standards

Table 2 Meter Size, Threads, Nominal Flow Rates and Dimensions

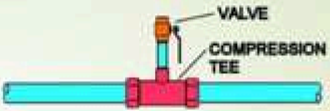
All dimensions in millimetres.

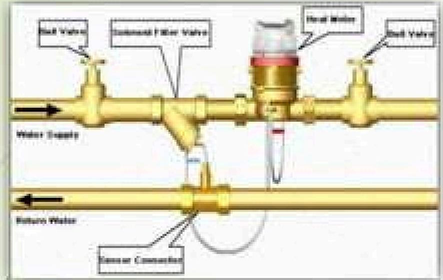
Meter Size	Threads	Nominal Flow Rate, Q_n in kl/h	Minimum Length of Threads on Either End of Body (*see* Fig. 2)		Overall Dimensions (*see* Fig. 1)					
					Length, *L*			Width, *W* (*Max*)	Height (*Max*)	
					With nipples	Without nipples			H_1	H_2
						Preferred	*Alternate*[1]			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
15	G $\frac{3}{4}$ B	1.5	10	12	250	165	110	100	50	180
20	G 1B	2.5	12	14	290	190	165	130	60	240
25	G 1$\frac{1}{4}$ B	3.5	12	16	380	260	-	170	65	260
40	G 2B	10	13	20	430	300	-	210	75	300
50	G 2$\frac{1}{2}$ B	15	15	25	470	330	-	270	115	300

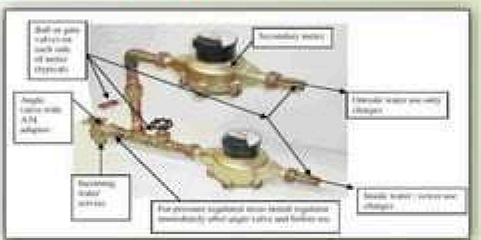
NOTE – Meters shall be supplied with nuts and nipples unless specified otherwise by the purchaser.

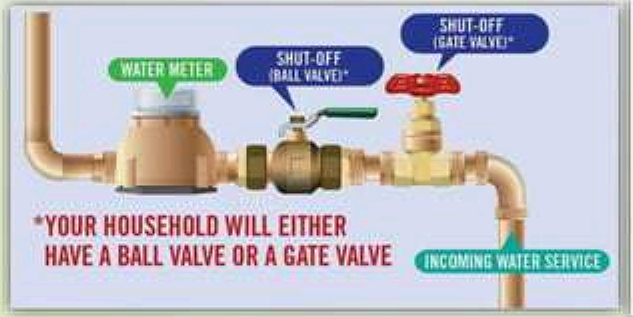


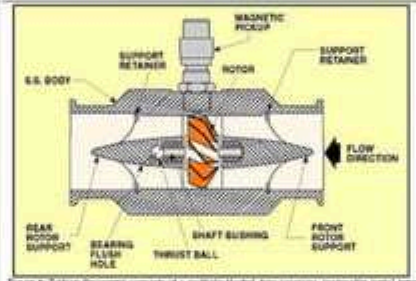
Plumbing


VALVE
COMPRESSION TEE


Heat Meter
Water Supply
Return Water
Sensor Connected




WATER METER
SHUT-OFF (BALL VALVE)*
SHUT-OFF (GATE VALVE)*
*YOUR HOUSEHOLD WILL EITHER HAVE A BALL VALVE OR A GATE VALVE
INCOMING WATER SERVICE

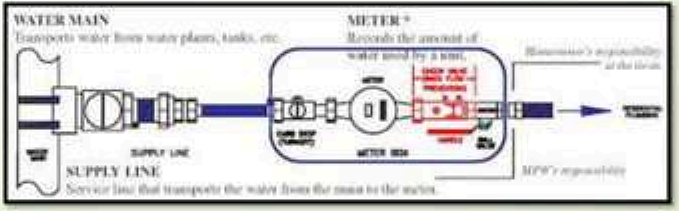

MAGNETIC PICKUP
SUPPORT RETAINER
ROTOR
SUPPORT RETAINER
S.S. BODY
FLOW DIRECTION
REAR ROTOR SUPPORT
BEARING FLUSH HOLE
THRUST BALL
SHAFT BUSHING
FRONT ROTOR SUPPORT

Backflow Valves

- External Pressure: if a foreign body other than the water from your main water supply has entered the system, say excess street water following heavy rains, a flood, or there is some debris mixed with the water that is stronger than the flow of the mains system, it can cause the standard water flow to get distorted and the added pressure can cause the valve to burst, break or come off.

Hazards of Backflow Valves Malfunctioning

- If the backflow valves in the mains water supply system are not functioning correctly and there is a chemical plant or industry of some sort located in the vicinity you run the risk of having your main water supply polluted. This is also true of situations where people have small workshops on their residential premises that are connected to the main supply.



Water Conservation

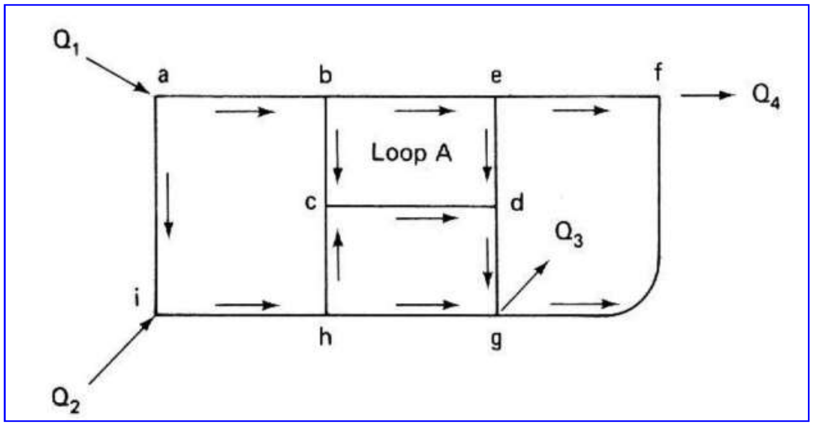
- Simple ways to save water 1. Turn off the tap while brushing your teeth. A running tap wastes more than six litres of water a minute.
- 2. Make sure that your washing machine and dishwasher (if you have one) are full before you use them. Try to use the most water and energy efficient settings.
- 3. Fix a dripping tap. This can save as much as 75 litres of water a day.
- 4. Use a bowl to wash up rather than leaving the hot tap running. You could save about 3500/- a year on your energy bills.
- 5. Install a water butt. The average rooftop collects 85,000 litres of water every year. A water butt is a great way to put some of this to use.
- 6. Check the overflow on your toilet cistern to make sure it is not using more water than necessary

Hydraulic Analysis of Water Networks

- The solution to the problem is based on the same basic hydraulic principles that govern simple and compound pipes that were discussed previously.
- The following are the most common methods used to analyze the Grid-system networks:
    1. Hardy Cross method.
    2. Sections method.
    3. Circle method.
    4. Computer programs (WaterCAD,Epanet, Loop, Alied...)

Hardy Cross Method

- This method is applicable to closed-loop pipe networks (a complex set of pipes in parallel).



- It depends on the idea of head balance method
- Was originally devised by professor Hardy Cross.

Assumptions / Steps of this method:

1. Assume that the water is withdrawn from nodes only; not directly from pipes.
2. The discharge, Q, entering the system will have (+) value, and the discharge, Q, leaving the system will have (-) value.
3. Usually neglect minor losses since these will be small with respect to those in long pipes, i.e.; Or could be included as equivalent lengths in each pipe.
4. Assume flows for each individual pipe in the network.
5. At any junction (node), as done for pipes in parallel,

$$\sum Q_{in} = \sum Q_{out} \quad \text{or} \quad \sum Q = 0$$

6. Around any loop in the grid, the sum of head losses must equal to zero: $\sum_{loop} h_f = 0$

   - Conventionally, clockwise flows in a loop are considered (+) and produce positive head losses; counterclockwise flows are then (-) and produce negative head losses.
   - This fact is called the head balance of each loop, and this can be valid only if the assumed Q for each pipe, within the loop, is correct.

- The probability of initially guessing all flow rates correctly is virtually null.
- Therefore, to balance the head around each loop, a flow rate correction (Δ) for each loop in the network should be computed, and hence some iteration scheme is needed.

7. After finding the discharge correction, Δ (one for each loop) , the assumed discharges Q_0 are adjusted and another iteration is carried out until all corrections (values of Δ) become zero or negligible. At this point the condition of :

$$\sum_{loop} h_f \cong 0.0$$ is satisfied.

Notes:

- The **flows in pipes common to two loops** are positive in one loop and negative in the other.
- When calculated corrections are applied, with careful attention to sign, pipes common to two loops receive both corrections.

How to find the correction value (Δ)

$$h_F = kQ^n \longrightarrow (1)$$
$$n = 2 \Rightarrow Darcy, Manning$$
$$n = 1.85 \Rightarrow Hazen \quad William$$

$$Q = Q_o + \Delta \longrightarrow (2)$$

$from\ 1 \,\&\, 2$

$$h_f = kQ^n = k(Q_o + \Delta)^n = k\left[Q_o^n + nQ_o^{n-1}\Delta + \frac{n(n-1)}{2}Q_o^{n-2}\Delta^2 + \ldots\right]$$

Neglect terms contains Δ^2 $\quad h_f = kQ^n = k\left(Q_o^n + nQ_o^{n-1}\Delta\right)$

For each loop

$$\sum_{loop} h_F = \sum_{loop} kQ^n = 0$$

$$\therefore \sum kQ^n = \sum kQ_o^n + \sum nkQ^{(n-1)}\Delta = 0$$

$$\Delta = \frac{-\sum kQ_o^n}{\sum nkQ_o^{(n-1)}} = \frac{-\sum h_F}{n\sum \frac{h_F}{Q_o}}$$

- Note that if Hazen Williams (which is generally used in this method) is used to find the head losses, then

$h_f = k\,Q^{1.85}$ ($n = 1.85$) , then

$$\Delta = \frac{-\sum h_f}{1.85 \sum \frac{h_f}{Q}}$$

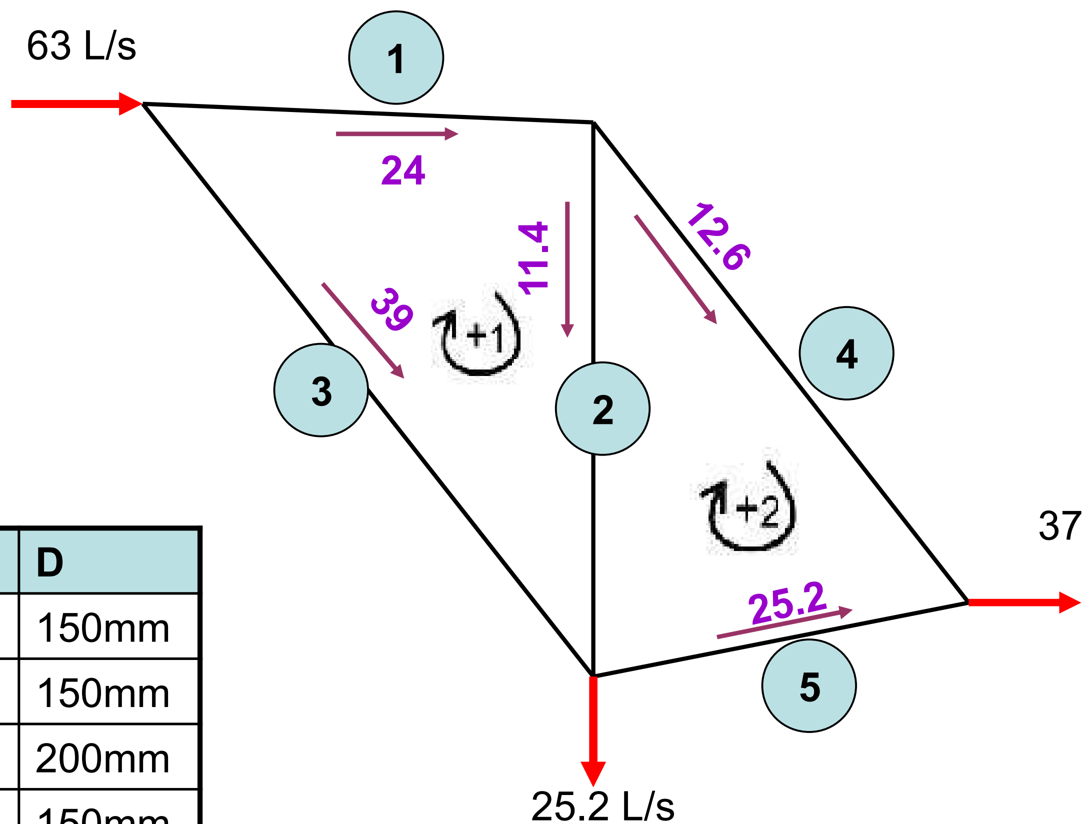
- If Darcy-Wiesbach is used to find the head losses, then

$h_f = k\,Q^2$ ($n = 2$) , then

$$\Delta = \frac{-\sum h_f}{2 \sum \frac{h_f}{Q}}$$

Example

Solve the following pipe network using Hazen William Method $C_{HW} = 100$



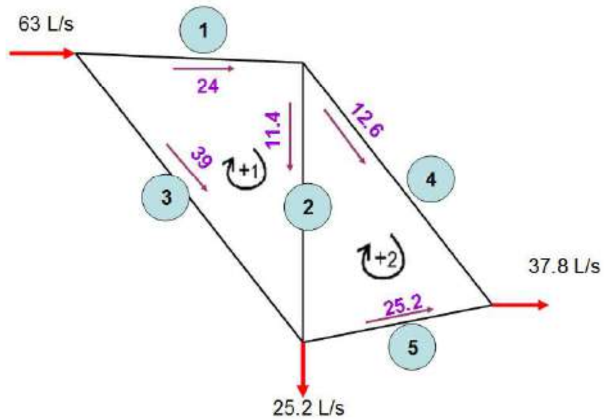
pipe	L	D
1	305m	150mm
2	305m	150mm
3	610m	200mm
4	457m	150mm
5	153m	200mm

$$h_f = \frac{10.7\,L}{C_{HW}^{\;1.852}\,D^{4.87}}\;Q^{1.852} \Rightarrow C_{HW} = 100, Q = in \quad \text{L/s}$$

$$h_f = \frac{10.7\,L}{C_{HW}^{\;1.852}\,D^{4.87}}\left(\frac{Q}{1000}\right)^{1.852}$$

$$h_f = \left\{6.02\times10^{-9}\,\frac{L}{D^{4.87}}\right\}Q^{1.852}$$

$$h_f = \{K\}\,Q^{1.852}$$



1st Iteration

Loop	Pipe	Dia (m)	L (m)	K	$Q_\circ$ (L/s)	h_f (m)	$h_f/Q_\circ$ (m/L/s)	Correction L/s	Q L/s
1	1	0.150	305	0.0187	+24.0	+6.68	0.28	-0.24	+23.76
	2	0.150	305	0.0187	+11.4	+1.69	0.15	-0.24+0.57	+11.73
	3	0.200	610	0.0092	-39.0	-8.09	0.21	-0.24	-39.24
						+0.28	0.64		
2	2	0.150	305	0.0187	-11.4	-1.69	0.15	-0.57+0.24	-11.73
	4	0.150	457	0.0280	+12.6	+3.04	0.24	-0.57	+12.03
	5	0.200	153	0.0023	-25.2	-0.90	0.04	-0.57	-25.77
						+0.45	0.43		

$$\Delta_1 = \frac{-\sum h_F}{n\sum \frac{h_F}{Q_o}} = \frac{-0.28}{1.85(0.64)} = -0.24$$

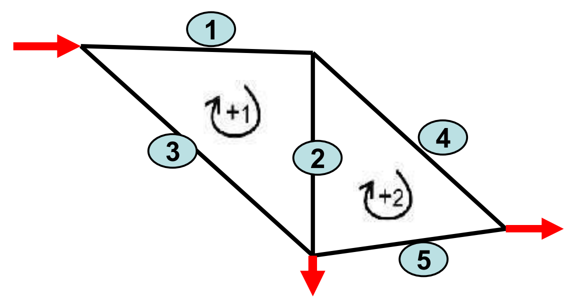
$$\Delta_2 = \frac{-\sum h_F}{n\sum \frac{h_F}{Q_o}} = \frac{-0.45}{1.85(0.43)} = -0.57$$

for pipe2 in loop 1

$$\Delta = \Delta_1 - \Delta_2$$

for pipe2 in loop 2

$$\Delta = \Delta_2 - \Delta_1$$



2^{nd} Iteration

Loop	Pipe	Dia (m)	L (m)	K	Q_o (L/s)	h_f (m)	h_f/Q_o (m/L/s)	Correction L/s	Q L/s
1	1	0.150	305	0.0187	+23.76	+6.56	0.28	-0.15	+23.61
	2	0.150	305	0.0187	+11.73	+1.79	0.15	-0.15+0.09	+11.67
	3	0.200	610	0.0092	-39.24	-8.17	0.21	-0.15	-39.39
						+0.18	0.64		
2	2	0.150	305	0.0187	-11.73	-1.78	0.15	-0.09+0.15	-11.67
	4	0.150	457	0.0280	+12.03	+2.79	0.23	-0.09	+11.94
	5	0.200	153	0.0023	-25.77	-0.94	0.04	-0.09	-25.86
						+0.07	0.42		

$$\Delta_1 = \frac{-\sum h_F}{n\sum \frac{h_F}{Q_o}} = \frac{-0.18}{1.85(0.64)} = -0.15$$

$$\Delta_1 = \frac{-\sum h_F}{n\sum \frac{h_F}{Q_o}} = \frac{-(0.07)}{1.85(0.42)} = -0.09$$

for pipe2 in loop $\underline{1}$

$\Delta = \Delta_1 - \Delta_2$

for pipe2 in loop $\underline{2}$

$\Delta = \Delta_2 - \Delta_1$

Example

Solve the following pipe network using Hazen William Method $C_{HW} = 120$

Iteration 1

الأنبوب	D(mm)	L(m)	Q_1 (m^3/s)	i m/1000 m	h_f, m	$\frac{h_f}{Q_1}$	Δ	Q_2
AB	508	915	0.175	1.62	1.48	8.46	+0.014	0.189
BE	406	1220	0.045	0.37	0.45	10.00	+0.014 − 0.006 = +0.008	0.053
EF	406	915	−0.088	−1.33	−1.22	13.86	+0.014 − 0.022 = −0.008	−0.096
FA	610	1220	−0.263	−1.41	−1.72	6.54	+0.014	−0.249
					Σ = −1.01	38.86		
BC	508	915	0.130	0.95	0.87	6.69	+0.006	0.136
CD	406	1220	0.088	1.33	1.62	18.41	+0.006	0.094
DE	305	915	−0.065	−3.15	−2.88	44.31	+0.006 − (−0.005) = +0.011	−0.054
EB	406	1220	−0.045	−0.37	−0.45	10.00	+0.006 − (0.014) = −0.008	−0.053
					Σ = −0.84	79.41		
FE	406	915	0.088	1.33	1.22	13.86	+0.022 − (0.014) = +0.008	0.096
EH	305	1220	0.045	1.48	1.81	40.22	+0.022 − (−0.005) = +0.027	0.072
HG	406	915	−0.088	−1.33	−1.22	13.86	+0.022	−0.066
GF	406	1220	−0.175	−4.85	−5.91	33.77	+0.022	−0.153
					Σ = −4.1	101.71		
ED	305	915	0.065	3.15	2.88	44.31	−0.005 − (0.006) = −0.011	0.054
DI	305	1220	0.045	1.48	1.81	40.22	−0.005	0.040
IH	305	915	−0.045	−1.48	−1.35	30.00	−0.005	−0.050
HE	305	1220	−0.045	−1.48	−1.81	40.22	−0.005 − (0.022) = −0.027	−0.072
					Σ = +1.53	154.75		

for Iteration 1

$$\Delta = \frac{-\sum kQ_o^n}{\sum nkQ_o^{(n-1)}} = \frac{-\sum h_f}{n\sum \frac{h_f}{Q_o}}$$

$$\Delta_1 = \frac{-(-1.01)}{1.85(38.86)} = +0.014$$

$$\Delta_2 = \frac{-(-0.84)}{1.85(79.41)} = +0.006$$

$$\Delta_3 = \frac{-(-4.1)}{1.85(101.71)} = +0.022$$

$$\Delta_4 = \frac{-(+1.53)}{1.85(154.75)} = -0.005$$

Iteration 2

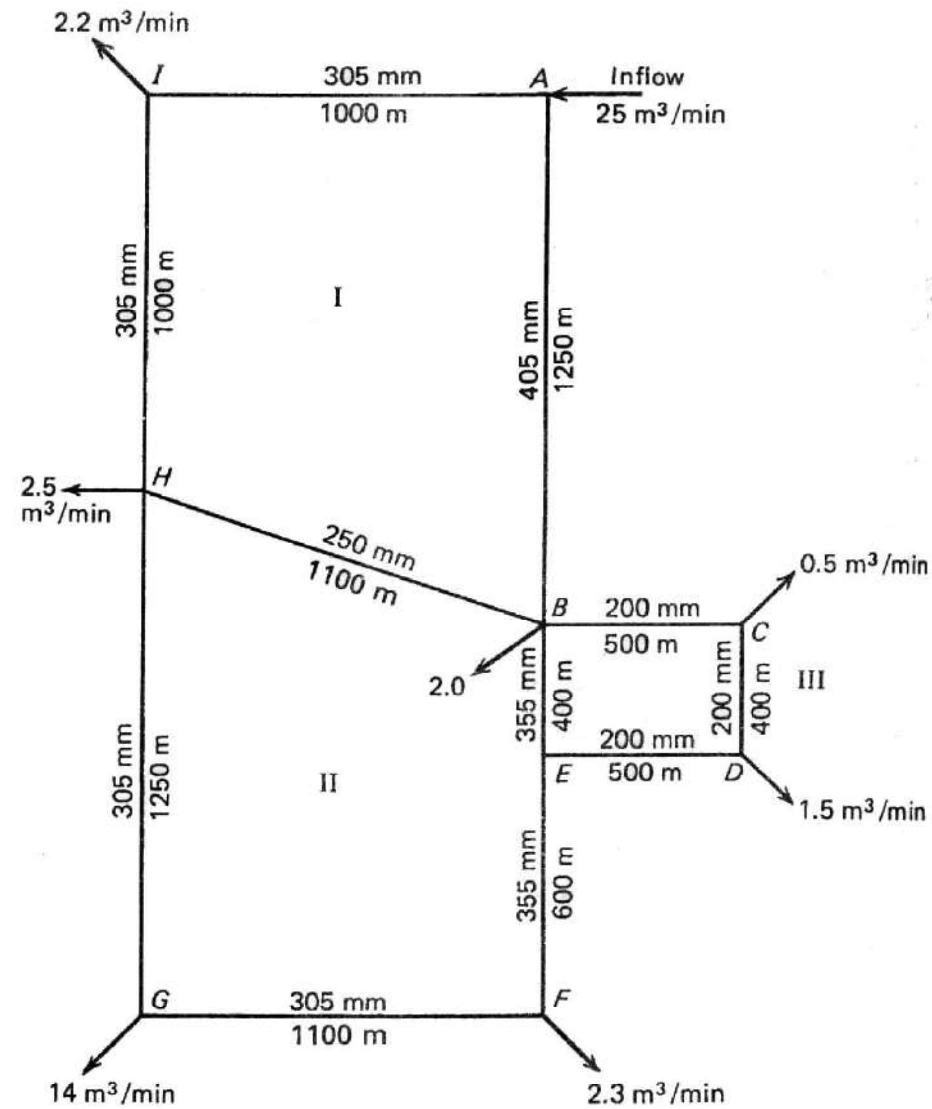
الأنبوب	Q_2	i	hf	hf/Q	Δ
AB	0.189	1.86	1.70	8.99	+0.009
BE	0.053	0.51	0.62	11.70	+0.009 + negl = +0.009
EF	−0.096	−1.57	−1.44	15.00	+0.009 − (−0.003) = +0.012
FA	−0.249	−1.28	−1.56	6.27	+0.009
			Σ = −0.68	41.96	
BC	0.136	1.02	0.93	6.84	negl
CD	0.094	1.48	1.80	19.15	negl
DE	−0.054	−2.28	−2.08	38.52	negl − 0.008 = −0.008
EB	−0.053	−0.51	−0.62	11.70	negl − 0.009 = −0.009
			Σ = +0.03	76.21	
FE	0.096	1.57	1.44	15.00	−0.003 − 0.009 = −0.012
EH	0.072	3.65	4.45	61.80	−0.003 − 0.008 = −0.011
HG	−0.066	−0.79	−0.72	10.91	−0.003
GF	−0.153	−3.75	−4.57	29.87	−0.003
			Σ = +0.6	117.58	
ED	0.054	2.28	2.08	38.52	+0.008 + negl = +0.008
DI	0.040	1.18	1.44	36.00	+0.008
IH	−0.050	−1.83	−1.67	33.40	+0.008
HE	−0.072	−3.65	−4.45	61.81	+0.008 − (−0.003) = +0.011
			Σ = −2.60	169.73	

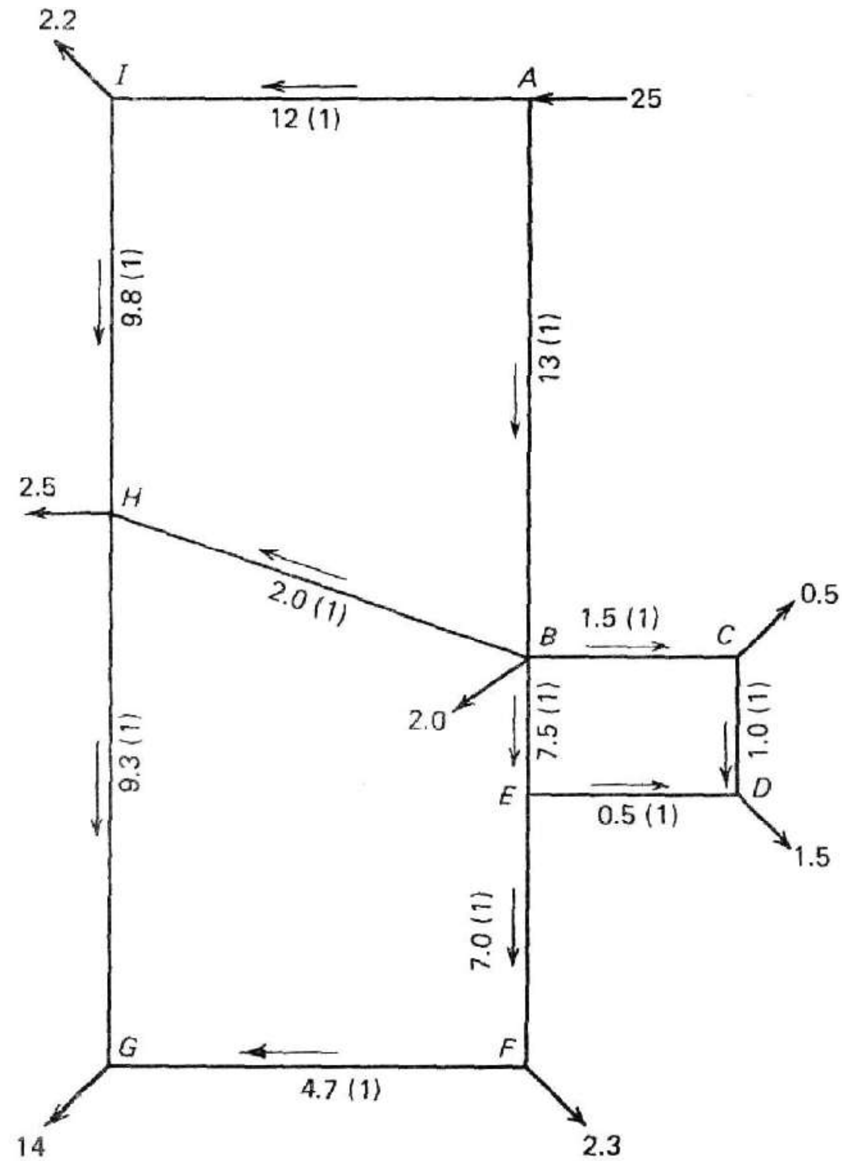
Iteration 3

الأنبوب	Q_3	i	hf	hf/Q	Δ	Q_4
AB	0.198	2.02	1.85	9.34	−0.001	0.197
BE	0.062	0.68	0.83	13.39	−0.001 − 0.005 = −0.006	0.056
EF	−0.084	−1.25	−1.14	13.57	−0.001 − 0.005 = −0.006	−0.090
FA	−0.240	−1.20	−1.46	6.08	−0.001	−0.241
			Σ = +0.08	42.38		
BC	0.136	1.02	0.93	6.84	+0.005	0.141
CD	0.094	1.49	1.82	19.36	+0.005	0.099
DE	−0.062	−2.97	−2.72	43.87	+0.005 + 0.001 = +0.006	−0.056
EB	−0.062	−0.68	−0.83	13.39	+0.005 + 0.001 = +0.006	−0.056
			Σ = −0.8	83.46		
FE	0.084	1.25	1.14	13.57	+0.005 + 0.001 = +0.006	0.090
EH	0.061	2.68	3.27	53.61	+0.005 + 0.001 = +0.006	0.067
HG	−0.069	−0.84	−0.77	11.16	+0.005	−0.064
GF	−0.156	−3.90	−4.75	30.45	+0.005	−0.151
			Σ = −1.11	108.79		
ED	0.062	2.97	2.72	43.87	−0.001 − 0.005 = −0.006	0.056
DI	0.048	1.68	2.05	42.71	−0.001	0.047
IH	−0.042	−1.31	−1.20	28.57	−0.001	−0.043
HE	−0.061	−2.68	−3.27	53.61	−0.001 − 0.005 = −0.006	−0.067
			Σ = +0.30	168.76		

Example

- The figure below represents a simplified pipe network.
- Flows for the area have been disaggregated to the nodes, and a major fire flow has been added at node *G*.
- The water enters the system at node *A*.
- Pipe diameters and lengths are shown on the figure.
- Find the flow rate of water in each pipe using the Hazen-Williams equation with $C_{HW} = 100$.
- Carry out calculations until the corrections are less then 0.2 m^3/min.


2.2 m³/min
I
305 mm
1000 m
A
Inflow
25 m³/min
305 mm
1000 m
I
405 mm
1250 m
H
2.5
m³/min
250 mm
1100 m
0.5 m³/min
B
200 mm
500 m
C
2.0
355 mm
400 m
200 mm
400 m
III
200 mm
E
500 m
D
1.5 m³/min
305 mm
1250 m
II
355 mm
600 m
G
305 mm
1100 m
F
14 m³/min
2.3 m³/min



2.2
I
A
25
12 (1)
9.8 (1)
13 (1)
2.5
H
2.0 (1)
B
1.5 (1)
C
0.5
2.0
7.5 (1)
1.0 (1)
9.3 (1)
E
0.5 (1)
D
1.5
7.0 (1)
G
F
4.7 (1)
14
2.3

First Correction

Loop I

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
AB	13	0.40	1250	0.0110	13.75	1.058
BH	2	0.25	1100	0.0033	3.63	1.815
HI	−9.8	0.30	1000	−0.0260	−26.00	2.653
IA	−12	0.30	1000	−0.0380	−37.80	3.150
					−46.42	8.676

$$\Delta_1 = -\frac{-46.42}{1.85(8.676)} = 2.9$$

Loop II

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
BE	7.5	0.35	400	0.0075	3.00	0.400
EF	7.0	0.35	600	0.0066	3.96	0.566
FG	4.7	0.30	1000	0.0067	6.68	1.423
GH	−9.3	0.30	1250	−0.0236	−29.54	3.177
HB	−2.0	0.25	1100	−0.0033	−3.63	1.815
					−19.53	7.381

$$\Delta_{II} = -\frac{-19.53}{1.85(7.381)} = 1.4$$

Loop III

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
BC	1.5	0.20	500	0.0058	2.91	1.937
CD	1.0	0.20	400	0.0028	1.10	1.110
DE	−0.5	0.20	500	−0.0008	−0.38	0.762
EB	−7.5	0.35	400	−0.0075	−3.00	0.400
					0.63	4.209

$$\Delta_{III} = -\frac{0.63}{1.85(4.209)} = -0.1$$

Second Correction

Loop I

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
AB	15.9	0.40	1250	0.0157	19.65	1.236
BH	3.5	0.25	1100	0.0094	10.34	2.954
HI	−6.9	0.30	1000	−0.0136	−13.60	1.971
IA	−9.1	0.30	1000	−0.0227	−22.70	2.495
					−6.31	8.656

$$\Delta_I = 0.4$$

Loop II

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
BE	9.0	0.35	400	0.0105	4.20	0.467
EF	8.4	0.35	600	0.0093	5.58	0.664
FG	6.1	0.30	1000	0.0108	10.80	1.770
GH	−7.9	0.30	1250	−0.0175	−21.88	2.769
HB	−3.5	0.25	1100	−0.0094	−10.34	2.954
					−11.64	8.624

$$\Delta_{II} = 0.7$$

Loop III

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
BC	1.4	0.20	500	0.0051	2.55	1.821
CD	0.9	0.20	400	0.0023	0.92	1.022
DE	−0.6	0.20	500	−0.0011	−0.55	0.917
EB	−9.0	0.35	400	−0.0105	−4.20	0.467
					−1.28	4.227

$$\Delta_{III} = 0.2$$

Third Correction

Loop I

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
AB	16.3	0.40	1250	0.0165	20.63	1.265
BH	3.2	0.25	1100	0.0080	8.80	2.750
HI	−6.5	0.30	1000	−0.0122	−12.20	1.877
IA	−8.7	0.30	1000	−0.0209	−20.90	2.402
					−3.67	8.294

$$\Delta_I = 0.2$$

Loop II

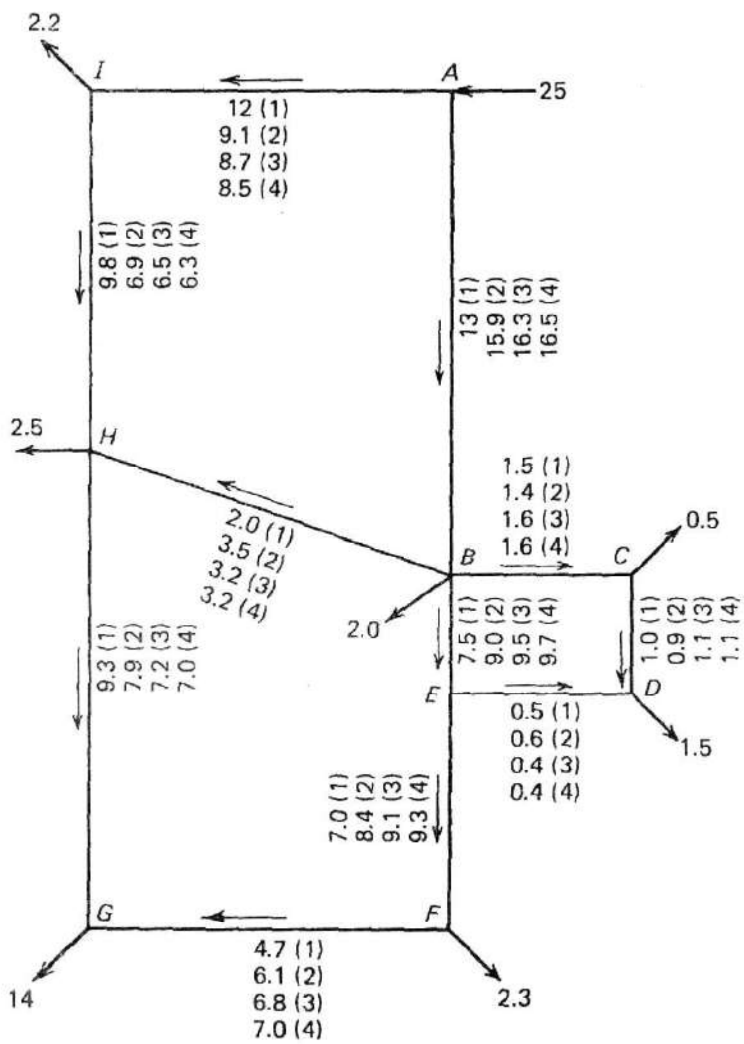
Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, m/m^3/min
BE	9.5	0.35	400	0.0116	4.64	0.488
EF	9.1	0.35	600	0.0107	6.42	0.705
FG	6.8	0.30	1000	0.0132	13.20	1.941
GH	−7.2	0.30	1250	−0.0147	−18.38	2.552
HB	−3.2	0.25	1100	−0.0080	−8.80	2.750
					−2.92	8.436

$$\Delta_{II} = 0.2$$

Loop III

Line	Flow, m^3/min	Dia, m	Length, m	s	h, m	h/Q, $m/m^3/min$
BC	1.6	0.20	500	0.0066	3.30	2.063
CD	1.1	0.20	400	0.0033	1.32	1.200
DE	−0.4	0.20	500	−0.0005	−0.25	0.625
EB	−9.5	0.35	400	−0.0116	−4.64	0.488
					−0.27	4.376

$$\Delta_{III} = 0.03$$

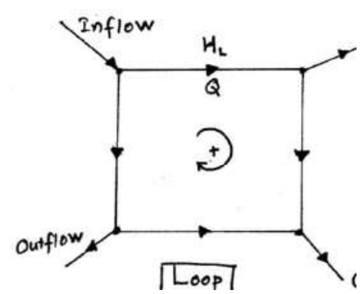

2.2
I
A
25
12 (1)
9.1 (2)
8.7 (3)
8.5 (4)
9.8 (1)
6.9 (2)
6.5 (3)
6.3 (4)
13 (1)
15.9 (2)
16.3 (3)
16.5 (4)
2.5
H
1.5 (1)
1.4 (2)
1.6 (3)
1.6 (4)
0.5
2.0 (1)
3.5 (2)
3.2 (3)
3.2 (4)
B
C
2.0
7.5 (1)
9.0 (2)
9.5 (3)
9.7 (4)
1.0 (1)
0.9 (2)
1.1 (3)
1.1 (4)
9.3 (1)
7.9 (2)
7.2 (3)
7.0 (4)
E
D
0.5 (1)
0.6 (2)
0.4 (3)
0.4 (4)
1.5
7.0 (1)
8.4 (2)
9.1 (3)
9.3 (4)
G
F
4.7 (1)
6.1 (2)
6.8 (3)
7.0 (4)
14
2.3

General Notes

- Occasionally the assumed direction of flow will be incorrect. In such cases the method will produce corrections larger than the original flow and in subsequent calculations the direction will be reversed.
- Even when the initial flow assumptions are poor, the convergence will usually be rapid. Only in unusual cases will more than three iterations be necessary.
- The method is applicable to the design of new system or to evaluate the proposed changes in an existing system.
- The pressure calculation in the above example assumes points are at equal elevations. If they are not, the elevation difference must be includes in the calculation.
- The balanced network must then be reviewed to assure that the velocity and pressure criteria are satisfied. If some lines do not meet the suggested criteria, it would be necessary to increase the diameters of these pipes and repeat the calculations.

Summary

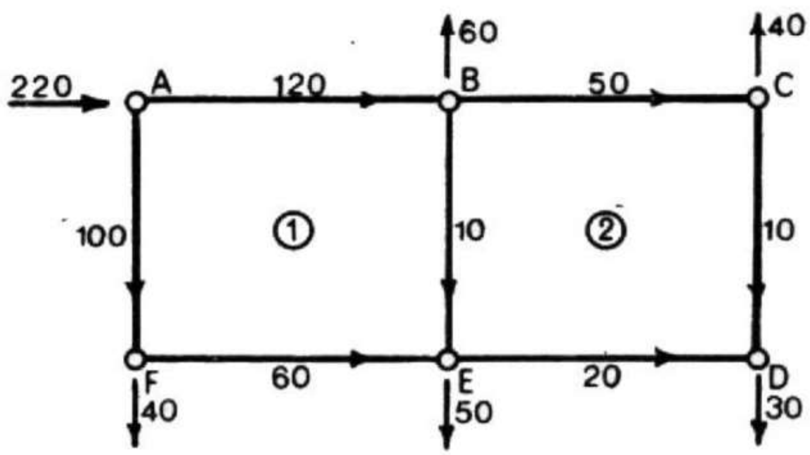
- Assigning clockwise flows and their associated head losses are positive, the procedure is as follows:
  - Assume values of Q to satisfy $\sum Q = 0$.
  - Calculate H_L from Q using $h_f = K^1Q^2$.
  - If $\sum h_f = 0$, then the solution is correct.
  - If $\sum h_f \neq 0$, then apply a correction factor, ΔQ, to all Q and repeat from step (2).
  - For practical purposes, the calculation is usually terminated when $\sum h_f < 0.01$ m or $\Delta Q < 1$ L/s.
  - A reasonably efficient value of ΔQ for rapid convergence is given by;



$$\Delta Q = -\frac{\sum H_L}{2\sum H_L/Q}$$

Example

- The following example contains nodes with different elevations and pressure heads.
- Neglecting minor loses in the pipes, determine:
  - The flows in the pipes.
  - The pressure heads at the nodes.



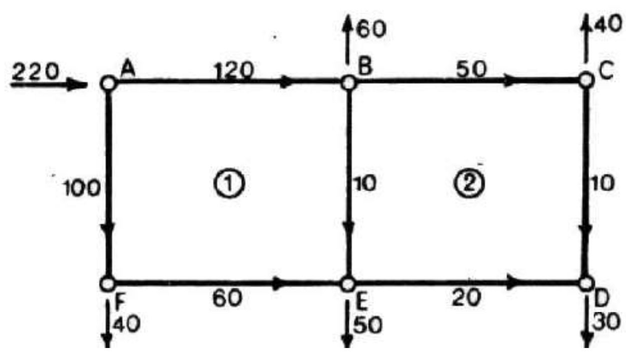
Pipe	AB	BC	CD	DE	EF	AF	BE
Length (m)	600	600	200	600	600	200	200
Diameter (mm)	250	150	100	150	150	200	100

Roughness size of all pipes = 0·06 mm
Pressure head elevation at A = 70 m o.d.

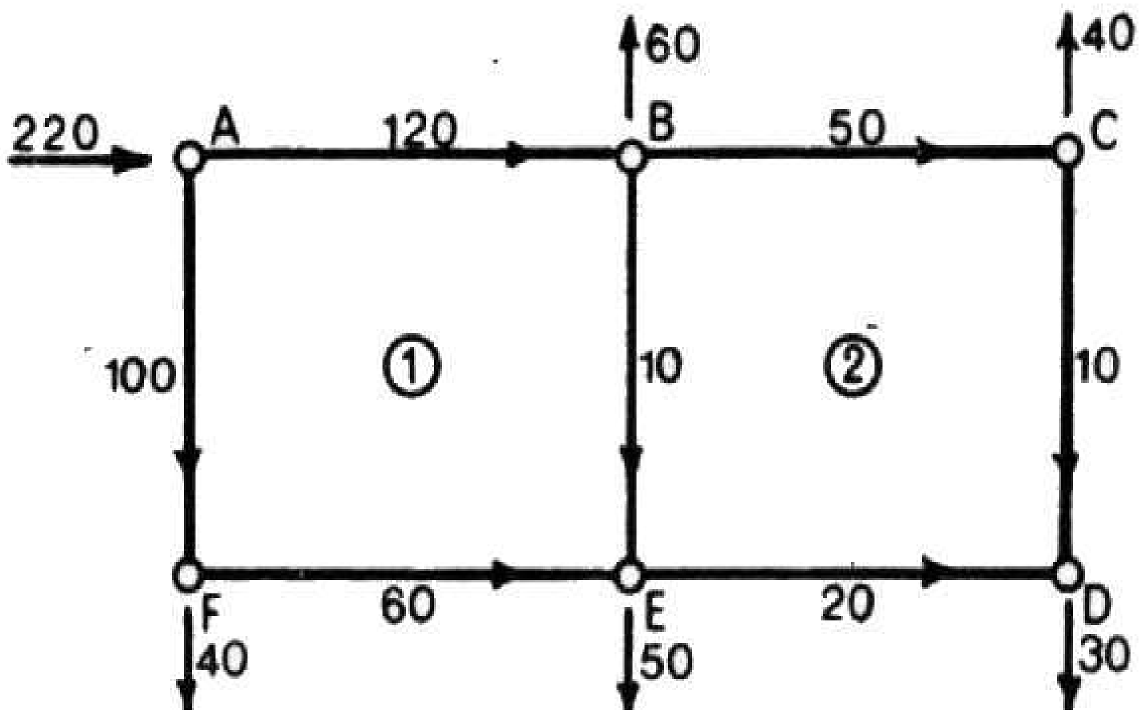
Assume T= 15^0C

Elevation of pipe nodes

Node	A	B	C	D	E	F
Elevation (m o.d.)	30	25	20	20	22	25

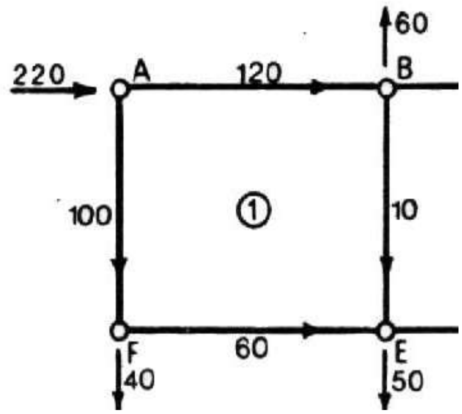


Assume flows magnitude and direction



First Iteration

- Loop (1)

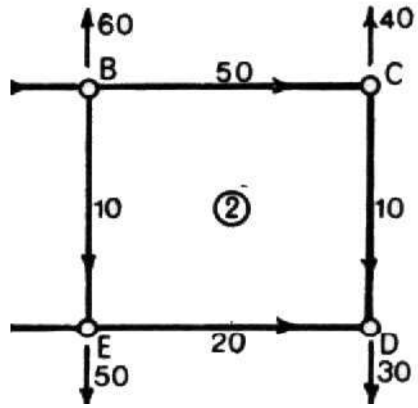


Pipe	*L* (m)	*D* (m)	*Q* (m^3/s)	*f*	h_f (m)	h_f/Q ($m/m^3/s$)
AB	**600**	**0.25**	**0.12**	**0.0157**	**11.48**	**95.64**
BE	**200**	**0.10**	**0.01**	**0.0205**	**3.38**	**338.06**
EF	**600**	**0.15**	**-0.06**	**0.0171**	**-40.25**	**670.77**
FA	**200**	**0.20**	**-0.10**	**0.0162**	**-8.34**	**83.42**
				Σ	**-33.73**	**1187.89**

$$\Delta = -\frac{-33.73}{2(1187.89)} = 0.01419 \text{ m}^3/\text{s} = 14.20 \text{ L/s}$$

First Iteration

- Loop (2)

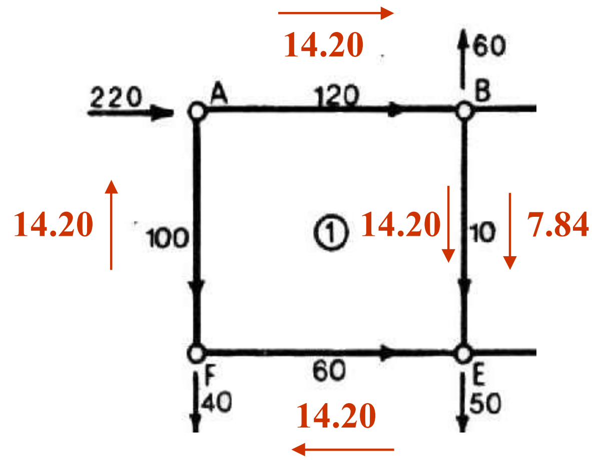


Pipe	*L* (m)	*D* (m)	*Q* (m^3/s)	*f*	h_f (m)	h_f/Q ($m/m^3/s$)
BC	600	0.15	0.05	0.0173	28.29	565.81
CD	200	0.10	0.01	0.0205	3.38	338.05
DE	600	0.15	-0.02	0.0189	-4.94	246.78
EB	200	0.10	-0.01	0.0205	-3.38	338.05
				Σ	23.35	1488.7

$$\Delta = -\frac{23.35}{2(1488.7)} = -0.00784\ \text{m}^3/\text{s} = -7.842\ \text{L/s}$$

Second Iteration

- Loop (1)

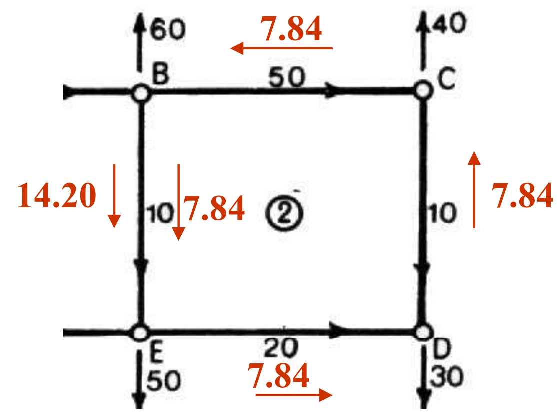


Pipe	L (m)	D (m)	Q (m^3/s)	f	h_f (m)	h_f/Q ($m/m^3/s$)
AB	**600**	**0.25**	**0.1342**	**0.0156**	**14.27**	**106.08**
BE	**200**	**0.10**	**0.03204**	**0.0186**	**31.48**	**982.60**
EF	**600**	**0.15**	**-0.0458**	**0.0174**	**-23.89**	**521.61**
FA	**200**	**0.20**	**-0.0858**	**0.0163**	**-6.21**	**72.33**
				Σ	**15.65**	**1682.62**

$$\Delta = -\frac{15.65}{2(1682.62)} = -0.00465 \text{ m}^3/\text{s} = -4.65 \text{ L/s}$$

Second Iteration

- Loop (2)

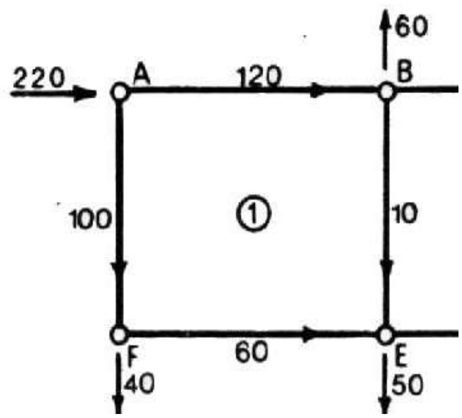


Pipe	L (m)	D (m)	Q (m^3/s)	f	h_f (m)	h_f/Q ($m/m^3/s$)
BC	**600**	**0.15**	**0.04216**	**0.0176**	**20.37**	**483.24**
CD	**200**	**0.10**	**0.00216**	**0.0261**	**0.20**	**93.23**
DE	**600**	**0.15**	**-0.02784**	**0.0182**	**-9.22**	**331.23**
EB	**200**	**0.10**	**-0.03204**	**0.0186**	**-31.48**	**982.60**
				Σ	**-20.13**	**1890.60**

$$\Delta = -\frac{-20.13}{2(1890.3)} = 0.00532 \text{ m}^3/\text{s} = 5.32 \text{ L/s}$$

Third Iteration

- Loop (1)

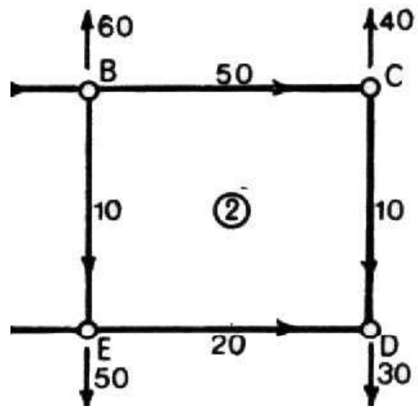


Pipe	L (m)	D (m)	Q (m^3/s)	f	h_f (m)	h_f/Q ($m/m^3/s$)
AB	**600**	**0.25**	**0.1296**	**0.0156**	**13.30**	**102.67**
BE	**200**	**0.10**	**0.02207**	**0.0190**	**15.30**	**693.08**
EF	**600**	**0.15**	**-0.05045**	**0.0173**	**-28.78**	**570.54**
FA	**200**	**0.20**	**-0.09045**	**0.0163**	**-6.87**	**75.97**
				Σ	**-7.05**	**1442.26**

$$\Delta = -\frac{-7.05}{2(1442.26)} = 0.00244 \text{ m}^3\text{/s} = 2.44 \text{ L/s}$$

Third Iteration

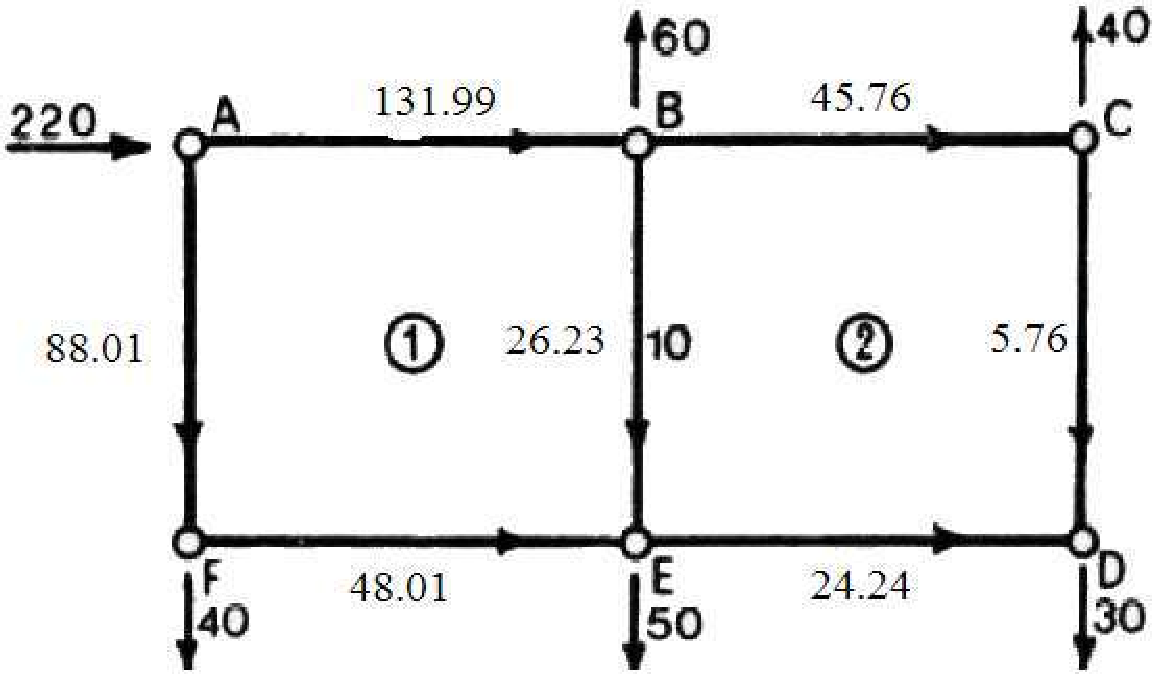
- Loop (2)



Pipe	*L* (m)	*D* (m)	*Q* (m^3/s)	*f*	h_f (m)	h_f/Q ($m/m^3/s$)
BC	600	0.15	0.04748	0.0174	25.61	539.30
CD	200	0.10	0.00748	0.0212	1.96	262.11
DE	600	0.15	-0.02252	0.0186	-6.17	274.07
EB	200	0.10	-0.02207	0.0190	-15.30	693.08
				Σ	6.1	1768.56

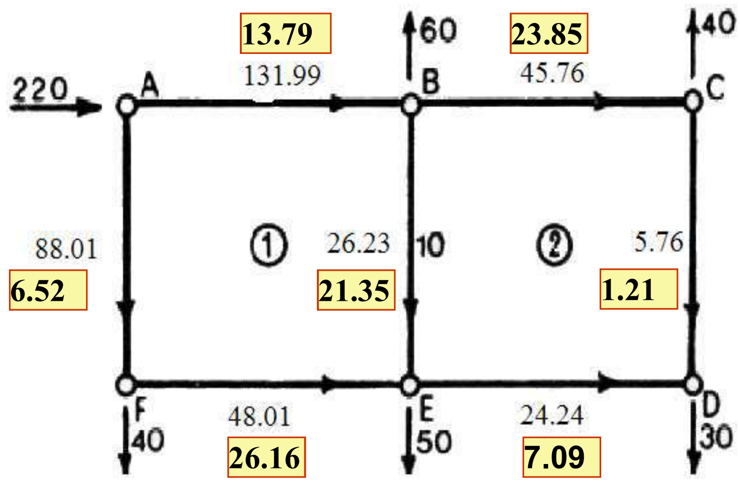
$$\Delta = -\frac{6.1}{2(1768.56)} = -0.00172\ \text{m}^3/\text{s} = -1.72\ \text{L/s}$$

After applying Third correction



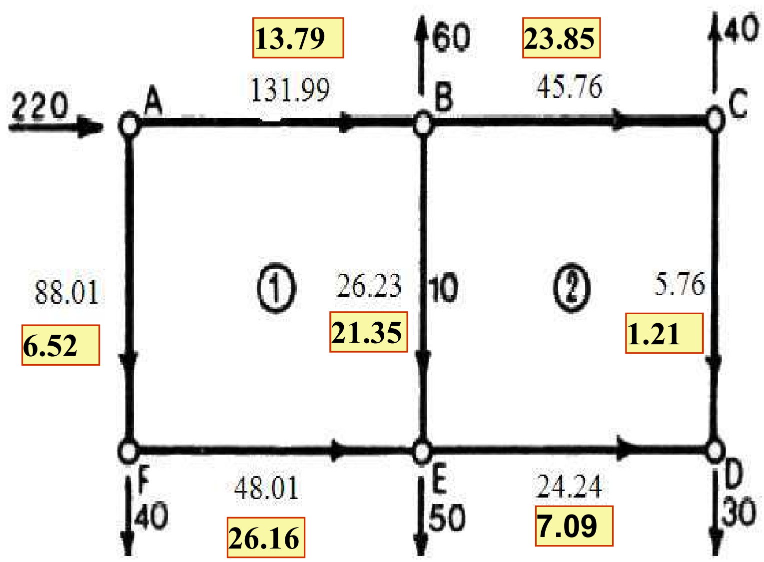
Velocity and Pressure Heads:

pipe	Q (l/s)	V (m/s)	h_f (m)
AB	**131.99**	**2.689**	**13.79**
BE	**26.23**	**3.340**	**21.35**
FE	**48.01**	**2.717**	**26.16**
AF	**88.01**	**2.801**	**6.52**
BC	**45.76**	**2.589**	**23.85**
CD	**5.76**	**0.733**	**1.21**
ED	**24.24**	**1.372**	**7.09**



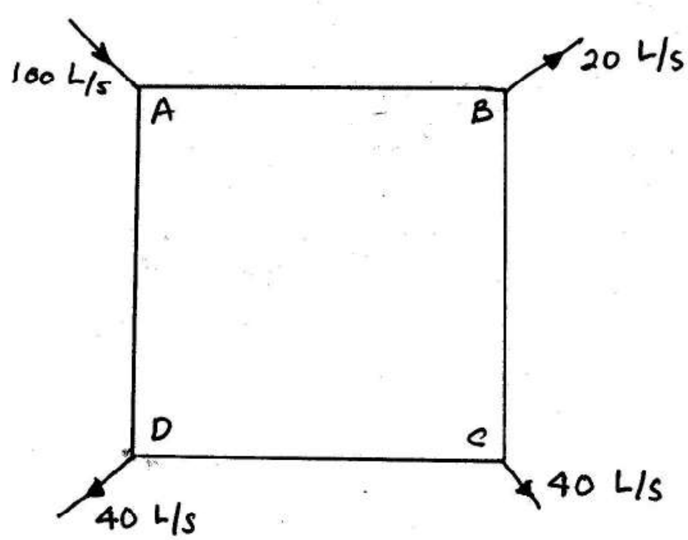
Velocity and Pressure Heads:

Node	$p/\gamma+Z$ (m)	Z (m)	P/γ (m)
A	**70**	**30**	**40**
B	**56.21**	**25**	**31.21**
C	**32.36**	**20**	**12.36**
D	**31.15**	**20**	**11.15**
E	**37.32**	**22**	**15.32**
F	**63.48**	**25**	**38.48**



Example

For the square loop shown, find the discharge in all the pipes. All pipes are 1 km long and 300 mm in diameter, with a friction factor of 0.0163. Assume that minor losses can be neglected.



•Solution:

- Assume values of Q to satisfy continuity equations all at nodes.
- The head loss is calculated using; $H_L = K^1Q^2$
- $H_L = h_f + h_{Lm}$
- But minor losses can be neglected: $\Rightarrow$ $h_{Lm} = 0$
- Thus $H_L = h_f$
- Head loss can be calculated using the Darcy-Weisbach equation

$$h_f = \lambda \frac{L}{D}\frac{V^2}{2g}$$

$$H_L = h_f = \lambda \frac{L}{D}\frac{V^2}{2g}$$

$$H_L = 0.0163 \, x \, \frac{1000}{0.3} \, x \, \frac{V^2}{2 \, x \, 9.81}$$

$$H_L = 2.77 \frac{Q^2}{A^2} = 2.77 \, x \, \frac{Q^2}{\left(\frac{\pi}{4} x \, 0.3^2\right)^2}$$

$$H_L = 554Q^2$$

$$H_L = K'Q^2$$

$$\therefore \quad K' = 554$$

First trial

Pipe	Q (L/s)	H_L (m)	H_L/Q
AB	60	2.0	0.033
BC	40	0.886	0.0222
CD	0	0	0
AD	-40	-0.886	0.0222
Σ		2.00	0.0774

Since $\sum H_L > 0.01$ m, then correction has to be applied.

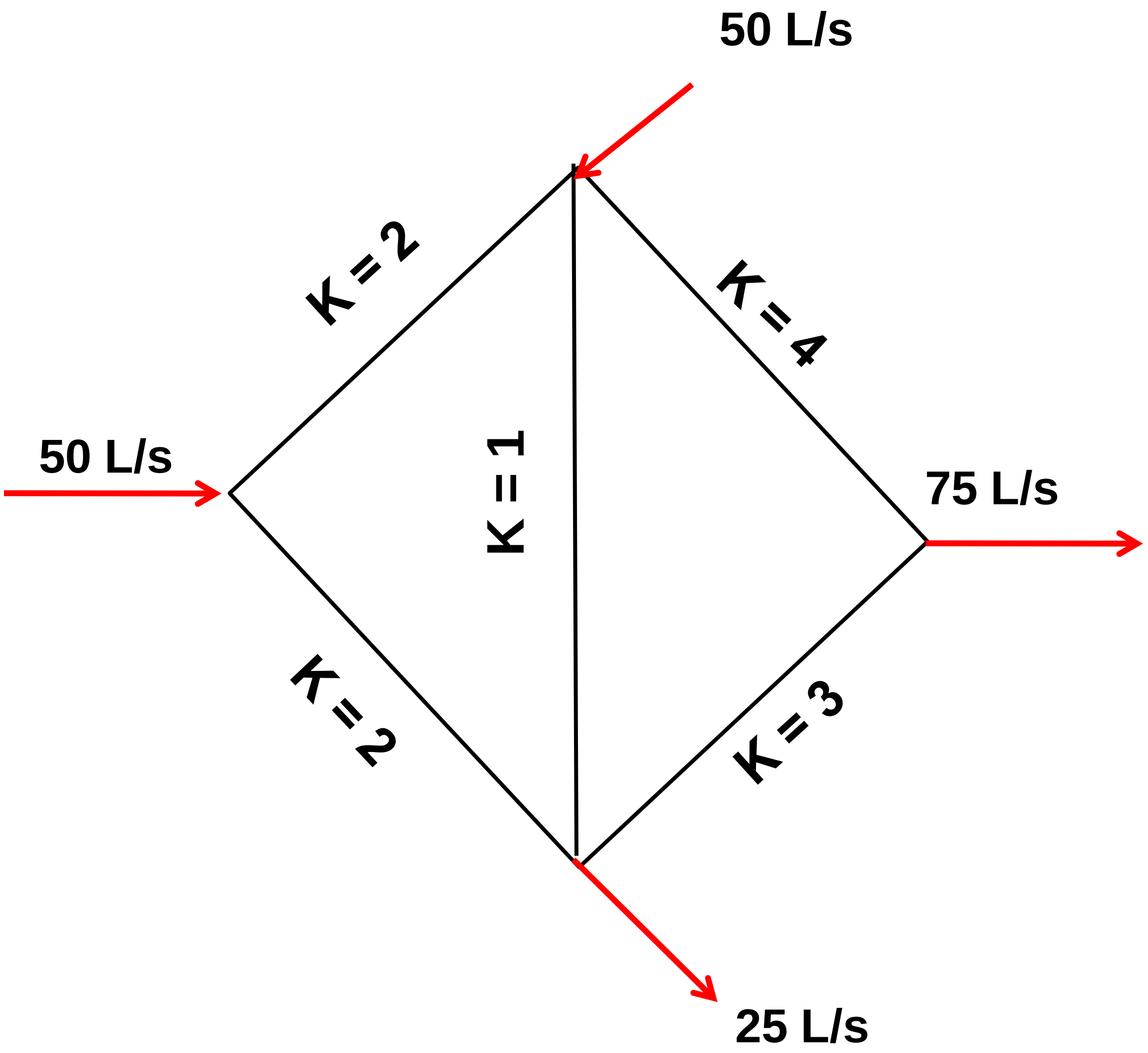
$$\Delta Q = -\frac{\sum H_L}{2\sum H_L/Q} = -\frac{2}{2x0.0774} = -12.92\,L/s$$

Second trial

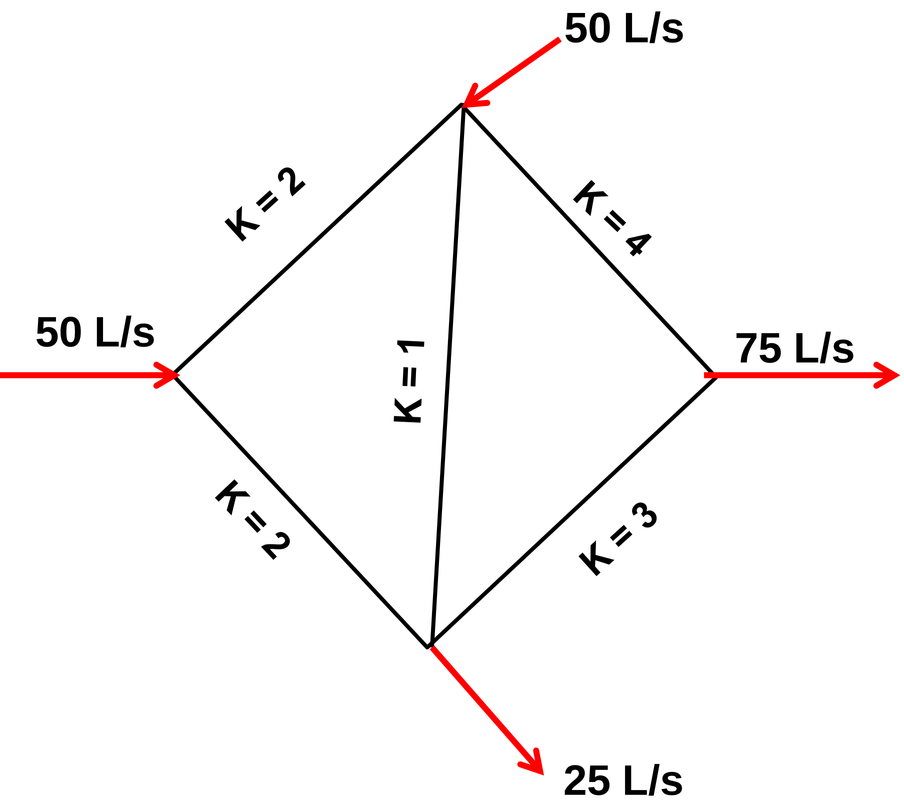
Pipe	Q (L/s)	H_L (m)	H_L/Q
AB	47.08	1.23	0.0261
BC	27.08	0.407	0.015
CD	-12.92	-0.092	0.007
AD	-52.92	-1.555	0.0294
Σ		-0.0107	0.07775

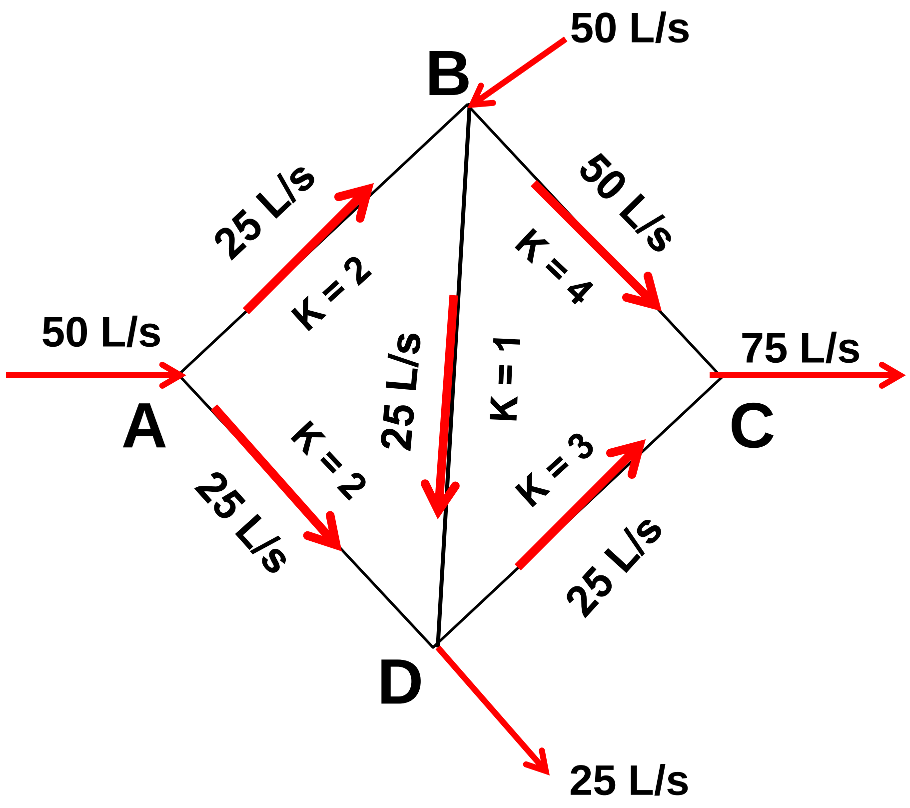
Since $\sum H_L \approx 0.01$ m, then it is OK.
Thus, the discharge in each pipe is as follows (to the nearest integer).

Pipe	Discharge (L/s)
AB	47
BC	27
CD	-13
AD	-53



50 L/s
K = 2
K = 4
50 L/s
K = 1
75 L/s
K = 2
K = 3
25 L/s





Loop 1 – ABDA

Loop 2 -- BCDB

First Correction Loop 1 - ABDA

Pipe	Assumed Flows, Qa (L/s)	K (given)	$H_L = K.Qa^2$	$\frac{H_L}{Q_a}$	Corrected Q after first correction Qa1 =Qa + Δ1
(1)	(2)	(3)	(4)	(5)	(6)
			Loop 1 - ABDA		
AB	25	2	1250	50	25 – 2.5 = 22.5
BD (common pipe)	25	1	625	25	25-2.5+12.5=+35
DA	-25	2	(-)1250	50	-25 – 2.5 = -27.5
		∑	(+)625	125	

$$\Delta_1 = \frac{(-)\sum H_L}{x.\sum \frac{H_L}{Q_a}}$$

$$\therefore \Delta_1 = (-)\frac{625}{2 \times 125} = (-)2.5$$

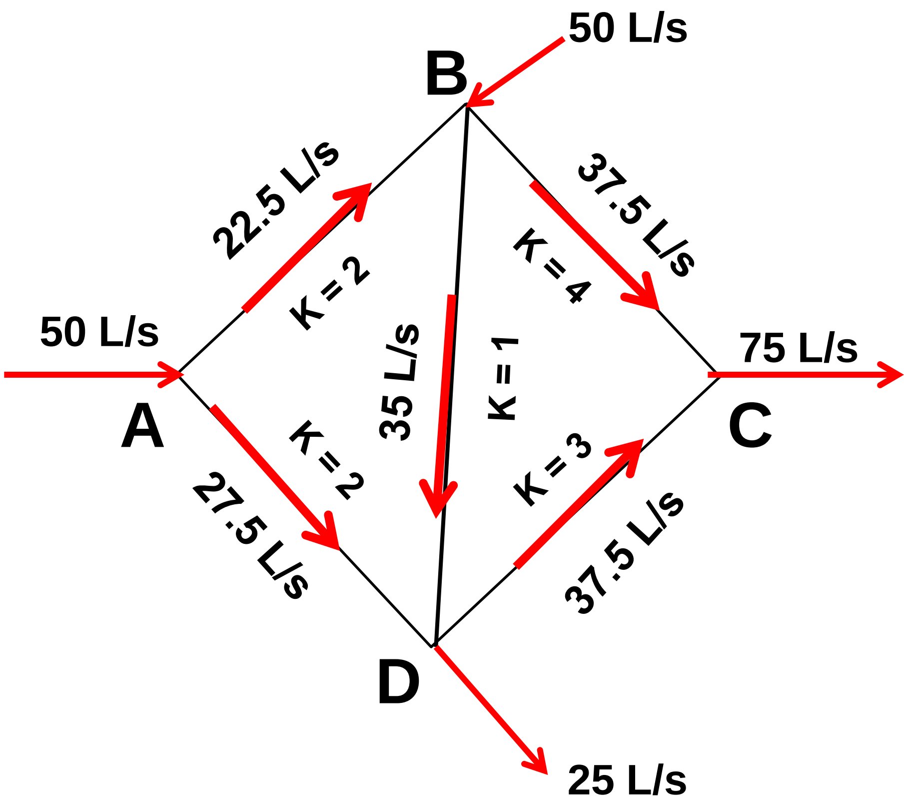
First Correction Loop 2 - BCDB

Pipe	Assumed Flows, Qa (L/s)	K (given)	$H_L = K.Qa^2$	$\left\lvert \frac{H_L}{Q_a} \right\rvert$	Corrected Q after first correction Qa1 =Qa + Δ1
(1)	(2)	(3)	(4)	(5)	(6)
Loop 2 - BCDB					
BC	50	4	10000	200	50-12.5=37.5
CD	-25	3	(-)1875	75	-25-12.5=(-)37.5
BD (common pipe)	-25	1	-625	25	-25+2.5-12.5= -35
		∑	(+)7500	300	

$$\therefore \Delta_1' = (-)\frac{7500}{2 \times 300} = (-)12.5$$

Flows after First Correction

Pipe	Corrected Discharge after Ist Correction, L/s
Loop ABDA	
AB	22.5
BD	35.0
DA	(-)27.5
Loop BCDB	
BC	37.5
CD	(-) 37.5
DB	(-) 35



Second Correction Loop 1 - ABDA

Pipe	Assumed Flows, Qa (L/s)	K (given)	$H_L = K.Qa^2$	$\left\lvert \frac{H_L}{Q_a} \right\rvert$	Corrected Q after first correction Qa1 =Qa + Δ1
(1)	(2)	(3)	(4)	(5)	(6)
		Loop 1 - ABDA			
AB	22.5	2	1012.5	45	22.5 – 2.7 = 19.8
BD (common pipe)	35	1	1225	35	35-2.7+0.3= + 32.6
DA	(-)27.5	2	(-)1512.5	55	-27.5 – 2.7 = (-) 30.2
		Σ	(+)725	135	

$$\Delta_1 = \frac{(-)\sum H_L}{x.\sum \frac{H_L}{Q_a}}$$

Δ_2 = (-) 725 / (2x135) = (-) 2.7

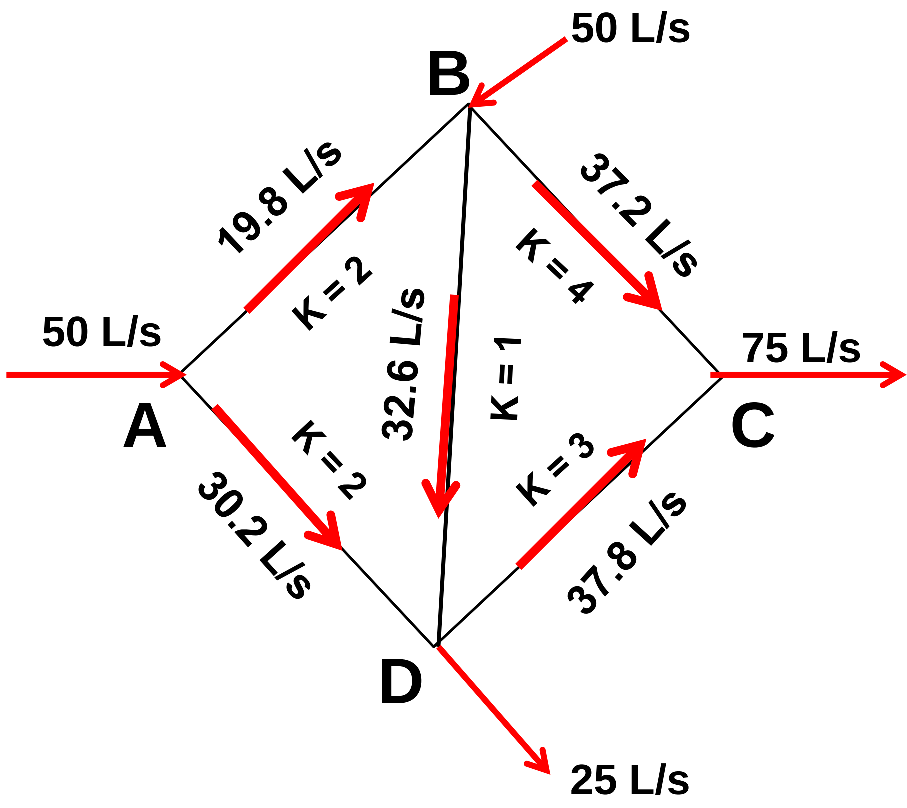
Second Correction Loop 2 - BCDB

Pipe	Assumed Flows, Qa (L/s)	K (given)	$H_L = K.Qa^2$	$\left\lvert \frac{H_L}{Q_a} \right\rvert$	Corrected Q after first correction Qa1 =Qa + Δ1
(1)	(2)	(3)	(4)	(5)	(6)
Loop 2 - BCDB					
BC	37.5	4	5625	150	37.5-0.30=37.2
CD	(-)37.5	3	(-)4218.75	112.5	-37.5-.3=(-)37.8
BD (common pipe)	(-)35.0	1	(-)1225	35	-35+2.7-0.3= -32.6
		∑	(+)181.25	297.5	

Δ_2 = (-) 181.25 / (2x297.5) = (-) 0.3046

Flows after Second Correction

Pipe	Corrected Discharge after Ist Correction, L/s
Loop ABDA	
AB	19.8
BD	32.6
DA	(-) 30.2
Loop BCDB	
BC	37.2
CD	(-) 37.8
DB	(-) 32.6

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Punjab University
P.G.I.
ISBT
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HARYANA
PUNJAB
RGCTP
(MOHALI)
CHANDIGARH AIRPORT
High Court
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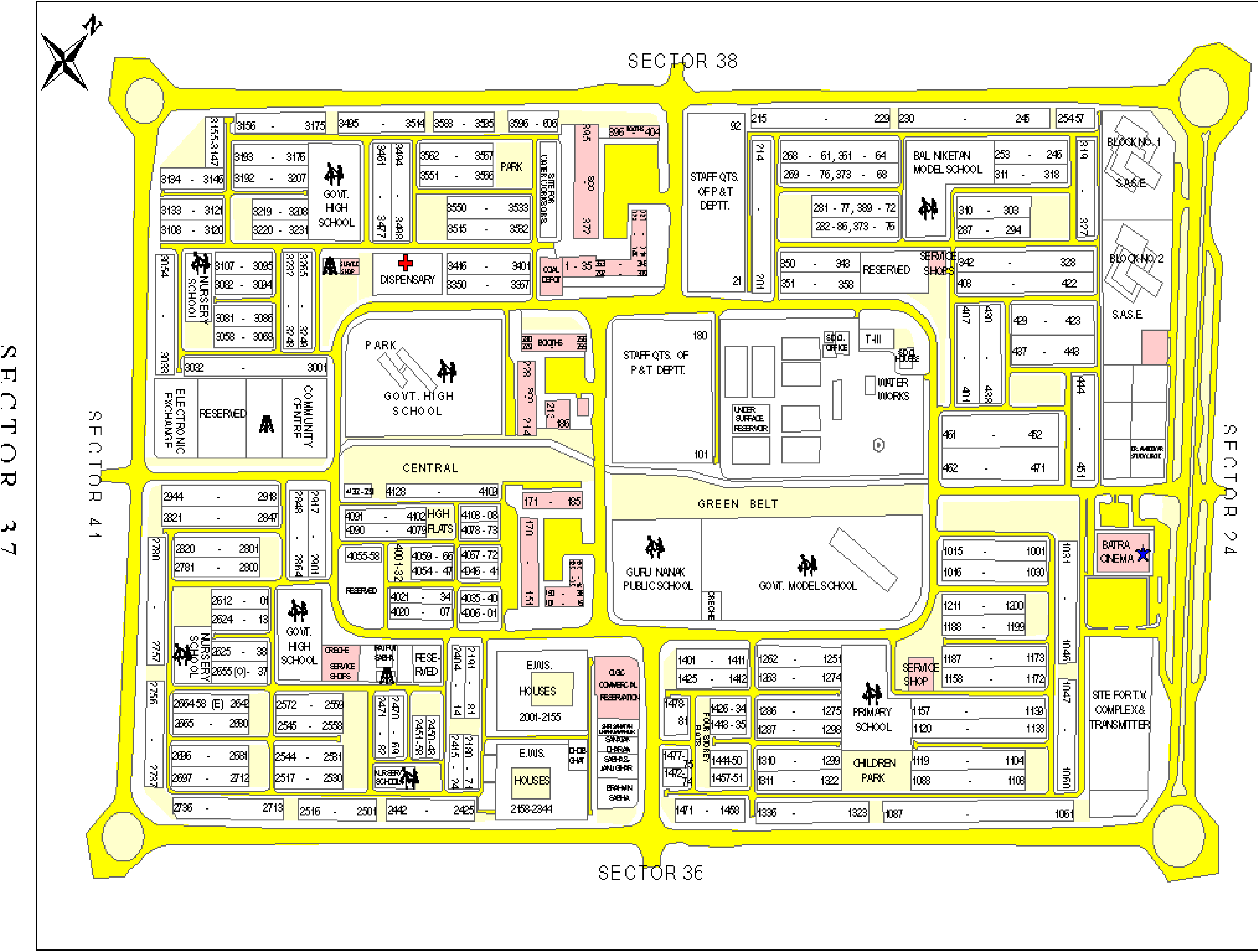
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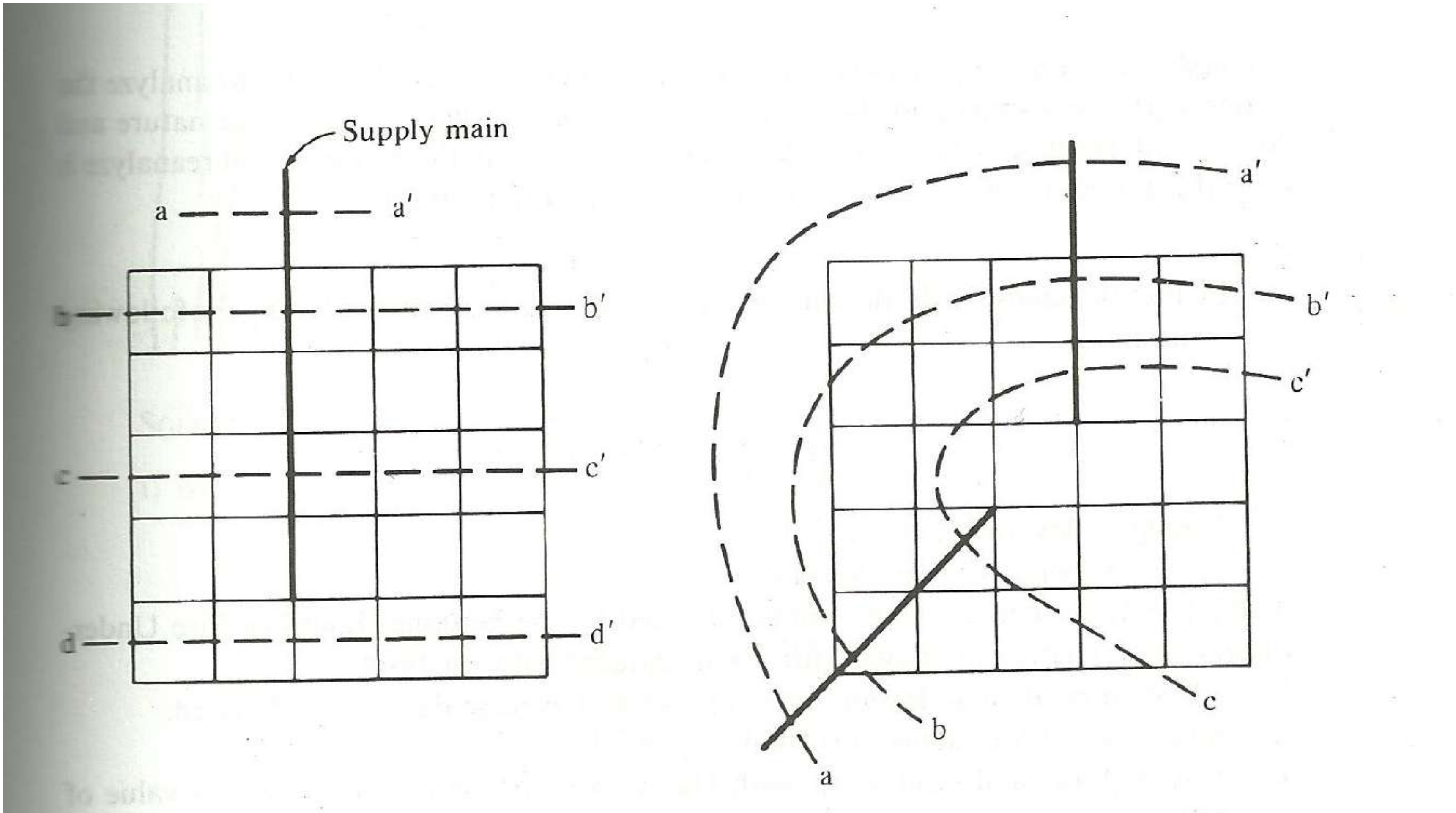
SECTOR 38
SECTOR 36
SECTOR 37
SECTOR 41
SECTOR 24
GOVT. HIGH SCHOOL
PARK
DISPENSARY
NURSERY SCHOOL
RESERVED
ELECTRONIC EXCHANGE
COMMUNITY CENTRE
CENTRAL
BOOTHS
COAL DEPOT
STAFF QTS. OF P&T DEPTT.
BAL NIKETAN MODEL SCHOOL
SERVICE SHOPS
BLOCK NO. 1
BLOCK NO. 2
S.A.S.E
T-III
WATER WORKS
UNDER SURFACE RESERVOIR
GREEN BELT
HIGH FLATS
GURU NANAK PUBLIC SCHOOL
GOVT. MODEL SCHOOL
CRECHE
BATRA CINEMA
E.W.S. HOUSES 2001-2155
E.W.S. HOUSES 2158-2344
FOUR STOREY FLATS
PRIMARY SCHOOL
CHILDREN PARK
SERVICE SHOP
SITE FOR T.V. COMPLEX & TRANSMITTER
BRAHMIN SABHA
CHOB GHAT

Method of Sections



(*a*) (*b*)