Project Progress Report

MET 330

Dr. Ayala

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2. Abstract

3. Table of Contents

4. List of Figures & List of Tables

5. Report Body

a. Job site location

Dayton, Ohio, United States

b. Specifications and design philosophy

- New coolant is delivered to the plant by railroad tank cars carrying 15,000 gal each. It has been decided that 3 tanker cars will be requester per delivery, totaling 45,000 gals.
- A holding tank for new coolant must be specified.
- The reservoir for the automated machining system must have a capacity of 1000 gal.
- 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.
- The dirty fluid is picked up by truck only once per month.
- A holding tank for the dirty fluid must be specified.
- The plant is being designed to operate two shifts per day, 7 days a week.
- Maintenance is normally performed during the third shift.
- The building is one-story high with a concrete floor.
- The floor level is at the same elevation as the railroad track.
- No storage tank can be inside the plant or under the floor except the 1000-gal reservoir that supplies the machining system.
- The roof top is 32 ft from the floor level and the roof can be designed to support a storage
- tank.
- The building is to be located in Dayton, Ohio, where the outside temperature may range from -20°F to +105 °F.

- The frost line is 30 in below the surface.
- You are not asked to design the system to supply the machines.
- The basic coolant storage and delivery system is to have the functional design sketched in the block diagram in Figure 2.
- If pumps are required, only SULZER pumps have to be selected.

C. Sources

- *Endmemo*. EndMemo. (n.d.). Retrieved November 22, 2021, from http://www.endmemo.com/sconvert/galus_minft3_s.php.
- https://www.gbrx.com/media/1466/tank29000.pdf
- *Hanger support spacing - rod sizes horizontal pipes*. Engineering ToolBox. (n.d.). Retrieved November 29, 2021, from https://www.engineeringtoolbox.com/piping-support-d_362.html.
- Maus, P. (2021, February 2). *Wind load calculator*. How Much Force Does the Wind Produce? Retrieved November 21, 2021, from https://www.omnicalculator.com/physics/wind-load.
- Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)
- *Pipe Flange: Carbon Steel, blind flange, 5 in pipe size, raised face blind flange*. Grainger. (n.d.). Retrieved November 21, 2021, from https://www.grainger.com/product/GRAINGER-APPROVED-Pipe-Flange-Carbon-Steel-30WH03.
- Project Document
- *Wrought steel pipe - bursting pressures*. Engineering ToolBox. (n.d.). Retrieved November 21, 2021, from https://www.engineeringtoolbox.com/wrought-steel-pipe-bursting-pressure-d_1123.html.

d. Materials and Specifications

i. Establish the pipe and tank material use

- Schedule 40 carbon steel pipes will be used (ASTM A106).
- Tanks will also be carbon steel (ASTM A106).
- Seams are electric resistance welded.

ii. Fluid characteristics

- 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.
- Viscosity and vapor pressure of the coolant are 1.50 times that of water at any temperature.

e. Preliminary drawings and sketches

i. Plot Plan

ii. Elevations

f. Design Calculations

i. Tank Specifications

1. Specify the size and location of all storage tanks.

Purpose:

Layout the piping system and determine the tank sizes.

Sources:

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

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. You are not asked to design the system to supply the machines.

Drawings and Diagrams

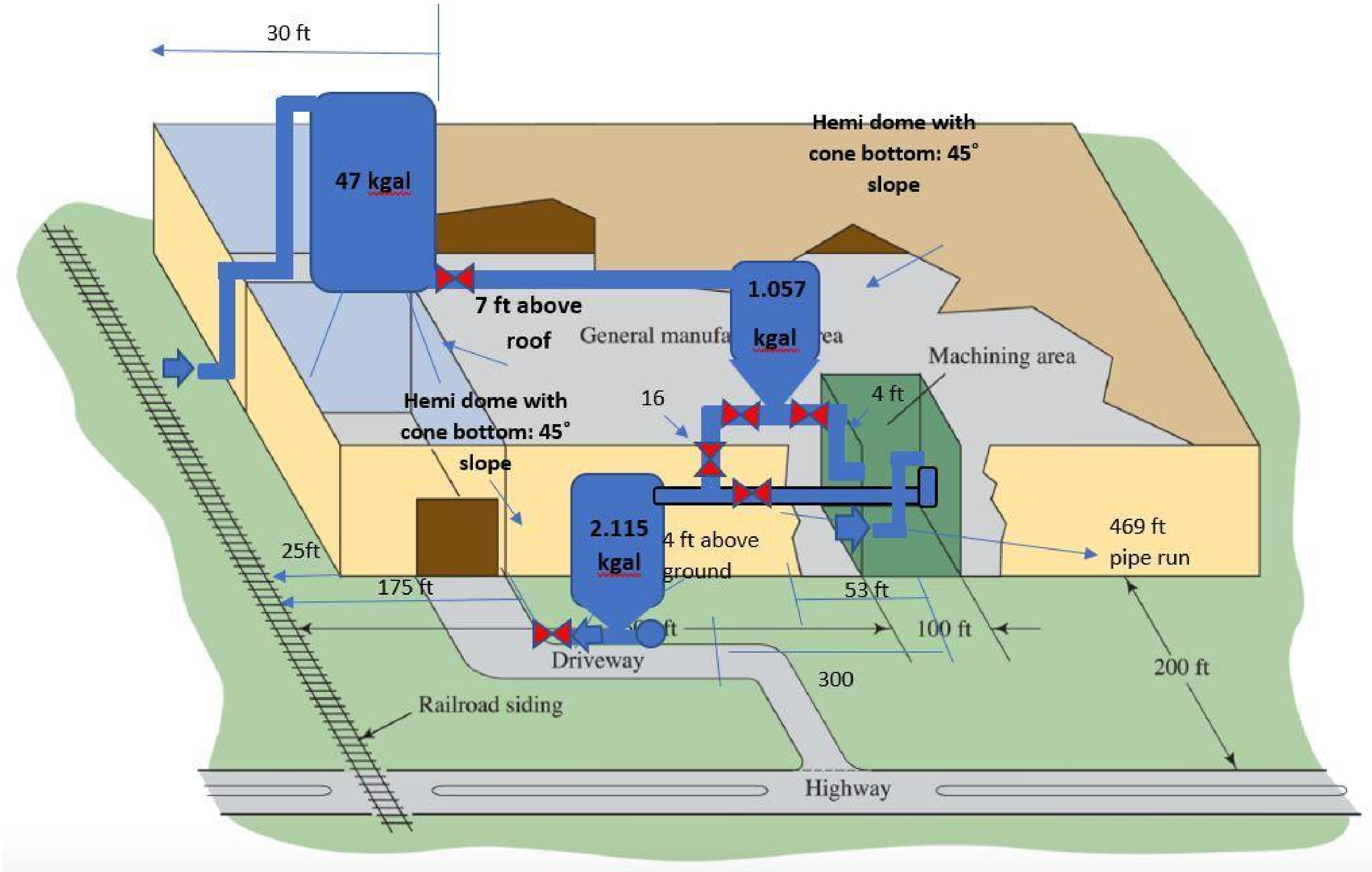


Figure 1: System Diagram

Materials:

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

Data and Variables:

- Distances in figure
- $\gamma = 58.656$ lb/ft^3

Procedure:

1. An initial delivery 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:

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

$D_{inner} = 20 \text{ ft}$

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

$= \pi 10^2$

$= 314.195 \text{ ft}^2$

$6015.625 \text{ ft}^3 = 314.195 \text{ ft}^2 (h) = 19.148 \text{ ft}$ of fluid

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

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

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

$V = 267.34 \text{ ft}^3 - 27.99 \text{ ft}^3 = 239.35 \text{ ft}^3$

$A = \pi r^2 = \pi 3^2 = 28.27 \text{ ft}^2$

$239.35 \text{ ft}^3 = 28.27 \text{ ft}^2 h = 8.464 + 3 \text{ ft} = 11.46 \text{ ft}$

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

$V = \frac{1000 \text{ gal}}{7.481} = 133.67 \text{ ft}^3 \qquad A = \pi r^2 = 28.27 \text{ ft}^2$

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

$V = 133.67 \text{ ft}^3 - 27.99 \text{ ft}^3 = 105.68 \text{ ft}^3$

$105.68 \text{ ft}^3 = 28.27 h = 3.73 \text{ ft} + 3 \text{ ft} = 6.73 \text{ ft}$

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.

Purpose:

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

Sources:

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

Design Considerations:

- The reservoir for the automated machining system must have a capacity of 1000 gal.
- Constant Properties
- Incompressible Fluids
- Assuming pressure is highest at the bottom of the tank

Drawings and Diagrams:

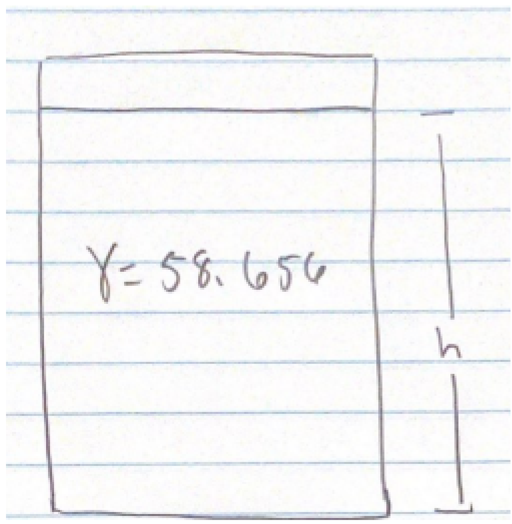


Figure 2: Determining Pressure at Bottom of a Tank

Data and Variables:

- Distances in figure
- γ = 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: $P = \gamma h$

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

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

$t = 0.055\ in$

$t_{min} = t + 0.08\ in = 0.055\ in + 0.08\ in = 0.135\ in$

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

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

$t_{nom} = 0.103\ in$

Reservoir: $P = 2.74\ psi$ $t = 0.0059\ in$ $t_{min} = 0.085\ in$

$t_{nom} = 0.098\ in$

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.

<u>Purpose:</u> Design a tank to allow for a future connection by designing a blind flange, include bolt calculations.
<u>Sources:</u>

- Mott, R., Untener, J.A, “Applied Fluid Mechanics”, 7th edition, Pearson Education, Inc (2015)
- *Pipe Flange: Carbon Steel, blind flange, 5 in pipe size, raised face blind flange*. Grainger. (n.d.). Retrieved November 21, 2021, from https://www.grainger.com/product/GRAINGER-APPROVED-Pipe-Flange-Carbon-Steel-30WH03.
- Project Document
- *Wrought steel pipe - bursting pressures*. Engineering ToolBox. (n.d.). Retrieved November 21, 2021, from https://www.engineeringtoolbox.com/wrought-steel-pipe-bursting-pressure-d_1123.html.

<u>Design Considerations:</u>

- Pressure is equal to pressure at bottom of the tank
- Bolt holes designed for ¾”

<u>Drawings and Diagrams:</u>

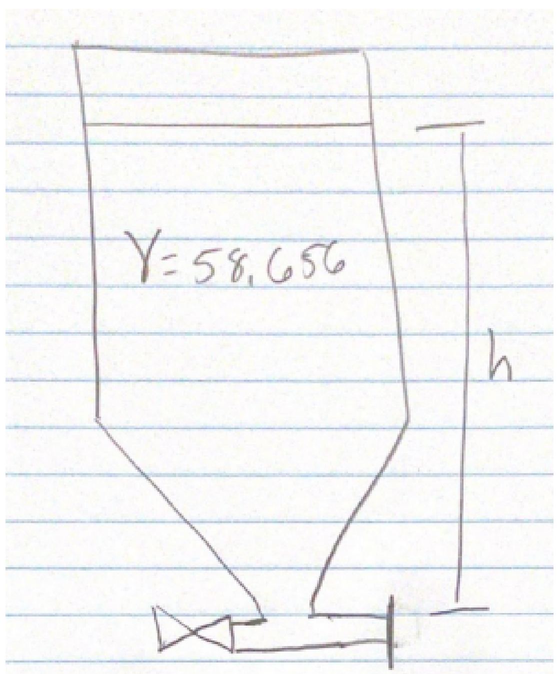


Figure 3: Future Connection

Data and Variables:

- Distances in figure
- γ = 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
    - o 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:

1.5 in pipe DN 40 OD_f = 5 in * by 25.4 = 127 mm

$$S_c = D_c \sqrt{\frac{0.125P}{\sigma_s}} + C$$

S_c = Thickness σ_s - standard = 240 MPa = 240,000 kPa

D_c = Diameter

P = pressure on head = 7.795 psi = 53.746525 X by 6.895

$$S_c = .127 \sqrt{\frac{0.125(53.746525)}{240}} + C$$

S_c = 0.6719366069 + C

required thickness = 0.67 mm

Minimum commercially available thickness = 12.7 mM

Blind flange Plate = 5 in diameter, 0.5 in thick

5 in Blind flange Grainger.com 4 bolt holes 7/8 in th.

Item # 30W403

ASME B16.5

L=2(.25+.75+.5+.0125)+.0125

= 1.4425 L minimum

Bolt Diameter 3/4 in Bolt length minimum = 1.44 in

Nut 3/4 in

L=2(s+n+h+rf)+g

s = 1/3 Diameter h = flange thickness g-gasket

n = bolt diameter rf = height of raised face

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

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

4. Specify wind load and weight of storage tanks for our civil engineer colleagues.

Purpose: Find the wind load and weight of the tanks to help design the required supports
Sources:

- Mott, R., Untener, J.A, “Applied Fluid Mechanics”, 7th edition, Pearson Education, Inc (2015)
- *https://www.journal-news.com/news/local/wind-gusts-mph-gust-recorded-high-winds-move-through-area/6WwUMeWK2GmirlzqRcCULJ/*
- *https://www.omnicalculator.com/physics/wind-load*
- Project Document

Design Considerations:

- Wind load pressure using max wind recorded for each tank
- Weight pressure for each tank, assuming full liquid volume

Drawings and Diagrams:

Data and Variables:
- Max recorded wind speed in location: Approx 70 mph = 102.7 ft/s
- Average Air Pressure = 14.18 psi = 2041.92psf
- large tank, v= 45.000 gal
- medium tank, v=
- small tank, v=
- sg = 0.94
- density of steel = 480.709 lb/ft^3
- density of water = 1.94 slug/ft^3
- kinematic velocity of air @ 60 F v= 1.58E-4 ft^2/s

Materials:
- Hydraulic Fluid
- Tank: Carbon Steel ASTM A106, Electric Resistance Welded
  - 45000 Gal
  - 2000 Gal

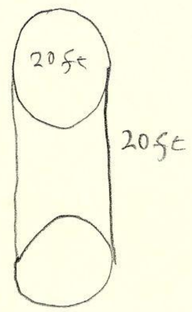
- 1000 Gal

Procedure:

1. Find area of tank
2. Multiply area of tank by thickness of steel for tank wall to find total surface area of tank
3. Use surface area and density to find weight of empty tank
4. Find mass of fluid
5. Find interior volume of tank
6. Use data from 4 and 5 to find weight of fluid
7. Combine weight of tank with weight of fluid for total weight
8. Find area of tank
9. Multiply area of tank by thickness of steel for tank wall to find total surface area of tank
10. Use surface area and density to find weight of empty tank
11. Find mass of fluid
12. Find interior volume of tank
13. Use data from 11 and 12 to find weight of fluid
14. Combine weight of tank with weight of fluid for total weight
15. Find area of tank
16. Multiply area of tank by thickness of steel for tank wall to find total surface area of tank
17. Use surface area and density to find weight of empty tank
18. Find mass of fluid
19. Find interior volume of tank
20. Use data from 18 and 19 to find weight of fluid
21. Combine weight of tank with weight of fluid for total weight
22. Find Reynold's Number for local air at maximum recorded wind speed
23. Find Coefficient of Drag from table in figure 17.6 in text book
24. Calculate wind load for tank
25. Find Reynold's Number for local air at maximum recorded wind speed
26. Find Coefficient of Drag from table in figure 17.6 in text book
27. Calculate wind load for tank
28. Find Reynold's Number for local air at maximum recorded wind speed
29. Find Coefficient of Drag from table in figure 17.6 in text book
30. Calculate wind load for tank

Calculations:

Wind Load + Weight



45,000 gal

$sg = 0.94$

0.385 in Steel = .03208333

$A = (2\pi r)\, h$

$r = 10 \quad h = 20 \quad A = 1256.637061 * .032 = 40.31710567$

$\rho = 7700\ kg/m^3 \div$ by $16.018 = 480.7092021\ lbs/ft^3$

$40.317 * 480.709 = 19,380.8037$

Sg to Mass

$0.94\left(1.94\ \frac{slug}{ft^3}\right) = 1.8236\ \frac{slug}{ft^3} = 58.71992\ \frac{lb}{ft^3}$

Int. Vol

$A = (2\pi r)h \quad = 180085.8187\ in^2$

$r = 119.8075\ in \quad h = 239.23 \qquad r = 9.983958335 \quad h = 19.93583334$

$V = \pi r^2 h = 6242.946993\ ft^3$

Weight = Vol * mass

$= 6242.946993\,(58.71992) = 366584.4654$

Total

$19,380.8037 + 366584.4654 = 385966.2691\ lb$

Wind load = area x pressure x cd

$R_e = \frac{VD}{\nu}$

$\nu_{air} @ 60^0F = 1.58 \times 10^{-4}$ ft²/s

Max Wind Speed in Dayton, Ohio ≈ 70 mph = 102.6669 ft/s

Pressure at Dayton, Ohio (avg) = 14.18 psi ≈ 2041.92 psf

$R_e = \frac{102.6669(20)}{1.58 \times 10^{-4}} = 12995810.13$

Extrapolating from fig. 17.6

$C_d = 1.24$

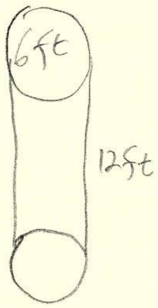
Area = 1256.637061 ft²

Wind load

$= 1256.637(2041.92)1.24 = 3181780.911 \frac{ft^3}{s}$

$\frac{ft}{s} ft^2 = \frac{ft^3}{s}$

66,973 N



2,000 gal

$sg = 0.94$

0.103 in Steel = .0085833 ft

$A = (2\pi r)h$

$r = 3ft$ $h = 12ft$ $A = 226.1946711\ ft^2$

$V = A * wall = 1.941504253\ ft^3$

$\rho = 7700\ kg/m^3 \div 16.018 = 480.7092021\ lb/ft^3$

$1.941 * 480.709 = 933.2989603\ lb$

Sg to mass

$0.94(1.94 \frac{slug}{ft^3}) = 1.8236 \frac{slug}{ft^3} = 58.71992 \frac{lb}{ft^3}$

Int Vol

$A = (2\pi r)h = 225.5477658\ ft^2$

$r = 2.995708333$ $h = 11.928333$

$V = \pi r^2 h = 337.8379603$

Weight = Vol * mass

$= 337.8379603(58.71992) = 19837.818$

Total

$933.2989603 + 19837.818 = 20771.1696\ lb$

$V_{windmax} = 102.6669\ ft/s$

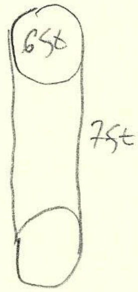
$\nu\ air @ 60°F = 1.58 \times 10^{-4}\ ft^2/s$

$R_e = \frac{102.6(12)}{1.58 \times 10^{-4}} = 7797030.38$

$C_d = 1.24$

$226.19(2041.92)1.24 = 572720.5643 \frac{ft^3}{s}$

12,055 N Wind Load



1,000 gal

$sg = 0.94$

0.098 in Steel = .0081666667

$A = (2\pi r)h = 131.94609156(.00816) = 1.077566285$

$r = 3$ ft $h = 7$ ft

$\rho = 7700\,kg/m^3 \div 16.018 = 480.7092021\ lb/ft^3$

$W_{steel} = 1.077(480.709) = 517.9960289$

Sg to mass

$0.94(1.94\ \frac{slug}{ft^3}) = 1.8236\ \frac{slug}{ft^3} = 58.71992\ \frac{lb}{ft^3}$

It Vol

$V = \pi r^2 h = 196.9217629\ ft^3$

$r = 2.995916667$ $h = 6.983666667$

Weight = Vol (mass)

$= 196.921(58.71992) = 11563.20668$

Total

$11563.2 + 517.996 = 12081.20271\ lb$

$V_{wind\,max} = 102.6609\ ft/s$

$\nu\ air @ 60°F = 1.58 \times 10^{-4}\ ft^2/s$

$R_e = \frac{102.66(7)}{1.58 \times 10^{-4}} = 4548267.722$

$C_d = 1.24$

$131.946(2041.92)\,1.24 = 334084.9703\ \frac{ft^3}{s}$

7,032 N Wind load

Summary:
The weight of the 45,000 gal tank is 385966 lb
The wind load on said tank is 66973 N
The weight of the 2,000 gal tank is 19838 lb
The wind load on said tank is 12055 N
The weight of the 1,000 gal tank is 11563 lb
The wind load on said tank is 7032 N

Analysis:
The data for wind load and weight for each tank is listed above for proper support computation by the civil engineers on this project.

5. Consider that one of your storage tanks could fail. To repair it the company decided to drain it using a pumped system with same flow rate you estimated but this time the fluid will go into an open channel that will take the fluid to a location far from the plant (you have to select such location). You are now also in charge of the design of such open channel system to dump the fluid to that location. The design should include the path of the channel and its cross section.

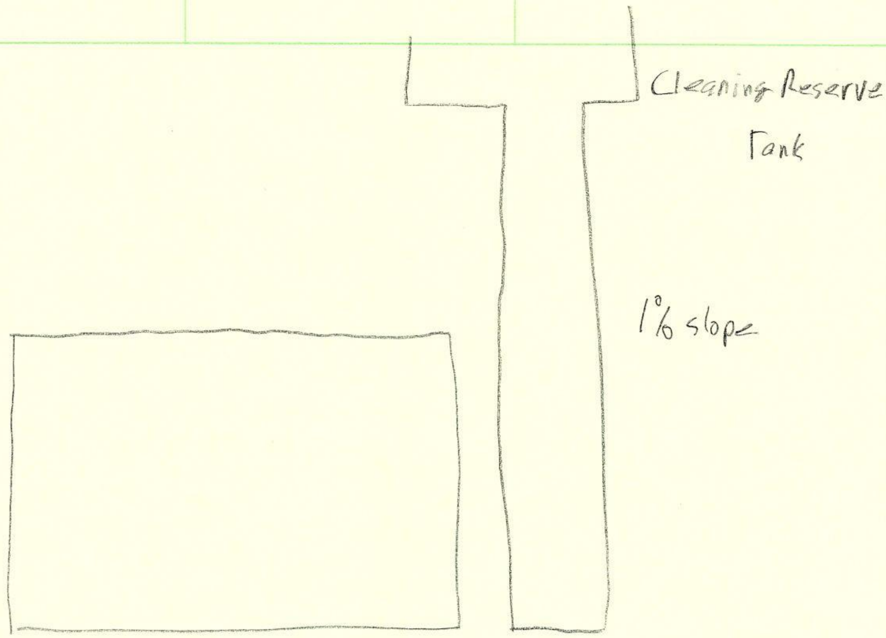
Purpose: To design an open channel that can take the fluid to a storage area should the holding tank fail
Sources:

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

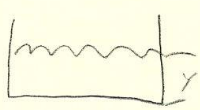
Design Considerations:

- Shape of channel
- Depth of channel
- Length of channel
- Width of channel
- Slope of channel

Drawings and Diagrams:



9.6ft/s   formed, unfinished Concrete $n = 0.017$



$b = 2y = T$

Rectangular Trench $A = 2y^2$

$y = 3 \quad b = 6$

$A = 18 \text{ ft}^2$

$Q = Av = 653.7384432 \text{ ft}^3/\text{s}$

$v = \frac{1.49}{n} R^{2/3} S^{1/2} = \frac{1.49}{.017} 1.5^{2/3} 0.1^{1/2} = 36.31880243 \text{ ft/s}$

$R = y/2 = 1.5$

$WP = 4y = 12$

$S = 0.1$

Data and Variables:

- Rectangular Channel
- 1% Slope
- Hydraulic Radius = 1.5
- Wetted Perimeter = 12
- roughness, n = 0.017
- Flow Rate = 9.6 ft/s
- Depth, y = 3 ft
- Width, b = 6 ft
- Area, A = 18 ft^2

Materials:

- Hydraulic Fluid
- Cement
- Concrete

Procedure:

1. Choose location for storage tank
2. Choose shape for channel
3. Choose slope for channel flow
4. Design channel based on fluid characteristics and required flow
5. Choose depth and width
6. Calculate flow rate and velocity to verify that it meets needs

Calculations:

Summary:

The channel is rectangular, with a flow velocity of 36 ft per second.

Analysis:

The channel is more than capable of handling the flow rate of 9.6 ft/s that the pipe design calls for.

ii. Flow rate

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.

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

Sources:

- *Endmemo*. EndMemo. (n.d.). Retrieved November 22, 2021, from http://www.endmemo.com/sconvert/galus_minft3_s.php.
- Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)
- Project Document

Design Considerations:

- Constant Properties
- Incompressible Fluids
- 8-hour work shifts
- Critical velocity of 9.6 ft/s

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 is 47 Kgal
- Reservoir is 1.057 Kgal
- Dirty tank is 2.115 Kgal

Procedure:

1. Use the chosen fill times and the tank volumes to determine the flow rate for each tank.
2. Use the flow rate and desired times to calculate time to empty and fill the tanks.

Table 1: Fill Times									
Tank Sizes		Desired Fill Times		Calculated Fill Flow Rate		Desired Empty Times		Calculated Empty Flow Rate	
47	Kgal	180	Mins	261.1111	GPM	20	Mins	52.85	GPM
1.057	Kgal	60	Mins	17.61667	GPM	20	Mins	52.85	GPM
2.115	Kgal	60	Mins	35.25	GPM	15	Mins	141	GPM

Calculations:

$$\frac{V}{T} = Q = \frac{47000\text{gal}}{180\text{ mins}} = 261.11\text{GPM}$$

$$\frac{V}{T} = Q = \frac{1057\text{gal}}{20\text{ mins}} = 52.85\text{ GPM}$$

Summary:

It will take 180 mins to fill the large tank with 45000 gallons of hydraulic fluid and 20 minutes to empty 1000 gallons into the reservoir tank.

It will take 60 minutes to fill the dirty tank with 2000 gallons of hydraulic fluid. It will take 20 mins to empty it.

It will take 60 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.

iii. Piping Size

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.

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

Sources:

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

Design Considerations:

- Constant Properties
- Incompressible Fluids
- Critical velocity of 9.6 ft/s

Drawings and Diagrams:

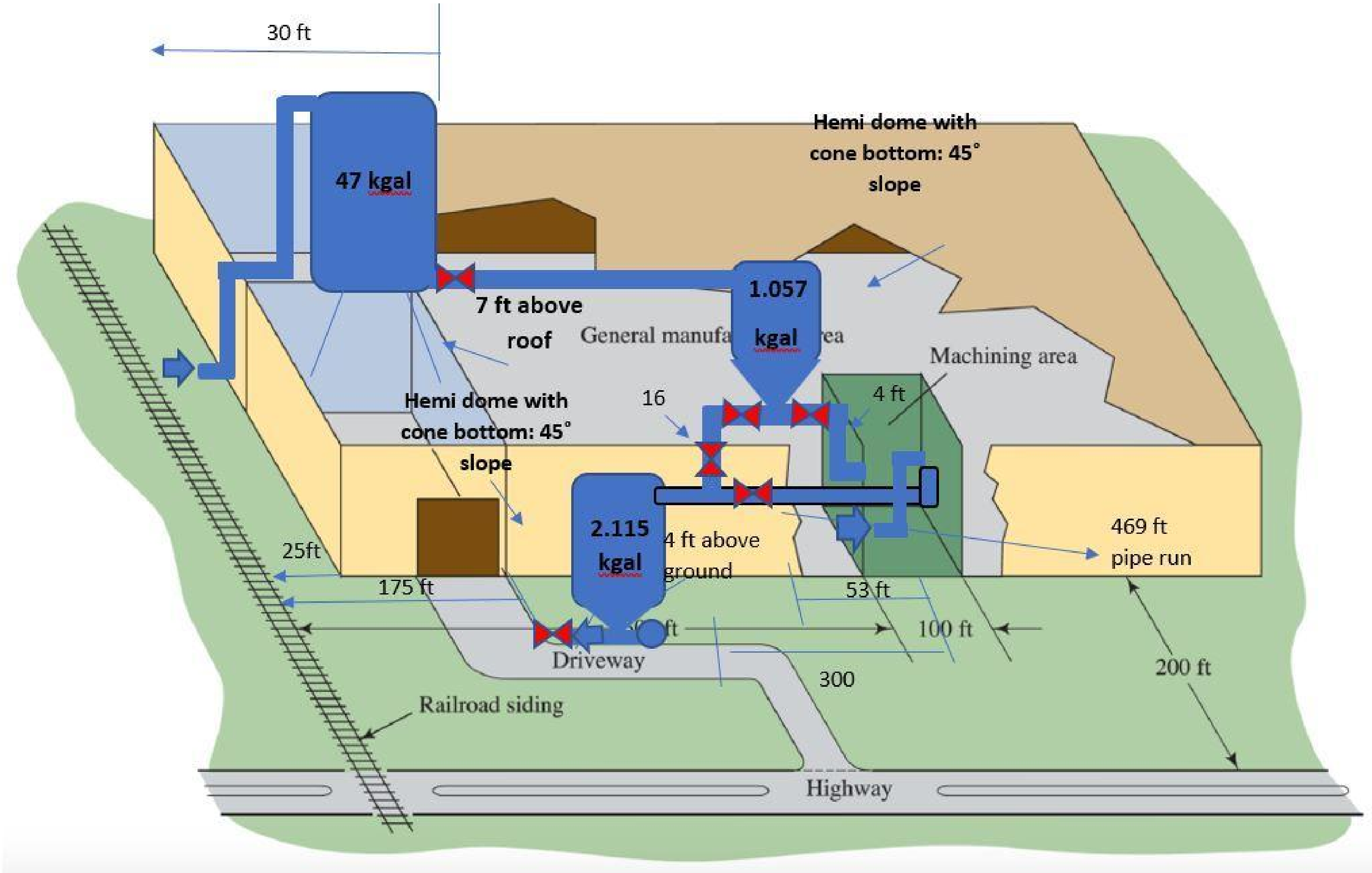


Figure 1: System Diagram

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
    - 47000 Gal
    - 2115 Gal
    - 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:

$$Q = VA \rightarrow \frac{Q}{V} = A$$

$$\frac{(261.11\,\text{GPM} \times 0.00222800093)}{9.6\,\text{ft/s}} = 0.0606\,\text{ft}^2$$

Table 2: Pipe Size									
System	**Flow rate**		**Velocity**		**Pipe Area**		**Nominal Pipe Size from App. F**	
Train to Large Tank (Discharge)	261.11	GPM	9.6	ft/s	0.0606	ft^2	3.5	in
Large tank to Feed Tank (Discharge)	52.85	GPM	9.6	ft/s	0.012266	ft^2	1.5	in
Feed tank to Machine Area (Suction)	52.85	GPM	9.6	ft/s	0.012266	ft^2	1.5	in
Machine Pump to Dirty Tank (Discharge)	105.70	GPM	9.6	ft/s	0.024531	ft^2	2	in
Feed tank to Dirty Tank (Discharge)	52.85	GPM	9.6	ft/s	0.012266	ft^2	1.5	in
Dirty Tank to Trucks (Discharge)	141	GPM	9.6	ft/s	0.032724	ft^2	2.5	in

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 1.5 in nominal diameter.
- The pipe length from the reservoir to the machining area will be 4 ft vertically. This pipe will have a 1.5 in nominal diameter.
- The pipe length from the reservoir to the emergency dirty tank dump will be 6 ft. This pipe will have a 1.5 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.
- The pipe from the dirty tank to the pump that feeds the trucks will be 3 ft long and have a 2.5 in nominal diameter.

Analysis:

These dimensions assume an industry standard critical velocity of 9.6 ft/s. 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:

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

   Design Considerations:

   - Constant Properties
   - Incompressible Fluids
   - Critical velocity of 9.6 ft/s

Drawings and Diagrams:

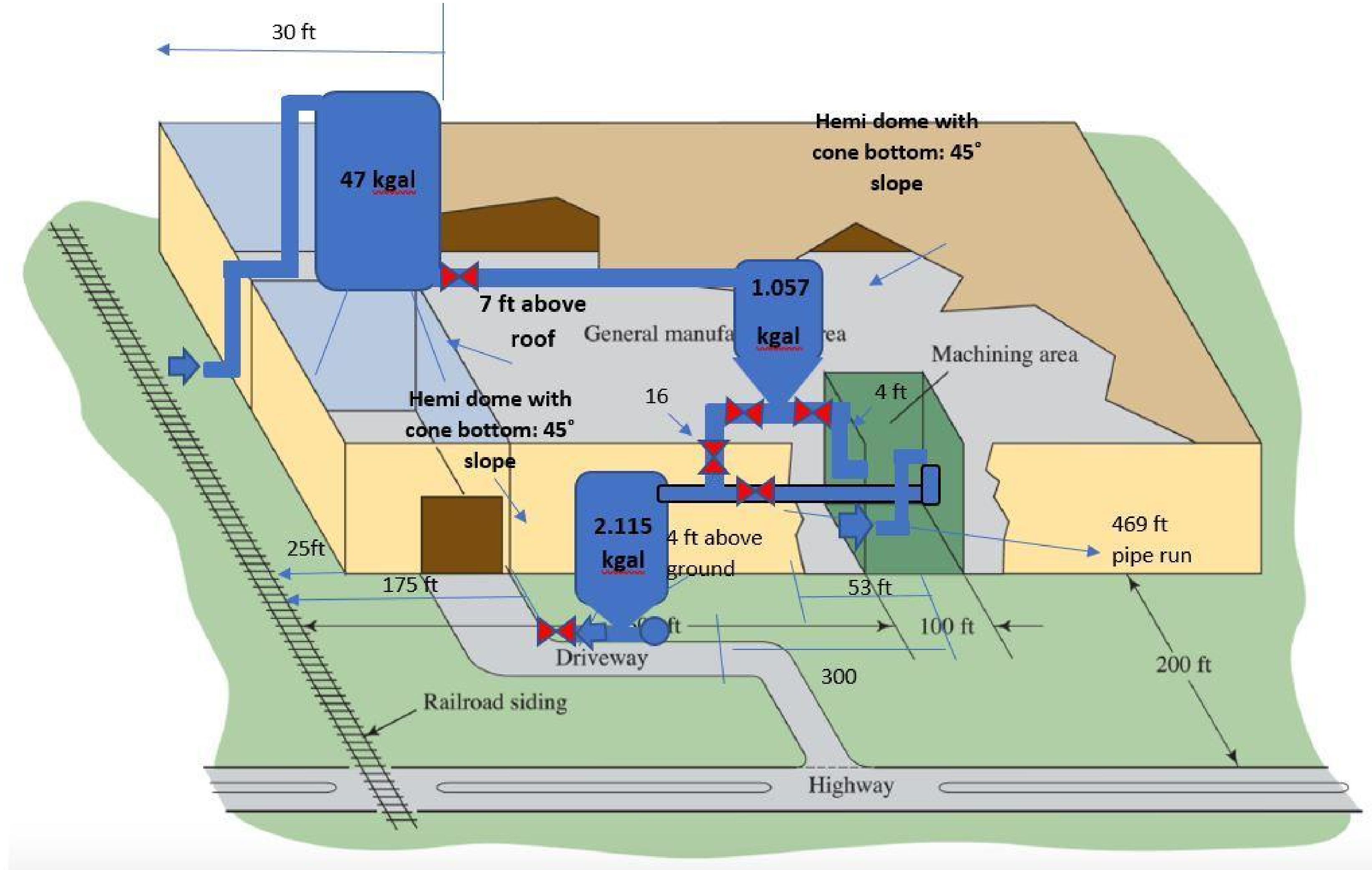


Figure 1: System Diagram

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:

- Train car to large tank
  - 4 Short Radius Elbows for 3 ½ in pipe
- Large tank to feed tank
  - 1 Gate valve for 1.5 in pipe
- Feed tank to machine area
  - 1 Standard Tee for 1.5 in pipe
  - 2 Short Radius Elbows for 1.5 in pipe
  - 1 Gate valve for 1.5 in pipe
- Feed tank to dirty tank
  - 1 Standard Tee for 1.5 in pipe (same tee used in previous system)
  - 1 Short Radius Elbow for 1.5 in pipe
  - 2 Gate valve for 1.5 in pipe
  - 1 Expander (1.5 in to 2 in)
  - 1 standard tee for 2 in pipe
- Machine pump to dirty tank
  - 3 Short Radius Elbows for 2 in pipe
  - 1 Gate valve for 2 in pipe
  - 1 standard tee for 2 in pipe (same tee used in previous system)
- Dirty tank to Trucks
  - 1 Standard Tee for 2.5 in pipe
  - 1 Gate valve for 2.5 in pipe

Analysis:

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

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:

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

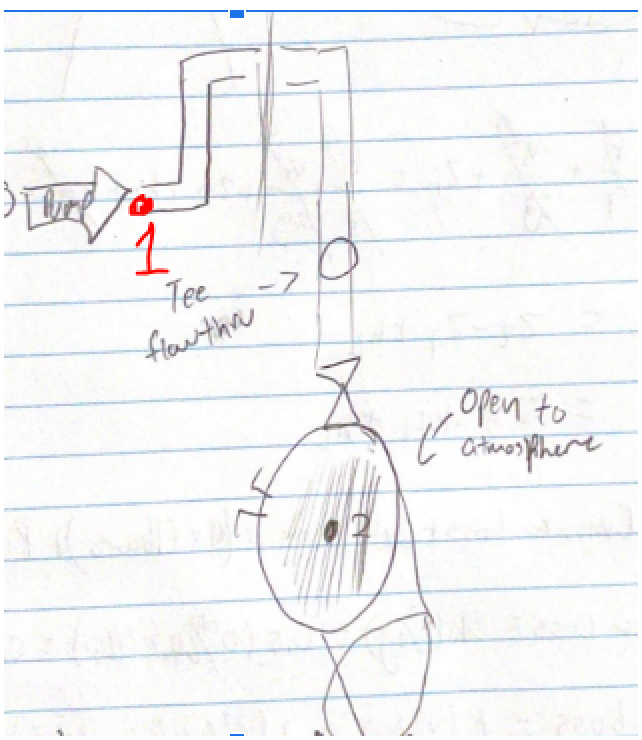


Figure 4: Pump from machinery area to dirty tank

Figure 5: Pressure for pump in train to large tank exit

<u>Data and Variables:</u>

- 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

<u>Materials:</u>

- Hydraulic Fluid
- Carbon Steel ASTM A106

<u>Procedure:</u>

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:

$$\frac{P_A}{\gamma} + \cancel{\frac{V_A^2}{2g}} + \cancel{z_A} = \cancel{\frac{P_B}{\gamma}} + \cancel{\frac{V_B^2}{2g}} + z_B + h_L + h_a$$

$$P_A = \gamma(z_B + h_L + h_a)$$

$$\left(54.654\,\frac{lb}{ft^3}(60ft + 96.025ft + 245.28ft)\right)/144$$

$$= 145.54\,psi$$

Pressure for pump in train to large tank exit:

$$P_a = \frac{58.656\,\frac{lb}{ft^3}(42ft + 6.77ft + 58.31\,ft)}{144} = 43.619\,psi$$

Pipe thickness example calculation:

$$t = \frac{PD}{2(SE + PY)} = \frac{(43.62\,psi)(4\,in)}{2(20000\,psi \times 0.85 + 43.619(0.4))}$$

$$t = 0.00512\,in$$

$$t_{min} = t + 0.08\,in = 0.00512\,in + 0.08\,in$$

$$t_{min} = 0.08512\,in$$

$$t_{nom} = \frac{t_{min}}{0.875} = \frac{0.08512\,in}{0.875}$$

$$t_{nom} = 0.097\,in$$

Thickness of pipes in each system:

Thickness of pipe from big tank to 1kg	
t	0.0002599
tmin	0.0802599
tnom	0.0917256
p	4.6520833
D	1.9
S	20000
E	0.85
Y	0.4

Thickness of pipe from train to big tank	
t	0.005126386
tmin	0.085126386
tnom	0.097287299
p	43.61900558
D	4
S	20000
E	0.85
Y	0.4

Thickness of pipe from feed tank to machine area	
t	0.0001532
tmin	0.0801532
tnom	0.0916036
p	2.7413533
D	1.9
S	20000
E	0.85
Y	0.4

Thickness of pipe from machine pump to dirty tank	
t	0.010131872
tmin	0.090131872
tnom	0.103007854
p	145.5424617
D	2.375
S	20000
E	0.85
Y	0.4

Thickness of pipe from feed tank to dirty tank	
t	0.0001532
tmin	0.0801532
tnom	0.0916036
p	2.7413533
D	1.9
S	20000
E	0.85
Y	0.4

Thickness of pipe from dirty tank to trucks	
t	0.000394887
tmin	0.080394887
tnom	0.091879871
p	4.670484028
D	2.875
S	20000
E	0.85
Y	0.4

Summary:
The maximum operating pressure in the piping from the train to the large tank is 43.62 psi.
The maximum operating pressure in the piping from the large tank to the feed tank is 4.65 psi.
The maximum operating pressure in the piping from the feed tank to the machine area is 2.74 psi.
The maximum operating pressure in the piping from the machine area to the dirty tank is 145.54 psi.
The maximum operating pressure in the piping from the feed tank to the dirty tank is 2.74 psi.
The maximum operating pressure in the piping from the dirty tanks to the trucks is 4.67 psi.

The nominal wall thickness for the piping from the train to the large tank is 0.0973 in.
The nominal wall thickness for the piping from the large tank to the feed tank is 0.0917 in.
The nominal wall thickness for the piping from the feed tank to the machine area 0.0916 in.
The nominal wall thickness for the piping from the machine area to the dirty tank is 0.103 in.
The nominal wall thickness for the piping from the feed tank to the dirty tank is 0.0916 in.
The nominal wall thickness for the piping from the dirty tanks to the trucks is 0.0918 in.

Analysis:
Because all 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.

10. Check your design for water hammer problems. Check if the pipe you selected can hold such over-pressure, if not, propose the use of a water-hammer arrestor by specifying the pressure that it will handle. (to final report section 5.f.iii)

Purpose: To find if the pipes in the design can withstand the effects of water hammer

Sources:

- https://www.engineeringtoolbox.com/wrought-steel-pipe-bursting-pressure-d_1123.html
- Mott, R., Untener, J.A, “Applied Fluid Mechanics”, 7th edition, Pearson Education, Inc (2015)
- Project Document

Design Considerations:

- Refer to step 9 pipe design information

Data and Variables:

- Longest pipe: 524 ft
- Schedule 40 steel pipe
- 2 in bursting pressure: 5185 psi
- 3 ½ in bursting pressure: 5610 psi

Materials:

- 2 in steel pipe
- 3 ½ in steel pipe

Procedure:

1. Determine a speed for valve closing
2. Find pressure caused by said valve closing speed in longest pipe

Calculations:

Find pressure change in pipe due to sudden valve closure

Water Hammer

$\Delta p = .070\, \Delta v\, \ell / \Delta t$ Longest Pipe 524 ft

$.070\,(9.6\ ft/s)(524)/(0.1) = 3521.28\ psi$ Closing time 0.1s

Sch 40 pipe

Bursting Pressure 2 in 5145 psi

3 1/2 in 5610 psi

Summary:

The maximum pressure in the pipes from the water hammer phenomenon is 3521 psi.

The burst pressure in the smaller 2 in pipe is 5185 psi, while the burst pressure in the larger 3 ½ in pipe is 5610 psi.

Analysis:

Using a sudden closure speed of 0.1 seconds, the water hammer phenomenon reached a value of 3521 psi, well below the bursting pressures of either pipe being used for this design, therefore, no arrestor is required.

iv. Provide pipeline support info

13. For one particular pipe system, decide the type of supports and determine the force acting upon each support. Your work here includes the distance between supports so the pipe does bend much. Our civil engineer colleagues need this.

Purpose: Determine the amount of hanger required to support one stretch of pipe. Also determine the type of hanger and distance the hangers are apart.

Sources:

- *Hanger support spacing - rod sizes horizontal pipes*. Engineering ToolBox. (n.d.). Retrieved November 29, 2021, from https://www.engineeringtoolbox.com/piping-support-d_362.html.
- Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)
- Project Document

Design Considerations:

- Refer to task 1 design considerations.
- Velocity in the pipes is 9.6 ft/s
- Tanks are at atmospheric pressure

Drawings and Diagrams:

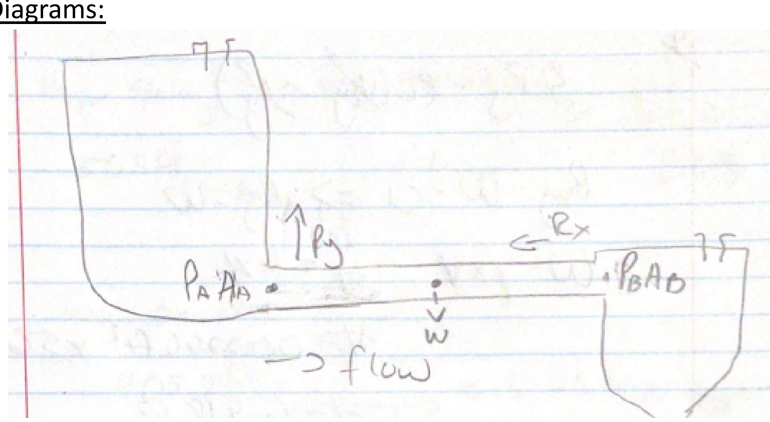


Figure 6: Piping Support FBD

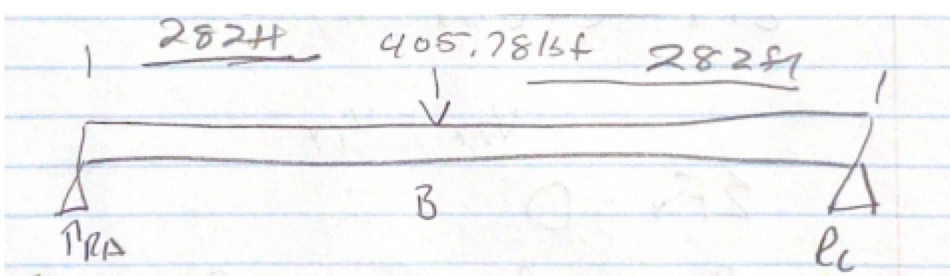


Figure 7: Piping Simply Supported Reaction Forces FBD

Data & Variables:

- ρ= 1.8236 slug/ft^3
- Length of 1 ½ in pipe= 564 ft
- V =9.6 ft/s
- Q= 52.85 GPM
- P_a= 1122.66 psf
- A= 0.012266 ft^2
- γ=58.656 lb/ft^3

Materials:

- Hydraulic Fluid
- Carbon Steel ASTM A106 piping

Procedure:

1. Determine reaction forces in the X and Y directions
2. Use pressure in bottom of large tank found in task 9
3. Use Bernoulli's to solve for pressure at inlet of the feed tank.
4. Use chart found in sources to determine the spacing for 1.5 in schedule 40 steel pipe
5. Divide Ry by number of hangers

Calculations:

$$\sum \vec{F} = \rho Q(\vec{V}_2 - \vec{V}_1)$$

X

$$\sum F_x = \rho Q(V_{2x} - V_{1x})$$

$$V_{2x} = V_{1x}$$

$$\sum F_x = 0$$

$$P_A A_A - R_x - P_B A_B = 0$$

$$R_x = (P_A - P_B)A$$

$P_A = 1122.55$ psf
$P_B = 1026.634$ psf

$$R_x = (1122.55\text{ psf} - 1026.634\text{ psf})\,0.012266\text{ ft}^2$$

$$\boxed{R_x = 1.176\text{ lbf}}$$

y

$$\Sigma F_y = \rho Q(\cancel{V_{2y}}^{0} - \cancel{V_{1y}}^{0})$$

$$R_y - W = 0 \Rightarrow R_y = W$$

$$W = \gamma \times \forall \qquad \forall = A \times L$$

$$\forall = 0.012266\ ft^2 \times 564\ ft$$

$$\forall = 6.918\ ft^3$$

$$W = 58.656\ lb/ft^3 \times 6.918\ ft^3 = 405.78\ lbs$$

$$\boxed{R_y = 405.78\ lbf}$$

$$\circlearrowleft M_A =$$

$$R_C \times (564\ ft) = 405.78\ lbf\ (282\ ft)$$

$$R_C = 202.89\ lbf$$

$$\circlearrowleft M_C = R_D \times (564\ ft) = 405.78\ lbf\ (282\ ft)$$

$$R_x = 202.89\ lbf$$

Hanger spacing every 9ft , $564ft/9ft = 62.667$ hangers

$564ft/63\text{ hangers} = 8.95$ ft apart ≈ 63

force on each hanger:

$405.78lbs/63\text{ hangers} = 6.44$ lbs per hanger

Summary:

Per the hanger support spacing chart noted in the sources, the pipe needs a support every 9 feet. With this distance there is not a whole number of hangers. The calculated 62.67 hangers were rounded up to 63 hangers. This number of hangers required the hangers to be placed about 8.95 ft apart from each other. Each hanger has 6.44 lbf acting on it from the pipe.

Analysis:

Rounding up to 63 hangers is safer than rounding down to 62 hangers because it provides extra support. The chart in the sources recommends 3/8" steel rods to be used to support the pipe.

v. Energy Losses

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.
Purpose: Calculate all the minor losses in system.
Sources:
    - Mott, R., Untener, J.A, "Applied Fluid Mechanics", 7th edition, Pearson Education, Inc (2015)
    - Project Document

Drawings and Diagrams:

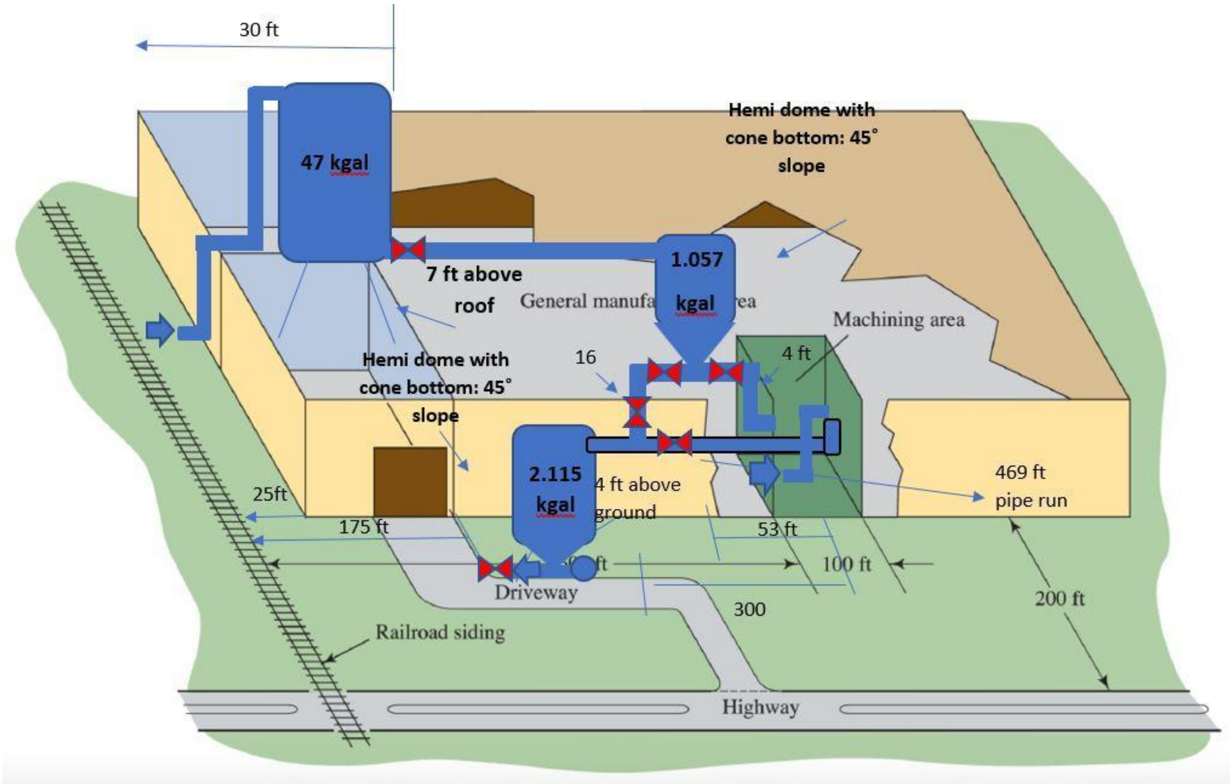


Figure 1: System Diagram

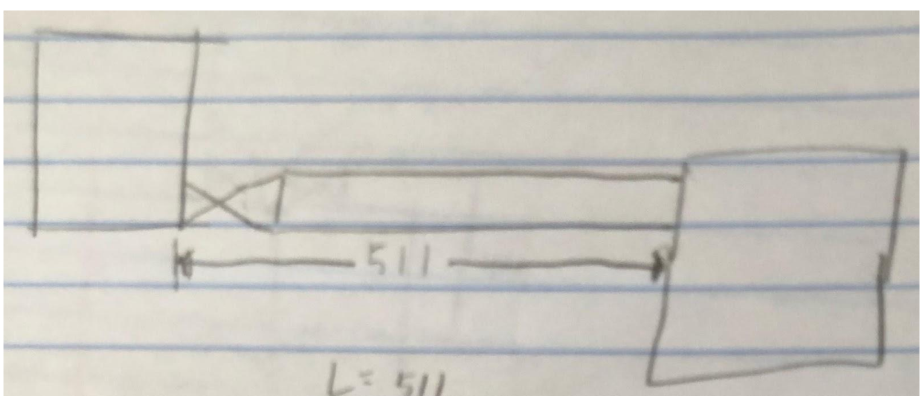


Figure 8: Large Tank to Reservoir Tank

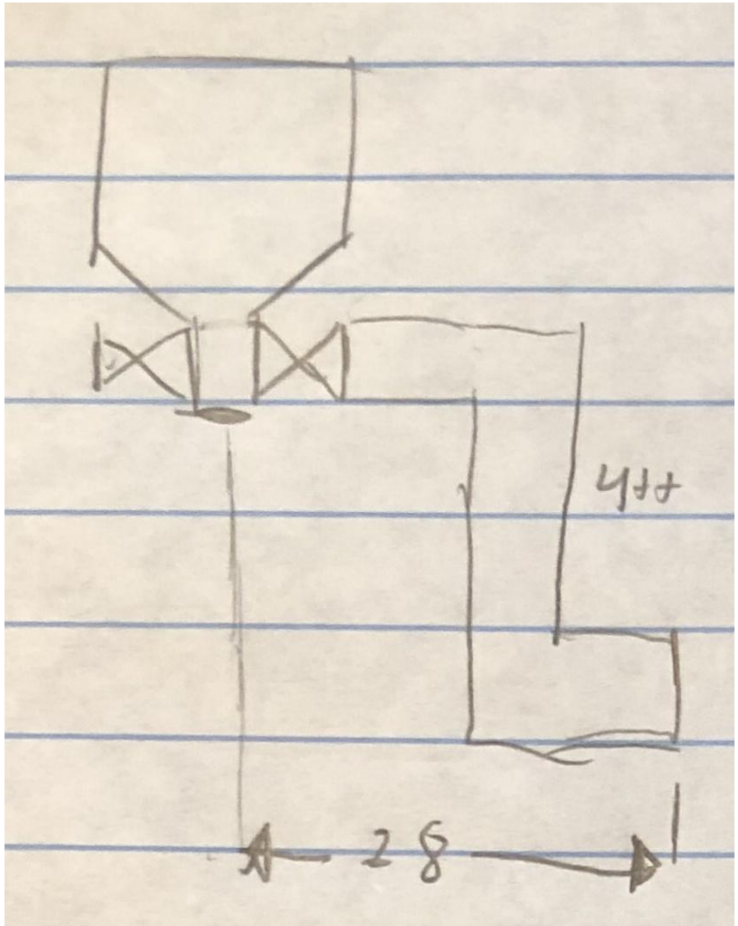


Figure 9: Reservoir Tank to Equipment

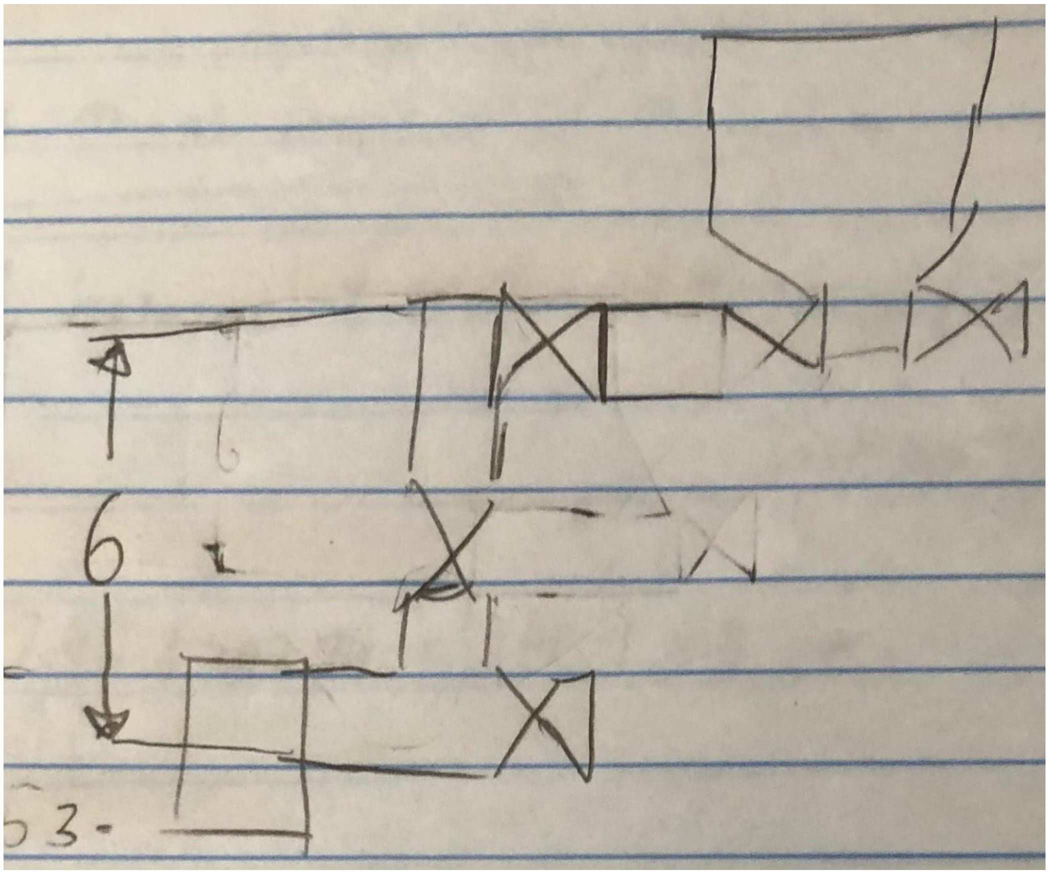


Figure 10: Reservoir Tank to Dirty Tank

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

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

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

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

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

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

Pipe Loss:

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

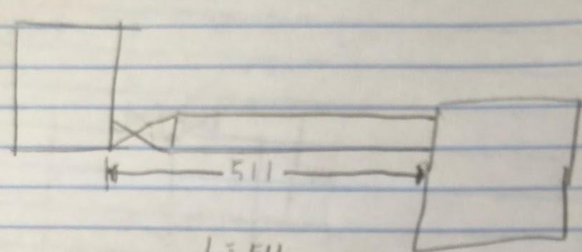
$$N_R = 1144.09 < 2000 = \text{Lam}$$

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

L Left because it is an independent variable

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

Section 1



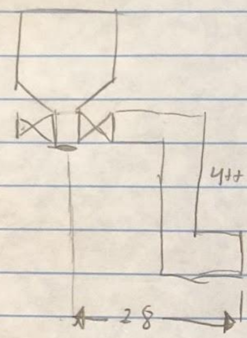
L = 511

$h_L = 0.4685(511) = 239.4$

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

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

Section 2



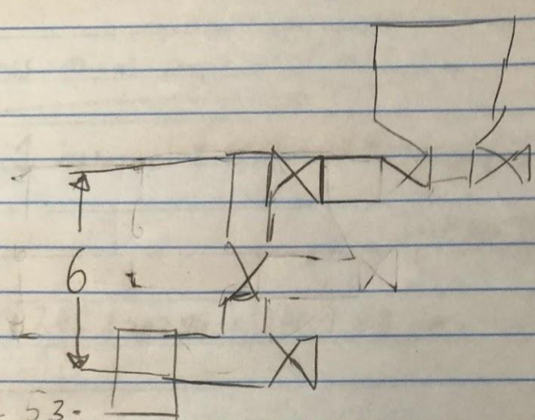
$L = 4 + 28 = 32\ ft$

$h_L = 0.4685(32) = 14.99$

$h_{L\,total} = EL + GL + 2EbL + h_L + EXL$

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

Section 3



$L = 485 - 53 -$

$L = 485 - 53 + 6 = 422$

$h_L = 0.4685(422) = 197.7$

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

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

202.74 ft

Total Loss minus pipe sections =

Section 1 $h_{L total}$ + section 2 $h_{L total}$ + Section 3 $h_{L total}$

240.76 + 17.95 + 202.74 = 461.45 ft

Table 3: Energy Losses											
System	Nr	D/e	f	ft	hl_elb	hl_gv	hl_exp	hl_tees (branch flow)	hl_pipes	hl_exit	hl_entrance
Train to Large Tank (Discharge)	1185185	23333.33	0.0123	0.0103	1.175	0.000	0	0.000	4.169	1.431	0.000
Large tank to Feed Tank (Discharge)	507936.5	10000.00	0.0144	0.0120	0.000	0.137	0	0.000	93.742	1.431	0.716
Feed tank to Machine Area (Suction)	507936.5	10000.00	0.0144	0.0120	0.686	0.137	0	1.029	0.661	0.000	0.000
Machine Pump to Dirty Tank (Discharge)	677248.7	13333.33	0.0137	0.0114	0.975	0.130	0	0.325	56.886	1.431	0.000
Feed tank to Dirty Tank (Discharge)	507936.5	10000.00	0.0144	0.0120	0.343	0.274	0.544	2.057	30.586	1.431	0.000
Dirty Tank to Trucks (Discharge)	846560.8	16666.67	0.0131	0.0109	0.000	0.125	0	0.936	0.270	0.000	0.000

Summary:

The system loses the most energy in sections with long stretches of pipe. Due to this the system losses 96,026 ft between the large tank and the feed tank, 59.75 ft between the machine pump and the dirty tank, and 35.24 ft between the feed tank and the dirty tank. The other losses are very minimal.

Analysis:

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

vi. Pump Selection

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.

<u>Purpose:</u>
Determine pumps required to run the system

<u>Sources:</u>

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

<u>Design Considerations:</u>

- Constant Properties
- Incompressible Fluids
- 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

<u>Drawings and Diagrams:</u>

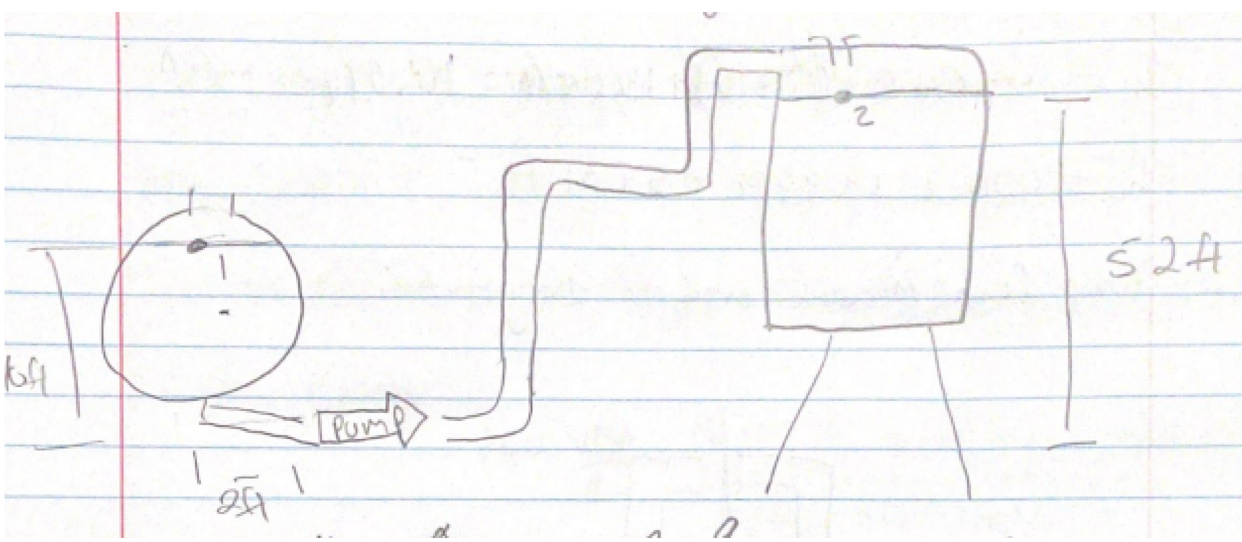


Figure 11: Pump from Train to Large Tank

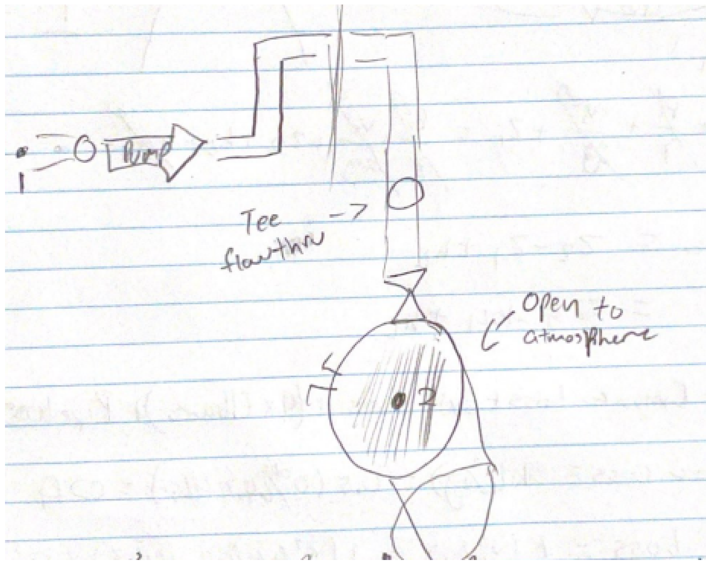


Figure 12: Pump from Machinery Area to Dirty Tank

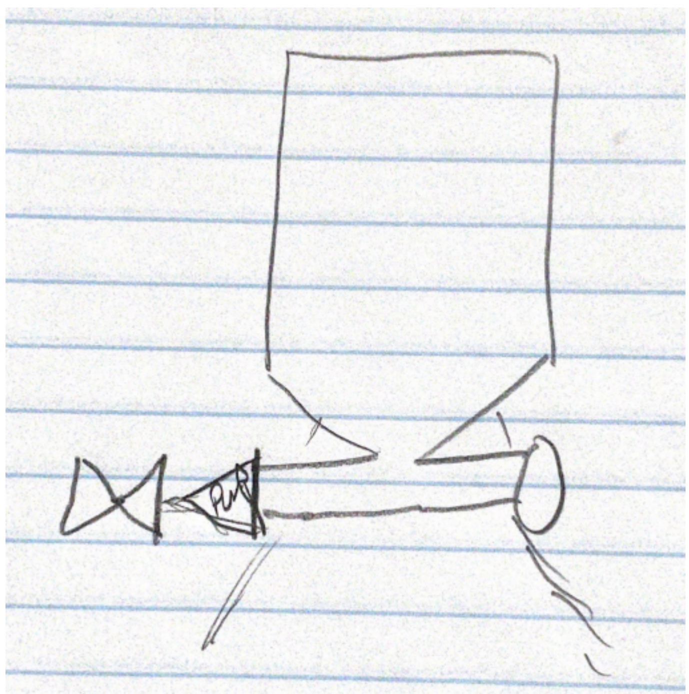


Figure 13: Pump from Dirty Tank to Trucks

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:

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 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 = Entrance Loss + Exit Loss + (4x Elbows) + Pipe loss

Entrance Loss $= K(v_2^2/2g) = 0.5(0^2\,ft/s^2 / 64.4\,ft/s^2) = 0\,ft$

Exit Loss $= K(v_1^2/2g) = 1(0^2\,ft/s / 64.4\,ft/s^2) = 0\,ft$

Pipe Loss: $N_R = \frac{vD\rho}{\eta} = \frac{(9.6\,ft/s)(0.2975\,ft)(1.85\,slugs/ft^3)}{(2.625 \times 10^{-3}\,lb\text{-}s/ft^2)}$

$N_R = 1984.08 < 2000$, 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:

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

$$N_R = 1149.09 < 2000\text{, Laminar flow}$$

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

$$h_L = 224.599\,ft$$

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

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

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

<u>Summary:</u>

Flow rate for the pump from train to large tank was determined to be 261.11 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 determined to be 105.7 GPM and a pump head of 245.28 ft was calculated. Flow rate from the dirty tank to the trucks was determined to be 141 GPM and a pump head of 11.89 ft was calculated.

<u>Analysis:</u>

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.

vii. Instrumentation Selection

6. Final Drawings

a. Plot Plan

b. Elevations View

c. Isometrics

7. Bill of Materials and Equipment List

8. Final Remarks

9. Appendix