IIT KHARAGPUR

NPTEL ONLINE
CERTIFICATION COURSES

NPTEL

Irrigation and Drainage

Lecture No: 31 Irrigation Pumps

Dr. DAMODHARA RAO MAILAPALLI
AGRICULTURAL AND FOOD ENGINEERING DEPARTMENT
IIT KHARAGPUR

Water Lifting Devices

- ✓ Used to lift groundwater, rain water stored in an underground reservoir and river water
- ✓ Classified Based on mode of operation:
  - Manually operated: Scoop, Don, Swing basket, Archimedean Screw
  - Operated by animals: Persian wheel, Chain pump, Rope and bucket
  - Electrical pumps: Gear pump, centrifugal pump, jet pump
- ✓ Cost of operation: Manual (3-4 times that of animal)> Animal (10-12 times that of electrical) > Electrical
- ✓ Cost associated to electrical pumps are cheaper

Principles of Water Lifting

✓ Water may be lifted by any of the following mechanical principles:

- **Direct lift:** Lifting water in a container.
- **Atmospheric pressure:** Water is lifted by atmospheric pressure by creating a vacuum in a chamber which sucks water up to a maximum pressure head of 1 atm (10.33 m).
- **Positive displacement:** Involves displacement of water from a lower to a higher level.
- **Creating a velocity head:** The momentum created by propelling or rotating water at high speed is utilized to create a flow or create a pressure.
- **Using the buoyancy of a gas:** Air (or other gas) bubbled through water will cause movement of column of water due to difference in specific gravity.
- **Using the impulse:** It results in a sudden sharp rise in water pressure to carry a small part of supply up to a considerably high level.

Irrigation Water Lifts: Classification

- Indigenous water lifts (Manual/ Animal)
  - Low head (1.2m)
  - Medium head (1.2-10m)
  - High head (>10m)
- Pumps
  - Positive displacement
  - Variable displacement

Pumps

- ✓ A pump is a mechanical appliance used to increase the pressure energy of a liquid, in order to lift it from a lower to a higher level

- ✓ Creates a low pressure at the inlet and a high pressure at the outlet ends of the pump

- ✓ Principle of working of a pump is distinctly different from the indigenous water lifts in which water is lifted by displacement through buckets, water wheels or screws

- ✓ Two basic groups: (i) **positive displacement pumps**, and (ii) **variable displacement pumps**

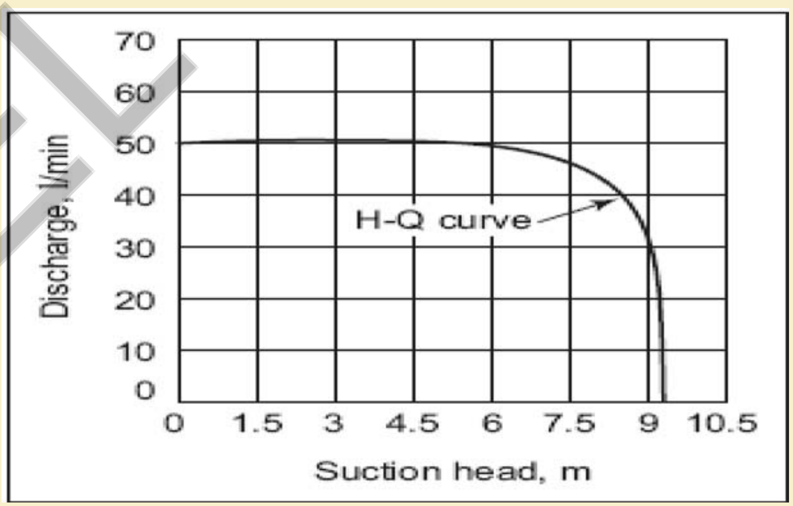
Positive Displacement Pumps

✓ **Positive displacement pump:**

- Fluid is physically displaced by mechanical devices: e.g. piston, gears, cams
- The volume of water delivered is constant, regardless of the head against which it operates
- The volume of water delivered varies with the speed of piston
- Contains large number of moving parts and require greater attention in maintenance

✓ **Variable displacement pump:**

- The discharge varies inversely as its pressure head



Relationship between suction head and discharge in a positive displacement pump

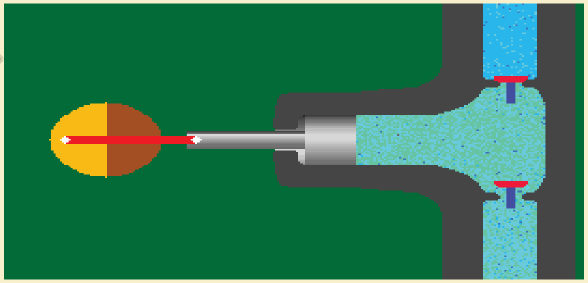
Positive Displacement Pumps

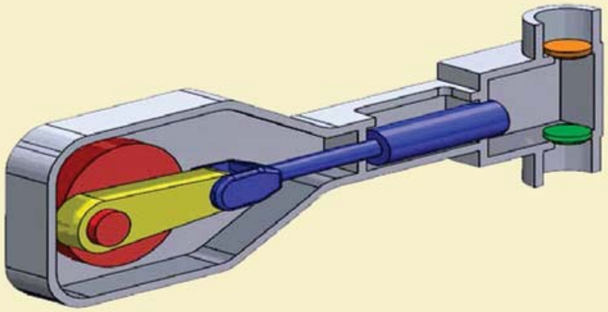
- Reciprocating pump
  - Lift pump
    - Shallow well pump
      - Single-acting plunger type
    - Deep well pump
      - Double-acting plunger type
  - Force pump
    - Shallow well pump
      - Single acting plunger type
    - Deep well pump
      - Single-acting plunger type
      - Double-acting plunger type
- Rotary pump
- Gear pump
- Helical rotor pump
- Diaphragm pump

Dr. D.R. Mailapalli
Agricultural and Food Engineering

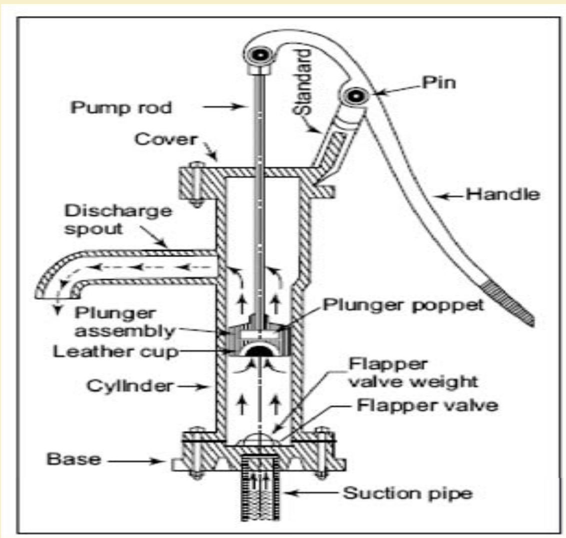
Reciprocating Pumps

- ✓ Consists of a piston or plunger working in close fitting cylinder
- ✓ The movement of piston displaces the water in a cylinder
- ✓ The capacity of reciprocating pumps depends on the size of the cylinder chamber and the length and speed of stroke of the piston
- ✓ Broadly classified as **lift pumps** and **force pumps**



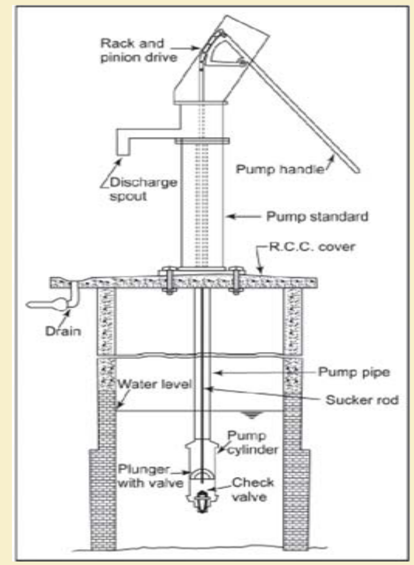


Reciprocating Pumps



Lift pumps

- ✓ **Lift pumps**
  - o Designed to pump water from the source to the level of the pump spout only
  - o They utilize atmospheric pressure to raise the water to the pump column
- ✓ **Force pumps**
  - o Designed to pump water to a higher elevation than the pump body
  - o Used to pump water from deep wells or to storage tanks in domestic water supply



Force pumps

Reciprocating Pumps

The basic relationship between pump discharge and design dimensions may be expressed as follows:

- ✓ Area swept by the pump piston: $A = \frac{\pi}{4} d^2$ d = diameter of the piston
- ✓ Volume swept per stroke: $\mathrm{V} = \mathrm{Al}$ l = stroke (length of piston)
- ✓ Volumetric efficiency: η_{vol}= % swept volume that is actually pumped (coefficient of discharge)
- ✓ Actual Volume per stroke: $q = \eta_{vol}\, V$
- ✓ Pump discharge rate: $Q = nq$ n = number of strokes per minute
- ✓ Slippage is the difference between the swept volume and the output per stroke:

Slippage : $X = V - q$

Force Required to Work a Reciprocating Pump

The force required to lift the piston:

$$Weight\ of\ the\ piston + Weight\ of\ pump\ rod + Weight\ of\ the\ column\ of\ water$$

Let,

a = area of cylinder, m^2 ; l = length of stroke, m; h = total height through which water is raised, m

P = force required to lift the piston (neglecting friction and weight of the piston and connecting rod), kg; w = specific weight of water, kg/m^3

Weight of water raised in one stroke = $w\,a\,l = 1000\,al$

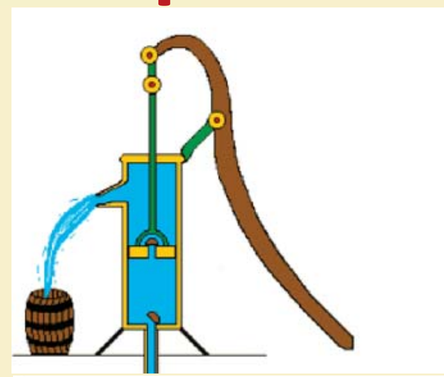
Work done in one upstroke = $1000\,a\,l\,h = P\,h$

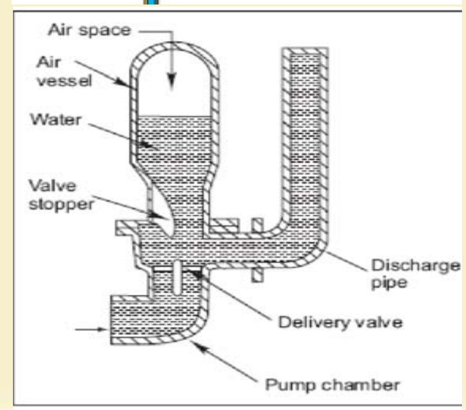
$$P = 1000\,al$$

Hence, P is independent of the diameters of the suction and delivery pipes, if friction is neglected.

Single-acting Reciprocating Pump

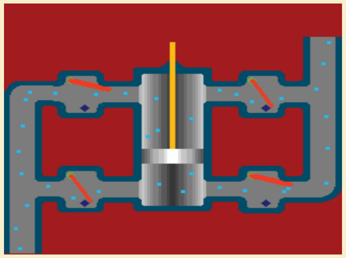
- ✓ One discharge stroke for every two strokes of the piston
- ✓ Water is delivered during alternate strokes of the piston
- ✓ The flow through the delivery pipe is, therefore, intermittent.
- ✓ An air vessel may be fixed over or near the delivery valve to provide a steady discharge.
- ✓ During the delivery stroke of the piston, the air in the air vessel is compressed
- ✓ During the suction stroke, the pressure of the air in the vessel maintains the flow of water through the delivery pipe

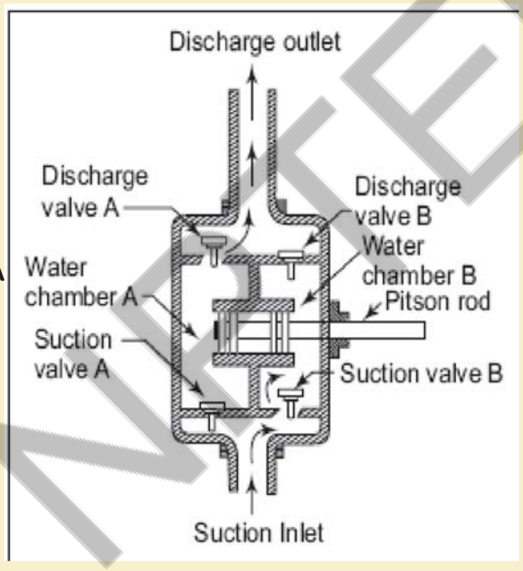




Double-Acting Reciprocating Pump

These are constructed with the piston and valves so arranged that water is pumped on both inward and outward movements of the piston





Right side stroke (outstroke):

- ✓ Draw water to chamber A through suction vale A
- ✓ Discharge valve A closes
- ✓ Suction valve B closes
- ✓ Discharge valve B opens

Left side stroke (instroke):

- ✓ Suction valve A closes
- ✓ Discharge valve B closes
- ✓ Suction valve B opens and draws water to chamber B
- ✓ Discharge valve A opens and discharges water out

Exercise 31.1:

A **single-acting** reciprocating pump has a piston of diameter 10 cm and stroke of 20 cm. The piston makes 40 double strokes per minute. The suction and delivery heads are 5 m and 10 m, respectively. Find (i) the discharge capacity of the pump in l/min, (ii) the force required to work the piston during the suction and delivery strokes, if the efficiency of the suction and delivery strokes are 50 and 60 per cent, respectively, and (iii) the hp required by the pump for its operation.

Solution:

1. Area of the piston = a= $\frac{\pi}{4}d^2$ = $\frac{3.14}{4} \times \frac{10}{100} \times \frac{10}{100}$ = 0.008 m^2

   Volume swept by piston/stroke = a × l = 0.008 × $\frac{20}{100} = 0.0016\, m^3$

   Pump discharge = 0.0016 × 40 = 0.064 m^3/min = 64 lpm

2. Average force in suction = $\frac{a \times Suction\ head \times Specific\ weight\ of\ water}{Efficiency\ of\ suction\ stroke}$

   $= \frac{0.008 \times 5 \times 1000}{0.5} = 80\ kg$

Average force in delivery = $\frac{a \times delivery\ head \times Specific\ weight\ of\ water}{Efficiency\ of\ delivery\ stroke}$

$$= \frac{0.008 \times 10 \times 1000}{0.60} = 133.3 \text{ kg}$$

3. Horse power required by the pump:

$$= \frac{Total\ force\ (suction + delivery) \times distance\ moved\ in\ m/min}{4560}$$

$$= \frac{(80+133.3) \times 40 \times (\frac{20}{100})}{4560}$$

$$= 0.374$$

Exercise 31.2:

A double-acting reciprocating pump has a piston of 20 cm diameter, and a piston rod of 5 cm diameter which is on one side of the piston only. The length of the piston stroke is 30 cm and the speed of the crank moving the piston is 50 rpm. The suction and discharge heads are 5 m and 10 m, respectively. Determine the discharge capacity of the pump in l/min and the hp required to operate the pump.

Solution:

Cross-sectional area of piston = $a = \frac{\pi}{4} d^2 = \frac{3.14}{4} \times \frac{20}{100} \times \frac{20}{100} = 0.031 \text{ m}^2$

Cross-sectional area of piston rod = $a_1 = \frac{3.14}{4} \times \frac{5}{100} \times \frac{5}{100} = 0.00196 \text{ m}^2$

(a) Force required to work the piston during **'out stroke'**:

1. For suction = a× suction head× sp.wt of water =1000 × 0.031×5

= 155 kg

2. $For\ delivery\ =\ (a-\ a_1)\times\ delivery\ head\ \times Specific\ weight\ of\ water$

$$=\ (0.031-0.00196)\ \times 10\times 1000\ =\ 290.4\ kg$$

$$Total\ force\ during\ \text{'}\boldsymbol{out\ stroke}\text{'}\ =\ 155+\ 290.4\ =\ 445.4\ kg$$

b. Force required to work piston during '**in stroke**':

1. $For\ suction\ =\ (a-\ a_1)\times\ suction\ head\ \times Specific\ weight\ of\ water$

$$=\ (0.031-0.00196)\ \times 5\times 1000\ \ =\ 145.2\ kg$$

2. $For\ delivery\ =\ a\times\ suction\ head\times Specific\ weight\ of\ water$

$$=1000\ \times\ 0.031\times 10$$

$$=\ 310\ kg$$

$$Total\ force\ during\ \text{'}\boldsymbol{in\ stroke}\text{'}\ =\ 145.2+310\ =\ 455.2\ kg$$

$$Discharge\ during\ \text{'}in\ stroke\text{'}\ =\ a\times\ l\times\ rpm\ =0.031\times\ (30/100)\ \times 50$$

$$=\ 0.465\ m^3/min=\ 465\ l/min$$

$$Discharge\ during\ \text{‘}out\ stroke\text{’} = (a - a_1) \times l \times rpm$$

$$= (0.031 - 0.00196) \times (30/100) \times 50$$

$$= 0.134\ m^3/\min = 435\ l/\min$$

$$Total\ quantity\ of\ water\ raised\ by\ pump = 465 + 435$$

$$= 900\ l/\min$$

$$Horse\ power\ required\ by\ the\ pump = \frac{Total\ force\ (Max.), kg \times distance\ moved, m/min}{4560}$$

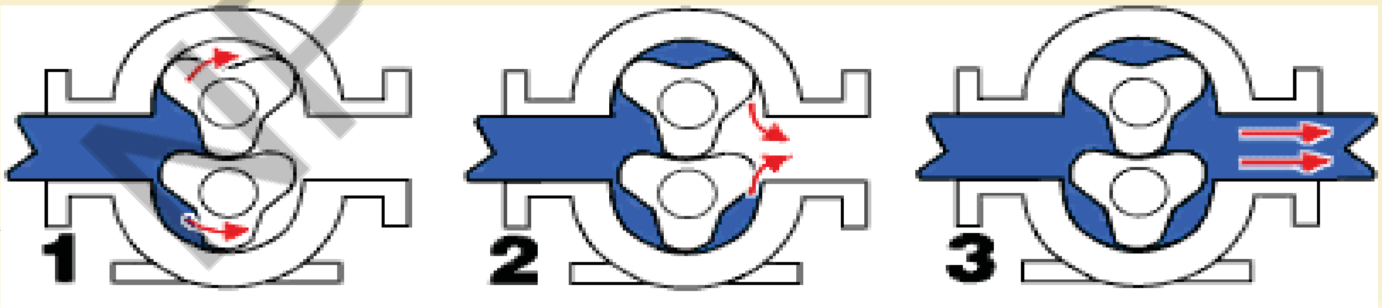
$$= \frac{455.2 \times \left(\frac{30}{100}\right) \times 50 \times 2}{4560} = 2.99$$

$$\cong 3\ hp$$

Rotary pumps

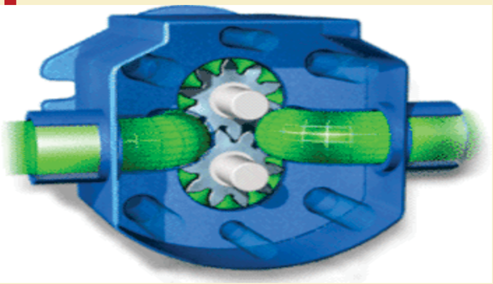
- ✓ A positive displacement pump with circular motion
- ✓ It has one or more rotary elements, generally gears and cams/vanes, that revolve continuously within a fixed casing
- ✓ It has no valves and the liquid flows through the passage in a continuous stream
- ✓ The two gears are fitted closely in the housing and meet with minimum clearance

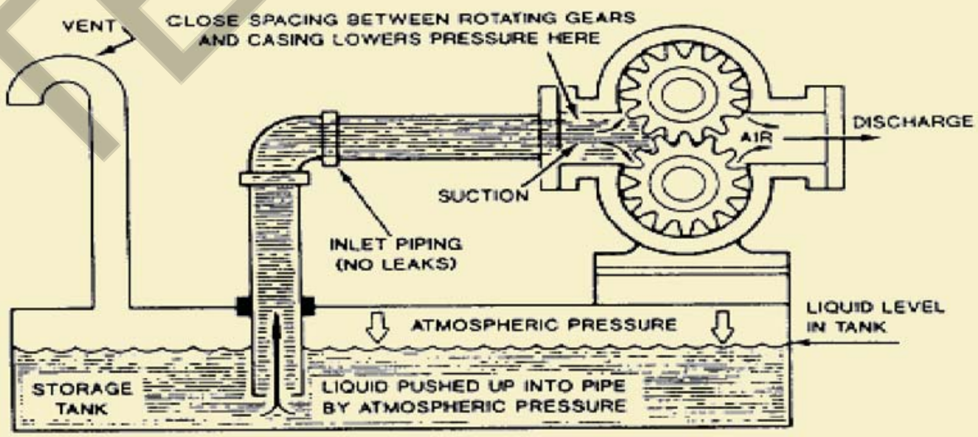
Vane type Rotary pump →



Gear type Rotary pump

- ✓ When the gears rotates in the direction shown, they push the water through the gears to the discharge spout creating a partial vacuum at the suction and draws water from suction
- ✓ It creates continuous flow
- ✓ Low speed pumps
- ✓ Used in shallow water
- ✓ Water should be free from sand and dirt

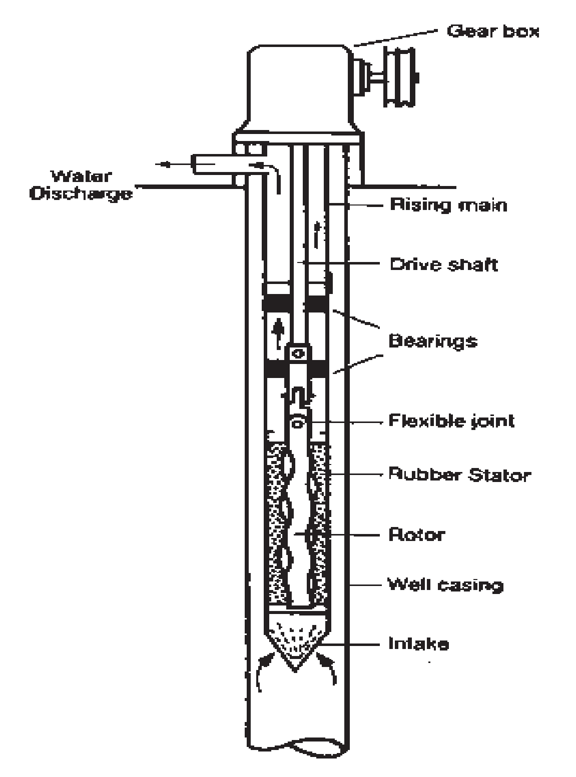




Gear pump located above the tank.

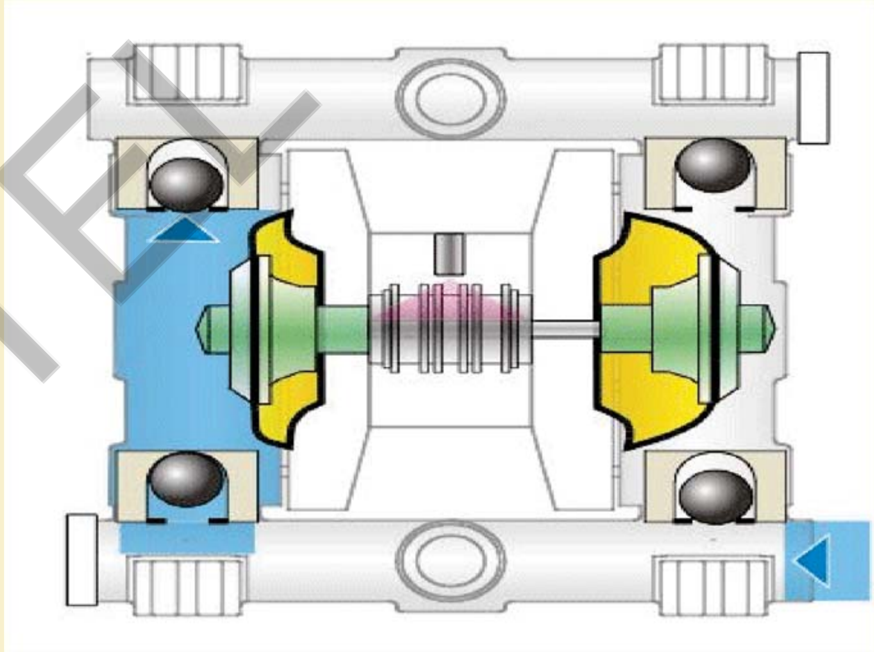
Helical Rotor Pump

- ✓ Consists of
  - ✓ Polished metal rotor or screw
  - ✓ Outer helical starter made of rubber
- ✓ As the rotor is rotated within the starter (1750 rpm), a continuous stream of water is pushed along the cavities in the starter.
- ✓ Water acts as a lubricant between the two elements of the pump
- ✓ Also called **cavity pumps**



Diaphragm pump

- ✓ Especially suitable for lifting water containing mud or other impurities
- ✓ The device consists of a pump chamber enclosed by flat rubber diaphragm on either side
- ✓ The movement of the diaphragm on either side contributes suction on one side and discharge on other side of the chamber



Thank You!!

Dr. D.R. Mailapalli
Agricultural and Food Engineering

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

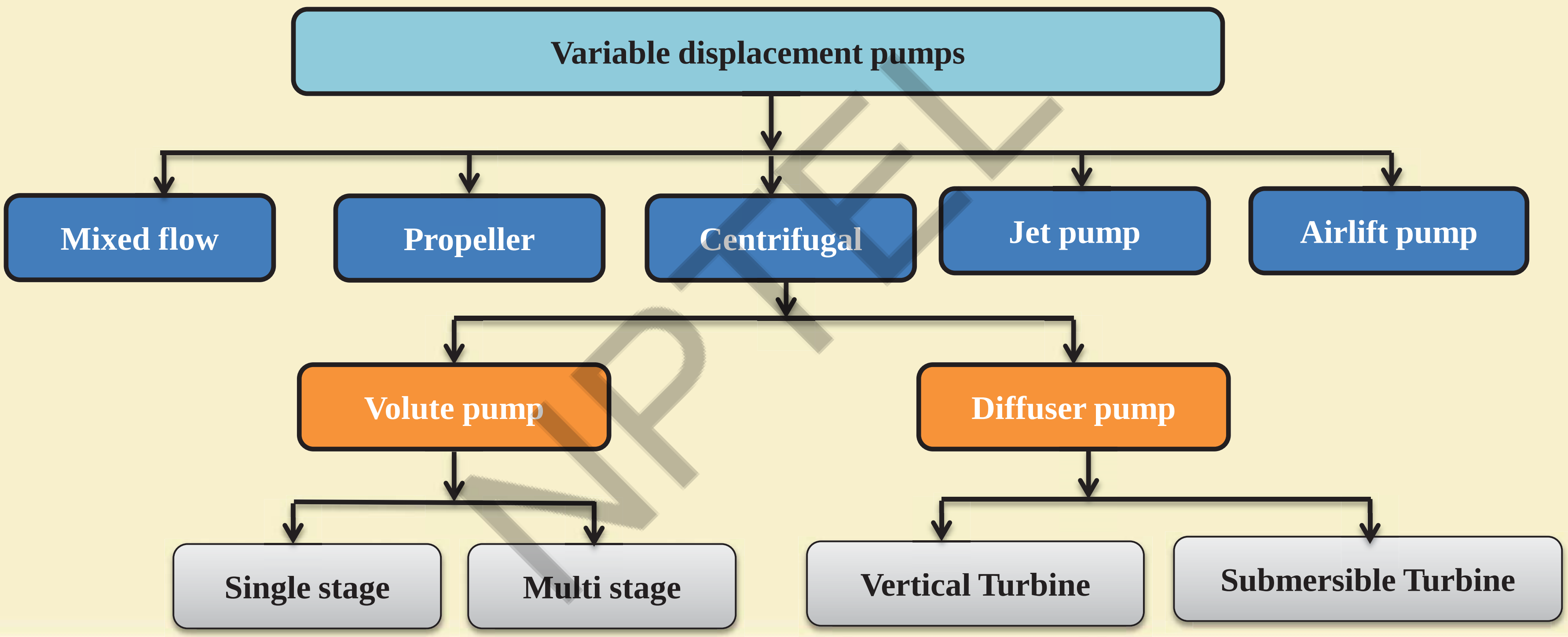
NPTEL

Irrigation and Drainage

Lecture No: 32 Centrifugal Pump: Basics

Dr. DAMODHARA RAO MAILAPALLI
AGRICULTURAL AND FOOD ENGINEERING DEPARTMENT
IIT KHARAGPUR

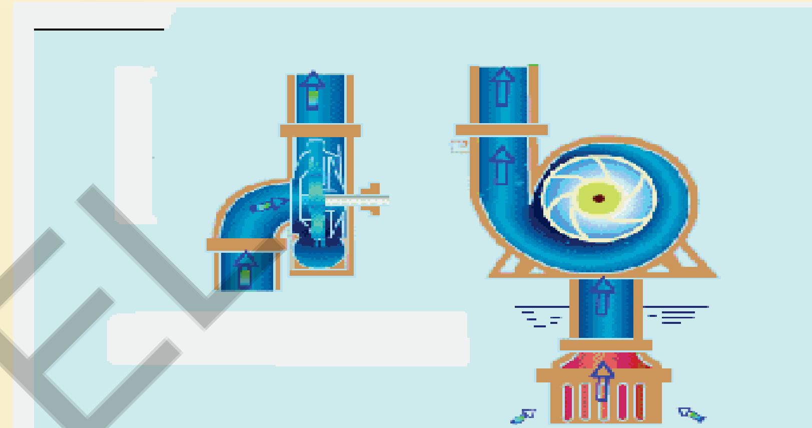
Classification

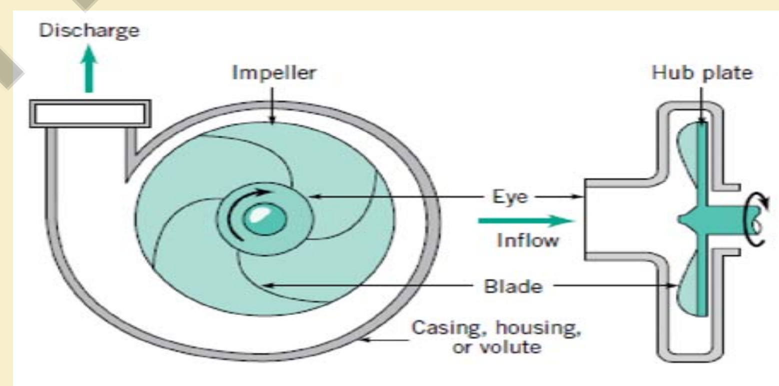


Centrifugal Pumps

Hydraulic Principle:

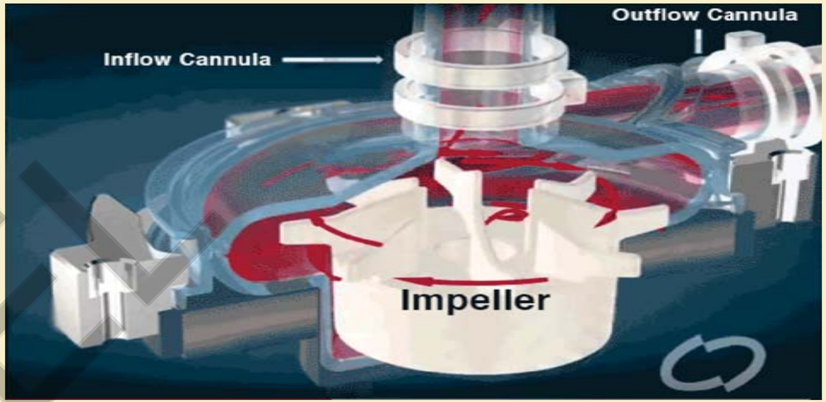
- ✓ Production of high velocity and partial transformation of this velocity into pressure head
- ✓ Initially, pump is filled with water (priming) and an impeller rotates inside the fixed & closed chamber
- ✓ The blades of the impeller rotates the liquid and imparts a high velocity to the water particle

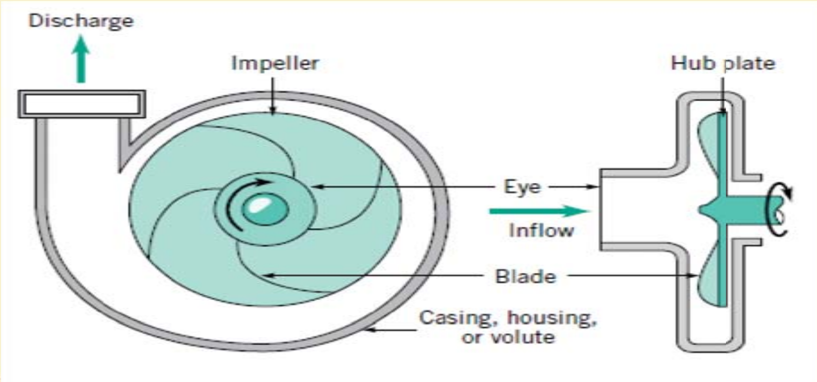




Centrifugal Pumps

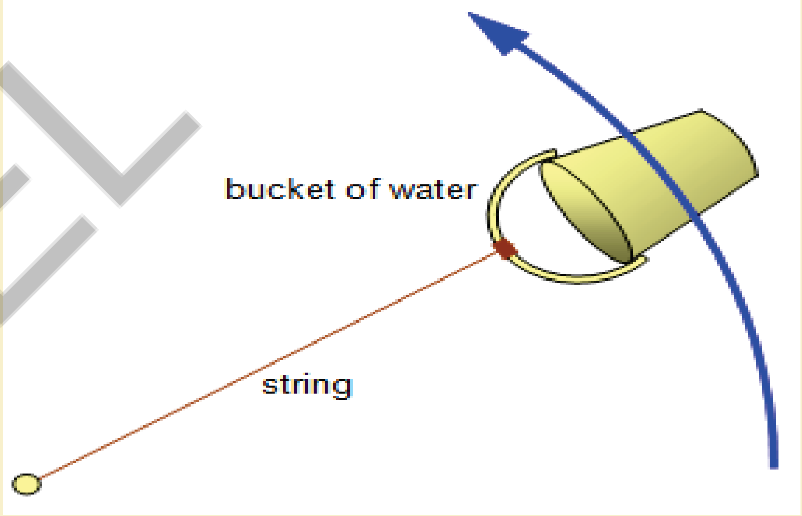
- ✓ The centrifugal force causes the water particles to be thrown from the impeller into the casing
- ✓ The forward flow through the impeller reduces pressure at the inlet allowing more water to be drawn in through the suction pipe by atmospheric pressure
- ✓ The liquid passes into the casing wherein high velocity is reduced and converted into pressure head





Example: Swing a bucket with water

- ✓ Water won't fall when the bucket is rotated due to centrifugal force
- ✓ Water flows out as jet when the bucket has hole in the bottom
- ✓ When the bucket is covered, the displaced water as jet will create vacuum inside the bucket
- ✓ This will help in draining water from a stationary bucket of water



Centrifugal Pumps: Classification

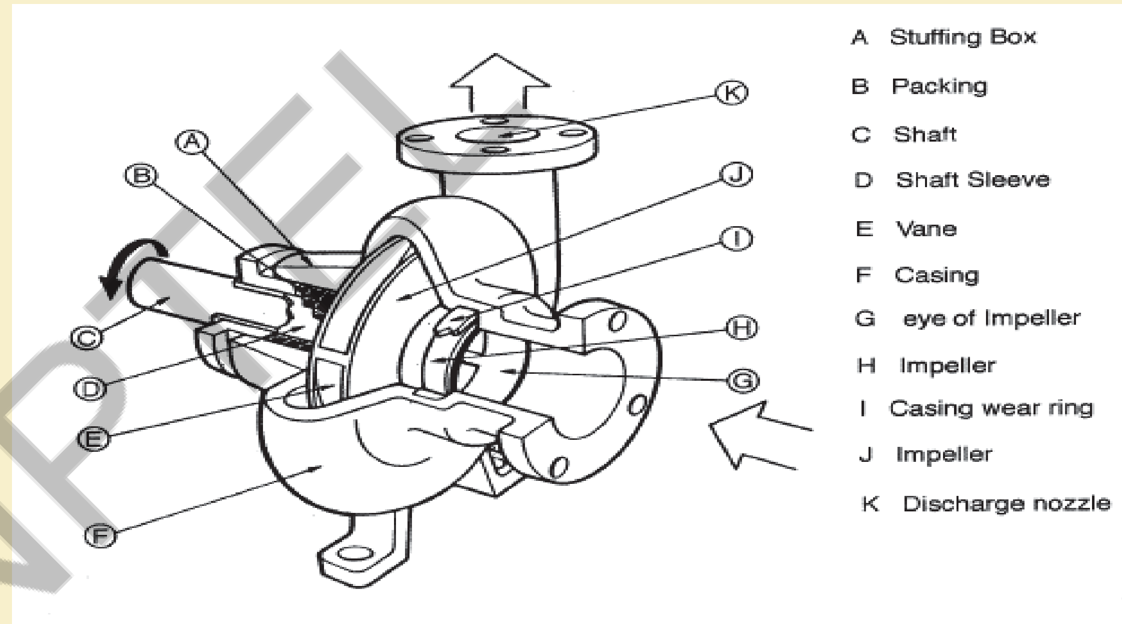
1. **Type of energy conversion**
   - ✓ Volute type
   - ✓ Diffuser/Turbine
2. **Number of stages**
   - ✓ Single stage
   - ✓ Multi stage
3. **Impeller type**
   - ✓ Open
   - ✓ Semi Open
   - ✓ Closed
   - ✓ Non-cloging
4. **Type of inlet suction**
   - ✓ Single suction
   - ✓ Double suction
5. **Axis of rotation**
   - ✓ Horizontal
   - ✓ Vertical
6. **Method of Drive**
   - ✓ Direct connection
   - ✓ With power transmission

Centrifugal Pumps: Parts

Volute Type

1. Rotating element: **Impeller**

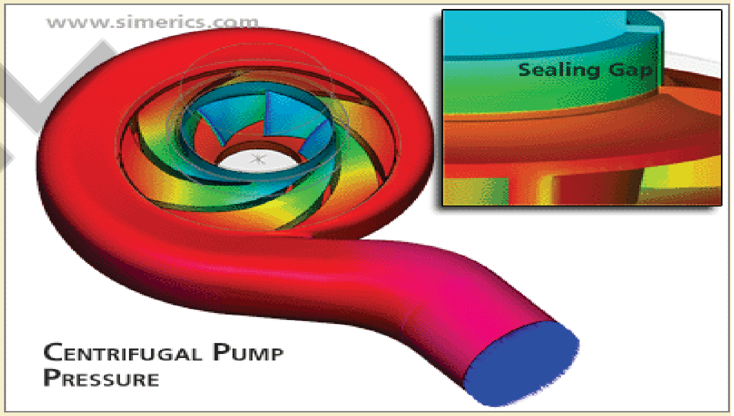
2. Stationary element: **Casing**



Centrifugal Pumps

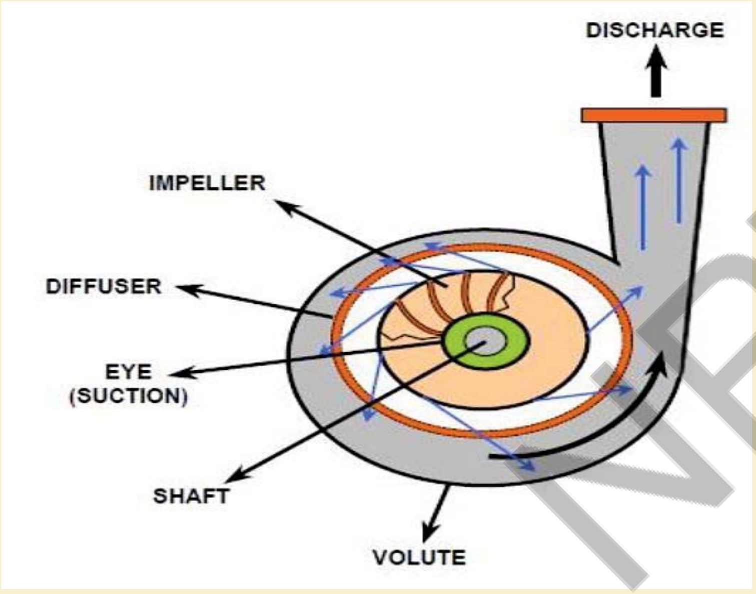
✓ **Volute centrifugal pump:**

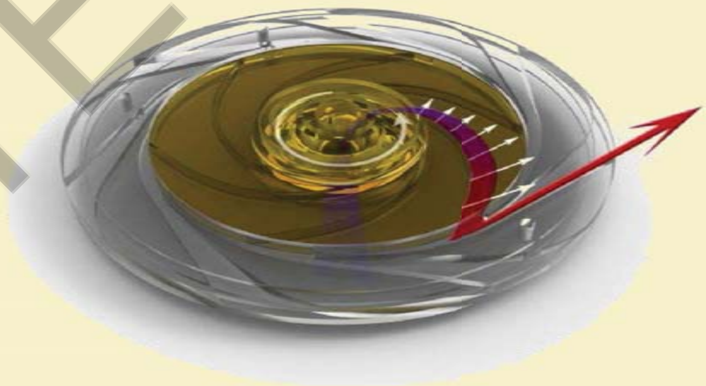
- Predominantly used in irrigation and drainage pumping
- Common in drinking water supply
- No diffusion vanes, but rather the outer casing is a spiral
- The form of the outer casing reduces water velocity (and eventual pressure) by creating an equal flow of water as it moves around the spiral
- The spiral is sometimes called a volute, hence the name for this particular type of pump



Centrifugal Pumps

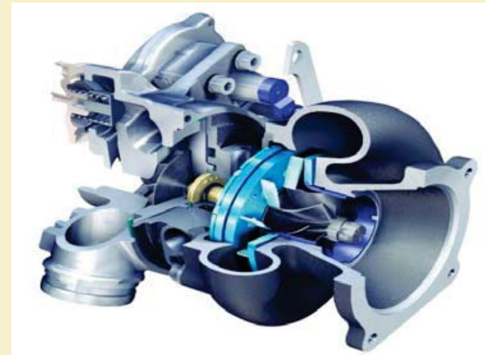
Diffuser (Turbine) Type

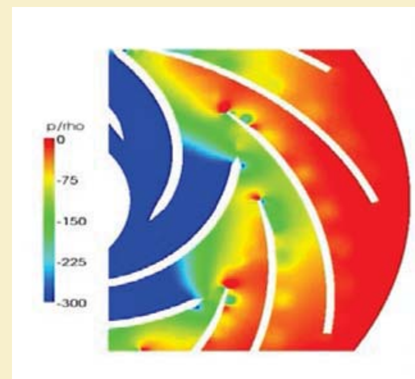




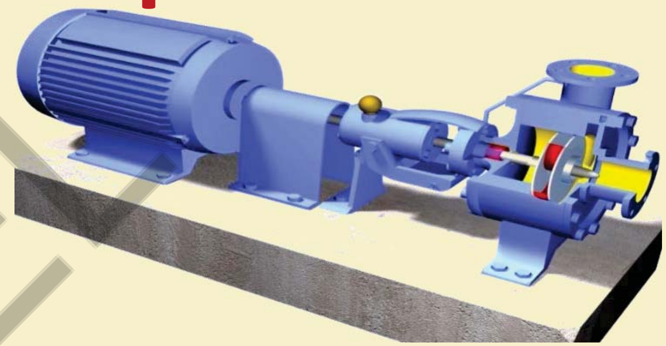
Turbine/Diffuser Pumps:

- Multiple diffusion vanes surround the rotating impeller
- As water is released from the center (or eye) of the impeller, it spins outwards as the impeller rotates
- Around the impeller's circumference are various diffusion vanes, passages that gradually widen and open into a circular or spiral casing
- The main role of diffusion vanes is to reduce the velocity of water slowly, thus transforming velocity into pressure
- Once in the outer casing, the water then circles or spirals around toward the nozzle, where it exits the pump





Centrifugal Pumps

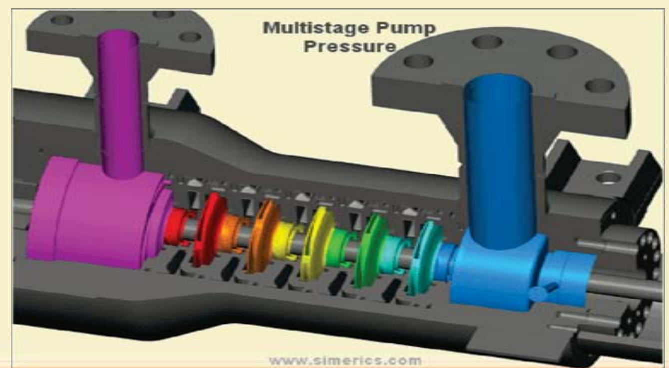


Single stage pumps:

- ✓ Total head is developed by a single impeller

Multi stage pumps:

- ✓ It has two or more impellers on a common shaft on a single casing
- ✓ Head and power regulation increases proportional to the number of stages
- ✓ The discharge capacity and efficiency are same as for single stage



Dr. D.R. Mailapalli
Agricultural and Food Engineering

Types of impellers:

1. Open impeller

- ✓ Vanes are free on both sides
- ✓ Less efficient

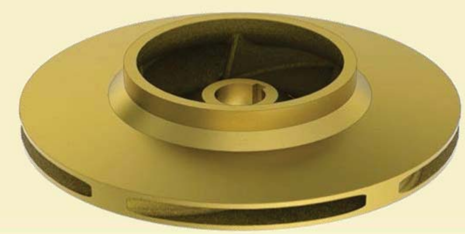
Non-Clogging Type

2. Semi-open impeller

- ✓ Vanes are free on one side and enclosed on the other
- ✓ More efficient than open impeller

3. Closed impeller

- ✓ Vanes are located between the two discs, all in a single casting
- ✓ Used in large pumps with high efficiencies and low required Net Positive Suction Head (NPSH)



Centrifugal Pumps: Frictional head

Frictional head calculation in pipe system:

- ✓ Head loss is due to energy required to overcome the resistance of pipe line and fittings
- ✓ Friction head exists in both suction and discharge sides of a pump
- ✓ It varies with rate of flow of water, pipe size, condition of the interior of the pipe and material of pipe

Loss of head due to friction in pipe by Darcy-Weisbach equation

$$H_f = \frac{4flv^2}{2gd}$$

Where,

f= coefficient of friction for pipe (fraction), l= length of pipe (m)

v= velocity of fluid in pipe (m/s), d= diameter of the pipe (m)

Example 32.1:

Compute the head loss due to friction in a pipe of 7.5 cm diameter and 100 m length ,when water is flowing at a velocity of 2 m/s. The value of f may be assumed to be 0.005.

Solution :

d = 7.5 cm, l = 100 m

v =2 m/s g =9.81m/s^2

Darcy-Weisbach equation

$$H_f = \frac{4flv^2}{2gd}$$

$$= \frac{4\times0.005\times100\times2\times2}{2\times9.81\times0.075} = \mathbf{5.43\ m}$$

Frictional loss in pipe fittings and pump accessories:

For strainer $h_f = k_s \frac{v2}{2g}$

Ks=0.95

For foot valve $h_f = k_f \frac{v2}{2g}$

K_f = 0.80

The specific speed of the pump:

- ✓ Is often used as an index to the operating characteristic of pump
- ✓ It express the relationship between the speed, discharge and the head

$$n_s = \frac{nQ^{1/2}}{H^{3/4}}$$

Where, n_s= specific speed, rpm; n=pump speed, rpm; Q= Pump discharge, m^3/sec; H= Total head, m

FRICTION LOSS CHARTS

PVC PIPE FRICTION LOSS

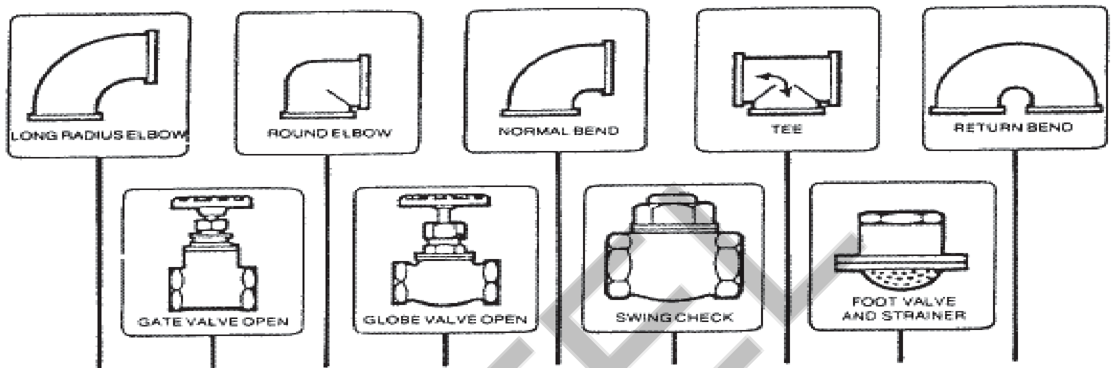
FLOW RATE		FRICTION LOSS (metres/100 metres of pipe)									
		Nom. 32mm		Nom. 40mm		Nom. 50mm		Nom. 80mm		Nom. 100mm	
L/s	GPM	PN9	PN12	PN9	PN12	PN9	PN12	PN9	PN12	PN9	PN12
0.4	5	0.48	0.54	0.25	0.29	0.09	0.1	-	-	-	-
0.5	7	0.7	0.8	0.37	0.42	0.13	0.14	-	-	-	-
0.6	8	0.97	1.1	0.51	0.58	0.17	0.2	-	-	-	-
0.7	9	1.27	1.44	0.66	0.77	0.23	0.26	-	-	-	-
0.8	11	1.61	1.82	0.84	0.97	0.29	0.33	-	-	-	-
0.9	12	1.98	2.24	1.03	1.19	0.35	0.4	0.06	0.06	-	-
1	14	2.38	2.7	1.24	1.43	0.42	0.48	0.07	0.08	-	-
1.2	16	3.29	3.74	1.72	1.98	0.59	0.67	0.09	0.11	-	-
1.4	18	4.33	4.91	2.25	2.6	0.77	0.88	0.12	0.14	-	-
1.6	21	5.49	6.23	2.86	3.3	0.97	1.11	0.15	0.18	-	0.05
1.8	24	6.77	7.68	3.52	4.06	1.2	1.37	0.19	0.22	0.06	0.06
2	26	8.17	9.27	4.25	4.9	1.45	1.65	0.23	0.26	0.07	0.08
2.5	33	12.18	13.83	6.33	7.3	2.15	2.45	0.34	0.39	0.1	0.12
3	40	16.89	19.18	8.77	10.12	2.97	3.4	0.46	0.53	0.14	0.16
3.5	46	22.29	-	11.56	13.35	3.92	4.47	0.61	0.7	0.18	0.21
4	53	-	-	14.7	16.98	4.98	5.68	0.77	0.89	0.23	0.26
4.5	60	-	-	18.18	20.99	6.15	7.02	0.95	1.1	0.29	0.33
5	66	-	-	-	-	7.43	8.49	1.15	1.32	0.34	0.39
5.5	73	-	-	-	-	8.82	10.07	1.37	1.57	0.41	0.47
6	79	-	-	-	-	10.32	11.78	1.6	1.83	0.48	0.55
7	92	-	-	-	-	13.62	15.59	2.11	2.42	0.63	0.72
8	106	-	-	-	-	-	19.82	2.68	3.07	0.8	0.91
9	119	-	-	-	-	-	24.54	3.31	3.8	0.98	1.13
10	132	-	-	-	-	-	29.71	4.0	4.59	1.19	1.36
11	145	-	-	-	-	-	-	4.75	5.46	1.41	1.62
12	158	-	-	-	-	-	-	5.56	6.39	1.65	1.89

POLYETHENE PIPE FRICTION LOSS METRIC

FLOW RATE		FRICTION LOSS (metres/100 metres of pipe)							
		OD 32mm		OD 40mm		OD 50mm		OD 63mm	
L/s	GPM	PN6.3	PN12.5	PN6.3	PN12.5	PN6.3	PN12.5	PN6.3	PN12.5
0.4	5	2.08	3.99	0.73	1.39	0.25	0.48	0.09	0.16
0.5	7	3.07	5.9	1.08	2.05	0.37	0.7	1.13	0.24
0.6	8	4.24	8.14	1.49	2.82	0.51	0.97	0.17	0.32
0.7	9	5.56	10.7	1.95	3.7	0.67	1.27	0.22	0.43
0.8	11	7.05	13.56	2.47	4.69	0.85	1.61	0.28	0.54
0.9	12	8.68	16.72	3.04	5.78	1.04	1.98	0.35	0.66
1	14	10.47	20.17	3.66	6.96	1.26	2.38	0.42	0.8
1.2	16	14.48	27.93	5.06	9.63	1.73	3.29	0.58	1.1
1.4	18	19.07	36.8	6.66	12.67	2.28	4.33	0.75	1.44
1.6	21	24.21	46.76	8.45	16.09	2.89	5.49	0.96	1.83
1.8	24	29.91	57.79	10.42	19.86	3.56	6.77	1.18	2.25
2	26	36.13	69.86	12.58	23.99	4.3	8.17	1.42	2.71
2.5	33	54.00	104.53	18.77	35.82	6.4	12.18	2.11	4.04
3	40	75.05	-	26.05	49.75	8.87	16.89	2.92	5.6
3.5	46	-	-	34.39	65.74	11.69	22.29	3.85	7.38
4	53	-	-	43.77	83.73	14.86	28.35	4.89	9.37
4.5	60	-	-	54.17	-	18.38	35.07	6.04	11.59
5	66	-	-	65.57	-	22.22	42.44	7.3	14.01
5.5	73	-	-	77.96	-	26.4	50.44	8.66	16.63
6	79	-	-	-	-	30.9	59.07	10.13	19.46
6.5	86	-	-	-	-	35.72	68.31	11.70	22.49
7	92	-	-	-	-	40.86	-	13.38	25.72

Charts courtesy of Grundfos Pumps.

Disclaimer: These friction loss charts are indicative only and must be confirmed by the manufacturer of the pipe you are using.



Pipe size mm	Equivalent length of straight pipe in metres, for calculating friction loss								
20	0.3	0.3	0.6	6.7	0.5	1.5	1.5	1.5	1.5
25	0.3	0.3	0.8	8.2	0.5	2.0	1.8	2.3	2.0
32	0.3	0.6	0.9	11.3	0.8	2.6	2.4	2.7	2.6
40	0.4	0.6	1.1	13.4	0.9	3.1	2.7	3.4	3.1
50	0.5	0.8	1.4	17.4	1.1	4.0	3.4	4.6	4.0
65	0.6	0.9	1.7	20.1	1.4	5.2	4.3	5.5	4.6
80	0.8	1.1	2.1	26.0	1.5	6.1	5.2	6.7	5.5
100	1.1	1.5	2.7	34.0	2.1	8.2	6.7	8.8	7.3
125	1.2	1.8	3.7	43.0	2.7	10.0	8.2	11.0	9.5
150	1.5	2.1	4.3	49.0	3.4	12.2	10.0	14.0	11.0
200	2.1	3.1	5.5	67.0	4.3	16.5	13.4	18.0	15.0
250	2.4	3.7	7.3	85.4	5.5	20.0	16.5	22.0	19.0
300	3.1	4.3	8.5	98.0	6.7	24.4	20.0	27.4	23.0

Thank You!!

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

NPTEL

Irrigation and Drainage

Lecture No: 33 Centrifugal Pumps: Power Requirement

Dr. DAMODHARA RAO MAILAPALLI

AGRICULTURAL AND FOOD ENGINEERING DEPARTMENT

IIT KHARAGPUR

Centrifugal Pump: Total Head

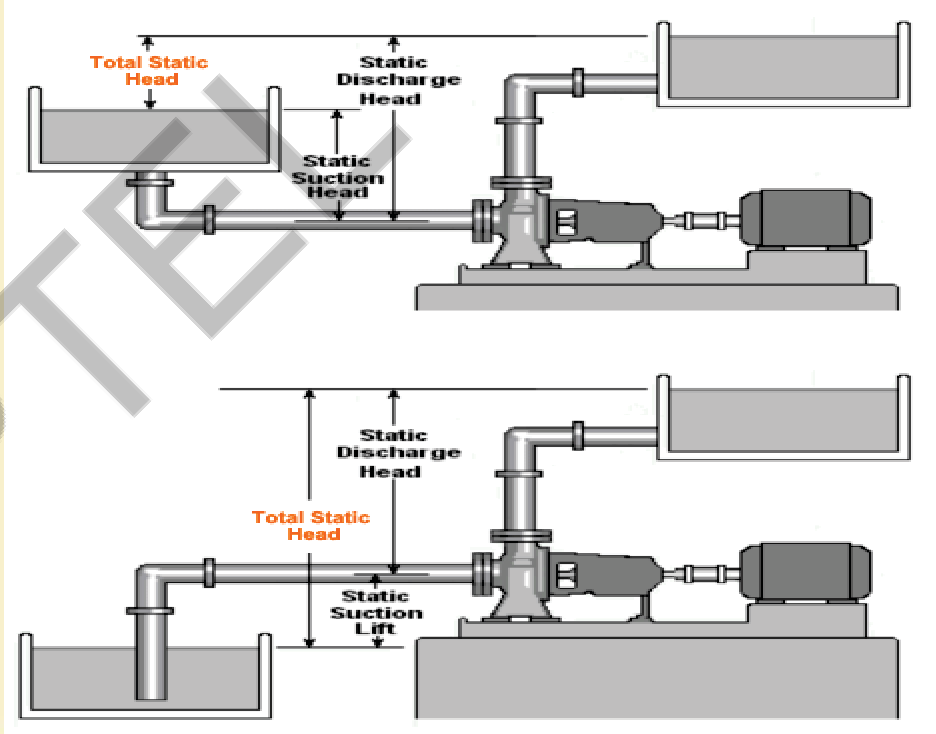
Total pumping head:

It is energy utilized to pump water

Two situations:

1) Water source is above the center line of pump
(submersible pump)

2) Water source is below the center line of pump

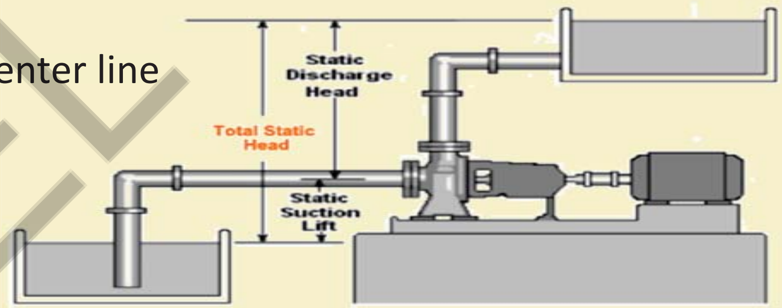


Centrifugal Pump: Total Head

1. Water resource is below the center line of pump:

a) Static suction lift (h_{ss})

Vertical distance from the free suction water level to the center line of pump



b) Total suction lift (H_s)

$$H_s = h_{ss} + h_{fs}$$

where,

h_{fs} = loss due to friction in suction pipe and fittings, m

c) Static discharge head (h_d):

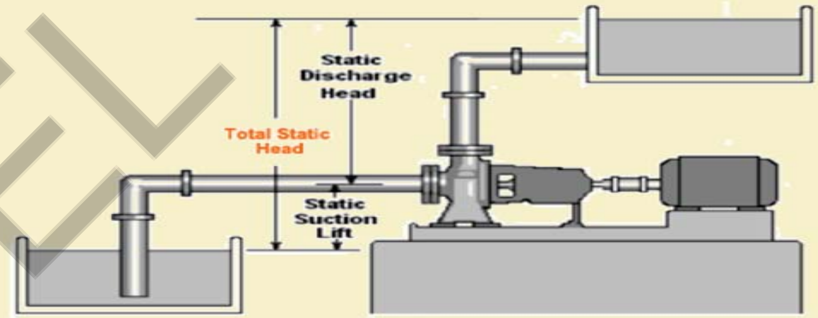
Vertical distance from the free discharge water level to the center line of pump

Centrifugal Pump: Total Head

d) Total discharge head (H_d):

$H_d = h_{sd} + h_{fd}$

where, h_{fd} = loss due to friction in delivery pipe and fittings, m



e) Velocity head (H_v):

Pressure required to create velocity of the flow in the pipe $H_v = v^2/2g$

f) Total head (H): $H_s + H_d + H_v$

$H = (h_{ss} + h_{fs}) + (h_{sd} + h_{fd}) + (v^2_s/2g + V^2_d/2g)$

Centrifugal Pump: Total Head

2. Water resource is above the center line of pump:

a) Static suction head (h_s)

Vertical distance from the free suction water level to the center line of pump

b) Total suction head (H_s)

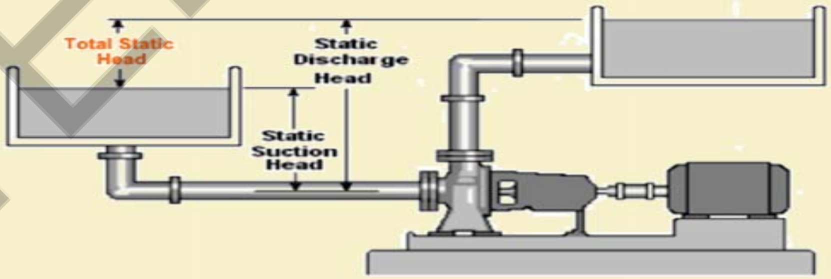
$H_s = -(h_s - h_{fs})$

where,

h_{fs} = loss due to friction in suction pipe fittings, m

c) Static discharge head (h_d):

Vertical distance from the free discharge water level to the center line of pump



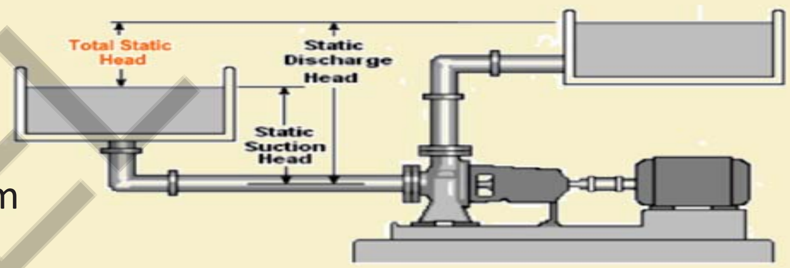
Centrifugal Pump: Total Head

d) Total discharge head (H_d):

$$H_d = h_d + h_{fd}$$

where,

h_{fd}= loss due to friction in delivery pipe fittings, m



e) Velocity head (H_v)

Pressure required to create velocity of the flow in the pipe

$H_v = v^2/2g$

f) Total head (H): $H_s + H_d + H_v$

$H = -(h_s - h_{fs}) + (h_d + h_{fd}) + (-v^2_s/2g + V^2_d/2g)$

Power Requirement in Pumps

To determine hp of the electric motor or engine to drive the pump

- ✓ **Water horse power (WHP)**

  It is theoretical power required for pumping

$$\text{WHP}=\frac{\text{DISCHARGE(lps)}\times\text{TOTAL HEAD , m}}{76}$$

$$=\frac{DISCHARGE\left(\frac{m^3}{s}\right)\times\text{TOTAL HEAD, m}}{0.076}$$

- ✓ **Shaft horse power (SHP)**

  It is the power required at the power shaft

$$\text{SHP}=\frac{\text{WHP}}{\text{PUMP EFFICIENCY}}$$

- ✓ **Brake horse power (BHP)**

  Actual hp supplied by the engine for driving a pump

  Incase of monoblockpump ,BHP=SHP

  Incase of belt driven pump, BHP= $\frac{WHP}{\eta d}$ where, ηd=drive efficiency

- ✓ **Input horse power (IHP):**

$$IHP=\frac{WHP}{\eta d \times \eta p \times \eta m}$$

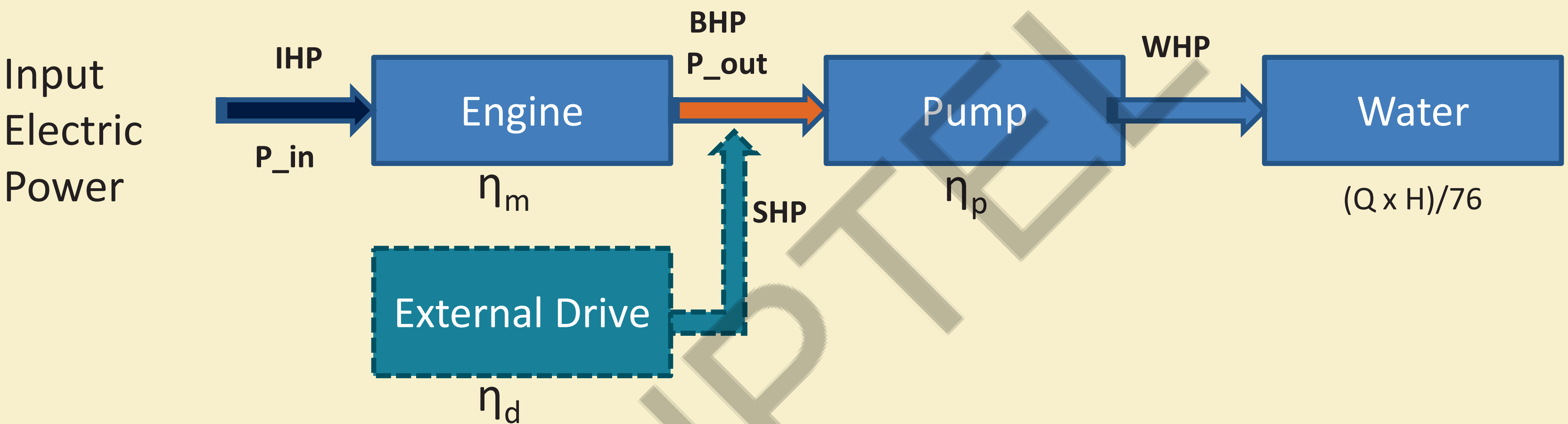
Where,

ηp= pump efficiency

ηm=motor efficiency

Kw input to electric motor= $\frac{BHP \times 0.746}{\eta m}$

Power Requirement in Pumps



$P\_in = VxI$

$P\_out = T \times \omega$
$= T \times rpm \times 2\pi \times 60$

$\eta_m = P\text{-}out/P\text{-}in$

Exercise 33.1:

A pump lifts 100,000 liters of water per hour operate at a total head of 20 m. Compute the WHP . If the pump has efficiency of 75%, what size of prime mover is required to operate the pump? If a direct driven electric motor with an efficiency of 80% is usual to operate the pump, compute the cost of electric energy in a units of 30 days. The pump is operated for 12 h daily for 30 days. The cost of electrical energy is ? 6 per unit

Solution :

$$\text{WHP} = \frac{\text{DISCHARGE(lps)} \times \text{TOTAL HEAD ,m}}{76}$$

$$= \frac{100000 \times 20}{60 \times 60 \times 76} = 7.3$$

$$\text{SHP} = \frac{\text{WHP}}{\text{PUMP EFFICIENCY}} = \frac{7.30}{0.75} = 9.73$$

Since the pump is direct driven , the SHP is same as BHP

Kw input to electric motor= $\frac{\mathrm{BHP}\times 0.746}{\eta m}$

$= \frac{9.73\times 0.746}{0.8}$

= 9.07 KW

Total energy consumption per month = 9.07×12×30

= 3265 KWH

Cost of electrical energy =3265×6 (1 unit= 1KWH)

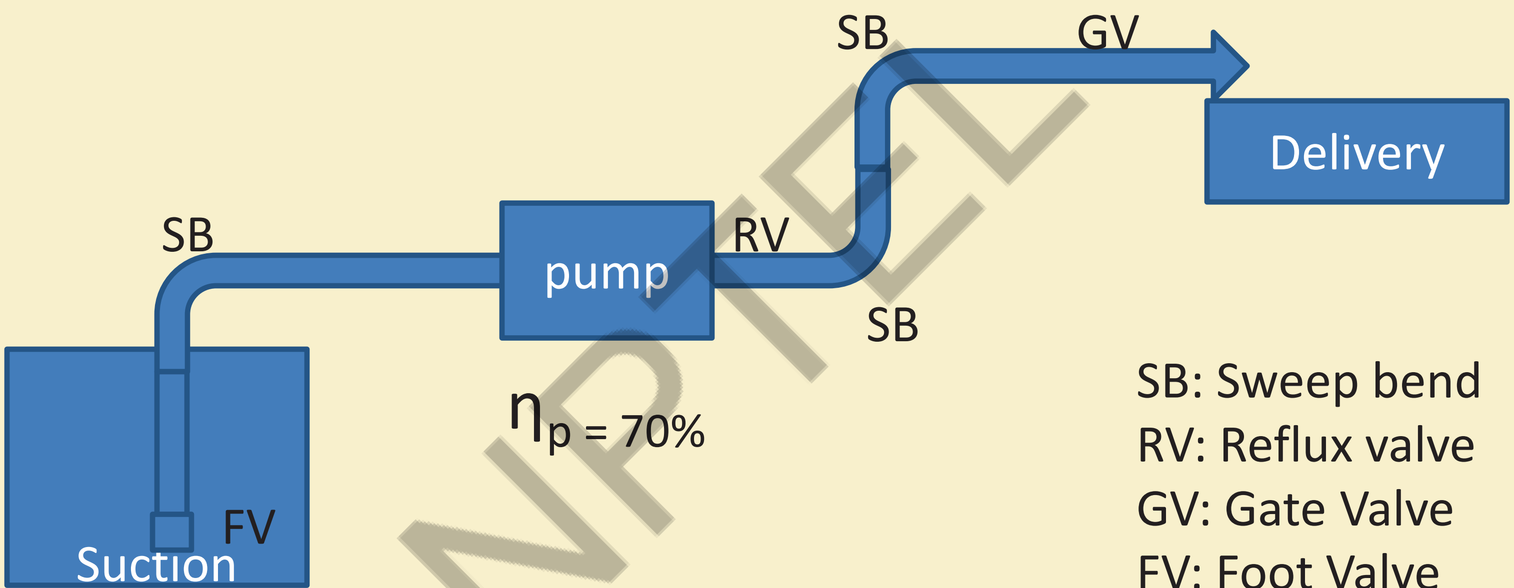
= ? **19,590**

Exercise 33.2:

A direct driven centrifugal pump coupled to a 3-phase electric motor is installed in a deep open well. The discharge rate of the pump is 20 lps. The pump efficiency is 70%. The center line of the pump is 60 cm vertical above the static water level and 6 m above the pumping water level. The suction pipe is 7.5 m long and 8 cm diameter. A foot valve with strainers is attached to the bottom of the suction pipe. The suction line in connected to the pump inlet by a long sweep bend of same size as the suction pipe. The pump discharges water into the top of the pump stand of an underground pipeline water distribution system. The vertical distance between the top of the stand and center line of the pump is 20 m. The total length of the 7 cm diameter discharge is 20m . The pipe fittings on the discharge side are three long sweep bends, one gate valve and one reflux valve, all of which are of the same size as the discharge pipe.

From the above data, compute

1) Total head
2) Water horse power
3) Brake horse power of the motor required to drive the pump



SB: Sweep bend
RV: Reflux valve
GV: Gate Valve
FV: Foot Valve

Solution :

Area of suction pipe $a_1 = \frac{\pi \times 8 \times 8}{4 \times 100 \times 100} = 0.005\ m^2$

Velocity of water in suction pipe $v_1 = \frac{Q}{a1} = \frac{20}{1000 \times 0.005} = 4$ m/s

Area of discharge pipe, $a_2 = 0.0038 m^2$

Velocity of water in the discharge pipe $v_2 = 5.26$ m/s

i. **Total head** = total suction lift + total discharge head

static suction lift = 6m

Head loss in suction pipe of 8 cm dia and 7.5 m length = 2.25 (from friction loss table)

Head loss in long sweep bend 8cm dia = 0.41 m

Head loss in strainer = $K_s \frac{v2}{2g} = 0.95 \times \frac{4 \times 4}{2 \times 9.81} = 0.77$ m

FRICTION LOSS CHARTS

PVC PIPE FRICTION LOSS

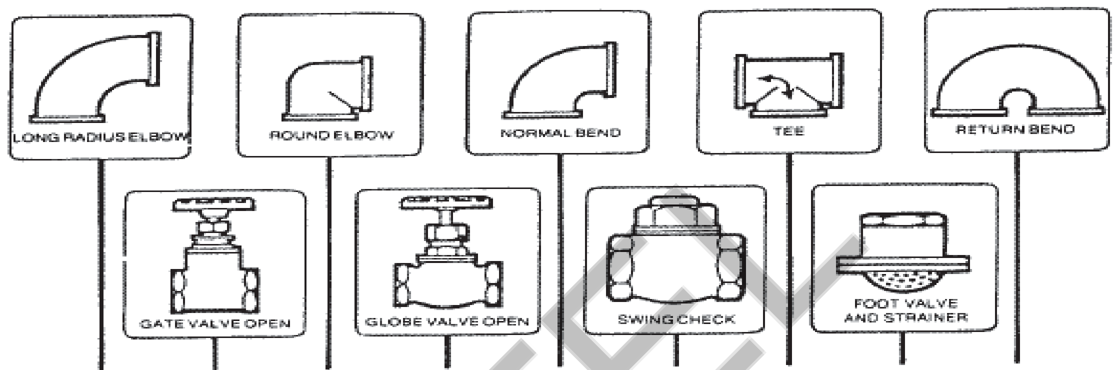
FLOW RATE		FRICTION LOSS (metres/100 metres of pipe)									
		Nom. 32mm		Nom. 40mm		Nom. 50mm		Nom. 80mm		Nom. 100mm	
L/s	GPM	PN9	PN12	PN9	PN12	PN9	PN12	PN9	PN12	PN9	PN12
0.4	5	0.48	0.54	0.25	0.29	0.09	0.1	-	-	-	-
0.5	7	0.7	0.8	0.37	0.42	0.13	0.14	-	-	-	-
0.6	8	0.97	1.1	0.51	0.58	0.17	0.2	-	-	-	-
0.7	9	1.27	1.44	0.66	0.77	0.23	0.26	-	-	-	-
0.8	11	1.61	1.82	0.84	0.97	0.29	0.33	-	-	-	-
0.9	12	1.98	2.24	1.03	1.19	0.35	0.4	0.06	0.06	-	-
1	14	2.38	2.7	1.24	1.43	0.42	0.48	0.07	0.08	-	-
1.2	16	3.29	3.74	1.72	1.98	0.59	0.67	0.09	0.11	-	-
1.4	18	4.33	4.91	2.25	2.6	0.77	0.88	0.12	0.14	-	-
1.6	21	5.49	6.23	2.86	3.3	0.97	1.11	0.15	0.18	-	0.05
1.8	24	6.77	7.68	3.52	4.06	1.2	1.37	0.19	0.22	0.06	0.06
2	26	8.17	9.27	4.25	4.9	1.45	1.65	0.23	0.26	0.07	0.08
2.5	33	12.18	13.83	6.33	7.3	2.15	2.45	0.34	0.39	0.1	0.12
3	40	16.89	19.18	8.77	10.12	2.97	3.4	0.46	0.53	0.14	0.16
3.5	46	22.29	-	11.56	13.35	3.92	4.47	0.61	0.7	0.18	0.21
4	53	-	-	14.7	16.98	4.98	5.68	0.77	0.89	0.23	0.26
4.5	60	-	-	18.18	20.99	6.15	7.02	0.95	1.1	0.29	0.33
5	66	-	-	-	-	7.43	8.49	1.15	1.32	0.34	0.39
5.5	73	-	-	-	-	8.82	10.07	1.37	1.57	0.41	0.47
6	79	-	-	-	-	10.32	11.78	1.6	1.83	0.48	0.55
7	92	-	-	-	-	13.62	15.59	2.11	2.42	0.63	0.72
8	106	-	-	-	-	-	19.82	2.68	3.07	0.8	0.91
9	119	-	-	-	-	-	24.54	3.31	3.8	0.98	1.13
10	132	-	-	-	-	-	29.71	4.0	4.59	1.19	1.36
11	145	-	-	-	-	-	-	4.75	5.46	1.41	1.62
12	158	-	-	-	-	-	-	5.56	6.39	1.65	1.89

POLYETHENE PIPE FRICTION LOSS METRIC

FLOW RATE		FRICTION LOSS (metres/100 metres of pipe)							
		OD 32mm		OD 40mm		OD 50mm		OD 63mm	
L/s	GPM	PN6.3	PN12.5	PN6.3	PN12.5	PN6.3	PN12.5	PN6.3	PN12.5
0.4	5	2.08	3.99	0.73	1.39	0.25	0.48	0.09	0.16
0.5	7	3.07	5.9	1.08	2.05	0.37	0.7	1.13	0.24
0.6	8	4.24	8.14	1.49	2.82	0.51	0.97	0.17	0.32
0.7	9	5.56	10.7	1.95	3.7	0.67	1.27	0.22	0.43
0.8	11	7.05	13.56	2.47	4.69	0.85	1.61	0.28	0.54
0.9	12	8.68	16.72	3.04	5.78	1.04	1.98	0.35	0.66
1	14	10.47	20.17	3.66	6.96	1.26	2.38	0.42	0.8
1.2	16	14.48	27.93	5.06	9.63	1.73	3.29	0.58	1.1
1.4	18	19.07	36.8	6.66	12.67	2.28	4.33	0.75	1.44
1.6	21	24.21	46.76	8.45	16.09	2.89	5.49	0.96	1.83
1.8	24	29.91	57.79	10.42	19.86	3.56	6.77	1.18	2.25
2	26	36.13	69.86	12.58	23.99	4.3	8.17	1.42	2.71
2.5	33	54.00	104.53	18.77	35.82	6.4	12.18	2.11	4.04
3	40	75.05	-	26.05	49.75	8.87	16.89	2.92	5.6
3.5	46	-	-	34.39	65.74	11.69	22.29	3.85	7.38
4	53	-	-	43.77	83.73	14.86	28.35	4.89	9.37
4.5	60	-	-	54.17	-	18.38	35.07	6.04	11.59
5	66	-	-	65.57	-	22.22	42.44	7.3	14.01
5.5	73	-	-	77.96	-	26.4	50.44	8.66	16.63
6	79	-	-	-	-	30.9	59.07	10.13	19.46
6.5	86	-	-	-	-	35.72	68.31	11.70	22.49
7	92	-	-	-	-	40.86	-	13.38	25.72

Charts courtesy of Grundfos Pumps.

Disclaimer: These friction loss charts are indicative only and must be confirmed by the manufacturer of the pipe you are using.



Equivalent length of straight pipe in metres, for calculating friction loss

Pipe size mm									
20	0.3	0.3	0.6	6.7	0.5	1.5	1.5	1.5	1.5
25	0.3	0.3	0.8	8.2	0.5	2.0	1.8	2.3	2.0
32	0.3	0.6	0.9	11.3	0.8	2.6	2.4	2.7	2.6
40	0.4	0.6	1.1	13.4	0.9	3.1	2.7	3.4	3.1
50	0.5	0.8	1.4	17.4	1.1	4.0	3.4	4.6	4.0
65	0.6	0.9	1.7	20.1	1.4	5.2	4.3	5.5	4.6
80	0.8	1.1	2.1	26.0	1.5	6.1	5.2	6.7	5.5
100	1.1	1.5	2.7	34.0	2.1	8.2	6.7	8.8	7.3
125	1.2	1.8	3.7	43.0	2.7	10.0	8.2	11.0	9.5
150	1.5	2.1	4.3	49.0	3.4	12.2	10.0	14.0	11.0
200	2.1	3.1	5.5	67.0	4.3	16.5	13.4	18.0	15.0
250	2.4	3.7	7.3	85.4	5.5	20.0	16.5	22.0	19.0
300	3.1	4.3	8.5	98.0	6.7	24.4	20.0	27.4	23.0

Head loss in foot valve = $K_f \frac{v2}{2g}$=0.8×$\frac{4\times4}{2\times9.81} = 0.65$ m

Velocity head (suction line)= $\frac{v2}{2g}$ = $\frac{4\times4}{2\times9.81}$ = 0.81 m

Total suction lift = 6 + 2.25 +0.77+ 0.65 + 0.81 + 0.41 =10.89 m

Static discharge head = 20 m

Head loss in discharge pipe of 7cm dia ad 20m length = $\frac{72\times20}{100}$ =14.4 m

Head loss in three long sweep bends, 7cm dia = 2.07 m

Head loss in gate valve of 7cm dia = 0.33 m

Head loss in reflux valve (based on foot valve and discharge velocity)=1.12 m

Velocity head (discharge line)= 1.40 m

Total discharge head =20+14.40+2.07+0.33+1.112+1.40 = 39.32 m

Total head = 10.89 + 39.32

= 50.21 m

ii. Water horse power = $\frac{20\times50.21}{76}$

= 13.21 hP

Brake horse power of motor required to drive the pump = $\frac{13.21}{70}\times100$

=18.87 hP

Thank You!!

Dr. D.R. Mailapalli
Agricultural and Food Engineering

IIT KHARAGPUR | NPTEL ONLINE CERTIFICATION COURSES

Irrigation and Drainage

Lecture No: 34 — Pump Characteristic Curves

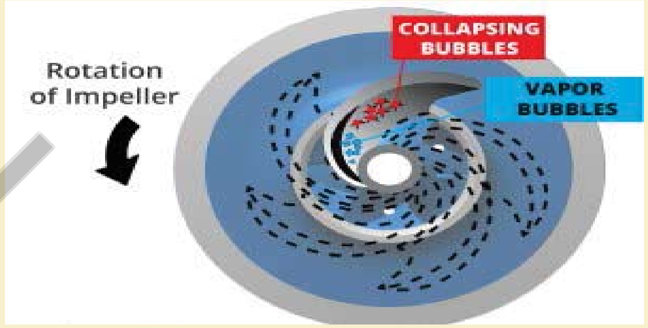
Dr. DAMODHARA RAO MAILAPALLI
AGRICULTURAL AND FOOD ENGINEERING DEPARTMENT
IIT KHARAGPUR

Centrifugal Pump: Cavitation

- ✓ If the pressure at any point inside a pump drops below the vapour pressure, corresponding to the temperature of the liquid, the liquid will vaporise and form cavities of vapour

- ✓ The bubbles of vapour are carried along the stream until a region of higher pressure is reached

- ✓ Cavitations occurs when they collapse or explode with tremendous shock on adjacent walls



Centrifugal Pump: Cavitation

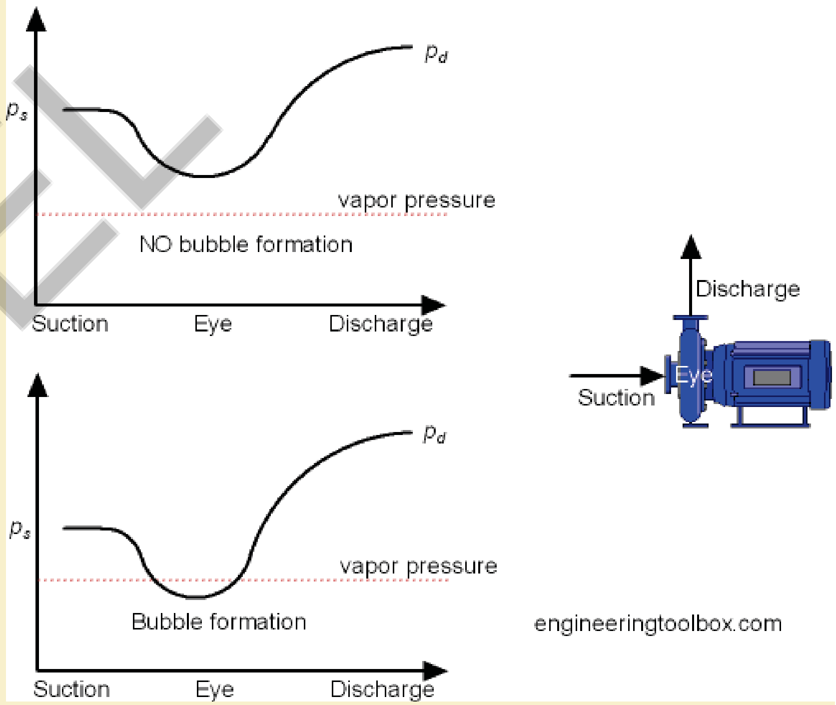
Cavitation coefficient (σ) = $\frac{H_{sv}}{H}$

where, H_{sv} = net positive suction head , m; H = total positive head, m

- The critical value of σ, at which cavitation will begin can be determined by testing the pump at constant speed and capacity at varying suction lifts
- Efficiency increases for lower σ value

  σ > 0.3 ⟹successful operation of pump

  safe suction lift (4.5 to 5 m for most of pumps)

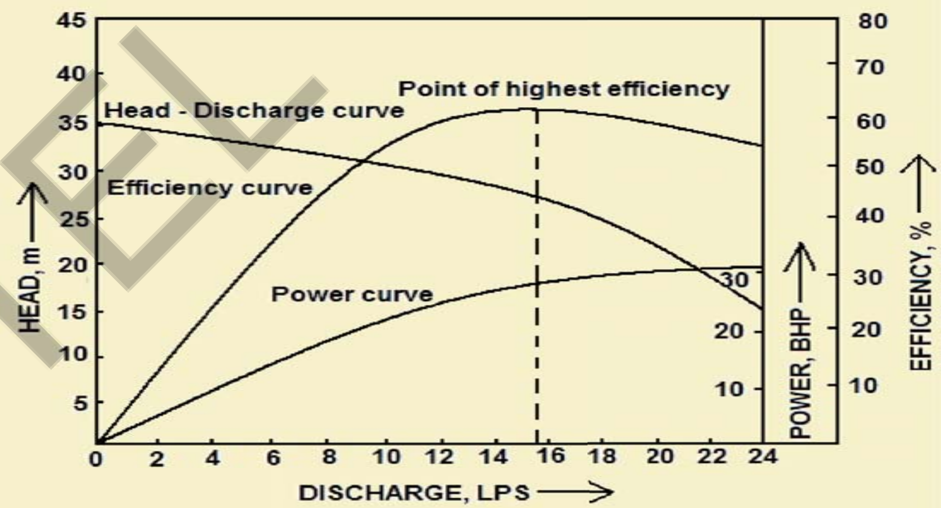


NET POSITIVE SUCTION HEAD(NPSH)

- ✓ The pressure head needed at the pump inlet may be termed as the net positive suction head or net required inlet head
- ✓ Total NPSH = NPSH + entrance and other frictional losses (in suction pipe)
- ✓ When pump water level is below the pump inlet
  - o NPSH = Atmospheric head-h_{ss}
- ✓ When pump water level is above the pump inlet
  - o NPSH = Atmospheric head + h_{ss}

Pump Characteristic Curves

- ✓ Centrifugal pumps have well defined operating properties that are expressed as Characteristics curves (performance curves)
- ✓ Knowledge on pump characteristics enables the selection of a pump for obtaining high efficiency at low operating costs



Characteristic Curves: Pumps in Series

- ✓ Incase of multi stage pumping operation, two or more pumps are connected and **operated in series**
  - o Single stages are connected in series
- ✓ Each stage adds an additional head to the fluid, but the

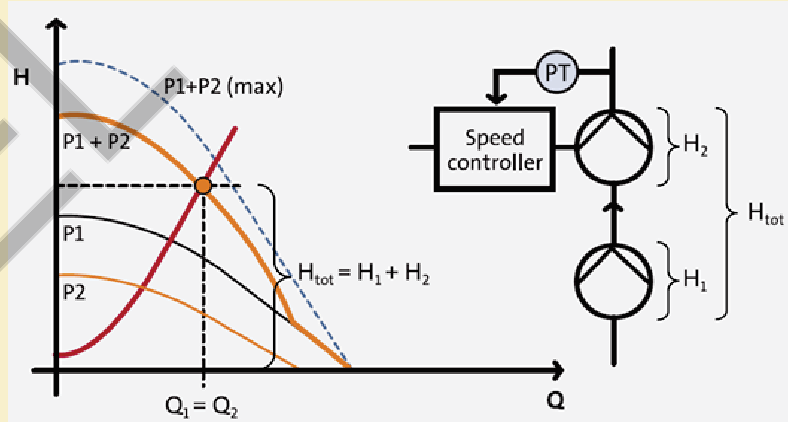
discharge is same

Discharge, $Q = Q_1 = Q_2$

Total Head, $H = H_1 + H_2$

Combined efficiency, $E_{series} = \frac{Q(H_1+H_2)}{102\times(BHP_1+BHP_2)}$

Where, H_1 = Total head for pump 1 ; H_2 = Total head for pump 2; BHP_1 = BHP of pump 1 in kW; BHP_2 = BHP of pump 2 in kW



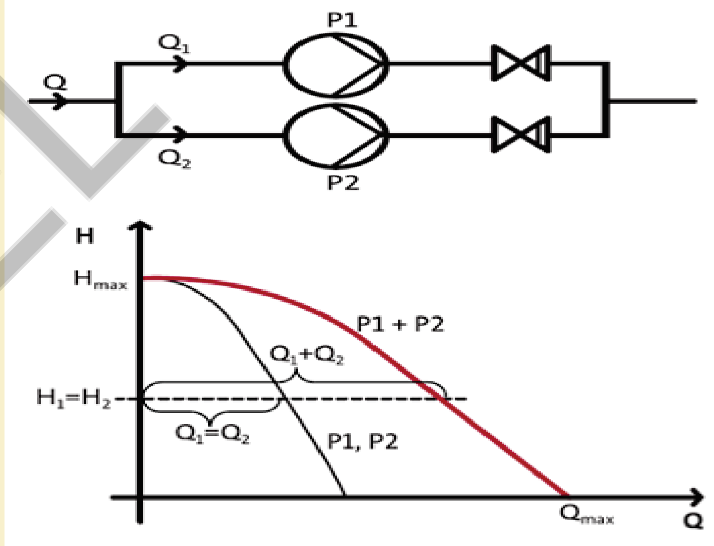
Characteristic Curves: Pumps in Parallel

- ✓ In this case water is pumped from a sump well by more than one pump in parallel
- ✓ the **head is constant**,

  $H = H_1 = H_2$
- ✓ Discharge is combined,

  $Q = Q_1 + Q_2$
- ✓ Combined Efficiency,

$$E_{Parallel} = \frac{H(Q_1 + Q_2)}{102 \times (BHP_1 + BHP_2)}$$



Two pumps connected in parallel with similar performance curves

Pump Performance

- ✓ Depends on design and installation
- ✓ Pump performance changes by changing the impeller diameter or speed using **affinity laws**
- ✓ **Affinity laws** are standard expressions that define changes in **pump capacity**, **head** and **BHP** when change is made to pump **speed**, impeller **diameter** or both

Affinity laws : Effect of change of pump **speed** on pump performance

$$Q = Q_1\left(\frac{n}{n_1}\right)^1 \qquad H = H_1\left(\frac{n}{n_1}\right)^2 \qquad P = P_1\left(\frac{n}{n_1}\right)^3$$

$$\frac{n}{n_1} = \frac{Q}{Q_1} = \sqrt{\frac{H}{H_1}} = \sqrt[3]{\frac{P}{P_1}}$$

Where, n_1 = Speed at which characteristics are known; n = desired new speed; Q_1 = pump capacity at n_1 rpm; Q = pump capacity at n rpm; P_1 = BHP at n_1, H_1 and Q_1; P = BHP at n, H and Q;

Affinity laws

Affinity laws : Effect of change of pump **Diameter** on pump performance

$$Q = Q_1\left(\frac{D}{D_1}\right)^1; \qquad H = H_1\left(\frac{D}{D_1}\right)^2; \qquad P = P_1\left(\frac{D}{D_1}\right)^3$$

$$\frac{D}{D_1} = \frac{Q}{Q_1} = \sqrt{\frac{H}{H_1}} = \sqrt[3]{\frac{P}{P_1}}$$

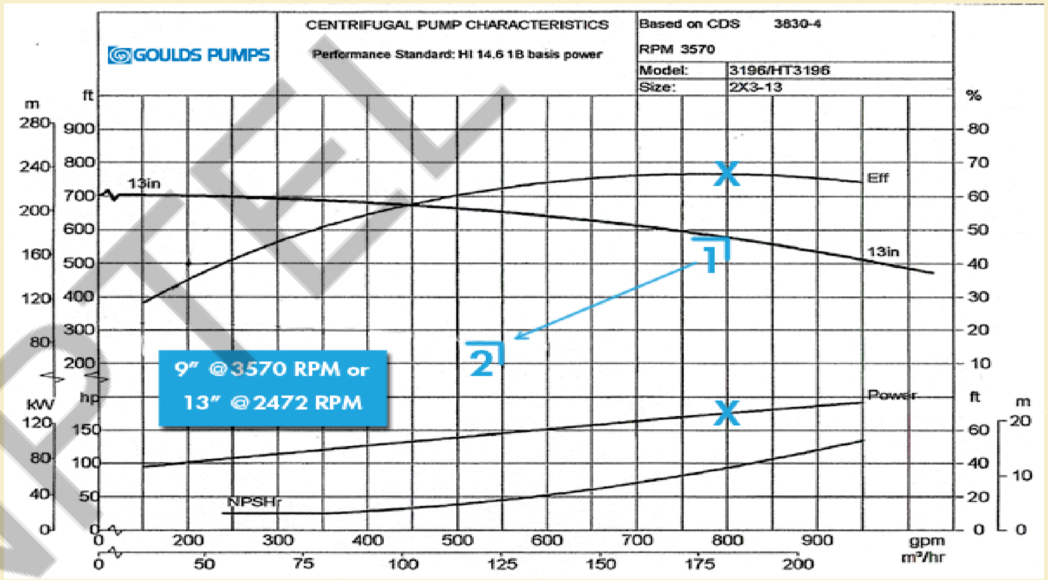
Combining the changes due to impeller speed and diameter

$$Q = Q_1\sqrt{\frac{D \times n}{D_1 \times n_1}}$$

Where, D_1 = Diameter of original impeller; D = Changed diameter of impeller; Q_1 = pump capacity at D_1; Q = pump capacity at D; P_1 = BHP at D_1, H_1 and Q_1; P = BHP at D, H and Q; D_1 = Diameter of original Impeller; D = Changed diameter of Impeller.

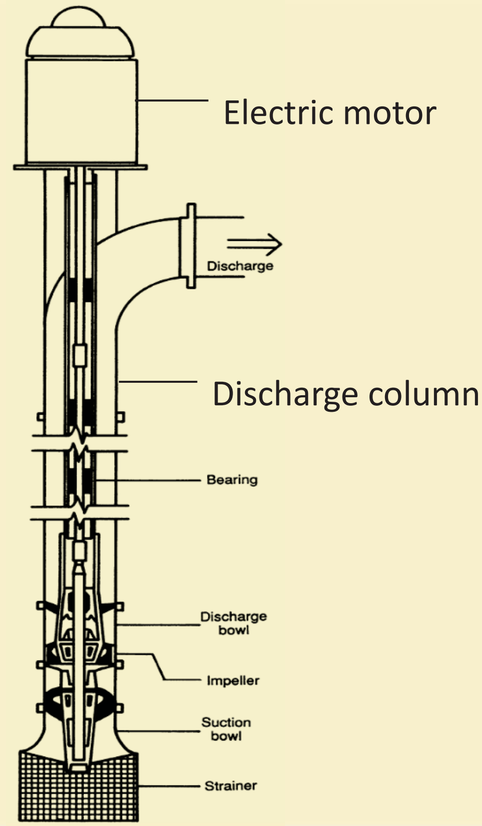
Affinity laws

- ✓ We have a pump with the initial operating point (1)
  - o Flow (Q): 800 GPM
  - o Head (H): 580’
  - o Horsepower (P): 175 HP
  - o Impeller diameter = 13”
  - o Pump speed = 3570 RPM
- ✓ Determine the pump output for a 9”impeller.
- ✓ Calculate the corresponding reduced speed to provide the same output with a 13”impeller.



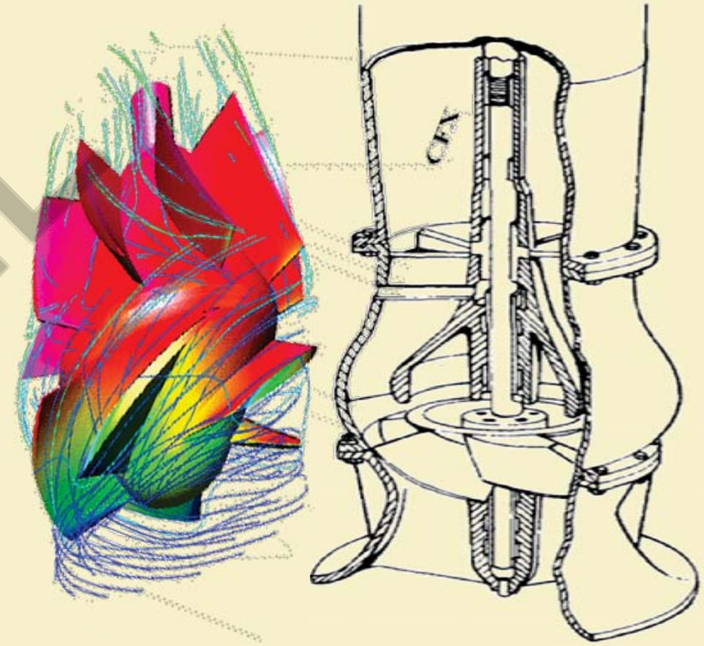
Propeller Pumps

- ✓ Adopted for high discharge and low head pumping
- ✓ Suitable to lift water from canals, rivers and streams
- ✓ Very popular in rice growing regions of south-east Asia
- ✓ The pressure head is developed mostly by the propelling or lifting action of the propeller blades on water
- ✓ Four sub-assemblies are
  - o Propeller and diffuser assembly
  - o Pump column
  - o Discharge column
  - o Pump drive



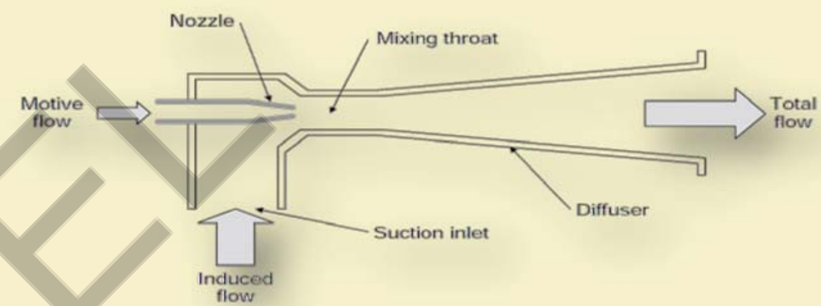
Mixed Flow Pumps

- ✓ It combines some of the features of both vertical turbine pump (centrifugal) and propeller pump
- ✓ Applicable for high discharge medium head (2.5 to 10 m)
- ✓ Extensively used for **drainage pumping** and pumping from canals, rivers or streams
- ✓ Head is developed partly by centrifugal force and partly by lift vanes on the liquid
- ✓ Flow enters axially and discharges in an axial and radial direction
- ✓ The main difference between the propeller and the mixed flow pump is the construction of the impeller, which gives outward thrust to water, in addition to imparting to it an upward velocity



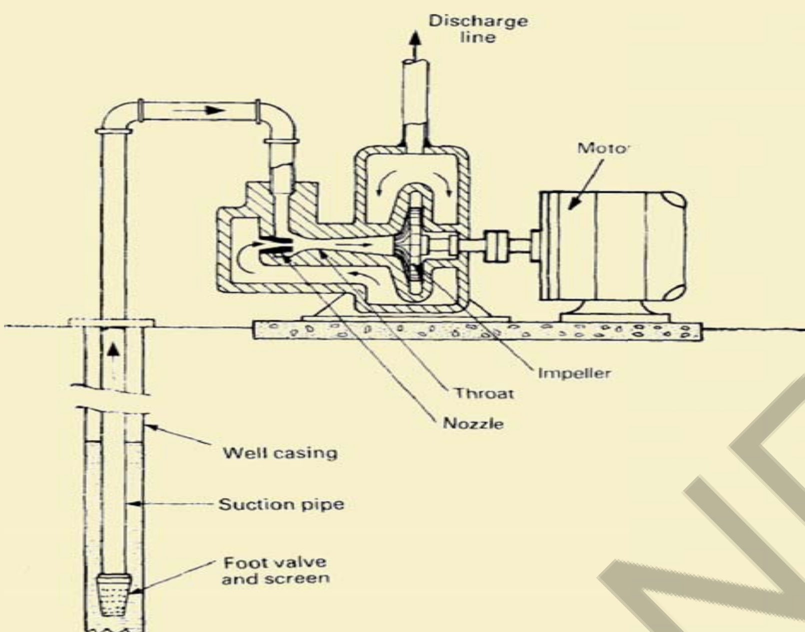
Jet Pumps (Ejector Pumps)

- ✓ Centrifugal pump with **jet assembly**
- ✓ Used to increase the suction lift
- ✓ **Types:**
  - ✓ **Shallow well jet pump**
    - ✓ jet assembly is inside the pump body
    - ✓ increases suction lift from 6.5 to 8.5m
  - ✓ **Deep well jet pump**
    - ✓ jet assembly is inside the well
    - ✓ suction lift can go up to 50m or 90 m (special jet pumps)

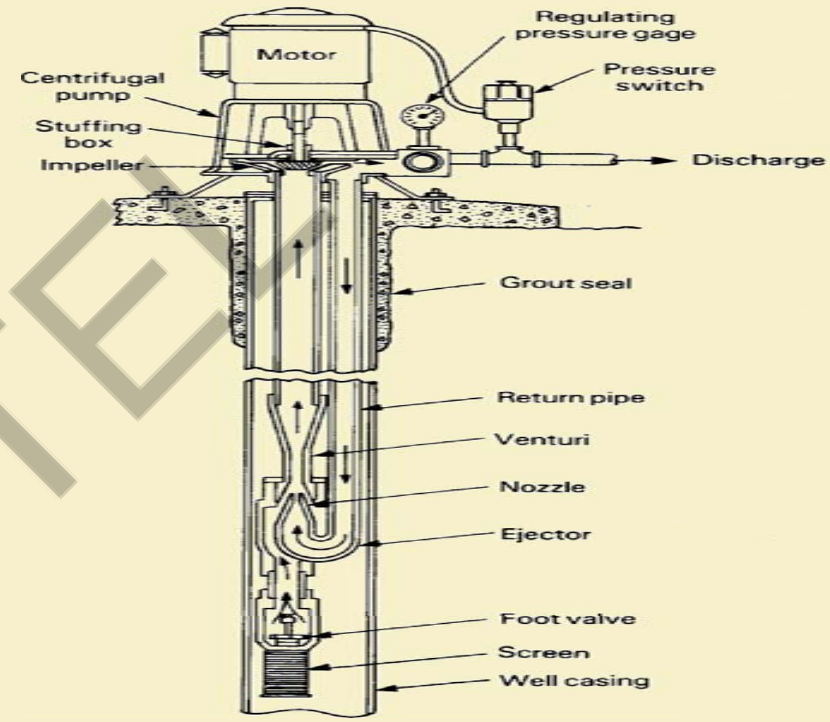


- ✓ Efficiency is mainly influenced by
  - o Nozzle throat ratio
- ✓ For small jet pumps
  - o Throat = nozzle diameter
  - o Length of throat = 6 × throat diameter

Jet Pumps: Types



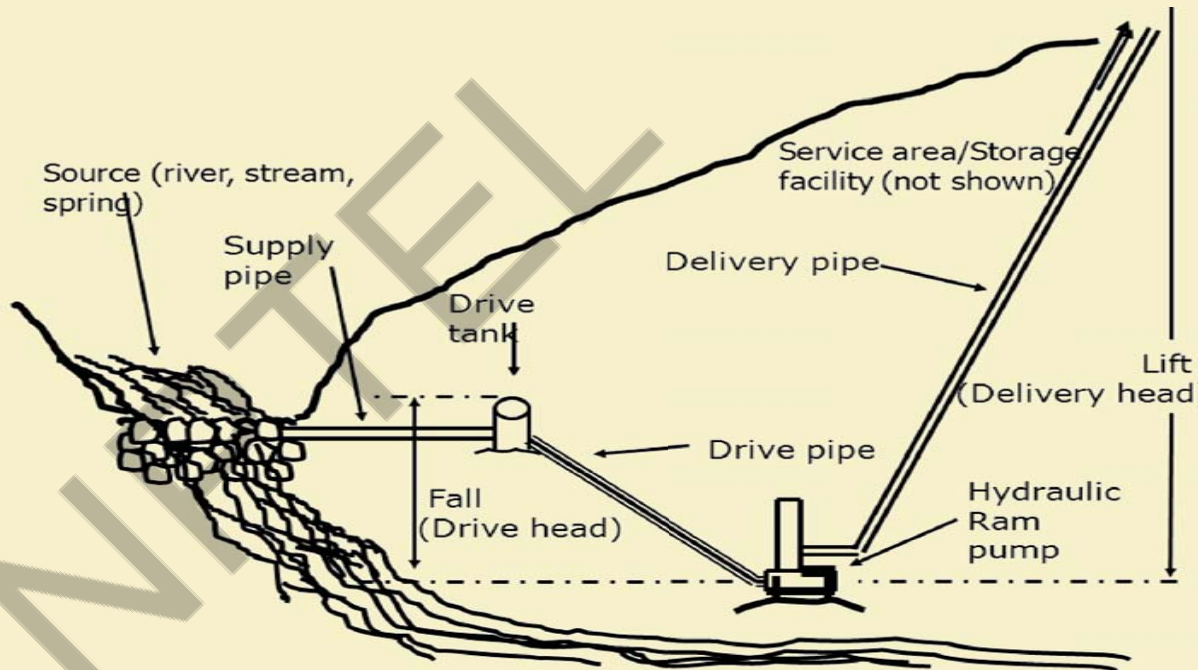
Shallow well jet pump



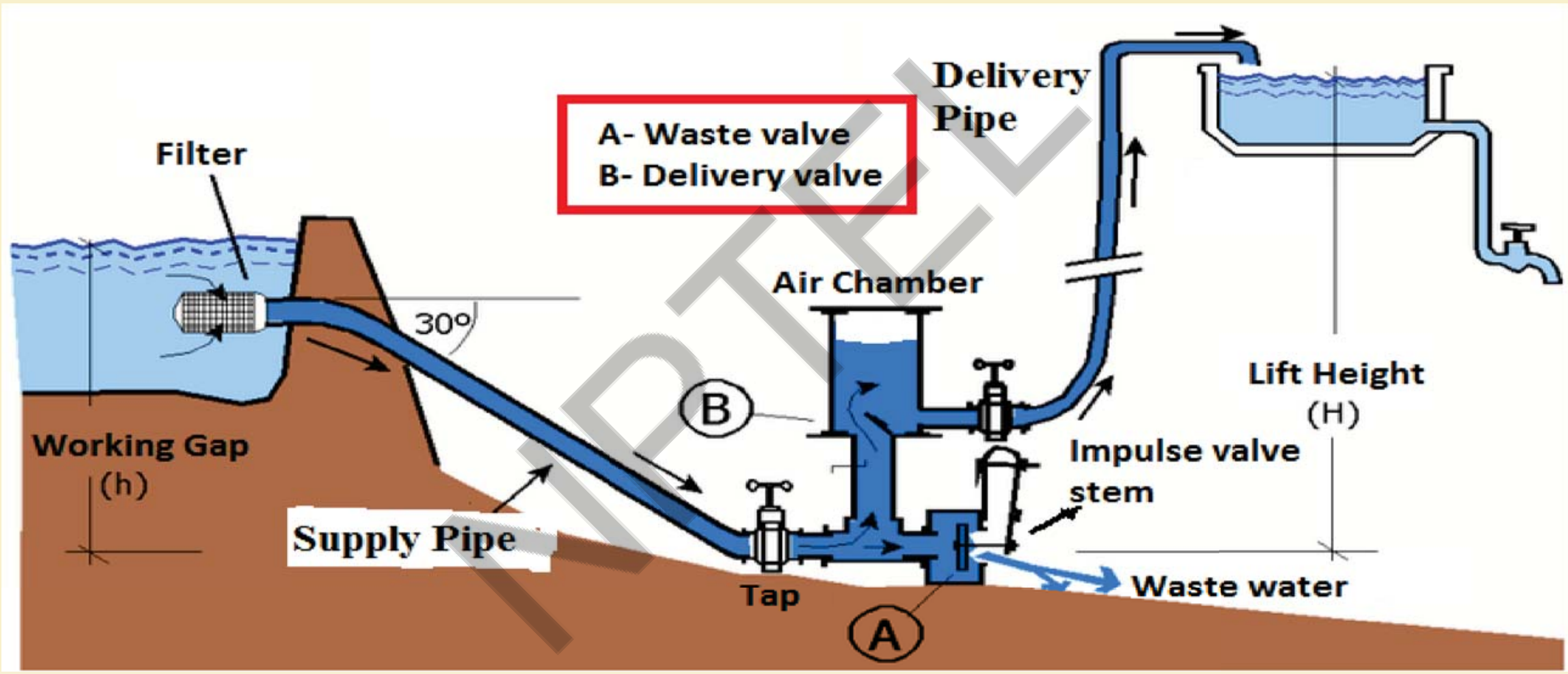
Deep well jet pump

Hydraulic Ram (Hydram)

- ✓ Water supply and irrigation in hilly areas
- ✓ Source of water may be a stream, a spring or an irrigation canal
- ✓ Simplicity of construction and the automatic operation of the hydraulic ram make it adapted to rural areas
- ✓ Works on the principle of water hammer



Hydraulic Ram: Working principle



Hydraulic Ram:

Advantages:

- ✓ Simple in construction and operation
- ✓ It does not incur any running cost, as it utilizes the energy of water available freely, and no fuel or electricity is required
- ✓ It has only two moving parts, the waste valve and the delivery valve, both of which are lubricated by the water itself.
- ✓ Ensures continuous water supply, as it operates throughout the day and night.
- ✓ Does not cause any pollution

Limitations:

- ✓ A minimum fall of 1 m from the stream to ram is required
- ✓ It lifts about 1/20th to 1/10th of the water supplied through the drive pipe.
- ✓ Since it works for 24 hours a day, a storage tank is necessary to store the night supply.

Thank You!!

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

NPTEL

Irrigation and Drainage

Lecture No: 35 Tutorial W7

Dr. DAMODHARA RAO MAILAPALLI

AGRICULTURAL AND FOOD ENGINEERING DEPARTMENT

IIT KHARAGPUR

Exercise W 7.1:

Which one of the following is a **WRONG** statement? **(GATE 2018)**

a. The head generated by a centrifugal pump at zero discharge is the 'shutoff head'.

b. To avoid cavitation in centrifugal pumps, the net positive suction head should be more than the theoretical atmospheric pressure.

c. According to the affinity laws of centrifugal pumps, the head varies with the square of the impeller speed.

d. Most of the turbine pumps have operational characteristics closer to those of the centrifugal pumps than the propeller pumps.

Exercise W7.2:

The pump used in high pressure orchard sprayer is **Plunger type positive displacement pump**

(GATE 2017)

Exercise W7.3:

When the water level in a well is at a depth of 7 m from the surface, the most suitable pump to lift water for irrigation is ****** ______________ **(GATE 2007)**

Exercise W7.4:

A pumping device that combines the advantages of both centrifugal and reciprocating pumps is known as **Rotary pump** **(GATE 2012)**

Exercise W7.5:

The brake horse power of a centrifugal pump having an impeller diameter of 200 mm is 1.86 kW. If the impeller is replaced with another impeller of 180 mm diameter, the brake power of the pump in kW will be __________ **(GATE 2014)**

Solution:

Given,

D_1 = Diameter of original Impeller = 200 mm

D = Changed diameter of Impeller = 180 mm

P1 = BHP at D_1= 1.86 KW

$$\frac{D}{D_1} = \sqrt[3]{\frac{P}{P_1}}$$

$$\frac{200}{180} = \sqrt[3]{\frac{1.86}{P_1}};$$

$$1.1111^3 = \frac{1.86}{P_1}$$

$$1.1111^3 = \frac{1.86}{P_1};$$

$$1.371 = \frac{1.86}{P_1}$$

$$P_1 = \frac{1.86}{1.371};$$

$$\boldsymbol{P_1 = 1.35}$$ **(Ans.)**

Exercise W7.6:

A six-stage centrifugal pump delivers 120 L/sec against a total head of 510 m. If the design speed of this pump is 1450 rpm, the specific speed of the pump will be __________ **(GATE 2017)**

Solution:

Given,

n =1450 rpm

Q= 120 L/sec = 0.12 m^3/s

Total head of six stage centrifugal pump = 510 m

$$Head = \frac{510}{6} = 85$$

$$n_s = \frac{nQ^{1/2}}{H^{3/4}}$$

$$n_s = \frac{1450 \times 0.120^{1/2}}{85^{3/4}}$$

$$n_s = \frac{1450 \times 0.3464}{27.99}$$

$$n_s = \frac{502.294}{27.99}$$

$\boldsymbol{n_s = 17.94}$ **rpm (Ans.)**

Exercise W7.7:

A 5 ha field under wheat crop is irrigated at 40% depletion of available moisture content. The field capacity, wilting point and bulk density of the soil in the field are 32% (on weight basis), 20% (on weight basis) and 1400 kg/m^3 respectively. To irrigate the field in a day of 10 hours, a pump is used which lifts 270 m^3 of water per hour against a total head of 20 m. **(GATE 2011)**

a. If the root zone depth is 0.8 m, the volume of water required to irrigate the field in m^3 will be ______

b. The pump is driven by an electric motor. If the pump, drive and motor efficiencies are 80%, 82% and 90% respectively, the required size of electric motor in horse-power will be______

Solution:

Given,

field capacity= 32%=0.32

wilting point= 20%= 0.2

bulk density= 1400 kg/m^3 = 1.4 g/cm^3

$Time = 10\ h$

$Head = 20\ m$

Pump efficiencies =80%

Drive efficiencies =82%

Motor efficiencies =90%

$$Available\ water = \frac{(field\ capacity - \ wilting\ point)}{100} \times \text{bulk density} \times rootzone\ depth$$

$$Available\ water = \frac{(32 - 20)}{100} \times 1.4 \times 80$$

$$= 13.44 \text{ cm}$$

$$Irrigation\ required = Available\ water \times \text{depletion of available moisture}$$

$$= 13.44 \times \frac{40}{100} = 5.376 \text{ cm}$$

$$volume\ of\ water = Area \times Irrigation\ required$$

$$volume\ of\ water = 5 \times 10000 \times 0.05376$$

$$= 2688\ \mathbf{m^3}$$

$$Pump\ horse - power = \frac{Discharge\ (lps) \times head(m)}{76 \times efficency}$$

$$Discharge = \frac{2688}{10} = 268.8 \text{ m}^3\text{/h}$$

$$Discharge = 74.67 \text{ l/sec}$$

$$Pump\ horse - power = \frac{74.67 \times 20}{76 \times 0.9 \times 0.82 \times 0.8} = \mathbf{33.28}$$

$$\cong \mathbf{33\ hp}$$

Thank You!!

Dr. D.R. Mailapalli
Agricultural and Food Engineering