Old Dominion University

MET 330

Pipeline System Design Project

Continental AG Manufacturing Plant

Green – Overbey – Smith

December 12, 2023

2. Abstract

Continental AG will be constructing a new manufacturing plant in Dayton, Ohio. This plant will include a new automated machining line which require that five separate machines be required with coolant. In addition to providing coolant to the machinery this project will show how our team plans to store, transport, and dispose of the coolant throughout the plant. Several factors were considered in our design such as location, production schedules/needs, staffing, as well as delivery and removal methods for the coolant. The intent of this project is to meet the needs of the customer while also being fiscally feasible.

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5. Report Body

a. Job site location

Continental AG Manufacturing plant in Dayton, Ohio

b. Specifications and design philosophy

- Need to supply coolant to the manufacturing plant
- Coolant can be supplied by railroad
- There must be a 15000gal holding tank, a 1000gal machine reservoir, and a holding tank for spent coolant

c. Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

d. Materials and specifications

- The tanks will be made of 304 stainless steel
- The piping will be plain carbon steel
- The fluid has the same freezing point and corrosiveness to water.
- The fluid is 1.5x more viscous than water
- The fluid has a specific gravity of 0.94tt

e. Preliminary drawings and sketches

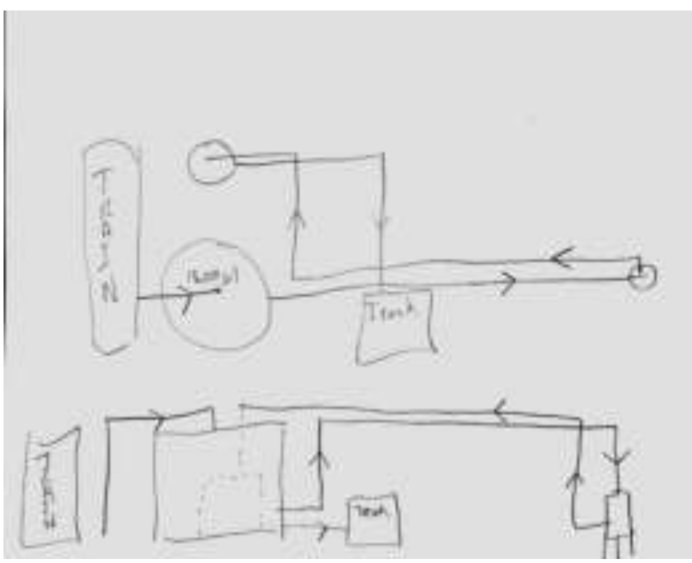


Figure 1 - Layout and Elevation Hand Sketch

f. Design calculations

i. Tank Specifications

Task 1

Purpose

The purpose is to specify the size and location of all storage tanks to be used in the design.

Drawings and Diagrams

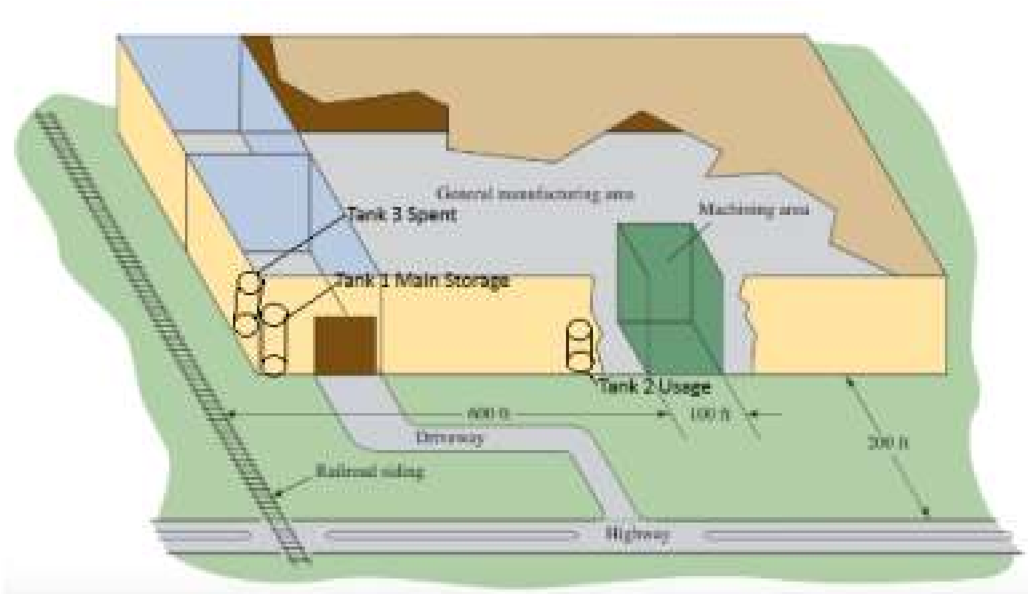


Figure 2 - Tank Locations

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

The tanks are to be located inside to prevent freezing of the coolant. The tanks will be installed at floor level near the walls of the facility. The spent tank will be near the truck bay allowing for easy removal of fluids. The main storage and spent tank will allow for extra usage in case of disruptions of service.

Data and Variables

Table 1 - Tank Sizing

Description	Symbol	Qty	Unit	Source
Tank 1 Size		20000	Gallon	Choose Size
Tank 2 Size		1000	Gallon	Choose Size
Tank 3 Size		6000	Gallon	Choose Size

Procedure

For this task the problem description given by the customer is to be read and understood. The variables must be taken into account and tank sizes and locations must be chosen.

Calculations

Table 2 - Tank Requirements

	Primary Size requirement	Contengancy Need	Size	Design Size
Tank 1	15000 Gallon	+/- 2 weeks delivery	5000 Gallon	20000 Gallon
Tank 2	1000 Gallon	None	0	1000 Gallon
Tank 3	5000 Gallon	Extra flush of usage	1000 Gallon	5000 Gallon

Summary

The sizes and locations of the three required coolant storage tanks were specified.

Materials

Coolant, 0.94 Specific Gravity

304 Stainless Steel

Analysis

Tank 1 Main Storage

Tank 1 is to be located in the southwest corner of the building. It will be 20000 gallons which will allow for 15000 gallon delivery, intake raised to avoid sediment and a +/- 2 week delivery window. The material selected was 304 Stainless Steel to avoid corrosion of the wetted surface.

Tank 2 Usage

Tank 2 is to be located on the south wall of the building next to the machining area. It will be 1000 gallons which is the specified size. The material selected was 304 Stainless Steel to avoid corrosion of the wetted surface.

Tank 3 Spent

Tank 3 is to be located in the southwest corner of the building next to tank 1. It will be 6000 gallons which will allow for 5 weeks of usage with the space for 1 additional emergency system dump. The material selected was 304 Stainless Steel to avoid corrosion of the wetted surface.

Task 2

Purpose

The purpose is to specify the tank material and the wall thickness of the storage tanks.

Drawings and Diagrams

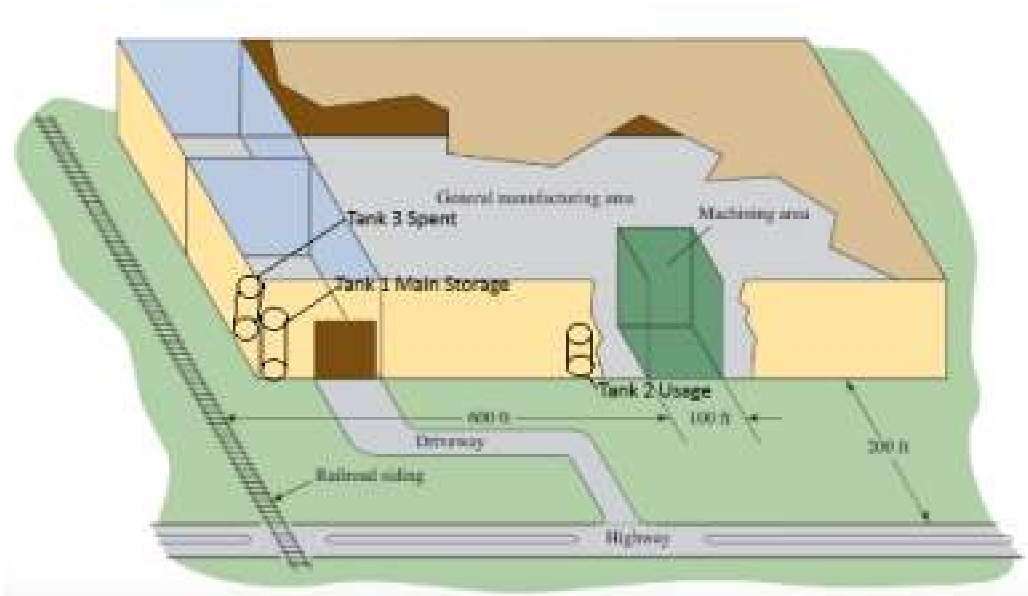


Figure 3 - Tank Overview

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Ryerson. (2023). *Online metals supplier - metal processing & distribution*. https://www.ryerson.com/

Engineer's Edge. (2023). *Maximum Allowable Stress Values ASME Pressure Vessel Code*

https://www.engineersedge.com/pressure,045vessel/maximum_allowable_stress_values_13906 .htm

Design Considerations

The coolant is to have the same corrosive properties as water and the tanks are to be vented to maintain atmospheric pressure at the surface. Therefore, corrosion will be a problem so this design uses 304 Stainless Steel. The wall thickness will be a standard US customary gauge thickness for ease of material acquisition. The tanks are inside but the coolant can be warm or cold when unloaded from the train car and upon usage. Consider a temperature range of 40 – 90F and use the most conservative value for that calculation.

Data and Variables

Table 3 - Tank Thickness Data

Description	Symbol	Qty	Unit	Source
Tank 1 Size		20000	Gallon	Choose Size
Tank 2 Size		1000	Gallon	Choose Size
Tank 3 Size		6000	Gallon	Choose Size
Tank 1 Volume	V	2673.8	ft^3	= 1 gallon / 7.48 ft^3
Tank 2 Volume	V	133.7	ft^3	= 1 gallon / 7.48 ft^3
Tank 3 Volume	V	802.1	ft^3	= 1 gallon / 7.48 ft^3
Specific Gravity coolant	SG	0.94		given
Allowable Stress (304)	S	12000	PSI	(Engineer's Edge, 2023)
Joint Quality Factor	E	0.8		Equation 11-9 (Mott, 2015)
Correction Factor	Y	0.4		Equation 11-9 (Mott, 2015)
Specific Weight (H2O)	gamma	62.4	lb/ft^3	Table A.2 (Mott 2015)
Specific Weight coolant	gamma	58.66	lb/ft^3	= SG * gamma (H2O)

Procedure

First convert the tank sizes from gallons to cubic feet. Then use that and guess the tank diameters and continue until the calculated height is close to the chosen diameter. Use this (The fluid height) to determine the pressure on the bottom of the tank with the equation P = gamma * h. Apply a safety factor of 2 and use the equation 11-9 (Mott 2015) to solve for wall thickness. Take this value and select a gauge that will be workable and satisfy the requirement.

Calculations

$$t = \frac{pD}{2(SE + pY)}$$

Table 4 - Tank Thickness Calculations

		D(ft)	H(ft)	P(gamma*H)	SF	Wall(in) t
Tank 1	**Main Storage**	15	15.13059	6.16	2	0.009627521
Tank 2	**Usage**	5.5	5.627081	2.29	2	0.001313055
Tank 3	**Spent**	10	10.21315	4.16	2	0.004332746

Summary

The material, wall thickness, and dimensions of the three storage tanks were specified.

Materials

Coolant, 0.94 Specific Gravity

304 Stainless Steel

Analysis

Tank 1 Main Storage

The tank is going to be 15 ft in diameter and have a height of 15.13 ft at the full level. It will be 16 ft tall in construction. The minimum wall thickness is calculated to be required at .009 in, however this thickness will be fragile and difficult to work with so 16-gauge 304 stainless steel is specified with a thickness of .0595 in (Ryerson 2023).

Tank 2 Usage

The tank is going to be 5.5 ft in diameter and have a height of 5.62 ft at the full level. It will be 6.5 ft tall in construction. The minimum wall thickness is calculated to be required at .001 in, however this thickness will be fragile and difficult to work with so 16-gauge 304 stainless steel is specified with a thickness of .0595 in (Ryerson 2023).

Tank 3 Spent

The tank is going to be 10 ft in diameter and have a height of 10.21 ft at the full level. It will be 11 ft tall in construction. The minimum wall thickness is calculated to be required at .004 in, however this thickness will be fragile and difficult to work with so 16-gauge 304 stainless steel is specified with a thickness of .0595 in (Ryerson).

Task 3

Purpose

The purpose is to provide a future additional connection to drain one of the tanks.

Drawings and Diagrams

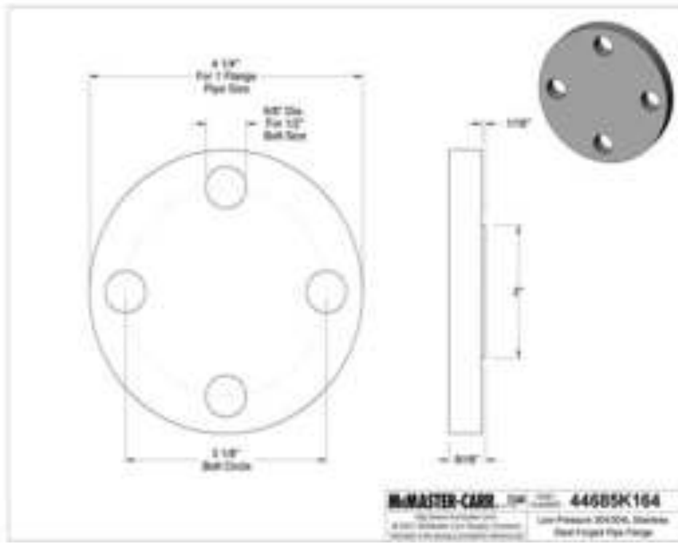


Figure 3 - Flange Drawing

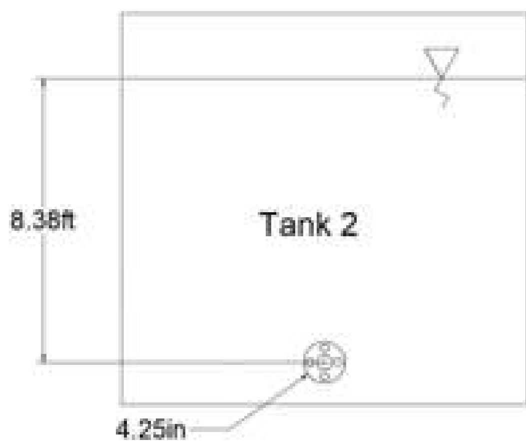


Figure 4 - Flange Location

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

The pressure on the flange will be evenly distributed across the hardware.

Data and Variables

Table 5 - Flange Variables

γ (lb/ft^3)	H_c(ft)	D (in)
58.7	8.377	4.25

Procedure

I will use the gamma-H equation to determine the pressure at the centroid of a new flange 8.25in above the base of tank 2. I will use this to determine a flange with the required pressure rating. I will then determine the force on the flange using the flange area and pressure. This value will be evenly distributed between the bolts of the flange.

Calculations

Table 6 - Flange Calculations

	P (lb/ft^2)	A (ft^2)	F_R (lb)	# bolts	Bolt Size	Force per bolt (lb)
Tank 2	491.755	0.099	48.446	4	.5-13	12.111

$$P = \gamma h = 58.7\ \text{lb/ft}^3 \cdot 8.38\ \text{ft} = 491.75\ \text{lb/ft}^2$$

$$A = \left(\frac{4.25\text{in}}{12\text{in}} \cdot 1\text{ft}\right)^2 \frac{\pi}{4} = 0.096\ \text{ft}^2$$

$$F_R = P_{avg} \times A = 491.75\ \text{lb/ft}^2 \cdot 0.096\ \text{ft}^2 = 48.45\ \text{lb}$$

$$\frac{48.45}{4\ \text{bolts}} = 12.11\ \text{lbs per bolt}$$

Summary

The flange has a diameter of 4.25in and the 4 bolts will each be 12.11lb.

Materials

Coolant, 0.94 Specific Gravity

304 Stainless Steel

.5-13 Bolts

Steel Flange

Analysis

The 4.25in flange addition will allow for future expansion of the system.

Task 12

Open Channel System

Purpose

To design an open channel system that will be able to take fluid from the tank to a far away location.

Drawings & Diagrams

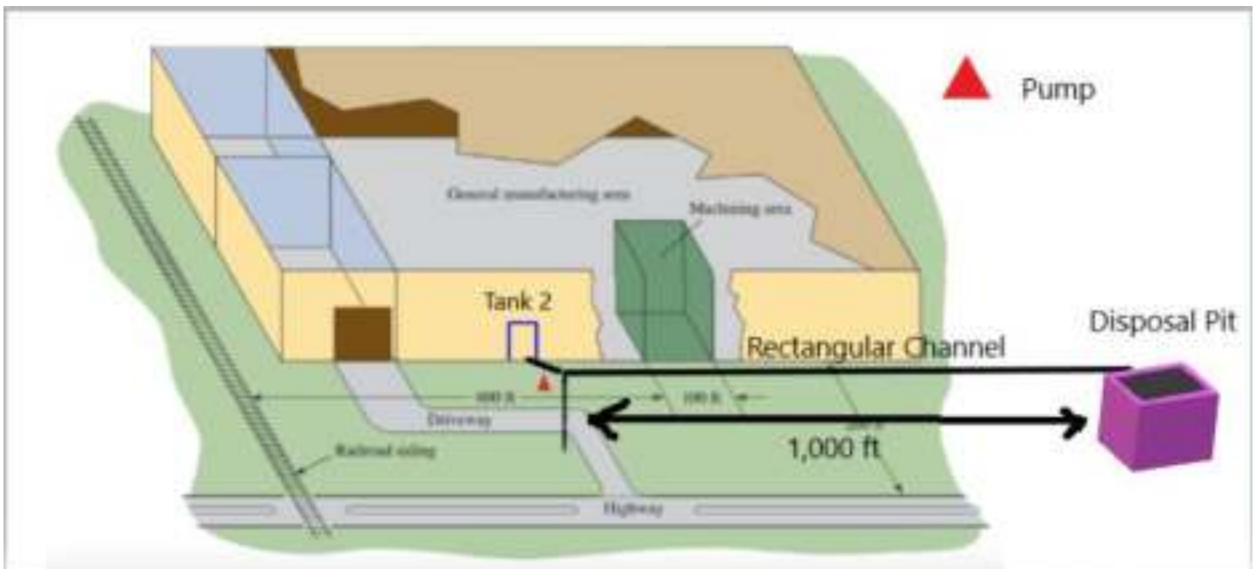


Figure 5 - Open Channel Location

Sources

Mott, R. L., & Untener, J. A. (2015). Applied Fluid Mechanics. Pearson.

Design Considerations

Will utilize our Usage (Tank 2) since it is the only tank not in the basement to empty. The channel will have to run along the outside of the building so that the fluid will be exposed to the atmosphere. A path for this specified channel will be dug out of the ground in front of the building. The channel will also have a rectangular cross section and its length will need to be far enough to take coolant far from the building. Also, the holding site will be slightly below the travel channel to help facilitate the forces of gravity.

Data and Variables

Table 7 - Open Channel Variables

$Q(\frac{ft^3}{s})$	Channel Length L (ft)	n	Slope S
0.3713	1000	0.012	0.001

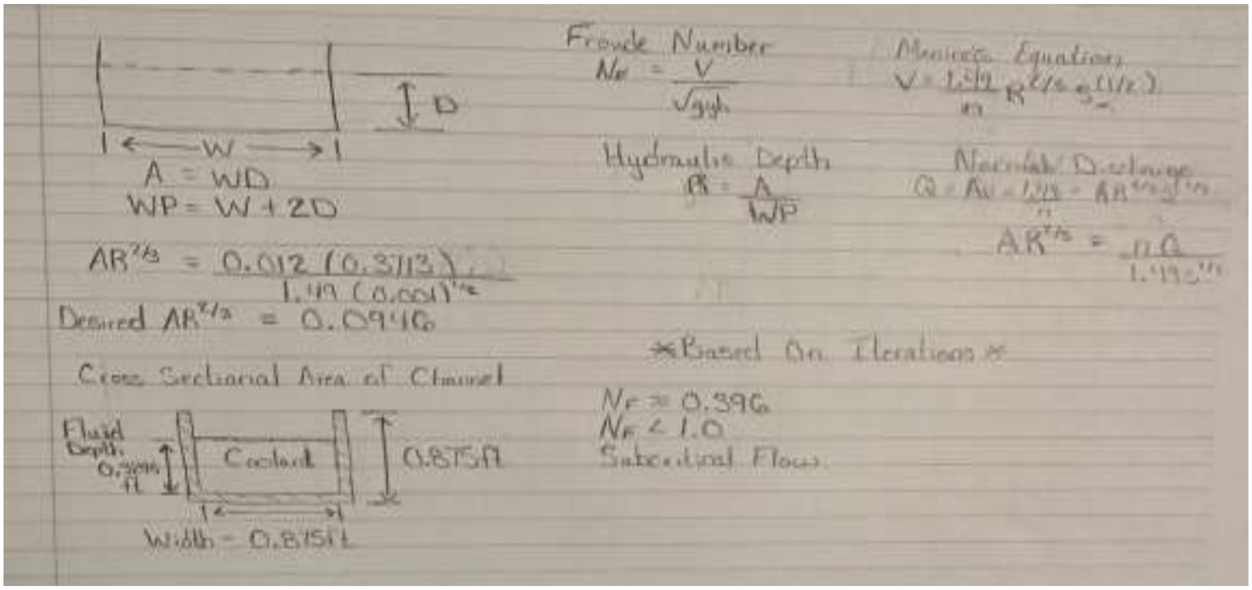
Procedure

The solution is calculated via iteration by first solving until our calculated flow rate matches our desired in our excel table.

Calculations

Table 8 - Open Channel Calculations

W(ft)	D(ft)	WP(ft)	A(ft^2)	R	v(ft/s)	$Q_{\max}(\frac{ft^3}{s})$	$AR^{2/3}$	yh	N_F
1.500	**0.750**	**3.000**	**1.125**	**0.375**	**2.042**	**2.2971**	**0.5850**	**0.750**	**0.415**
1.250	**0.625**	**2.500**	**0.781**	**0.313**	**1.808**	**1.4126**	**0.3598**	**0.625**	**0.403**
1.125	**0.563**	**2.250**	**0.633**	**0.281**	**1.686**	**1.0666**	**0.2716**	**0.563**	**0.396**
1.000	**0.500**	**2.000**	**0.500**	**0.250**	**1.558**	**0.7791**	**0.1984**	**0.500**	**0.388**
1.000	**0.375**	**1.750**	**0.375**	**0.214**	**1.406**	**0.5273**	**0.1343**	**0.375**	**0.405**
0.875	**0.375**	**1.625**	**0.328**	**0.202**	**1.351**	**0.4434**	**0.1129**	**0.375**	**0.389**
0.875	**0.350**	**1.575**	**0.306**	**0.194**	**1.318**	**0.4036**	**0.1028**	**0.350**	**0.393**
0.875	**0.340**	**1.555**	**0.298**	**0.191**	**1.304**	**0.3878**	**0.0988**	**0.340**	**0.394**
0.875	**0.330**	**1.535**	**0.289**	**0.188**	**1.289**	**0.3722**	**0.0948**	**0.330**	**0.395**
0.875	**0.330**	**1.534**	**0.288**	**0.188**	**1.288**	**0.3714**	**0.0946**	**0.330**	**0.396**



Summary

Our channel will be a rectangular shape with a width of 0.857ft and a fluid depth of 0.3295ft. It will be a foot higher than the start of the disposal pit at the end of the 1,000ft channel.

Materials

Coolant, 0.94 Specific Gravity

Channel, material unpainted steel

Analysis

The dimensions of the emergency disposal pit will be 20ft x 20ft x 8ft Deep. Which could hold over 20,000 gallons of fluid in case we ever had a failure in our tank 1 as well.

ii. Flow rate

Task 4

Purpose

The purpose is to specify the tank fill and empty times and to calculate the required flow rates for each system involved.

Drawings and Diagrams

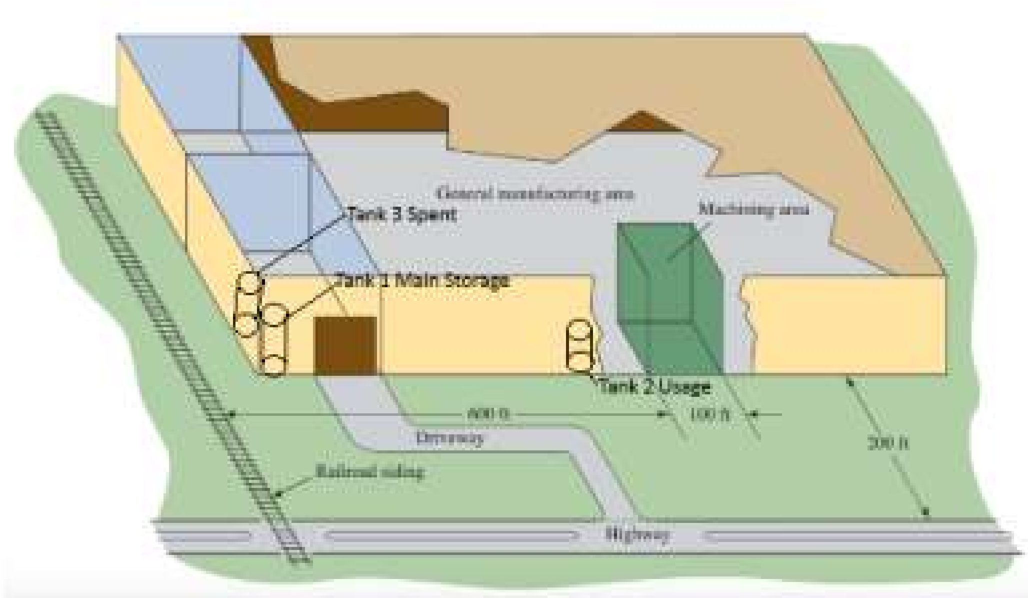


Figure 6 - Plant Overview

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

The flow rates need to specified such that the filling and emptying times are not excessive for workers, while balancing the costs of filling and emptying faster.

Data and Variables

Table 9 - Tank Fill Variables

Description	Symbol	Qty	Unit	Source
Tank 1 fill volume	Vf1	15000	Gallon	Problem Description
Tank 2 fill volume	Vf2	1000	Gallon	Problem Description
Tank 3 fill volume	Vf3	1000	Gallon	Problem Description
Tank 3 empty vol	Ve3	6000	Gallon	Problem Description
Tank 1 fill time	Tf1	90.0	min	Choose Time
Tank 2 fill time	Tf2	60.0	min	Choose Time
Tank 3 fill time	Tf3	60.0	min	Choose Time
Tank 3 empty time	Te3	90.0	min	Choose Time
GPM to ft^3/s		449	GPM/ft^3/s	Table K.1 (Mott 2015)

Procedure

First specify a reasonable time for each pumping based on the problem statement. Calculate the volume required for that pumping and convert it to gallons per minute. Then convert that to Q for the remainder of the tasks in cubic feet per second.

Calculations

Table 10 - Tank Fill Calculations

				=Gal/min	=GPM/449
Source	**Destination**	**Gallon**	**Minute**	**Q (GPM)**	**Q (ft^3/s)**
Train	**Tank 1**	15000	90.0	166.67	0.371195249
Tank 1	**Tank 2**	1000	60.0	16.67	0.037119525
Tank 2	**Tank 3**	1000	60.0	16.67	0.037119525
Tank 3	**Truck**	6000	90.0	66.67	0.148478099

Summary

The pumping time and corresponding flow rates were determined.

Materials

Coolant, 0.94 Specific Gravity

304 Stainless Steel tanks

Analysis

Train to Tank 1 Main Storage

The railcar emptying time was fixed to 90 minutes and a flow rate of 167 gallons per minutes was determined. Then using the conversion factor from Table K.1 in Mott (2015) was used to convert it to a cubic feet per minute measurement.

Tank 1 Main Storage to Tank 2 Usage

The usage tank filling time time was fixed to 60 minutes and a flow rate of 17 gallons per minutes was determined. Then using the conversion factor from Table K.1 in Mott (2015) was used to convert it to a cubic feet per minute measurement.

Tank 2 Usage to Tank 3 Spent

The usage tank drain to spent time was fixed to 60 minutes and a flow rate of 17 gallons per minutes was determined. Then using the conversion factor from Table K.1 in Mott (2015) was used to convert it to a cubic feet per minute measurement.

Tank 3 Spent to Truck

The spent tank emptying time was fixed to 90 minutes when at full capacity and a flow rate of 67 gallons per minutes was determined. Then using the conversion factor from Table K.1 in Mott (2015) was used to convert it to a cubic feet per minute measurement.

iii. Pipe sizing

Task 5

Purpose

The purpose is to specify the layout, material type, and sizing of the pipes.

Drawings and Diagrams

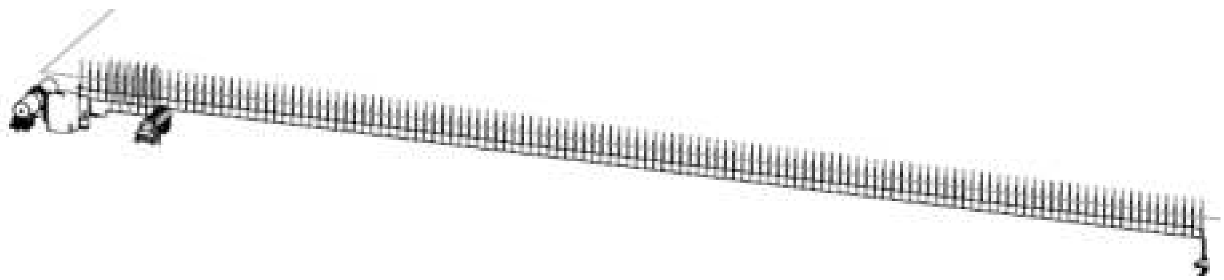


Figure 7 - Piping Isometric View

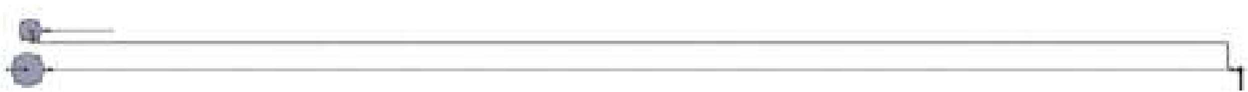


Figure 8 - Piping Layout View

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

Incompressible fluid

Data and Variables

Table 11 - Piping size Variables

γ (lb/ft^3)	Q_1 (ft^3/s)	Q_2 (ft^3/s)	Q_3 (ft^3/s)	Q_4 (ft^3/s)
58.7	0.371	0.037	0.037	0.149

Procedure

The pipe size will be determined using table F.1 in Applied Fluid Mechanics. The correct size will be used based on the flow rate found in the previous task for each tank. I will then layout the piping on a drawing.

Calculations

Table 12 - Pipe Sizing Calculations

	Size (NPS)	Length (ft)	Material	Actual Velocity (ft/s)
Overall		1285	Plain Carbon Steel	
Train to Tank 1	2.5in	20	Plain Carbon Steel	11.13
Tank 1 to 2	1in	619	Plain Carbon Steel	6.18
Tank 2 to 3	1in	631	Plain Carbon Steel	6.18
Tank 3 to Truck	2in	12	Plain Carbon Steel	6.37

$Q = 0.37\ ft^3/s$

$V = 3\ m/s = 9.84\ ft/s$

$$A = Q/V = \frac{0.37\ ft^3/s}{9.84\ ft/s} = 0.038\ ft^2$$

Actual pipe from chart F.1
2.5 NPS

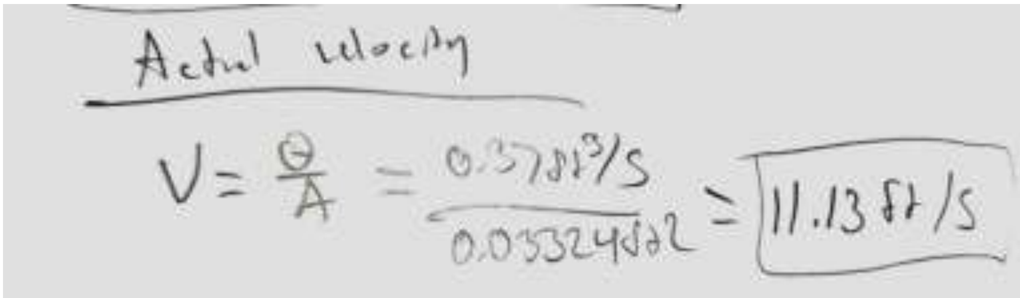


Table 13 - Table F.1 Pipe Sizing Information

From Table F.1 (Applied Fluid Mechanics, 7th edition)						
Nominal Pipe Size		Inside diameter			Flow Area	
NPS (in)	DN (mm)	(in)	(ft)	(mm)	(ft^2)	(m^2)
2 1/2	65	2.469	0.2058	62.7	0.03324831	0.003088869
1	25	1.049	0.0874	26.6	0.006002	0.000558
2	50	2.067	0.1723	52.5	0.023303	0.002165

Summary

The piping system will use plain carbon steel pipes at 2.5in, 1in, and 2in NPS sizes.

Materials

Coolant, 0.94 Specific Gravity

Steel Piping

Analysis

By using the target velocity of 3 m/s we were able to determine the correct pipe sizing for the entire layout. The closest available pipe size was picked and those diameters were used to determine the actual velocity of the fluid.

Task 6

Purpose

Define any fittings needed to build the system.

Drawings and Diagrams

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

Incompressible fluid.

Data and Variables

Table 14 - Fittings Variables

Description	Symbol	Qty	Unit	Source
Train to Tank 1 Pipe		2.5”	NPS	Task 5
Tank 1 to Tank 2 Pipe		1”	NPS	Task 5
Tank 2 to Tank 3 Pipe		1”	NPS	Task 5
Tank 3 to Truck Pipe		2”	NPS	Task 5

Procedure

Look at the design mapping and count the fittings.

Calculations

Table 15 - Fittings Calculations

Source	Destination	Elbow	Gate Valve	Pumped	Pipe Spec
Train	**Tank 1**	2	2	Yes	NPS 2.5" S40

Tank 1	**Tank 2**	3	2	Yes	NPS 1" S40
Tank 2	**Tank 3**	6	2	Yes	NPS 1" S40
Tank 3	**Truck**	2	2	Yes	NPS 2" S40

Summary

The fittings, valves, and elbows were identified and specified.

Materials

Coolant, 0.94 Specific Gravity

Schedule 40 Steel Pipe

Analysis

Train to Tank 1 Main Storage

This section will use 2 Elbows and 2 Gate Valves. IT will be pumped and made with 2.5” NPS Schedule 40 Pipe.

Tank 1 Main Storage to Tank 2 Usage

This section will use 3 Elbows and 2 Gate Valves. IT will be pumped and made with 1” NPS Schedule 40 Pipe.

Tank 2 Usage to Tank 3 Spent

This section will use 6 Elbows and 2 Gate Valves. IT will be pumped and made with 1” NPS Schedule 40 Pipe.

Tank 3 Spent to Truck

This section will use 2 Elbows and 2 Gate Valves. IT will be pumped and made with 2” NPS Schedule 40 Pipe.

Task 9

Purpose

The purpose is to specify pipe wall thickness necessary for the systems.

Drawings and Diagrams

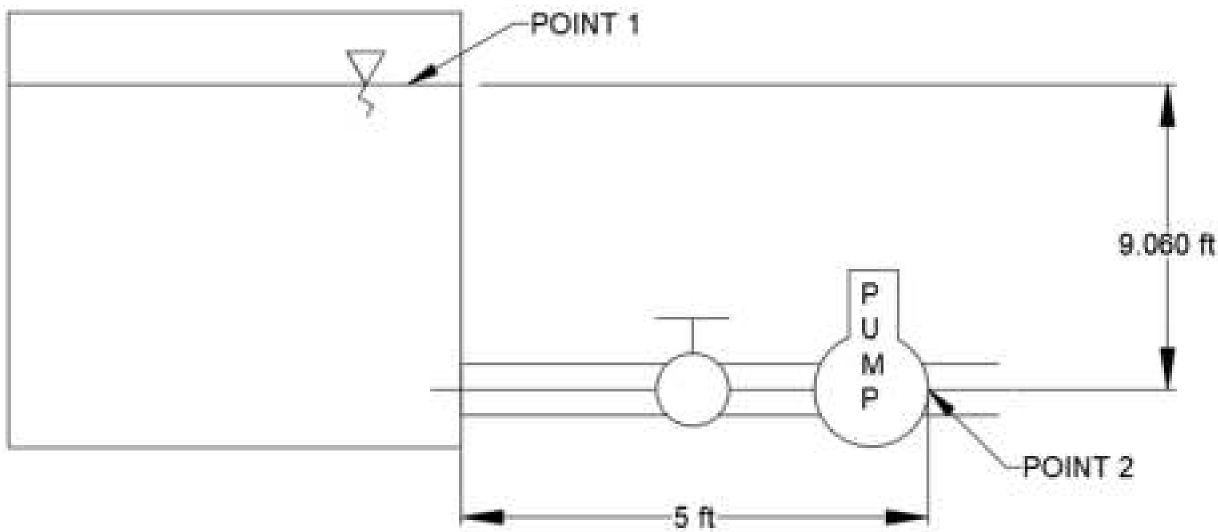


Figure 9 - Operating Pressure Drawing

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

The highest pressure should occur at the pump discharge.

Data and Variables

Table 16 - Pipe Thickness Variables

h_A (ft)	$h_{L,ent}$ (ft)	$h_{L,valve}$ (ft)	γ (lb/ft^3)	S (MPa)	E	Y
135.67	0.464	0.362	58.7	138	0.85	0.40

Procedure

The pipe wall thickness will be determined by calculating the maximum pressure of the system. The highest pressure will be found immediately downstream of pump #2. I will use Bernoulli's equation to calculate the pressure after the pump. I use this value to calculate the minimum wall thickness of the pipe. Then I will then choose the pipe schedule that most fits our desired function.

Calculations

Table 17 - Pipe Thickness Calculations

P_2 (lb/ft^2)	t_{min} (ft)	$T_{sch\ 40}$ (ft)
6677.9	.000119	.0111

$$h_{L,ent} = 0.464\ ft$$

$$h_{L,elb} = 8 \cdot 0.0235 \cdot \frac{11.13^2}{2(32.2)} = 0.362$$

$$h_{L,pipe} = f \cdot \frac{L}{D} \cdot \frac{v^2}{2g} = .029 \cdot \frac{5}{0.0874} \cdot \frac{11.13^2}{64.4}$$

$$= 32.1\ ft$$

$$h_{L,total} = 0.464 + 0.362 + 32.1 = 32.89$$

$$h_A = 135.67$$

$$P_1 = 0$$

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

$$0 + 0 + 100 + 135.67 = \frac{P_2}{58.7} + \frac{11.13^2}{64.4} + 0 + 32.89$$

$$P_2 = 58.7(113.76) = 6677.9\ lb/ft^2$$

Wall Thickness Formula

$$t = \frac{P \cdot D}{2(S \cdot E + P \cdot Y)} \qquad S = 138\ MPa = 2.9 \times 10^6\ lb/ft^2,\quad E = 0.85,\quad Y = 0.40$$

$$t_{min} = \frac{6677.9\ lb/ft^2 \cdot .0874\ ft}{2(2.9\times10^6 (0.85) + 0.40(6677.9))} = 1.19 \times 10^{-4}\ ft$$

Sch 40 wall thickness = 0.133 in = 0.0111 ft

$$0.0111\ ft > 0.000119\ ft$$

Summary

The minimum thickness for the system pressure is 0.000119ft.

Materials

Coolant, 0.94 Specific Gravity

304 Stainless Steel

Pump

Gate Valve

Analysis

Since the schedule 40 wall thickness is greater than the required wall thickness based on the max system pressure, the chosen pipe will be meet the pressure requirements.

Task 10

Purpose

The purpose is to check for instances of water hammer within the systems.

Drawings and Diagrams

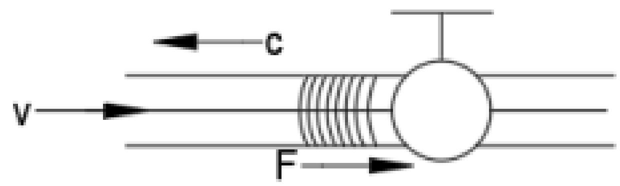


Figure 10 - Water Hammer Drawing

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

Water hammer is most likely to occur in our system at the gate valves.

Data and Variables

Table 18 - Water Hammer Variables

E_o (psi)	E (lb/ft^2)	δ (ft)	ρ ($slug/ft^3$)
316,000	4.18×10^9	0.0111	1.82

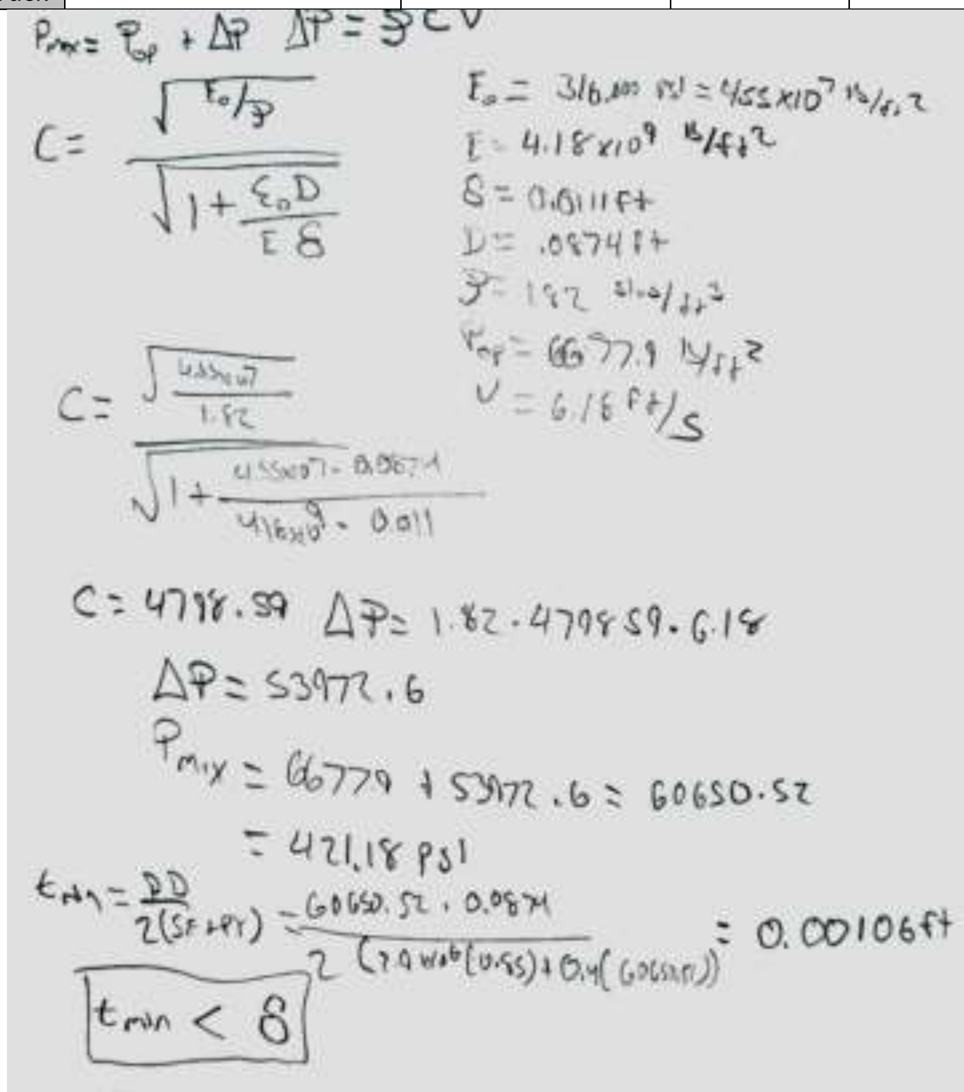
Procedure

First, I will calculate the possible change in pressure behind the valves. I will add this to the operating pressure to determine the maximum pressure. This value will be used to determine the minimum wall thickness for the max pressure. This value will then be compared to the wall thickness of our pipe to determine if the given pipe is sufficient.

Calculations

Table 19 - Water Hammer Calculations

System	PMax (lb/ft^2)	Tmin (ft)	Tactual (ft)	Arrestor Needed?
Train to Tank 1	97203.12	.0017	.0169	No
Tank 1 to 2	60650.52	.0011	.0111	No
Tank 2 to 3	60650.52	.0011	.0111	No
Tank 3 to Truck	55631.97	.0010	.0128	No



Summary

The pipe thickness is adequate to withstand the additional pressure from water hammer.

Materials

Coolant, 0.94 Specific Gravity

Steel

Valves

Analysis

All the chosen pipes are thick enough to withstand the possible max pressure that could be introduced by water hammer. Water hammer arrestors will not be necessary.

iv. Provide pipeline support info

Task 13

Support on Pipelines

Purpose

Select the type of supports on a pipe system and determine the forces acting on each support.

Drawings & Diagrams

B3198H - Hinged Extension Split Pipe Clamp

Size Range: 3/8" (10mm) to 3" (80mm) pipe

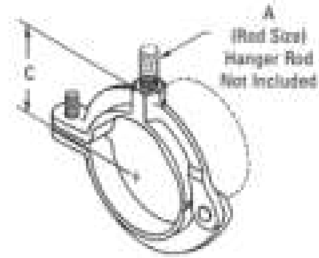
Material: Malleable Iron

Function: Designed for suspending non-insulated pipe horizontally or vertically.

Approvals: Conforms to Federal Specification WW-H-171E & A-A-1192A, Type 25 and Manufacturers Standardization Society ANSI/MSS SP-69 & SP-58, Type 12.

Standard Finish: Plain or Electro-Galvanized

Order By: Part number and finish.



Part No.	Pipe Size in.	Pipe Size (mm)	Rod Size A	C in.	C (mm)	Design Load Lbs.	Design Load (kN)	Approx. Wt./100 Lbs.	Approx. Wt./100 (kg)
B3198H-3/8	3/8"	(10)	3/8"-16	31/32"	(24.6)	180	(.80)	9	(4.1)
B3198H-1/2	1/2"	(15)	3/8"-16	1 1/16"	(27.0)	180	(.80)	12	(5.4)
B3198H-3/4	3/4"	(20)	3/8"-16	1 7/32"	(30.9)	180	(.80)	12	(5.4)
B3198H-1	1"	(25)	3/8"-16	1 11/32"	(34.1)	180	(.80)	13	(5.9)
B3198H-1 1/4	1 1/4"	(32)	3/8"-16	1 19/32"	(39.7)	180	(.80)	18	(8.1)
B3198H-1 1/2	1 1/2"	(40)	3/8"-16	1 23/32"	(43.6)	180	(.80)	21	(9.5)
B3198H-2	2"	(50)	3/8"-16	2"	(50.8)	180	(.80)	44	(19.9)
B3198H-2 1/2	2 1/2"	(65)	1/2"-13	2 11/32"	(59.5)	300	(1.33)	73	(33.1)
B3198H-3	3"	(80)	1/2"-13	2 23/32"	(69.0)	300	(1.33)	95	(43.1)

Figure 11 - Pipe Support Information

Sources

Mott, R. L., & Untener, J. A. (2015). Applied Fluid Mechanics. Pearson

Cooper B-Line

Design Considerations

The weight of the fluid and the steel pipes must be considered. Depending on the orientation of the pipe it may experience various vertical and horizontal forces. Design with a standard of maximum pipe deflection of about 5%, In between ranges of 1% - 10%. Assume pipes are full of coolant. Will utilize a hinged extension split pipe clamp has the hanger support.

Data and Variables

Table 20 - Pipe Support Variables

D_O(in)	$D_I(in)$	ρ_c(slug/ft^3)	ρ_c(lb./in^2)	E(lb./in^2)	$g(ft/s^2)$
1.049	1.315	1.8236	0.284	2.9×10^7	32.2

Procedure

To find out what supports may be necessary in our piping system we must find the mass or of both the pipes and the coolant. Once we find the mass of both, we will use the formula $\gamma = \frac{FL^3}{48EI}$, to find the length between supports. Finally sum of forces will be computed to find the individual forces acting on a support.

Calculations

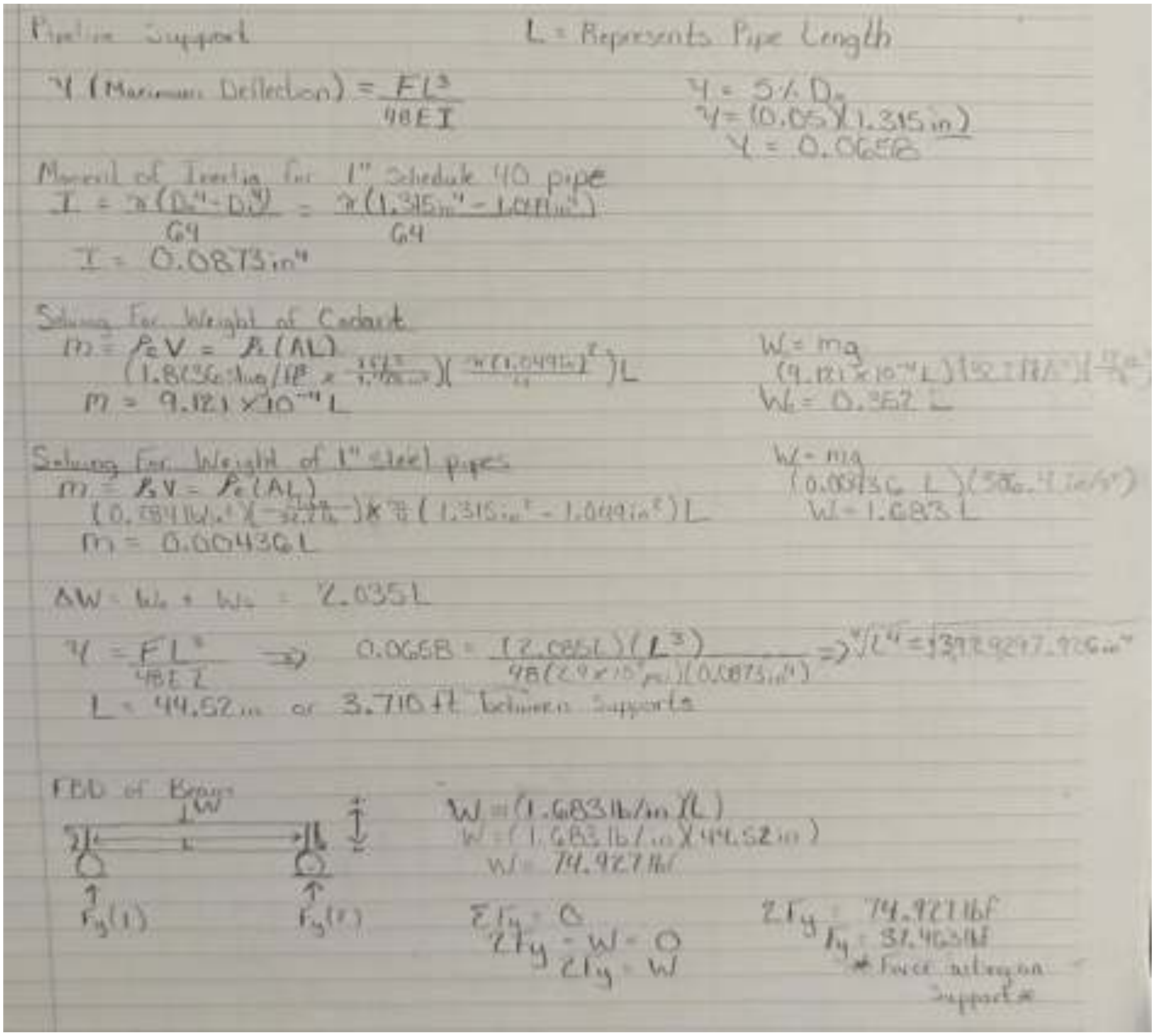


Figure 12 - Pipe Support Calculations

Summary

The length between each support will be 3.710ft and the force acting at each support is 37.463lbf.

Materials

Coolant, 0.94 Specific Gravity

1" Schedule 40 Pipe

B3198H – Hinged Extension Split Pipe Clamp

Analysis

The chosen hanger support will be able to withstand forces whether its horizontal or vertical in pipe orientation.

v. Energy losses

Task 7

Purpose

The purpose is to calculate the energy losses in the systems and solve for the required pump heads.

Drawings and Diagrams

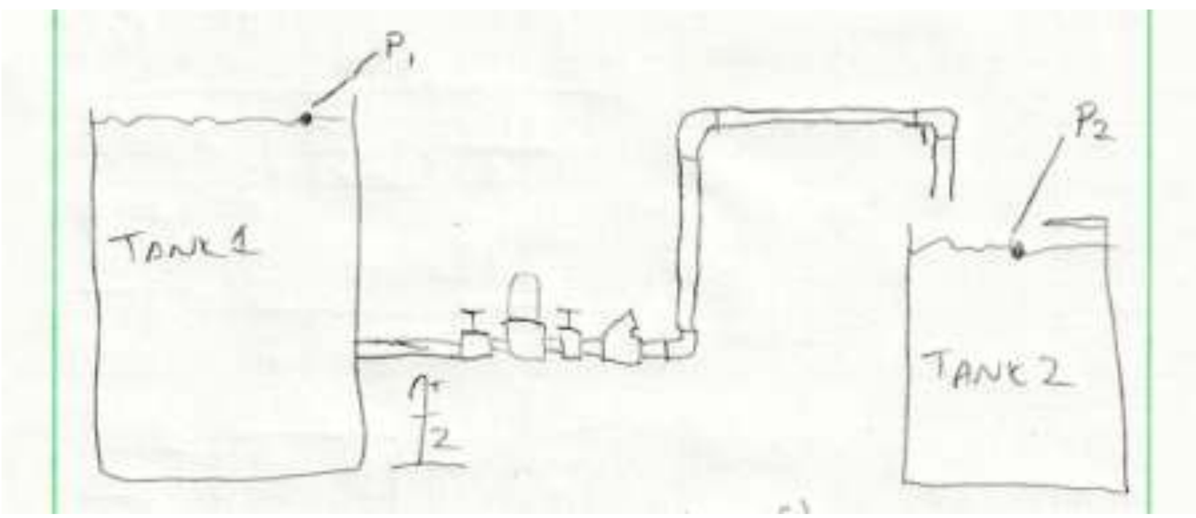


Figure 13 - Tank 1 to 2 Drawing

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

Incompressible fluid.

Data and Variables

Table 21 - Energy Loss Variables

Description	Symbol	Qty	Unit	Source
1" S40 ID	D	0.0874	ft	Table F.1 (Mott 2015)
1" S40 FA	A	0.006	ft^2	Table F.1 (Mott 2015)
2" S40 ID	D	0.1723	ft	Table F.1 (Mott 2015)
2"S40 FA	A	0.0233	ft^2	Table F.1 (Mott 2015)
2.5" S40 ID	D	0.2058	ft	Table F.1 (Mott 2015)
2.5" S40 FA	A	0.03326	ft^2	Table F.1 (Mott 2015)
Temp of Coolant	T	40-90	F	Must Choose
Specific Gravity		0.94		given in description
kinematic viscosity *	v	1.89E-05	ft^2/s	Table A.2 (Mott 2015)
Roughness	e	1.500E-04	ft	Table 8.2 (Mott 2015)
K of Square-Edge Inlet	Kinlet	0.5		Figure 10.4 (Mott 2015)
K of Gate valve	Kgate	8*fT		Figure 10.17 (Mott 2015)
K of Swing Check	Kswcheck	100 * fT		Figure 10.18 (Mott 2015)
K of 90 degree elbow	Kelbow	30 * fT		Figure 10.23 (Mott 2015)
Fluid Level of Tank 1	15.13		ft	Task 2
Fluid Level of Tank 2	5.63		ft	Task 2
Fluid Level of Tank 3	10.21		ft	Task 2

*Value chosen was largest value to give smallest Reynold's number and highest friction factor.

Procedure

Calculate Reynold's Number, Major and Minor Losses for each section. Solve Bernoulli's Equation for hA.

Calculations

$$h_L = f \times \frac{L}{D} \times \frac{v^2}{2g}$$

Table 22 - Energy Loss Calculations

	Q/A	VD/v					
Q (Ft^3/s)	V (ft/s)	Re	D/e	f (Moody)	fT (Moody)	L	hL(major)

Train to Tank 1	0.3713	11.16355983	1.22E+05	1372	0.021	0.0185	20	3.94933034
Tank 1 to Tank 2	0.03713	6.188333333	2.86E+04	583	0.028	0.023	619	117.92307
Tank 2 to Tank 3	0.03713	6.188333333	2.86E+04	583	0.028	0.023	631	120.209139
Tank 3 to Truck	0.1485	6.365195028	5.80E+04	1149	0.024	0.02	12	1.05158594

$$h_L = K\frac{v^2}{2g}$$

Minor Losses

Count (Sys1/2/3/4)	1/1/1/1	2/2/2/2	1/1/1/1	2/3/6/2		
K ->	0.5	8 * fT	100 * fT	30 * fT		
	Entrance	**Gate**	**Sw Check**	**90 Elbow**	**hL Minor**	**hL Total**
Train to Tank 1 (2.5")	0.9675859	0.572810872	3.580068	2.148041	7.26850553	11.217836
Tank 1 to Tank 2 (1")	0.2973251	0.218831254	1.367695	1.230926	3.11477747	121.03785
Tank 2 to Tank 3 (1")	0.2973251	0.218831254	1.367695	2.461852	4.34570327	124.55484
Tank 3 to Truck (2")	0.3145629	0.193267475	1.207922	0.724753	2.44050518	3.4920911

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

	Z1	**Z2**	**hL**	**hA**
Train to Tank 1	5	15.13059471	11.21784	21.34843
Tank 1 to Tank2	15.130595	5.627080677	121.0378	111.5343
Tank 2 to Tank 3	5.6270807	10.21315143	124.5548	129.1409
Tank 3 to Truck	10.213151	12	3.492091	5.27894

$$R_e = VD/\nu \rightarrow \frac{\frac{Q}{A} \cdot D}{\nu} \rightarrow \frac{\frac{0.0373\ ft^3/s}{0.006\ ft^2} \cdot 0.0874\ ft}{1.89 \times 10^{-5}\ ft^2/s} = 2.86 \times 10^4$$

$$D/\varepsilon = \frac{0.0874\ ft}{1.5 \times 10^{-4}\ ft} = 583$$

from Moody Chart $f = 0.028 \quad f_T = 0.023$

$$h_L = f \cdot \frac{L}{D} \cdot \frac{V^2}{2g} \rightarrow 0.028 \cdot \frac{619\ ft}{0.0874\ ft} \cdot \frac{6.188\ ft/s^2}{2 \cdot 32.2\ ft/s^2} = \boxed{117.9\ ft}$$

Minor

$$h_L = k \cdot \frac{V^2}{2g}$$

Entrance

$k = 0.5$

$$0.5 \cdot \frac{V^2}{2g} = \boxed{0.297}$$

Gate (2)

$k = 8 \cdot f_T$

$$2 \cdot 8 \cdot 0.023 \cdot \frac{V^2}{2g} = \boxed{0.219'}$$

Sw Check

$k = 100 \cdot f_T$

$$100 \cdot 0.023 \cdot \frac{V^2}{2g} = \boxed{1.37'}$$

90 Elbow (3)

$k = 30 \cdot f_T$

$$3 \cdot 30 \cdot 0.023 \frac{V^2}{2g} = \boxed{1.23'}$$

$$h_{L\,minor} = 0.297 + 0.219 + 1.37 + 1.23 = \boxed{3.11'}$$

$$h_L = h_{L\,major} + h_{L\,minor} \rightarrow 117.9\text{ ft} + 3.1\text{ ft} = \boxed{121\text{ ft}}$$

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

$$h_A = z_2 - z_1 + h_L$$

$$5.6' - 15.1' + 121' = \boxed{112'}$$

Summary

The energy losses were determined, Bernoulli’s was solved and hand calculations were performed.

Materials

Coolant, 0.94 Specific Gravity

304 Stainless Steel tanks

New Steel Schedule 40 Pipe

Analysis

Train to Tank 1 Main Storage

This section will require a pump head of 21.3 feet.

Tank 1 Main Storage to Tank 2 Usage

This section will require a pump head of 111.5 feet.

Tank 2 Usage to Tank 3 Spent

This section will require a pump head of 129.1 feet.

Tank 3 Spent to Truck

This section will require a pump head of 5.3 feet.

vi. Pump selection

Task 8

Purpose

The purpose is to identify the required number of pumps and the pump head.

Drawings and Diagrams

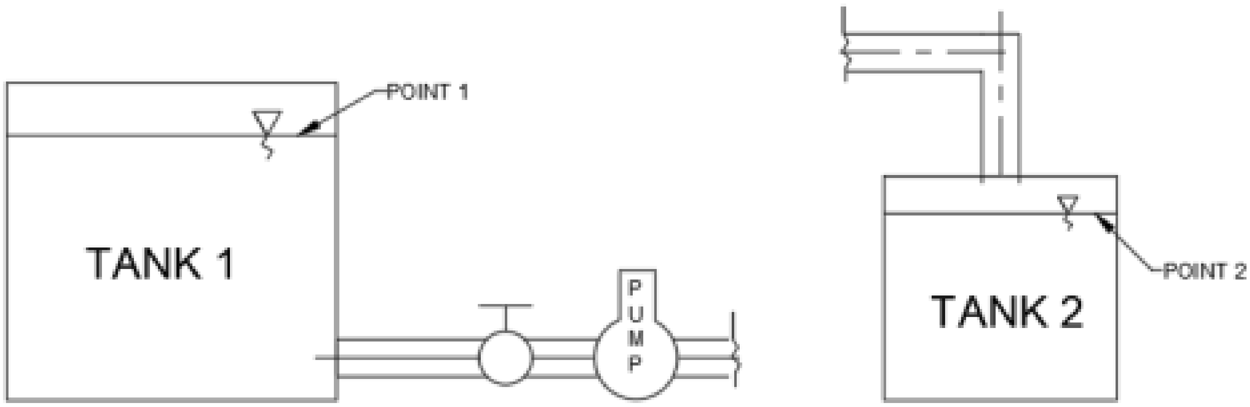


Figure 14 - Tank 1 to 2 Pump Head

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

Incompressible fluid.

Data and Variables

Table 23 - Pump Head Variables

γ (lb/ft^3)
58.7

Procedure

I will use Bernoulli's equation for each system to determine the pump head.

Calculations

Table 24 - Pump Head Calculations

	H_A (ft)	Q (ft^3/s)
Pump 2 (Tank 1 to Tank 2)	21.348	0.371
Pump 2 (Tank 1 to Tank 2)	135.674	0.037

Pump 3 (Tank 2 to Tank 3)	108.767	0.037
Pump 4 (Tank 3 to Truck)	14.739	.149

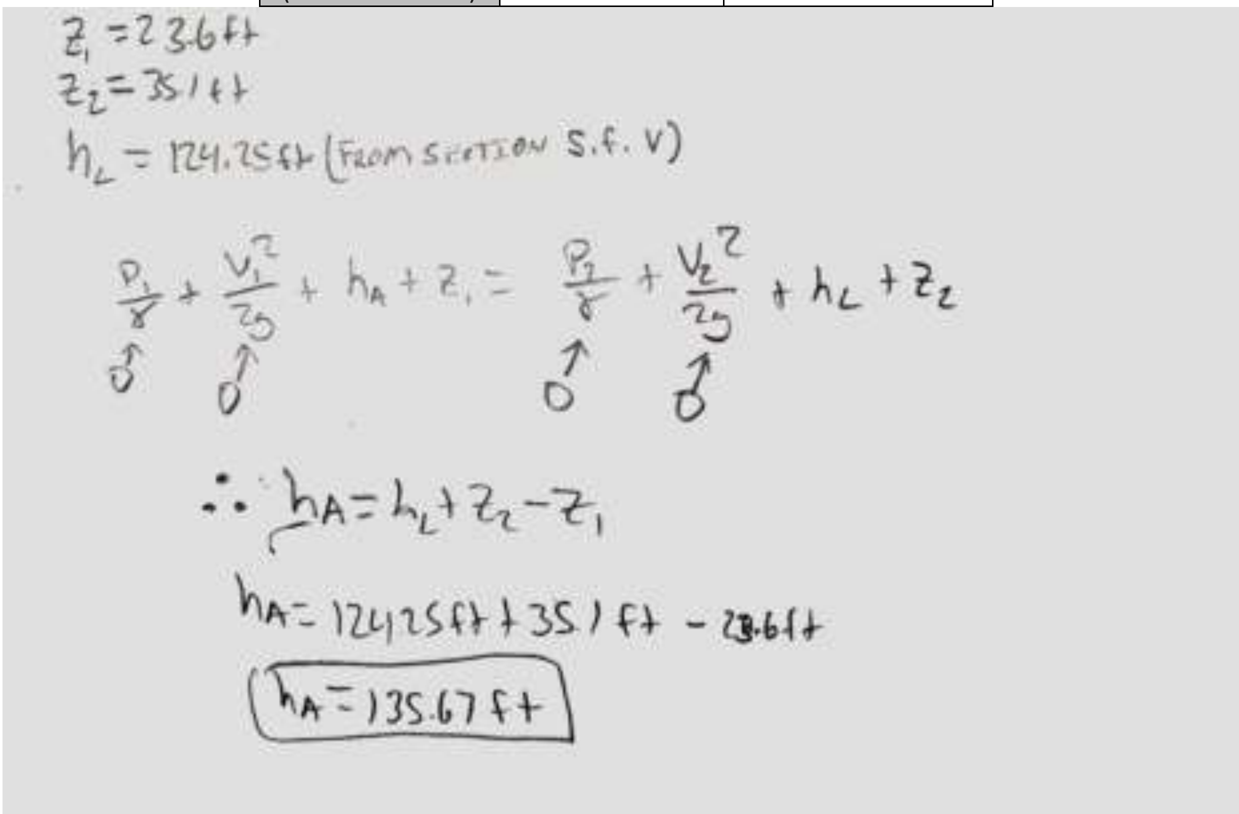


Figure 15 - Pump Head Calculations

Summary

The four pumps require a pump head of 21.3, 135.7, 108.8, and 14.7.

Materials

Coolant, 0.94 Specific Gravity

Steel

Pumps

Valves

Analysis

Using Bernoulli's equation allowed us to calculate the required pump head for all the pumps in our system. This information will be important for pump selection.

Task 15

Purpose

To specify the number and types of pumps that will be required to run the 4 systems.

Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

Incompressible fluid.

Cost should be minimized.

Data and Variables

Table 25 - System Pump Requirements

Description	Symbol	Qty	Unit	Source
Tr to T1 head	hA	21.3	ft	Task 7
Tr to T1 flow	Q	0.3713	ft^3/s	Task 4
T1 to T2 head	hA	111.5	ft	Task 7
T1 to T2 flow	Q	0.03713	ft^3/s	Task 4
T2 to T3 head	hA	129	ft	Task 7
T2 to T3 flow	Q	0.03713	ft^3/s	Task 4
T3 to Truck head	hA	5.3	ft	Task 7
T3 to Truck flow	Q	0.1485	ft^3/s	Task 4

Procedure and Analysis

In order to minimize cost the pumps used will be centrifugal radial flow kinetic pumps with 60Hz motors. Other types were considered but this is the most cost effective for this kind of system. As there is tolerance in the delivery window the customer may decide on backup pumps but the initial design will have 1 per system.

Refer to data table in this task for the Q and head requirements to select the pumps.

Task 16

Pump Selection

Purpose

Specify the characteristics of the chosen pumps, point of operation, and actual pump size and weight.

Drawings & Diagrams

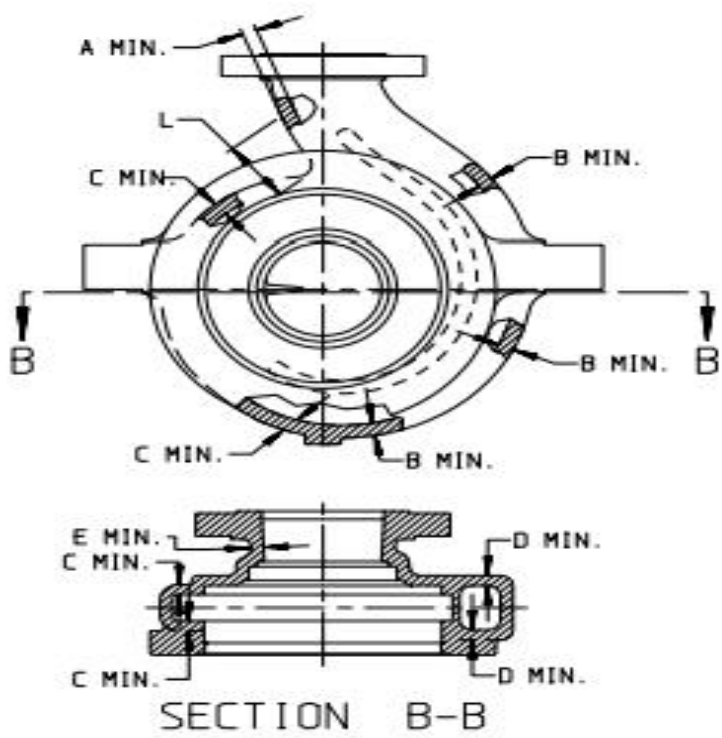


Figure 16 - Pump Cross-Section

Sources

Mott, R. L., & Untener, J. A. (2015). Applied Fluid Mechanics. Pearson.
Sulzer Catalog

Design Consideration

Viscosity for coolant happens to be on the lower side of the spectrum. Flow rate and pump head will play an important role in selection. We will use pumps provided by the Sulzer catalog.

Data and Variables

Table 26 - Pump Head & Flow Data

Pump #	H_A (ft)	$Q(\frac{ft^3}{s})$
Pump 1 (Train to Tank 1)	**21.34843**	**0.371**
Pump 2 (Tank 1 to Tank 2)	**111.5343**	**0.0371**
Pump 3 (Tank 2 to Tank 3)	**129.1409**	**0.0371**
Pump 4 (Tank 3 to Truck)	**5.27894**	**0.1485**

Procedure:

For chosen pumps, point of operation, and actual pump size and weight will be stated. Some of the information is for our civil engineer colleagues we are working with. We will include pump curves with the system curve and point of operation.

Summary

Table 27 - Pump Specifications

Pump #	Pump Type	Impeller Size(IN)	Pump Weight(lbs)	Speed(RPM)	Efficiency(%)
Pump 1	2 x 3 x 7.5A -1 OHH	5.25	409	3520	57.8
Pump 2	1 x 2 x 7.5 - 1 OHH	6.00	362	3520	15
Pump 3	1 x 2 x 7.5 - 1 OHH	6.00	362	3520	15
Pump 4	1 x 2 x 7.5 - 1 OHH	5.25	362	3520	37

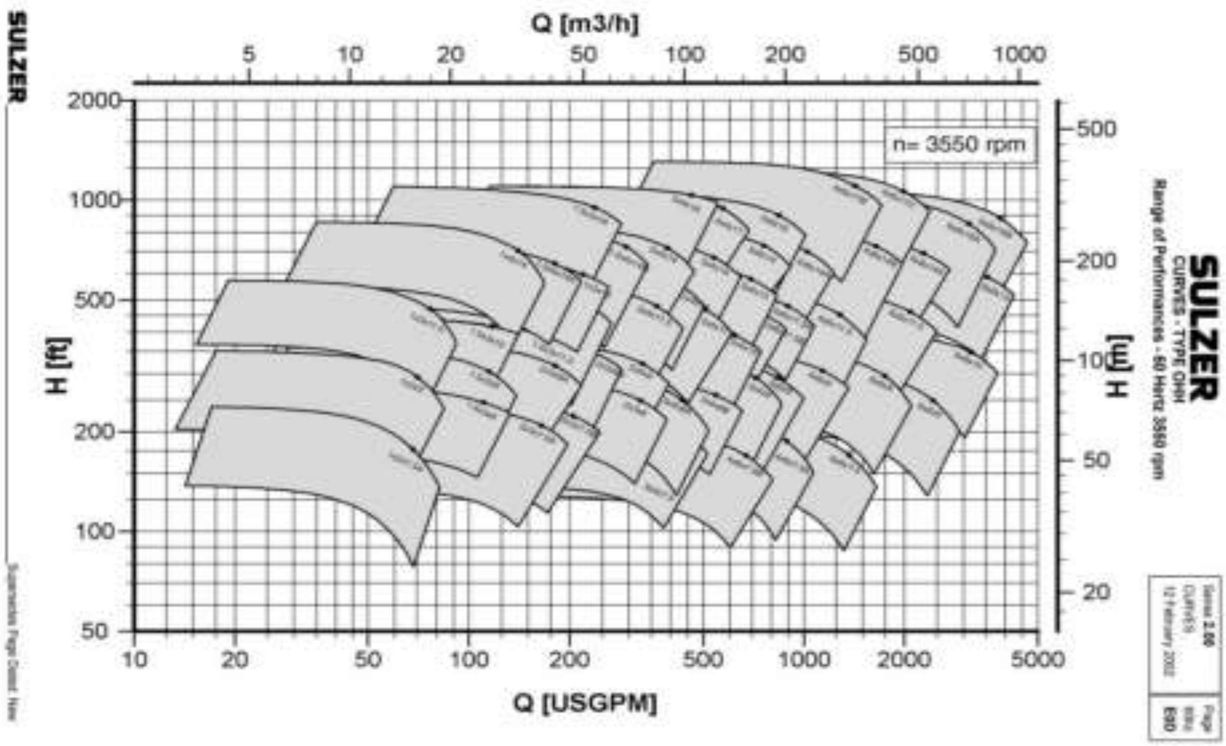


Figure 17 - Pump Range Of Performance

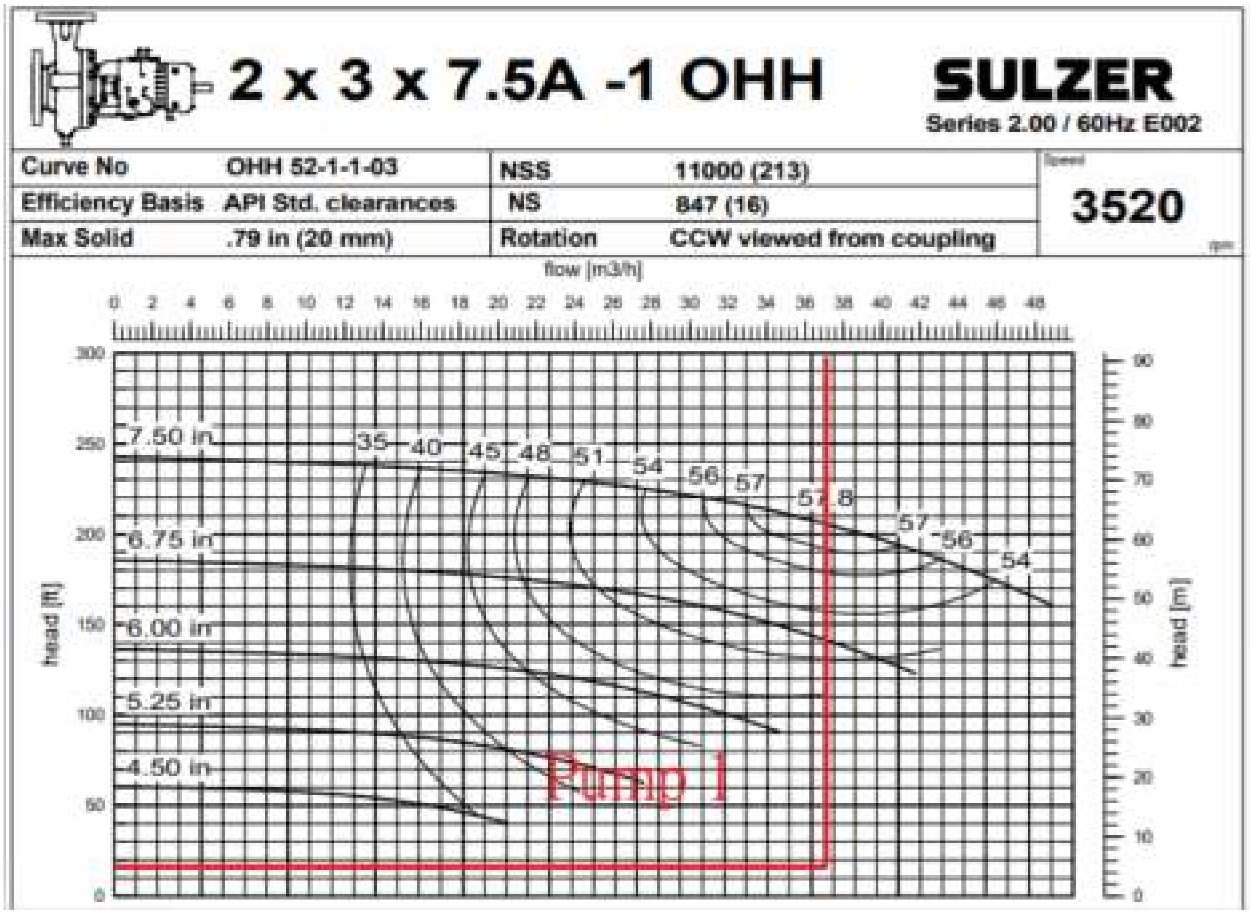


Figure 18 - Pump Curve #1

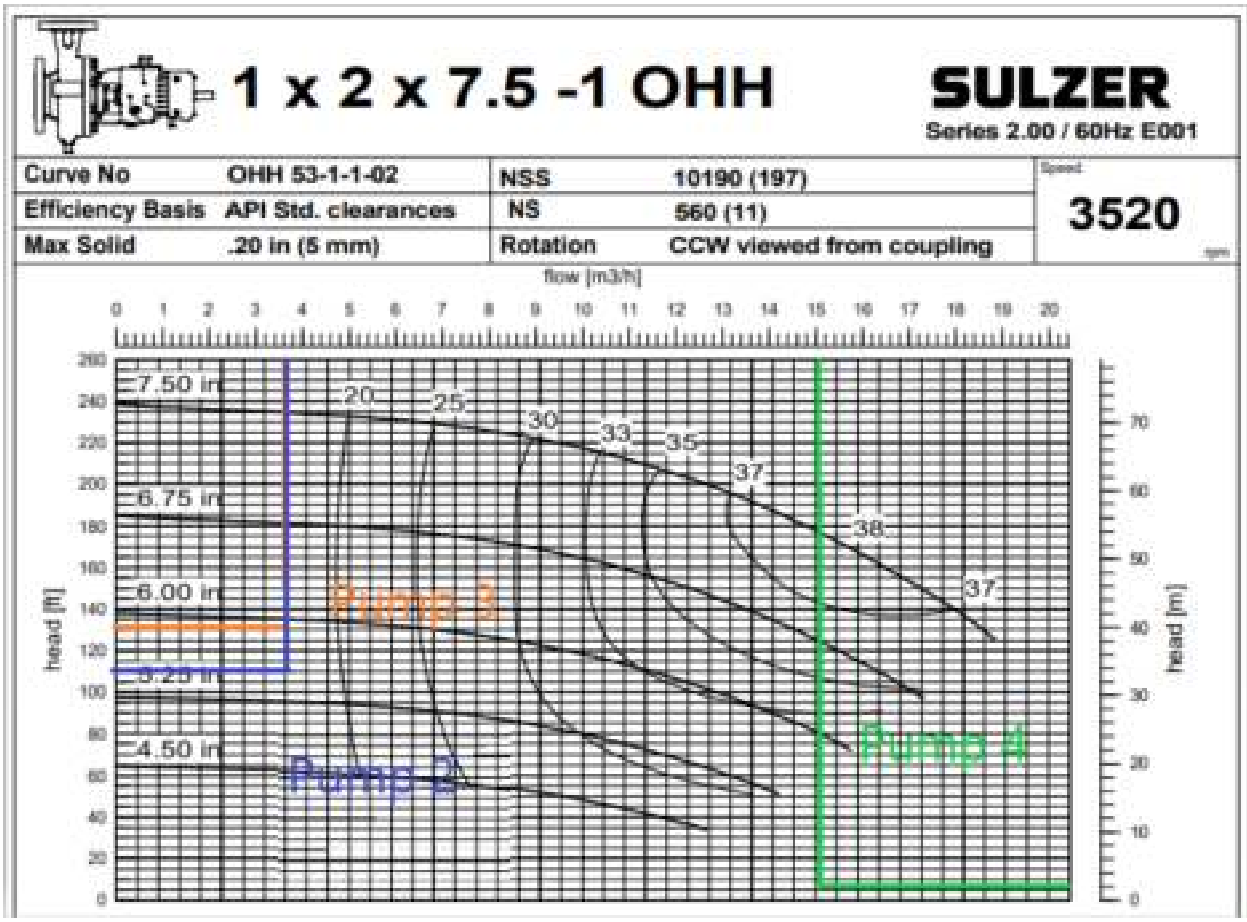


Figure 19 - Pump Curve #2

Table 28 - Pump Size Information

PUMP SIZE	PUMP wt lbs	DNs	DNd	O	B	e	P	h1	i	H	y
		in									
1x2x7.5-1	362	2	1	0	30	6.89	33.03	18	**5.83**	27.06	5
2x3x7.5A-1	409	3	2	0	30	9.84	36.10	18	**9.28**	27.06	5

Materials

Sulzer 1 x 2 x 7.5 -1 OHH Pump

Sulzer 2 x 3 x 7.5A -1 OHH Pump

Analysis

We will utilize the same type of pump for most our piping system. However, they will have varying impeller sizes. Our pump 1 with our largest flowrate requiring the largest pump. They meet the flow rate and pump head requirements for every aspect of our system.

Task 17

Power Requirement

Purpose

Is to specify the electrical motor requirements for the pumps in our piping system.

Drawings & Diagrams

Figure 20 - Electric Motor Diagram

Sources

Mott, R. L., & Untener, J. A. (2015). Applied Fluid Mechanics. Pearson.

Design Considerations

The specified power of the electrical motor for the pump is approximately 1.10 times the required power of the pump. We want to aim for the most efficient use of energy consumption. Will consider the flow rate and pump head of the system for each pump.

Data and Variables

Table 29 - Pump Head & Flow Power Requirements Data

Pump #	H_A (ft)	$Q(\frac{ft^3}{s})$
Pump 1 (Train to Tank 1)	**21.34843**	**0.371**
Pump 2 (Tank 1 to Tank 2)	**111.5343**	**0.0371**
Pump 3 (Tank 2 to Tank 3)	**129.1409**	**0.0371**
Pump 4 (Tank 3 to Truck)	**5.27894**	**0.1485**

Procedure

Using our pump head value H_A and flow rate Q we can compute the power required by the pump. The formula for pump power is $P_A = \frac{\gamma Q h_A}{n}$. However, we will be multiplying P_A by a factor of 1.10 to compute the power required by the electric motor.

Calculations

Figure 21 - Power Requirement Calculations

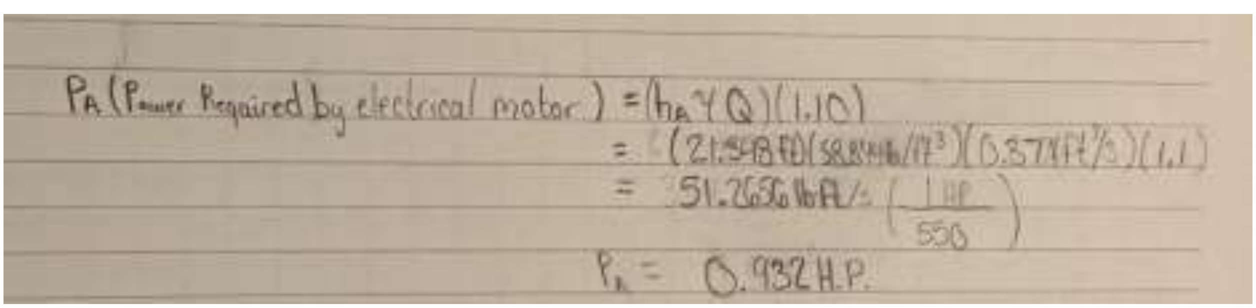


Table 30 - Pump Power

Pump #	H_A (ft)	$Q(\frac{ft^3}{s})$	Pa(Required Power)HP
Pump 1	**21.34843**	**0.371**	**0.932**
Pump 2	**111.5343**	**0.0371**	**0.4870**
Pump 3	**129.1409**	**0.0371**	**0.5639**
Pump 4	**5.27894**	**0.1485**	**0.0923**

Summary

The electric motor power required for each pump goes as followed Pump 1 - 0.932 HP, Pump 2 – 0.487 HP, Pump 3 – 0.564 HP, and Pump 4 -0.0923 HP.

Materials

Electric Motor

Pumps

Analysis

With this calculated, we now know what is required in terms of power in HP for our pumps to be able to perform.

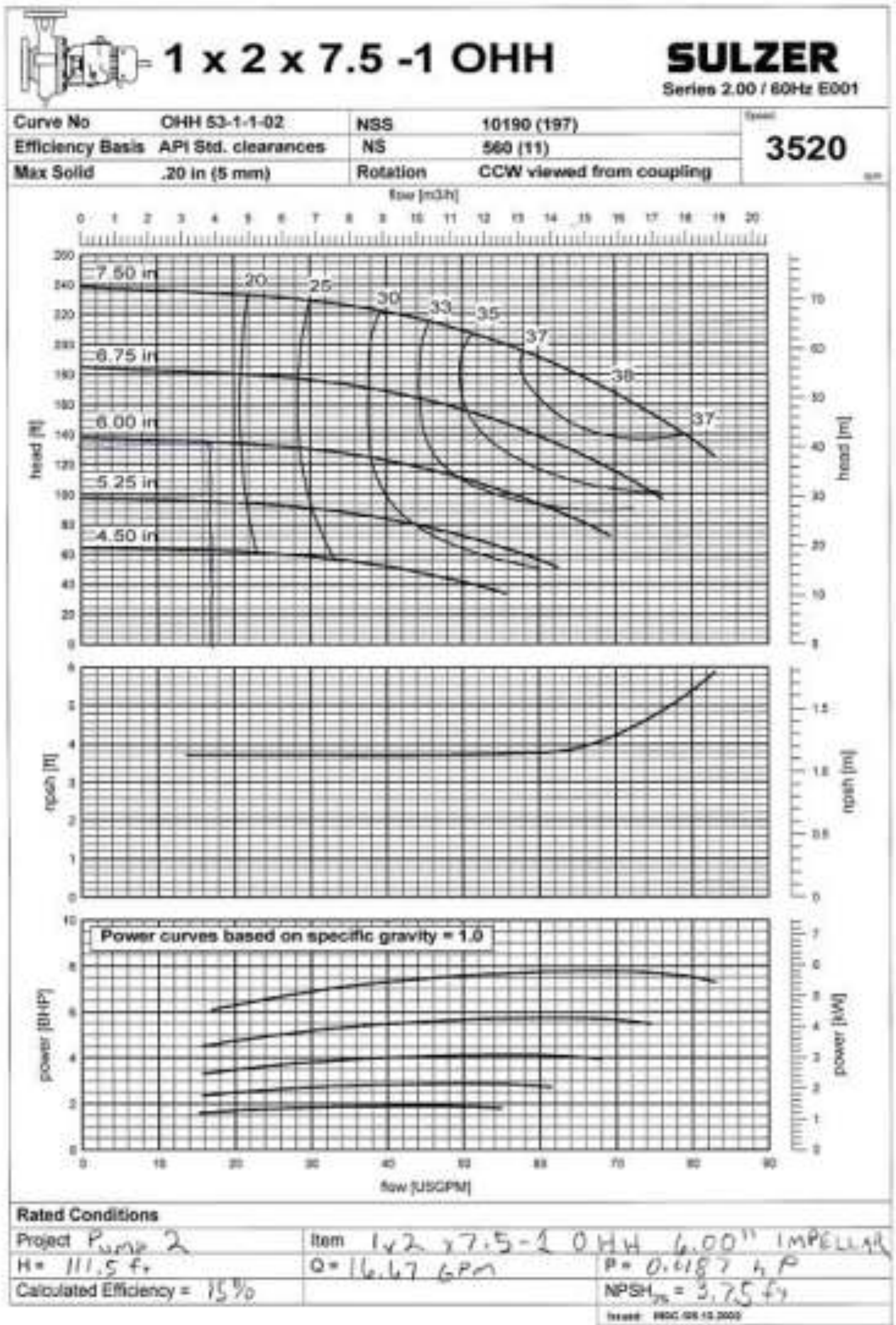
Task 18

Purpose

To verify the chosen pump's NPSHr is available in the system.

Drawings and Diagrams

Figure 22 - Full Pump Curve Diagram



Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Dayton Ashrae (2023). *Psychrometrics.* https://daytonashrae.org/psychrometrics/psychrometrics.shtml

Design Considerations

Incompressible fluid.

Pump intake from tank at level pipe with less than 10 ft of pipe before pump.

Data and Variables

Table 31 - NPSH Data

Description	Symbol	Qty	Unit	Source
NPSHR Pump 1	NPSHr1	7.5	ft	Sulzer Catalogue
NPSHR Pump 2	NPSHr2	3.75	ft	Sulzer Catalogue
NPSHR Pump 3	NPSHr3	3.75	ft	Sulzer Catalogue
NPSHR Pump 4	NPSHr4	4.25	ft	Sulzer Catalogue
Specific Gravity Coolant	SG	0.94		given
Atmospheric Pressure	Patm	14.18	PSIA	(Dayton 2023)
Specific Weight of Water			lb/ft^3	Table 13.2 (Mott 2015)
Vapor Pressure Head (90F)	hvp	1.618	ft	Table 13.2 (Mott 2015)

Procedure

Use catalog NPSHr values for each pump. Use average atmospheric pressure for Dayton, Ohio to calculate the static pressure head. Due to changing levels in tanks use worst cast of fluid in line with pump as a 0 elevation difference. Look at energy losses in task 7 on the suction side of the pumps. Look up the vapor pressure head. Calculate the HPSAa for each and compare that it is sufficiently larger than the required.

Calculations

Figure 23 - NPSH Calculations

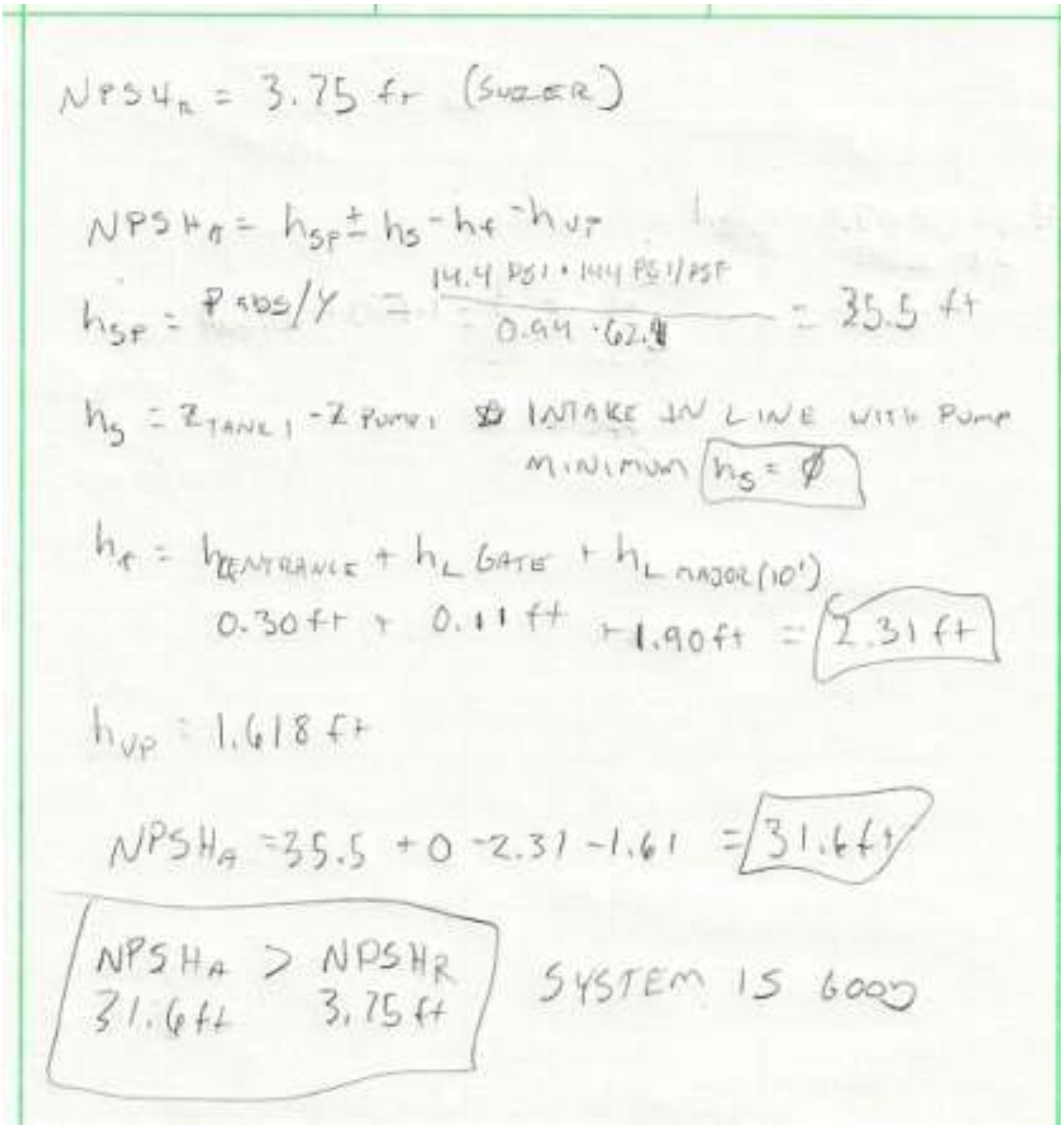


Table 32 - NPSH Calculations

$$NPSH_A = h_{sp} \pm h_s - h_f - h_{vp}$$

	NPSHr	hsp	hs	hL minor	hL major	hf	hvp	HPSHa
Pump 1	7.5	34.97996	0	1.253991	1.974665	3.228657	1.618	30.1333
Pump 2	3.75	34.97996	0	0.406741	1.905058	2.311798	1.618	31.05016
Pump 3	3.75	34.97996	0	0.406741	1.905058	2.311798	1.618	31.05016

Pump 4	4.25	34.97996	0	0.411197	0.876322	1.287518	1.618	32.07444

Summary

There is sufficiently more NPSH available for each pump there will not be a problem with cavitation.

Materials

Coolant, 0.94 Specific Gravity

New Steel Schedule 40 Pipe

Sulzer pumps specified in Task 16.

Analysis

All four systems are safe from cavitation.

vii. Instrumentation selection

Task 14

Purpose

To design flow measurement for the Usage tank fill circuit as it is time dependent for workflow.

Drawings and Diagrams

Figure 24 - Flow Nozzle Diagram

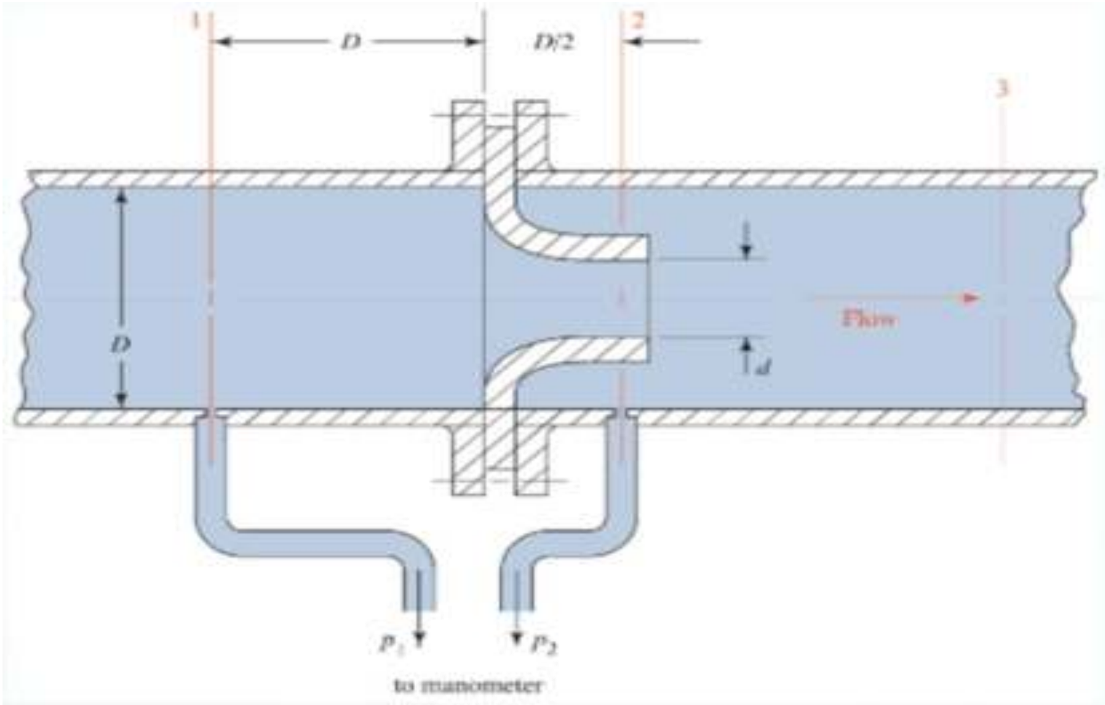
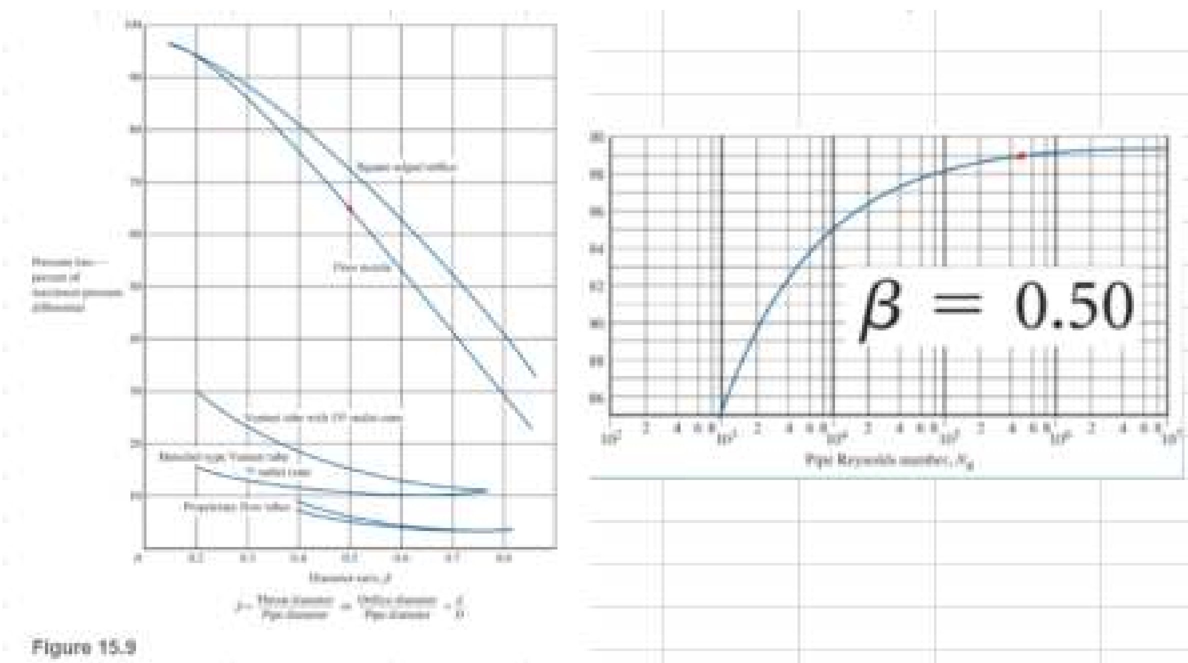


Figure 25 - Reynold's Number Curve



Sources

Mott, R. L., & Untener, J. A. *(2015). Applied Fluid Mechanics. Pearson.*

Design Considerations

Incompressible fluid.

A flow nozzle is to be installed on a horizontal section and there will be 0 elevation change around the flow nozzle. The flow nozzle will use a d/D ratio of 0.5.

Data and Variables

Table 33 - Flow Measurement Data

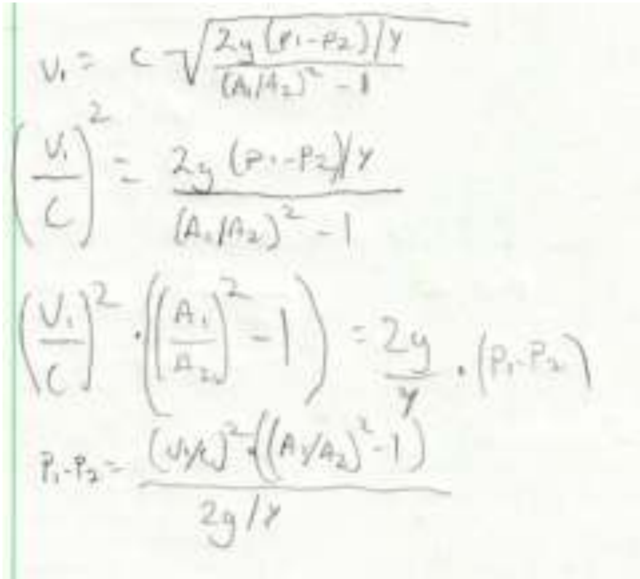
Description	Symbol	Qty	Unit	Source
System Q	Q	0.03713	ft^3/s	Task 4
Pipe Area	A	0.006	ft^2	Table F.1 (Mott 2015)
Pipe Diameter	D	0.0874	ft	Table F.1 (Mott 2015)
gamma of Coolant (60F)	gamma	58.844	lb/ft^3	Table A.2 (Mott 2015) * SG
kinematic viscosity	v	1.40E-05	ft^2/s	Table A.2 (Mott 2015)
Velocity	V	6.188333	ft/s	Section 5.f.v, (Q/A)
Reynold's Number	Re	3.86E+04		Section 5.f.v, (VD/v)
friction factor	f	0.028		Section 5.f.v, Fig 8.7 (Mott 2015)
Discharge Coefficient	C	0.97		Figure 15.5 (Mott 2015)
Pressure Loss %		65%		Figure 15.9 (Mott 2015)
Pump Head	hA	121	ft	Task 7

Procedure

Using Reynolds number of the system as calculated in section 5.f.v and the d/D ratio of 0.50 for the flow nozzle and the chart estimate the discharge coefficient. Plug all known values into equation 15.4(Mott 2015) to solve for DeltaP. Use the DeltaP from the previous step to calculate the system pressure loss and divide this loss by gamma of coolant to determine additional hL due to this meter.

Calculations

Figure 26 - Pressure Loss Calculations



$$v_1 = C\sqrt{\frac{2g(p_1 - p_2)/\gamma}{(A_1/A_2)^2 - 1}}$$

rV1	6.188333	ft/s
C	0.97	
A1	0.006	ft^2
D2(D1*.5)	0.0437	ft
A2(Pi*R^2)	0.0015	ft^2
2g	64.4	
gamma	58.844	

(V1/C)^2	40.70089
(A1/A2)^2-1	15.00284
2g/gamma	1.094419

DeltaP	557.9479	lb/ft^2
	3.874638	lb/in^2

Table 34 - Pressure Loss Calculations

$$p_1 - p_3 = \gamma h_L$$

PL = DeltaP*.65	**PL**	362.666136	lb/ft^2
PL = P1 -P3 = gamma*hL	**gamma**	58.844	lb/ft^3
	hL(PL/ga)	6.163179525	ft

Table 35 - Head Loss Calculations

Summary

The DeltaP at the flow nozzle described in this system will be 3.9 PSI and this will represent an additional energy loss of 6.2 ft.

Materials

Coolant, 0.94 Specific Gravity

New Steel Schedule 40 1” Pipe

Analysis

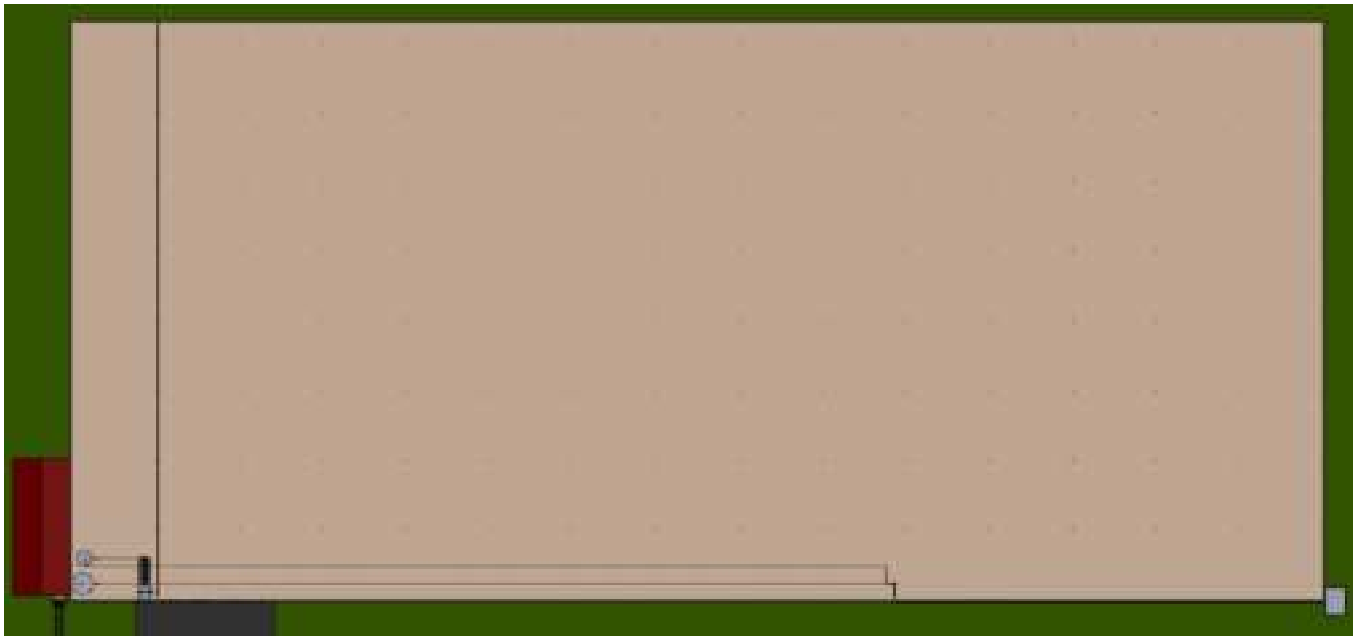
The flow nozzle causes a pressure drop in the line which indicates an energy loss. The designer has to balance the energy loss with the need to create enough of a deltaP for easier and more stable measurements.

6. Final drawings

g. Plot plan

Overall Layout

Figure 27 - Plot Plan

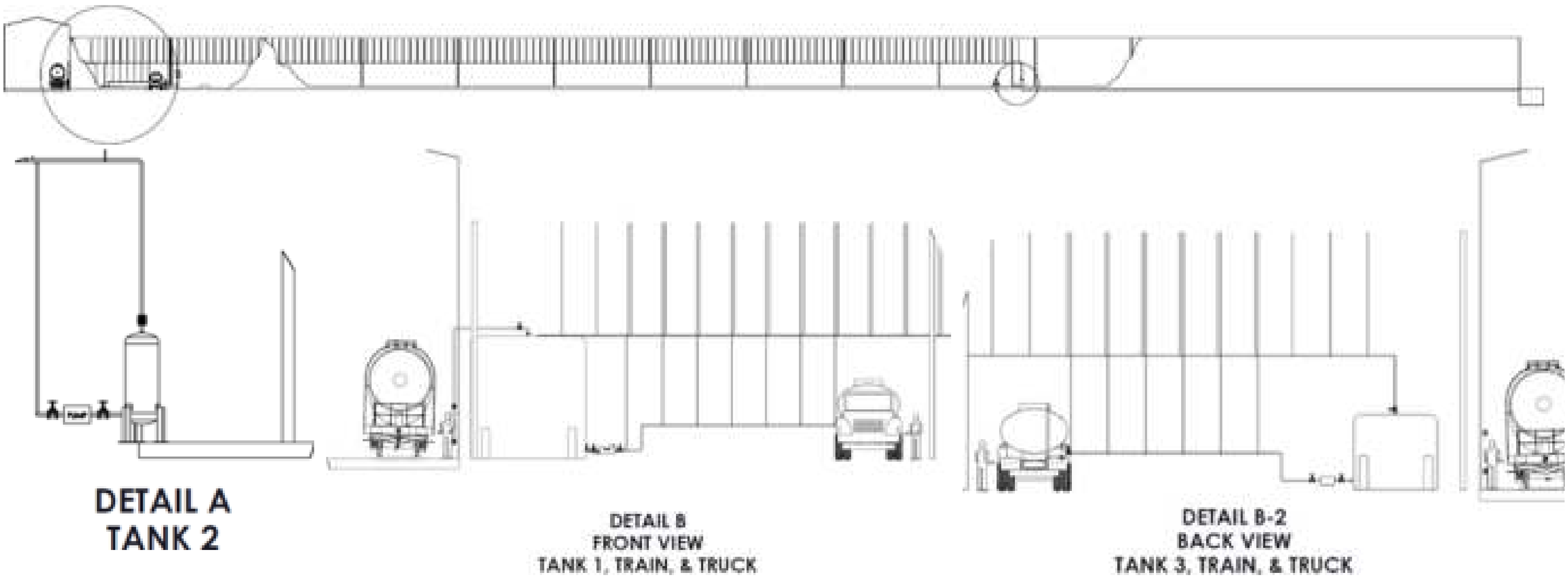


Piping Layout

Figure 28 - Piping Layout

h. Elevations view

Figure 29 - Elevation Views



i. Isometrics

Figure 30 - Isometric Views

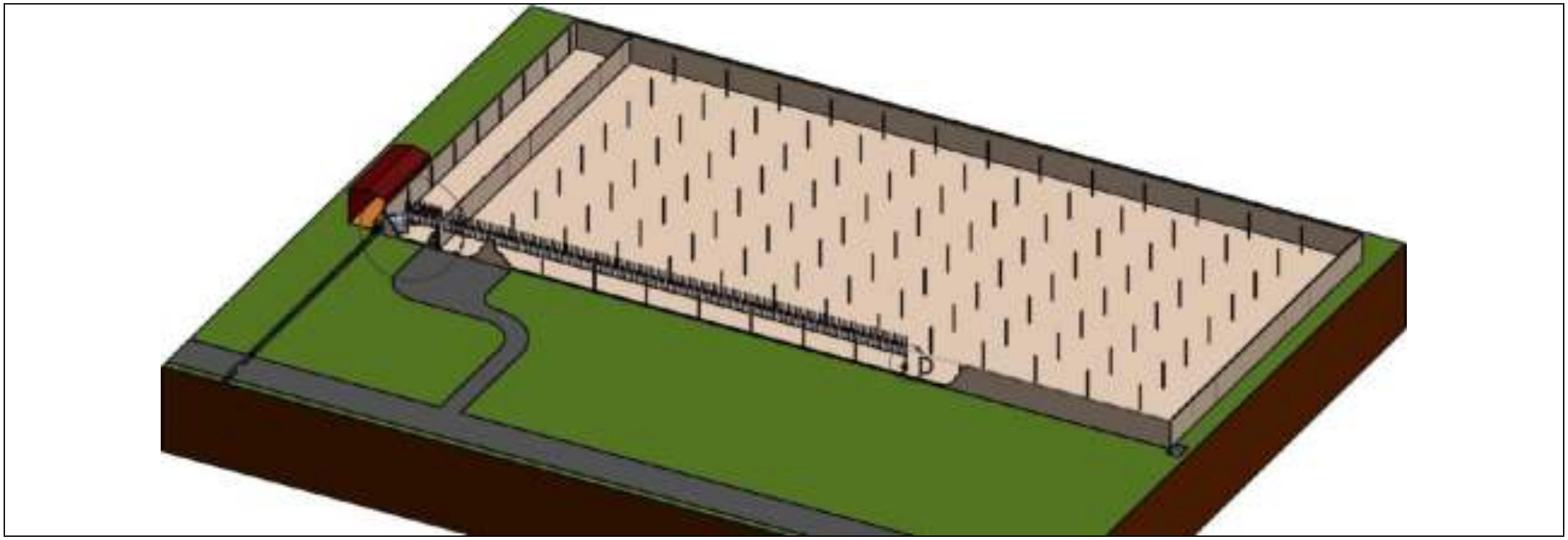


Figure 31 - Isometric Detail Views

7. Bill of materials and equipment list

Task 20

Purpose

To identify parts needed for designed system.

Sources

Report body

Design Considerations and Procedure

Pipe at length will be ordered in 10’ sections with coupling for each section. Some extra pipe will be ordered for cut and thread on site. There will be gate valves and unions around the pumps and check valves for service. Pipe supports and threaded rod will be ordered. Civil will be responsible for mounts for the threaded rod.

Bill of Materials

ID #	Item Description	UOM	Quantity
1	Tank 1 , Fabricated 20000 Gallon Tank, D 15', H 16', 16 Guage 304 Stainless Steel	EA	1
2	Tank 2, Fabricated 1000 Gallon Tank, D 5.5', H 6.5', 16 Guage 304 Stainless Steel	EA	1
3	Tank 3, Fabricated 1000 Gallon Tank, D 10', H 11', 16 Guage 304 Stainless Steel	EA	1
4	Blind Flange McMaster Carr, 44685K164	EA	1
5	Hex Head Bolts, .5"-13, 304 Stainless Steel	EA	4
6	2.5" NPS S40 Pipe, 10' Sections	EA	3
7	2.5" NPS S40 Gate Valves	EA	2
8	2.5" NPS S40 Couplings.	EA	2
9	2.5" NPS Unions	EA	2
10	2.5" NPS 90 elbows	EA	2
11	2.5" NPS Swing Check Vlave	EA	1
12	1" NPS S40 Pipe, 10' Sections	EA	130
13	1" NPS S40 Gate Valves	EA	4
14	1" NPS S40 Couplings.	EA	130
15	1" NPS Unions	EA	4
16	1" NPS 90 elbows	EA	9
17	1" NPS Swing Check Vlave	EA	2
18	2" NPS S40 Pipe, 10' Sections	EA	2
19	2" NPS S40 Gate Valves	EA	2
20	2" NPS S40 Couplings.	EA	2
21	2" NPS Unions	EA	2
22	2" NPS 90 elbows	EA	2
23	2" NPS Swing Check Vlave	EA	1
24	Split Pipe Clamp, B3198H-2.5"	EA	30
25	Split Pipe Clamp, B3198H-1"	EA	650
26	Split Pipe Clamp, B3198H-2"	EA	10

27	Threaded Rod 3/8"-16	FT	1000
28	Threaded Rod 1/2"-13	FT	20
29	Flat Washer, 1/2"	EA	100
30	Lock Washer, 1/2"	EA	100
31	Nuts, 1/2"	EA	100
32	Flat Washer, 3/8"	EA	1000
33	Lock Washer, 3/8"	EA	1000
34	Nuts, 3/8"	EA	1000
35	Sulzer Pump 2 x 3 x 7.5A-1 OHH 5.25" Impeller	EA	1
36	Sulzer Pump 1 x 2 x 7.5-1 OHH 6" Impeller	EA	2
37	Sulzer Pump 2 x 3 x 7.5-1 OHH 5.25" Impeller	EA	1
38	Flow Nozzel for 1" pipe D/d of 0.5 with manometer	EA	1

Table 36 - Bill of Materials

Analysis

All four systems have been analyzed and parts listed for the whole job.

8. Final remarks

This design proposed in this report is a good solution to the design limitations placed in the client's request for proposal document. The solutions presented are thought to be both cost effective and respectful. To the long-term needs of an operating factory. A few highlights of design decisions worth focusing on are the selection of stainless-steel tank materials, the selection of flow rates and the installation style of the system pumps.

The team at TOWM Engineering discussed tank material at the beginning of the project and whereas, carbon steel would have sufficed it was decided to go with 304 stainless steel and to make all tanks out of 16-gauge material even though thinner would have done. The design of all tanks is to have the fluid surface vented to atmosphere and as such near the fluid lines you would have the corrosive mix of a water based fluid and prevalent oxygen. This effect will decrease the life of the tank and make the coolant dirty which can have a negative effect on the machining equipment and the machined products. The lack of oxygen in the system piping on an ongoing basis gave the team the confidence to use steel schedule 40 pipe.

The next task was to select flow rates for the various pumped systems. Here a very short period could have been selected but that would have greatly increased cost and conversely a very long period could have been selected. The team took a balanced approach and chose 90 minutes for the delivery and shipping pumps and 60 for the emptying and filling cycles, each for a total of 2 hours and believes that this represents a balance of the two extremes. We believe that this approach respects the employee's time without driving up capital costs too much. At TOWM Engineering we aim to be your partner in a well-run factory.

The predominance of system maintenance will be around the pumps. The system was designed with ease of maintenance and throttling in mind. The flow order for parts is suction gate valve, then union, then pump, then union, then swing check valve, then gate valve. This allows easy access to the pump and the swing check which are the two components with the lowest expected mean time between failures. The throttling gate valve, downstream of the pump, is close to the pump giving the technicians easy access to instrumentation and the pump while throttling the system for optimal pump performance.

These design decisions highlight our design philosophy at TOWM engineering, and we hope they highlight our approach to the many tradeoffs inherent in an engineering design. We aim to optimize for lowest total cost of ownership of the installed system which must consider the capital, maintenance, and operations costs.

9. Appendix

Lee Green:

During this process I learned a lot about fluid mechanics and how much changes move throughout the project. I will definitely have more sympathy for mechanical engineers when I have problems getting electrical motor requirement data from them in the future. I understand better the complexity of designing systems and the parts of the process I have not been professionally involved in. The process of the project is intimidating at the first of the semester but us working together on homework improves the team cohesion. I generally don't mind working in groups professionally but am not a huge fan of it in school. This process worked better than many I have been involved with before and it was pleasantly surprising. I have honed my intention to piping systems and my understanding of seeing good design and problems and knowing why.

Sherron Overbey:

One of my biggest takeaways from this project was the importance of effective teamwork. I joined their team on the latter part of the semester. They welcomed me with open arms and appreciated being able to contribute to an actual team. This project taught me how to hit the ground running. Since I wasn't there at the start of the semester I had to play catch up to familiarize myself with the direction they were already going. Fitting in and being flexible to work towards the common goal of designing this piping system. Working on this project will benefit me in my career being able to problem solve methodically. Navigating the various technical demands and intricacies put it into a real-life perspective that I will be able to take with me forever. My knowledge of piping system increased working with two other brilliant minds that have more industry experience. As a student there is so much that you can take away than just in the classroom.

Christopher Smith:

Something I've learned during the project is how important the smallest of details can be to the overall project. Throughout the completion we've had multiple instances of having to change different variables and calculations and seeing how it can cascade through multiple other parts of the project has been eye opening. For example, one of the most recent changes was a changing the number of fittings in one of the systems. This changed the energy losses for that system, but also affected the pump head, which in turn affected which pump selection. All in, this small change required 6 different tasks to be updated. Another takeaway I've had is the importance of looking at the "big picture" of the whole project and the individual systems within it. When the project is first presented it is quite overwhelming, but by stepping back and just figuring out what needs to happen, it became a much more attainable goal.