4.7 SLIP OF RECIPROCATING PUMP

The discharge of a single acting reciprocating pump and a double acting reciprocating pump are given by equations 4.1 and 4.5 respectively. But in actual practice, the actual discharge is less than the theoretical discharge. The difference between theoretical discharge and actual discharge is known as **slip of the pump**. This is due to leakage and friction in the pipe lines. The ratio of actual discharge to its theoretical discharge is known as **co-efficient of discharge** (C_d). If coefficient of discharge is given in terms of percentage, then it is known as **volumetric efficiency.**

$$\text{Slip} = Q_{th} - Q_a$$

It can be expressed in terms of percentage,

$$\text{(ie) Percentage of slip} = \frac{Q_{th} - Q_a}{Q_{th}} \times 100$$

$$= \left(1 - \frac{Q_a}{Q_{th}}\right) \times 100 = (1 - C_d) \times 100 \quad \text{... (4.9)}$$

$$C_d = \frac{Q_a}{Q_{th}} = \text{co–efficient of discharge}$$

4.7.1 Negative Slip

When actual discharge is greater than the theoretical discharge, the slip of the pump will be negative. This slip is known as **negative slip**. It occurs, when suction pipe is long, delivery pipe is short and the pump is running at very high speed.

Problem 4.1: *A single acting reciprocating pump has a plunger of diameter 150 mm, stroke of 300 mm length and discharges 200 litres of water per minute at 40 rpm. Neglecting losses, find: 1. Theoretical discharge; 2. Co-efficient of discharge, and 3. percentage slip of the pump.*

Given:

Piston dia, $D = 150 \text{ mm} = 0.15 \text{ m}$; Stroke length, $L = 300 \text{ mm} = 0.3 \text{ m}$

Actual discharge $Q_a = 200 \text{ l/min}$

$$= \frac{200}{60 \times 1000} \text{ m}^2\text{/sec} = 0.003333 \text{ m}^3\text{/sec}$$

Speed $N = 40$ rpm $\qquad (\because 1\text{lit} = 1000 \text{ m}^3)$

Solution:

Area of the piston

$$A = \frac{\pi}{4} D^2 = \frac{\pi}{4}(0.15)^2 = 0.0176738 \text{ m}^2$$

(i) Theoritical discharge,

$$Q_{th} = \frac{LAN}{60} = \frac{0.3 \times 0.0176714 \times 40}{60} = \mathbf{0.00353429 \text{ m}^3\text{/sec}}$$

(ii) Coefficient of discharge $C_d = \frac{Q_a}{Q_{th}} = \frac{0.00333333}{0.00353476} = \mathbf{0.9430}$

(iii) Percentage of slip $= \left(\frac{Q_{th} - Q_a}{Q_{th}}\right) \times 100$

$$= \left[\frac{0.00353476 - 0.00333333}{0.00353476}\right] \times 100 = \mathbf{5.6985\%}$$

4.8 INDICATOR DIAGRAM

The diagram drawn for reciprocating pump in such a way that pressure head in the cylinder is marked in y axis (ordinate) and stroke length of piston is taken in x axis (abscissa), is known as **indicator diagram**.

This diagram shows pressure head of the liquid in the cylinder corresponding to any position during suction and delivery strokes.

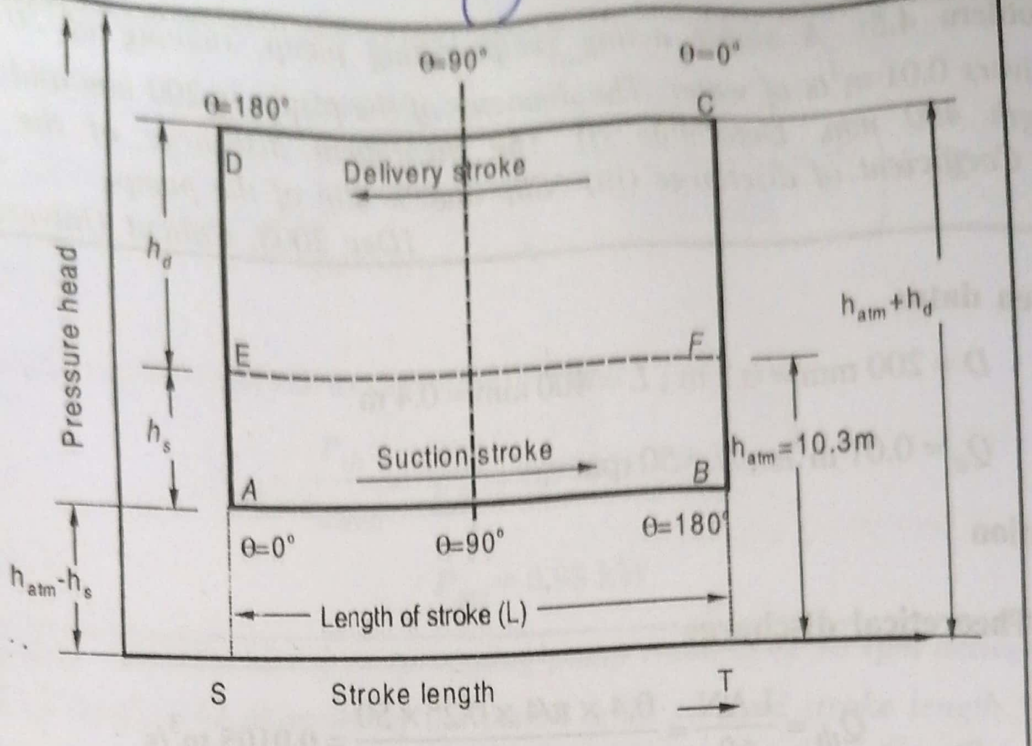

Fig 4.3 Ideal Indicator Diagram.

We know that pressure in the cylinder during suction stroke is less than the atmospheric pressure, and pressure in the cylinder during delivery stroke is more than the atmospheric pressure.

We know, atmospheric pressure head $h_{atm} = 10.3$ m of water

Let h_s = Suction head of the pump

h_d = Delivery head of the pump

The line AB represents pressure head during suction stroke.

So the absolute pressure head in the cylinder during suction stroke is equal to $h_{atm} - h_s$ as shown in **Fig. 4.3** and it is constant throughout the suction stroke.

ie $h_A = h_B = h_{atm} - h_s$

The line EF represents the atmospheric pressure head $h_E = h_F = 10.3$ m

The line CD represents the pressure head during delivery stroke.

4.10 AIR VESSELS

CA4 (3)

Air vessel is a closed chamber having an opening at its bottom side fitted to the suction pipe and delivery pipe, close to the cylinder. Compressed air is filled up inside the air vessel. The purpose of air vessel is to give uniform flow of liquid (to get uniform velocity of flow).

During first half of the delivery stroke, the piston accelerates to force the water into delivery pipe with more velocity than average velocity. The excess flow of water flows into the air vessel compressing the air inside the air vessel. During second half of the delivery stroke, the piston moves with deceleration (negative acceleration) forcing the water into the delivery pipe with a less velocity than the average velocity. Now the water stored in the air vessel starts flowing into the delivery pipe to make up the deficiency of flow. So the discharge in the delivery pipe above the air vessel becomes

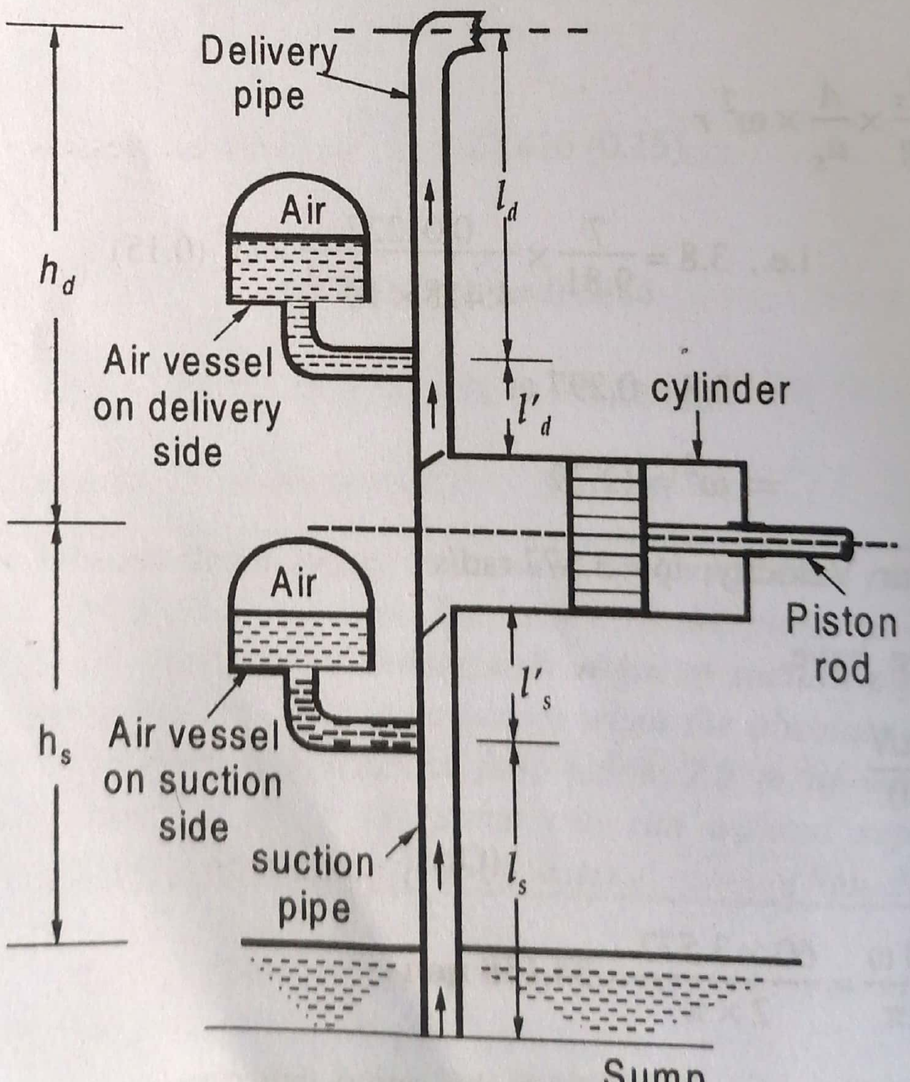

Fig 4.7 Reciprocating pump with air vessels.

4.12 HYDRAULIC RAM

A hydraulic ram is a cyclic water pump that uses the momentum of a relatively large amount of moving water to pump a relatively small amount of water uphill. In the device, the effect of water hammer is used to develop pressure that allows a portion of the input water to be lifted to a point higher than where the water originally started. To use a ram pump, the source of water must be situated above the pump. For example, a pond on a hillside, so that the pump can be located below the pond.

Hydraulic rams are used for two main reasons.

- They do not require an external source of power. The force of moving water (kinetic energy) gives them the power they need.
- They are extremely simple with just two moving parts - a spring or weight loaded waste valve and a delivery check valve. Hence these pumps are cheap to build, easy to maintain and reliable.

The device is also called as **hydram.**

The basic components of a hydraulic ram are

- Inlet/Supply pipe
- Inlet valve
- Chamber
- Waste valve
- Delivery check valve
- Outlet/Delivery pipe
- Air vessel

The sequence of operation is as follows:

$= 78.5\%$

4.13 HYDRAULIC ACCUMULATOR

Accumulator is used as an auxiliary power source. It is a device which stores the potential energy of the fluid held under pressure by an external source against some dynamic force from **gravity, mechanical springs** and **compressed gases**. The pressurized fluid is released to the system on demand. That is the stored potential energy in the accumulator acts as a quick secondary source of power and does useful work as required by the system.

Accumulators improve the system efficiency by reducing the pump requirement.

The following are the three basic types of accumulators used in hydraulic systems.

1. Gravity type (or) weight loaded type
2. Spring loaded type
3. Gas loaded type

Weight loaded (or) Gravity type accumulator

This type of accumulator consists of vertical steel cylinder containing piston with packings to prevent leakage. A dead weight is added on the top of the piston.

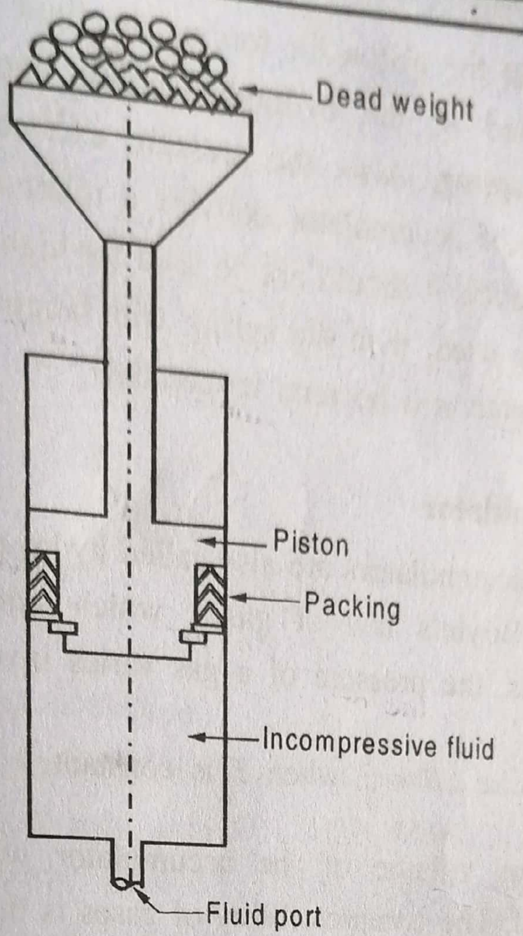

Fig: 4.12 Weight - loaded accumulator

This dead weight due to gravitation force provides the potential energy in the accumulator. This type of accumulator provides a constant fluid pressure through out the full volume output of the unit regardless of rate and quantity of output. But this type of accumulator is extremely heavy in weight and large in size and hence is not suitable for mobile equipment.

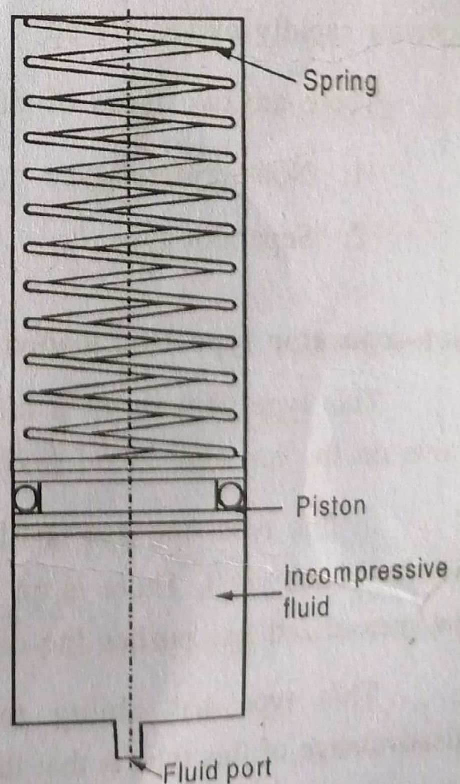

Fig: 4.13 Spring Type Accumulator

Spring type accumulator

A spring type accumulator is similar to gravity type except that the piston is preloaded with compressed spring. Here the spring is the source of

4.16 JET PUMP

3

Jet pumps, also known as ejector pumps, are devices capable of handling and transporting all forms of motive fluid including gas, steam, or liquid. They are mainly used for household water supply from well, driven point system, or open water source.

Jet pumps are centrifugal pumps with an ejector (venturi nozzle) attached at the discharge outlet. Jet pump is used when the suction lift of the centrifugal pump exceeds the permissible limits.

They function based upon the Venturi effect of Bernoulli's principle - utilizing constriction to reduce pressure and provide suction. After the pump

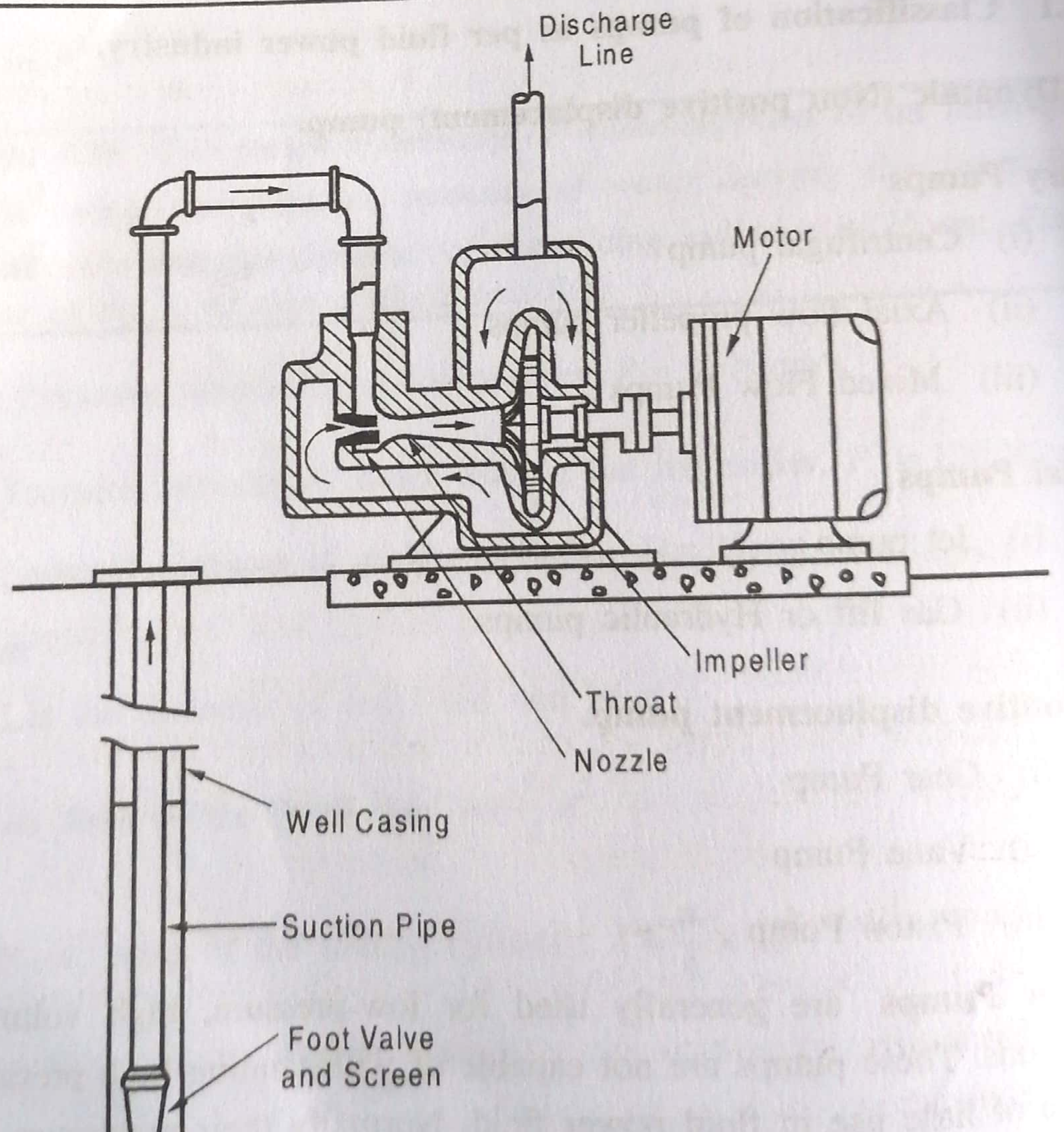

Fig: 4.18 Jet Pump System