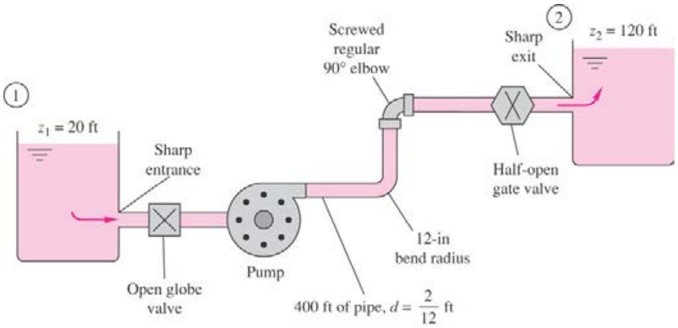
December 4, 2013

NAME

Fluids-ID

Quiz 13.

Water is pumped between two reservoirs at a flow rate Q = 0.2 ft^3/s through a pipe with a total length ℓ = 400 ft and a diameter d = 2 in. The roughness ratio is ε/d = 0.001. Compute the pump horsepower, P, required. Minor losses are not negligiable. ($P = \rho g Q h_p$; ρ = 1.94 slugs/ft^3; ν = 0.000011 ft^2/s; g = 32.2 ft/s^2; 1 hp = 550 ft·lbf/s)



- ***Energy Eq.:***

$$\frac{p_1}{\rho g}+\frac{V_1^2}{2g}+z_1+h_p=\frac{p_2}{\rho g}+\frac{V_2^2}{2g}+z_2+\frac{V^2}{2g}\left(\frac{f\ell}{d}+\sum K_L\right)$$

- ***Friction factor, f:***

$$\frac{1}{\sqrt{f}}=-1.8\log\left[\left(\frac{\varepsilon/d}{3.7}\right)^{1.11}+\frac{6.9}{Re}\right]$$

Loss	K_L
Sharp entrance	0.5
Open globe valve	6.9
12-in bend	0.25
Regular 90° elbow	0.95
Half-closed gate valve	2.7
Sharp exit	1.0

Note: Attendance (+2 points), format (+1 point)

Solution:

Since $p_1 = p_2$ and $V_1 = V_2 \approx 0$, the energy equation becomes

$$h_p = z_2 - z_1 + \frac{V^2}{2g}\left(\frac{f\ell}{d}+\sum K_L\right)$$ (+3 points)

With the flow rate known,

$$V=\frac{Q}{A}=\frac{0.2\ \text{ft}^3/\text{s}}{\frac{1}{4}\pi\left(\frac{2}{12}\ \text{ft}\right)^2}=9.17\ \text{ft/s}$$

Calculate the Reynolds number,

$$Re = \frac{Vd}{\nu} = \frac{9.17\left(\frac{2}{12}\right)}{0.000011} = 139{,}000$$

For ε/*d* = 0.001, the pipe friction factor,

$$f = \left\{-1.8\log\left[\left(\frac{\varepsilon/d}{3.7}\right)^{1.11} + \frac{6.9}{Re}\right]\right\}^{-2} = 0.0214$$ (+2 points)

Minor losses are

$$\sum K_L = 0.5 + 6.9 + 0.25 + 0.95 + 2.7 + 1.0 = 12.3$$ (+1 points)

Thus, the pump head hp becomes,

$$h_p = 100\text{ ft} + \frac{(9.17\text{ ft/s})^2}{2(32.2\text{ ft/s}^2)}\left(\frac{0.0214(400)}{\frac{2}{12}} + 12.3\right) = 183\text{ ft}$$

The pump must provide a power to the water of

$$P = \rho g Q h_p = [1.94(32.2)\text{ lbf/ft}^3](0.2\text{ ft}^3/s)(183\text{ ft}) = 2286\text{ ft}\cdot\text{lbf/s}$$

The conversion factor is 1 hp = 550 ft·lbf/s. Therefore

$$P = \frac{2286}{550} = 4.2\text{ hp}$$ (+1 points)