Project Progress Report

MET 330

Dr. Ayala

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1. **Specify the size and location of all storage tanks. (to final report section 5.f.i)**

Purpose: Layout the piping system and determine the tank sizes.

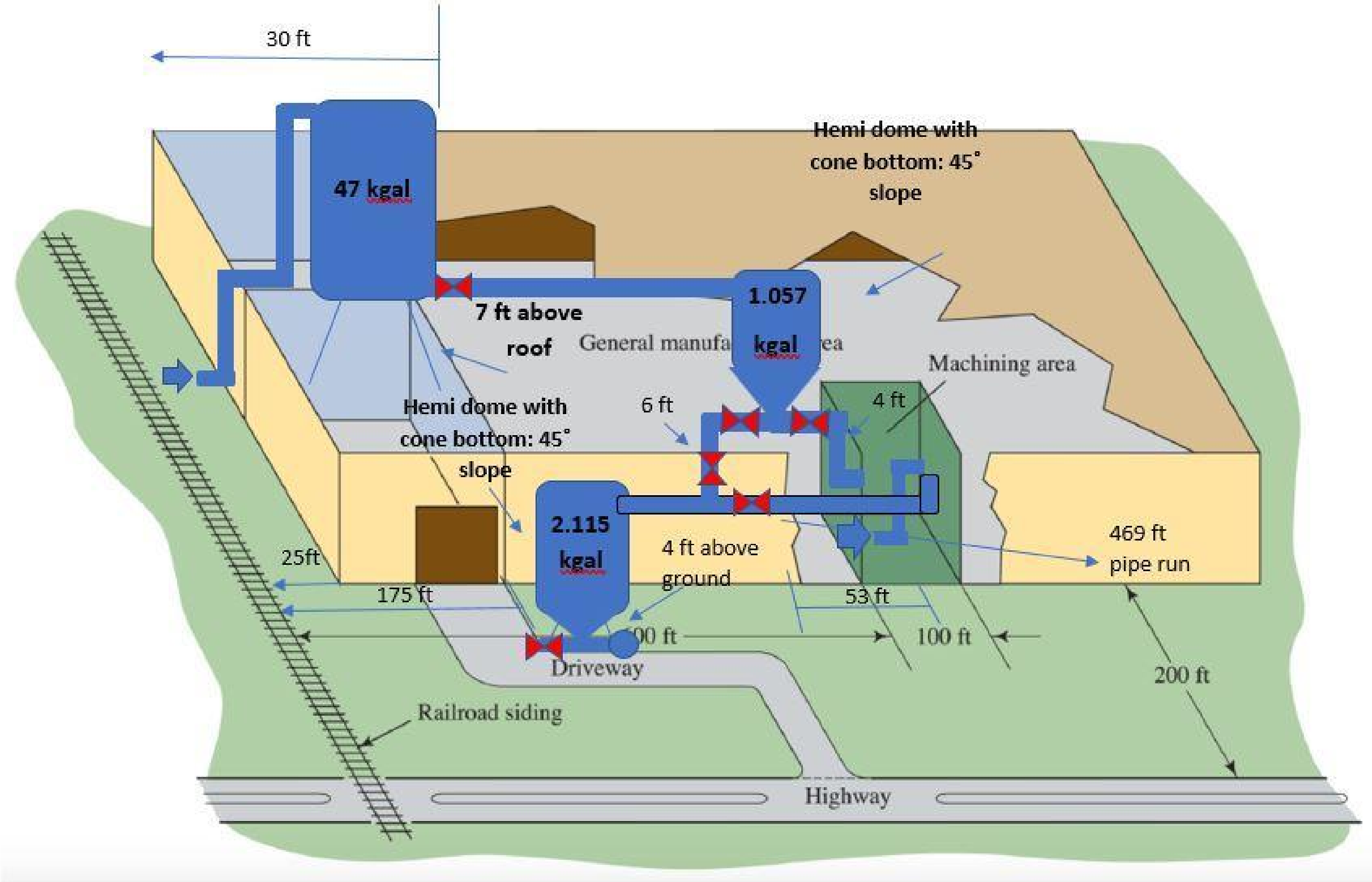
Sources:

- Project Document
- Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7^{th} edition, Pearson Education, Inc (2015)

Design Considerations:

1. New coolant is delivered to the plant by railroad tank cars carrying 15,000 gal each. A holding tank for new coolant must be specified.
2. The reservoir for the automated machining system must have a capacity of 1000 gal.
3. The 1000-gal tank is normally emptied once per week. Emergency dumps are possible if the coolant becomes overly contaminated prior to the scheduled emptying.
4. The dirty fluid is picked up by truck only once per month.
5. A holding tank for the dirty fluid must be specified.
6. The plant is being designed to operate two shifts per day, 7 days a week.
7. Maintenance is normally performed during the third shift.
8. The building is one-story high with a concrete floor.
9. The floor level is at the same elevation as the railroad track.
10. No storage tank can be inside the plant or under the floor except the 1000-gal reservoir that supplies the machining system.
11. The roof top is 32 ft from the floor level and the roof can be designed to support a storage tank.
12. The building is to be located in Dayton, Ohio, where the outside temperature may range from -20˚F to +105˚F.
13. The frost line is 30 in below the surface.
14. The coolant is a solution of water and soluble oil with a specific gravity of 0.94 and a freezing point of 0˚F. Its corrosiveness is approximately the same as that of water.
15. Assume that the viscosity and vapor pressure of the coolant are 1.50 times that of water at any temperature.
16. You are not asked to design the system to supply the machines.
17. The basic coolant storage and delivery system is to have the functional design sketched in the block diagram in Figure 2.

Drawings and Diagrams



Materials:

- Hydraulic Fluid
- 3 Tanks: Carbon Steel ASTM A106, Electric Resistance Welded
    - 47000 Gal
    - 2115 Gal
    - 1057 Gal

Data and Variables:

- Distances in figure
- γ = 58.656 lb/ft^3

Procedure:

1. An initial deliver of 45000 gallons of hydraulic fluid was decided on.
2. A diameter of 20 ft was chosen for the large holding tank and the height was calculated based on the volume and diameter.
3. The same process to determine the size of the tanks was used for the two smaller tanks, with the addition of a 45˚ cone bottom to aid with emptying.
4. The tanks were laid out in a way to take advantage of gravity and minimize pump usage.
5. Dimensions were added based on given dimensions, tank diameters, and approximate location of tanks.

Calculations:

Large Tank Size:

$$V = \frac{45000\,gal}{7.481} = 6015.625\,ft^3$$

$D_{inner} = 20ft$

$V = Ah \qquad A = \pi r^2$

$= \pi 10^2$

$= 314.195\,ft^2$

$6015.625ft^3 = 314.195\,ft^2\,(h) = 19.14ft$ of fluid

2000 gallon Tank: $\quad D_{inner} = 6ft$

$$V = \frac{2000\,gal}{7.481} = 267.34\,ft^3$$

45° cone bottom: $V \frac{1}{3}(h)(\pi r^2) = \frac{1}{3}(3)(\pi 3^2) = 27.99\,ft^3$

$V = 267.34ft^3 - 27.99ft^3 = 239.35ft^3$

$A = \pi r^2 = \pi 3^2 = 29.27ft^2$

$239.35ft^3 = 29.27ft^2 h = 8.46ft + 3ft = 11.46ft$

1000 gallon Tank: $\quad D_{inner} = 6ft$

$$V = \frac{1000\,gal}{7.481} = 133.67\,ft^3 \quad A = \pi r^2 = 29.27ft^2$$

45° cone bottom: $V \frac{1}{3}(h)(\pi r^2) = 27.99ft^3$

$V = 133.67\,ft^3 - 27.99ft^3 = 105.68ft^3$

$105.68ft^3 = 29.27h = 3.73ft + 3ft = 6.73ft$

Summary:
The large tank must be 20 ft in diameter with a height of 20 ft. Rounding from the calculated height of 19.148 ft to 20 ft allows the piping to fill the tank from above the surface of the fluid when nearing the full 45000 gallons.

The dirty tank must be 6 ft in diameter with a height of 12 ft. Rounding from the calculated height of 11.46 ft to12 ft allows the piping to fill the tank from above the surface of the fluid when nearing the full 2000 gallons.

The coolant reservoir tank must be 6 ft in diameter with a height of 7 ft. Rounding from the calculated height of 6.73 ft to 7 ft allows the piping to fill the tank from above the surface of the fluid when nearing the full 1000 gallons.

Analysis:
Rounding the tank heights to allow for room above the fluid results in tank volumes of 47000 gallons, 2115 gallons, and 1057 gallons. Due to the arrangement of the tanks, only 2 pumps will be required in the entire system.

2. Select tank material and specify wall thickness of storage tanks. (to final report section 5.f.i)

Purpose:

Chose the material the tanks will be made of and determine the required thickness of the tanks.

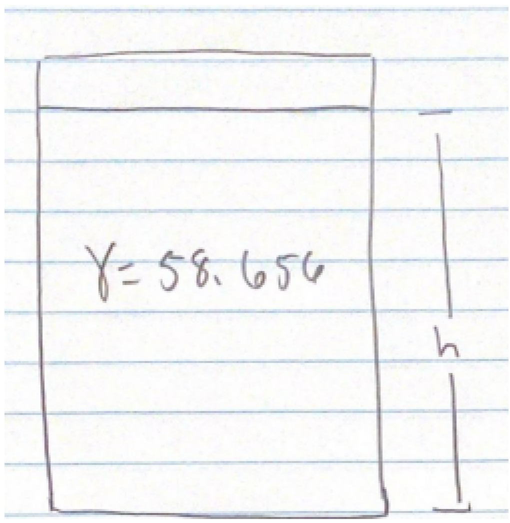
Sources:

- Project Document
- Mott, R., Untener, J.A, “Applied Fluid Mechanics”, 7th edition, Pearson Education, Inc (2015)

Design Considerations:

Refer to task 1 design considerations.

Drawings and Diagrams:



Data and Variables:

- Distances in figure
- $\gamma = 58.656\ lb/ft^3$
- S= 20000 psi
- E = 0.85
- Y= 0.4

Materials:

- Hydraulic Fluid
- 3 Tanks: Carbon Steel ASTM A106, Electric Resistance Welded
    - 47000 Gal
    - 2115 Gal
    - 1057 Gal

Procedure:

1. Gamma height equation was used to determine the pressure at the bottom of each tank.
2. The pressure was then plugged into equation 11.9 from the textbook to determine the wall thickness of the tank.

Calculations:

Large tank: $P = \gamma h$

$$P = 58.456\ lb/ft^3\,(19.1489) = \frac{1122.55\ psf}{144} = 7.795\ psi$$

$$t = \frac{PD}{2(SE)+PY} = \frac{(7.795psi)(240in)}{2(20000psi \times 0.85) + (7.795psi \times 0.4)}$$

$t = 0.55in$

$t_{min} = t + 0.08in = 0.55in + 0.08in = 0.135in$

$$t_{nom} = \frac{t_{min}}{0.875} = \frac{0.135in}{0.875} = 0.154in$$

Dirty tank: $P = 4.67psi$ $t = 0.0099in$ $t_{min} = 0.089in$
$t_{nom} = 0.103in$

Resivior: $P = 2.74psi$ $t = 0.0059in$ $t_{min} = 0.085in$
$t_{nom} = 0.098in$

Summary:
The nominal thickness for the large tank is 0.154 in
The nominal thickness for the dirty tank is 0.103 in
The nominal thickness for the large tank is 0.098 in

Analysis:
Applying a 2.5 factor of safety, the large tank thickness becomes 0.385 in. The dirty tank thickness becomes 0.258 in. The reservoir becomes 0.245 in.

3. Provide a future additional connection to drain ONE OF THE TANKS. Design the blind flange required to hold the pressure for such connection (size, thickness, etc.). This should include the number of bolts and nuts and the size of them. (to final report section 5.f.i)

Purpose: Design a tank to allow for a future connection by designing a blind flange, include bolt calculations.

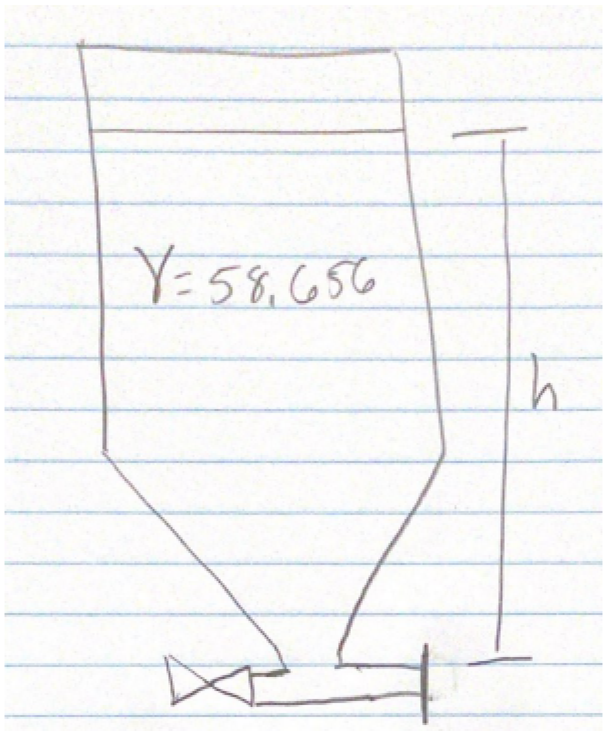
Sources:

- Project Document
- Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)

Design Considerations:

Refer to task 1 design considerations.

Drawings and Diagrams:



Data and Variables:

- Distances in figure
- $\gamma = 58.656\ lb/ft^3$
- S= 20000 psi
- E = 0.85
- Y= 0.4

Materials:

- Hydraulic Fluid
- 1 Tank: Carbon Steel ASTM A106, Electric Resistance Welded
  - 2115 Gal

Procedure:

1. Use pressure determined in task 2 to find the thickness of the blind flange using equation 11.9 from the textbook.
2. Calculate amount of bolts and their sizes.

Calculations:

$$P = \gamma h = 58.65\ lb/ft^3\ (11.46) = \frac{672.55\ psf}{7.491} = 4.67\ psi$$

$$t = \frac{PD}{2(SE)+(PY)} = \frac{(4.67\ psi)(2.067\ in)}{2(20000\ psi)(0.85) + (4.67\ psi * 0.4)} = 0.000284\ in$$

$$t_{min} = t + 0.08 = 0.000284\ in + 0.08 = 0.0802\ in$$

$$t_{nom} = \frac{t_{min}}{0.975} = \frac{0.0802\ in}{0.875} = 0.092\ in$$

D 18' $D = 6$ ft $D = 6$ ft $sg = 0.94$

$h = 20'$ $h = 5$ ft $h = 10$ ft $\gamma = \frac{.94}{62.4} = 0.01506 \frac{lb}{ft^3}$

$A = \frac{\pi d^2}{4}$

$283.5287\ ft^2$ $28.274\ ft^2$ $28.274\ ft^2$

$\gamma 20 = 0.30228$ $\gamma 5 = 0.0753$ 0.15064

$\frac{lb}{ft^3} \cdot ft$ $\frac{lb}{ft^2} \cdot ft^2 = lb$

85.422 psf   2.129 psf   4.2593 psf

$sg = \frac{\gamma}{\gamma_{water}}$ $\gamma = \frac{sg}{\gamma_{water}}$

= .593 psi   = .01479 psi   = 0.02958 psi

2.372 psi/19 =   0.05916 psi/6 =   0.1183 psi/6 =

0.1248 psi/bolt   0.00986 psi/bolt   0.0197 psi/bolt

4.67 psi

D = 2.067

$3.35560514\ in^2$

F = 1.3917 psi   SF4 = 5.5668/6 bolts = 0.9278 psi/bolt

Summary:

The thickness of the blind flange is calculated as 0.092 in.

There will be 6 bolts.

Analysis:

Applying the 2.5 factor of safety, the thickness becomes 0.25 in.

A factor of safety of 4 is applied to the bolts.

4. Estimate the time required to fill and empty all tanks (you are supposed to fix them). Specify the desired flow rate to fill and empty all tanks. (to final report section 5.f.ii)

Purpose: Use the chosen flow rates to determine the time to fill and empty each tank.

Sources:

- Project Document
- Mott, R., Untener, J.A, “Applied Fluid Mechanics”, 7th edition, Pearson Education, Inc (2015)

Design Considerations:

Refer to task 1 design considerations.

Drawings and Diagrams:
N/A
Materials:
- Hydraulic Fluid
- 3 Tanks: Carbon Steel ASTM A106, Electric Resistance Welded
    - 47000 Gal
    - 2115 Gal
    - 1057 Gal

Data and Variables:

- Large tank: 250 GPM to fill 100 GPM to empty
- Dirty tank: 100 GPM to fill and empty
- Reservoir: 100 GPM to fill and empty

Procedure:

1. Use the chosen flow rates and the tank volumes with the formula to solve for the time it takes to fill and empty the tanks.

Calculations:

Flow rates

47kgal tank

$250\ gpm = \frac{45000\ gal}{mins}$

$min = 180\ min = \frac{1}{60} = 3$ hours to fill

1057gal tank

$100\ gpm = \frac{1000\ gal}{mins}$

$mins = 10\ mins = 0.166$ hours to fill

2,115gal tank

$100gpm = \frac{2000\ gal}{min} = 20min = 0.33$ hours to fill

Summary:

It will take 3 hours to fill the large tank with 45000 gallons of hydraulic fluid and 10 minutes to empty 1000 gallons into the reservoir tank.

It will take 20 minutes to fill the dirty tank with 2000 gallons of hydraulic fluid. It will take the same amount of time to empty it.

It will take 10 minutes to drain the reservoir of 1000 gallons of hydraulic fluid.

Analysis

All the tanks are equipped with gate valves so their flow rates can be altered depending on need. The flow rates are assumed the gate valve is 100% open.

5. Specify the layout of the piping system, the material type and sizes of all pipes, and the lengths required. **Please note that if choosing to have a system driven by gravity, the pipe calculations are different to the case of pumped systems**. Please also remember that for a pumped system, the pipe size is chosen with the critical velocity criteria and the desired flow rate. **(to final report section 5.f.iii)**

Purpose: Determine pipe length, size, and types for the system.

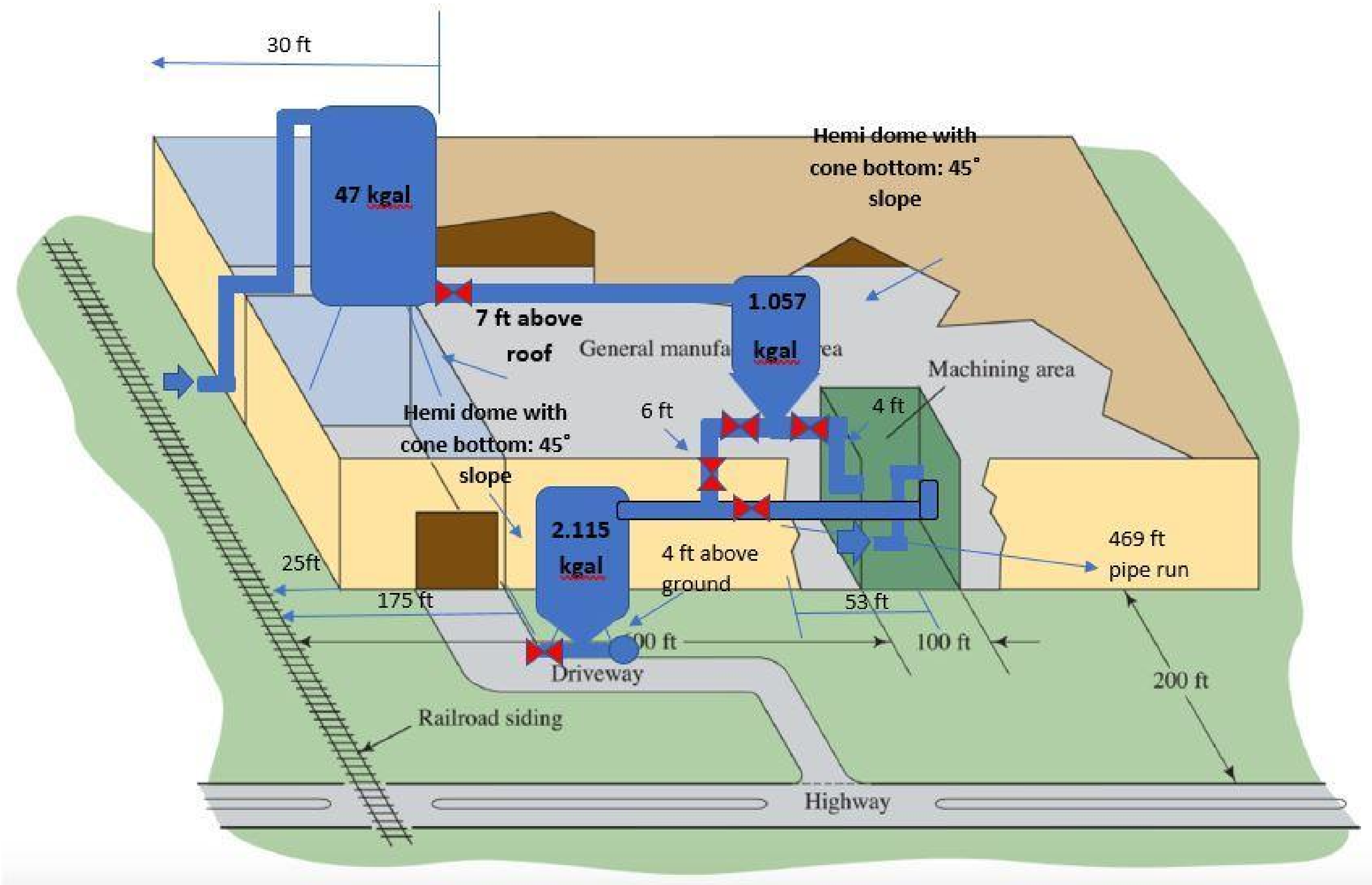
Sources:

- Project Document
- Mott, R., Untener, J.A, “Applied Fluid Mechanics”, 7th edition, Pearson Education, Inc (2015)

Design Considerations:

Refer to task 1 design considerations.

Drawings and Diagrams:



Data and Variables:

- Large tank: 250 GPM to fill 100 GPM to empty
- Dirty tank: 100 GPM to fill and empty
- Reservoir: 100 GPM to fill and empty

Materials:

- Hydraulic Fluid
- 3 Tanks: Carbon Steel ASTM A106, Electric Resistance Welded
    - o 47000 Gal
    - o 2115 Gal
    - o 1057 Gal

Procedure:

1. Use chosen flow rate and critical velocity to determine the flow area of the pipes in each section using the Q= AV equation.

2. Find nearest pipe flow area on Appendix F of textbook (round up).

Calculations:

47kgal tank to empty, 1kgal and 2kgal fill.

2in pipe @ 9.6 ft/s

$Q = AV = 0.222 = A(9.6) = 0.025\ ft^2$

$Q = AV$

$250\ gpm = a \times V$

↳ $3\ m/s = 9.6\ ft/s$

$0.556793 = a(9.6)$

$a = 0.0579$

a = 3½ in pipe inlet

Summary:

- The length of pipe from the railroad up to the large tank will be a horizontal length of 10 ft and vertical length of 52 feet. The pipe will be 3 ½ in nominal diameter.
- The length of pipe from the large tank to the reservoir will be 524 ft horizontally with no vertical distance. This pipe will have a 2 in nominal diameter.
- The pipe length from the reservoir to the machining area will be 4 ft vertically. This pipe will have a 2 in nominal diameter.
- The pipe length from the reservoir to the emergency dirty tank dump will be 6 ft. This pipe will have a 2 in nominal diameter.
- The pipe from the machining area pump to the dirty reservoir will have a height of 16 ft and a horizontal length of 469 ft. This pipe will have a 2 in nominal diameter.

Analysis:

These dimensions assume an industry standard critical velocity of 9.6 ft/s. Adjustment to account for gravity fed system may be required in the future when it is discussed in class. Carbon Steel ASTM A106 will be used for the pipe to aid in welding of similar metals.

6. Specify the number, types, material, and size of all valves, elbows, and fittings. **Please note that if choosing to have a system driven by gravity, the pipe calculations are different to the case of pumped systems**. Please also remember that for a pumped system, the pipe size is chosen with the critical velocity criteria and the desired flow rate. **(to final report section 5.f.iii)**

   Purpose: Create a parts list of required valves, elbows, and fittings.

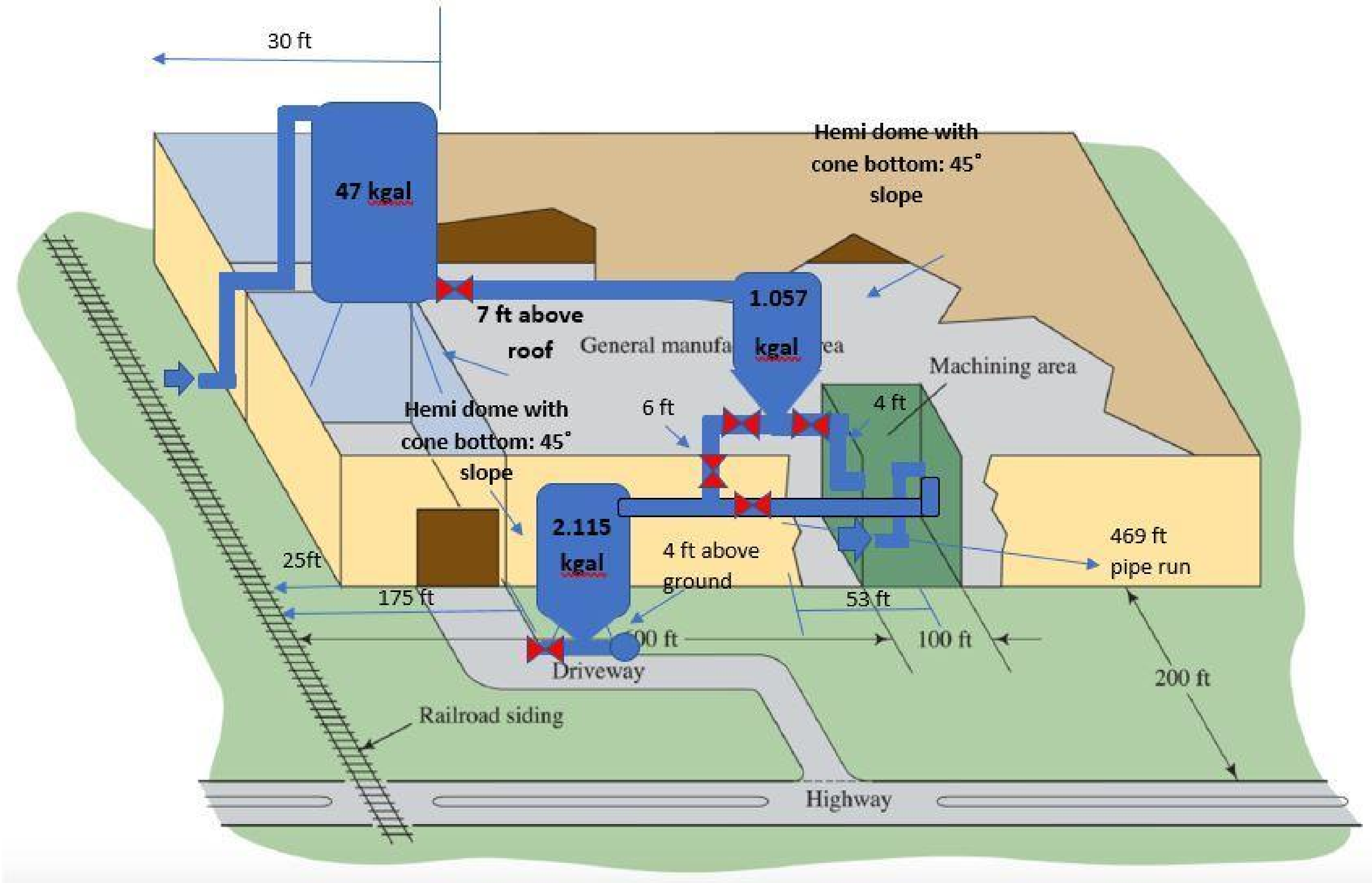
   Sources:

   - Project Document
   - Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)

   Design Considerations:

   Refer to task 1 design considerations.

Drawings and Diagrams:



Data and Variables:

- **N/A**

Materials:

- Hydraulic Fluid
- Carbon Steel ASTM A106

Procedure:

1. Use piping layout from diagram to list required parts.

Calculations:

Sizes are based on pipe sizes calculated in task 5.

Summary:

- 6 Gate Valves for 2 in pipe
- 4 Short Radius Elbows for 3 ½ in pipe
- 6 Short Radius Elbows for 2 in pipe
- 3 Standard Tees for 2 in pipe

Analysis:

All material will match material of piping indicated in task 5.

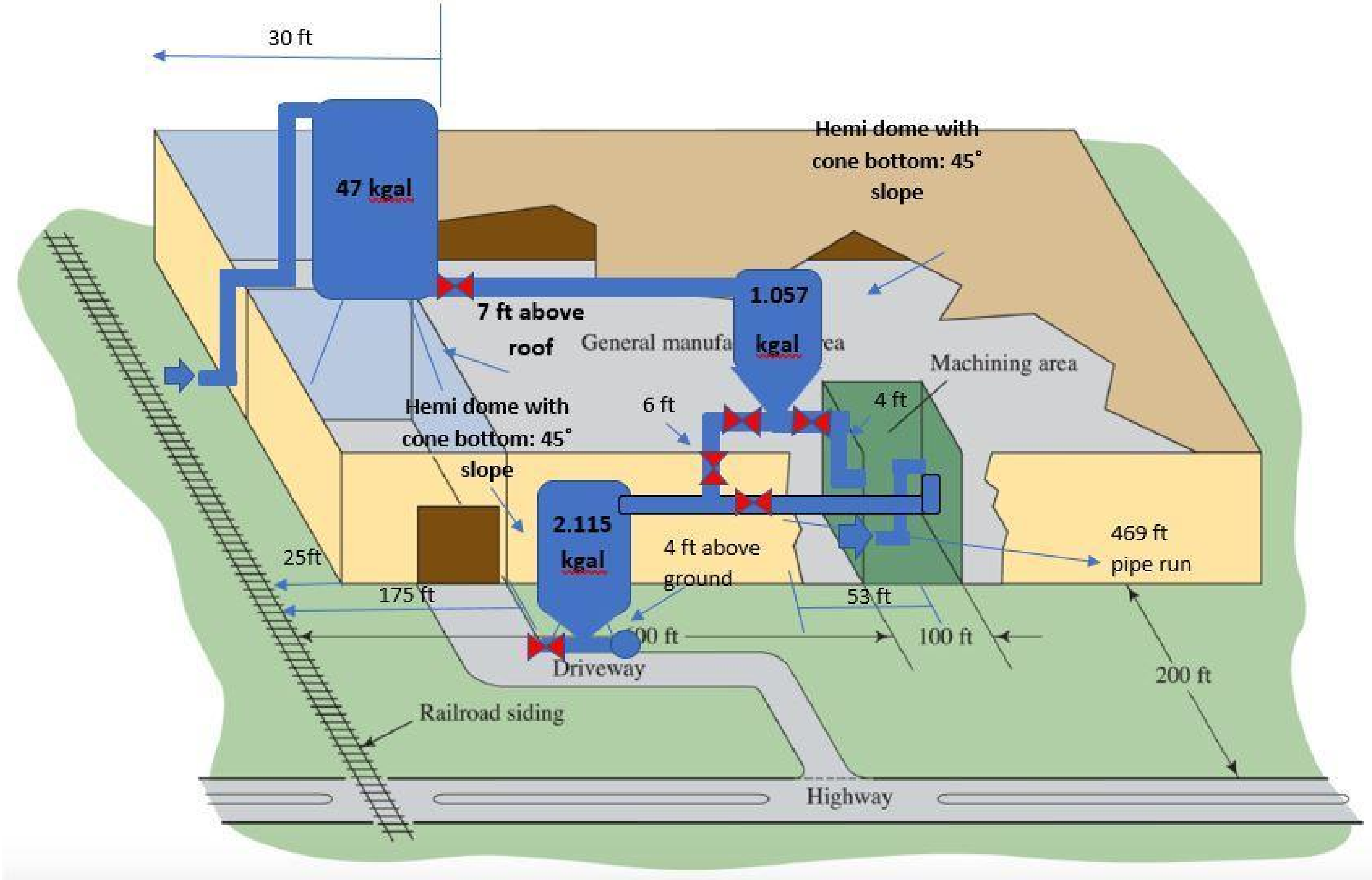
7. Develop the hydraulic analysis of all parts of the system; this includes energy losses due to friction and minor losses. You should list the energy losses per section(s) of each of the coolant sub-systems. For this task, you are allowed to use software but one of the coolant sub-systems MUST be calculated by hand and compare against the software results. (to final report section 5.f.v)

Purpose: Calculate all the minor losses in system.

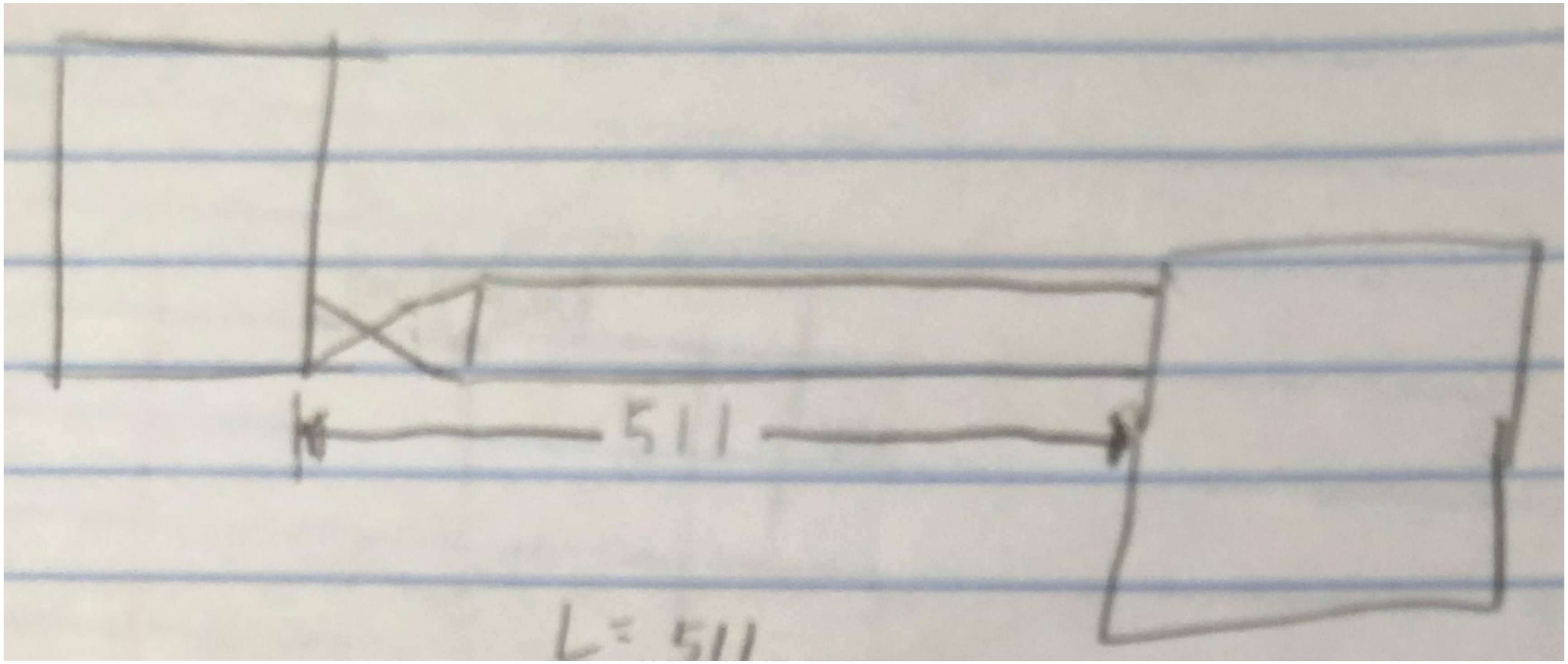
Sources:

- Project Document
- Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)
- https://www.gbrx.com/media/1466/tank29000.pdf

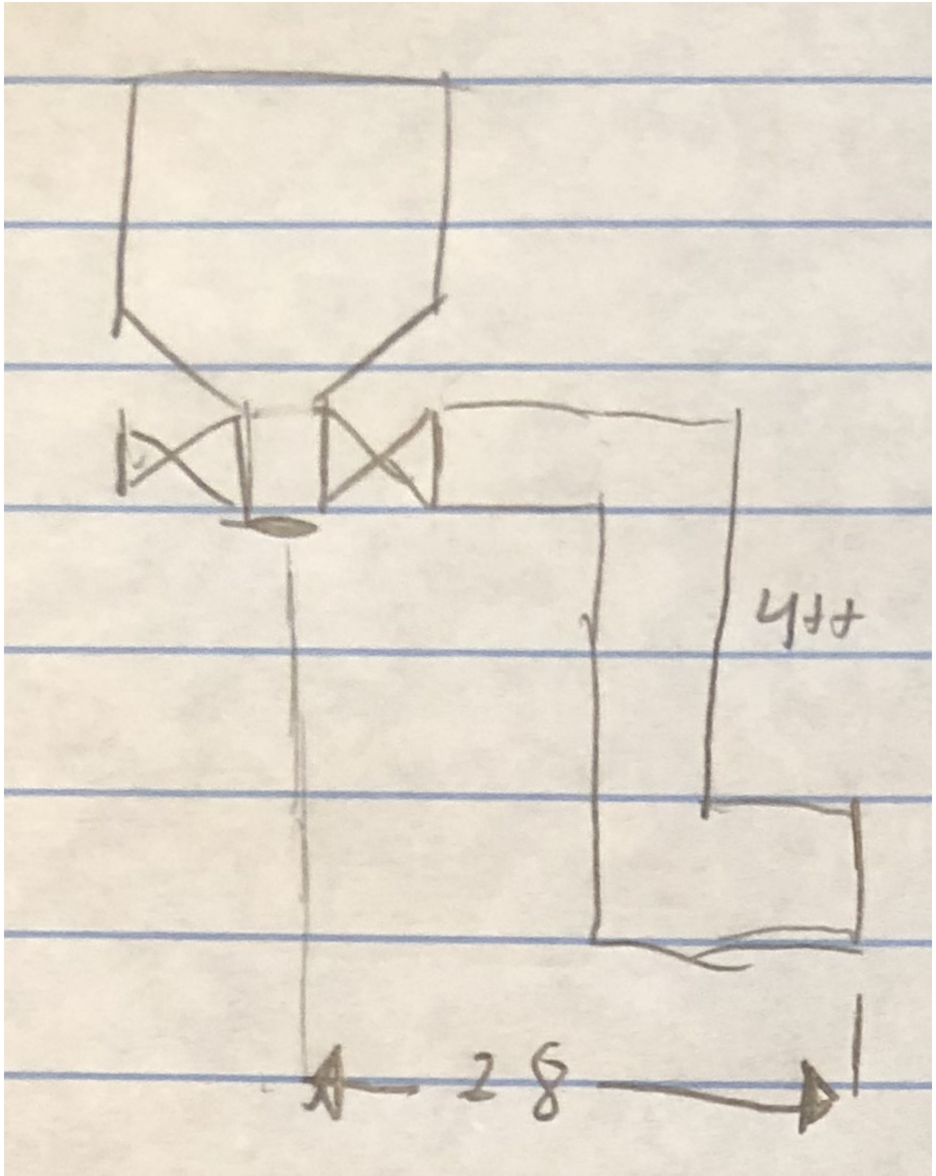
Drawings and Diagrams:



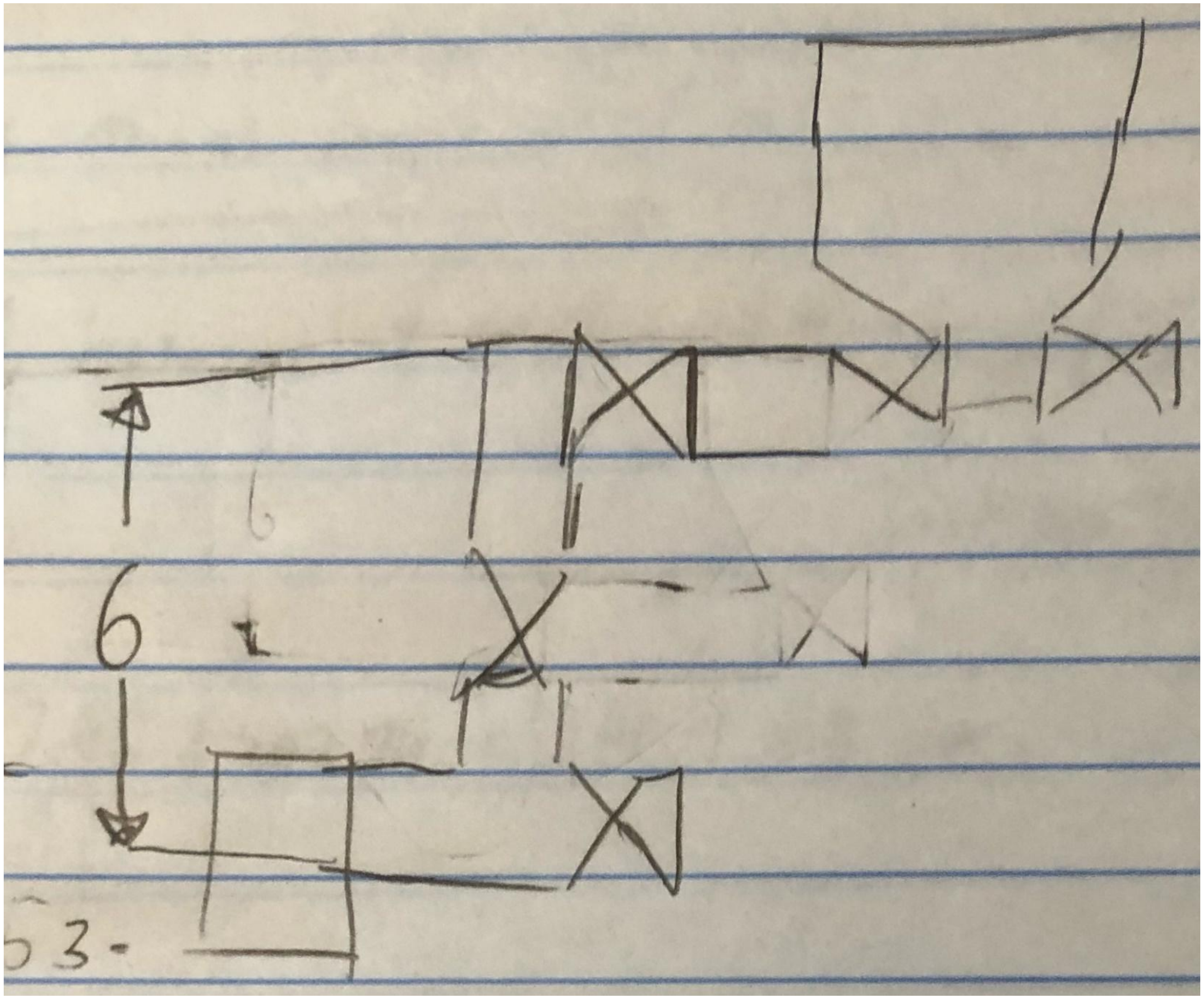
Large Tank to Reservoir Tank:



Reservoir Tank to Equipment:



Reservoir Tank to Dirty Tank:



Data and Variables:

- **γ=58.656 lb/ft3**
- **V1=V2=0 ft/s**
- **Vp= 9.6 ft/s**
- **g= 32.2 ft/s2**
- **Di of 2 in pipe= 0.1723 ft**
- **ρ= 1.8236 slug/ft3**
- **Length of 3 ½ in pipe= 84 ft**
- **Length of 2 in pipe= 485 ft**

Materials:

- **Hydraulic Fluid**
- **Carbon Steel ASTM A106**

Procedure:

Large Tank to Reservoir Tank:

1. Set points at the surface of each tank to assume zero velocity.
2. Solve Bernoulli's for pump head
3. Solve for entrance loss, exit loss, elbow loss, and pipe loss.
4. Add together total losses

Reservoir Tank to Equipment:

1. Set points at the surface of each tank to assume zero velocity.
2. Solve Bernoulli's for pump head
3. Solve for entrance loss, exit loss, elbow loss, and pipe loss.
4. Add together total losses

Reservoir Tank to Dirty Tank:

1. Set points at the surface of each tank to assume zero velocity.
2. Solve Bernoulli's for pump head
3. Solve for entrance loss, exit loss, elbow loss, and pipe loss.
4. Add together total losses

Total loss minus losses in pimp sections(8)

1. Add together total losses

Calculations:

$$h_a = \cancel{\frac{P_1}{\gamma_1}} + \cancel{\frac{V_1^2}{2g}} + \cancel{z_1} = \cancel{\frac{P_2}{\gamma_1}} + \cancel{\frac{V_2^2}{2g}} + \cancel{z_2} + h_L$$

$$h_a = h_L$$

h_L = entrance Loss + exit Loss + valve Loss + friction Loss + Elbow loss

Entrance Loss = $K\left(\frac{V_1^2}{2g}\right) = .5\left(\frac{9.6^2}{64.4}\right) = 0.72$ ft = EL

Exit Loss = $K\left(\frac{V_2^2}{2g}\right)$ $1\left(\frac{0^2}{64.4}\right) = 0$ ft = ExL

Gate Valve Loss = $K\left(\frac{V_p^2}{2g}\right) = .44\left(\frac{9.6^2}{64.4}\right) = 0.64$ ft = GL

Elbow loss = $K\left(\frac{V_p^2}{2g}\right) = .57\left(\frac{9.6^2}{64.4}\right) = 0.8$ ft = EbL

T. Lose = $K\left(\frac{V_p^2}{2g}\right)$ $1.1\left(\frac{9.6^2}{64.4}\right)$ 1.59 ft = TL

PiPe Loss:

$$N_R = \frac{VDP}{\eta} = \frac{9.6(.172)(1.82)}{2.6\times10^{-3}}$$

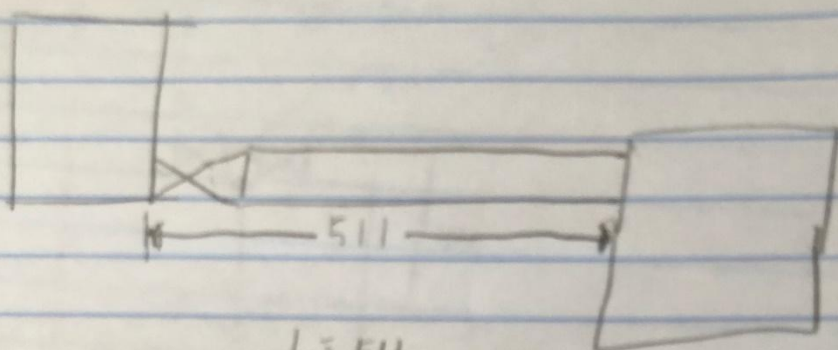
$$N_R = 1144.09 < 2000 = \text{Lam}$$

$$h_L = \frac{32\eta LV}{\gamma D^2} = \frac{32(2.6\times10^{-3})L(9.6)}{58.65(0.1723)} \quad L$$

L Lira. because it is an independent Variable

$$h_L = \frac{0.8064L}{1.7212} = 0.4685L$$

Section 1



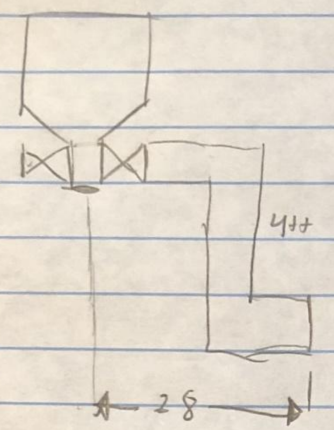
$L = 511$

$h_L = 0.4685(511) = 239.4$

$h_{L\,total} = EL + GL + h_L + ExL$

$h_{L\,total} = 0.72 + 0.64 + 239.4 + 0 = 240.76$ ft

Section 2



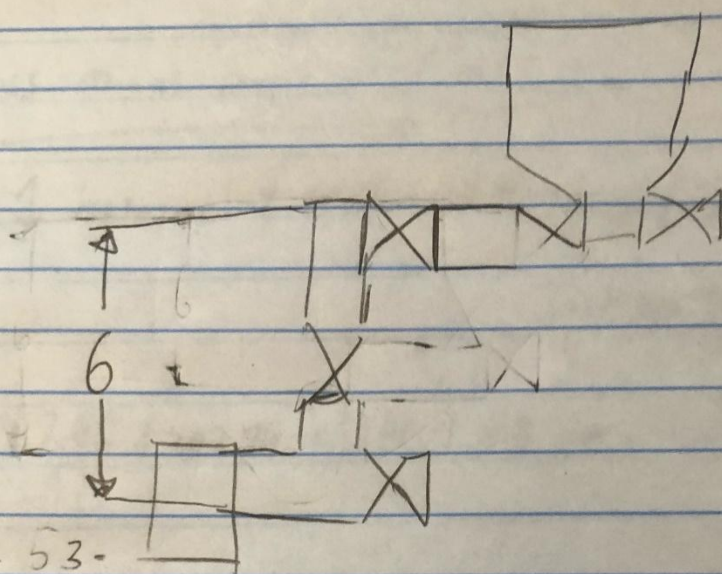
$L = 4 + 28 = 32\,ft$

$hL = 0.4685(32) = 14.99$

$h_{L_{TOTAL}} = EL + GL + 2EbL + hL + EXL$

$h_{L_{TOTAL}} = .72 + .64 + 2(.8) + 14.99 + .0 = 17.95\,ft$

Section 3



$L = 485 - 53 + 6 = 422$

$h_L = 0.4685(422) = 197.7$

$h_{L\,total} = EL + 3GL + EbL + TL + EXL + h_L$

$= .72 + 3(.64) + .8 + 1.59 + 0 + 197.7 = ?$

202.74 ft

Total Loss minus pipe sections =

section 1 hLtotal + section 2 hLtotal +

Section 3 hLtotal

240.76 + 17.95 + 202.74 = 461.45 ft

Summary:

The first loss after the pump section is from the large tank to the Reservoir Tank which is 240.26ft. Then out of the Reservoir Tank there is two options for lose the first being when it goes in to the equipment with a loss of 17.95 ft, or it can go to the dump with the dirty tank, with a loss of 20274ft. with a total system lose of 461.45 ft minus the loses in the Pump Sections(8).

Analysis:

Most losses are from Friction in the pipes but that also being said with complexity of this system these losses are negatable.

8. How many pumps do you need? What are the requirements (this is, you have to provide pump head and flow rate) of each pump? For this task, you are allowed to use software but one of the coolant sub-systems MUST be calculated by hand and compare against the software results. **(to final report section 5.f.vi)**

Purpose: Determine pumps required to run the system

Sources:

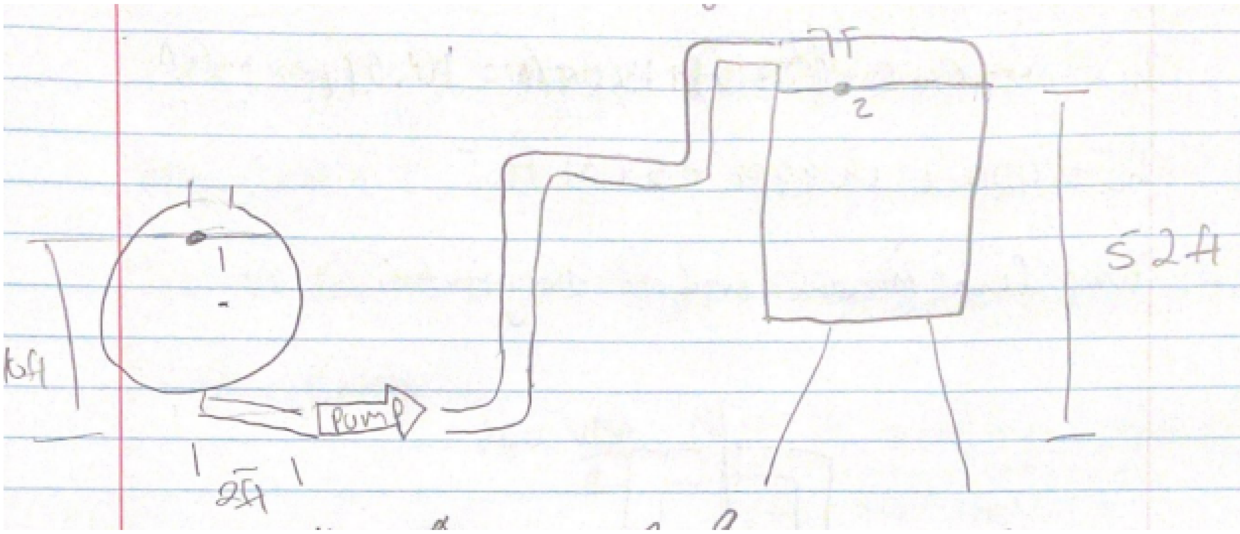
- Project Document
- Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)
- https://www.gbrx.com/media/1466/tank29000.pdf

Design Considerations:

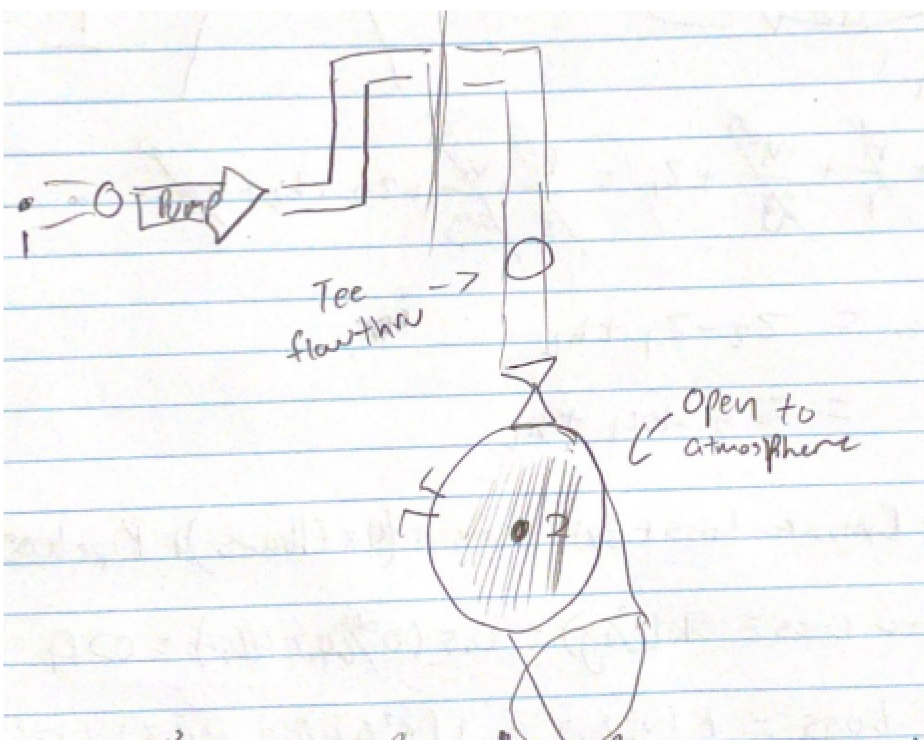
- Refer to task 1 design considerations.
- Standard tanker car is 8 ft in diameter and will be approximately 2 feet above the ground.
- Standard tanker cars are vented to atmosphere during unloading
- Assume atmospheric pressure at machinery outlet
- Standard critical velocity of 9.6 ft/s assumed at machinery outlet

Drawings and Diagrams:

Pump from train to large tank:



Pump from machinery area to dirty tank:



Data and Variables:

- γ=58.656 lb/ft^3
- V_1=V_2=0 ft/s
- V_p= 9.6 ft/s
- g= 32.2 ft/s^2
- D_i of 3 ½ in pipe= 0.2975 ft
- D_i of 2 in pipe= 0.1723 ft
- ρ= 1.8236 slug/ft^3
- Length of 3 ½ in pipe= 84 ft
- Length of 2 in pipe= 485 ft

Materials:

- Hydraulic Fluid
- Carbon Steel ASTM A106

Procedure:

Pump from train to large tank:

5. Set points at the surface of each tank to assume zero velocity.
6. Solve Bernoulli's for pump head
7. Solve for entrance loss, exit loss, elbow loss, and pipe loss.
8. Add together total losses and plug in to Bernoulli's to solve for pump head.

Pump from machining area to dirty tank:

1. Set points at the outlet of machining area and surface of dirty tank
2. Solve Bernoulli's for pump head
3. Solve for exit loss, elbow loss, tee loss, and pipe loss.
4. Add together total losses and plug in to Bernoulli's to solve for pump head.

Calculations:

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

$$h_a = z_2 - z_1 + h_L$$

$$= 52\,ft - 10\,ft + h_L$$

$$h_L = \text{Entrance Loss} + \text{Exit Loss} + (4 \times \text{Elbows}) + \text{Pipe loss}$$

$$\text{Entrance loss} = K(v_2^2/2g) = 0.5(0^2\,ft/s^2 / 64.4\,ft/s^2) = 0\,ft$$

$$\text{Exit loss} = K(v_1^2/2g) = 1(0^2\,ft/s / 64.4\,ft/s^2) = 0\,ft$$

$$\text{Pipe Loss: } N_R = \frac{vD\rho}{\eta} = \frac{(9.6\,ft/s)(0.2975\,ft)(1.85\,slugs/ft^3)}{(2.425 \times 10^{-3}\,lb\text{-}s/ft^2)}$$

$$N_R = 1984.08 < 2000, \text{ laminar flow}$$

$$f_L = \frac{64}{N_R} = \frac{64}{1984.08} = 0.032$$

$$h_L = \frac{32\eta L v}{\gamma D^2} = \frac{32(2.625 \times 10^{-3}\,lb\text{-}s/ft^2)(84\,ft)(9.6\,ft/s)}{(58.656\,lb/ft^3 \times (0.2975\,ft)^2)} \rightarrow$$

Elbowloss $= k(v_p^2/2g) = 0.57(9.6 ft/s^2 / 64.4 ft/s^2) = 0.816 ft$

Pipeloss = 13.05 ft

$h_{L\,total} = 0 + 0 + 4(0.816) ft + 13.05 ft = 16.3 ft$

$h_a = 42 ft + 19.99 ft = 58.31 ft$.

Pump from Machine area to dirty tank:

$$h_a + \cancel{\frac{P_1}{\gamma}} + \frac{V_1^2}{2g} + \cancel{Z_1} = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + Z_2 + h_L + \cancel{h_R}$$

$$h_a = -\frac{V_1^2}{2g} + Z_2 + h_L$$

$$= \frac{-9.6^2 ft/s}{2(32.2 ft/s^2)} + 16 ft + h_L$$

h_L = Elbow loss + Tee loss + Pipe loss + Exit loss + Gate Valve loss

Exit Loss $= 1.0\,(v_1^2/2g) = 1(9.6^2\,ft/s/64.4\,ft/s^2) = 1.43\,ft$

Elbow loss $= K(v_p^2/2g) = 0.57(9.6^2\,ft/s/64.4\,ft/s^2) = 0.816\,ft$

Tee loss (flow thru) $= k(v_p^2/2g) = 1.11(9.6^2\,ft/s/64.4\,ft/s^2) = 1.59\,ft$

Laminar pipe loss:

$$N_R = \frac{vD\rho}{\eta} = \frac{(9.6\,ft/s)(0.1723\,ft)(1.8236\,slugs/ft^3)}{(2.625\times10^{-3}\,lbs/ft^2)}$$

$N_R = 1149.09 < 2000$, Laminar flow

$$h_L = \frac{32\eta L v_p}{\gamma D^2} = \frac{32(2.625\times10^{-3}\,lbs/ft^2)(485\,ft)(9.6\,ft/s)}{58.656\,lb/ft^3(0.1723\,ft)^2}$$

$h_L = 224.599\,ft$

Gate Valve loss: $K(v_p^2/2g) = 0.44(9.6\,ft/s/64.4\,ft/s^2) = 0.64\,ft$

$h_{L\,total} = 1.43\,ft + (3(0.816\,ft)) + 1.59\,ft + 224.599\,ft + 0.64\,ft = 230.71\,ft$

$$h_a = -\frac{9.6^2\,ft/s}{2(32.2\,ft/s^2)} + 16\,ft + 230.71\,ft = 245.28\,ft$$

Summary:

Flow rate for the pump from train to large tank was set to 250 GPM and a pump head of 58.31 ft was calculated. Flow rate for the pump from the machinery area to the dirty tank was set to 100 GPM and a pump head of 245.28 ft was calculated.

Analysis:

The pump from the machining area to the dirty tank requires more power because it has a significantly longer distance for the fluid to travel.

9. Specify pipe wall thickness (schedule). You need for this the maximum operating pressure of the system. In a pumped system this pressure is typically at the exit of the pump. (to final report section 5.f.iii)

Purpose: Determine pumps required to run the system

Sources:

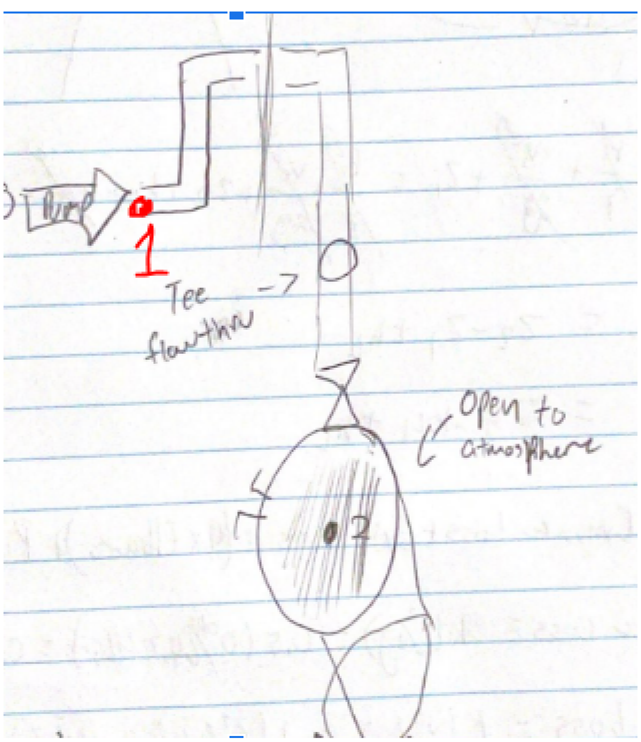
- Project Document
- Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)
- https://www.gbrx.com/media/1466/tank29000.pdf

Design Considerations:

- Refer to task 1 design considerations.
- Velocity in the pipes is 9.6 ft/s (industry standard for flow rate of 100 GPM)
- Tanks are at atmospheric pressure

Drawings and Diagrams:

Pump from machinery area to dirty tank:



Pressure for pump in train to large tank exit:

Data and Variables:

- γ=58.656 lb/ft^3
- ρ= 1.8236 slug/ft^3
- Length of 3 ½ in pipe= 84 ft
- Length of 2 in pipe= 485 ft
- S= 20000 psi
- E = 0.85
- Y= 0.4

Materials:

- Hydraulic Fluid
- Carbon Steel ASTM A106

Procedure:

1. Determine maximum operating pressure.
2. Plug pressure in to equation 11.9 from the textbook to solve for thickness, minimum thickness, and nominal thickness
3. Use the tables in the appendix for steel pipe dimensions to determine which schedule lines up with the nominal wall thickness

Calculations:

Pressure in machinery area pump exit:

$$h_a + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + z_2 + h_L + \cancel{h_R}$$

$$P = \gamma\left(-\frac{V_1^2}{2g} - z_1 + z_2 + h_L - h_a\right)$$

$$= 61.654\,\text{lb/ft}^3\left(-\frac{9.6\,\text{ft/s}^2}{64.4\,\text{ft/s}^2} + 16\,\text{ft} + 230.72\,\text{ft} - 245.28\,\text{ft}\right)$$

$$P = \frac{168.4\,\text{lb/ft}^2}{144} = 1.17\,\text{psi}$$

Thickness of 2 in pipe:

$P_2 = P_1 - \gamma(z_1 - z_2 + V_1^2/2g - V_2^2/2g - h_L + h_p)$

$0 - 58.656(16 - 9.6^2/2g + 230.71 - 245.28)$

$16 - 1.431 + 230.71 - 245.28$

$P = 168.4\ lb/ft^2 / 144 = 1.17\ psi$

$$t = \frac{pD}{2(SE + pY)} \qquad S = 20\ ksi \quad Y = .4 \quad E = 1.0$$

$$\frac{1.17(2.375)}{2(20{,}000 \cdot .85 + 1.17 \times .4)} = 8.173 \times 10^{-5}\ in$$

$t_{min} = 8.173 \times 10^{-5} + .08 = .08008173\ in$

$t_{nom} = .08008173/(.875) = .0915\ in$

Pressure for pump in train to large tank exit:

$$h_A + \frac{P_1}{\gamma} + \frac{v_1^2}{2g} + \cancel{z_1} = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{v_2^2}{2g}} + z_2 + h_L + \cancel{h_R}$$

$$P_1 = \gamma\left(-\frac{v_1^2}{2g} + z_2 + h_L - h_A\right)$$

$$P_1 = 56.654\ lb/ft^3\left(\frac{-9.6 ft/s^2}{64.4 ft/s^2} + 52 ft + 16.34 - 58.34\right)$$

$$P_1 = 669.9\ psi/144 = 4.65\ psi$$

Thickness of 3 ½ in pipe:

$$P_1 = \gamma\left(-\frac{v_1^2}{2g} + z_2 + h_L - h_A\right)$$

$$P_1 = 56.656\left(\frac{-9.6^2}{64.4} + 52 + 16.3 - 58.3\right)$$

$$P_1 = 669.9\ psi/144 = 4.65\ psi$$

$$t = \frac{pD}{2(SE + pY)} = \frac{4.65(4)}{2(20{,}000 \cdot .85 + 4.65 \times .4)}$$

$$t = 5.47 \times 10^{-4}\ in$$

$$t_{min} \quad 5.47 \times 10^{-4} + .08 = .080547\ in$$

$$t_{nom} = .080547/.875 = .0921\ in$$

Summary:
The maximum operating pressure in the 2 in sections of pipe is 1.17 psi.
The maximum operating pressure in the 3 ½ in sections of pipe is 4.65 psi.
The nominal wall thickness for the 2 in sections of pipe was calculated to be 0.0915 in.
The nominal wall thickness for the 2 in sections of pipe was calculated to be 0.0920 in.
Analysis:
Because both wall thicknesses are well below the listed wall thicknesses for the respective pipe sizes in the schedule 40 table, schedule 40 pipe will be used for the entire system.