LNCT GROUP OF COLLEGES

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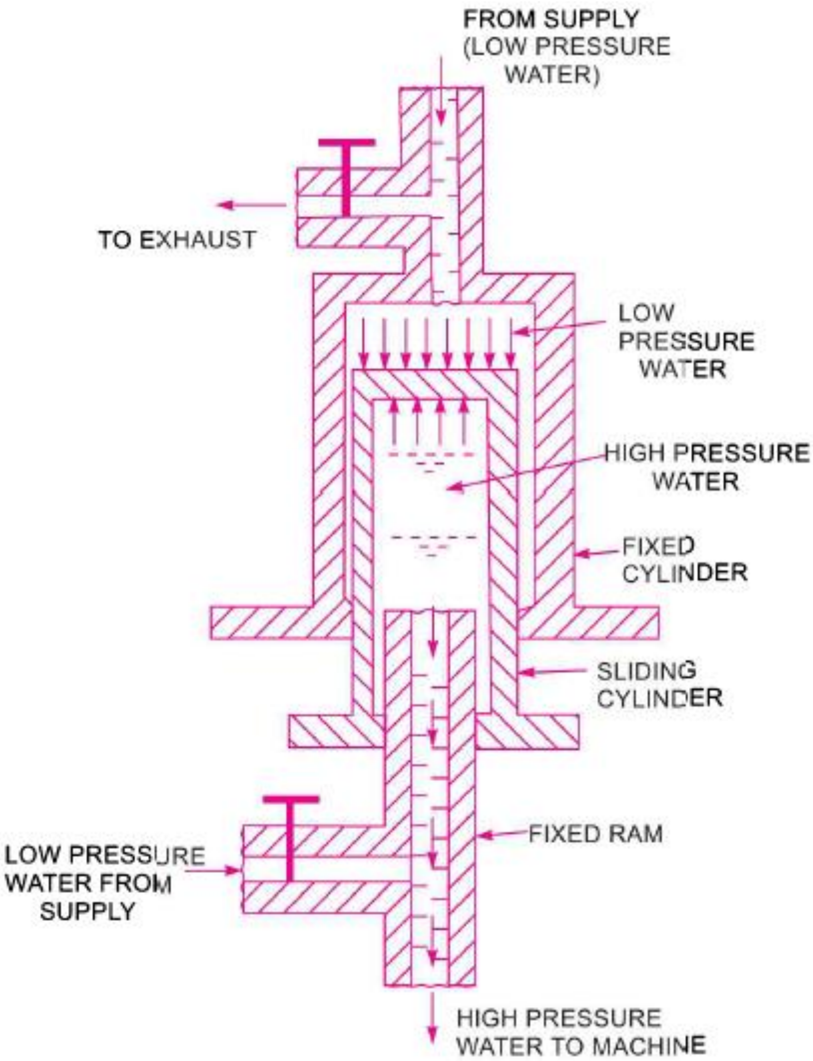
Topic: Hydraulic intensifier and hydraulic ram (as per RGPV Syllabus)

## THE HYDRAULIC INTENSIFIER

The device, which is used to increase the intensity of pressure of water by means of hydraulic energy available from a large amount of water at a low pressure, is called the hydraulic intensifier. Such a device is needed when the hydraulic machines such as hydraulic press requires water at very high pressure which cannot be obtained from the main supply directly.

A hydraulic intensifier consists of fixed ram through which the water, under a high pressure, flows to the machine. A hollow inverted sliding cylinder, containing water under high pressure, is mounted over the fixed ram. The inverted sliding cylinder is surrounded by another fixed inverted cylinder which contains water from the main supply at a low pressure as shown in Fig.



A large quantity of water at low pressure from supply enters the inverted fixed cylinder. The weight of this water pressure the sliding cylinder in the downward direction. The water in the sliding cylinder gets compressed due to the downward movement of the sliding cylinder and its pressure is thus increased. The high pressure water is forced out of the sliding cylinder through the fixed ram, to the machine as shown in Fig.

Let $p$ = Intensity of pressure of water from supply to the fixed cylinder (low pressure water),

$A$ = External area of the sliding cylinder,

$a$ = Area of the end of the fixed ram, and

$p^*$ = Intensity of the pressure of water in the sliding cylinder (high pressure water).

The force exerted by low pressure water on the sliding cylinder in the downward direction

$$= p \times A.$$

The force exerted by the high pressure water on the sliding cylinder in the upward direction

$$= p^* \times a.$$

Equating the upward and downward forces,

$$p \times A = p^* \times a.$$

$$p^* = \frac{p \times A}{a}.$$

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**Problem** *The diameters of fixed ram and fixed cylinder of an intensifier are 8 cm and 20 cm respectively. If the pressure of the water supplied to the fixed cylinder is 300 N/cm², find the pressure of the water flowing through the fixed ram.*

**Solution.** Given :

Dia. of fixed ram, $d = 8$ cm

$\therefore$ Area of fixed ram, $a = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times 8^2 = 16\,\pi\ \text{cm}^2$

Dia. of fixed cylinder, $D = 20$ m

$\therefore$ Area of fixed cylinder, $A = \frac{\pi}{4} \times 20^2 = 100\,\pi\ \text{cm}^2$

Intensity of supply pressure, $p = 300\ \text{N/cm}^2$

Let the intensity of pressure of water flowing through fixed ram

$$= p^*$$

$$p^* = \frac{p \times A}{a} = \frac{300 \times 100\pi}{16\pi} = \textbf{1875 N/cm}^2\textbf{. Ans.}$$

**Problem** *The pressure intensity of water supplied to an intensifier is 20 N/cm² while the pressure intensity of water leaving the intensifier is 100 N /cm². The external diameter of the sliding cylinder is 20 cm. Find the diameter of the fixed ram of the intensifier.*

**Solution.** Given :

Supply pressure, $p = 20\ \text{N/cm}^2$

Intensity of pressure leaving the intensifier,

$$p^* = 100\ \text{N/cm}^2$$

External dia. of sliding cylinder, $D = 20$ cm

∴ Area of sliding cylinder, $A = \frac{\pi}{4} \times 20^2 = 100\ \pi\ \text{cm}^2$

Let the dia. of the fixed ram $= d$

∴ Area of the fixed ram, $a = \frac{\pi}{4} d^2$

$$p^* = \frac{p \times A}{a}$$

$$100 = \frac{20 \times 100\pi}{\frac{\pi}{4} d^2} = \frac{20 \times 100 \times 4}{d^2}$$

$$\therefore \quad d = \sqrt{\frac{20 \times 100 \times 4}{100}} = \sqrt{80} = \mathbf{8.94\ cm.\ Ans.}$$



## THE HYDRAULIC RAM

The hydraulic ram is a pump which raises water without any external power for its operation. When large quantity of water is available at a small height, a small quantity of water can be raised to a greater height with the help of hydraulic ram. It works on the principle of water hammer.

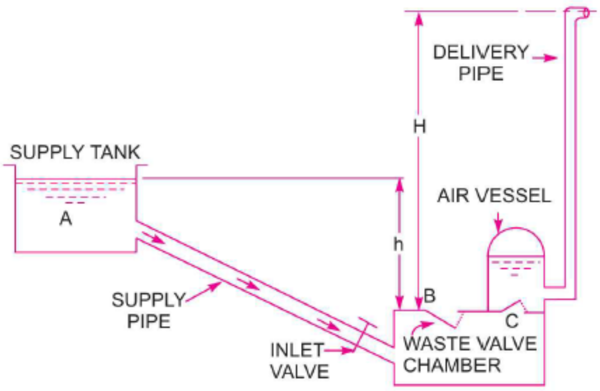

Fig. shows the main components of the hydraulic ram. When the inlet valve fitted to the supply pipe is opened, water starts flowing from the supply tank to the chamber, which has two valves at *B* and *C*. The valve *B* is called waste valve and valve *C* is called the delivery valve. The valve *C* is fitted to an air vessel. As the water is coming into the chamber from supply tank, the level of water rises in the chamber and waste valve *B* starts moving upward. *A* stage comes, when the waste valve *B* suddenly closes. This sudden closure of waste valve creates high pressure inside the chamber. This high pressure force opens the delivery valve *C*. The water from chamber enters the air vessel and compresses the air inside the air vessel. This compressed air exerts force on the water in the air vessel and small quantity of water is raised to a greater height as shown in Fig.

When the water in the chamber loses its momentum, the waste valve *B* opens in the downward direction and the flow of water from supply tank starts flowing to the chamber and the cycle will be repeated.

Let $W$ = Weight of water flowing per second into chamber,

$w$ = Weight of water raised per second,

$h$ = Height of water in supply tank above the chamber,

$H$ = Height of water raised from the chamber.

The energy supplied by the supply tank to ram

= Weight of water supplied × Height of supply water

$= W \times h$ ...(*i*)

Energy delivered by the ram = Weight of water raised × Height through which water is raised

$= w \times H$ ...(*ii*)

∴ Efficiency of the hydraulic ram,

$$\eta = \frac{\text{Energy delivered by the ram}}{\text{Energy supplied to the ram}} = \frac{w \times H}{W \times h}$$

The above expression of efficiency was given by D' Aubuisson and hence known as *D' Aubuisson's*

Energy delivered by the ram $= w \times (H - h)$

Energy supplied $= (W - w)\, h$

∴ Efficiency,

$$\eta = \frac{w \times (H - h)}{(W - w) \times h}$$

Equation is known as *Rankine's efficiency*.

The above two efficiencies, in terms of discharge is written as,

D' Aubuisson's
$$\eta = \frac{q \times H}{Q \times h}$$

Rankine's
$$\eta = \frac{q(H - h)}{(Q - q) \times h}$$

where $q$ = Discharge of delivery pipe,

$Q$ = Discharge through supply pipe.

**Problem** *The water is supplied at the rate of 0.02 $m^3$ per second from a height of 3 m to a hydraulic ram, which raises 0.002 $m^3/s$ to a height of 20 m from the ram. Determine D' Aubuisson's and Rankine's efficiencies of the hydraulic ram.*

**Solution.** Given :

Discharge through supply pipe, $Q = 0.02 \text{ m}^3/\text{s}$

Supply head, $h = 3$ m

Discharge raised, $q = 0.002 \text{ m}^3/\text{s}$

Height of water raised from hydraulic ram, $H = 20$ m

Using equation

D' Aubuisson's $\eta = \frac{q \times H}{Q \times h} = \frac{.002 \times 20}{.02 \times 3} = .6667 = \mathbf{66.67\%.\ Ans.}$

Rankine's efficiency is given by equation

Rankine's $\eta = \frac{q(H-h)}{(Q-q) \times h}$

$$= \frac{0.002 \times (20-3)}{(0.020 - .0002) \times 3} = \frac{0.002 \times 17}{.018 \times 3} = 0.6296 = \mathbf{62.96\%.\ Ans.}$$

**Problem** *The water is supplied at the rate of 3000 litres per minute from a height of 4 m to a hydraulic ram, which raises 300 litres/minute to a height of 30 m from the ram. The length and diameter of the delivery pipe is 100 m and 70 mm respectively. Calculate the efficiency of the hydraulic ram if the co-efficient of friction f = .009.*

**Solution.** Given :

Discharge supplied, $Q = 3000$ litres/minute

$$= \frac{3000}{60} \text{ lit/s} = \frac{3000}{60 \times 1000} \text{m}^3/\text{s} = 0.05 \text{ m}^3/\text{s}$$

Supply head, $h = 4$ m

Discharge raised, $q = 300 \text{ lit/min} = \frac{0.3}{60} = .005 \text{ m}^3/\text{s}$ $\quad (\because \ 300 \text{ lit} = 0.3 \text{ m}^3)$

Height of water raised from hydraulic ram, $H = 30$ m

Length of delivery pipe, $L = 100$ m

Dia. of delivery pipe, $d = 70 \text{ mm} = .07$ m

Co-efficient of friction, $f = .009$

Head lost due to friction in delivery pipe is

$$h_f = \frac{4fLV^2}{d \times 2g} = \frac{4 \times .009 \times 100 \times V^2}{.07 \times 2 \times 9.81} \qquad ...(i)$$

But $V$ = Velocity of water in delivery pipe

$$= \frac{\text{Discharge in delivery pipe}}{\text{Area}}$$

$$= \frac{q}{\frac{\pi}{4}d^2} = \frac{0.005}{\frac{\pi}{4} \times (.07)^2} = 1.299 \simeq 1.3 \text{ m/s.}$$

Substituting this value of $V$ in equation ($i$), we get

$$h_f = \frac{4 \times .009 \times 100 \times (1.3)}{.07 \times 2 \times 9.81} = 4.43 \text{ m}$$

$\therefore$ Effective head developed by the ram

$$= H + h_f = 30 + 4.43 = 34.43 \text{ m}$$

D' Aubuisson's efficiency is given by equation

$$\eta = \frac{q \times \text{Effective head}}{Q \times h} \qquad \text{(Here } H = \text{Effective head)}$$

$$= \frac{.005 \times 34.43}{0.05 \times 4} = 0.8607 = \mathbf{86.07\%.\ Ans.}$$

Rankine's efficiency is given by equation

$$\eta = \frac{q(\text{Effective head} - h)}{(Q - q) \times h}$$

$$= \frac{.005\,(34.43 - 4.0)}{(.05 - .005) \times 4.0} = \frac{.005 \times 30.43}{.045 \times 4.0} = 0.8453 = \mathbf{84.53\%.\ Ans.}$$