DEPARTMENT OF CIVIL ENGINEERING

Final Assignment (Spring 2020) Subject: Water demand supply and Distribution
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Q1. Desalination and its method

Answer. **Desalination** is a water supply option that is used widely around the world and involves taking the salt out of water to make it drinkable. Many countries use desalination as a way of creating a more reliable water supply that is not dependent on rain.

Desalination Methods.

Two distillation technologies are used primarily around the world for desalination: thermal distillation and membrane distillation.
Thermal distillation technologies are widely used in the Middle East, primarily because the region's petroleum reserves keep energy costs low. The three major, large-scale thermal processes are multistage flash distillation (MSF), multi-effect distillation (MED), and vapor compression distillation (VCD). Another thermal method, solar distillation, is typically used for very small production rates. Membrane distillation technologies are primarily used in the United States. These systems treat the feed water by using a pressure gradient to force feed the water through membranes. The three major membrane processes are electrodialysis (ED), electrodialysis reversal (EDR), and reverse osmosis (RO).

Thermal technologies

Multi-stage flash distillation

Multi-stage flash distillation is a process that sends the saline feed water through multiple chambers (Fig. 1). In these chambers, the water is heated and compressed to a high temperature and high pressure. As the water progressively passes through the chambers, the pressure is reduced, causing the water to rapidly boil. The vapor, which is fresh water, is produced in each chamber from boiling and then is condensed and collected.

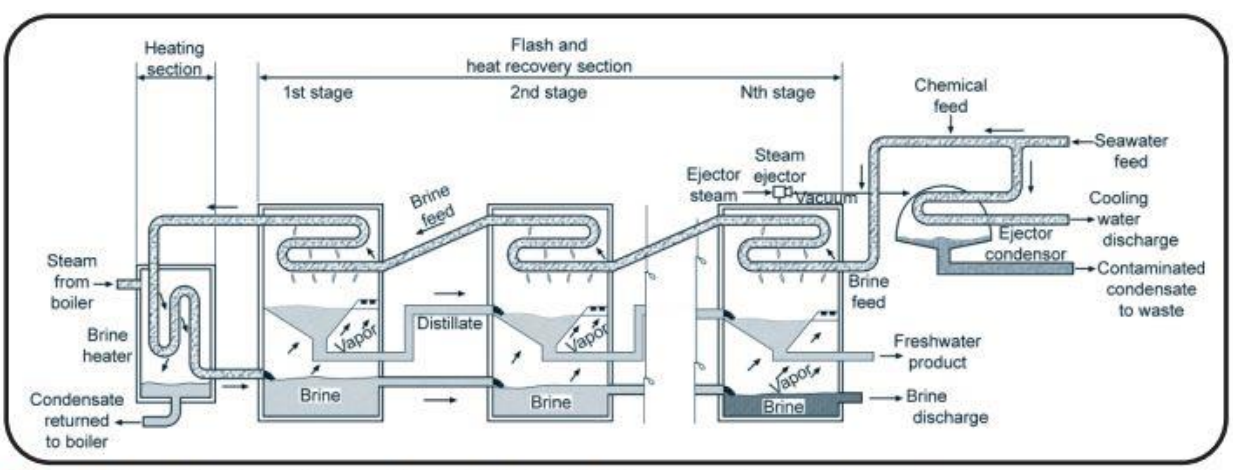


Figure 1. Example of a multi-stage flash distillation (MSF) process (Source: Buros, 1990).

Multi-effect distillation Multi-effect distillation employs the same principals as the multi-stage flash distillation process except that instead of using multiple chambers of a single vessel, MED uses successive vessels (Fig. 2). The water vapor that is formed when the water boils is condensed and collected. The multiple vessels make the MED process more efficient.

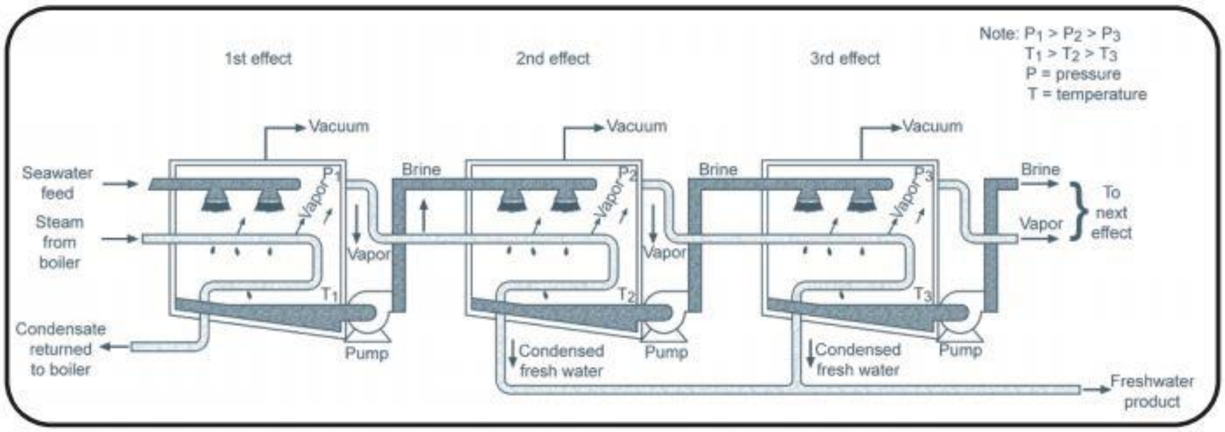


Figure 2. Example of a multi-effect distillation (MED) process (Source: Buros, 1990).

Vapor compression distillation

Vapor compression distillation can function independently or be used in combination with another thermal distillation process. VCD uses heat from the compression of vapor to evaporate the feed water (Fig. 3). VCD units are commonly used to produce fresh water for small- to medium-scale purposes such as resorts, industries, and petroleum drilling sites.

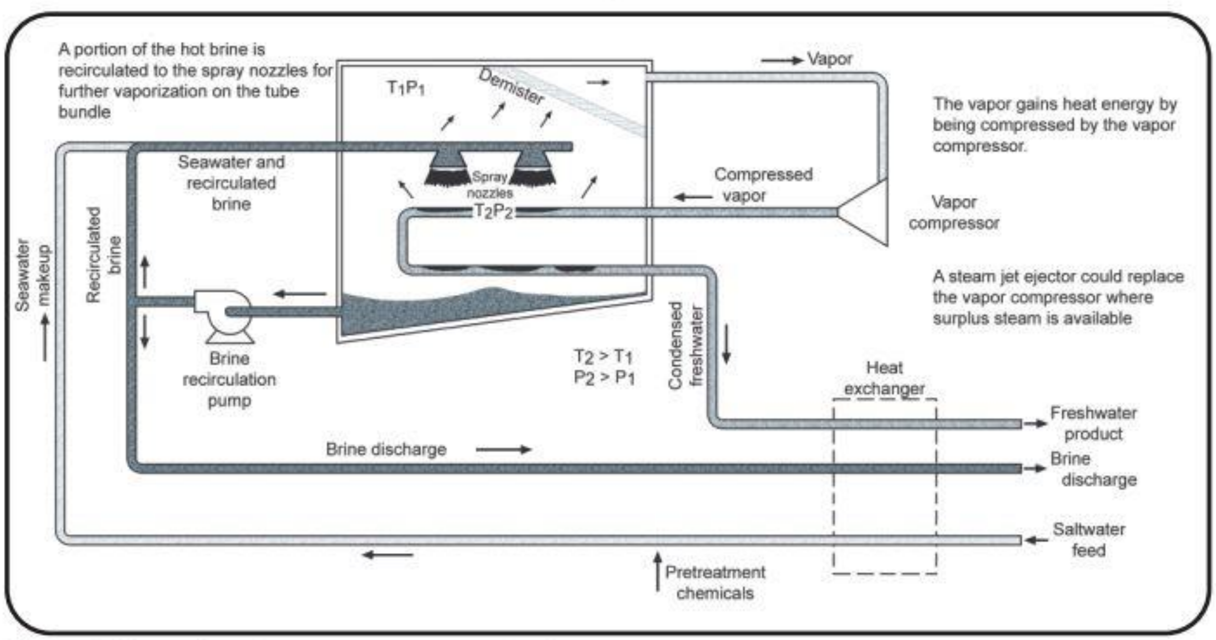


Figure 3. Example of a vapor compression distillation (VCD) process (Source: Buros, 1990).

Solar distillation

Solar desalination is generally used for small scale operations (Fig. 4). Although the designs of solar distillation units vary greatly, the basic principles are the same. The sun provides the energy to evaporate the saline water. The water vapor formed from the evaporation process then condenses on the clear glass or plastic covering and is collected as fresh water in the condensate trough. The covering is used to both transmit radiant energy and allow water vapor to condense on its interior surface. The salt and un-evaporated water left behind in the still basin forms the brine solution that must be discarded appropriately.

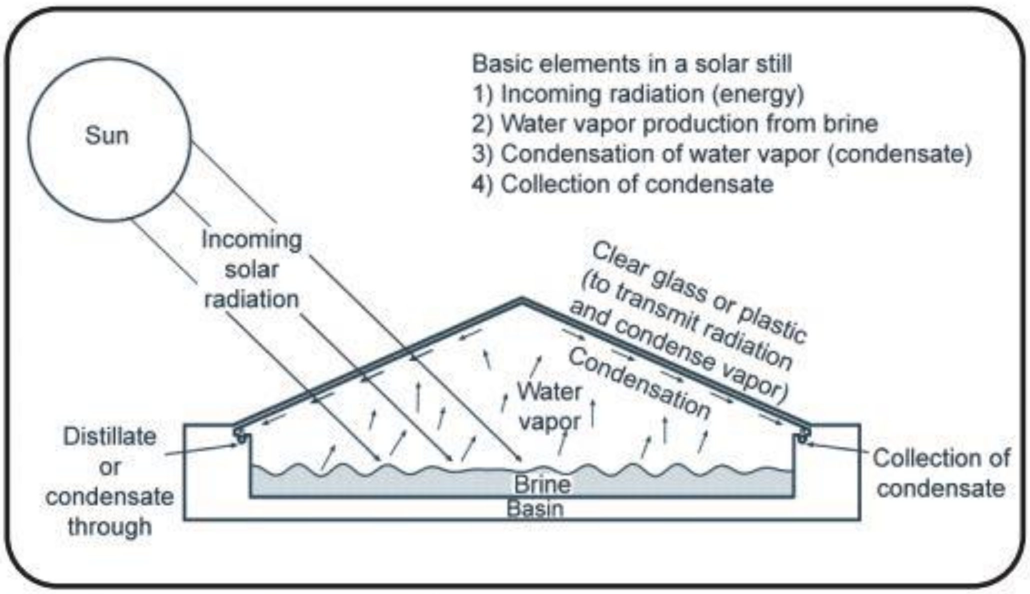


Figure 4. *Example of a solar still desalination process (Source: Buros, 1990).*

This practice is often used in arid regions where safe fresh water is not available. Solar distillation units produce differing amounts of fresh water, according to their design and geographic location. Recent tests on four solar still designs by the Texas AgriLife Extension Service in College Station, Texas, have shown that a solar still with as little as 7.5 square feet of surface area can produce enough water for a person to survive.

Membrane technologies A membrane desalination process uses a physical barrier—the membrane—and a driving force. The driving force can be an electrical potential, which is used in electrodialysis or electrodialysis reversal, or a pressure gradient, which is used in reverse osmosis.

Membrane technologies often require that the water undergo chemical and physical pretreatment to limit blockage by debris and scale formation on the membrane surfaces. Table 1 (page 5) details the basic characteristics of membrane processes.

Table 1. General characteristics of membrane processes (Source: Metcalf and Eddy, 2003).

Membrane process	Membrane driving force	Typical separation mechanism	Operating structure (pore size)	Typical operating range, (μm)	Permeate description	Typical constituents removed
Microfiltration	Hydrostatic pressure difference or vacuum in open vessels	Sieve	Macropores (> 50 nm)	0.08–2.0	Water + dissolved solutes	TSS, turbidity, protozoan oocysts and cysts, some bacteria and viruses
Ultrafiltration	Hydrostatic pressure difference	Sieve	Mesopores (2–50 nm)	0.005–0.2	Water + small molecules	Macromolecules, colloids, most bacteria, some viruses, proteins
Nanofiltration	Hydrostatic pressure difference	Sieve + solution/ diffusion + exclusion	Micropores (< 2 nm)	0.001–0.01	Water + very small molecules, ionic solutes	Small molecules, some hardness, viruses
Reverse osmosis	Hydrostatic pressure difference	Solution/ diffusion + exclusion	Dense (< 2 nm)	0.0001–0.001	Water + very small molecules, ionic solutes	Very small molecules, color, hardness, sulfates, nitrate, sodium, other ions
Dialysis	Concentration difference	Diffusion	Mesopores (2–50 nm)	--	Water + small molecules	Macromolecules, colloids, most bacteria, some viruses, proteins
Electrodialysis	Electromotive force	Ion exchange with selective membranes	Micropores (< 2 nm)	--	Water + ionic solutes	Ionized salt ions

Electrodialysis and electrodialysis reversal

The membranes used in electrodialysis and electrodialysis reversal are built to allow passage of either positively or negatively charged ions, but not both. Ions are atoms or molecules that have a net positive or net negative charge. Four common ionic molecules in saline water are sodium, chloride, calcium, and carbonate.

Electrodialysis and electrodialysis reversal use the driving force of an electrical potential to attract and move different cations (positively charged ions) or anions (negatively charged ions) through a permeable membrane, producing fresh water on the other side (Fig. 5).

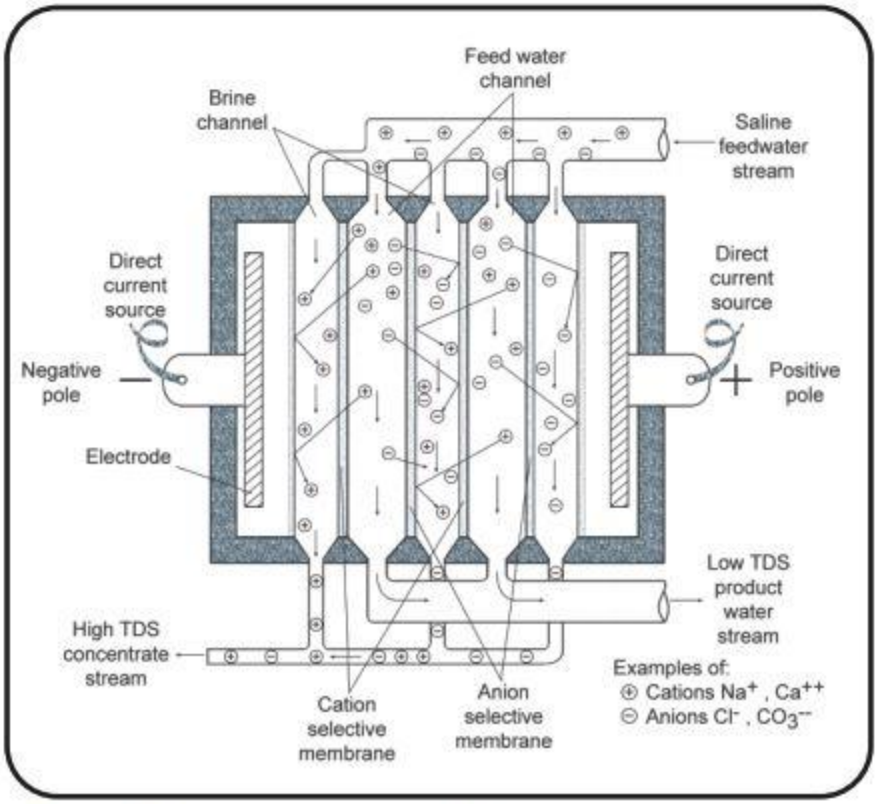


Figure 5. Example of an electrodialysis process showing the basic movements of ions in the treatment process (Source: Buros, 1990).

The cations are attracted to the negative electrode, and the anions are attracted to the positive electrode. When the membranes are placed so that some allow only cations to pass and others allow only anions to pass, the process can effectively remove the constituents from the feed water that make it a saline solution.

The electrodialysis reversal process functions as does the electrodialysis process; the only difference is that in the reverse process, the polarity, or charge, of the electrodes is switched periodically. This reversal in flow of ions helps remove scaling and other debris from the membranes, which extends the system’s operating life.

Reverse osmosis

Reverse osmosis uses a pressure gradient as the driving force to move high-pressure saline feed water through a membrane that prevents the salt ions from passing (Fig. 6).

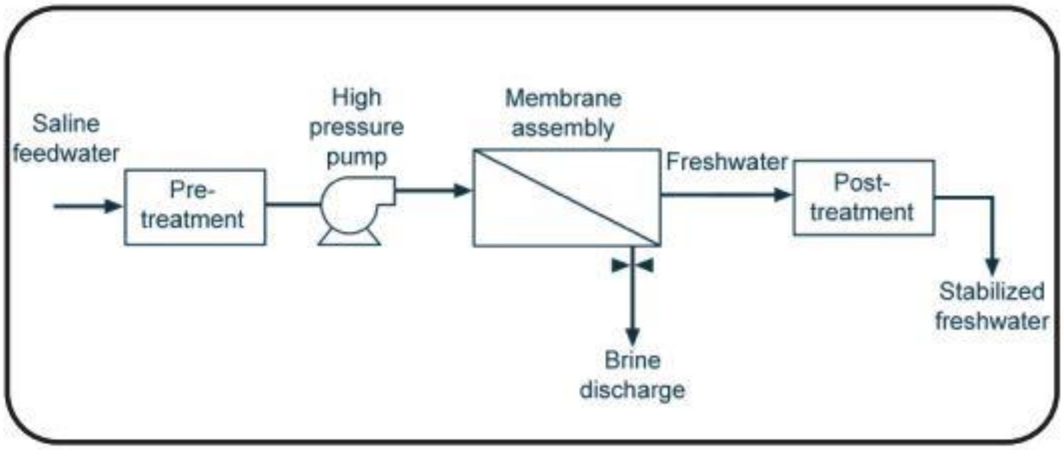


Figure 6. Basic components of a membrane treatment process.

There are several membrane treatments processes, including reverse osmosis, nanofiltration, ultrafiltration, and microfiltration. The pore sizes of the membranes differ according to the type of process (Fig. 7).

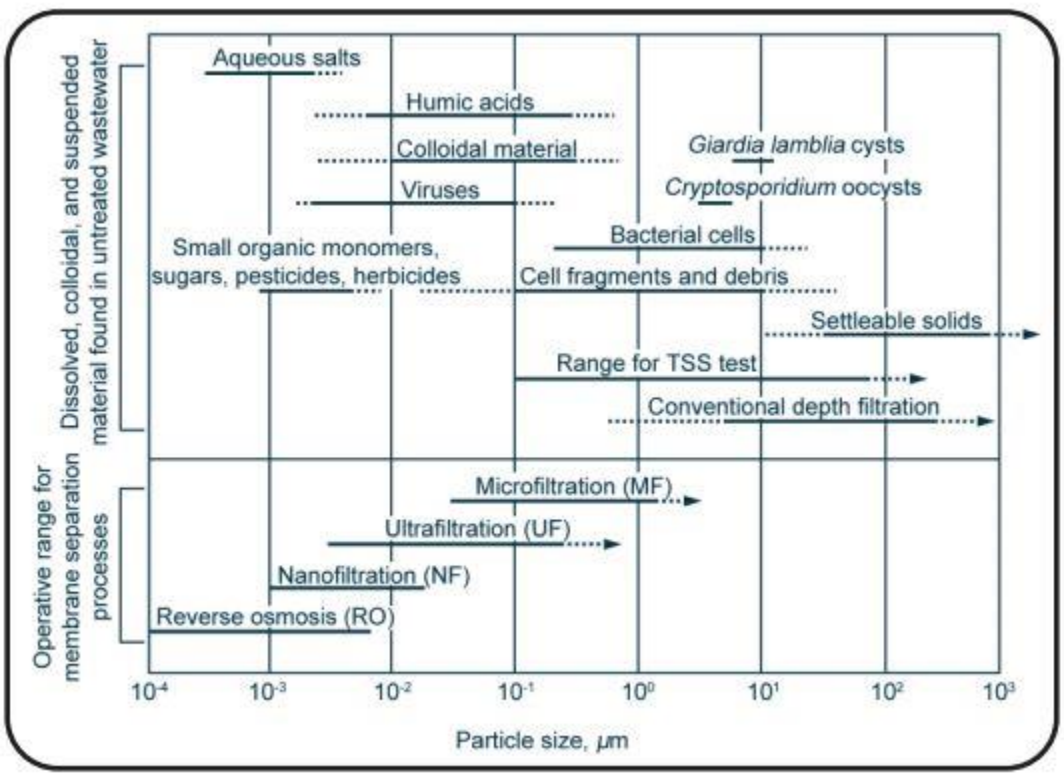


Figure 7. Range of nominal membrane pore sizes for reverse osmosis (RO), nanofiltration (NF), ultrafiltration (UF), and microfiltration (MF) (Source: Metcalf and Eddy, 2003).

Because the RO membrane has such small pores, the feed water must be pretreated adequately before being passed through it. The water can be pretreated chemically, to prevent biological growth and scaling, and physically, to remove any suspended solids.

The high-pressure feed water flows through the individual membrane elements. The spiral RO membrane element is constructed in a concentric spiral pattern that allows alternating layers of feed water and brine spacing, RO membrane, and a porous product water carrier (Fig. 8). The porous product water carrier allows the fresh water to flow into the center of the membrane element to be collected in the product water tube.

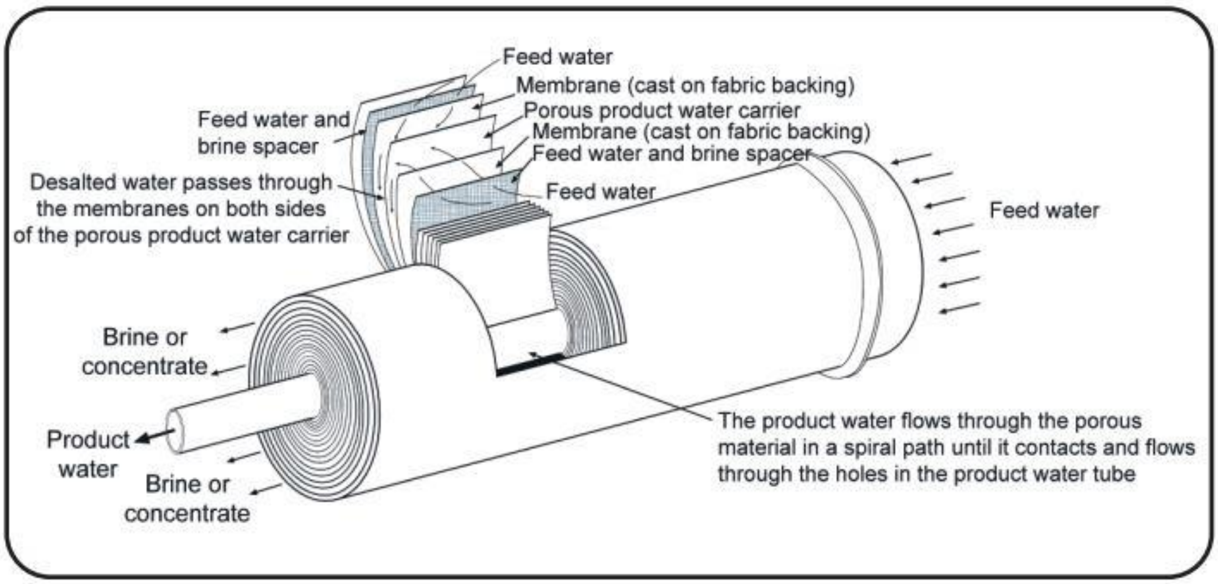


***Figure 8.* Cutaway view of a spiral reverse osmosis membrane element (Source: Buros, 1990).**

To enable each pressure vessel to treat more water, the individual membrane elements are connected in series (Fig. 9). After the water passes through the membrane elements within the pressure vessels, it goes through post treatment. Post treatment prepares the water for distribution to the public.

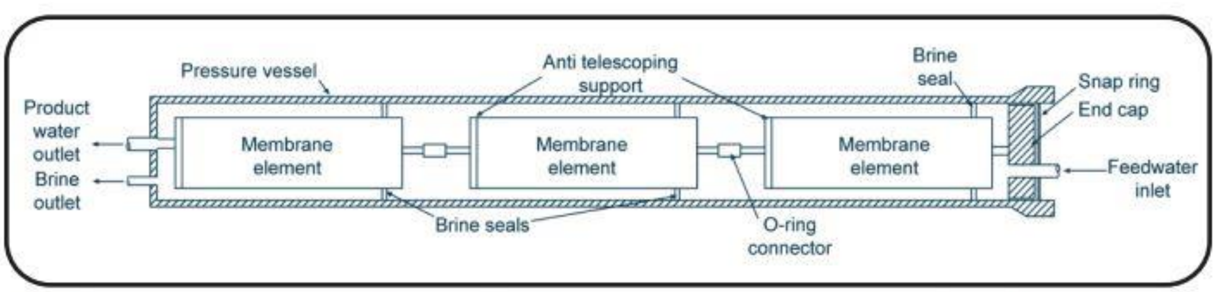


***Figure 9.* Cross section of a pressure vessel with three membrane elements (Source: Buros, 1990).**

Concentrate management options

Both thermal and membrane desalination processes produce a stream of brine water that has a high concentration of salt and other minerals or chemicals that were either removed during the desalination process or added to help pretreat the feed water. For all the processes, the brine must be disposed of in an economical and environmentally friendly way.

Options for discharging the brine include discharge into the ocean, injection through a well into a saline aquifer, and evaporation. Each option has advantages and disadvantages. In all cases, the brine water should have a minimal impact on the surrounding water bodies or aquifers. Specific considerations for the water quality include saline concentration, water temperature, dissolved oxygen concentrations, and any constituents added as pretreatment.

Que No 2. Merits and Demerits of Water Distribution System.

Ans. Methods of Setting Water Distribution System Layouts

Different methods of laying out distribution system are as follows:

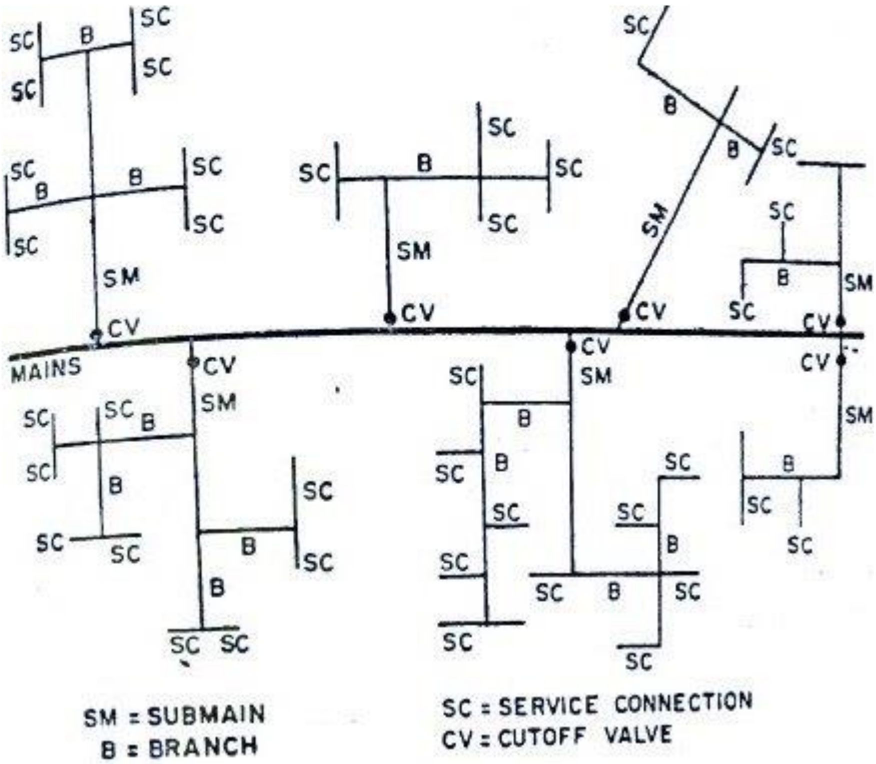
- Dead end system
- Grid iron system
- Ring system
- Radial system

<u>Dead End Water Distribution System</u>

Dead end system, the name itself defining that it contains dead ends in the pipe system. So, the water does not flow continuously in the dead-end system. In this system the whole pipe network is divided into several sub networks. Those are namely main line, sub mains, branch lines and service connections.

Firstly, one main line is laid through the center of the city or area. Sub mains are laid on both sides of the main line and then sub mains divided into branch lines from which service connections are given. At every starting point of sub main line, a cut off valve is provided to regulate the flow during repair works etc.

Overall, this network diagram will look like a tree shape, so it is also called as tree system. This type of system is used mostly for the olden cities which are built in irregular manner without any planning. Now a days, this system is not preferable.



Advantages of Dead-End System

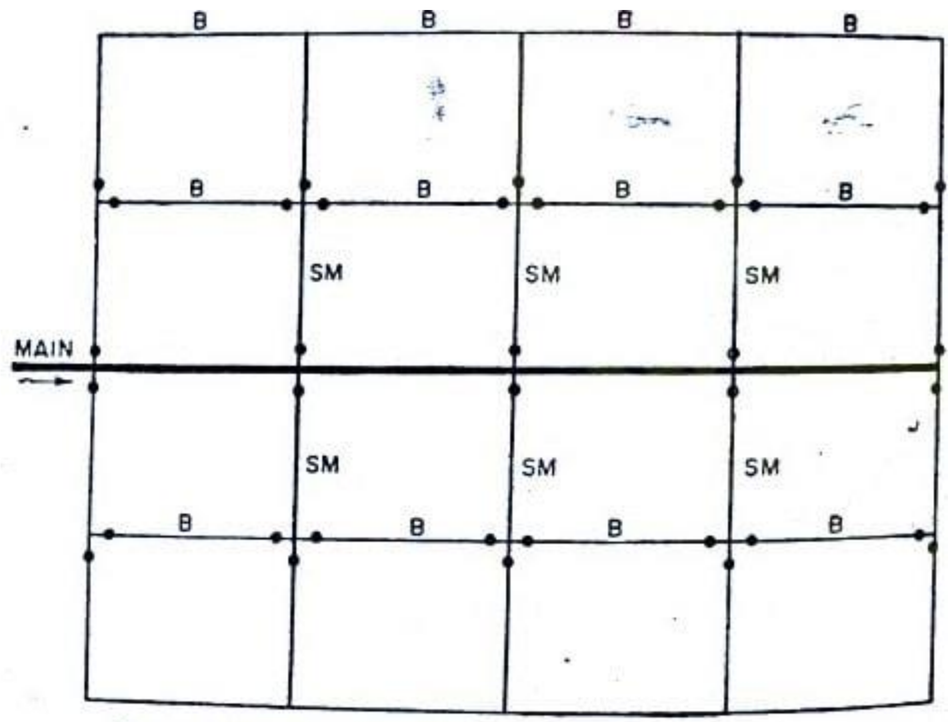
- Pipes in this network can be laid easily.
- The pressure and discharge in each pipe can be determined very easily and accurately which makes design calculations very simple.
- The diameters of pipes of main, sub mains and branches can be designed based on the required demand of population. So, cost of the project can be reduced.
- Dead end system requires less number of cutoff valves.

Disadvantages

- The pressure is not constant and is very less at remote parts.
- Because of dead ends water stagnation takes place which results in deposition of sediment. To remove this sediments, more number of scour valves are to be provided at the dead ends which increase economy.
- If there is any damage occurs in the branch line, the whole portion should be stopped to repair that which creates discomfort to the other users in that sub main line.
- In this system, Limited discharge is available for firefighting.

Grid Iron Water Distribution System

Grid iron system also contains main lines, sub mains and branch lines. But in this system dead ends are eliminated by interconnecting all the lines. Hence, the water flow continuously in this system without stagnating. So, this system is also called as interlaced system or reticulation system. It is more suitable for well-planned cities.



Advantages of Grid Iron System

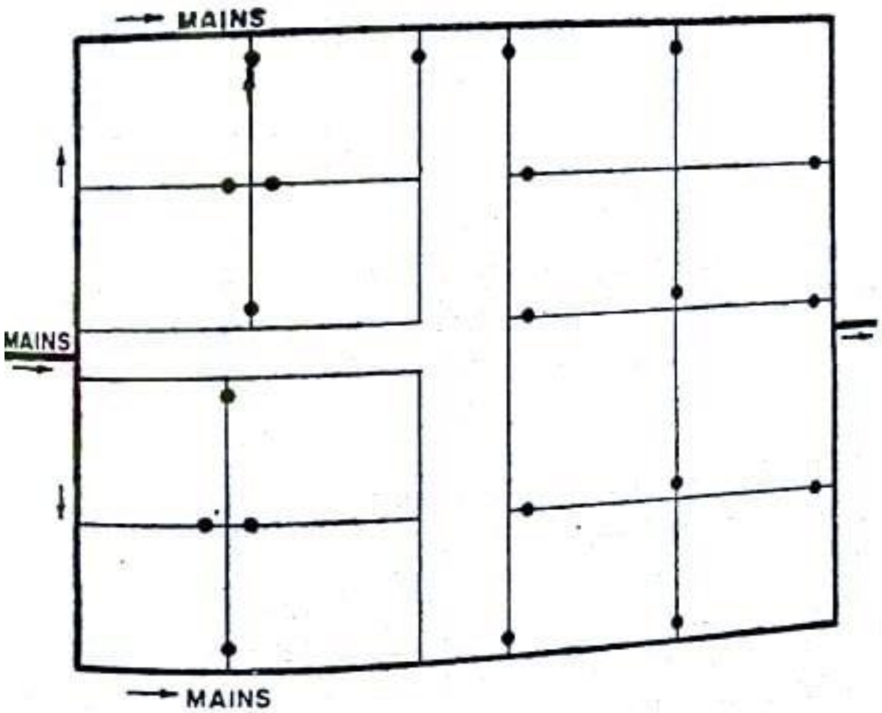
- Water will flow continuously without any dead ends or sediment deposits.
- Head loss is minimum in this case because of interconnection of pipes.
- The discharge will meet the required discharge for firefighting.
- Repair works can be easily done just by closing cutoff valve in that line which do not affect the other users.

Disadvantages

- Because of circulating flow from all directions, the pipes used in this system should be of large diameters and longer lengths.
- We cannot determine the accurate discharge, velocity or pressure in a particular pipe. So, design is difficult.
- Laying of pipes will be done by skilled workers which consume more cost.
- Cutoff valves required should be more in this system.

Ring Water Distribution System

Rain system can also be called as circular system in which the main pipeline is provided around the city or area i.e., peripherally. From this main line, the branch lines are projected perpendicularly, and they are also connected with each other. So, every street of the distributed area will get enough quantity of water. For a town with well-planned streets and roads, Circular system is more suitable.



Advantages of Ring System

- No stagnation of water
- Repair works can be done without affecting larger network.
- Large quantity of water is available for firefighting.

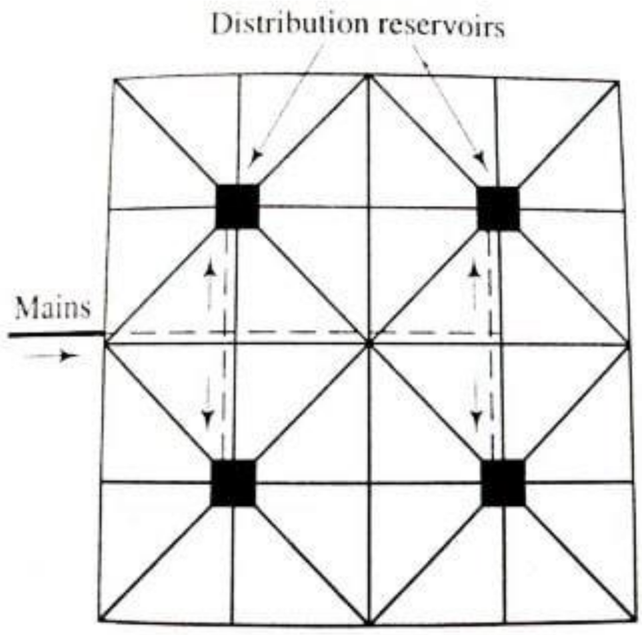
Disadvantages

- Longer length and large diameter pipes are required.
- More number of cutoff valves are necessary.
- Skilled workers are necessary while laying pipes.

Radial Water Distribution System

Radial system is quite opposite to the ring system. In this system, whole area is divided into small distribution districts or zones and an individual distribution reservoir is provided for each distribution zone. The reservoir provided is generally of elevated type. From this reservoir the pipelines are laid radially to the surrounded streets.

All distribution reservoirs relate to main line which is passing through center of the city. This type of system is suitable for areas with radially designed roads.



Advantages of Radial System

- The water distributed with high velocity and high pressure.
- Head loss is very small because of quick discharge.

Disadvantages

Cost of the project is more because of number of individual distribution reservoirs.

Recommendation for hilly areas would be **Radial water distribution** system If we've enough budget,

With this we will have high velocity and pressure with head loss as minimum and quick discharge.

Q No 3, Types of reservoirs.

Answer.

Depending upon their elevation w.r.t ground it may be classified into:
1.Surface reservoirs 2. Elevated reservoirs

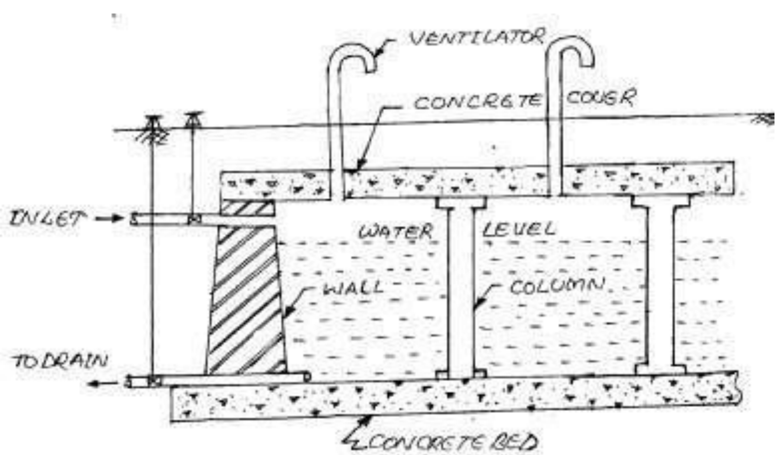
1.Surface reservoirs:

These are also called ground reservoir.

Mostly circular or rectangular tank. Underground reservoirs are preferred especially when the size is large. In case of gravity system, underground reservoirs are generally constructed on high natural grounds and are usually made of stones, bricks, plain or reinforced cement concrete.

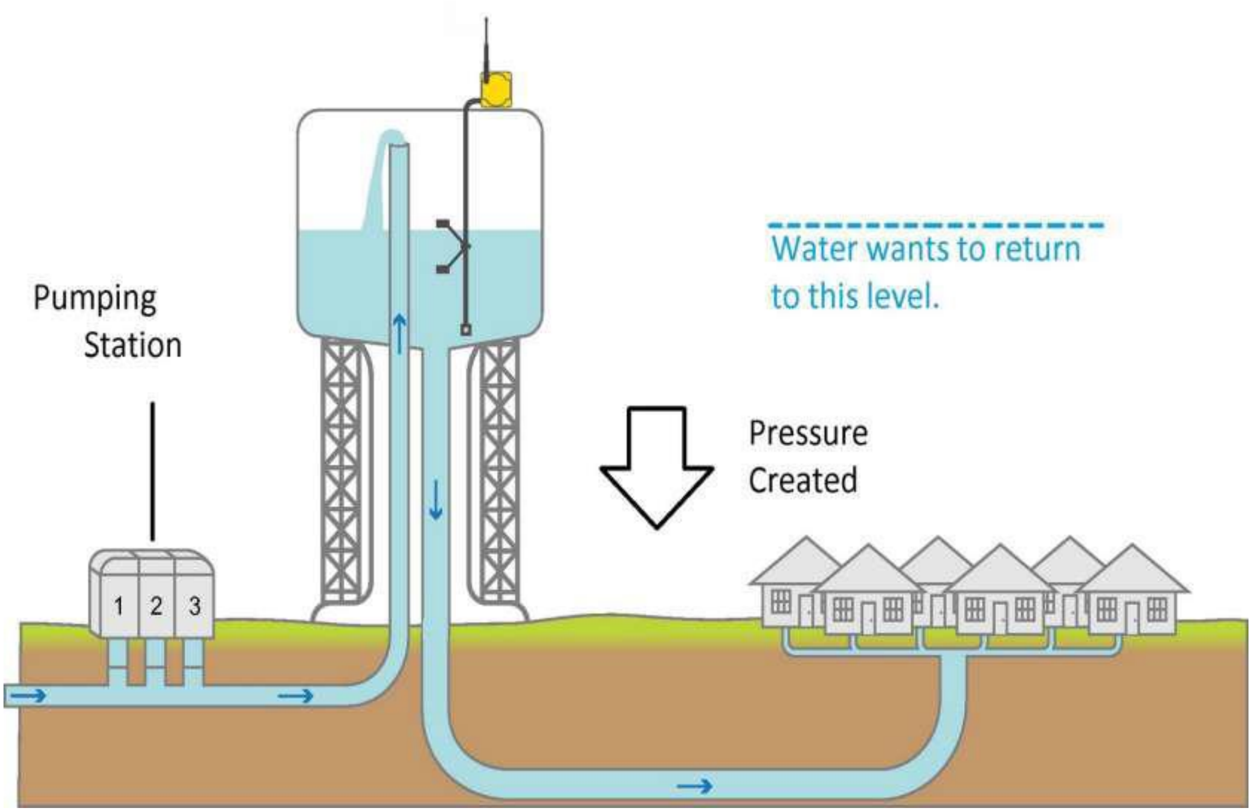
The side walls are designed to take up the pressure of the water, when the reservoir is full and the earth pressure when it is empty. The position of ground water table is also considered while designing these reservoirs. The floors of these reservoirs may be constructed with R.C.C slab or stone blocks with enough water proofing. To obtain water tightness bitumen compounds are used at all construction joints. For aeration of water and inspection, manholes, ventilation pipes and stairs are provided.

1.**Surface reservoirs:**



Elevated Storage Reservoirs:

Elevated Storage Reservoirs (ESRs) also referred to as Overhead Tanks are required at distribution areas which are not governed and controlled by the gravity system of distribution.
These are rectangular or circular in shape.
If the topography of the town is not suitable for gravity system, the elevated tank or reservoir are used to provide enough pressure head.
They are constructed where combine gravity and pumping system of water distribution is adopted.



The total storage capacity of a distribution reservoir is the summation of:
1.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).
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.
□Fire demand maybe calculated by the given formulas:

□The total reservoir storage can finally be worked out by adding all the three storages.

$$Q_F = 65\sqrt{P}(1-0.01\sqrt{P})$$

Q_F = fire demand l/s
P = population in thousands

$$Q_F = 53\sqrt{P}$$

Q_F = fire demand l/s
P = population in thousands

$$Q_F = 320 * C\sqrt{A}$$

Q_F = fire demand flow m^3/d
A = areas of all stories of the building under consideration (m^2)
C = constant depending on the type of construction;

Q No 4. Pumps usage in water supply scheme and calculation of pump curve.

Primary objective of pumping system is to:
1.Transfer liquid from source to destination
2.Circulate liquid around a system

Pumping System

- Main components of pumping systems:

1.Pumps
2.Prime movers: electric motors, diesel engines, air system
3.Piping to carry fluid
4.Valves to control flow in system
5.Other fittings, control, instrumentation

Pumping System Characteristics
Pumping systems are generally designed for:
1.Head: Sum of kinetic and potential energy of liquid expressed in unit of length (meters / feet)
2.Flow / Discharge: Quantity of water pumped per unit time. It is expressed in gallons / day, Liters / minute etc.
3.Pressure the flowing liquid / water should have enough pressure at the destination and is normally expressed in pounds per square inch (psi).

Pumping System Characteristics Head is of two types:
1) Static Head:

- Vertical distance between the source and destination.
- It is independent of flow conditions. 2) Friction head:
- Resistance to flow in pipe and fittings
- Depends on size, pipes, pipe fittings, flow rate, nature of liquid.
- Closed loop system only has friction head
- (no static head)

Pumping System Characteristics System Head is the sum of static head and friction head Static Head at any pressure is given as:

$$\text{Head (in feet)} = \frac{\text{Pressure (psi)} \times 2.31}{\text{Specific gravity}}$$

Types of Pumps

1) Positive Displacement Pumps: For each pump revolution

- Fixed amount of liquid taken from one end
- Positively discharged at another end If pipe blocked
- Pressure rises
- Can damage pump Used for pumping fluids other than water?

Types of Pumps 1) Positive Displacement Pumps: Reciprocating pump

- Displacement by reciprocation of piston plunger
- Used only for viscous fluids and oil wells Rotary pump
- Displacement by rotary action of gear, cam or vanes
- Several sub-types
- Used for special services in industry

2) Dynamic pumps:

Mode of operation

- Rotating impeller converts kinetic energy into pressure or velocity to pump the fluid Two types

- Centrifugal pumps: pumping water in industry – 75% of pumps installed
- Special effect pumps: specialized conditions

Types of Pumps 2) Dynamic pumps: Centrifugal Pumps: How it works?

- Liquid forced into impeller
- Vanes pass kinetic energy to liquid: liquid rotates and leaves impeller
- Volute casing converts kinetic energy into pressure energy

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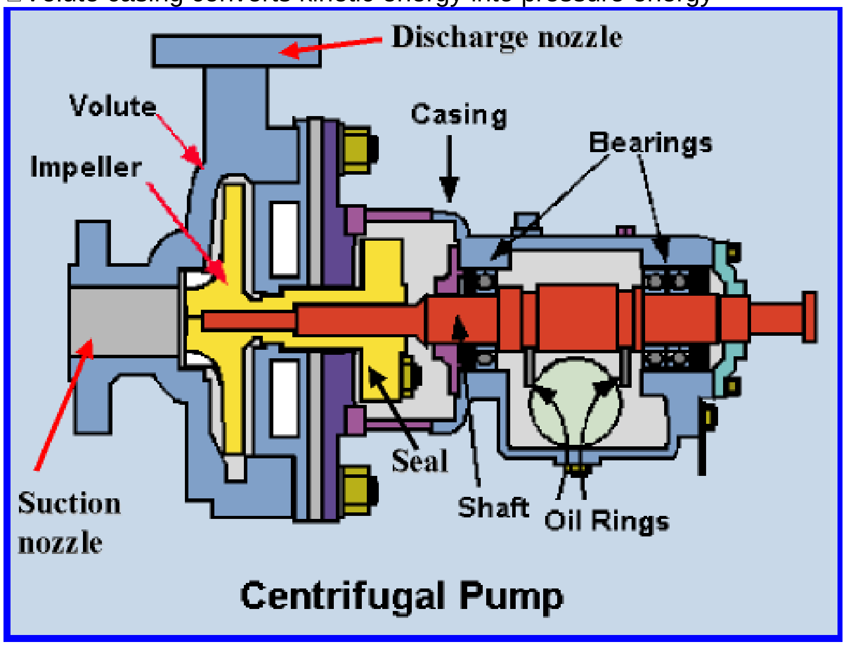

Centrifugal Pump

Types of Pumps

2) Dynamic pumps: Centrifugal Pumps: Components Impeller:

- Main rotating part that provides centrifugal acceleration to the fluid
- Number of impellers = number of pump stages
- Impeller classification: direction of flow, suction type and shape/mechanical construction Shaft:
- Transfers torque from motor to impeller during pump start up and operation

Pumps Assessment Difficulties in Pump Assessment

- Absence of pump specification data to assess pump performance
- Difficulties in flow measurement and flows are often estimated
- Improper calibration of pressure gauges & measuring instruments
- Calibration not always carried out
- Correction factors used

Pumps Assessment Energy Efficiency Opportunities

- Selecting the right pump
- Controlling the flow rate by speed variation
- Pumps in parallel to meet varying demand
- Eliminating flow control valve
- Start/stop control of pump
- Impeller trimming