 Name: SOLUTION

CE 3305 Engineering Fluid Mechanics
Exercise Set 24
Spring 2014

1. Problem 14.27, pg 550
2. Problem 14.41, pg 551

PROBLEM 14-27

Given → A pump having the characteristics given in ~~the~~ Figure 14.10 pumps water at 20° C from a reservoir at an elevation of 366 m to a reservoir at an elevation of 450 m through a 36 cm steel pipe. If the pipe is 610 m long, what will be the discharge through the pipe?

Find → Discharge through the pipe

Properties → Table A5 → $\rho = 998\ kg/m^3$
$\nu = 10^{-6}\ m^2/s$

Solution →

$$\Delta Z = 450 - 366 = 84m$$

Assume $\Delta h = 90m$ because its greater than ΔZ

$$\Rightarrow Q = .24\ m^3/s \quad [\text{Figure } 14.10]$$

Using flow rate equation →

$$V = \frac{Q}{A} = \frac{.24 m^3}{s} \left| \frac{1}{\left(\frac{\pi}{4}\right)(.36m)^2} \right. \Rightarrow V = 2.36 m/s$$

Using Reynolds equation →

$$Re = \frac{VD}{\nu} = \frac{2.36\ m}{s} \left| .36m \right| \frac{s}{10^{-6}\ m^2}$$

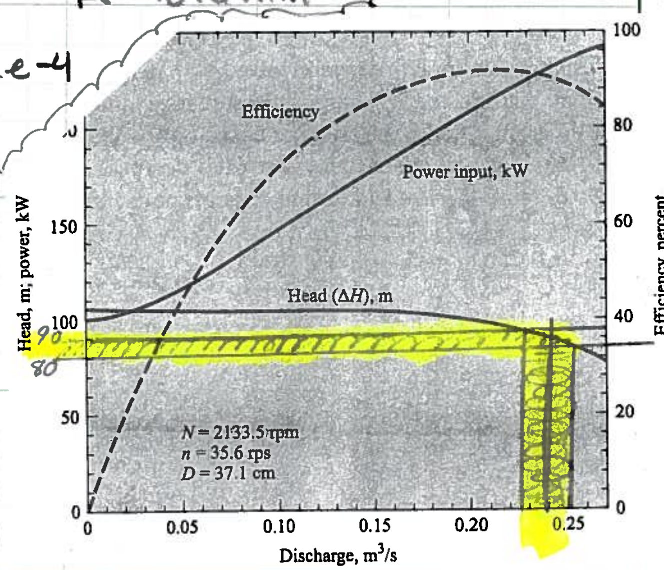
$$\Rightarrow Re = 8.5e5$$

Using table 10.4 → steel pipe → $k_s = .046mm$

$$\Rightarrow \frac{k_s}{D} = \frac{.046mm}{360mm} = 1.2e-4$$

Using Figure 10.14 →

$$f = .014$$



Energy Equation →

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + h_p = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + h_t + h_L$$

Since pressures are the same at both reservoirs and velocities are zero →

$$h_p = z_2 - z_1 + h_L \qquad \text{Eq } 1$$

$$\Rightarrow h_L = \frac{V^2}{2g}\left[1 + \frac{fL}{D}\right] = \frac{Q^2}{2A^2 g}\left[1 + \frac{fL}{D}\right] \qquad \text{Eq } 2$$

Combining Equations 1 and 2

$$h_p = z_2 - z_1 + h_L$$

$$h_p = 450 - 366 + \frac{Q^2}{2\left(\frac{\pi}{4}(.36)^2\right) \times 9.81\,m/s^2}\left[1 + \frac{.014(610)}{.36}\right]$$

$$h_p = 84 + 122Q^2$$

Plotting the system curve for both the pump and the system shows an operating point where the system and pump curve intersect. The intersection point is the discharge through the pipe

$$\Rightarrow \boxed{Q = .228\ m^3/s}$$

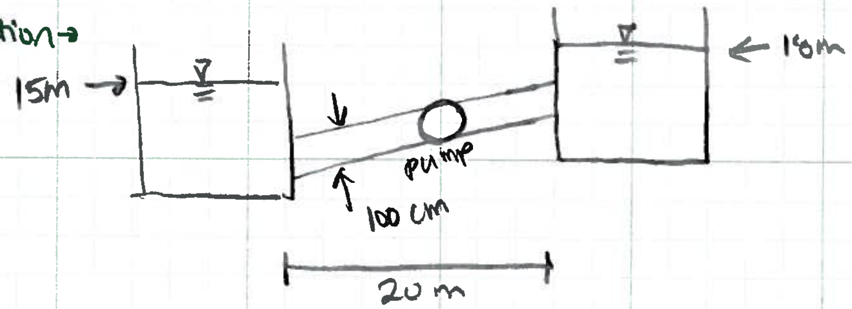
Discussion → After we guess the pump head using Fig. 14.10, we can calculate the flow rate and Reynolds number. The friction loss in the pipe can be found using the Darcy-Weisbach friction factor. The energy equation between the two reservoirs allows us to generate the system curve. The operating point is where the system and pump curve intersect.

PROBLEM 14.41

Given → A pump is needed to pump water at a rate of .2 m^3/s from the lower to the upper reservoir shown in the figure. What type of pump would be best for this operation if the impeller speed is to be 600 rpm? Assume f = .02 and K_e = .5

Find → Type of Pump.

Solution →



Energy Equation →

$$h_p = \Delta z + \left[1 + K_e + f\frac{L}{D}\right]\frac{V^2}{2g}$$

$$V = \frac{Q}{A} = \frac{.2 m^3}{s} \Big/ (\pi/4)(.1m)^2 = 25.5 \, m/s$$

$$\Rightarrow h_p = 3 + \left[1 + .5 + \frac{.02(20)}{.1}\right]\left[\frac{(25.5 m/s)^2}{2(9.81 m/s^2)}\right]$$

$$\Rightarrow h_p = 185 m$$

Specific Speed →

$$n_s = n\sqrt{Q} \Big/ [g^{3/4} h^{3/4}]$$

$n = 10 rps$
$Q = .2 m^3/s$

$$\Rightarrow n_s = \frac{10 \, rps \, (.2 m^3/s)^{1/2}}{(9.81 m/s^2 \cdot 185 m)^{3/4}}$$

$$\Rightarrow n_s = .016$$

From Figure 14.13 ⇒ $\boxed{\text{Use a radial flow pump}}$