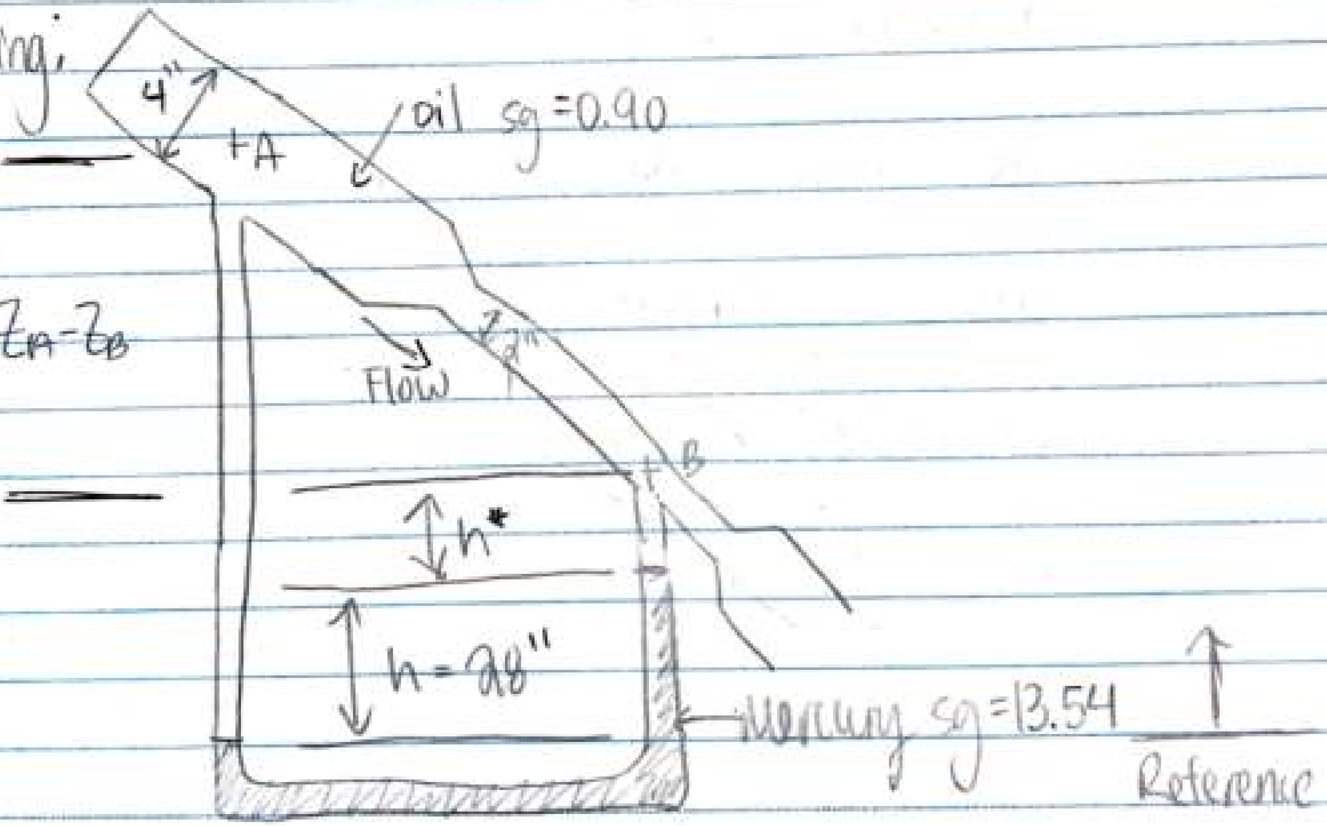
Dylan Arnold MET330 Summer 2023
HW04 June 11th, 2023 Professor Ayala
University ID: 01166349

6.79 Oil with a specific gravity of 0.90 is flowing downward through the venturi meter. If the manometer deflection "h" is 28in, [calculate the volume flow rate of oil] → Purpose

Drawing:




Source:
Mott and Untener. Applied Fluid Mechanics. 7th Edition. 2015. Pearson

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Problem 6.79 continued

Design Considerations:
The following must be assumed:
1) Incompressible fluid
2) Isothermal process
3) Steady State
4) No Energy losses (not true but in chapter where energy losses are not considered)

Data and Variables:
Diameter A = 4in
Diameter B = 2in
h = 28in
$sg_{oil}$ = 0.90
$sg_{mercury}$ = 13.54
$\gamma_{water}$ = 62.4 lb/ft$^3$ or 9.81 kN/m$^3$

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Problem 6.79 Continued:

Procedure:
Pick a reference point!
Be careful with units.
Use Bernoulli's Equation

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

Decide 2 points to apply to equation.
Manometer gives us enough info to indicate pressure difference between A + B.
Flow rate equation $Q = V \cdot A$

$$\Delta p = \gamma \cdot h \qquad \frac{Q^2}{2g}\left(\frac{1}{A_A^2} - \frac{1}{A_B^2}\right) = \frac{p_B - p_A}{\gamma} + (z_A - z_B)$$

$$Q = \sqrt{\frac{2g\left(\frac{p_B - p_A}{\gamma} + (z_A - z_B)\right)}{\frac{1}{A_A^2} - \frac{1}{A_B^2}}}$$

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$$p_A + \gamma_{oil}\left((z_A - z_B) + h^* + h\right) - \gamma_{mercury} h - \gamma_{oil} h^* = p_B$$

$$\frac{p_B - p_A}{\gamma_{mercury}} = (z_A - z_B) + \left(1 - \frac{\gamma_{mercury}}{\gamma_{oil}}\right)h$$

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Problem 6.79 Continued

or $$\frac{P_B - P_A}{\gamma_{mercury}} = (z_A - z_B) + \left(1 - \frac{sg_{mercury}}{sg_{oil}}\right)h$$

plug

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

Area Calculation:

$$A_A = \frac{\pi}{4} D_A^2 = \frac{\pi}{4}(4)^2 \cdot \frac{1 ft^2}{144 in^2} = 0.0873 ft^2$$

$$A_B = \frac{\pi}{4} D_B^2 = \frac{\pi}{4}(2)^2 \cdot \frac{1 ft^2}{144 in^2} = 0.0218 ft^2$$

$$Q = \sqrt{\frac{2 \cdot 32.2 \frac{ft}{s^2}\left(1 - \frac{13.54}{0.90}\right) \cdot 28 in \cdot \frac{1 ft}{12 in}}{\frac{1}{(0.0873 ft^2)^2} - \frac{1}{(0.0218 ft^2)^2}}}$$

$$\boxed{Q = 1.034 \frac{ft^3}{s}}$$



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Problem 6.79 Continued

Summary:
The flow rate in the venturi is 1.07 $\frac{ft^3}{s}$

Materials:
Oil and mercury

Analysis:
We can estimate flow rate without velocities.
However, we had to calculate pressure
difference in manometer first.

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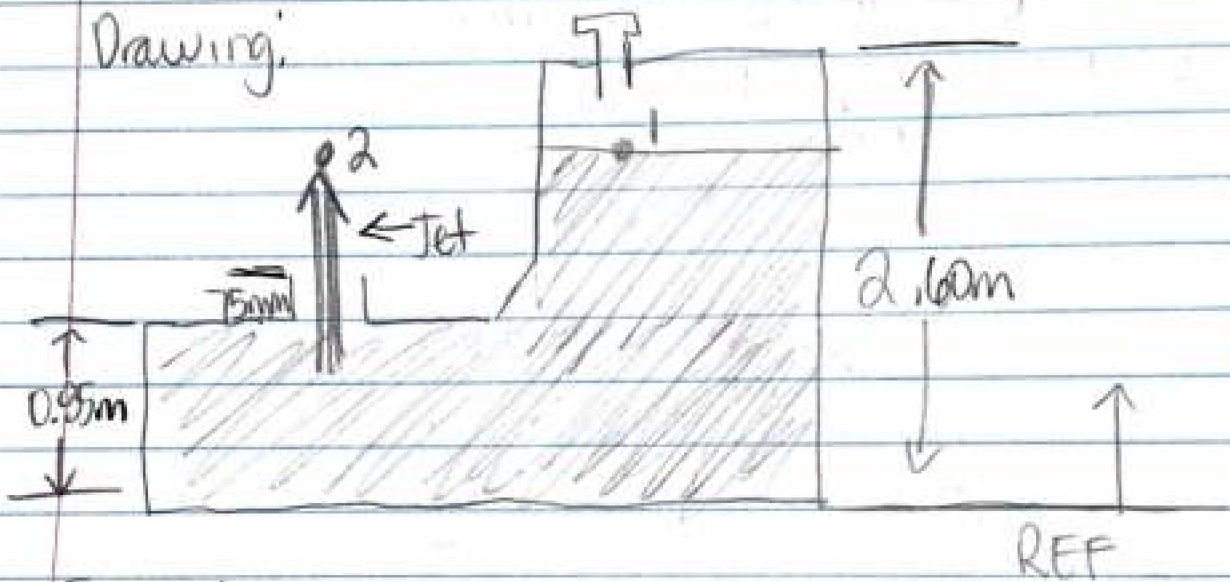
6.91 To what height will the jet of fluid rise?
← Purpose

Drawing:




Source:
Mott and Untener. 7th Edition. Applied Fluid Mechanics. Pearson. 2015.

Design Considerations:
1. Incompressible Fluid
2. Isothermal Process
3. Steady State
4. No energy losses

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Problem 6.91 Continued

Data and Variables
Various length of vessel provided.
$p = 0.0$ psig above water surface.
$\gamma_{water} = 9.81\ kN/m^3$

Procedure:
Bernoulli's Equation Moving Fluid

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

Solving for height at PT2

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

$$z_2 = \frac{p_1 - p_2}{\gamma} + z_1 \rightarrow z_2 = z_1$$

Summary:
The highest point the jet will reach is 2.6m
Materials:
Water
Analysis: If energy loss considered, the height decreases. PT2 has less energy to reach higher point.

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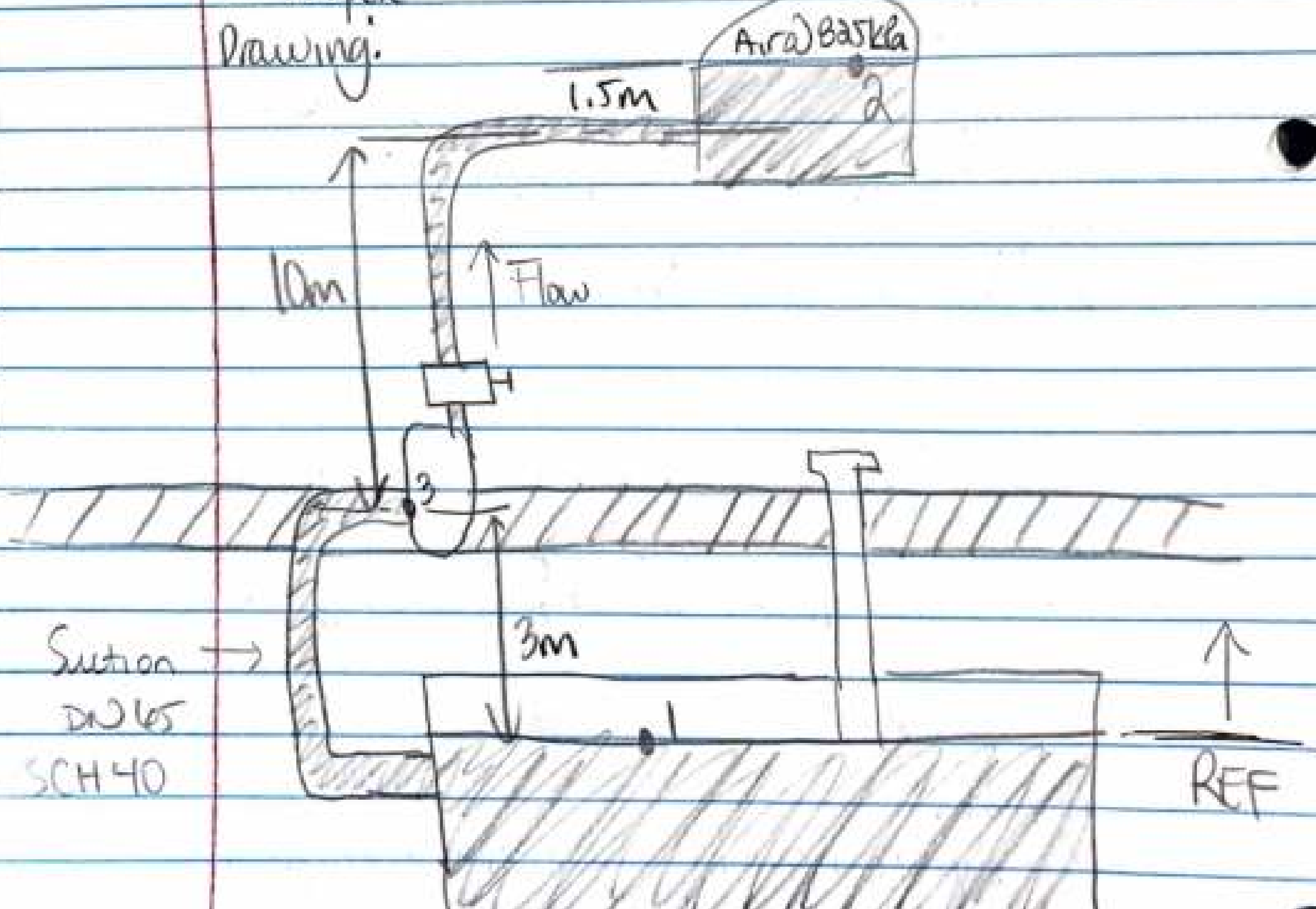
7.16 A pump delivering 840 L/min of crude oil (sg = 0.85) from drum to first processing stage a) total energy loss is 4.2 N·m/N flowing oil, calculate power delivered
b) if energy loss in suction pipe is 1.4 N·m/N, calculate pressure at pump inlet
← Purpose

Drawing:

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Problem 7.16 Continued

Source: Mott and Untener. 7th Edition. Applied Fluid Mechanics. Pearson. 2015

Design Considerations:

1) Incompressible Fluid
2) Isothermal Process
3) Steady State

Data and Variables:

Dimensions given in drawing. Pipe Sizes - Back of book

Pressures above liquid surfaces as indicated;

$sg_{oil} = 0.85$

$Q = 840 \ L/min = 0.014 \ m^3/s$

$h_{L\,sys} = 4.2m$

$h_{L\,suction} = 1.4m$

Procedure:

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

$P = \gamma Q h_A$

$$h_A = \frac{p_2 - \cancel{p_1}^{\,0}}{\gamma} + \frac{\cancel{v_2^2}^{\,0} - \cancel{v_1^2}^{\,0}}{2g} + z_2 - \cancel{z_1}^{\,0} + h_{L12}$$

$$h_A = \frac{p_2}{\gamma} + z_2 + h_{L12}$$

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

$$P = (0.85 \cdot 9810 \ N/m^3)(0.014 \ m^3/s)(117.64m) = \boxed{13.733 \ kW}$$

a

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Problem 7.16 Continued:

$$\cancel{\frac{p_1}{\gamma}}^0 + \cancel{\frac{V_1^2}{2g}}^0 + \cancel{z_1}^0 = \frac{p_3}{\gamma} + \frac{V_3^2}{2g} + z_3 + h_{L13}$$

$$\frac{p_3}{\gamma} = -\frac{V_3^2}{2g} - z_3 - h_{L13}$$

$$V_3 = \frac{Q}{A_3} \qquad A_3 = 3.09 \times 10^{-3}\ m^2$$

$$V_3 = \frac{0.0014\ m^3/s}{3.09 \times 10^{-3}\ m^2} = 4.531\ m/s$$

$$p_3 = (0.85 \times 9810\ N/m^3)\left(-\frac{(4.531\ m/s)^2}{2 \cdot 9.81\ m/s^2} - 3m - 1.4m\right)$$

$$\boxed{p_3 = -45.41\ kPa}\ B$$

Summary:
Power at pump is 13.73 kW
Pressure at inlet is −45.41 kPa
Materials: 0.1
Analysis:
Power of pump is proportional to head + flow rate
Pump head depends on energy losses, discharge pressure, + elevation at which we want to elevate fluid. Too negative of pressure could cause CAVITATION. Continued on PG 11 

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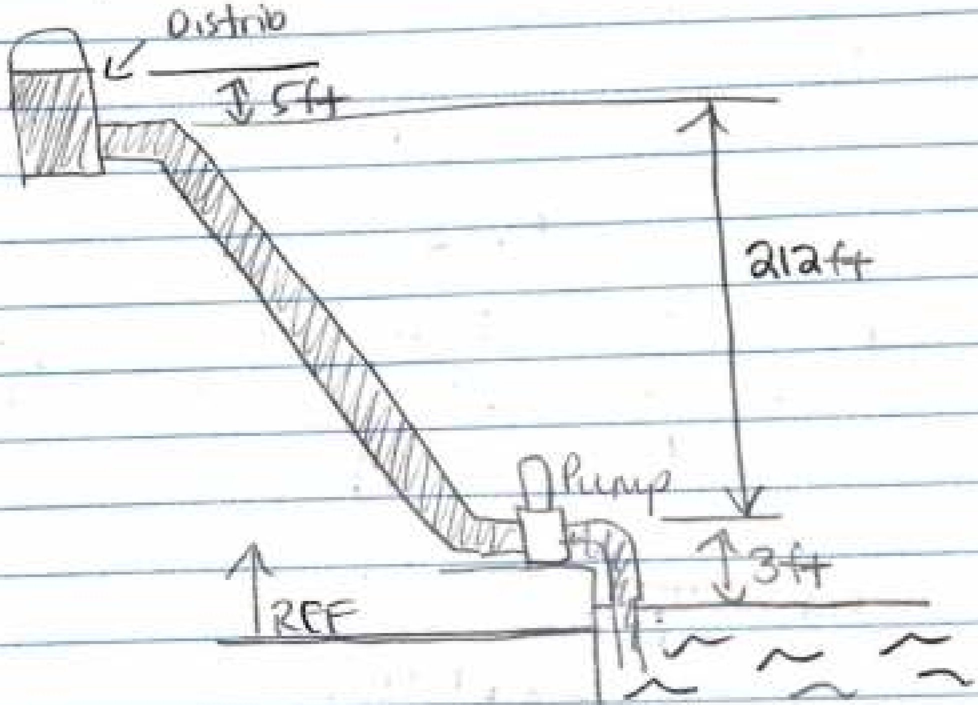
7.42 Distribution tank maintain pressure in cabin 30.0psig above water. Energy loss = 15.5 lb-ft/lb in piping. When pump is delivering 40 gal/min, compute horsepower delivered by pump to water. ← Purpose

Drawing:

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Design Considerations:
1) Incompressible Fluid
2) Isothermal Process
3) Steady State

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Problem 7.42 continued

Data and Variables:

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

$h_L = 15.5\ ft$

$p = 30\ psig$

Dimensions given

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

$$P_M = \frac{P_A}{\eta_A} = \frac{\gamma Q h_A}{\eta_A}$$

$$h_A = \frac{p_2 - \cancel{p_1}^{0}}{\gamma} + \frac{\cancel{v_2^2}^{0} - \cancel{v_1^2}^{0}}{2g} + z_2 - \cancel{z_1}^{0} + h_{L12}$$

$$h_A = \frac{p_2}{\gamma} + z_2 + h_{L12}$$

$$h_A = \frac{30\ lb/in^2 \cdot \frac{144\ in^2}{1\ ft^2}}{62.4\ lb/ft^3} + 220\ ft + 15.5\ ft$$

$h_A = 304.73\ ft$ $\quad P_A = \gamma Q h_A$

$$P_A = 62.4\ lb/ft^3 \cdot 0.089\ ft^3/s \cdot 304.73\ ft$$

$1\ HP = 550\ lb \cdot ft/s$

$P_A = 1692.35\ lb \cdot ft/s$ $\quad \boxed{P_A = 3.077\ HP}$

Continued on Pg 13

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Problem 7.42 Continued

Summary:

Power of motor is 3.077 HP

Materials:

Water

Analysis:

Power delivered by motor to pump will always be greater than required hydraulic power, because of some internal energy losses

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