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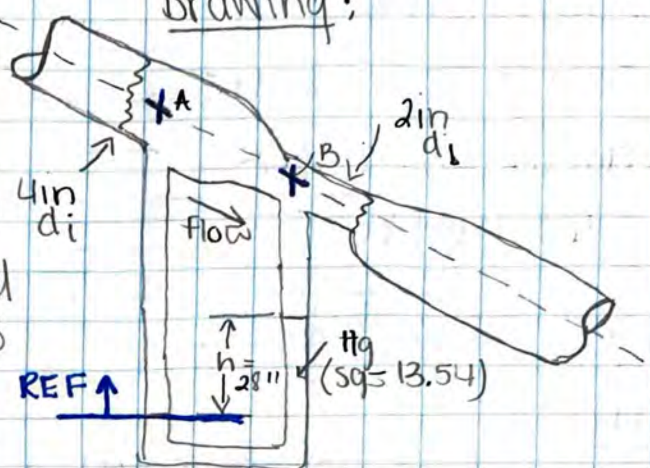
MET330
Homework

Chapter 6

#6-79: Oil w/ sg of 0.90 is flowing downward thru venturi meter. If manometer deflection h is 28 in, calc. volume flow rate of oil

Drawing:



Purpose: Calculate flow rate passing through oil.

Data:
$sg_{oil} = 0.90$
$sg_{hg} = 13.54$
$h = 28\,in = 2.33\,ft$
$d_A = 4\,in$
$d_B = 2\,in$
$\gamma_{water} = 9.81\,kN/m^3$

Design Considerations:
1. Incompressible fluid
2. Isothermal process
3. Steady state
4. No energy loss

$A_A = \frac{\pi}{4}(4)^2 = 12.56/144 = 0.0872\,ft^2$
$A_B = \frac{\pi}{4}(2)^2 = 3.14/144 = 0.0218\,ft^2$

Procedure:
- Pick reference point
- Choose pts to apply equation
- Decide equations:

Bernoulli's
$$\frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2$$

Flow Rate Equation: $Q = V \times A$
Pressure difference: $\Delta p = \gamma \times h$

Calculations

EQ ①
$$Q = \sqrt{\frac{2g\left(\frac{P_b - P_a}{\gamma} + (z_a - z_b)\right)}{\frac{1}{A_A^2} - \frac{1}{A_B^2}}}$$

EQ ②
$$\frac{P_b - P_A}{\gamma_{hg}} = (z_a - z_b) + \left(1 - \frac{sg_{hg}}{sg_{oil}}\right)h$$

$$Q = \sqrt{\frac{2g\left(1 - \frac{sg_{hg}}{sg_{oil}}\right)h}{\frac{1}{A_A^2} - \frac{1}{A_B^2}}}$$

$$Q = \sqrt{\frac{2 \times 32.2\frac{ft}{s^2}\left(1 - \frac{13.54}{0.90}\right) \times 2.33\,ft}{\frac{1}{(0.0872\,ft^2)^2} - \frac{1}{(0.0218\,ft^2)^2}}}$$

$$\boxed{Q = 1.03\,\frac{ft^3}{s}}$$

Summary: The flow rate is $1.03\,\frac{ft^3}{s}$

Materials: Mercury, Oil

Analysis: The flow rate of pipeline can be determined without knowing the velocity, when you calculate the pressure difference between two points

6.82 Oil with SW of 55.0 lb/ft³ flows from A to B. Calculate volume flow rate of the oil.

Purpose: calculate flow rate passing through oil.

Data:

$SW_{oil} = 55.0\ lb/ft^3$

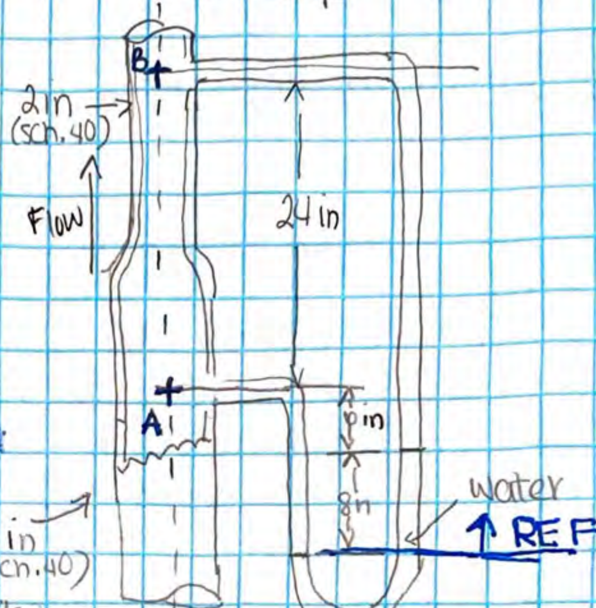
$d_A = 4.026\ in = 0.0884\ ft^2$

$d_B = 2.067\ in = 0.0233\ ft^2$

$SW_{water} = 62.4\ lb/ft^3$

h = various h as listed

Drawing:



Procedure

- choose reference
- choose points
- identify equations

$\Delta h = \left(\frac{P_A}{\gamma_{oil}} + z_a\right)\left(\frac{P_B}{\gamma_{oil}} + z_b\right)$

Volume flow rate: $Q = A_B v_B$

Bernoulli's:

$\frac{P_A}{\gamma_{oil}} + z_a + \frac{v_A^2}{2g} = \frac{P_B}{\gamma_{oil}} + z_B + \frac{v_B^2}{2g}$

Design Considerations:

1. incompressible fluid
2. isothermal process
3. steady state
4. no energy loss

Calculation

$\Delta h = \left(8\ in \cdot \frac{1\ ft}{12\ in}\right)\left(\frac{62.4\ lb/ft^3}{55.0\ lb/ft^3} - 1\right) = 0.6667 \times 0.1345 = 0.0897\ ft$

$\frac{P_A}{\gamma_{oil}} + z_a + \frac{v_A^2}{2g} = \frac{P_B}{\gamma_{oil}} + z_B + \frac{v_B^2}{2g} \rightarrow \Delta h = \frac{v_B^2 - v_A^2}{2g}$

$v_a = v_B\left(\frac{A_B}{A_A}\right) = v_B\left(\frac{0.0233\ ft^2}{0.0884\ ft^2}\right) = 0.26316\ v_B$

$0.0897\ ft = \frac{v_B^2 - (0.26316\ v_B)^2}{2(32.2\ ft/s^2)}$

$v_B^2 = \frac{0.0897\ ft^2 \times 64.4\ lb/ft^3}{0.9305}\ \sqrt{6.208}$

$= 2.49\ ft/s$

$Q = A_B v_B = 0.0233\ ft^2 \times 2.49\ ft/s =$

$0.0581\ ft^3/s$

Summary: The flow rate is $0.0581\ ft^3/s$

Materials: water, oil

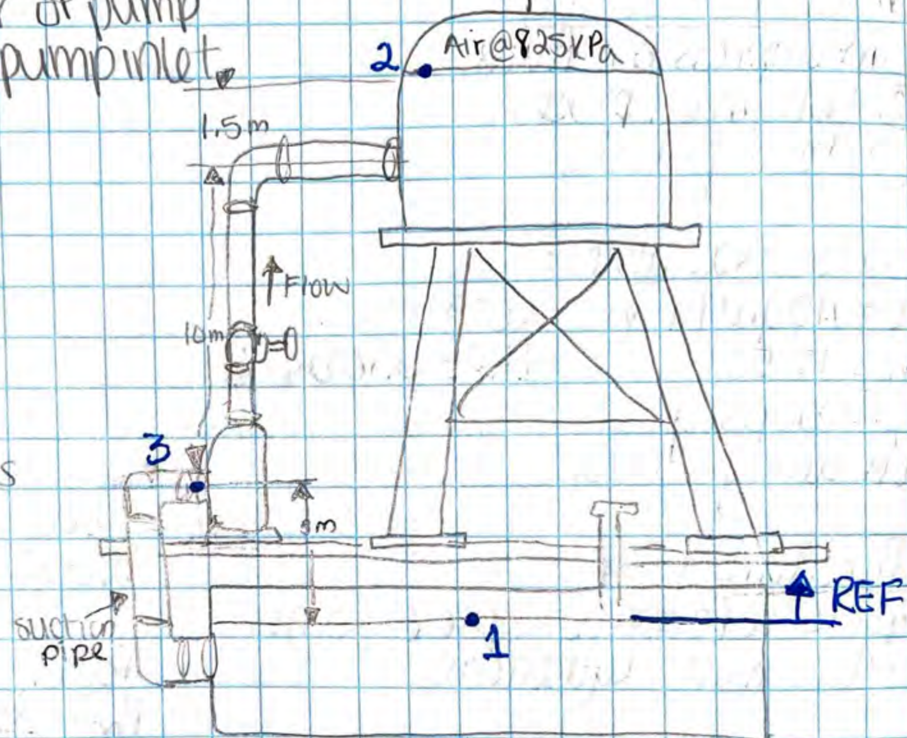
Analysis: When the elevation increases the pressure in the pipe decreases, the change to a smaller diameter pipe helps to account for pressure loss causing the liquid to flow at a faster rate.

Chapter 7

#7-16: A pump delivers 840 L/min of crude oil (sg = 0.85) from underground storage drum to 1st stage of processing system
(a) if total energy loss is 4.2 N·m/N, calc power delivered by pump.
(b) if energy loss in suction pipe is 1.4 N·m/N, calculate pressure @ inlet.

Purpose
(a) compute the power of pump
(b) compute pressure at pump inlet

Drawing:



Design Considerations:
① incompressible fluid
② Isothermal process
③ Steady state

Data:
$Q = 840 L/min = 0.014 m^3/s$
$sg_{oil} = 0.85$
$h_{L\,sys.} = 4.2 m$
$h_{L\,suc\,pipe} = 1.4 m$

Procedure:
· Pick reference · pick points
· determine equations
Pump power: $P = \gamma Q h_A$

$$h_A + \frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_{L12}$$

Summary: The power of pump is 13.73 kW and pressure @ inlet of pump is −45.41 kPa

Materials: oil

Calculations

$$h_A = \frac{P_2}{\gamma} + z_2 + h_{L12}$$

$$= \frac{825 kPa}{0.85 \times 9810 \frac{N}{m^3}} + 14.5m + 4.2m = 117.64m$$

$P = \gamma Q h_A$
$P = (0.85 \times 9810 \frac{N}{m^3})(0.014 m^3/s \times 117.64 m)$
$P = 13.733 kW$

Analysis: Power of pump is ∝ to the head + flow rate. The pressure at inlet pump is negative, or below atmospheric pressure.

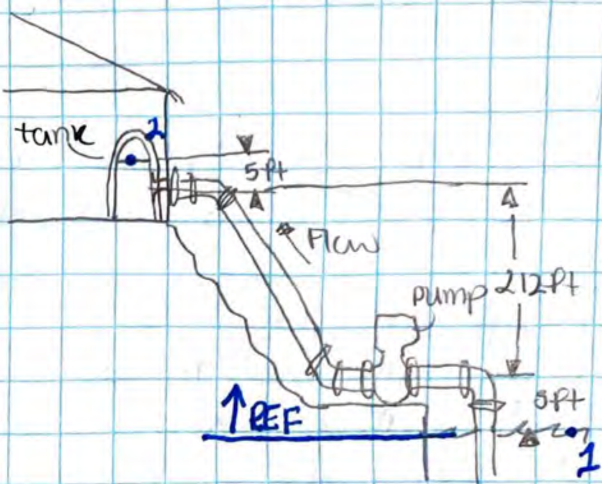
$$\frac{P_3}{\gamma} = -\frac{v_3^2}{2g} - z_3 - h_{L13} \qquad v_3 = \frac{Q}{A_3}$$

$$v_3 = \frac{0.014 m^3/s}{3.09 \times 10^{-3} m^2} = 4.531 m/s$$

$$P_3 = (0.85 \times 9810 \frac{N}{m^3})\left(-\frac{(4.531 \frac{m}{s})^2}{2 \cdot 9.81 \frac{m}{s^2}} - 3m - 1.4m\right) = -45.41 kPa$$

#7-42 Professor Crocker is building cabin on hillside; distribution tank maintains p = 30.0 psig above water. Energy loss = 15.5 ft, when pump delivery 40 gal/min, compute horsepower delivered by pump to water.

Drawing:



Purpose: compute HP delivered by pump to water

Design considerations:
1. incompressible fluid
2. Isothermal process
3. Steady state

Data + Variables:

$Q = 40\,gal/min = 0.089\,ft^3/s$

$h_L = 15.5\,ft$ $\quad 1HP = 550\,lb\cdot ft/s$

$p = 30\,psig$

Efficiency = 0.72

Procedure:
- pick reference
- pick points
- determine equations

Bernoullis:

$$h_A + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_{L12}$$

Power Pump:

$$P_m = \frac{P_a}{\eta_a} = \frac{\gamma Q h_A}{\eta_A}$$

Calculations:

$$h_A = \frac{P_2 - P_1}{\gamma} + \frac{V_2^2 - V_1^2}{2g} + z_2 - z_1 + h_{L12} \rightarrow h_A = \frac{P_2}{\gamma} + z_2 + h_{L12}$$

$$h_A = \frac{\frac{30\,lb}{in^2} \times \frac{144\,in^2}{ft^2}}{62.4\,\frac{lb}{ft^3}} + 220\,ft + 15.5\,ft = 304.73\,ft$$

$$P_a = \gamma Q h_A$$

$$P_A = 62.4\,\frac{lb}{ft^3} \times 0.089\,\frac{ft^3}{s} \times 304.73\,ft$$

$$P_A = \frac{1692.35\,\frac{lb\cdot ft}{s}}{550\,\frac{lb\cdot ft}{s}} = 3.077\,HP$$

$$P_m = \frac{3.0771\,HP}{0.72} = \boxed{4.2736\,HP}$$

Materials: water

Analysis

Due to internal losses in the pump, the power delivered to pump by motor will always be greater than the required power.

Summary: The power of the motor of the pump is 4.2736 HP.