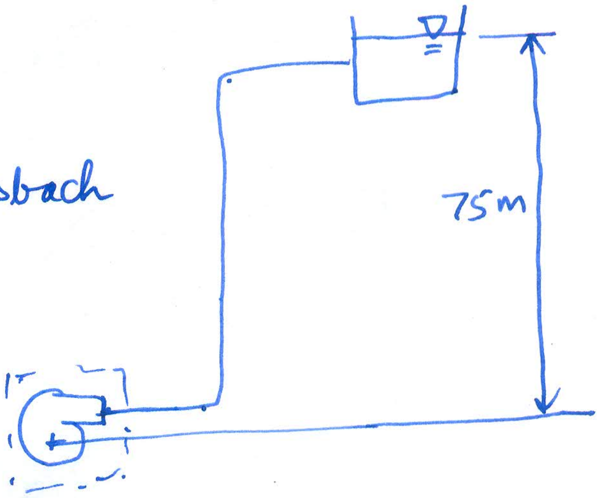
Water is required to be pumped to the overhead tank of a building of vertical height 75 m from the sump level. The total equivalent length of the delivery pipe is 80 m. The pipe diameter is 50 mm, its friction factor is 0.024. Determine the power required to pump water at a rate of 10 lps. The mechanical losses of the pump are equal to 0.2 kW. The hydraulic efficiency of the pump is 93.6%. Assume leakage and return flow losses as 0.2 lps. Also find η_m, η_v and η_o. Take $\rho = 1000\ kg/m^3$. $g = 9.81\ m/s^2$



$$h_l = f \cdot \frac{l_e}{d} \cdot \frac{V_2^2}{2g}$$ Darcy-Weisbach Eqn.

$Q = 10$ lps $\quad V_2 = \frac{Q}{A_2}$

$d = 50$ mm.

$$= \frac{10 \times 10^{-3}}{\frac{\pi}{4} \times \left(\frac{50}{1000}\right)^2} \ m/s$$

$$= 5.1\ m/s$$

$$h_l = 0.024 \times \frac{80}{\left(\frac{50}{1000}\right)} \times \frac{5.1^2}{2 \times 9.81}\ m = 50.9\ m$$

$$\frac{\not{m} V_2^2}{\not{m}\, 2g} = \frac{5.1^2}{2 \times 9.81}\ m \qquad \frac{mgh}{mg} = \frac{\frac{1}{2} m V_2^2}{mg}$$

$$= 1.3$$

$$P = \dot{m} g (\underbrace{75 + 50.9 + 1.3}_{127.2}) = 1000 \times 10 \times 10^{-3} \times 9.81 \times 127.2$$

$= ~~1272\ W = 1.272\ kW~~$

12.5 kW

$P =$ ✓

$\eta_h = \frac{P}{P_n} = 0.936$

$P_n = \frac{P}{0.936} = \frac{12.5 \; \cancel{1.272}}{0.936} \; kW = 13.35 \; kW$

$\eta_v = \frac{\dot{m}}{\dot{m} + \delta\dot{m}} = \frac{10}{10 + 0.2} = \frac{10}{10.2} = 0.98$

$\eta_v = \frac{P_n}{P_r} = \cancel{\frac{13.35}{0.97}} \quad \frac{13.35}{P_r}$

$P_r = \frac{13.35}{0.98} = 13.62 \; kW$

$P_s = P_r +$ mechanical loss

$= 13.62 + 0.2 \; kW$

$= 13.82$

$\eta_m = \frac{13.62}{13.82} = 0.985$

$\eta_o = \eta_m \times \eta_v \times \eta_h = 0.985 \times 0.98 \times 0.936$

$= 0.903$

Scaling of m/c

Similarity principle

Q H η

P H η

model ~~
~~pro~~ prototype ~~

$gH \propto V^2$ $\qquad$ $mgH \sim \frac{mV^2}{2}$

$V \propto ND$

$gH \propto N^2D^2$ $\qquad L^2T^{-2}$

$\pi_2 = \frac{gH}{N^2D^2}$

$Q \propto \text{Area} \times \text{velocity}$

$\propto D^2 \times ND$

$\propto ND^3 \qquad L^3T^{-1}$

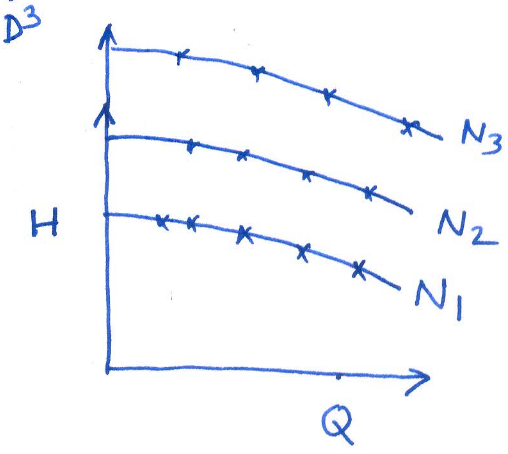
$\pi_1 = \frac{Q}{ND^3}$

$P \propto \rho Q g H$

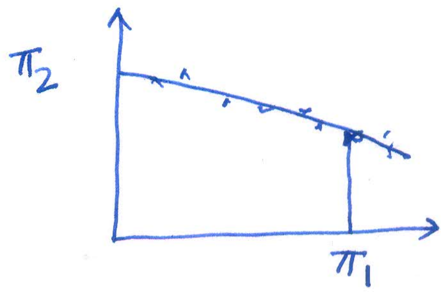
$\propto \rho \times ND^3 \times N^2D^2$

$\propto \rho N^3 D^5$

$\pi_3 = \frac{P}{\rho N^3 D^5}$



$$\frac{Q_1}{N_1 D_1^3} = \frac{Q_2}{N_2 D_2^3} = \pi_1$$

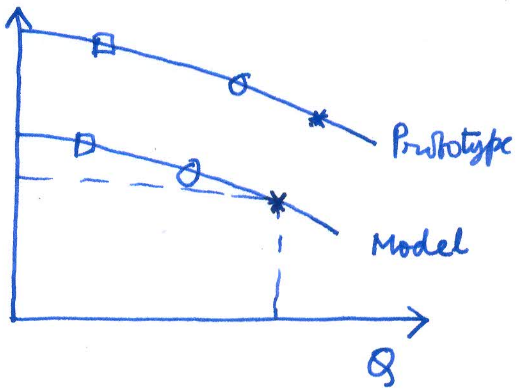


$$\frac{Q_m}{N} \quad \left.\frac{Q}{ND^3}\right|_m = \left.\frac{Q}{ND^3}\right|_p$$

$$\frac{Q_p}{N_p D_p^3} = \frac{Q_m}{N_m D_m^3}$$

$$Q_p = Q_m \times \frac{N_p}{N_m} \times \left(\frac{D_p}{D_m}\right)^3$$

$\frac{D_p}{D_m}$ = scale factor



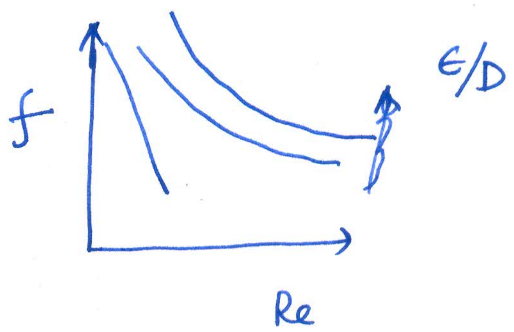
P = ~~Prot~~ Prototype

m = model

$$\left.\frac{gH}{N^2D^2}\right|_m = \left.\frac{gH}{N^2D^2}\right|_p$$

~~$H_p =$~~ $$\frac{H_p}{N_p^2 D_p^2} = \frac{H_m}{N_m^2 D_m^2}$$

$$H_p = H_m \times \frac{N_p^2}{N_m^2} \times \left(\frac{D_p}{D_m}\right)^2$$



$$\frac{1-\eta_p}{1-\eta_m} = \left(\frac{D_m}{D_p}\right)^{1/5} \quad \text{Moody}$$

Ex

A model pump, handling water, has head 4.5m, flow rate 0.025 m^3/s, power 1.47 kW running at 1450 rpm. The scale model is 1:8 and the prototype is to run at 600 rpm. The model diameter is 0.09m. Find out the head, flow rate and power of the prototype pump. $\rho = 1000$ kg/m^3, $g = 9.81$ m/s^2

Model	Prototype
$H_m = 4.5m$	$H_p =$
$Q_m = 0.025\ m^3/s$	$Q_p =$
$N_m = 1450$ rpm	$N_p = 600$ rpm

$$\frac{Q_p}{N_p D_p^3} = \frac{Q_m}{N_m D_m^3}$$

$$Q_p = Q_m \times \frac{N_p}{N_m} \times \left(\frac{D_p}{D_m}\right)^3$$

$$= 0.025 \times \frac{600}{1450} \times 8^3$$

$$= 5.3\ m^3/s$$

$$\frac{gH_p}{N_p^2 D_p^2} = \frac{gH_m}{N_m^2 D_m^2}$$

$$H_p = H_m \times \frac{N_p^2}{N_m^2} \times \left(\frac{D_p}{D_m}\right)^2$$

$$= 4.5 \times \frac{600^2}{1450^2} \times 8^2$$

$$= 49.3\ m$$

$$\text{Power} = \rho Q g H \big/ _m = 1000 \times 0.025 \times 9.81 \times 4.5$$

$$= 1.1\ kW$$

$$\eta_m = \frac{1.1}{1.47} = 0.75 \qquad \eta_p = 0.835$$

$$P_s = \frac{1000 \times 5.3 \times 9.81 \times 49.3}{0.835}$$

$$= 3070\ kW$$