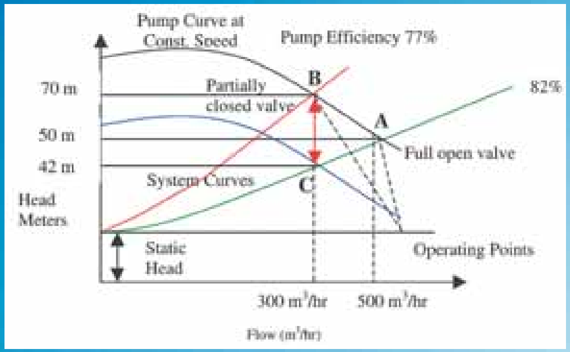
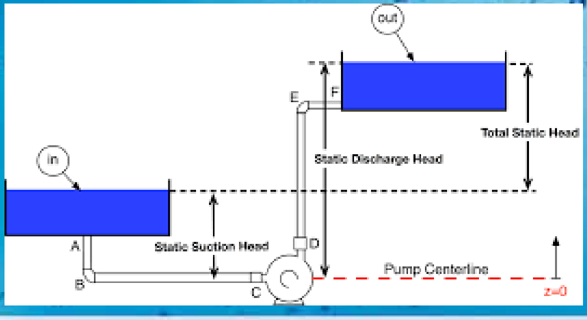


Chapter 4

Pumping System



Indian Plumbing Association

Pumps

- Introduction
- Terminology
- Classification of Pumps
- Pump Selection
- Pump Characteristics
- Hydro Pneumatic Booster Systems
- Storm Water and Drainage Pumps

Pressure, friction and flow are three important characteristics of a pump system -

Pressure is the driving force responsible for the movement of the fluid.

Friction is the force that slows down fluid particles.

Flow rate is the amount of volume that is displaced per unit time.

Introduction

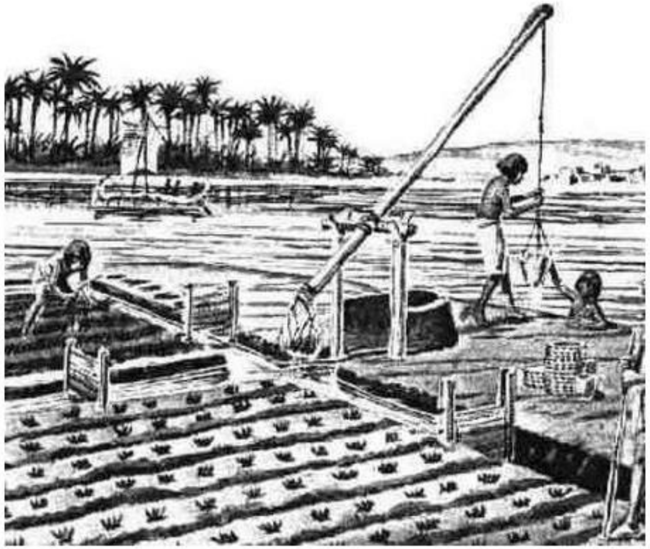
- **Simple Definition - Pump is a machine used to lift water from a lower level to a higher level.**
- The pump is a mechanical devise that raises the energy of fluids by converting kinetic energy, imparted by its prime mover, into hydraulic energy.
- Pumping is required to transfer the fluid from lower to a higher location through a pipe or a channel. This transfer of fluid against gravity requires energy which can be imparted through a pump.
- The pumping systems accounts for an estimated 30% of the electricity used in the building / industrial sector, it amounts to almost approx. 15% of the total electricity consumption of the country.
- Energy management is a concept, devised by the industry for the efficient use of energy without compromising production quality, safety and environmental standards.

The First Pumps

Pumping systems are as old as 7000B.C.

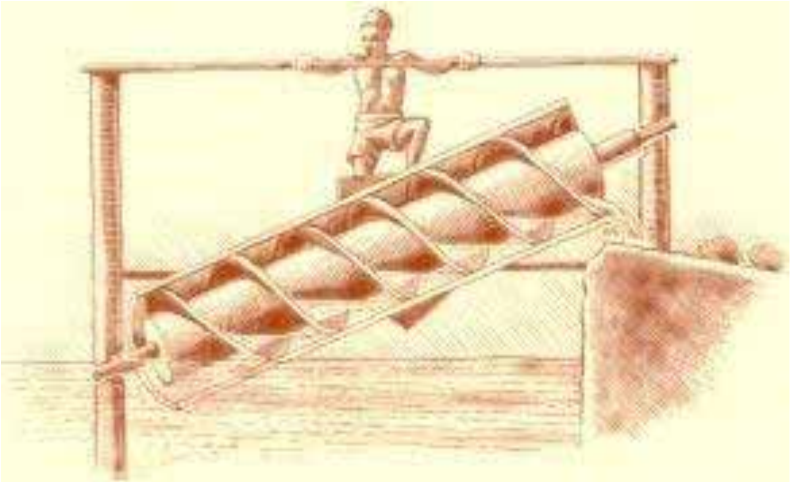
7,000 and 5,000 B.C

Shadoof by Egyptians

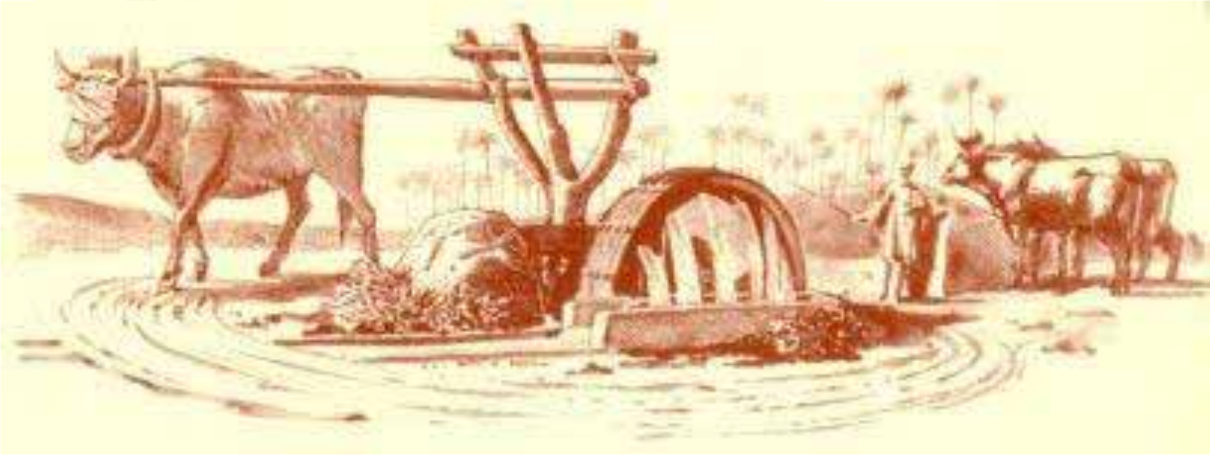


2000 B.C

Evolution of Pumping Systems



Archimedean Screw – 200 B.C



Saqia Water Wheel – 150 B.C – By Egyptians

Terminology

- **Atmospheric Pressure:**

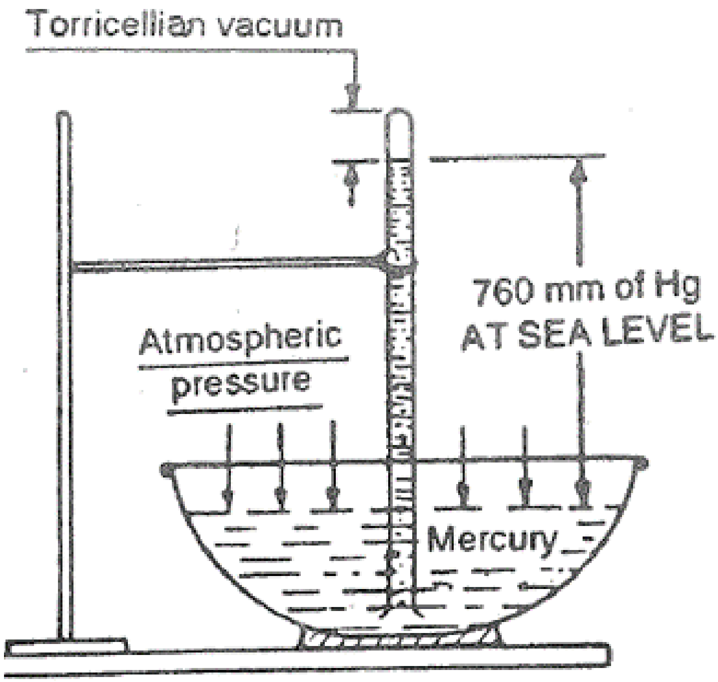
Air in the atmosphere seems weightless, but it has some weight. The atmospheric air extends above the earth surface for more than 100miles. Such a thick layer of air exerts a good deal of pressure on the earth surface. The weight of air at sea level is 14.7lbs for each square inch of area (1 Kg/ sqcm). This is termed as atmospheric pressure.

- **Absolute Pressure:**

It is the pressure above the absolute Zero. It may be above or below atmospheric pressure .

- **Barometric Pressure** :

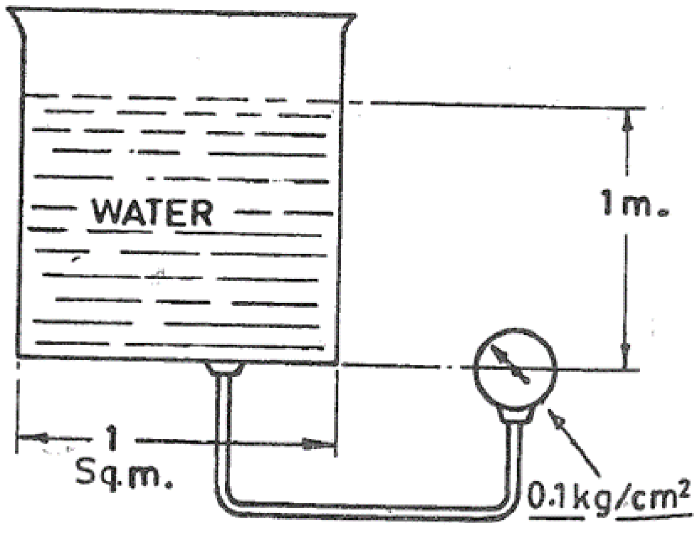
It is the atmospheric pressure at the locality being considered and varies mainly with altitude and slightly with atmospheric conditions



The atmospheric pressure balances the mercury column of 760 mm height.

Head:

Fundamentally head refers to a difference in the liquid levels at two different elevations. For instance, a difference in level between the surface of the water in a well and surface of water in a overhead tank is a head. The sketch indicates the head and corresponding pressure in pressure gauge



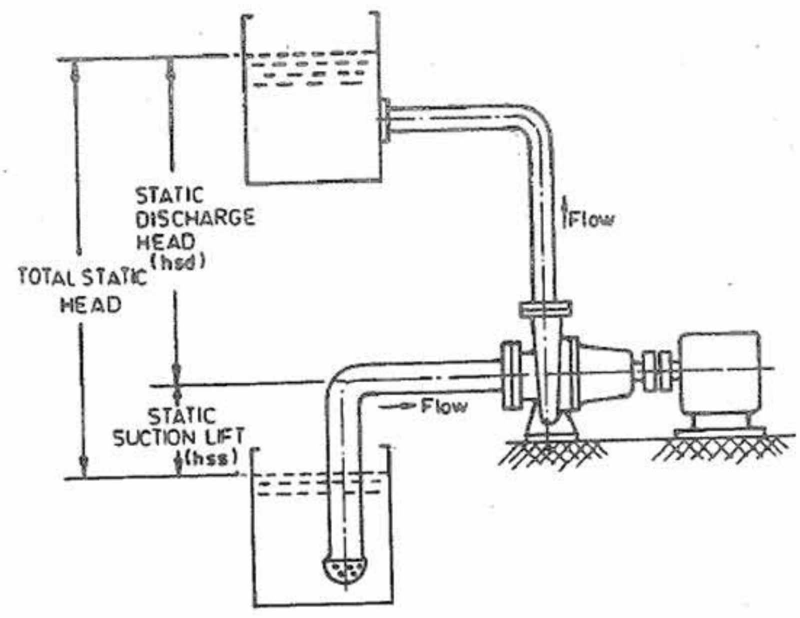
Concept of Head

Static Head:

This refers to difference in elevation. The term static is used to differentiate the head from dynamic head in which fluid in motion is involved.

Static Suction Lift:

If the suction liquid level is below the center line of the pump, it is called a Static suction lift. The term suction refers to the entry side of the pump. This is the difference in elevation between the center line of the pump and the level of the liquid in the suction well of the water storage tanks or well .



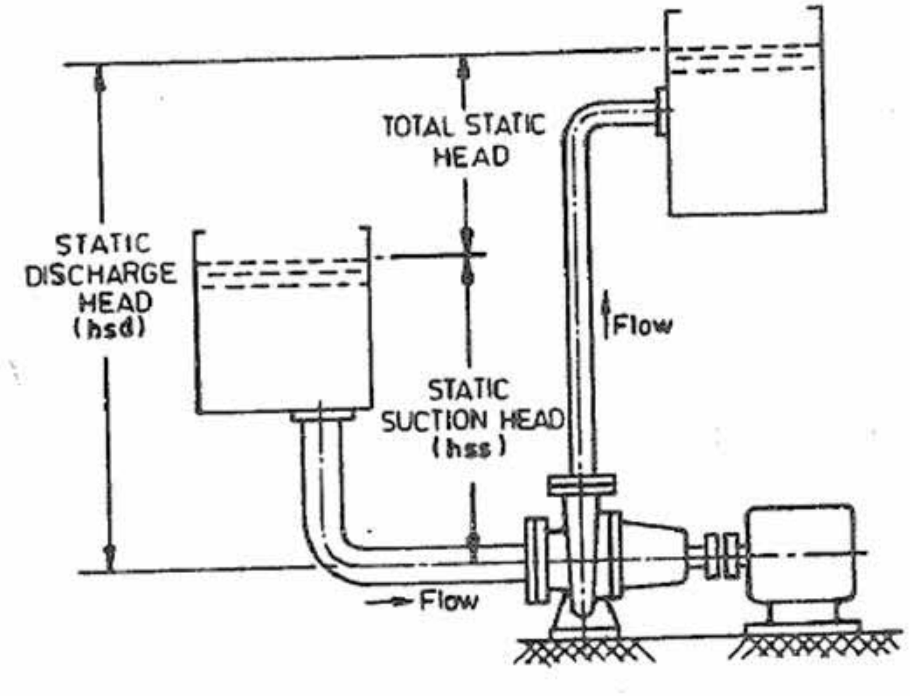
Pump With Suction Lift

Total Suction Lift:

This is the sum of static suction lift, friction and entrance losses in the suction piping. When the water is flowing through a pipe or foot valve it meets resistance by way of friction. Therefore, the energy required to lift water is more than what static lift indicates. The amount of friction can be converted into equivalent of head, and this term added to static lift, makes it total suction lift. Total suction lift as determined on test is the reading of a liquid manometer or vacuum gauge connected to the pump suction, expressed as feet or metre of liquid minus the velocity head at the point of gauge attachment.

Static Suction Head:

This is the vertical distance in feet or meter from the centerline of the pump to the suction liquid level, when the source of liquid supply is above centerline represented.



Pump With Suction Head

Total Suction Head:

This is the static suction head less friction and entrance losses in the suction piping, plus any pressure head existing on the suction supply side.

Static Discharge Head:

This is the vertical distance in feet or metre from the centerline of the pump to the discharge liquid level.

Total Discharge Head:

This is the sum of the static discharge head, friction and exit losses in the discharge piping plus the velocity head and pressure head in feet or metre at point of discharge. Total discharge head determined on test is the reading of a pressure gauge at the discharge of the pump expressed as feet or metre of liquid and corrected to pump centerline, plus the velocity head at the point of gauge attachment.

Total Static Head:

This is the vertical distance in feet or metre from suction liquid level to discharge liquid level. In other words, it is the sum of static suction lift and static discharge head.

Friction Head:

This is the equivalent head expressed as feet or metre of liquid required to overcome the friction caused by the flow through the pipe and pipe fittings. The wall of the pipe causes resistance to the flow of water. There are energy losses when water has to pass through a bend, a valve of foot valve etc. These losses are experimentally found and tabulated, or formulae are given for calculating the losses. These losses differ for different sizes , different materials, and different velocities. The losses are connected into equivalent of liquid feet or metre head.

Pressure Head:

This is the head in feet or meter of liquid in a closed vessel from which the pump takes its suction or against which the pump discharges. The suction and discharge vessel are under pressure, therefore, the pump has to work against this pressure in the discharge line over and above the static discharge head. Whereas the pressure in the suction line acts as if it was static suction head, and acts to reduce the work of the pump.

Total Dynamic Head:

This is the sum of total discharge head and total suction lift when suction lift in exists. It is the total discharge head minus the total suction head where suction head exists. Sometimes it is being referred to as T.D.H.

Velocity Head:

This is the head required to create velocity of flow in the liquid. It is equivalent head in feet or meter through which the liquid would have to fall to acquire the given velocity.

Net Positive Suction Head:

This is the total suction head of liquid determined at the suction nozzle less the vapour pressure of liquid. This term is sometimes abbreviated as N.P.S.H. The NPSH Value of a Pump is the Minimum absolute Pressure that has to be present at the suction of the pump to avoid cavitation. NPSH is always measured in meters or feet. When the flow increases, the NPSH values increases.

Capacity of pump

Capacity (Q) means the flow rate with which the liquid is moved or pushed by the pump to the desired point in the process. It is commonly measured in either Litres per minute (LPM) or cubic meters per hr (cum/hr)

$$Q = A \times V$$

Where –

Q is Capacity / flow rate in cum/sec

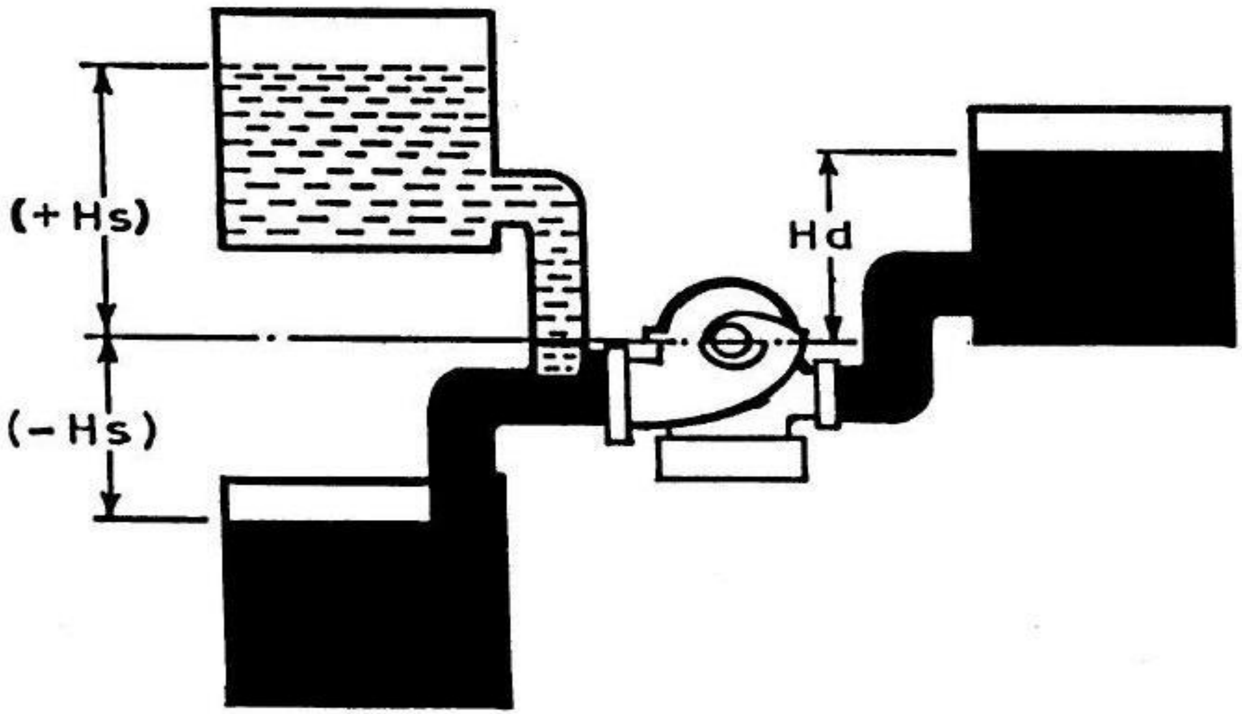
V is velocity in m/sec

A is area of pipe in sq. m

-

TOTAL HEAD OF PUMP

Total Head = Hsuction + Hdischarge + Hlosses



The Head "H" of a pump is the useful mechanical energy transmitted by the pump to the product, related to weight of the product, expressed in "m".

PRESSURE

Pressure to head conversion formula

$$\text{Head in m} = \frac{\text{Pressure (Kg/cm}^2\text{) x 10}}{\text{Specific gravity}}$$

A given centrifugal pump with a given impeller diameter and speed will raise a liquid to a certain height regardless of the weight of the liquid.

Brake KW Calculation

$$Bkw = \frac{\text{Sp. Gravity x Capacity x Head}}{\text{367 x Efficiency}}$$

$$= \frac{\rho \times Q \times H}{367 \times \eta}$$

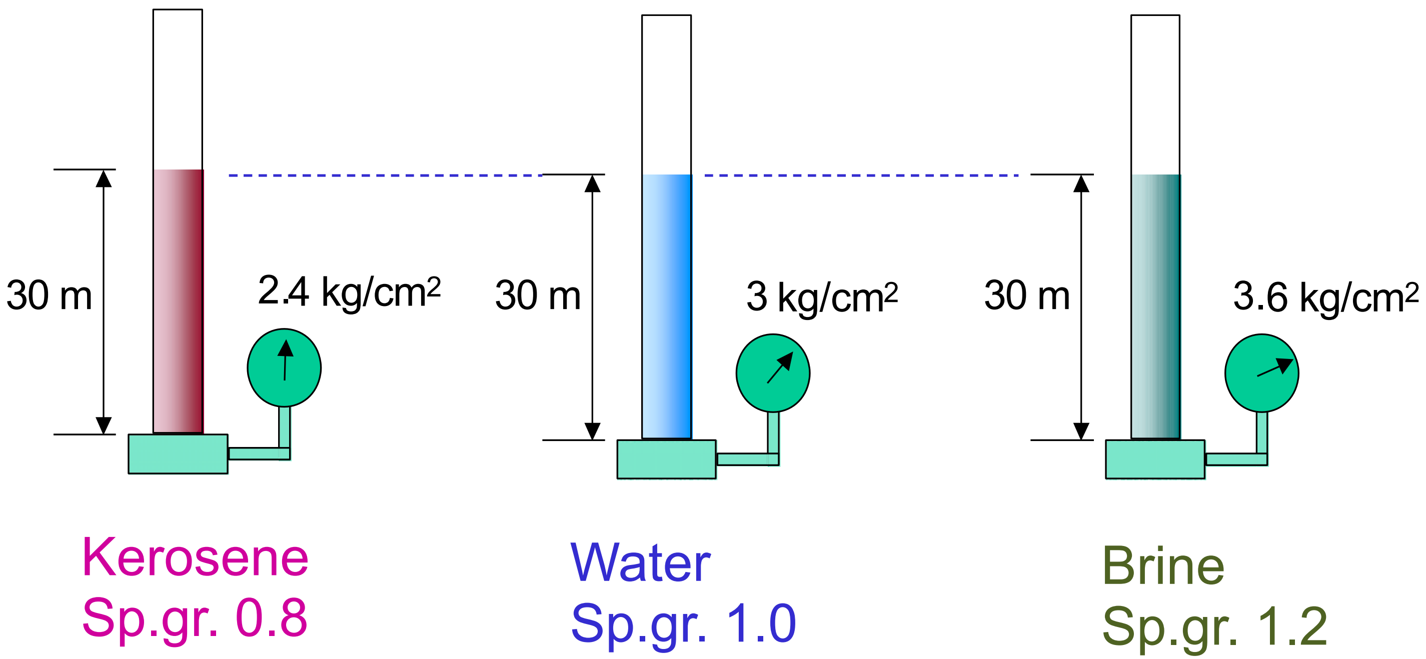
Q = Capacity in M^3/Hr

H = Head in Metres

ρ = Specific Gravity

η = Efficiency

The relationship of pressure and head



H (mts) = P * 10/sg

Classification of Pumps

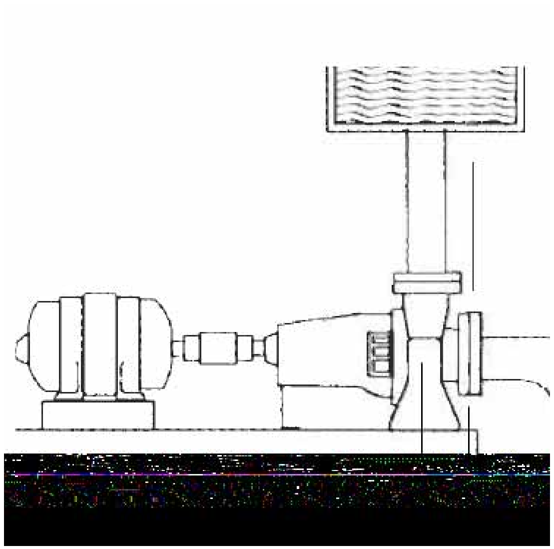
- Centrifugal pumps - High discharge and Medium Head
- Centripetal pumps - Low discharge and High Head
- Reciprocating pumps - Low discharge and High Head
- Gear / Screw pumps - Handling sludge / Oil
- Air Operated - Corrosive chemicals Diaphragm Pumps

Basic Parameters Required for Choosing Centrifugal Pumps

- Liquid to be handled
- Flow rate in Cu.m/hr / LPM / LPH
- The total head in Mtrs
- Specific gravity
- Viscosity
- Temperature

Net Positive Suction Head Required

NPSHr



It is the energy in the liquid required to overcome the friction losses from the suction nozzle to the eye of the impeller without causing vaporization.

Remember :

• NPHSr is a characteristic of the pump and is indicated on the pump's curve.

•It varies by design, size, and the operating conditions.

• An easy way to understand NPSHr is to call it the minimum suction pressure necessary to keep the pumped fluid in a liquid state.

•According to the Standards of the Hydraulic Institute, a suction lift test is performed on the pump and the pressure in the suction vessel is lowered to the point where the pump suffers a 3% loss in total head. This point is called the **NPSHr** of the pump.

Net Positive Suction Head Available

NPSHa

This is the energy in the fluid at the suction connection of the pump over and above the liquid's vapor pressure.

It is a characteristic of the system.

Remember :

NPSHa only deals with the suction side of the pump.

NPSHa and NPSHr

During pump operation,

NPSHa should be always greater than the NPSHr

$$NPSHa > NPSHr$$

As a general guide the **NPSHa** should be a minimum 10% or 1 meter above the **NPSHr**, whichever is greater.

NPSHa is in system which user want pump for.

Therefore you have to calculate it

HOW ?

Formula of NPSHa is….

NPSHa = Ha +/- Hs - Hvp - Hf

Where,

NPHSa is Net Positive Suction Head Available

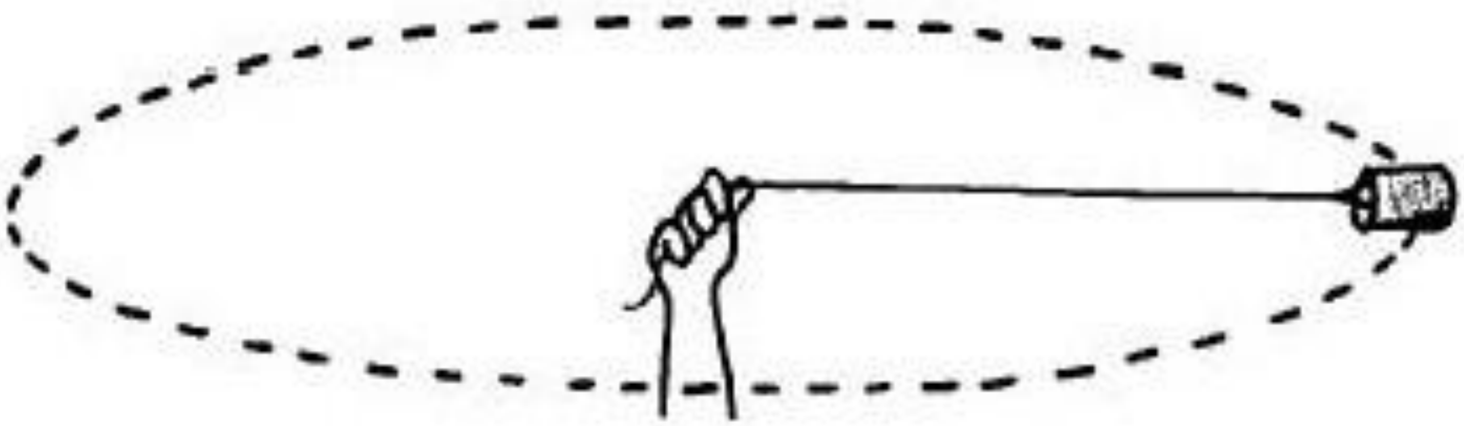
Ha is pressure head (i.e. Barometric pressure of the suction vessel converted to head)

Hs is Static suction head (i.e. the vertical distance between the eye of the first stage impeller centerline and the suction liquid level)

Hvp is Vapour pressure head (i.e. vapour pressure of the liquid at its maximum pumping temperature converted to head)

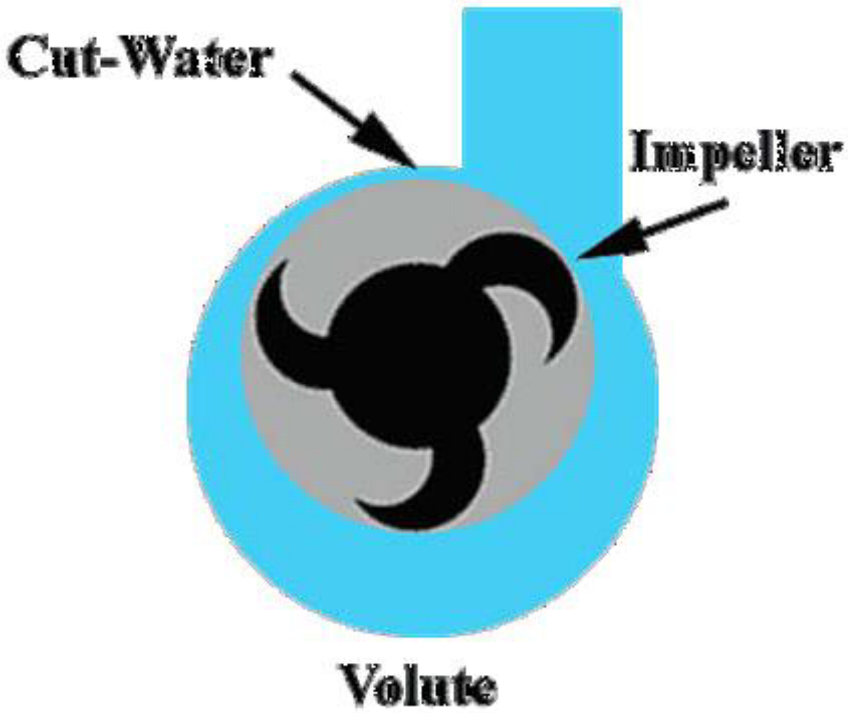
Hf is Friction head (i.e. friction and entrance pressure losses on the suction side converted to head)

Centrifugal Force



- A pail of water swinging in a circle
- centrifugal force holds the water in the pale
- A hole is bored at the bottom of the pale
- Water will be thrown out
- The distance the water traverses and volume that flows out depends upon the velocity of the rotating pale.

Principle of Centrifugal Pump

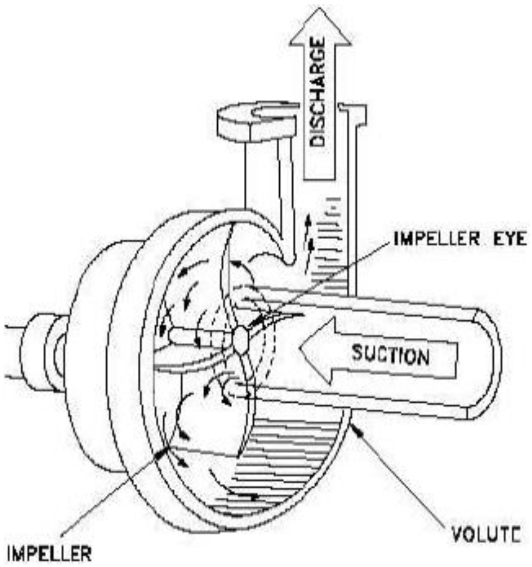


The centrifugal Pump has an impeller with radial vanes which rotate, draw water in to the centre of the pump and discharge it by centrifugal force.

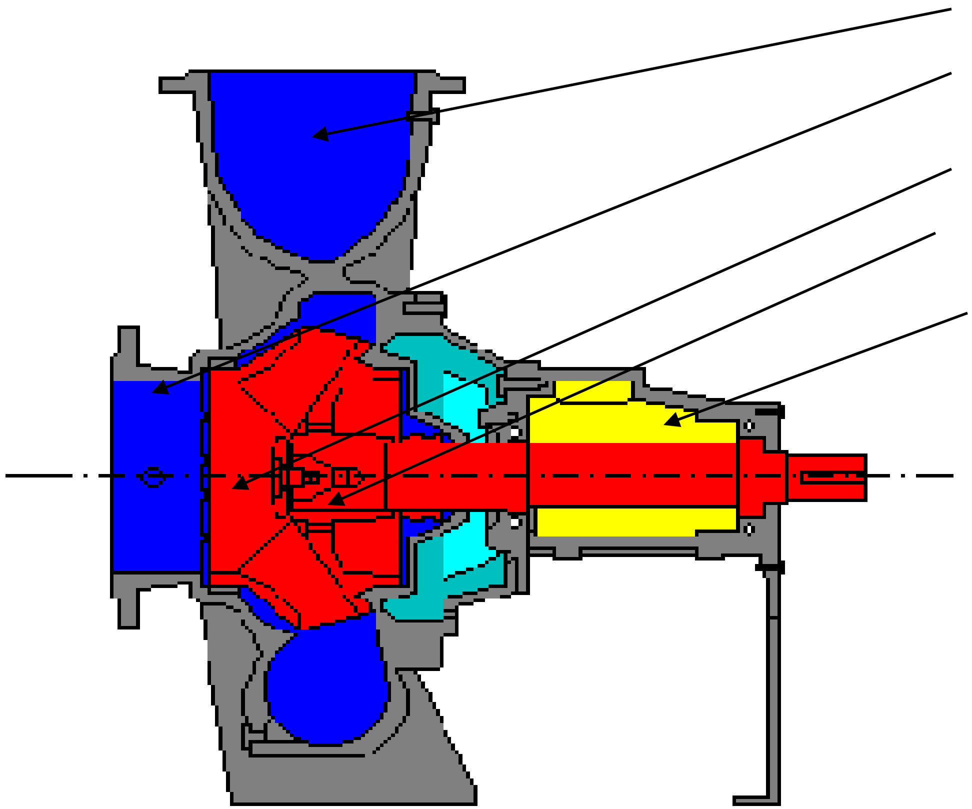
Pump Basics

- The Centrifugal Pumps, which is one of the type of roto dynamic pump commonly used.

- The centrifugal Pump has an impeller with radial vanes which rotate, draw water in to the Centre of the pump and discharge it by centrifugal force.



Parts in the Centrifugal Pumps



Centrifugal pumps are further classified :–

Based on Suction Type

- Single-suction: Liquid inlet on one side.
- Double-suction: Liquid inlet to the impeller symmetrically from both sides.

Based on Mechanical Construction

- Closed: Shrouds or sidewall enclosing the vanes.
- Open: No shrouds or wall to enclose the vanes.
- Semi-open or vortex type.

Types of Pumps – On Mounting

- Depending on the mounting of Motor or prime Mover.

- Vertical

- Horizontal

Types of Pumps - on mounting of Pump/Motor

- Surface Mounted

- Submersible

Types of Pumps – On Coupling

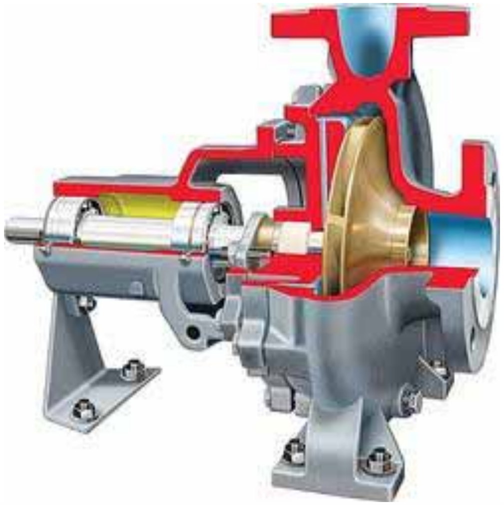
- Depending on the way they are coupled or driven by prime mover

- Coupled

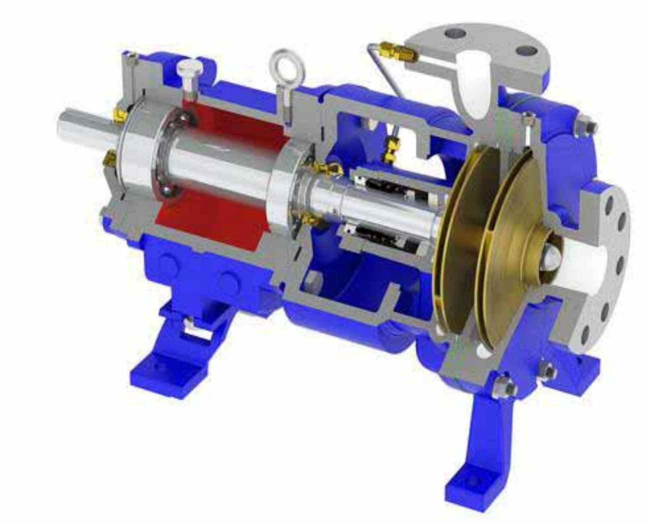
- Monoblock

Types of Pumps – On Staging

- Single Stage Pumps



- Multistage Pumps



Types of Pumps – On Suction & Discharge

Depending on the orientation of suction and discharge ;

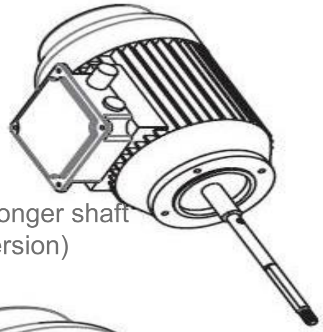
- In Line

- Side Suction Top Discharge

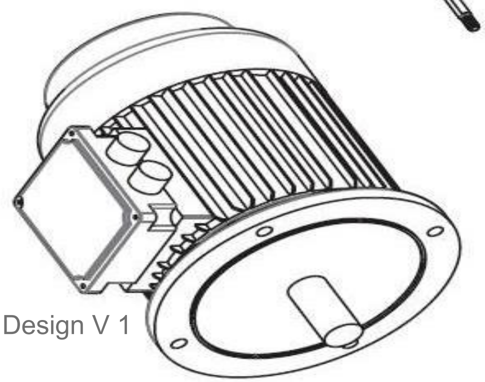
Prime Mover

- Prime movers are power transmission devices to impel / propel the pump
- All pumps require a prime mover which is device that rotates the impellers mounted on shaft.
- The type of prime movers used in pump applications are –
  1. Electric Motors – Induction Motors
  2. Diesel Engines
  3. Steam / Gas or Hydraulic Turbines
  4. Steam Engines

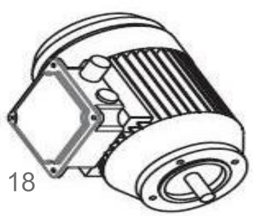
Electric Motors



Motor with longer shaft
(VM Version)



Design V 1



Design V 18

- Motors are the prime movers to the pump.
- They are classified based on the mounting such as Horizontal/ Vertical.
- They are further divided in to normal shaft or extended shaft on how they are used in Pumps.
- Depending upon the usage they are classified as S1,S2,S3 etc.

Selection of Motors for Pumps

- Motors to have only 10 – 15% excess power over pump's requirement to run on optimum efficiency.
- Motor speeds to match the manufacturer's choice to have better efficiency of the pump.
- Choose Energy Efficient Motor in general and it is most preferred when load is highly fluctuating like Boiler feed, Reverse Osmosis System, Water Treatment, Cooling Water Systems.

Reason for Excess Power Consumption

- Wrong selection on type of pump
- Over designed / Under designed pump
- Improper layout
- Old inefficient pump
- Multiple smaller size pumps
- Ad-hoc decisions taken during break down.

Improving the Efficiency of Motor

- Reduction of Iron losses achieved by low loss magnetic material or reduced flux density.
- Reduction of Copper losses achieved by increased copper section and consequently increasing the core length.
- Maintaining uniform low air gap between stator and rotor to reduce the slip.
- Reducing weight and dimension of the fan to reduce windage loss.

Effect of Rewinding Motor

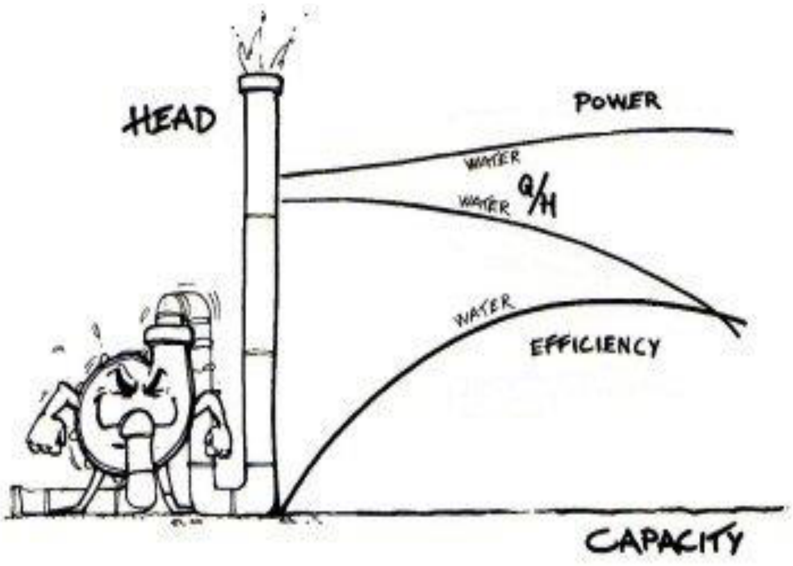
- Rewinding reduces efficiency.
- More no of rewinding reduces efficiency drastically even to the tune of 10% of the original efficiency.
- It is always better to change to new motor to save on loss of efficiency thereby increasing the energy cost.
- It would be better to replace with high efficiency motor, cost of which would be paid back by the cost of energy saved over a period of time.

Starters

- Direct On Line - DOL
- Star- Delta
- VFD starter
- Soft starters

Pump Performance Curves

- The Head – flow curve.
- The Efficiency curve
- The Energy curve
- NPSH Curve



The Head-Flow Curve

The pump companies develop their curves using head in meters (H). They specify the pumps only in height (H) and not in pressure (Bar)

The reason

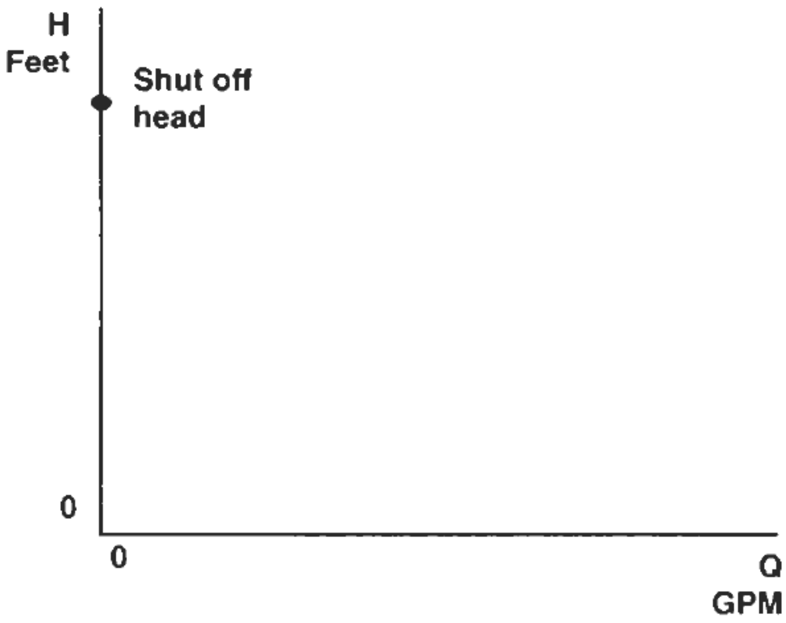
- When the companies manufacture pump they do not know the liquid that the pump will be pumping,
- But they know the elevation to which pump can raise liquid.
- By knowing the Head, Pressure could be calculated using following formula.

$$P_{(bar)} = \frac{\text{Head (mtr) x Specific gr}}{10,2}$$

The Head-Flow Curve

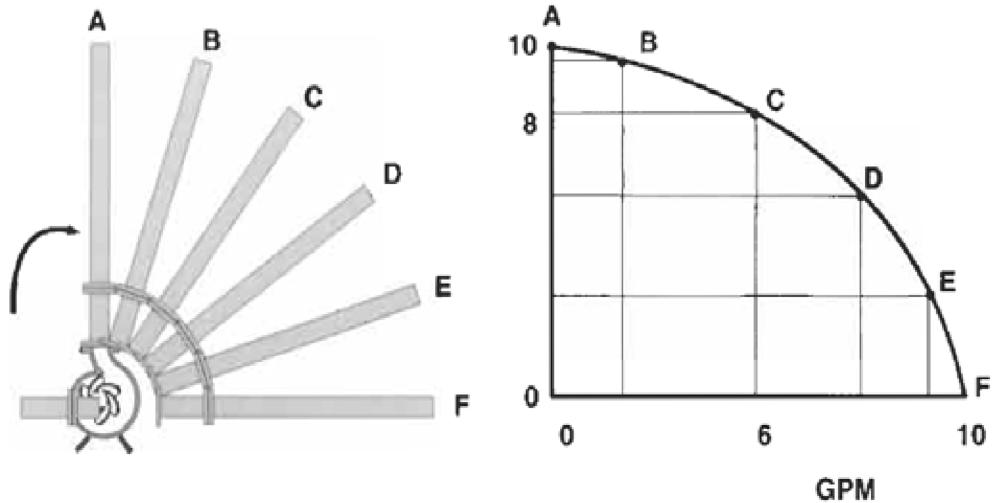
The matrix of the pump curve graph is the same as the mathematical ‘x-y’ graph.

- On the horizontal line – The flow is shown normally in m3/hr or lpm or lps
- The vertical line -The head in feet or meters.



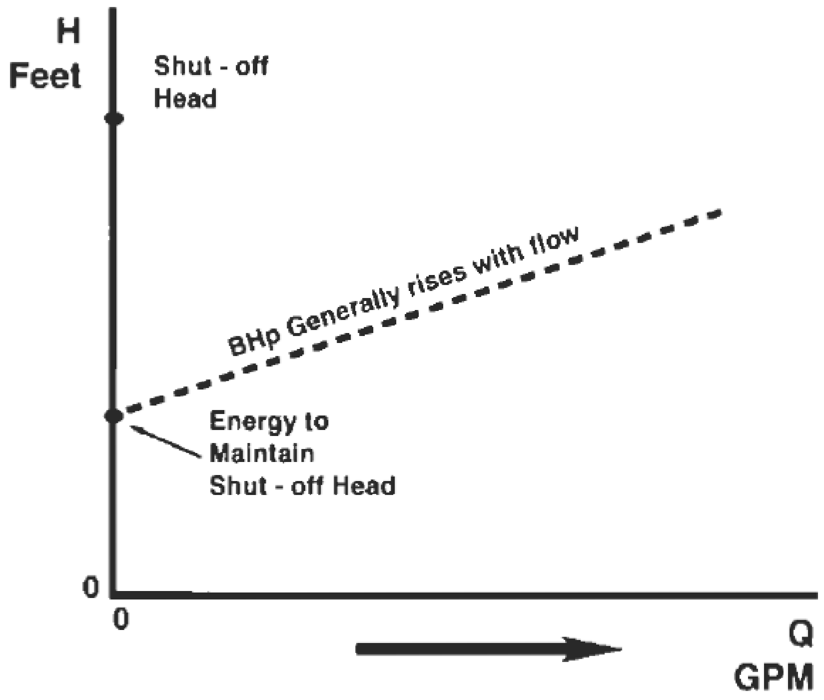
The Head-Flow Curve

The pump can elevate a liquid in a vertical tube up to a point where the weight of the liquid and gravity will permit no more elevation. This point on the pump curve would be the ‘**shut-off head**’.



Once again, imagine starting a pump and raising the fluid in a vertical tube to the point of maximum elevation. On the curve this would be maximum head at zero flow. Now, rotate the running pump on its centerline 90°, until the vertical tube is now in a horizontal position.

The Energy - BHp Curve



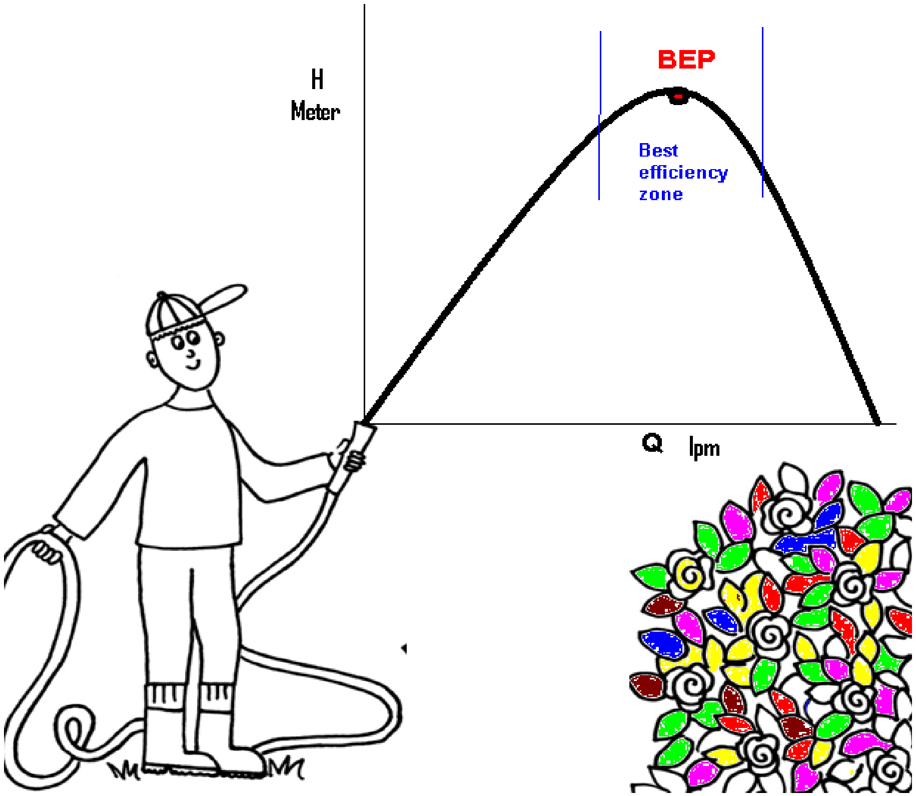
The brake horsepower (BHp) is the energy required by the pump.

Consider the following:
The pump consumes a certain quantity of energy just to maintain shut-off head.

Then, as flow begins and increases, the horsepower consumption normally increases.

(On certain specific duty pumps, the BHp may remain mostly flat or even fall with an increase in flow.)

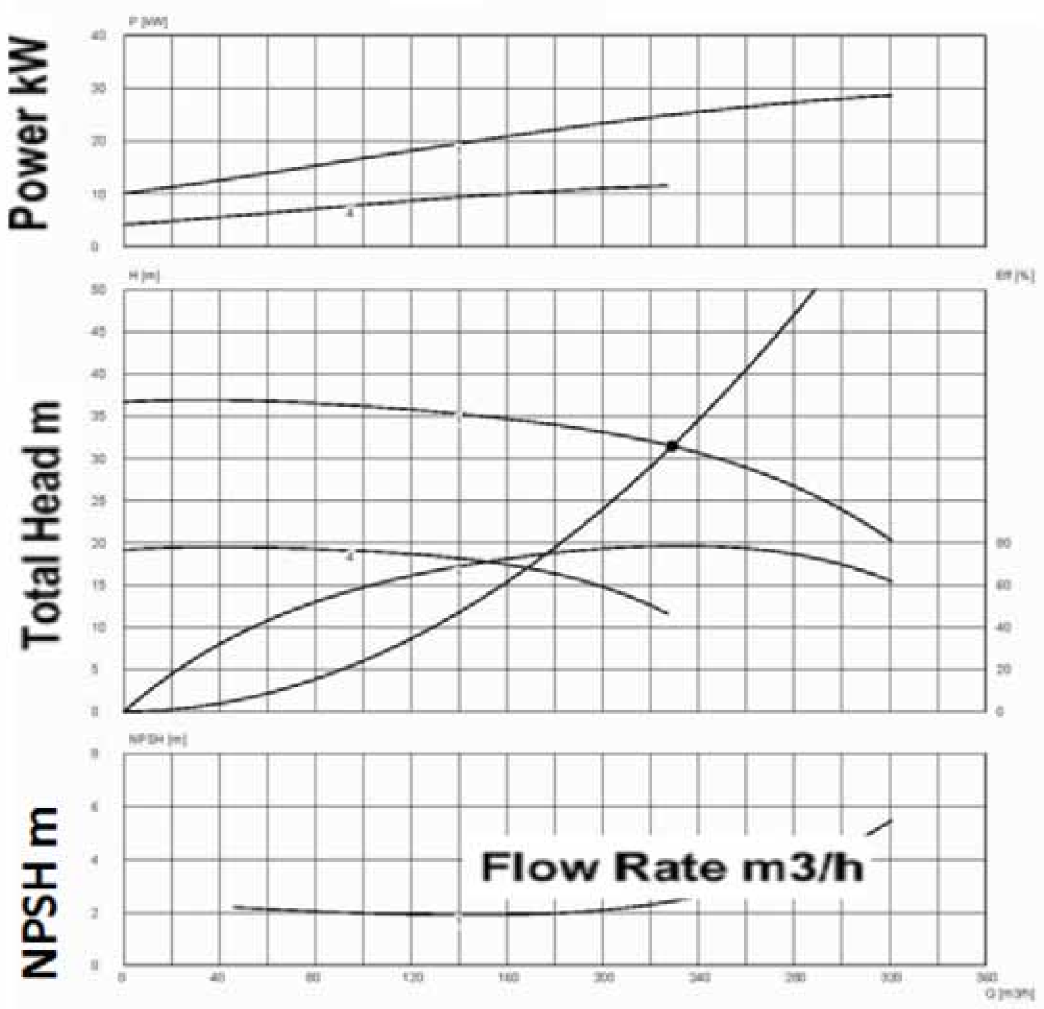
The Pump Efficiency Curve



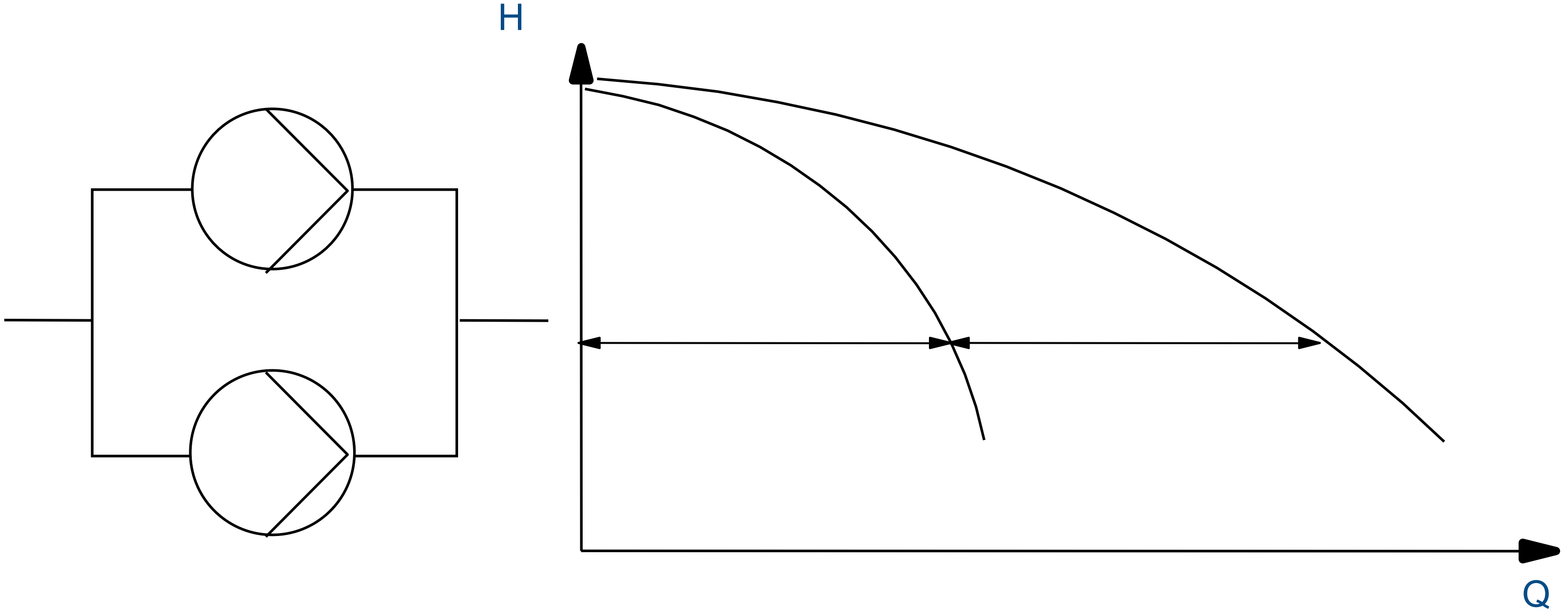
Imagine a small pump connected to a garden hose squirting a stream of water across the lawn.

- Direct the flow from the hose up into the air at about a 45-deg angle
- The stream of water would attain a specific height into the air and a specific distance.
- The elevation that attains the best distance, when plotted onto the pump curve, is called Best Efficiency Point (BEP)
- The efficiency curve of a pump is seen as the trajectory or arc of a stream of water.

Typical Pump Characteristic Curves



Parallel Operation of Pumps



Theoretic:

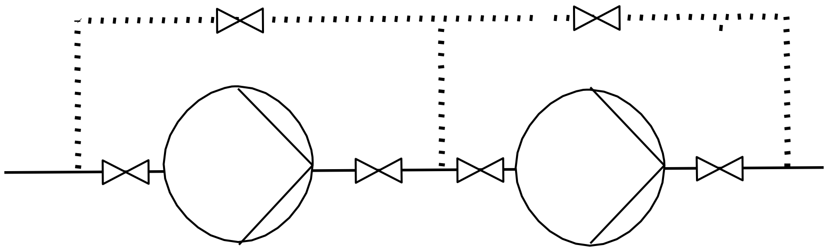
Double flow **[2 x Q]**

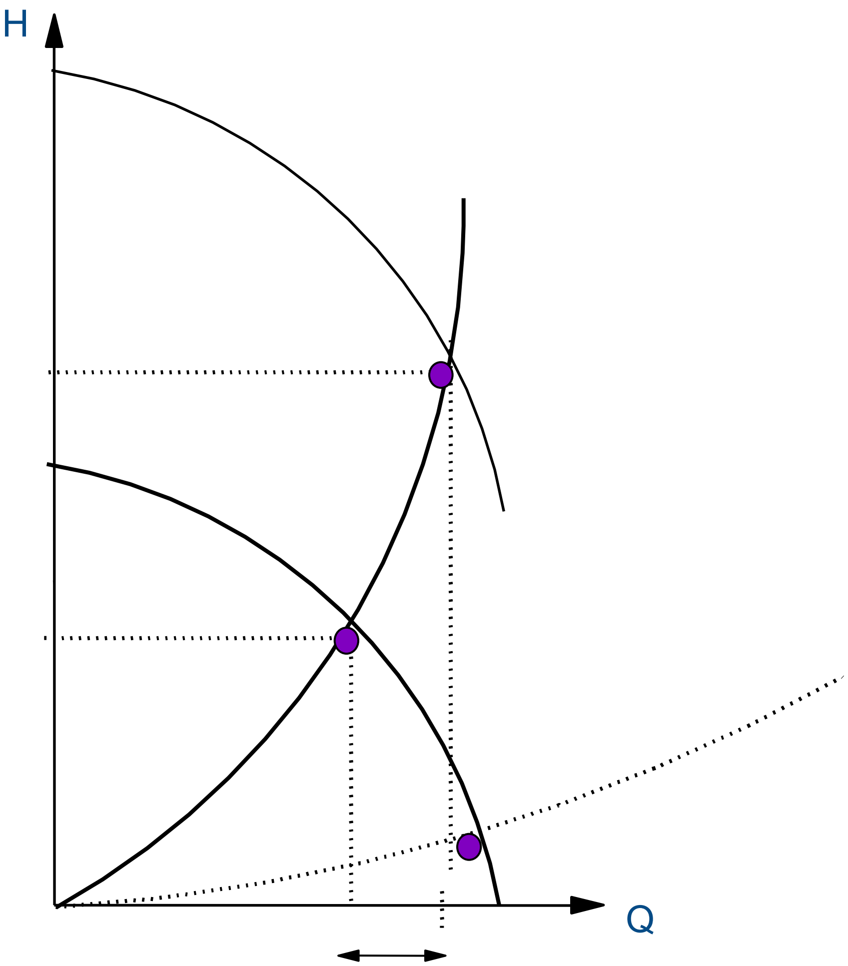
Same head **[1 x H]**

Benefits of pumps in parallel

- Improved operating economy
  - Only the required number of pumps in operation
- High efficiency
  - Each pump runs at high point of efficiency
  - Low power consumption
- Reliability
  - Redundancy
  - Service
  - Pump failure
- Wide performance range
- Improved adaptation of duty point
  - Parallel operation improves adaptation to varying demands

Series operation of Pumps





Theoretic:

Double head [2 x H]

Same flow [1 x Q]

Hydropneumatic Boosters Methods of Boosting, Methods of Distribution

Main Purpose of a Booster Set

- Boosting a sufficient amount of water against minimum required pressure, keeping the water quality at the highest level

Hydro Vs Overhead Tank……General issues

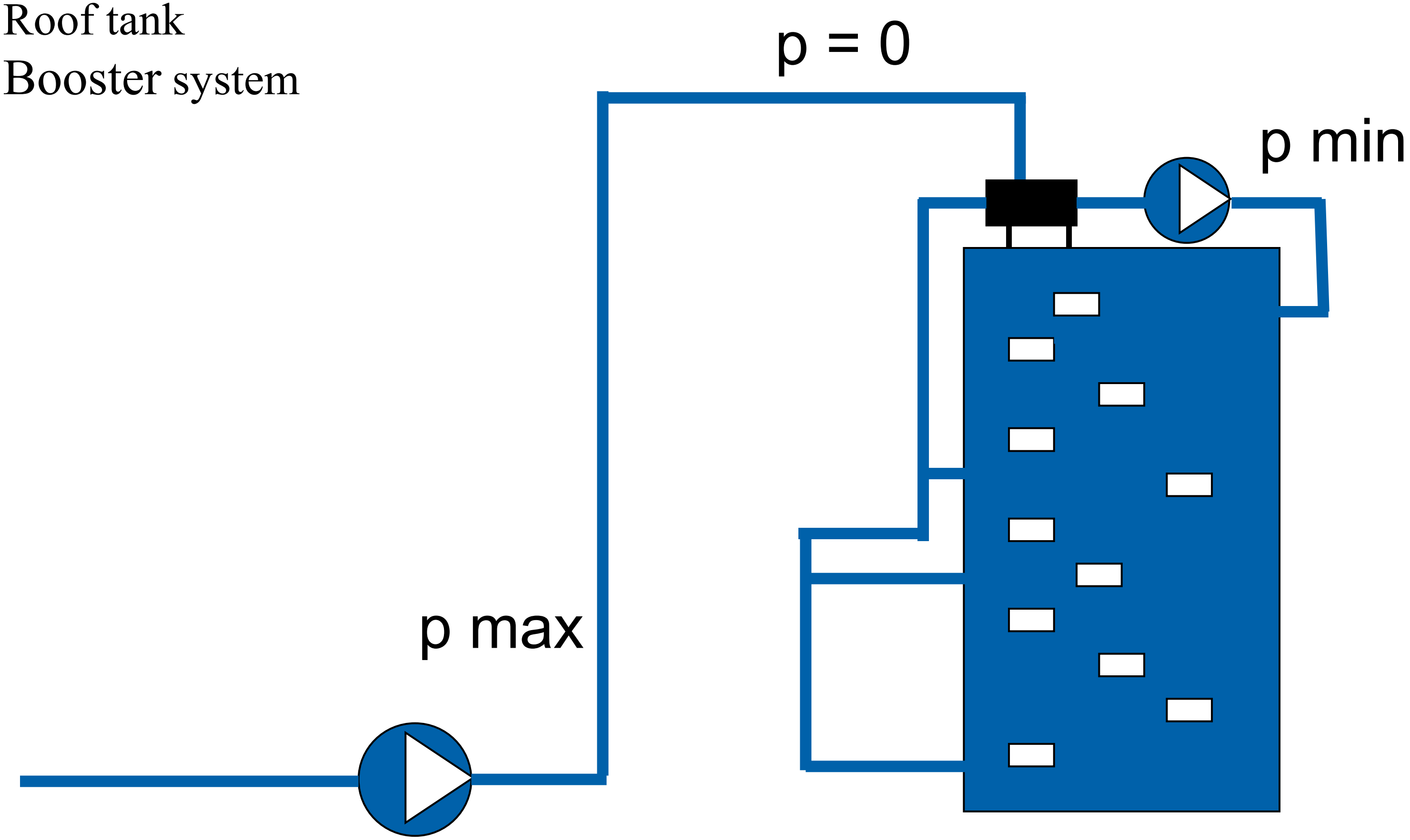
- Maintenance could be a problem...
- No water in case of power failure…
- Systems are costly compared to overhead tanks…
- Too advanced systems and it could be difficult to run these systems…
- These systems are useful for only Hotels…
- Why should builder pay money unnecessarily on these systems when they do not get any returns…

What are the options if overhead tank is still there

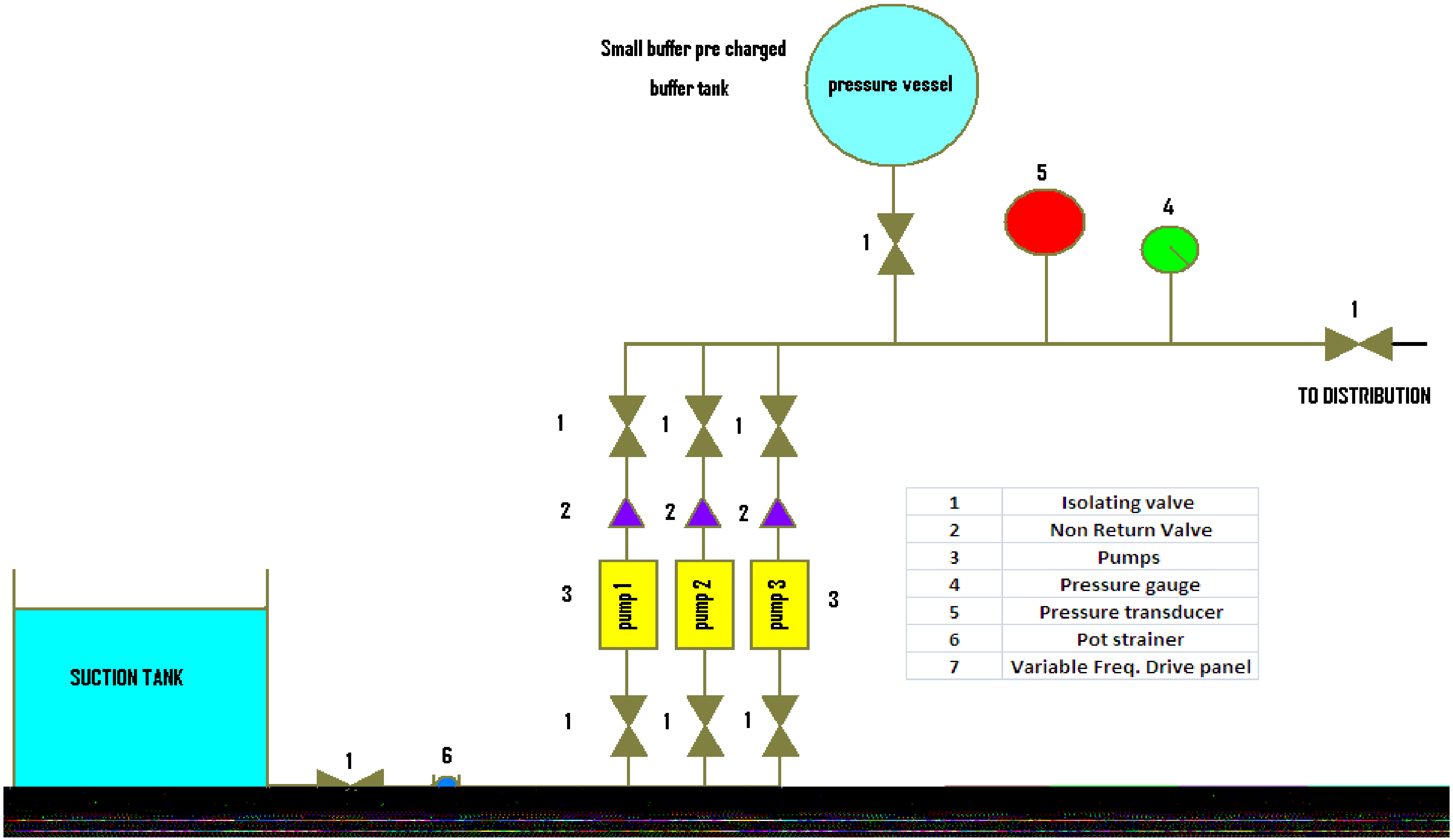
- Small booster for top floors
- Pressure reducing valves for other floors
- Control the roof tank level with control

Piping layout (Booster with O/H Tank)

- Roof tank
- Booster system



Schematic Diagram of Hydro-pneumatic Systems



1	Isolating valve
2	Non Return Valve
3	Pumps
4	Pressure gauge
5	Pressure transducer
6	Pot strainer
7	Variable Freq. Drive panel

Hydro-Unit Main Components

- **Pumps**
- Non-return valves
- Shut-off valves
- Pressure gauge
- Control panel
- Headers
- Pressure tank
- Control device

high efficiency
stainless steel

Hydro-Unit Controllers

The two types of the systems available in the market are:

1. Booster sets with constant or fixed speed
2. Booster sets with variable speed

Innovative system

1. Booster sets with jockey pump

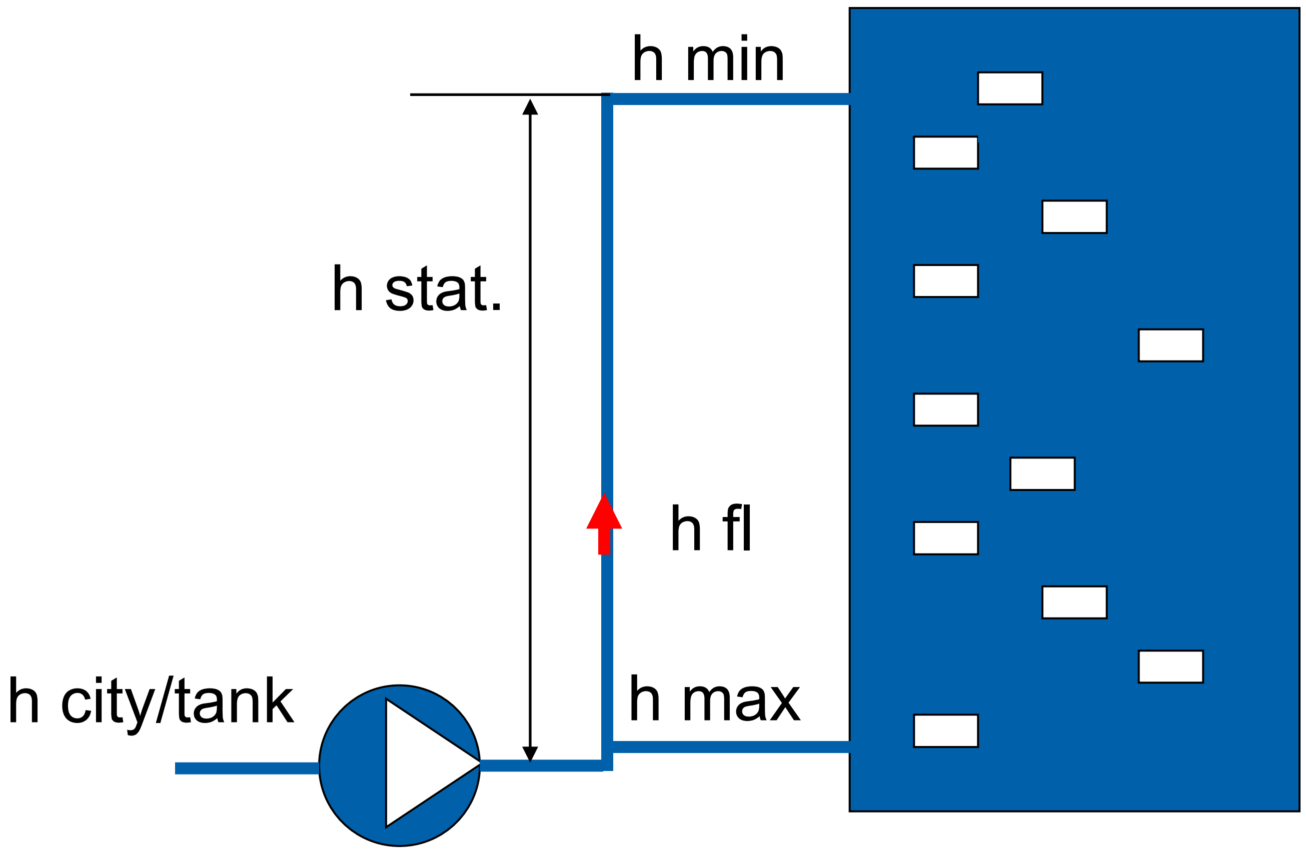
Frequency controlled booster sets

- Single frequency converter
- Multiple frequency converters
- Integrated frequency converters

Basic Calculation of Booster Sets

- Required head
- Required capacity
- The relationship is the pump curve!

Required Head H [m]



Required Head H [m]

h min (10 – 30 m)

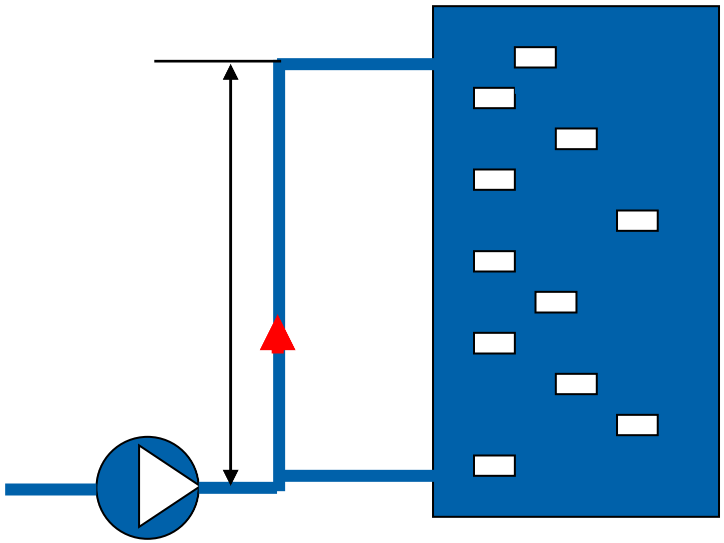
h stat.

h fl (1 m / 10 m stat.)

\- h city/tank

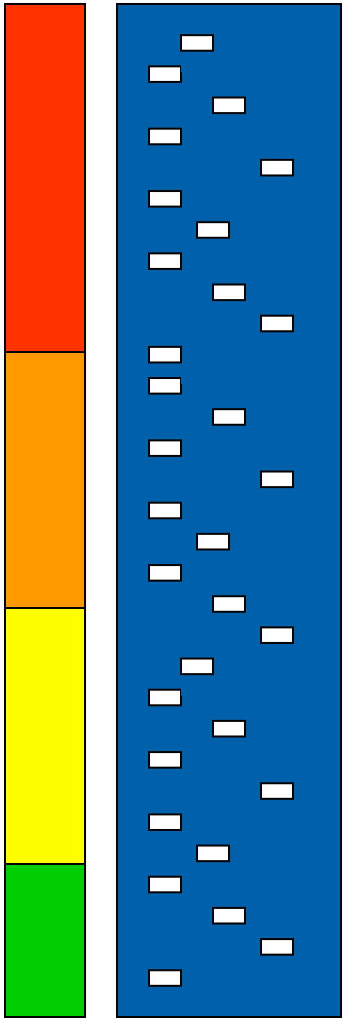
---

h req.



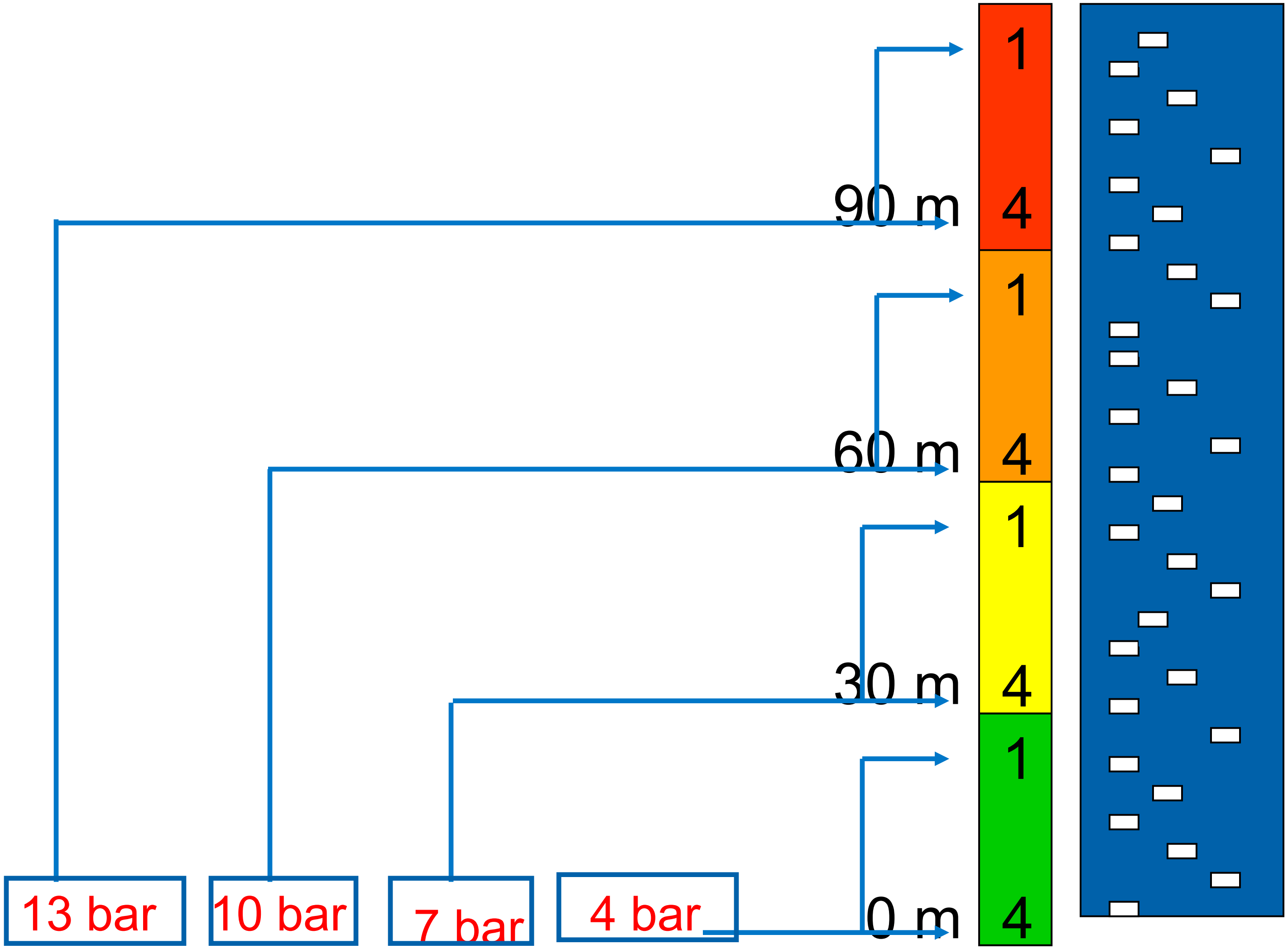
Zones 1 – 4 bar

120 m / 40 floors

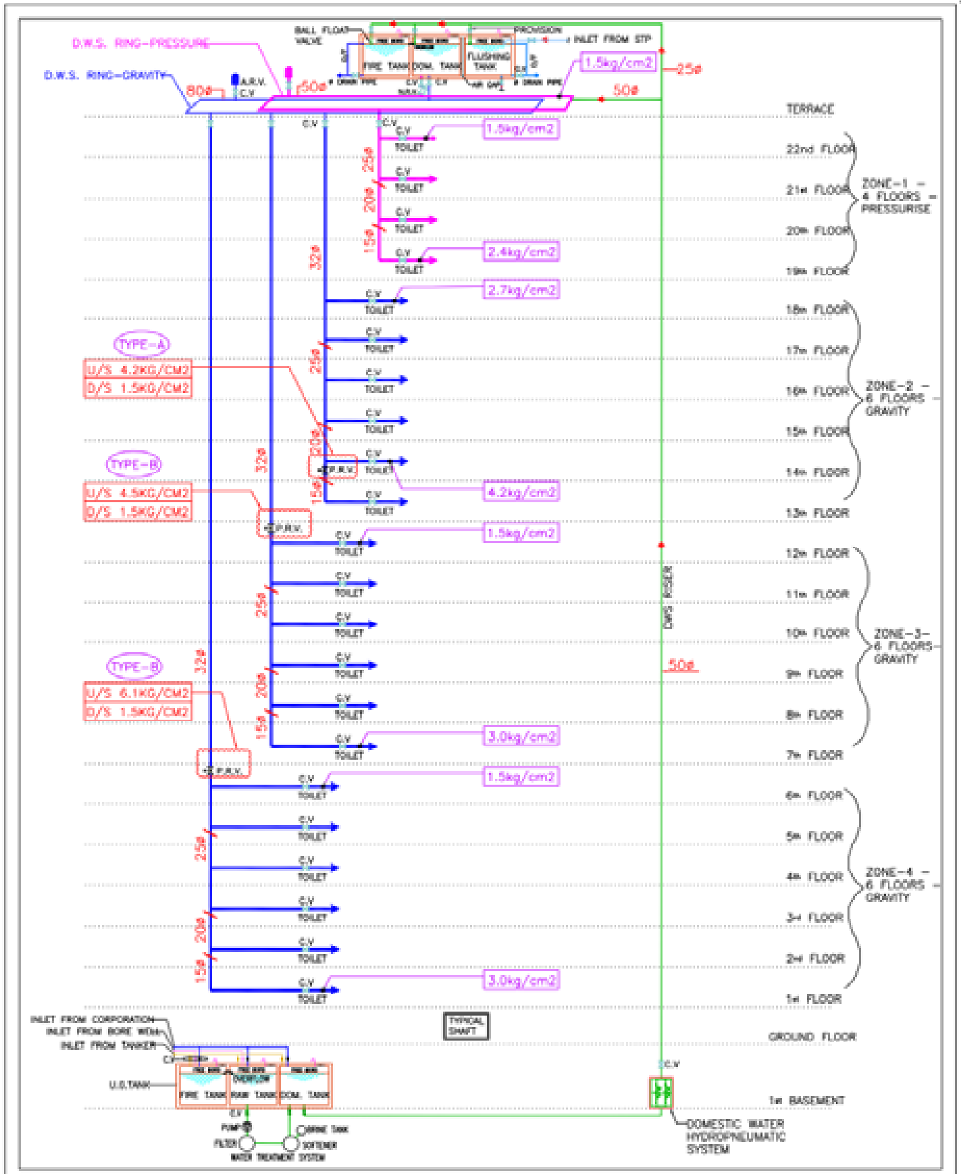


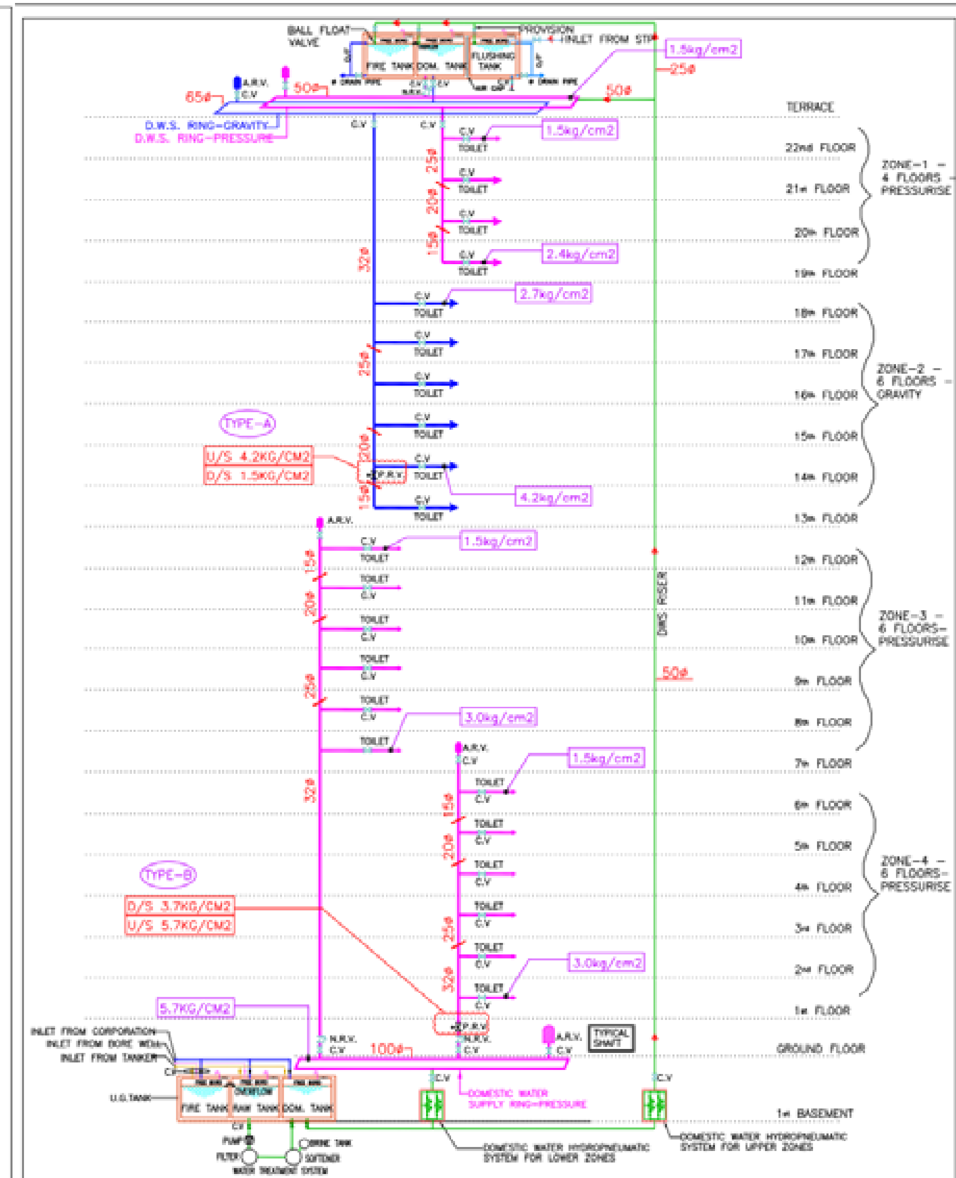
- Min head = 10 m
- Max head = 40 m
- Zone range = 30 m
- Floors 30/3 = 9- 10 floors per zone

Zones 1 – 4 bar



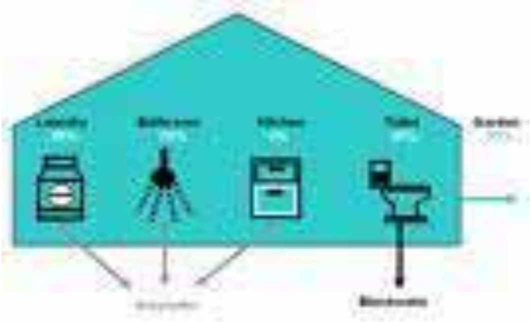
HPN System Options





Storm Water and Drainage Pumps

Storm water and Drainage Pumps



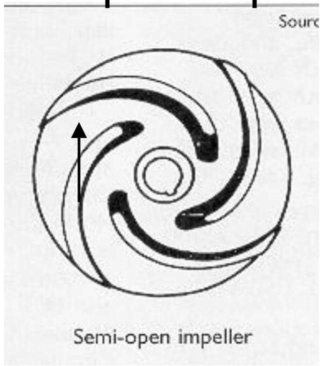
Sullage: The waste water which comes from bath rooms, Kitchens, Wash basins etc is known as Sullage waste water.

Sewage: The waste water coming from latrines, Urinals, Stable industrial waste, ground water and surface water including Sullage water is known as sewage water.

Type of Impellers

- Mainly 3 types of impellers are used for storm water and drainage pumps

Semi Open Impeller



Open Impeller

Closed impeller

Open Impellers

- The pumps with open impeller are used where the liquid to be pumped is with solids. The height of the vane determines the solid size it can handle.

Semi Open Impellers

- As the name suggests, these are used where some solids are present in the liquid.
- Typically used for handling muddy water.

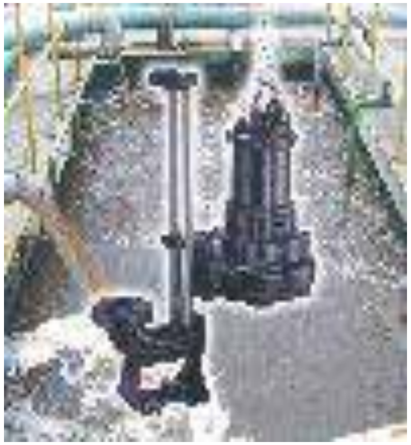
Closed Impellers

- The Pumps with closed impellers are used where in the transportation of liquid is clear and does not contain any solids or fibrous material

Closed impeller

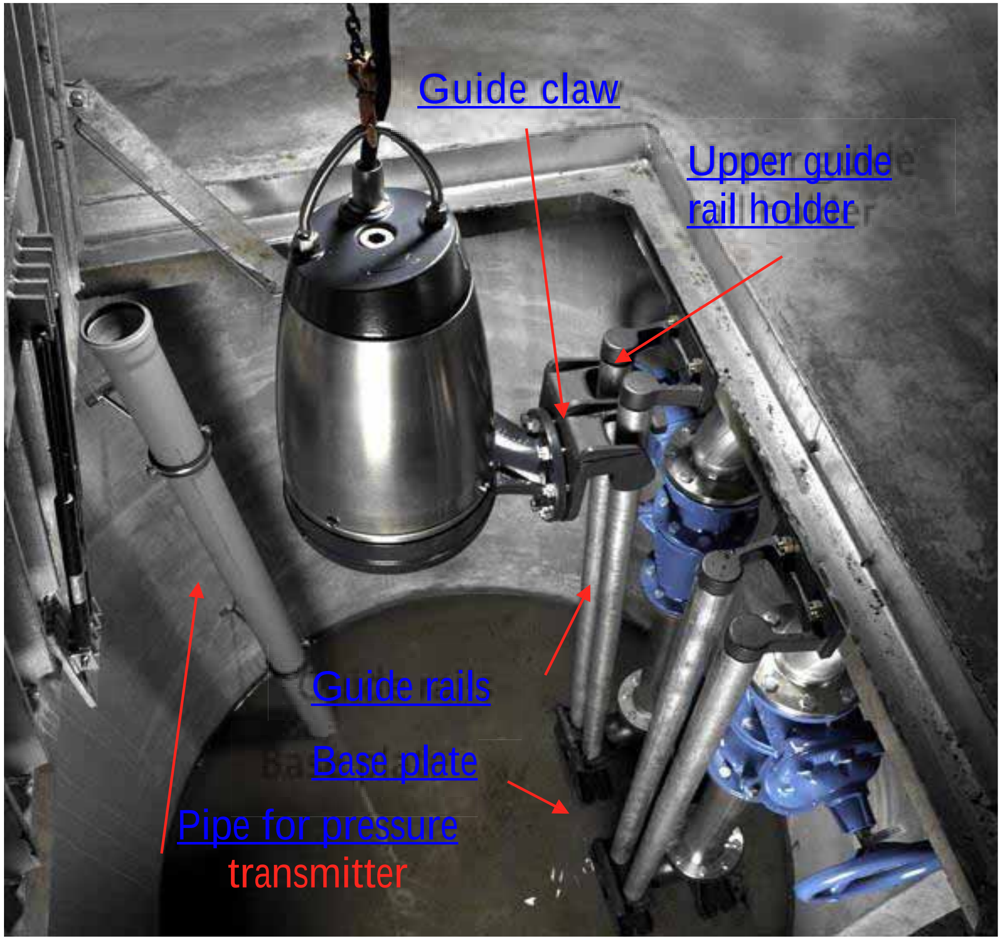
After seeing the type of the impellers, now it is clear that for **handling muddy water**, we have to use pumps with either **semi open or open type impellers**.

Dry & Wet Pit Installation



- In case of dry pit installation access to the wet well should not be through the dry well.
- The dry well should have a gas tight seal when mounted directly above the wet well.
- Submersible pumps if used, should be readily removable and replaceable without dewatering the wet well or requiring personnel to enter the wet well.
- A hoist and accessories for removing the pumps from the wet well should be provided.

Submerged installation in Wet Pit



A submersible non-clog pump operates underwater. The motor is sealed water-tight and designed to operate in submerged conditions.

Submerged installation in Wet Pit

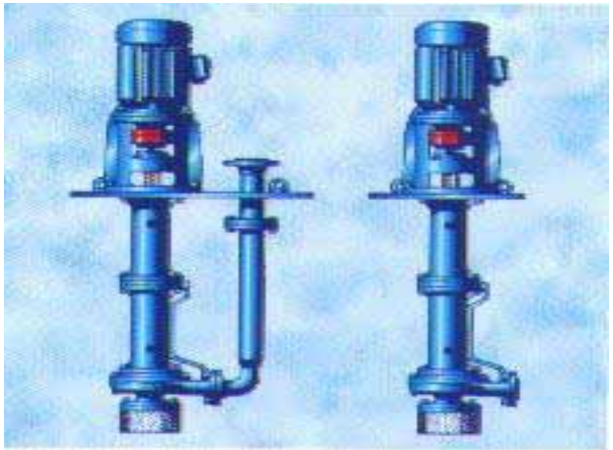
- The pumps are removable for maintenance without a person entering in the wet well.

- A pump can be easily hoisted out on guide rails by a person standing on the ground surface. The electrical control panel is mounted on posts above ground. This type of station normally includes a separate valve chamber. It is considered the lowest cost sewage pump station for many reasons.

Dry Pit Installation

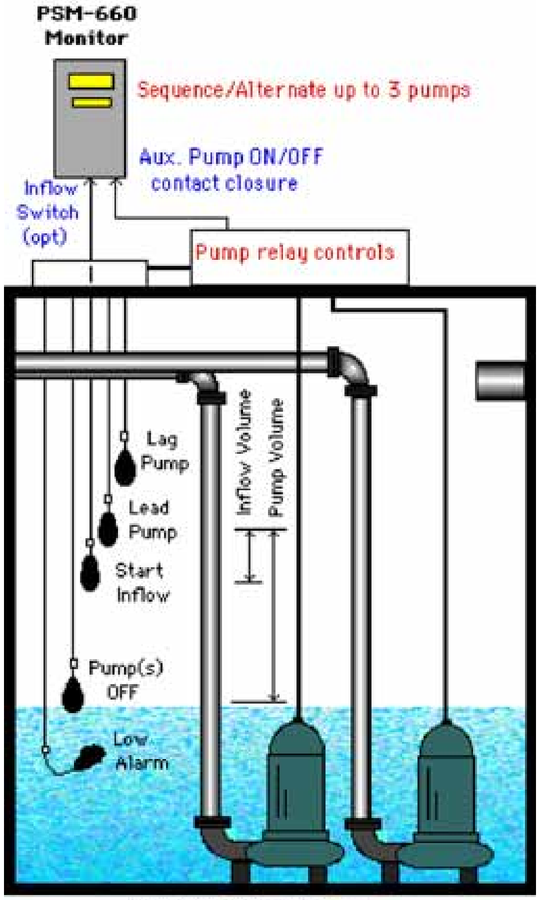
- Dry pit stations are more expensive than wet pit stations. (Construction Cost)
- Dry pit stations are more appropriate where pump and motor size increases. Over all maintenance cost of these are less than the submersible.
- Ease of access for personnel to perform routine and emergency pump maintenance of pumps, valves, and other equipments compare to submersible wet pit.

- The storm water or sewage water pumping stations with wet well are provided with extended or long shaft pumps where in space and depth is constrain. The maximum shaft height can be of 2.0 mts.
- Now a days where the space has become constrain, the use of dry pit stations are not recommended.



- Submersible type pumps can also be used in a dry pit configuration, thus eliminating the long shafts. In this type of pumps the provision for cooling motor is made. All other advantages of dry well pit explained earlier also are applicable here.

Sewage Pump Stations

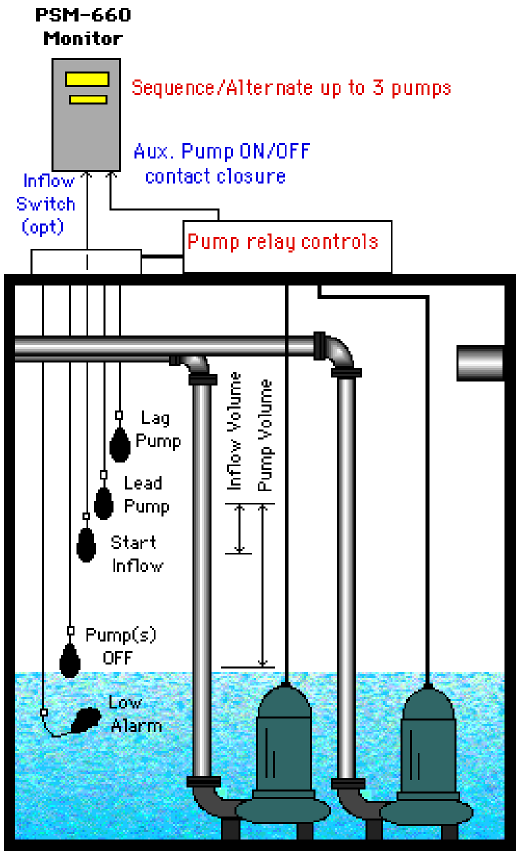


Wet Well with 2 Pumps

How Sewage Pump Stations Operate?

Most sewage pump stations operate on a float-type system.

- As the wastewater flows into the wet well by gravity, the water level in the wet well rises until the maximum operating level is reached. At the high level, a float switch is actuated to turn on a pump. With the pump running, the water level falls. The pump keeps running until the water level reaches the low level. At the low level, another float switch is actuated to turn off the pump.



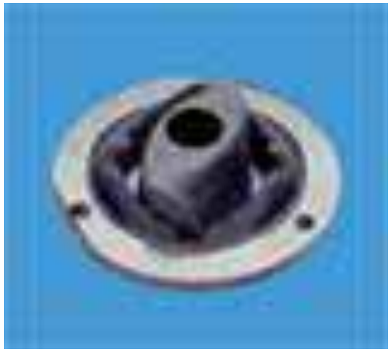
Wet Well with 2 Pumps

- The cycle is repeated several times during the day. The station can include a high water alarm that alerts you when the pump has failed or isn't pumping out fast enough to keep up with the flow.
- Pump Control Level.

  high level alarm / float set at 300mm above standby cut-in level
- emergency level alarm set at 500mm above standby cut-in level
- Pump control is to be set for not greater than 6 hours detention period or 30 min of peak flow

Submersible Grinder Pump

- A submersible grinder pump is similar to a non-clog pump except that it grinds up the solid matter in sewage rather than pumping it.
- A grinder pump can have smaller discharge piping than a non-clog pump.



Pump Controller

The pump controller is to switch off pump under the following conditions:

- Low water level.
- Thermostatic overload is tripped;
- Any pump failure.

Points to take care while installation

- At least two pump units should be provided, each capable of handling the expected maximum flow.

- Where three or more units are provided, they shall be designed to fit actual flow conditions and must be of such capacity that, with any one unit out of service, the remaining units will have capacity to handle the maximum sewage flow.

- When the incoming flow rate in the station is less than ½ of the average design flow, the design of the sump should take care septic nature of the sewage and reduce the holding time in the wet well. Normally detention time of 15 to 30 minutes of peak flow is considered.
- Some times the use of variable-speed pumps are considered, particularly when the pump station delivers flow directly to a treatment plant, so that sewage will be delivered at approximately the same rate as it is received at the pump station. This system has it's own advantages and disadvantages.

Selection of Material for the pumps.

- When the sewage and storm water are carried together (in short if the system is combined type), it is better to have all rotating parts in Alloy Cast Iron instead of only CI.
- When the pumps are selected for handling industrial sewage it is advisable to go for stainless steel impeller.
- There is present trend to specify all parts in stainless steel. This is really not necessary.
- The best possible combination for pumps parts are as under.
  - Casing: CI
  - Impeller: Alloy CI
  - Shaft: AISI410
  - Fasteners: SS
  - Motor body for submersible pump in CI for domestic and SS for Industry.

SUMMARY AND CONCLUSIONS

- Install all measuring instruments like pressure gauge and flow meters
- Choose the required duty parameters
- Choose the correct size of pump and motor
- Do not oversize the pump or motor and waste power
- Do not throttle the valve for continuous operation instead change the impeller dia or change the pump
- Choose high efficiency motors to save on power
- Use VFD only when there is requirement for longer variable outputs.
- Last but not the least create routine maintenance schedule to avoid break down.

Thank you

- Any Questions?

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