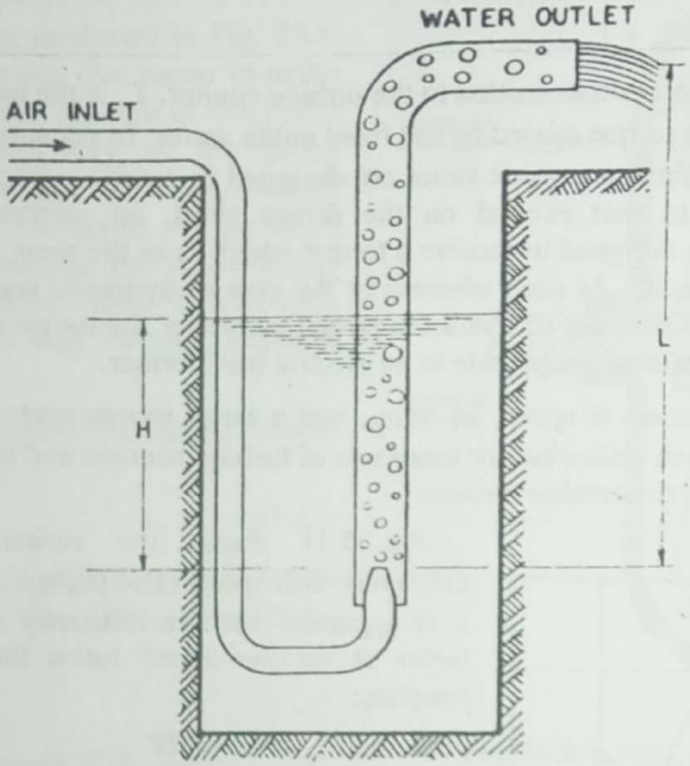

Fig. 25.12 Air lift pump

Illustrative Example 25.1. *An accumulator has a ram of 0.2 m diameter and lift of 6 m. Water is supplied at a pressure of 5900 kN/m². Find the necessary load on the ram and the capacity of the accumulator in kW hours.*

Solution:

$$\text{Load on ram} = pA = 5900 \times \frac{\pi}{4} \times 0.2^2$$

$$= 185.35 \text{ kN}.$$

Capacity of the accumulator

$$pAH = (185.35 \times 6) = 1112.1 \text{ kN-m}$$

Since $1 \text{ kW hour} = (1000 \times 60 \times 60)$ N-m

∴ Capacity of accumulator

$$= \frac{1112.1 \times 10^3}{1000 \times 60 \times 60} = 0.309 \text{ kW hour}$$

Illustrative Example 25.2. *An accumulator has a ram 0.3 m diameter and 6 m lift and is loaded with 800 kN total weight. If packing friction is equivalent to 5 percent of the load on the ram, determine the power being delivered to the machine, if the ram falls steadily through its full range in 90 seconds and if at the same time the pumps are delivering 30 litres per second through the accumulator.*

Solution:

The pressure of water produced by the falling ram of the accumulator is equal to the pressure of the water supplied to the machine. Thus the pressure head H when the loaded ram is falling is

$$H = \frac{p}{w} = \frac{800 \times 10^3 \times (1 - 0.05)}{(\pi/4)(0.3)^2 \times 9810}$$

$$= 1096 \text{ m of water}$$

Power supplied by the pump

$$= wQH$$

$$= 9810 \times 30 \times 10^{-3} \times 1096$$

$$= 322\,553 \text{ W} = 322.553 \text{ kW}$$

Power supplied by the accumulator

$$= \text{weight} \times \text{distance moved/second}$$

$$= \frac{(800 \times 10^3 \times 0.95) \times 6}{90}$$

$$= 50\,667 \text{ W} = 50.667 \text{ kW}$$

$\therefore$ Total power delivered to the machine

$$= (322.553 + 50.667) = 373.22 \text{ kW}$$

Illustrative Example 25.3. *A power of 30 kW is required to be applied to the ram of a press from an accumulator through a 100 mm diameter pipe 1500 m long. If the loss in transmission is to be 2 percent find the diameter of the ram of the press which is loaded with 1200 kN. Take Darcy's f for pipe as 0.04.*

Solution:

Let H be the head supplied by the accumulator and V be the velocity of flow in the pipe.

Then $$h_f = \frac{2H}{100} = \frac{flV^2}{2gd} = \frac{0.04 \times 1500 \times V^2}{2 \times 9.81 \times 0.10}$$

or $$V^2 = (6.54 \times 10^{-4})H$$

or $$V = (2.56 \times 10^{-2})\sqrt{H}$$

$\therefore$ Discharge $$Q = aV$$

$$= (\pi/4)(0.10)^2 (2.56 \times 10^{-2})\sqrt{H}$$

$$= 2.01 \times 10^{-4}\sqrt{(H)}$$

$\therefore$ $$\text{Power} = 30 \times 10^3 = wQH\ (1 - 0.02)$$

$$= 9810 \times 2.01 \times 10^{-4}\sqrt{(H)} \times H \times 0.98$$

or $$H = \left(\frac{30 \times 10^3}{9810 \times 2.01 \times 10^{-4} \times 0.98}\right)^{2/3}$$

$$= 622.33 \text{ m}$$

Now if D is the diameter of the ram of the press, then

$$\frac{1200 \times 10^3}{(\pi/4)D^2 \times 9810} = 622.33$$

$$D^2 = 0.25$$

$$\therefore \quad D = 0.5 \text{ m}$$

i.e., the diameter of the ram of the press = 0.5 m.

Illustrative Example 25.4. *The diameter of the two parts of the ram of a differential accumulator are 150 mm and 130 mm, and stroke length is 1.2 m. If the pressure of water is 9810 kN/m² when the load is either at rest at the upper end of the stroke or the load is moving with uniform velocity, what will be the weight of the loaded cylinder? How much energy can be stored in this accumulator? What will be the diameter of the ram of an ordinary accumulator to move the same load with the help of the same water pressure?*

Solution:

Area of the brass bush or sleeve

$$a = \frac{\pi}{4}[(0.15)^2 - (0.13)^2] = 4.4 \times 10^{-3} \text{ m}^2$$

$\therefore$ Weight of the loaded cylinder is

$$W = (p \times a)$$

$$= (9810 \times 4.4 \times 10^{-3}) = 43.164 \text{ kN}$$

Energy stored in the accumulator

$$= WH$$

$$= (43.164 \times 1.2)$$

$$= 51.8 \text{ kN.m} = 51.8 \times 10^3 \text{ J}$$

For an ordinary accumulator

$$W = p \times A$$

or

$$43.164 = 9810 \times \frac{\pi}{4} \times D^2$$

$$\therefore \quad D = 7.48 \times 10^{-2} \text{ m}$$

$$= 74.8 \text{ mm} \approx 75 \text{ mm}$$

Illustrative Example 25.5. *A hydraulic accumulator has sliding ram of 500 mm diameter which slides through 10 m in 4 minutes during its working stroke, while weight on the ram including its self weight is equivalent to 400 kN. The pump supplies water at 0.01 m³/s rate and packing friction amounts to 5% of total load. Determine (i) pressure intensity of water; (ii) power delivered to machine supplied by accumulator; (iii) power required to drive the pump having efficiency 76%*

Solution:

Diameter of sliding ram

$$D = 500 \text{ mm} = 0.5 \text{ m}$$

$$\therefore \quad \text{Area } A = \frac{\pi D^2}{4}$$

$$= \frac{\pi \times (0.5)^2}{4} = 0.196 \text{ m}^2$$

Weight on ram including self weight

$$W = 400 \text{ kN}$$

Packing friction $= 5\%$ of total load

$$= \frac{5}{100} \times 400 = 20 \text{ kN}$$

∴ Net load on the sliding ram

$$= (400 - 20) = 380 \text{ kN}$$

(*i*) Pressure intensity of water

$$p = \frac{380}{0.196} = 1938.78 \text{ kN/m}^2$$

(*ii*) If Q is the total discharge of water supplied to the machine, q is the discharge of water supplied by the pump and h is the stroke length of the accumulator ram, then

$$Ah = (Q - q)\, t$$

or $$0.196 \times 10 = (Q - 0.01) \times (4 \times 60)$$

∴ $$Q = 0.0182 \text{ m}^3/\text{s}$$

Therefore power delivered to the machine

$$= p \times Q$$

$$= 1938.78 \times 10^3 \times 0.0182$$

$$= 35.286 \times 10^3 \text{ W}$$

$$= 35.286 \text{ kW}$$

(*iii*) Power required to drive the pump

$$= \frac{pq}{\eta}$$

$$= \frac{1938.78 \times 10^3 \times 0.01}{0.76}$$

$$= 25.51 \times 10^3 \text{ W}$$

$$= 25.51 \text{ kW}$$

Illustrative Example 25.6. *An hydraulic intensifier supplying water to a hydraulic press gets water from supply main at a pressure of 5000kPa. It has to intensify the pressure to 40 000 kPa. The stroke of the intensifier is 1.2 m and its capacity is 24 litres. Find the diameter of the ram and the external diameter of the sliding cylinder of the intensifier.*

Solution:

If a is the cross-sectional area of the fixed ram and H is the stroke then the capacity of the intensifier

$$= (a \times H) = 24 \times 10^{-3} \text{ m}^3$$

or $$\left(\frac{\pi}{4} \times d^2 \times 1.2\right) = 24 \times 10^{-3}$$

∴ $$d = 0.16 \text{ m} = 160 \text{ mm}$$

Also from equation 25.5, we have

or $$5000 \times \left(\frac{\pi}{4} \times D^2\right) = 40\,000 \times \left(\frac{\pi}{4} \times 0.16^2\right)$$

$$D = 0.453 \text{ m} = 453 \text{ mm}$$

Illustrative Example 25.7. *An intensifier has a ram of diameter 0.2 m and sliding cylinder of diameter 1 m. Calculate the pressure of water on low pressure side if the pressure of water on high pressure side is to be 24 500 kN/m². The loss due to friction at each of the packing of the intensifier is 5% of total pressure on each piston.*

Solution:

Force on the end of the sliding cylinder

$$= pA$$

5% of it is lost due to friction at the packing.

Therefore net force on the sliding cylinder

$$= (p \times A)\, 0.95 = F$$

Again 5% of this force F is lost due to friction at the packing between the fixed ram and the sliding cylinder.

Thus net force on the fixed ram

$$= F \times 0.95$$

Also if p_1 is the pressure intensity on the fixed ram and a is its cross-sectional area, then

$$F \times 0.95 = p_1 \times a$$

or $$(p \times A \times 0.95) \times 0.95 = p_1 \times a$$

or $$p \times \frac{\pi}{4} \times (1)^2 \times (0.95)^2 = 24\,500 \times \frac{\pi}{4} \times (0.2)^2$$

$$\therefore \quad p = 1086 \text{ kN/m}^2$$

Illustrative Example 25.8. *Water, to a hydraulic intensifier with diameter of sliding ram and fixed ram being 250 mm and 100 mm respectively, is supplied through a pipeline 80 m long, 50 mm diameter and with Darcy's f = 0.0225 under a head of 12.5 m to fixed cylinder. During working stroke the sliding ram travels 0.8 m in 30 seconds. Determine (i) pressure head delivered at out let of fixed ram; (ii) power delivered by intensifier during working stroke. (iii) Revise these figures if each packing is assumed to offer friction of 5% of imposed load.*

Solution:

Diameter of sliding ram

$$D_1 = 250 \text{ mm} = 0.25 \text{ m}$$

$$\therefore \quad \text{Area} \quad A_1 = \frac{\pi}{4} \times (0.25)^2 = 0.0491 \text{ m}^2.$$

Diameter of fixed ram

$$D_2 = 100 \text{ mm} = 0.10 \text{ m}$$

$$\therefore \quad \text{Area} \quad A_2 = \frac{\pi}{4} \times (0.10)^2 = 0.00785 \text{ m}^2$$

Stroke length of sliding ram

$$h = 0.8 \text{ m}$$

The discharge of low pressure liquid entering the fixed cylinder

$$Q_1 = \frac{A_1 h}{t}$$

$$= \frac{0.0491 \times 0.8}{30} = 1.31 \times 10^{-3} \text{ m}^3/\text{s}$$

The head loss due to friction in the supply pipe

$$h_f = \frac{fLV^2}{2gd} = \frac{fLQ^2}{12.1d^5}$$

$$\therefore \quad h_f = \frac{0.0225 \times 80 \times (1.31 \times 10^{-3})^2}{12.1 \times (0.05)^5}$$

$$= 0.82 \text{ m}$$

The pressure head of the low pressure liquid in the fixed cylinder

$$H_1 = (12.5 - 0.82)$$

$$= 11.68 \text{ m}$$

(*i*) Therefore the pressure head delivered at the outlet of the fixed ram

$$H_2 = H_1 \left(\frac{A_1}{A_2}\right)$$

$$= 11.68 \left(\frac{0.0491}{0.00785}\right)$$

$$= 73.06 \text{ m}$$

(*ii*) The discharge of the high pressure liquid delivered by the intensifier

$$Q_2 = Q_1 \left(\frac{A_2}{A_1}\right)$$

$$= 1.31 \times 10^{-3} \times \left(\frac{0.00785}{0.0491}\right)$$

$$= 2.094 \times 10^{-4} \text{ m}^3/\text{s}$$

Therefore power delivered by the intensifier

$$= w Q_2 H_2$$

$$= (9810 \times 2.094 \times 10^{-4} \times 73.06)$$

$$= 150.08 \text{ W}$$

(*iii*) Since there are two packings and each packing offers a friction of 5% of imposed load, the pressure head delivered at the outlet of the fixed ram

$$H_2' = H_1 \left(\frac{A_1}{A_2}\right) (1 - 0.05)^2$$

$$= 11.68 \times \left(\frac{0.0491}{0.00785}\right) (0.95)^2$$

$$= 65.93 \text{ m}$$

Power delivered by the intensifier

$$= w Q_2 H_2'$$

$$= (9810 \times 2.094 \times 10^{-4} \times 65.93)$$

$$= 135.43 \text{ W}$$

Illustrative Example 25.9. *In a testing machine the force is applied to specimen by hydraulic pressure on a ram of 0.25 m diameter. The maximum force required is 1 000 kN and the frictional resistance at the ram may be taken as an additional 50 kN. The water is supplied from an accumulator consisting of a vertical cylinder with a loaded plunger 1.125 m diameter. Find the necessary load on the plunger if friction causes a resistance of 20 kN to its motion.*

Solution:

The total pressure required on the ram

$$= (1000 + 50) = 1050 \text{ kN}$$

∴ Pressure intensity required to be developed at the ram of the machine

$$= \frac{1050}{(\pi/4)(0.25)^2} = 21390.4 \text{ kN/m}^2$$

Let W kN be the load on the plunger, then the net force is $(W - 20)$ kN.

The pressure intensity developed by the plunger of the accumulator

$$= \frac{(W-20)}{(\pi/4)(1.125)^2}$$

Thus equating the two, we get

$$21\,390.4 = \frac{(W-20)}{(\pi/4)(1.125)^2}$$

$$\therefore \quad W = 21\,282.48 \text{ kN}$$

Illustrative Example 25.10. *Find the power of the motor to drive the plunger of a hydraulic press lifting 10 kN to a height of 1 m in 10 minutes. The diameter of ram and plunger are 150 mm and 25 mm respectively. Take stroke of plunger as twice of diameter of the ram. Find also the number of strokes required by the plunger.*

Solution:

Work done by the press per second

$$= \frac{(10\times10^3)\times1}{10\times60} = 16.67 \text{ N-m}$$

∴ Power of the motor required to drive the plunger

$$= 16.67 \text{ N-m/s} = 16.67 \text{ W}$$

Volume of water displaced as the ram is lifted through 1 m

$$= \left[\frac{\pi}{4}(0.15)^2\times1\right] \text{m}^3$$

Similarly the volume of water displaced during each stroke of the plunger

$$= \left[\frac{\pi}{4}(0.025)^2\times2\times0.15\right] \text{m}^3$$

$$\therefore \quad \text{No. of strokes} = \frac{\frac{\pi}{4}(0.15)^2\times1}{\frac{\pi}{4}(0.025)^2\times2\times0.15} = 120$$

Illustrative Example 25.11. *A hydraulic press has a ram of 150 mm diameter and plunger of 30 mm diameter, with stroke length of 250 mm. Weight exerted by press ram amounts to 5886 N and distance moved is 1.2 m in 20 minutes. Determine (i) the force applied on the plunger; (ii) number of strokes performed by the plunger; (iii) work done by the press ram; and (iv) power required to drive the plunger.*

Solution:

Diameter of ram $D = 150 \text{ mm} = 0.15 \text{ m}$

Area of ram $A = \frac{\pi}{4}(0.15)^2 = 0.0177 \text{ m}^2$

Diameter of plunger $d = 30 \text{ mm} = 0.03 \text{ m}$

Area of plunger $a = \frac{\pi}{4}(0.03)^2 = 0.00707 \times 10^{-1} \text{ m}^2$

Weight exerted by press ram

$$W = 5886 \text{ N}$$

(*i*) Force applied on the plunger

$$F = \left(\frac{a}{A}\right) W$$

$$= \left(\frac{0.00707 \times 10^{-1}}{0.0177}\right) \times 5886$$

$$= 235.11 \text{ N}$$

(*ii*) Stroke length of plunger $x = 250 \text{ mm} = 0.25 \text{ m}$

Distance moved by ram $y = 1.2 \text{ m}$

Therefore number of strokes performed by the plunger

$$n = \frac{Ay}{ax}$$

$$= \frac{0.0177 \times 1.2}{0.00707 \times 10^{-1} \times 0.25}$$

$$= 120.17 \approx 120$$

(*iii*) Work done by the press ram

$$= (5886 \times 1.2) \text{ N.m}$$

$$= 7063.2 \text{ N.m}$$

(*iv*) Power required to drive the plunger is equal to the work done by the press ram per second.

Thus power required to drive the plunger

$$= \frac{7063.2}{20 \times 60}$$

$$= 5.886 \text{ W}$$

Illustrative Example 25.12. *A hydraulic lift raises a load of 80 kN through a height of 12 m once every 2 minutes, the speed of lifting being 0.6 m per second. It is worked from an accumulator which is being constantly charged by a pump. The pressure of water is 3 450 kN/m², the efficiency of lift is 75*