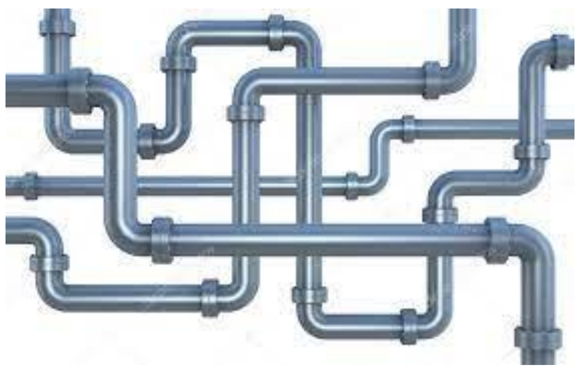
Full Pipeline System Design of a Manufacturing Plant for CONTINENTAL AG

MET 330 Design Project

Old Dominion University
December 14, 2021



Andrew Bresnahan
Erin Fitzpatrick
Hannah Wolfe

Abstract

A manufacturing company, Continental AG, is designing a new facility in which five machines in an automated machining line will be supplied with coolant from the same reservoir. This project covers the design of the system to handle the coolant from the time it reaches the plant in railroad tank cars until the dirty coolant is removed from the premises.

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2. Project Body

2.a. Building Location

The new facility is to be located in Dayton, Ohio, where the outside temperature may range from -20°F to +105°F. The building is one story high. The floor level is at the same elevation as the railroad track. The roof top is 32 ft from the floor level and the roof can be designed to support a storage tank.

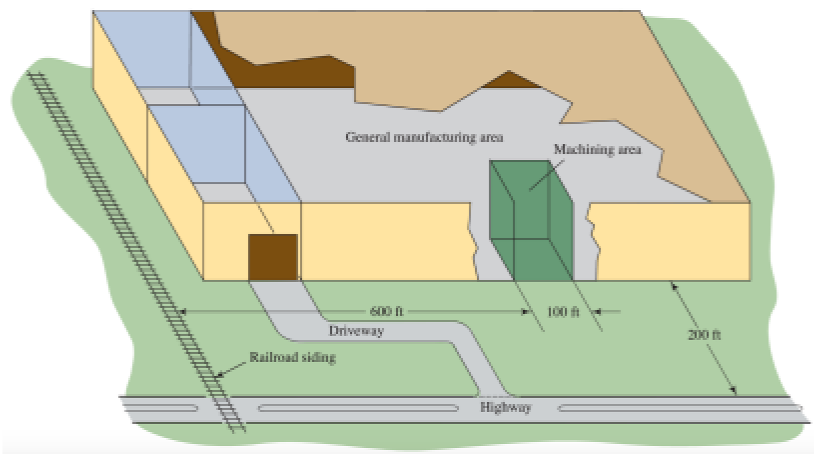


FIGURE 1

2.b. Specifications and Design Philosophy

The following data, design requirements, and limitations are given:

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 -20o F to +105 o 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 o 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.

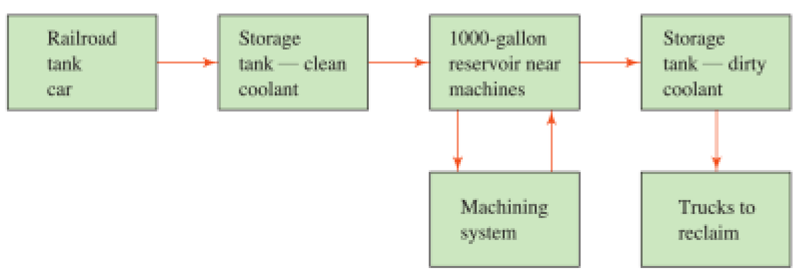


FIGURE 2. Block diagram of coolant system.

18. If pumps are required, only SULZER pumps have to be selected

2.c. Sources

MET 330 “Engineering Project Description” PDF

Applied Fluid Mechanics, Seventh edition, Robert L. Mott /Joseph A Untener

“301-1/4 Hard Tempered Stainless Steel Sheet & Coil - AMS 5517.” *United Performance Metals,* https://www.upmet.com/products/stainless-steel/301-14-hard#:~:text=At%201%2F4%20Hard%2C%20Type,yield%20strength%20of%2075%2C000.

http://servicemetal.net/pdfs/150Blind.pdf
https://www.bmssi.ca/blind-flange-fabrication/

https://www.google.com/url?sa=i&url=https%3A%2F%2Fonlinemetalsupply.com%2F2- 375-od-2-nps-schedule-40-304-304l-stainless-steel-pipe seamless%2F&psig=AOvVaw2E9r3zGRivPd6hKfg 7UJj&ust=1634351539566000&source=images&cd=vfe&ved=0CAkQjhxqFwoTCJjYuomw y_MCFQAAAAdAAAAABAJ

2.d. Materials and Specifications

2.d.i. Pipe and Tank Material

Stainless steel

2.d. 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. Assume that the viscosity and vapor pressure of the coolant are 1.50 times that of water at any temperature

2.e. Preliminary Drawings and Sketches

2.e.i. Plot Plan

2.e. ii. Elevations

2.f. Design Calculations

2.f.i. Tank Specifications

Task 1

Purpose:

Determine the size and location of all storage tanks

Drawings and Diagrams:

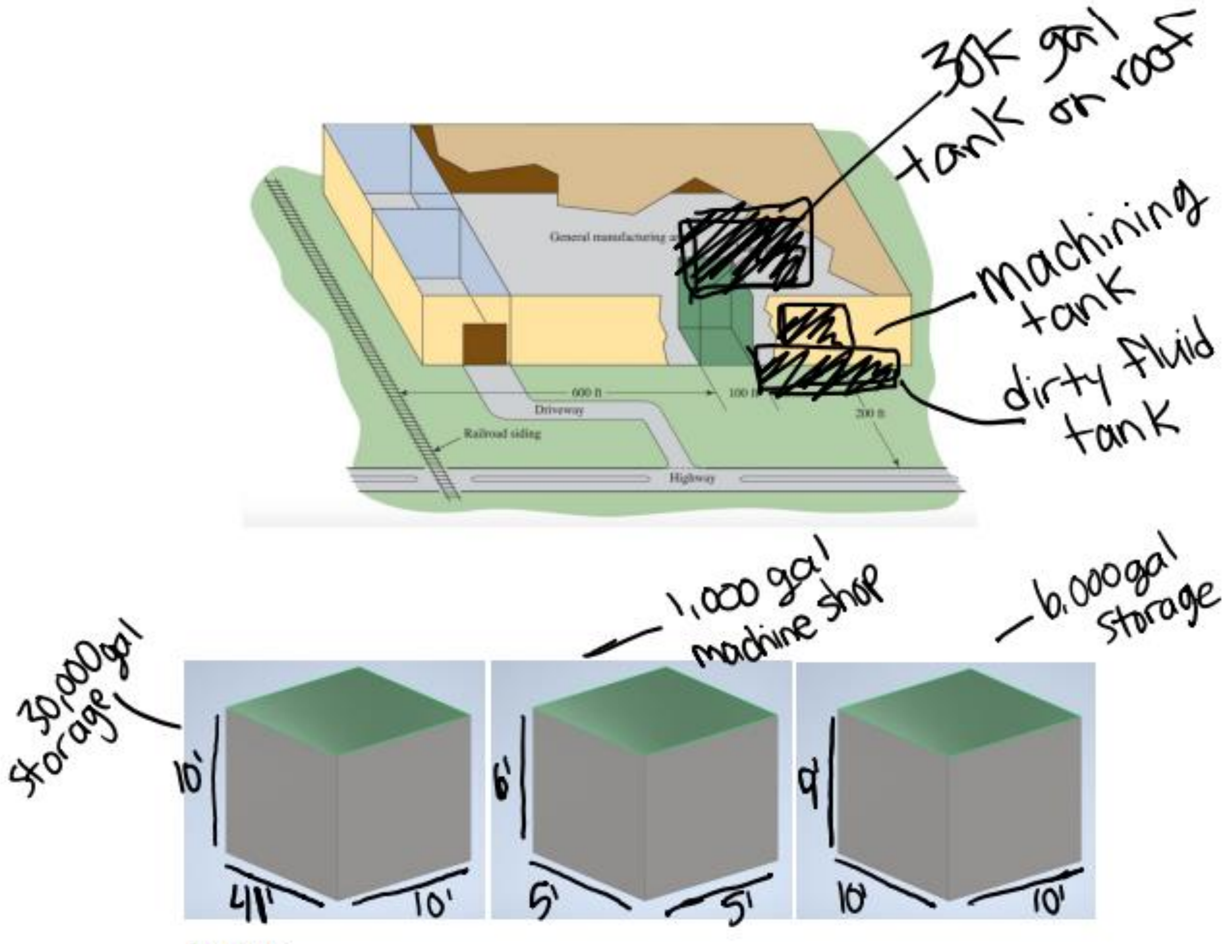


FIGURE 3

Design Considerations:

Temperature Range from -20° to +105° F

15,000 gallons delivered once a week

Machining system tank of 1000 gallons

Holding talk for dirty fluid is needed

No storage tank (except 1000-gal reservoir) can be inside

Roof can support a storage tank

Data and Variables:

30,000-gallon tank

1000-gallon tank

6000-gallon tank

Procedure:

We opted to choose the location of our largest tank to be on the roof, next to the railroad tracks. This allowed for less pipe to be used between the rail cars and the tank. By placing the other tanks by the highway, it made it closer for the truck picking up the waste product and stacking them let the machine storage tank be gravity fed into the waste tank. We calculated the size needed in order for the tanks to hold the necessary amount of liquid using an online converter. Given that volume is length*width*height, we calculated it for all 3 tanks from the sizes above and then converted ft^3 to gallons.

Calculations:

$10'*10'*9'=900ft^3$

$900ft^3*1ft^3/7.481gal$ (conversion) = 6732.5 gallons

$5'*5'*6'=150ft^3$

$150ft^3*7.481=1122.1$ gallons

$10'*10'*41'= 4100ft^3$

$4100ft^3*1ft^3/7.481$(conversion) =30670.1 gallons

Summary:

Each tank size does not give the perfect number of gallons that are needed. However, we tried to choose numbers so that they were very close so that you did not have to spend too much money for any given tank.

Materials:

3 stainless steel tanks

Analysis:

By selecting each tank to be the sizes listed above, it gives a little extra space in each for a “safety factor” in case the measurements were not 100% accurate.

Task 2

Purpose:

Determine storage tank material and wall thickness

Drawings and Diagrams:

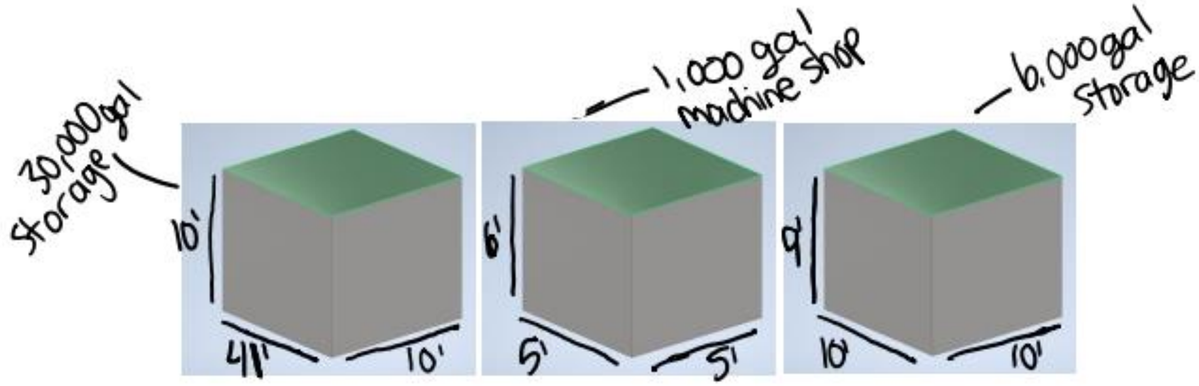


FIGURE 4

Design Considerations:

Temperature Range from -20° to +105° F

Has to withstand 69.4 psi

Data and Variables:

15000 gallons for each rail carload of coolant

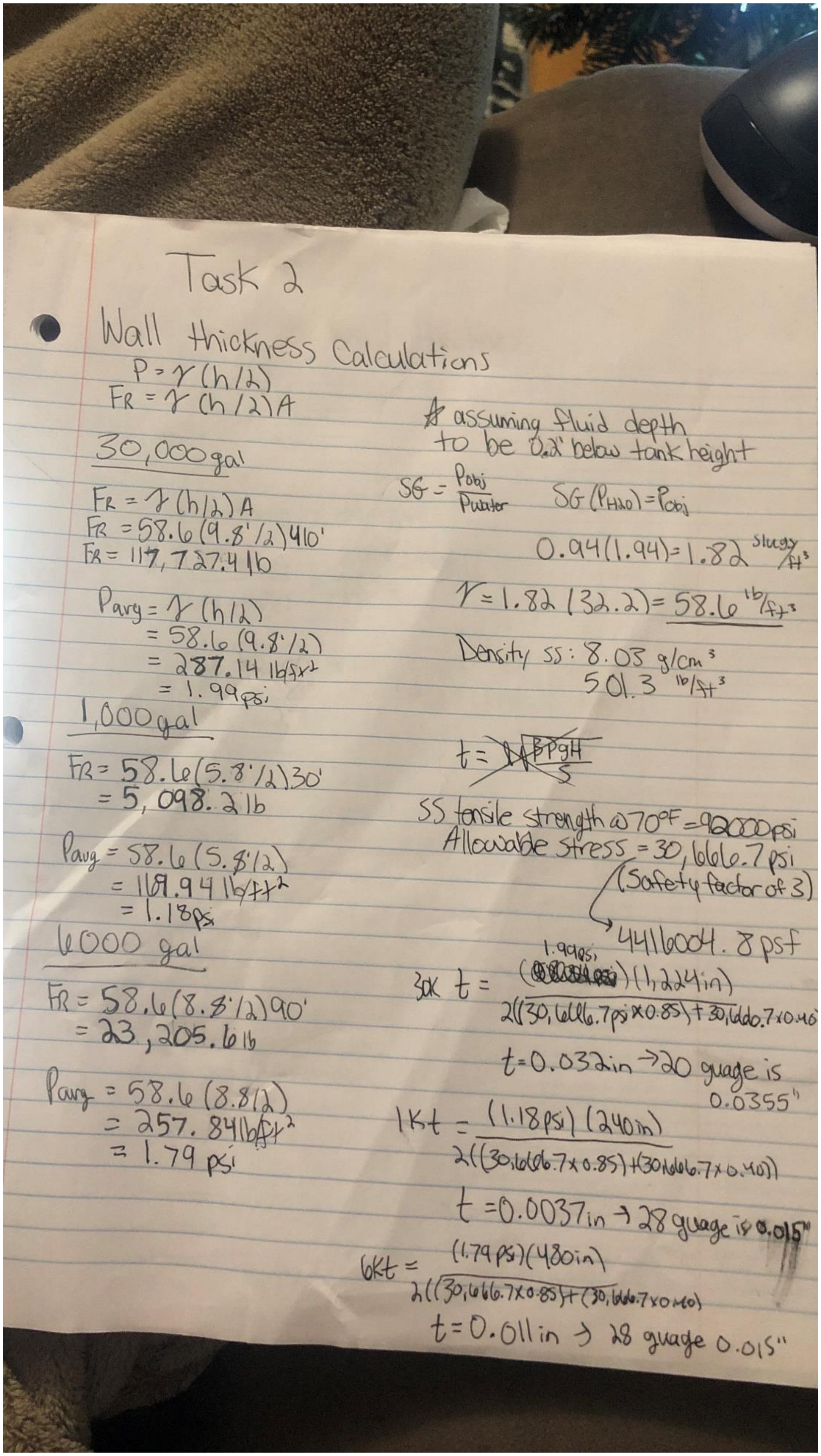
1000 gallons needed for the machine shop

6000 gallons needed holding tank

Procedure:

1) Determine how much psi each tank must withstand
2) Choose a material that will not fail at those conditions

Calculations:



Task 2

Wall thickness Calculations

$P = \gamma (h/2)$

$F_R = \gamma (h/2) A$

30,000 gal

$F_R = \gamma (h/2) A$

$F_R = 58.6 (9.8'/2) 410'$

$F_R = 117,727.4$ lb

$P_{avg} = \gamma (h/2)$

$= 58.6 (9.8'/2)$

$= 287.14$ lb/ft^2

$= 1.99$ psi

1,000 gal

$F_R = 58.6 (5.8'/2) 30'$

$= 5,098.2$ lb

$P_{avg} = 58.6 (5.8'/2)$

$= 169.94$ lb/ft^2

$= 1.18$ psi

6000 gal

$F_R = 58.6 (8.8'/2) 90'$

$= 23,205.6$ lb

$P_{avg} = 58.6 (8.8/2)$

$= 257.84$ lb/ft^2

$= 1.79$ psi

* assuming fluid depth to be 0.2' below tank height

$SG = \frac{\rho_{obj}}{\rho_{water}}$ $SG(\rho_{H_2O}) = \rho_{obj}$

$0.94(1.94) = 1.82$ slugs/ft^3

$\gamma = 1.82 (32.2) = 58.6$ lb/ft^3

Density SS: 8.03 g/cm^3

501.3 lb/ft^3

~~$t = \sqrt{\frac{\beta \rho g H}{S}}$~~

SS tensile strength @ 70°F = 92000 psi

Allowable stress = 30,666.7 psi (Safety factor of 3)

→ 4416004.8 psf

30K $t = \frac{(1.99\text{psi})(1,224\text{in})}{2((30,666.7\text{psi} \times 0.85) + 30,666.7 \times 0.40)}$

$t = 0.032$ in → 20 guage is 0.0355"

1K $t = \frac{(1.18\text{psi})(240\text{in})}{2((30,666.7 \times 0.85) + (30,666.7 \times 0.40))}$

$t = 0.0037$ in → 28 guage is 0.015"

6K $t = \frac{(1.79\text{psi})(480\text{in})}{2((30,666.7 \times 0.85) + (30,666.7 \times 0.40))}$

$t = 0.011$ in → 28 guage 0.015"

Summary:

The 30,000 gallon tank requires at least 20 gauge stainless and the 1000 gallon and 6000 gallon tanks both used 28 gauge stainless.

Materials:

20 and 28 gauge Stainless Steel plate

Analysis:

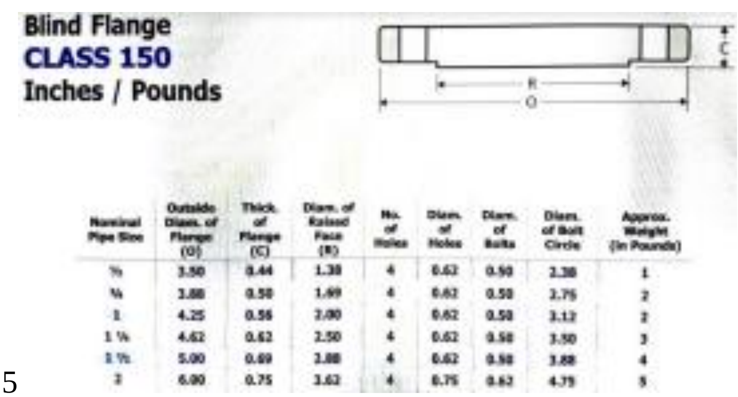
Having a slightly thicker plate to create the tanks than necessary ensures that they will not fail. Using stainless steel was a decision made with the thought in mind that it will not corrode nearly as quickly as carbon steel would have. If carbon would have been chosen, the tank could have rusted on the inside from the water in the coolant or outside from rain. Corrosion inside a tank can contaminate the product inside or create leaks.

Task 3

Purpose:

Provide a future additional connection to drain one of the tanks. Design a blind flange.

Drawings and Diagrams:


Blind Flange
CLASS 150
Inches / Pounds

Nominal Pipe Size	Outside Diam. of Flange (O)	Thick. of Flange (C)	Diam. of Raised Face (R)	No. of Holes	Diam. of Holes	Diam. of Bolts	Diam. of Bolt Circle	Approx. Weight (in Pounds)
½	3.50	0.44	1.38	4	0.62	0.50	2.38	1
¾	3.88	0.50	1.69	4	0.62	0.50	2.75	2
1	4.25	0.56	2.00	4	0.62	0.50	3.12	2
1 ¼	4.62	0.62	2.50	4	0.62	0.50	3.50	3
1 ½	5.00	0.69	2.88	4	0.62	0.50	3.88	4
2	6.00	0.75	3.62	4	0.75	0.62	4.75	5

FIGURE 5

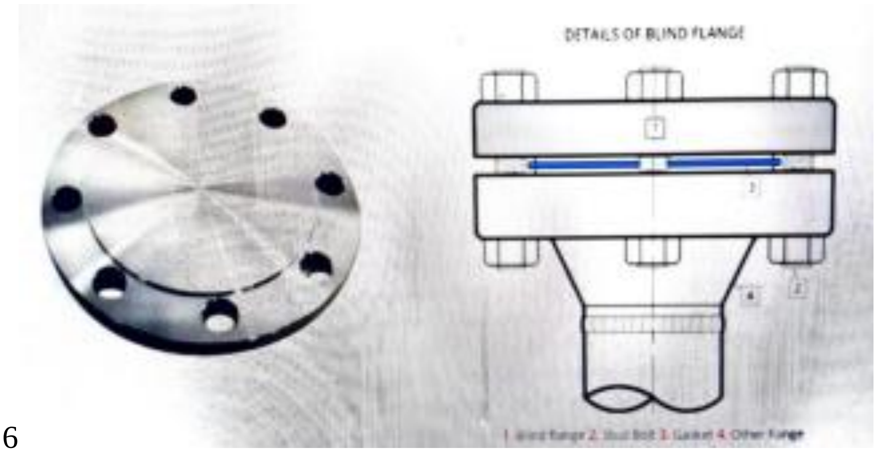


FIGURE 6

Sources:

MET 330 project PDF

Applied Fluid Mechanics, Seventh edition, Robert L. Mott / Joseph A Untener

Design Considerations:

The flange has to withstand 1.8psi

Design it around 2" pipe

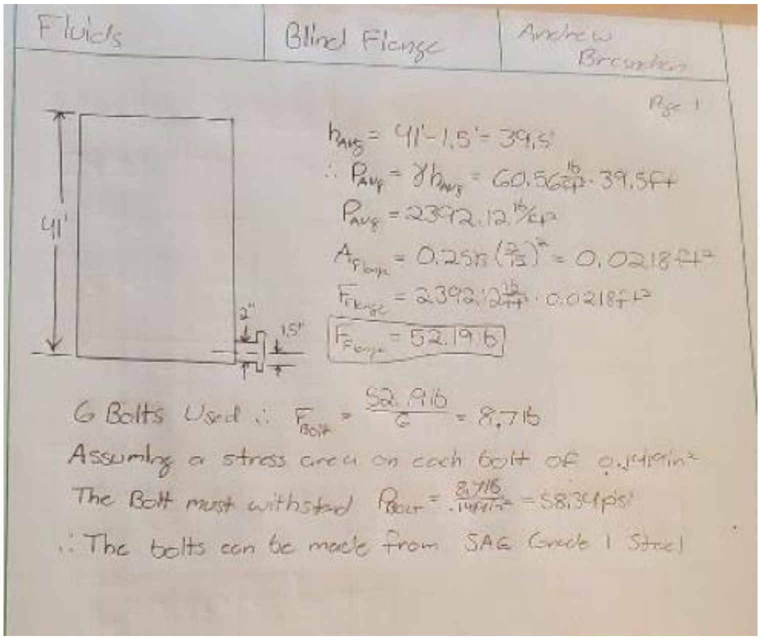
Data and Variables:

Flange inside diameter: 2in
Flange outside diameter: 6in
Thickness of flange: 0.75in
Thickness of plate: 0.75in
Diameter of raised face: 3.62in
Diameter of bolt circle: 4.75in
Number of holes: 4
Diameter of holes: 0.75in
Number of bolts: 4
Diameter of bolts: 0.62in
Number of nuts: 4
Total weight: 5lbs

Procedure:

1) Find area, gravity, and volume
2) Find mass
3) Find pressure by dividing mass*gravity by area

Calculations:



Summary:

The flange needed to be able to withstand 1.8 lb/in^3 of pressure without failing or being damaged.

Materials:

Stainless steel nuts, bolts, and flange

Analysis:

By determining the pressure in the tank, we were able to figure out that the flange had to be 3/4" thick if the ID is 2" and the OD is 6". It was given a bolt circle of 4.75" and with 4 holes filled with 0.62" diameter bolts. This flange was designed to hold 150 lb/in^3, so it is plenty big enough to withstand the pressure in the tank.

Task 11

Purpose:

The purpose of this task was to determine the wind loading and weight of the tanks used in the design.

Design Considerations:

This task was performed under the assumption that the average wind speed of the windiest month in Dayton, Ohio was 16.9 $\frac{ft}{s}$, the density of the stainless steel used was 7.85$\frac{lb}{ft^3}$, and the density of air was .0024 $\frac{slug}{ft^3}$.

Data and Variables:

C_D = Drag Coefficient

F_D = Drag Force

W_M = Weight of Metal

W_F = Weight of Fluid

V_F = Volume of Fluid

V_M = Volume of Metal

D_M = Density of Metal

A = Area Acted on by Wind

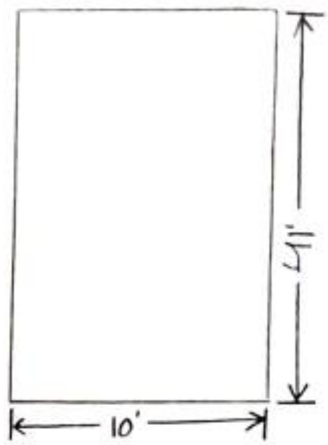
Procedure:

Once all properties were determined, the formula for drag force was used to determined using the appropriate formula. Then, the volume of both the metal and liquid in each tank were determined. These values were then combined with the densities of both to determine the overall weight of the full tank. This process was repeated for all three tanks.

Calculations:

Wind Loading 3014 gallon Page 1

Avg. Wind Speed In Dayton Ohio - $11.5 \frac{miles}{hr} = 16.9 \frac{ft}{s}$



$\rho_{AIR} = 0.0024 \frac{slug}{ft^3}$

$C_D = 1.6$

$F_D = C_D \left(\frac{\rho V^2}{2}\right) A = 1.6 \left(\frac{.0024 \frac{slug}{ft^3} \cdot 16.9^2 \frac{ft}{s}}{2}\right) \cdot 410 ft^2$

$F_D = 222.67 lb$

Weight of Tank

Weight of Fluid: $W_F = \gamma_F V = 60.56 \frac{lb}{ft^3} \cdot (41' \cdot 10' \cdot 10')$

$W_F = 248296 lb$

Weight of Metal: $W_M = D_M \cdot V_M$

$V_M = t(2LW + 4LH) = \left(\frac{.0355''}{12}\right) ft \left(2(10 \cdot 10) + 4(41 \cdot 10)\right)$

$V_M = 5.44 ft^3 \therefore W_M = 7.85 \frac{lb}{ft^3} \cdot 5.44 ft^2 = 42.73 lb$

Total Weight: $W = W_M + W_F = 248338.73 lb$

Wind Loading

1K Gallon

Page 2

$$F_D = C_D\left(\frac{\rho V^2}{2}\right)A$$

$$F_D = 1.6\left(\frac{.0.0024\frac{slug}{ft^3}\cdot 16.9^2\frac{ft}{s}}{2}\right)\cdot(5'\cdot 6')$$

$$\boxed{F_D = 16.45\text{ lb}}$$

Weight of Tank

Fluid Weight: $W_F = \gamma_F V = 60.56\frac{lb}{ft^3}(6'\cdot 5'\cdot 5') = 9084$ lb

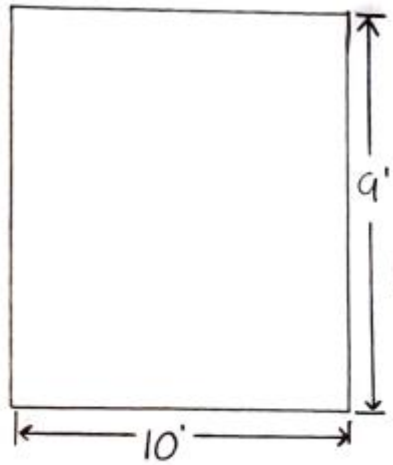
Metal Weight: $W_M = D_M \cdot V_M = 7.85\frac{lb}{ft^3}\cdot\left(\frac{.015''}{12}\right)ft\left((2\cdot 5'\cdot 5') + (4\cdot 6'\cdot 5')\right)$

$W_M = 1.67$ lb

Total Weight: $\boxed{W = 9085.67\text{ lb}}$

6k Gallon Page 3

Wind Loading



$$F_D = C_D \left(\frac{\rho V^2}{2}\right) A$$

$$F_D = 1.6 \left(\frac{.0024 \frac{slugs}{ft^3} \cdot 16.9^2 \, ft/s}{2}\right)(9' \cdot 10')$$

$$\boxed{F_D = 49.35 \, lb}$$

Weight of Tank

Fluid Weight: $W_F = \gamma_F V = 60.56 \frac{lb}{ft^3} \cdot (10' \cdot 10' \cdot 9')$

$W_F = 54504 \, lb$

Metal Weight: $W_M = D_M V_m$

$V_m = t(2 \cdot 10' \cdot 10' + 4 \cdot 9' \cdot 10') = \left(\frac{.015''}{12}\right) ft \, (200' + 360') = .7 \, ft^3$

$W_M = 7.85 \frac{lb}{ft^3} \cdot 0.7 \, ft^3 = 5.495 \, lb$

Total Weight: $\boxed{W = 54509.5 \, lb}$

Summary:

It was determined that for the 30,000-gallon tank, the wind loading was 222.67 lb while the weight was 248338.73 lb. For the 1,000-gallon tank, it was determined that the wind loading

was 16.45 lb while the weight was 9085.67 lb. Finally, for the 6,000-gallon tank, it was determined that the wind loading was 49.35 lb, while the weight was 54509.5 lb.

Materials:

Tanks and fluid that meet the specified parameters.

Analysis:

In conclusion, the wind loading is most substantial on the largest tank as was suspected meaning that it will require a large number of lateral supports. It will also be necessary to conduct additional analysis on the roof section where it will be located due to its significant weight.

Task 12

Purpose:

The purpose of this task was to determine the design of an open channel to bring draining fluid from the main storage tank to another location.

Drawings and Diagrams:

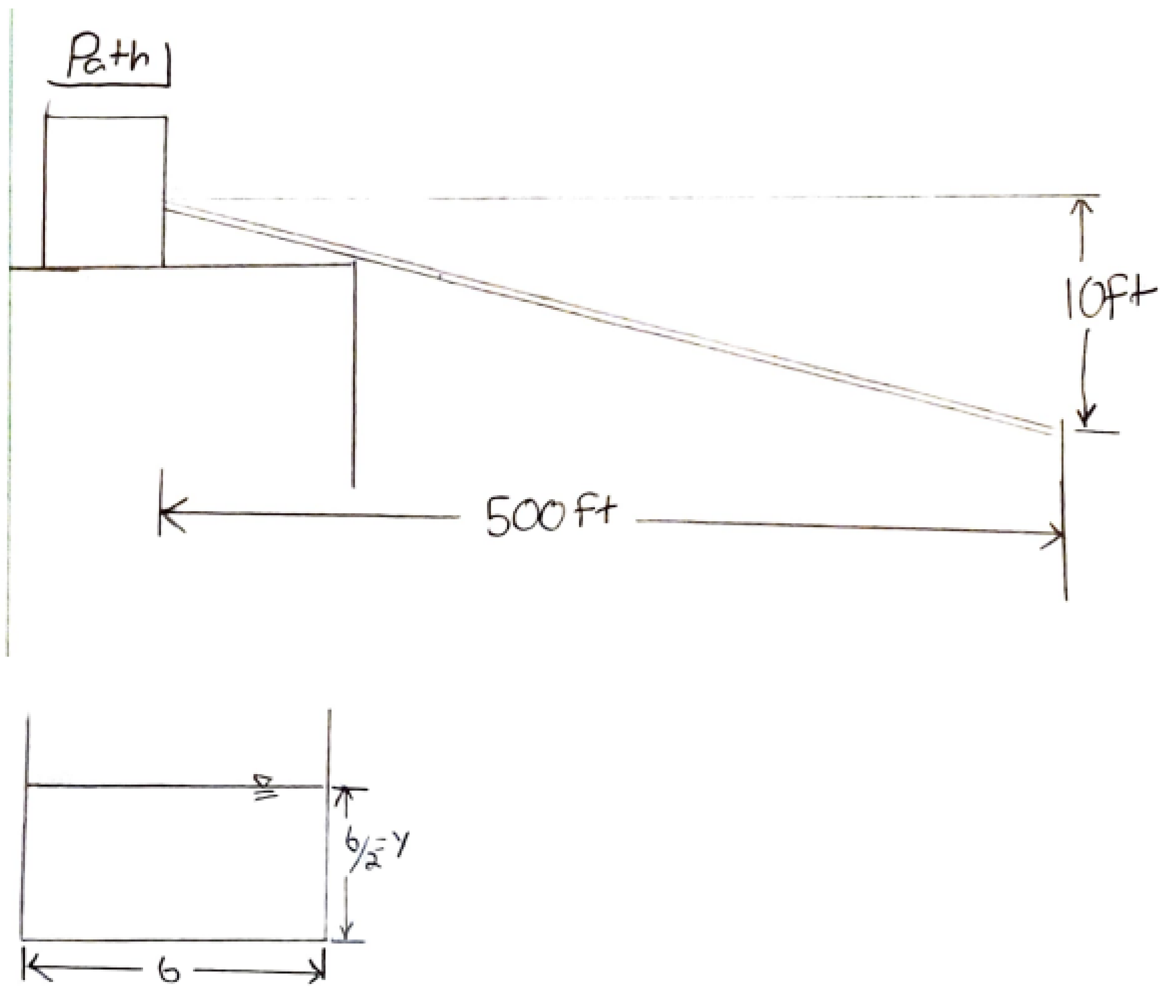


FIGURE 7

Design Considerations:

This task was performed under the assumption that the fluid was being carried to a storage location that was elevated so that the channel only has to provide for a 10 foot drop and has to carry the fluid 500 feet over land. It was also decided that the channel would be made of smooth unpainted steel.

Data and Variables:

A = Flow Area

b = Width of Bottom

y = Flow Depth

R = Hydraulic Radius

WP = Wetted Perimeter

n = Manning's n

S = Slope of Channel

Procedure:

The idea that the flow depth would be half the flow base was used to develop a formula for area and hydraulic radius based on the width of the base. These were then plugged into the correct version of Manning's equation in order to determine the base width. This value was then used to determine the flow depth.

2.f. ii. Flow Rate

Task 4

Purpose:

Estimate the time it takes to fill and empty the tanks and specify the desired flow rate

Drawings and Diagrams:

		[illegible]		[illegible]		[illegible]	
Sch 40 Pipe Size	ID (range)	OD	GPM	GPH	GPM	GPH	GPM	GPH
1/2"	.50-.60"	.85"	7 gpm	420 gph	14 gpm	840 gph	[illegible]	[illegible]
3/4"	.75-.85"	1.06"	11 gpm	660 gph	23 gpm	1,410 gph	[illegible]	[illegible]
1"	1.00-1.03"	1.33"	16 gpm	960 gph	37 gpm	2,220 gph	[illegible]	[illegible]
1.25"	1.25-1.36"	1.67"	25 gpm	1,500 gph	62 gpm	3,750 gph	[illegible]	[illegible]
1.5"	1.50-1.60"	1.90"	35 gpm	2,100 gph	81 gpm	4,830 gph	[illegible]	[illegible]
2"	1.95-2.05"	2.38"	55 gpm	3300 gph	127 gpm	7,650 gph	[illegible]	[illegible]
2.5"	2.35-2.45"	2.89"	80 gpm	4800 gph	190 gpm	11,400 gph	[illegible]	[illegible]
3"	2.90-3.05"	3.50"	140 gpm	8,400 gph	273 gpm	16,350 gph	[illegible]	[illegible]
4"	3.85-3.95"	4.50"	240 gpm	14,400 gph	480 gpm	28,800 gph	[illegible]	[illegible]
5"	4.95-5.05"	5.563"	380 gpm	22,800 gph	750 gpm	45,000 gph	1100 gpm	[illegible]
6"	5.85-5.95"	6.61"	550 gpm	33,000 gph	1100 gpm	66,000 gph	1700 gpm	[illegible]
8"	7.98"	8.625"	950 gpm	57,000 gph	1900 gpm	114,000 gph	2800 gpm	[illegible]

FIGURE 8

Design Considerations:

Data and Variables:

6-hour fill time

2” pipe

30000 gallons

Procedure:

1) Determine pipe diameter
2) Determine volume
3) Find flow rate

Calculations:

Pipe Inner Diameter 2"   Fill Time 6hours

Volume: 30,000 US gallons

$$\therefore Q = \frac{30000\,gal}{6\,hours} = \frac{4010.42\,ft^3}{21600\,sec} = 0.1857\,\frac{ft^3}{sec}$$

(See Hydraulic Analysis Task 7)

Summary:

The flow rate of the 30,000-gallon tank is 0.1857 ft^3/s. This is assuming that there is a fill time of 6 hours and a pipe diameter of 2". The flow rates of the other tanks are 0.074 ft^3/s and 0.167 ft^3/s (see Hydraulic Analysis Task 7).

Materials:

3 stainless steel tanks (30000, 6000, and 1000 gallons) with all previously listed components. (Valves, pipe, elbows, fittings)

Analysis:

According to the chart given, at average pressure 2" schedule 40 pipe can withstand 157 gpm. Our system only has a flow rate of 83.3 gpm (converted from 0.1857 ft^3/s). This means that the size pipe that was chosen is equipped to handle the flow rate in this system.

2.f.iii. Pipe Sizing

Task 5

Purpose:

Specify the layout of the piping system, material type and size of pipes, and lengths

Drawings and Diagrams:

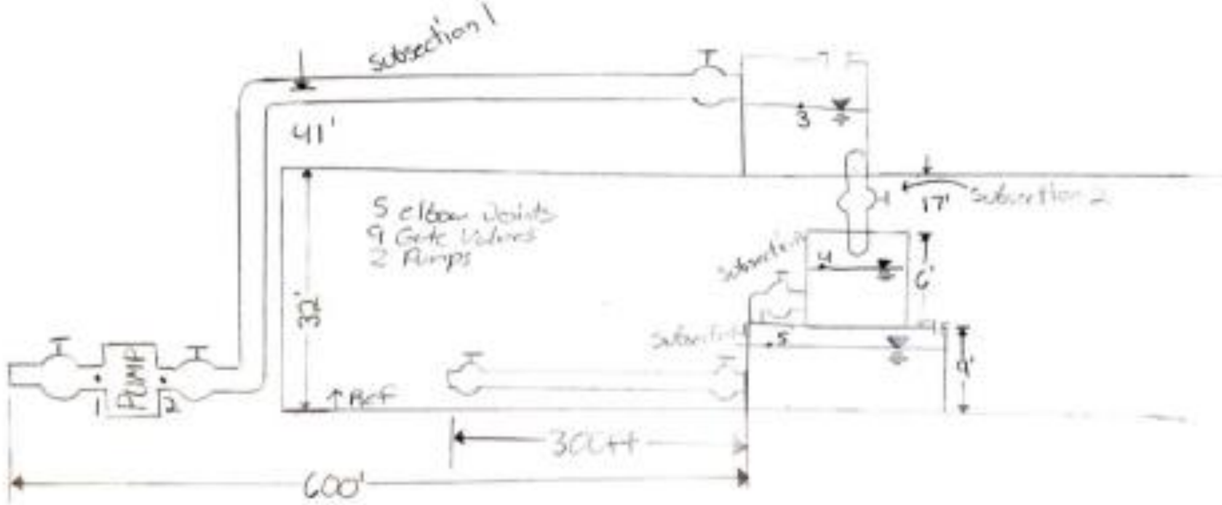


FIGURE 9

Design Considerations:

Cost of the project

Material of pipe

Flow rate

Coolant properties

Data and Variables:

Q = Volumetric Flow Rate

Procedure:

1) Determine fill time
2) Find flow rate
3) Use flow rate to determine the appropriate pipe size

Calculations:

Pipe Inner Diameter 2" Fill Time 6hours

Volume: 30,000 US gallons

$$\therefore Q = \frac{30000\,gal}{6\,hours} = \frac{4010.42\,ft^3}{21600\,sec} = 0.1857\,\frac{ft^3}{sec}$$

Summary:

After assigning a fill time of 6 hours, it was determined that the flow rate for 30,000 gallons was 0.1857 ft^3/s.

Materials:

2 1/2” schedule 80 pipe

Analysis:

2 1/2” schedule 80 pipe is a very common size which will make it easier for the customer to find and buy. This also makes it easier to find information about it. Most importantly, it is equipped to handle the flow rate of the system.

Task 9

Purpose:

Specify wall thickness

Drawings and Diagrams:

STEEL SCHEDULE 80 PIPE

Size (nominal)	O.D. (Inches)	I.D. (Inches)	Wall Thick-ness	Weight per Foot (lbs)		Threads per Inch
				Plain Ends	T&C	
1/8	0.405	0.215	0.095	0.31	0.32	27
1/4	0.540	0.302	0.119	0.54	0.54	18
3/8	0.675	0.423	0.126	0.74	0.75	18
1/2	0.840	0.546	0.147	1.09	1.10	14
3/4	1.050	0.742	0.154	1.48	1.49	14
1	1.315	0.957	0.179	2.17	2.20	11 1/2
1-1/4	1.660	1.278	0.191	3.00	3.05	11 1/2
1-1/2	1.900	1.500	0.200	3.63	3.69	11 1/2
2	2.375	1.939	0.218	5.03	5.15	11 1/2
2-1/2	2.875	2.323	0.276	7.67	7.83	8
3	3.500	2.900	0.300	10.26	10.46	8

FIGURE 10

Design Considerations:

Strength of the pipe

Material

Corrosion factors

Actual vs nominal size

Data and Variables:

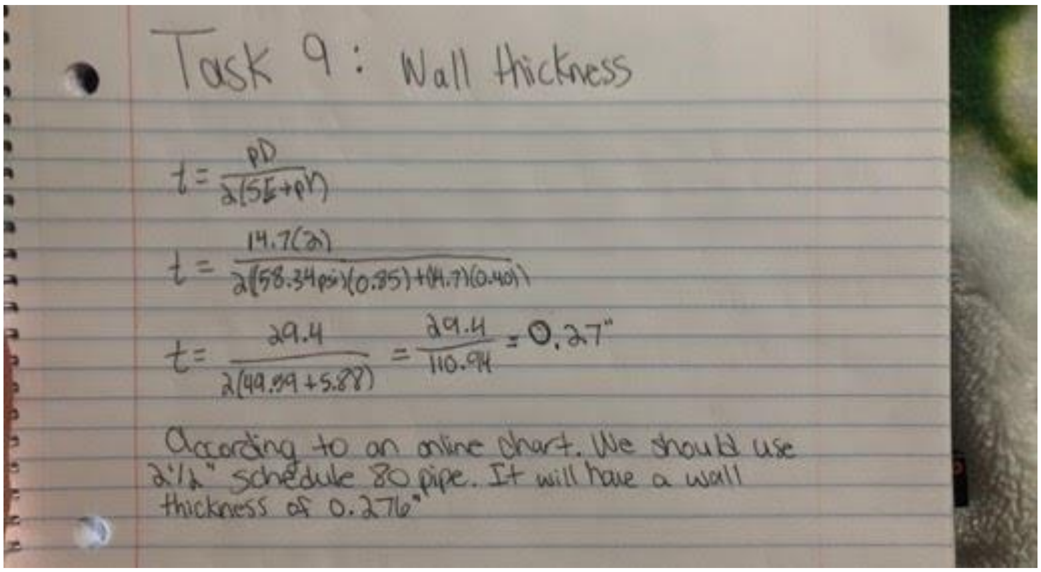
ID: 2.067”

OD: 2.375”

Procedure:

1) Find the pressure and flow rate that the pipe needs to withstand
2) Choose a pipe that is capable of handing the found factors

Calculations:



Summary:

The system will require 2 ½” schedule 80 pipe which has a wall thickness of 0.276” and we needed at least 0.27”.

Materials:

2 1/2” schedule 80 stainless pipe

Analysis:

By selecting schedule 80 2 1/2” stainless pipe it ensured that the necessary pressure would not be exceeded, therefore the pipe would not fail. It also made calculations simpler and charts easier to find because this is a very common pipe size.

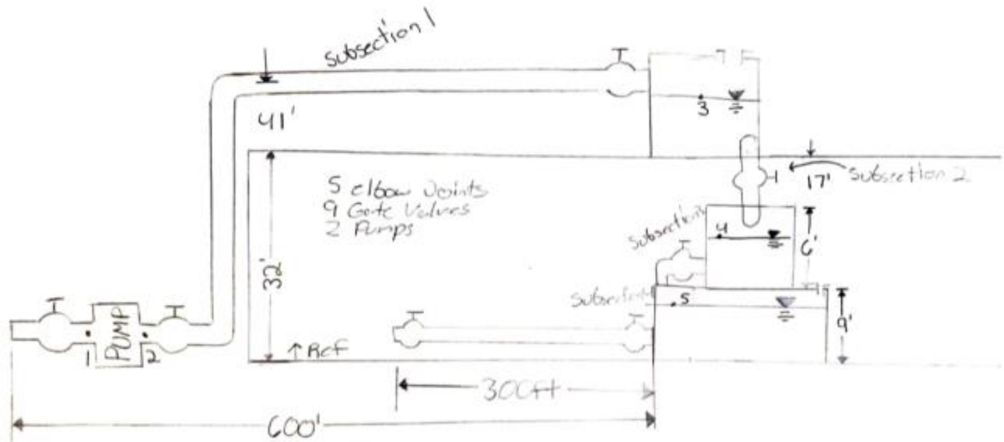
Task 6

Purpose:

Specify the number, types, material, and size of all valves, elbows, and fittings

Drawings and Diagrams:

FIGURE 11



Design Considerations:

Gate valve is being used

Standard elbow

Pipe fittings

Data and Variables:

9 stainless steel gate valves

5 stainless standard elbows for schedule 40 2 1/2” pipe

1 stainless blind flange

6 pipe flanges to fit 2 1/2” pipe

Procedure:

1) Determine the layout of the pipe in the system.
2) Use the layout to find where and what fitting are needed

Calculations:

2 1/2” pipe was already determined, so we worked around that and chose standard elbows, pipe flanges, and gate valves all to fit 2 1/2” pipe and stainless to go with the same material chosen for the tank and pipe.

Summary:

Choosing pipe size and doing the pipe layout ahead of time made it very simple to choose the appropriate fittings. They all had to match the drawing and be equipped to fit 21/2” schedule 80 pipe.

Materials:

Stainless steel valves, elbows, fittings

Analysis:

Based on the drawing, 3 gate valves were needed for each pump, totaling 9. 5 pipe elbows were used, one blind flange was required per the project assignment, and 6 pipe flanges were used (2 for each pump). By making all of the tanks close together and vertical it limited the number of fittings needed and the uniform pipe size also made it so that all fittings were uniform size as well.

Task 10

Purpose

The purpose of this task was to determine whether or not an occurrence of water hammer would burst the pipes used in the system.

Drawings and Diagrams

N/A

Design Considerations

This task was completed under the assumption that the bulk modulus of the fluid was 300,000 psi and the elastic modulus of stainless steel was 28000000 psi. The calculations were performed on subsection 1 as this section has both the highest velocity and the highest operating pressure, making it the most likely to fail in the event of water hammer.

Data and Variables

E_o = Bulk Modulus of Fluid

E = Elastic Modulus of Pipe

C = Velocity of Wave

P_{MAX} = Maximum Pressure Experienced During Water Hammer

Procedure

Once all properties obtained, the proper formula was used to find the wave velocity. This was then combined with the operating velocity of the system and the density of the fluid to determine the max pressure change. This was then summed with the operating pressure to find the maximum pressure experienced during water hammer.

2.f. iv. Pipeline Support Information

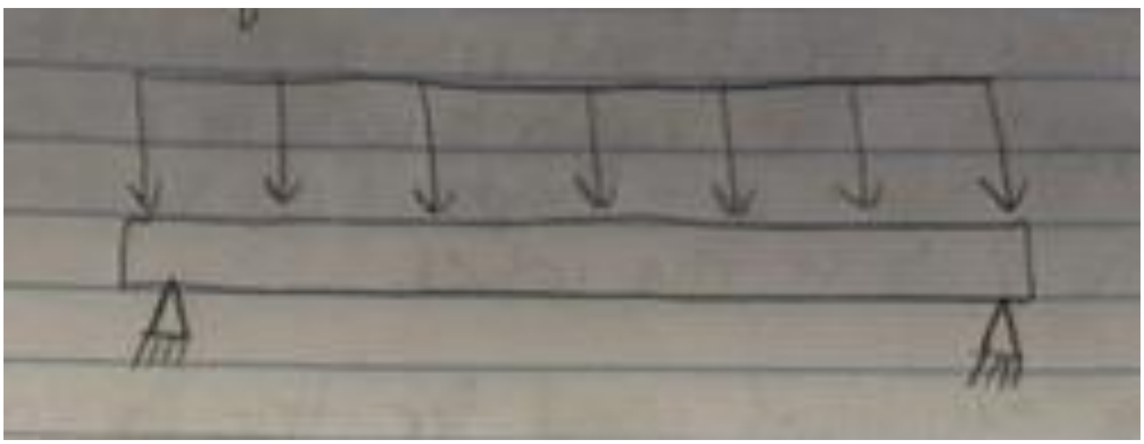
Task 13

Purpose:

Determine the type of supports and the force on each support

Drawings and Diagrams:

FIGURE 12



Design Considerations:

Pipe is being treated as though it is a solid beam with an evenly

distributed load

Data and Variables:

L= 300 ft

Sg= 0.94

W= 7.661 lb/ft (300ft)= 2298.3 lb for 300 ft

Procedure:

1) Calculate weight/ft of 21/2” Schedule 80 SS Pipe

2) Apply load across 300 ft and calculate force on each support

Calculation:

Calc: $W = 2{,}298.3\ lb$ for 300 ft

W coolant 1 ft $= 0.94 \times 62.4 = 58.7\ lb/ft^3$

12 foot intervals: $(7.661 \times 12) + (58.7 \times 12) = 796.332$ per 12 ft

Materials:

Preformed concrete supports, 21/2” Schedule 80 Pipe, coolant

Summary:

Since this pipe is on the ground, I would recommend using concrete supports. The supports will be placed 12 ft apart with emphasis on supporting the pipes at the valves.

Analysis:

The equations used for this particular section can be used for any other pipe section of the project. The weight of one foot of pipe, one foot of coolant, and specific gravity will remain the same for the entirety of the system.

2.f.v. Energy Losses

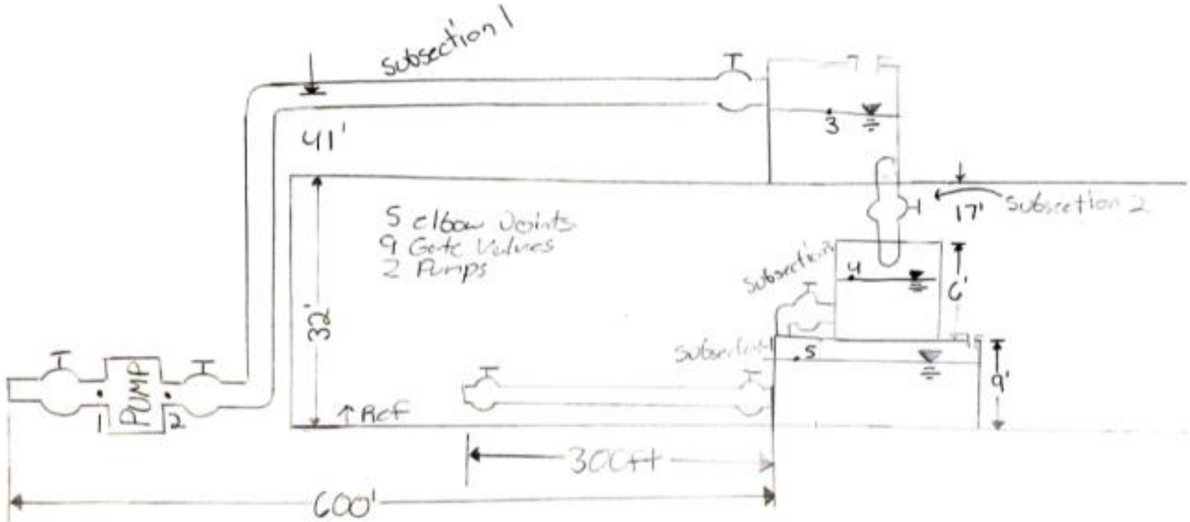
Task 7

Purpose:

Develop hydraulic analysis of all parts of the system, including energy losses.

Drawings and Diagrams:

FIGURE 13



Design Considerations:

Temperature range from -20 °F to +105 °F.

Age of the pipe

The coolant is a solution of water and soluble oil with a specific gravity of 0.94
Coolant freezing point of 0° F.

Coolant 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

Data and Variables:

Q = Volumetric Flow Rate of Section
A = Internal Area of Pipes

D =Inner Diameter of Pipes

Re = Reynolds Number

f = Friction Number

ϵ = Roughness of Pipe

η = Viscosity of Fluid

ρ = Density of Fluid

γ = Specific Weight of Fluid

sg = Specific Gravity of Fluid

h_{LPIPE} = Energy Losses due to Friction

h_{LEL} = Energy Losses in Elbows

h_{LEN} = Entrance Losses

h_{LV} = Energy Losses in Valves

h_{LT} = Total Energy Losses in Section

P_1 = Pressure at Pump Inlet

V_1 = Velocity at Pump Inlet

z_1 = Height of Pipe at Pump Inlet

P_2 = Pressure at Pump Outlet

V_2 = Velocity at Pump Outlet

z_2 = Height of Pipe at Pump Outlet

P_3 = Pressure at Fluid Surface in Tank 1

V_3 = Velocity at Fluid Surface in Tank 1

z_3 = Height of Fluid Surface in Tank 1

P_4 = Pressure at Fluid Surface in Tank 2

V_4 = Velocity at Fluid Surface in Tank 2

z_4 = Height of Fluid Surface in Tank 2

P_5 = Pressure at Fluid Surface in Tank 3

V_5 = Velocity at Fluid Surface in Tank 3

z_5 = Height of Fluid Surface in Tank 3

Procedure:

1) Determine the diameter and fill time
2) Find the flow rate and area
3) Use those values to find V
4) Find friction factor
5) Find energy losses
6) Apply to Bernoulli's
7) Repeat for each subsection

Calculations:

Subsection 1 hydraulic Analysis

Pipe Inner Diameter 2" Fill Time 6hours

Volume: 30,000 US gallons

$\therefore Q = \frac{30000 \text{ gal}}{6 \text{ hours}} = \frac{4010.42 \text{ ft}^3}{21600 \text{ sec}} = 0.1857 \frac{\text{ft}^3}{\text{sec}}$

$A = 0.25\pi\left(\frac{2}{12}\right)^2 = 0.0218 \text{ ft}^2$

$S.G = 0.94$

$V = \frac{Q}{A} = \frac{0.1857 \frac{\text{ft}^3}{\text{sec}}}{0.0218 \text{ ft}^2} = \boxed{8.51 \text{ ft/sec}}$

$\therefore \gamma = 0.94\left(62.43 \frac{\text{lb}}{\text{ft}^3}\right) = 60.56 \frac{\text{lb}}{\text{ft}^3}$

$\rho_{coolant} = \frac{60.56 \frac{\text{lb}}{\text{ft}^3}}{32.2 \text{ ft/s}^2} = 1.88 \text{ slugs/ft}^3$

$\eta_{coolant} = 1.5\eta_{H_2O} = 1.5\left(3.23 \cdot 10^{-5} \frac{\text{lb} \cdot \text{s}}{\text{ft}^2}\right)$

$\eta_c = 4.85 \cdot 10^{-5} \frac{\text{lb} \cdot \text{s}}{\text{ft}^2}$

$Re = \frac{\rho v D}{\eta} = \frac{1.88 \frac{\text{slug}}{\text{ft}^3} \cdot 8.51 \frac{\text{ft}}{\text{sec}} \cdot 0.167 \text{ ft}}{4.85 \cdot 10^{-5} \frac{\text{lb} \cdot \text{s}}{\text{ft}^2}} = \boxed{54978.69}$ Turbulent Flow

$f = \frac{0.25}{\left(\log\left(\frac{1}{3.7\left(\frac{D}{\epsilon}\right)} + \frac{5.74}{Re^{0.9}}\right)\right)^2} = \boxed{0.0205}$

Energy losses Between Points 2 + 3

$h_{L_{pipe}} = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right) = 0.0205\left(\frac{590' + 32' + 41'}{\left(\frac{2}{12}\right)'}\right)\left(\frac{\left(8.51 \frac{\text{ft}}{\text{s}}\right)^2}{64.4 \text{ ft/s}^2}\right)$

$\boxed{h_{L_{pipe}} = 91.5 \text{ ft}}$

$h_{L_{valve}} = K\left(\frac{V^2}{2g}\right) \quad K = 8f = 8 \cdot 0.0205$

$h_{L_{valve}} = 0.1636\left(\frac{8.51 \frac{\text{ft}}{\text{s}}^2}{64.4 \text{ ft/s}^2}\right) = 0.184 \text{ ft/valve}$

$h_{LV} = 0.184 \cdot 2 = \boxed{0.368 \text{ ft}}$

$h_{L_{elbow}} = K\left(\frac{V^2}{2g}\right) \quad K = 30f = 30 \cdot 0.0205 = 0.6136$ Page 3

$h_{LE} = 0.6136\left(\frac{8.51 \frac{\text{ft}}{\text{s}}^2}{64.4 \text{ ft/s}^2}\right) = 0.69 \text{ ft per elbow}$

$h_{LE} = 0.69 \text{ ft} \cdot 2 = \boxed{1.38 \text{ ft}}$

$\therefore h_{LT} = 1.38 \text{ ft} + 0.368 \text{ ft} + 91.5 \text{ ft} = \boxed{93.25 \text{ ft}}$

Applying Bernoulli's

$\frac{P_2}{\gamma} + \frac{V_2^2}{2g} + Z_2 = \frac{P_3}{\gamma} + \frac{V_3^2}{2g} + Z_3 + h_L$

$\frac{P_2}{60.56} + \frac{8.51^2}{64.4} = (32 + 41) + 93.25$

$\boxed{P_2 = 10{,}000 \text{ lb/ft}^2 = 69.4 \text{ psi}}$

Pump Head:

$h_A = \Delta z + h_L = 93.25 \text{ ft} + 73 \text{ ft} = \boxed{166.25 \text{ ft}}$

Fluids	Proj. Tasks 4-7	Andrew Bresnahan

Subsection 2 Hydro. Analysis Revision

$Q = 0.074 ft^3/s$

Bernoulli's

$$\frac{P_A}{\gamma} + \frac{V_A^2}{2g} + Z_A = \frac{P_B}{\gamma} + \frac{V_B^2}{2g} + Z_B + h_L$$

$$\therefore Z_3 = \frac{V_{3B}^2}{2g} + Z_{3B} + h_L \quad \therefore 73ft = \frac{V_{3B}^2}{2g} + 15ft + h_L$$

$$\therefore 58ft = \frac{V_{3B}^2}{2g} + h_L$$

Energy Losses Due to Friction

$$h_{LF} = f\left(\frac{L}{D}\right)\left(\frac{V_{3B}^2}{2g}\right) = f\left(\frac{17.5'}{D}\right)\left(\frac{8Q^2}{g\pi^2 D^4}\right)$$

Valve Losses

$$h_{Lv} = 2k\left(\frac{V^2}{2g}\right) = 16f\left(\frac{8Q^2}{g\pi^2 D^4}\right)$$

Elbow Losses

$$h_{LEL} = K\left(\frac{V^2}{2g}\right) = 30f\left(\frac{8Q^2}{g\pi^2 D^4}\right)$$

Entrance Losses

$$h_{Len} = 0.5\left(\frac{8Q^2}{g\pi^2 D^4}\right)$$

$$\therefore 58ft = \left(\frac{8Q^2}{g\pi^2 D^4}\right)\left(1 + 46f + f\left(\frac{17.5'}{D}\right) + 0.5\right)$$

$$\therefore 58ft = \left(\frac{0.0001378}{D^4}\right)\left(1.5 + 46f + \frac{17.5f}{D}\right)$$

Fluids	Proj. Tasks 4-7	Andrew Bresnahan

Subsection 3 Hydro. Analysis Revision

$Q = 0.074\ ft^3/s$

Bernoullis

$$\frac{P_4}{\gamma} + \frac{V_4^2}{2g} + z_4 = \frac{P_{AB}}{\gamma} + \frac{V_{AB}^2}{2g} + z_{AB} + h_L$$

$$15ft = 9ft + \frac{V^2}{2g} + h_L \therefore 6ft = \frac{V^2}{2g} + h_L$$

$$6ft = \left(\frac{0.0001378}{D^4}\right)\left(1.5 + 46f + \frac{3f}{D}\right)$$

Fluids	Proj. Tasks 4-7	Andrew Bresnahan

Subsection 4 Hydraulic Analysis

$Q = 0.167\ ft^3/s \quad D = 2" = 0.167' \quad A = 0.0218\ ft^2$

$V = \frac{Q}{A} = \frac{0.167}{0.0218} = 7.64\ ft/s$

$Re = \frac{\rho V D}{\mu} = \frac{1.88 \cdot 7.64 \cdot (\frac{2}{12})}{4.85 \cdot 10^{-5}} = 49352.5$ ∴ Turbulent

$f = \frac{0.25}{\left(\log\left(\frac{1}{3.7(\frac{D}{\varepsilon})} + \frac{5.74}{Re^{.9}}\right)\right)^2} = 0.024$

Energy Losses

Friction)

$h_{Lf} = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right) = .024\left(\frac{300'}{0.167'}\right)\left(\frac{7.64^2}{64.4}\right) = \boxed{39.08'}$

Valves)

$h_{Lv} = 4(8f)\left(\frac{V^2}{2g}\right) = \boxed{0.7'}$

Entrance)

$h_{LEN} = 0.5\left(\frac{V^2}{2g}\right) = \boxed{0.45'}$

Total)

$\boxed{h_L = 40.23'}$

Bernoulli's (Assuming Near-Empty tank + 9' Vertical truck tank

$\frac{P_U}{\gamma} + \frac{V_U^2}{2g} + z_U + h_A = \frac{P_T}{\gamma} + \frac{V_T^2}{2g} + z_T + h_L$

$\therefore h_A = h_L + z_T = 40.23' + 9'$

$\boxed{h_A = 49.23 ft}$

Subsection 2					
LHS	58				
D (ft)	V (ft/s)	Re	f	RHS (ft)	%diff
0.083	13.6768	44002.8	0.02668	24.2504	58%
0.07	19.2285	52174.7	0.02699	54.4656	6%
0.069	19.7899	52930.9	0.02703	58.352	-1%
Subsection 3					
LHS	6				
D (ft)	V (ft/s)	Re	f	RHS (ft)	%diff
0.083	13.6768	44002.8	0.02668	10.7183	-79%
0.095	10.4399	38444.5	0.02657	6.02464	0%
0.1	9.42198	36522.3	0.02656	4.84832	19%

Summary:

By applying the procedure above, we were able to find the pressure and total losses for each subsection.

Materials:

3 stainless tanks with pipe, valves, pumps, fittings, elbows

Analysis:

The calculations indicated that the head pressure of the lower two tanks is constant. It also gave the information about the psi at each subsection that allows us to choose the appropriate size pump so that we do not get one too powerful or not powerful enough. It is also important to note that the truck can be filled from the lowest tank without a pump because of the constant pressure head in the tank.

2.f.v. Pump Selection

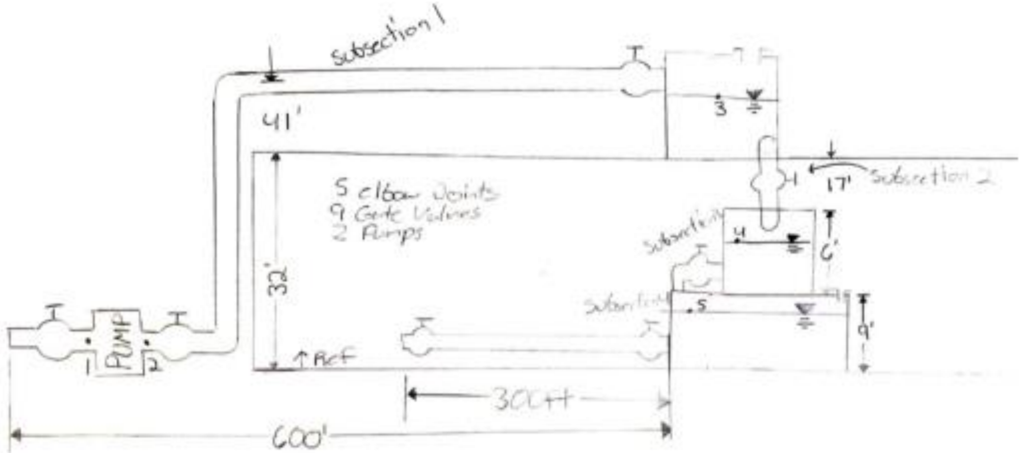
Task 8

Purpose:

Determine the amount of pumps needed and its requirements

Drawings and Diagrams:

FIGURE 14



Design Considerations:

Flow rate

Pump size

Budget

Pump location

Tank/pipe/pump material

Coolant properties

Temperature conditions

Data and Variables:

83.3gpm (30000-gallon tank)

166.25ft from pump head

Procedure:

1) Determine how many pumps are necessary
2) Determine the psi that the pump must be able to handle
3) Determine flow rate
4) Find a pump that can work under all of these conditions

Calculations:

N/A

Summary:

The pump must be able to run at 83.3 gpm, 166.25ft, and 69.4psi.

Materials:

2 pumps

Analysis:

Sulzer pumps must be used. At this time, I am unsure of the exact appropriate pump but we determined that it should be a jet pump and be able to withstand 83.3 gpm and 69.4 psi without being so large and expensive it breaks the budget.

Tasks 15 and 16

Purpose:

The purpose of this task was to specify the pumps used in the design of the system.

Drawings and Diagrams:

Subsection 1 Pump:

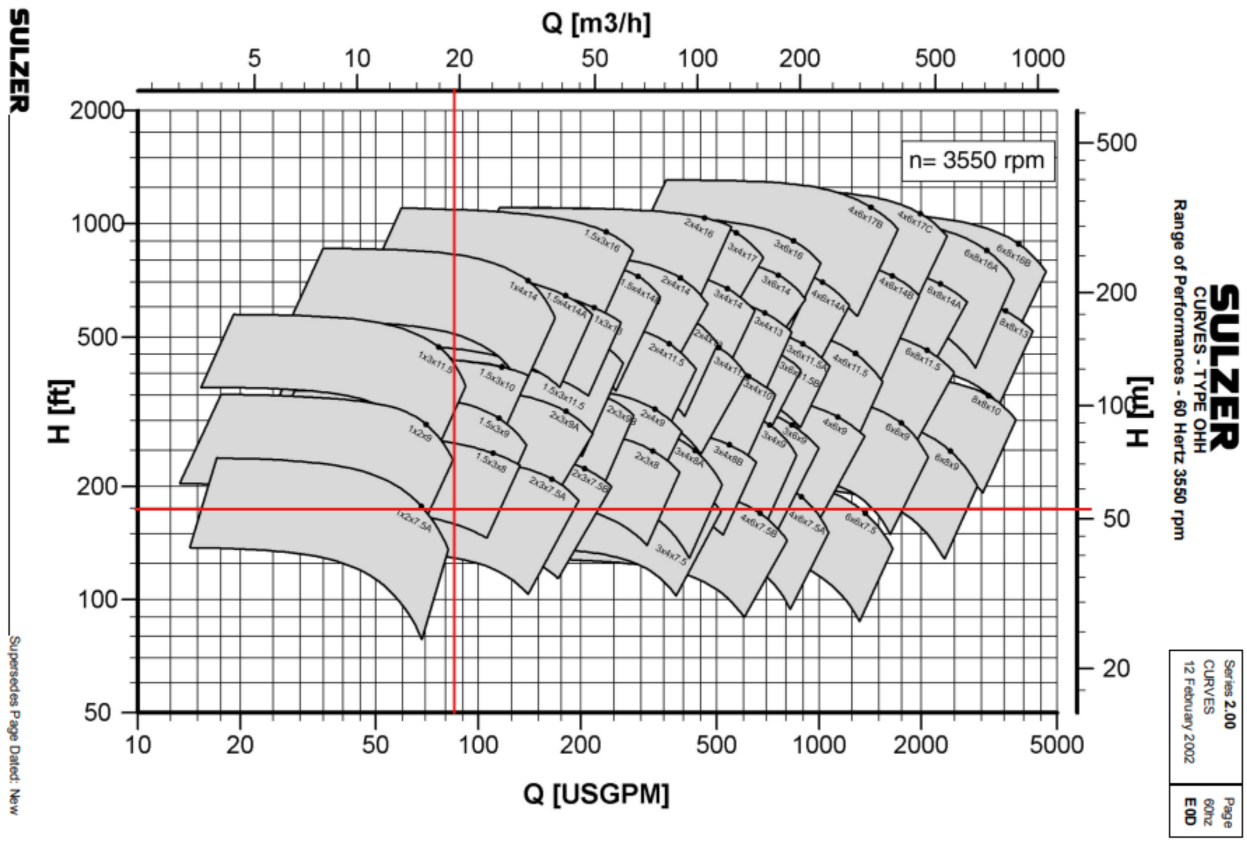

SULZER
CURVES - TYPE OHH
Range of Performances - 60 Hertz 3550 rpm
n= 3550 rpm
Q [m3/h]
Q [USGPM]
H [ft]
H [m]
Series 2.00
CURVES
12 February 2002
Page
60hz
E0D
Supersedes Page Dated: New

FIGURE 15

FIGURE 16

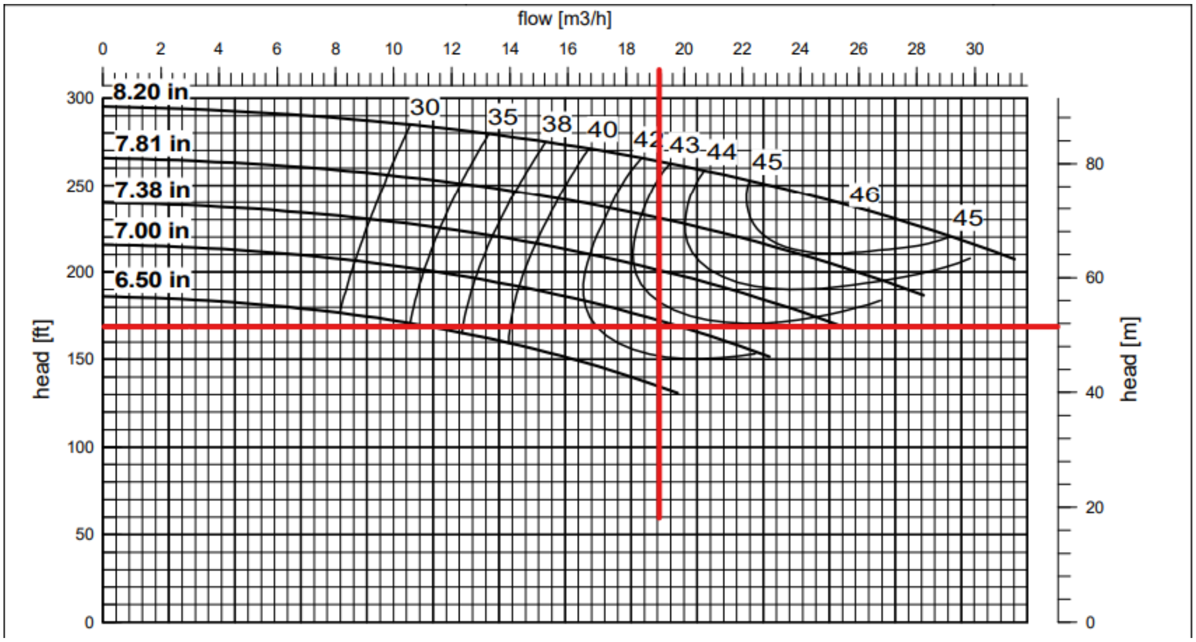


FIGURE 17

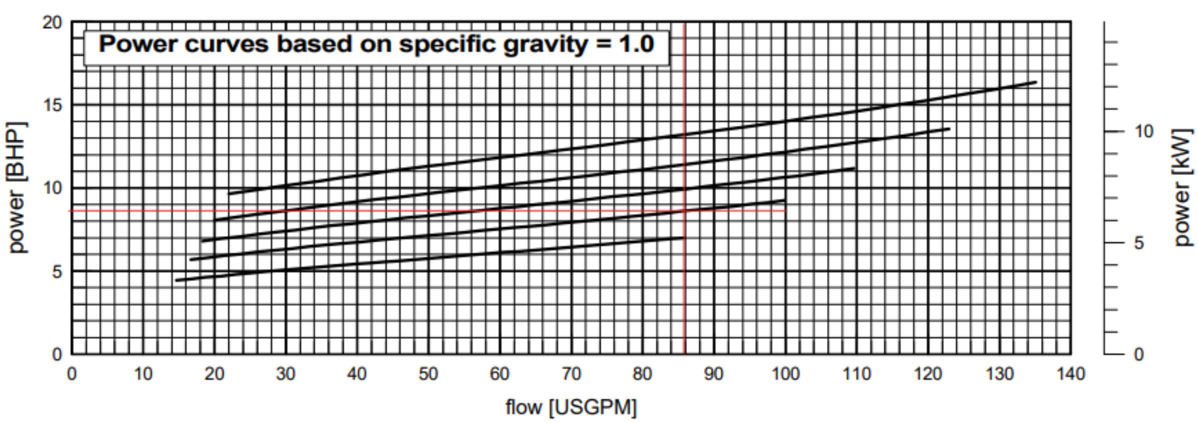


FIGURE 18

Subsection 4 Pump:

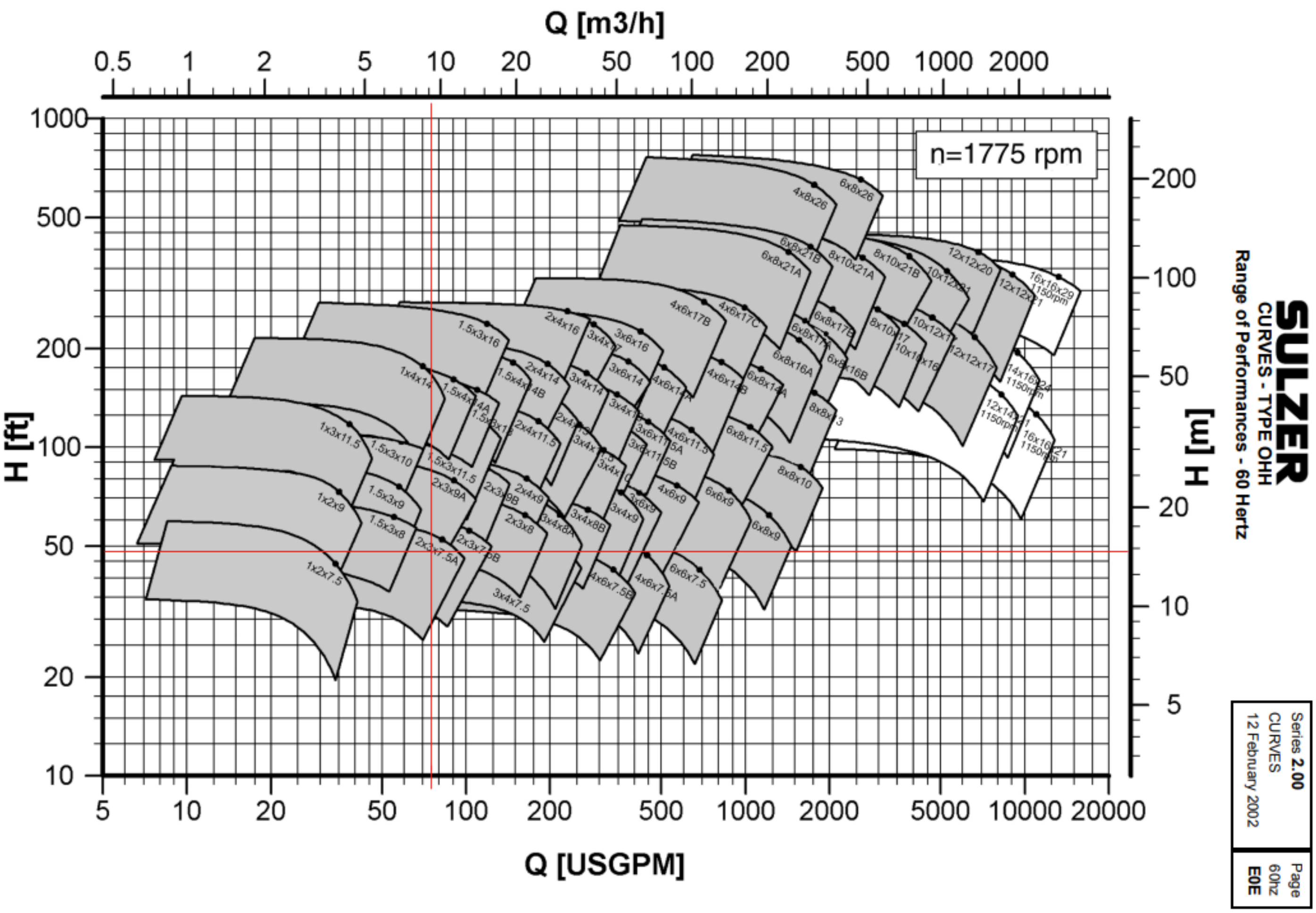


FIGURE 19

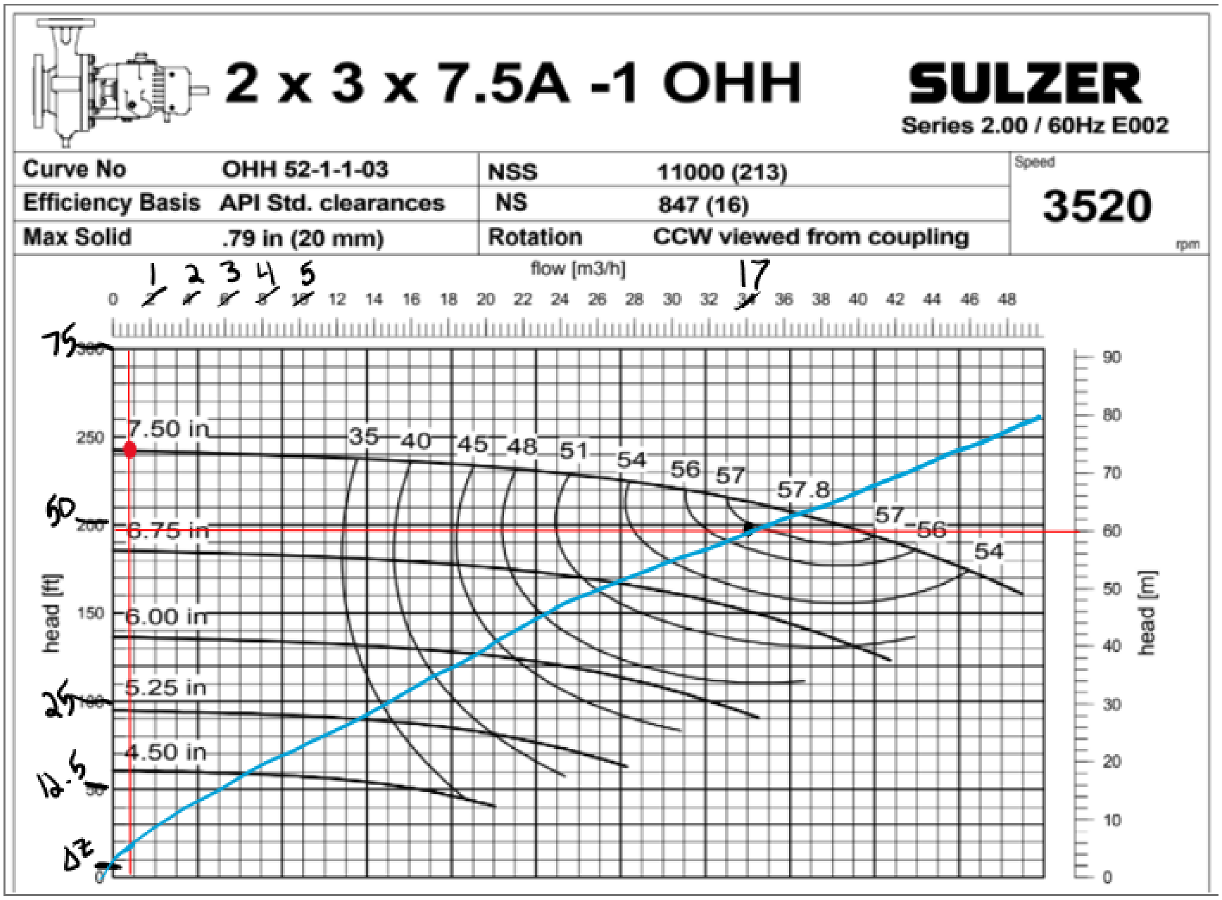
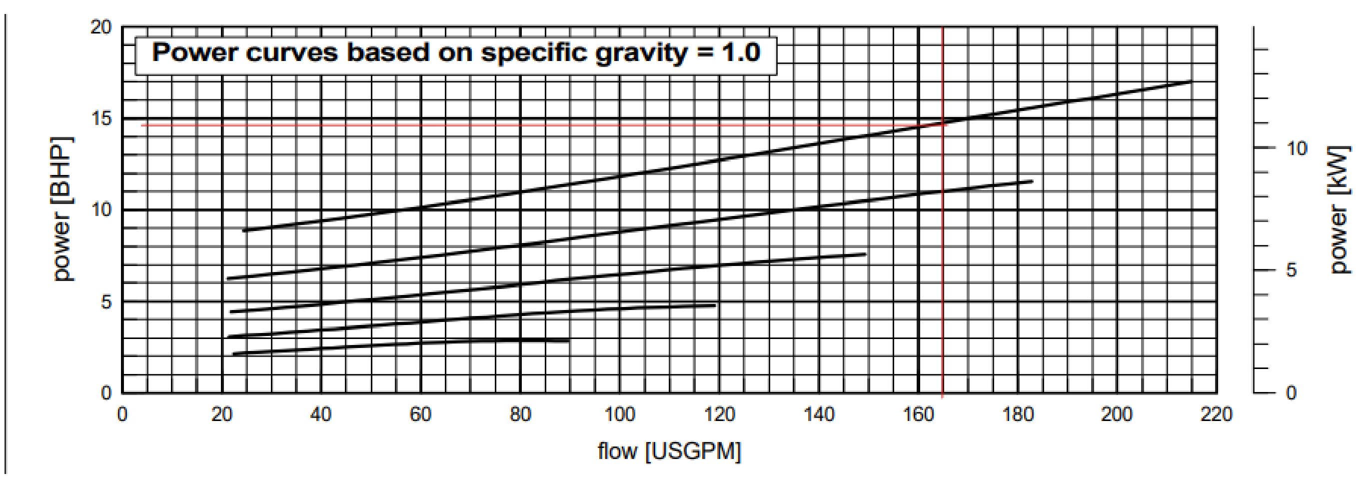


FIGURE 20



Design Considerations:

This task was performed under the assumption that Sulzer pumps will be preferred by the client.

Data and Variables:

N/A

Procedure:

The pump head and flow rate of each pump was used to determine the necessary pump from the provided catalog. The power curves for the specified pumps were then used to determine the point of operation and impeller diameter for each. For the first subsection pump the point of operation fell on one of the impeller curves, meaning that calculating a system curve was not necessary. However, the original operation point for the fourth subsection pump fell outside, so plotting the system curve for the pump was necessary to decide the new point of operation.

Calculations:

$$h_A = \Delta z + \overline{K} Q^2 \quad \text{Subsystem 4}$$

$$\left(\frac{V^2}{2g}\right) = \frac{Q^2}{2gA^2} = 32.67Q^2$$

<u>Energy Losses</u>

$$h_{LF} = .024\left(\frac{300}{.167}\right) \cdot 32.67Q^2 = 1408.7Q^2$$

$$h_{LV} = 4 \cdot (8 \cdot 0.024) \cdot 32.67Q^2 = 25.094Q^2$$

$$h_{LE} = 0.5 \cdot 32.67Q^2 = 16.34Q^2$$

$$\therefore h_L = 1450.13Q^2$$

$$h_A = 9' + 1450.13Q^2$$

<u>Plotting System Curve</u>

For $Q = 0 \rightarrow h_A = 9'$

For $Q = .167 \rightarrow h_A = 49.44'$

For $Q = .3 \rightarrow h_A = 139.51'$

Summary:

It was determined that the subsection 1 pump will be a Sulzer 1.5x3x8 operating at 3550 RPM with a 7 in. impeller and requires about 8.8 BHP. This pump will be operating at the originally intended pump head of 166.25 ft. and flow rate of 1857 ft3s . The subsection 4 pump will be a Sulzer 2x3x7.5A operating at 1775 RPM with a 7.5 in. impeller. The point of operation for this pump means that it will operate at a pump head of 60 ft. and a flow rate of .188 ft3s and requires about 1.6 BHP after the application of affinity laws.

Materials:

The aforementioned Sulzer pumps.

Analysis:

These pumps were selected over positive displacement pumps due to their ability to produce a large pump head and a consistent flow rate to the system. This will allow for better operation throughout the lifetime of the system.

Task 17

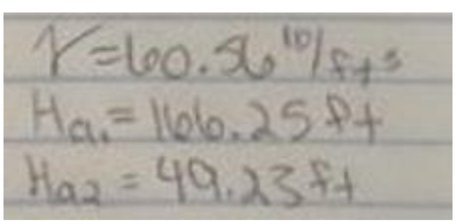
Purpose:

Determine the electrical motor requirements for 2 pumps

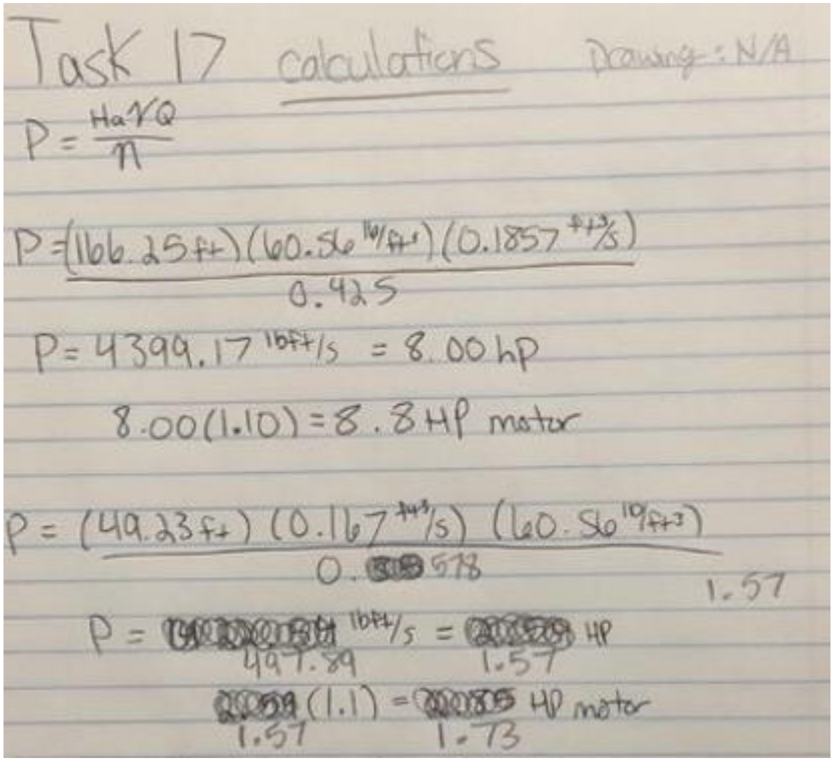
Drawings and Diagrams:

N/A

Data and Variables:



Calculations:



Summary:

The first pump requires an 8.8 HP motor and the second pump requires a 2.85 HP motor.

Analysis:

As expected, the pump that is used for 166.25 ft requires a motor over 5 x bigger than the pump for 49.23 ft.

Task 18

2.f.vii. Instrumentation Selection

Task 14

Measuring Device Selection for Subsection 1

Pressure Gauge:

Type: Bourdon Tube Pressure Gage

Pressure Range: 0-100 psig

Location: Immediately after the Gate Valve after the Pump

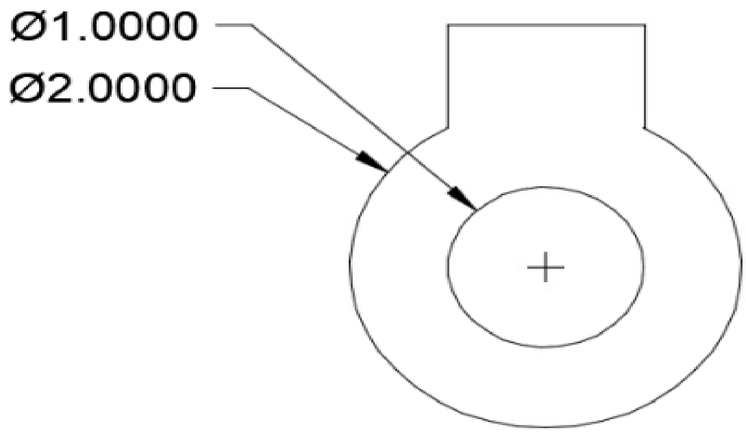
Flow Meter:

Type: Straight Bore Orifice

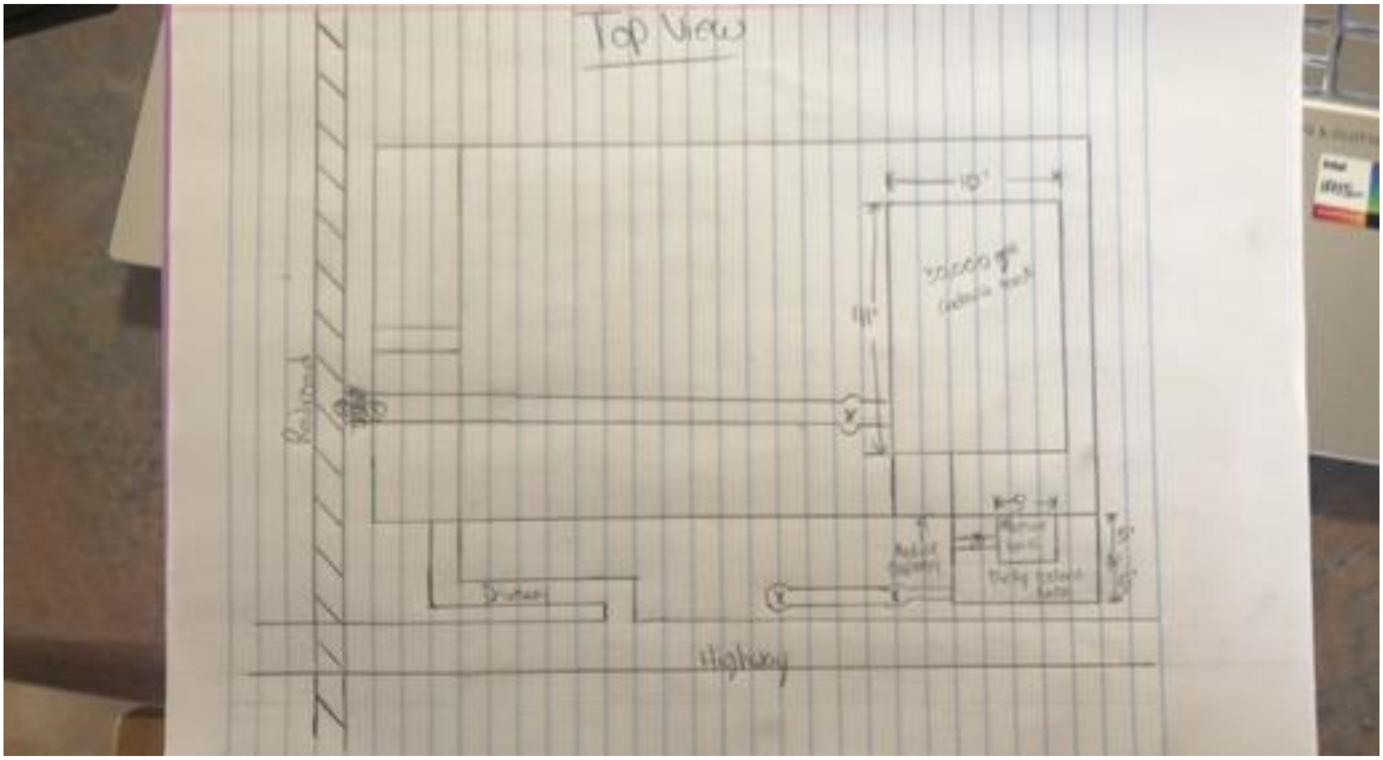
Location: After Pressure Gauge

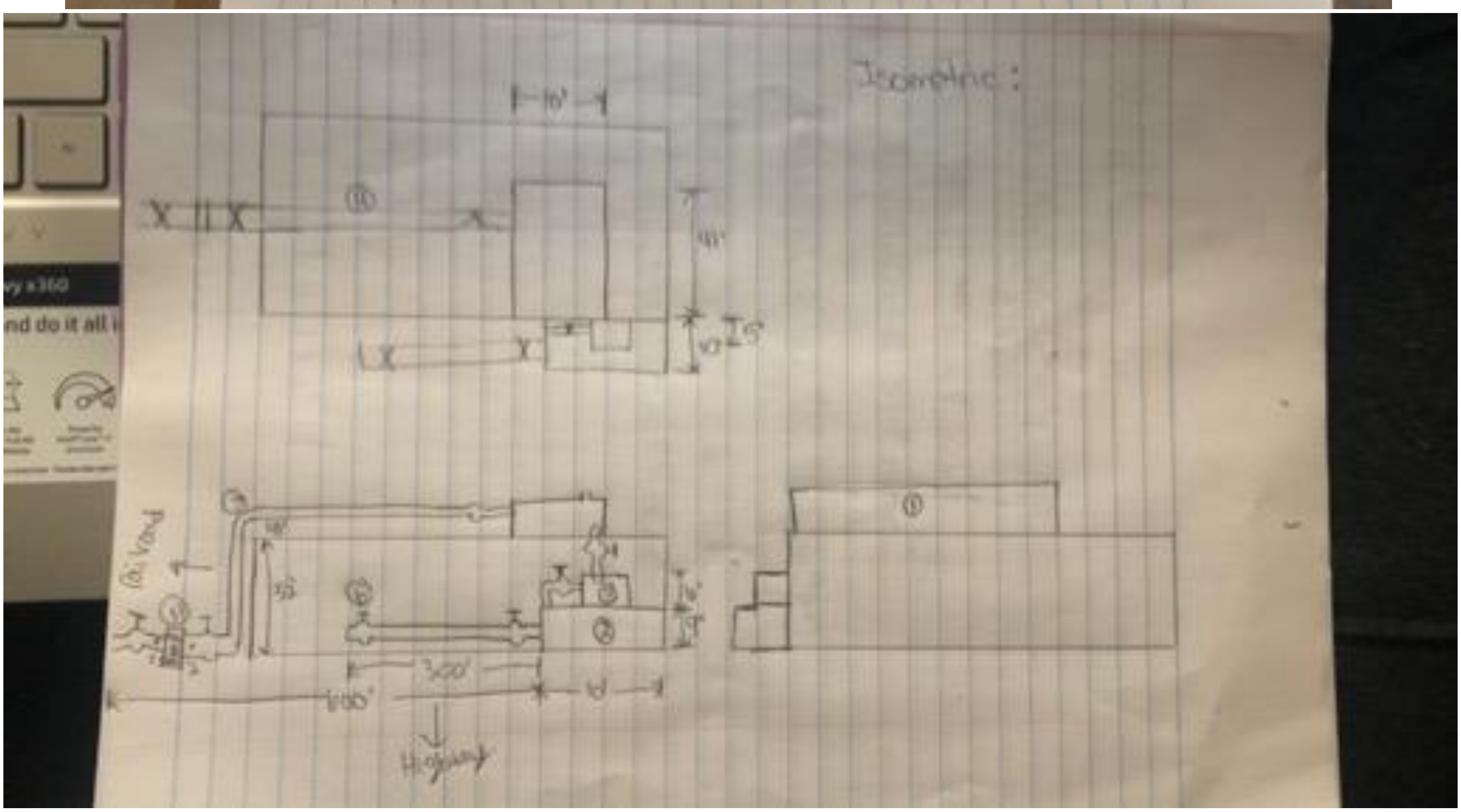
Dimension: d/D = .5

d = 1"



3. Final Drawings FIGURES 21 and 22





4. Bill of Materials and Equipment List

Part Number	Name	Quantity/amount	Material/Brand
1	Clean coolant tank	1; 30,000 gallons	Stainless steel
2	Dirty coolant tank	1; 6,000 gallons	Stainless steel
3	Machine shop tank	1; 1,000 gallons	Stainless steel
4	2 1/2" schedule 80 pipe	Approx. 850 ft	Stainless steel
5	Blind Flange	1; $0.0218 ft^2$	Stainless steel
6	Valve	9; Gate valve	Stainless Steel
7	Elbow	5; standard 90°	Stainless steel
8	Nuts	6	Stainless
9	Bolts	6	Grade 1 steel
10	Supports	25; for 300' 2 ½" sch80	Concrete
11	Pump	2	Sulzer
12	Pressure gauge	1	n/a
13	Flow measurement instrument	1	n/a
14	Electrical motor	1; 8.00 HP	Sulzer: 1.5x3x8
15	Electrical Motor	1; 2.85 HP	Sulzer: 2x3x7.5A

5. Final Remarks

The members of Group 11 have learned a lot throughout this project experience. We would like to thank Dr. Ayala for all he has taught us during the Fall 2021 semester.

6. Appendix

Andrew Bresnahan

Project Reflection

§ Do you think what you learn is important for your professional career?

Yes

§ Where do you think you will be using everything you learned?

I will be using not only the class material, but what I learned about working in a team both in my senior design project and throughout my professional career.

§ How would you explain the project and your contribution to the project in a job interview?

The project required me to work in a team in order to see the design of an industrial pipeline system through from conception to completion.

§ How would you explain how your strengths helped you contribute to the project in a job interview?

I used my understanding of the material and ability to communicate within a team to help both complete tasks given to me, but also aid others where necessary.

§ How would you explain in a job interview how your weaknesses affected your ability to work on this project and how did you address them (or what part of the class helped you address them)?

My propensity to procrastinate would have held me back significantly during this project, however, my teammates helped motivate me to complete tasks ahead of time so they could be compiled into the final report.

§ Explain the technical strengths and weaknesses in your project.

The main strengths in our project are the writing and many of the calculations and their readability. However, we mainly waned when it came to finding information that was not available through Ayala's class.

§ If you were starting the class over again, what advice would you give yourself to ensure that you had a successful semester and a successful final project?

I would tell myself to start on the project ASAP and to ensure that I understood how the various tasks flow into each other as that is crucial to getting them done in a timely manner.

Hannah Wolfe

Individual Reflection

MET 330 Final Project

12/14/21

- Do you think what you learn is important for your professional career?
  Yes. I can see a lot of benefit for my future from the things I learned in this project as well as fluid mechanics. The final project was one of the first times I have been asked to work on a group project and it was definitely a learning curve. With that being said, I would much prefer working in a group, as opposed to individually, for as many other classes or professional settings that will allow it. It gave a really good insight of how it will be when we are assigned an actual project from an employer and how the client/bosses opinions matter and the input of your colleagues can be really beneficial. I also think working in a group taught some responsibility and patience because your team relied on you, and sometimes you had to wait until they were able to do things that were needed.

- Where do you think you will be using everything you learned?
  Using the actual topics of fluid mechanics will be dependent on the type of career I end up going into. The concepts in the group project will be useful any time that I could be assigned a project for a client or my company. It was presented very similarly to how I would imagine a project in a company would be.

- How would you explain the project and your contribution to the project in a job interview?
  I would first point out that it was a very good learning experience and my first project in college thus far that was assigned with a group to mimic how the workplace will be. The purpose of the project was to design a pipeline system for a manufacturing facility. We were asked to include pumps, valves, and 3 different sized tanks. The goal was to be able to move coolant from a rail car on the ground to a storage tank and a machine shop tank, then have it drain or be pumped into a dirty coolant tank and be able to empty that tank into a truck to be removed. That makes it seem simple, but I soon learned that it was no task for the faint of heart. We had many other design considerations to consider, motors to account for, support for the pipes, computing tank sizes and fill times, and pump variables just to name a few. In the end, we were able to use nearly all the concepts we learned in Fluid Mechanics to finish what I believe to be a well-done project.

- How would you explain how your strengths helped you contribute to the project in a job interview?
  I would say that my biggest strength in the project was making sure I asked as many questions as necessary to ensure I was completing my part correctly. At times I did struggle, but by having a professor and teammates to reach out to, I was able to learn a lot and do my portions of the project to the best of my ability. I was also able to stay in communication with my group and professor which was a huge help in making sure we were all informed of all things necessary pertaining to the class or the project.

- How would you explain in a job interview how your weaknesses affected your ability to work on this project and how did you address them (or what part of the class helped you address them)?
  One of my biggest flaws in the project was having a lack good time management. I do think that I improved with this as the project came to an end because I knew that I had other group members depending on me. I was also able to realize that it is best to not tackle too much on your own when you have others there to help you. As one of my good friends says, "Teamwork makes the dream work" and for a project like this that couldn't have been truer.

- Explain the technical strengths and weaknesses in your project.
  One strength of my group project was that we were able to take criticism and use it to make our project better. One weakness was that we chose to use rectangular tanks instead of cylindrical. We assumed this would make it simpler, but it did not. I struggled to find the appropriate thickness equation because all the equations were designed around cylinder tanks. I'm sure that our project still is not perfect, but speaking for myself, I learned a lot and that was the biggest goal in my opinion.

- If you were starting the class over again, what advice would you give yourself to ensure that you had a successful semester and a successful final project?
  If I were to start this class over, I would like to try to be more dedicated to it. I really enjoyed learning the material, but I feel like it only scratched the surface of what could have been learned or better understood had I spent more time on it. With that being said, I do feel like I did well for it being my first full semester at ODU taking 14 credits.

Erin Fitzpatrick

Reflection

I believe what we learned in this class is extremely important for our professional careers, especially what we learned during this project. I believe I will use not only the content, but the teamwork skills and technical report writing in my future career. The project involved designing a pipeline system. I had to communicate with my team, split up tasks, and help put together a final report. I think my teammates were able to pull through and make up for my weaknesses. My strengths were organizing the report and communicating to my teammates where I needed help. Someone starting this class over should always get as much done as early as possible.