ENGR 292 Fluids and Thermodynamics

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Pump and Pipe Example

Design a Pump and Pipe System for the starter problem of Technologist

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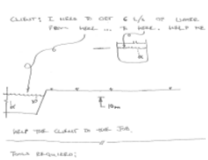
Step 1

Rough Layout



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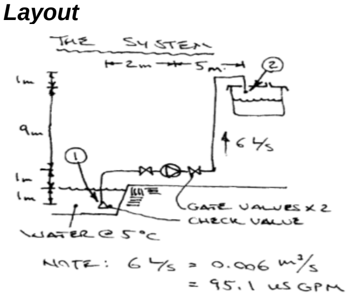
Step 1 (cont'd)

Rough Layout



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Step 2

Pipe Size (Discharge):

- $Q = vA$ → $A = \frac{Q}{v}$
- $A = \frac{\pi D^2}{4}$ → $D = \sqrt{\frac{4A}{\pi}}$
- v : ***Recommended Velocity***
  - ***We choose*** $v = 3m/s$ ***(Design)***
  - ***So*** $A = \frac{Q}{v} = \frac{0.006\ m^3/s}{3\ m/s} = 0.002m^2$

  $\therefore D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{(4)(0.002)}{\pi}} \approx 0.050463m = 50.463mm$

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Step 2 (cont'd)

Pipe Size:

- ***Choose a close real size***
- ***http://www.engineeringtoolbox.com/asme-steel-pipes-sizes-d_42.html***
- ***SCH 40 … ID=52.501mm***
- ***That is for 2" SCH 40 Pipe***
- $D_{Discharge} = 52.501 \times 10^{-2}m$
- $A_{Discharge} = 21.648 \times 10^{-4}m^2$

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Step 3

Suction Line Size:

- ***One standard size larger than the discharge***
- ***Choose 2 1/2" SCH 40***
- ***ID=62.713mm***
- $D_{Suction} = 62.713 \times 10^{-2} m$
- $A_{Suction} = 30.889 \times 10^{-4} m^2$

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Step 4

Calculate Actual Flow Velocity of Discharge

$$\mathrm{v}_{Discharge} = \frac{Q}{A_{Discharge}} = \frac{0.006 m^3/s}{21.648 \times 10^{-4} m^2}$$
$$= 2.77\ m/s$$

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Step 4 (cont'd)

Calculate Actual Flow Velocity of Suction

$$\mathrm{v}_{Suction} = \frac{Q}{A_{Suction}} = \frac{0.006 m^3/s}{30.889 \times 10^{-4} m^2}$$
$$= 1.94\ m/s$$

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Step 5

Determine the Reynolds Number

$$N_R = \frac{\mathrm{v} D \rho}{\mu}$$

$$at\ 5℃\ \ldots$$
$$\rho = 999.9\ kg/m^3$$
$$\mu = 1.519 \times 10^{-4} kg/(ms)$$

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Step 5 (cont'd)

Reynolds Number (Discharge)

$$N_{R\_Discharge} = \frac{\mathrm{v}_{Discharge} D_{Discharge} \rho}{\mu}$$
$$= \frac{(2{,}77)(52.501 \times 10^{-3})(999.9)}{1.519 \times 10^{-4}} = 9.6 \times 10^4$$

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Step 5 (cont'd)

Reynolds Number (Suction)

$$N_{R\_Suction} = \frac{\mathrm{v}_{Suction} D_{Suction} \rho}{\mu}$$
$$= \frac{(1.94)(62.713 \times 10^{-3})(999.9)}{1.519 \times 10^{-4}} = 8.0 \times 10^4$$

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Step 6

Pipe Material: Commercial Steel

http://www.pipeflow.com/sitemap/pipe-roughness

Roughness:

$$e = 0.0045\ (mm)$$

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Step 7

Relative Roughness:

Discharge Pipe:

$$\frac{e}{D_{Discharge}} = \frac{0.0045}{52.501} = 0.00086$$

Suction Pipe:

$$\frac{e}{D_{Suction}} = \frac{0.0045}{62.713} = 0.00072$$

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Step 8

Friction Factor:

From Moody Diagram

$$f_{Discharge} = f_{Suction} \approx 0.0217$$

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Step 9

Pipe Length:

$$L_{Discharge} = 9 + 1 + 1 + 5 = 16\ (m)$$
$$L_{Suction} = 1 + 1 + 2 = 4\ (m)$$

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Step 10

Pipe Head Loss:

$$h_L = f\frac{L}{D}\frac{\mathrm{v}^2}{2g}$$

$$h_{L\_Discharge} = (0.0217)\frac{16}{52.501 \times 10^{-3}}\frac{(2.77)^2}{2(9.81)}$$
$$= 2.59\ (m)$$

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Step 10 (cont'd)

Pipe Head Loss:

$$h_L = f\frac{L}{D}\frac{\mathrm{v}^2}{2g}$$

$$h_{L\_Suction} = (0.0217)\frac{4}{62.713 \times 10^{-3}}\frac{(1.94)^2}{2(9.81)}$$
$$= 0.266\ (m)$$

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Step 11

Fitting Head Loss: Minor Losses:

$$h_L = \left[\sum K\right] \frac{v^2}{2g}$$

Step 11 (cont'd)

Fitting Head Loss: Minor Losses

Discharge:

- ***2 gate valves: $K = 0.16$ each***
- ***3 elbows: $K = 0.39$ each***
- ***Discharge: $K = 1.0$***

$$h_{L\_Discharge} = [(0.16) \times 2 + (0.39) \times 3 + (1.0) + 0] \frac{1.94^2}{2 \times 9.81}$$
$$= 0.974\ (m)$$

Step 11 (cont'd)

Fitting Head Loss: Minor Losses

Suction:

- ***1 check valve: $K = 2.0$ each***
- ***1 elbow: $K = 0.39$ each***

$$h_{L\_Suction} = [(2.0) + (0.39)] \frac{1.94^2}{2 \times 9.81}$$
$$= 0.458\ (m)$$

Step 12

Determine the pump head:

Reorder the general energy equation:

$$\frac{p_1}{\gamma} + z_1 + \frac{v_1^2}{2g} + h_A - h_R - h_L = \frac{p_2}{\gamma} + z_2 + \frac{v_2^2}{2g}$$

To:

$$h_A = \frac{p_2 - p_1}{\gamma} + z_2 - z_1 + \frac{v_2^2 - v_1^2}{2g} + h_R + h_L$$

Step 12 (cont'd)

Determine the pump head:

$$p_1 = \rho g h = (999.9)(9.81)(1) = 9.81 \text{ kpa (gage)}$$

$$p_2 = 0 \text{ kpa (gage)}$$
$$\boldsymbol{\gamma = \rho g = 999.9 \times 9.81 = 9.81\ kN/m^3}$$

Step 12 (cont'd)

Determine the pump head:

So

$$h_A = \frac{p_2 - p_1}{\gamma} + z_2 - z_1 + \frac{v_2^2 - v_1^2}{2g} + h_R + h_L$$
$$= \frac{0 - 9.81}{9.81} + [(1 + 1 + 9) - 0] + \frac{2.77^2 - 1.94^2}{2 \times 9.81} + 0$$
$$+ [0.266 + 0.458 + 2.59 + 0.974] = 14.49\ (m)$$

Step 13

Pump Selection – Pump Curves

$$Q = 95.1 \ (US\ GPM)$$
$$\mathrm{h_A} = 14.49\ (m) = 47.54\ (ft)$$

After a little searching …

B&G Model 1510 – 2E at 1150 PRM can be an option

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Step 14

Check Suction Design:

$$\boldsymbol{NPSH_A > NPSH_R}$$

Or Change Design !

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