Full Pipeline System Design of a Manufacturing Plant for CONTINENTAL AG

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2. Abstract:

Continental AG is requesting the design of a system to handle the coolant that is supplied to a new manufacturing facility. Three tanks are needed to be designed, one clean coolant tank, one reservoir tank, and one dirty coolant tank. The piping system to deliver coolant to each tank must be designed as well. The coolant from the clean coolant tank will be delivered to the reservoir tank, the coolant from the reservoir tank will be delivered to the dirty coolant tank, which then would get delivered to the truck that disposes the dirty coolant. It is important to consider the size and location of the tanks, material, flow rate, layout of the piping system, how many pumps are needed, wall thickness, and wind load and weight of the tanks.

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5. Report Body:

5.a. Job Site Location

The manufacturing facility will be built in Dayton, Ohio.

5.b. Specifications and Design Philosophy

The requirements for this facility are to have three tanks, a clean coolant tank (tank 1), a reservoir tank (tank 2), and a dirty coolant tank (tank 3). A railroad tank car will bring 15,000 gallons of new coolant and must transferred to the clean coolant tank. The reservoir tank must have a capacity of 1000 gallons and will be emptied once per week. The dirty coolant will be picked up once per month by a truck. The time it takes to empty and fill the clean coolant tank is 4 hours. It will take the reservoir tank 1 hour to empty and fill up. Lastly, the dirty coolant tank will require 2 hours to fill and empty.

5.c. Sources

- Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7th ed. Pearson Edu. (2015)
- https://weatherspark.com/h/y/15863/2021/Historical-Weather-during-2021-in-Dayton-Ohio-United-States#Figures-WindSpeed
- Spotts, M.F., Shoup, T.E., "Design of Machine Elements" 8th ed. Pearson Edu. (2004)

5.d. Materials and Specifications

5.d.i. Establish the pipe and tank material to use

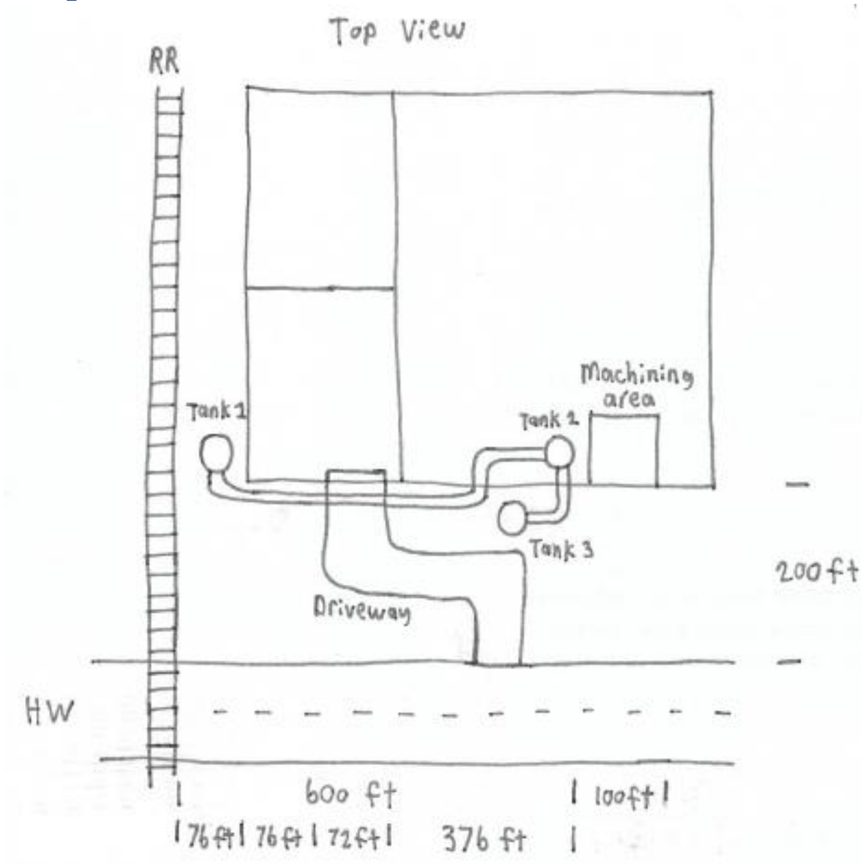
The pipe material from the railcar to tank 1 is 1.5 inch schedule 40 steel. The pipe material from tank 1 to tank 3 is ¾ inch schedule 40 steel. The pipe material from tank 3 to the truck is 1.25 inch schedule 40 steel. The tank material is 304 stainless steel.

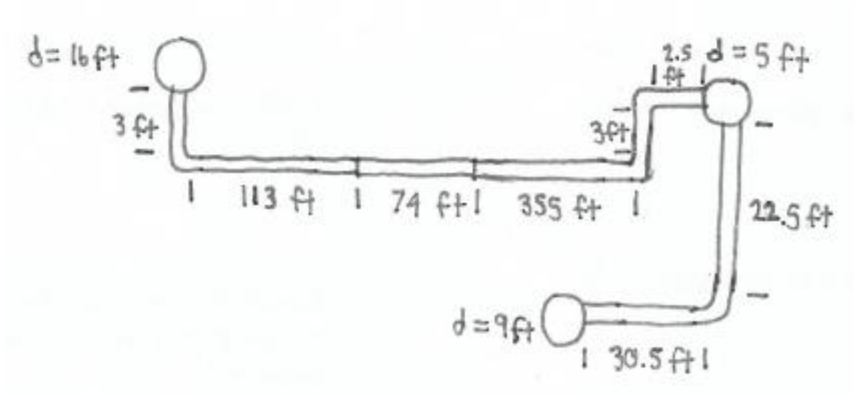
5.d.ii. Fluid characteristics

The coolant being used is a solution of water and soluble oil. It has a specific gravity of 0.94 for and a specific weight of 58.66lb/ft^3. The viscosity and vapor pressure of the coolant are 1.50 times that of water.

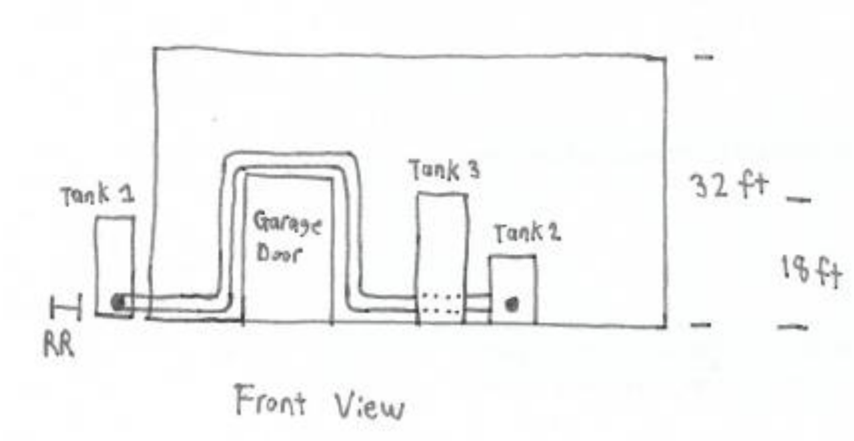
5.e. Preliminary Drawing and Sketches

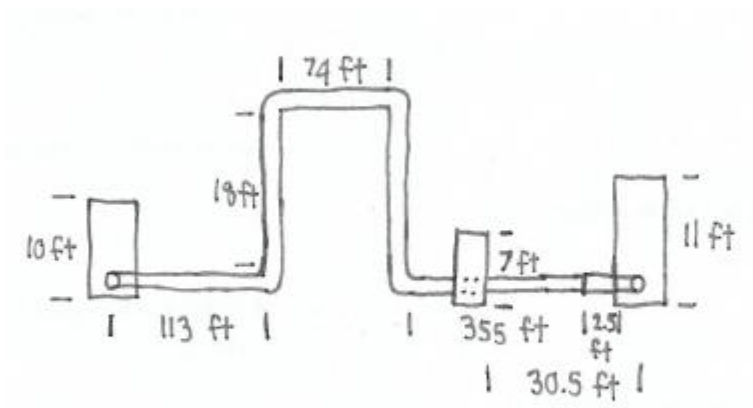
5.e.i. Plot plan





5.e.ii. Elevations





5.f. Design Calculations

5.f.i. Tank specifications

Task 1 - Size and Location of All Tanks

<u>Purpose:</u>
Determine the shape, dimensions, and location for all three tanks.

Drawings:

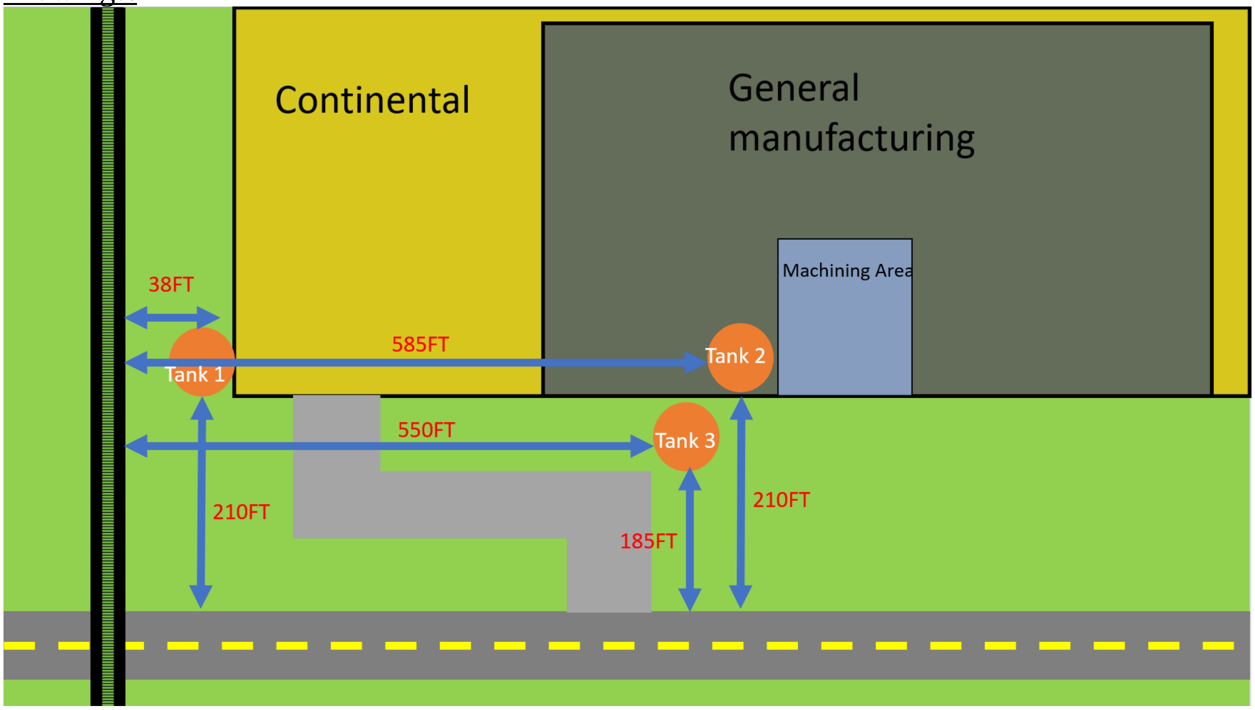


Figure 1 – Layout of tanks

Sources:

Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7th ed. Pearson Edu. (2015)

Design Considerations:

Each tank must be capable of holding a certain volume of fluid in order for the system to function properly. All tanks will be cylindrical in shape. Tank location should be chosen to minimize pipe length and increase functionality.

Variables:

Tank 1: Clean Storage Tank	Tank 2: Reservoir Tank	Tank 3: Dirty Storage Tank
D = tank inside diameter	h = tank inside height	

Procedure:

Determine the necessary capacity of each tank, then select appropriate dimensions. Pick location based upon functionality, minimizing pipe length wherever it is practical.

Calculations:

Tank 1 capacity = 15,000 gal = 2,005.3 ft^3. D = 16 ft., h = 10 ft.

$$V = \frac{\pi * D^2}{4} * h = \frac{\pi * 16^2}{4} * 10 = 2010.6\ ft^3$$

Location should be near the railroad tracks, but also near the building:
38 ft. from the railroad tracks and 210 ft. from the highway.

Tank 2 capacity = 1,000 gal = 133.7 ft^3. D = 5 ft., h = 7 ft.

$$V = \frac{\pi * D^2}{4} * h = \frac{\pi * 5^2}{4} * 7 = 137.4\ ft^3$$

Location should be near the machining area and inside the building:
585 ft. from the railroad tracks and 210 ft. from the highway.

Tank 3 capacity = 5000 gal = 688.5 ft^3. D = 9 ft., h = 11 ft.

$$V = \frac{\pi * D^2}{4} * h = \frac{\pi * 9^2}{4} * 11 = 699.8\ ft^3$$

Location should be fairly close to tank 2, but also near the driveway:
550 ft. from the railroad and 185 ft. from the highway.

<u>Summary:</u>
All tanks are cylindrical.
Tank 1 dimensions: D = 16 ft., h = 10 ft.
Tank 1 location: 38 ft. from the railroad and 210 ft. from the highway
Tank 2 dimensions: D = 5 ft., h = 7 ft.
Tank 2 location: 585 ft. from the railroad and 210 ft. from the highway
Tank 3 dimensions: D = 9 ft., h = 11 ft.
Tank 3 location: 550 ft. from the railroad and 185 ft. from the highway

<u>Materials:</u>
Tanks will be manufactured from 304 Stainless Steel.

<u>Analysis:</u>
Each tank is designed to have a capacity slightly larger than the necessary volume in order to prevent over-filling.

Task 2 - Wall Thickness of all Tanks

<u>Purpose:</u>

Choose material for tanks and calculate wall thickness.

<u>Sources:</u>

Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7th ed. Pearson Edu. (2015)
<u>Design Considerations:</u>

The tank should be thick enough to handle the most amount of pressure, which is at the bottom of the tank.

<u>Data and Variables:</u>

Diameter of clean coolant tank, D_c = 16 ft = 192 in

Diameter of reservoir tank, D_r = 5 ft = 60 in

Diameter of dirty coolant tank, D_d = 9 ft = 108 in

Height of clean coolant tank, H_c = 10 ft = 120 in

Height of reservoir tank, H_r = 7 ft = 84 in

Height of dirty coolant tank, H_d = 11 ft = 132 in

Longitudinal joint quality factor, E = 0.85

Correction factor, Y = 0.40

Factor of safety = 2

Yield strength for stainless steel 304 = 29,733 psi

Procedure:

First the material is chosen. The pressure at the bottom of each of the tanks must be calculated. Finally, using the pressure calculations, the thickness can be calculated for each tank.

Calculations:

$$Allowable\ stress = yield\ strength \div factor\ of\ safety = \frac{29{,}733psi}{2} = 14{,}866.50psi$$

$$\gamma = sg \times \gamma_{water} = 0.94 \times 62.4\frac{lb}{ft^3} = 58.66\frac{lb}{ft^3} = 0.03395lb/in^3$$

Clean coolant tank:

$$p_c = \gamma h = \left(0.03395\frac{lb}{in^3}\right)(120in) = 4.0736\ lb/in^2$$

$$t_c = \frac{p_c D_c}{2(SE + p_c Y)} = \frac{\left(4.0736\frac{lb}{in^2}\right)(192in)}{2\left(\left(14{,}866.5\frac{lb}{in^2} \times 0.85\right) + \left(4.0736\frac{lb}{in^2} \times 0.4\right)\right)} = 0.03094in$$

$$Corrosion\ allowance\ factor, t_{min} = t + A = 0.03094in + 0.08in = 0.11094in$$

Reservoir tank:

$$p_r = \left(0.03395\frac{lb}{in^3}\right)(84in) = 2.8518\ lb/in^2$$

$$t_r = \frac{\left(2.8518\frac{lb}{in^2}\right)(60in)}{2\left(\left(14{,}866.5\frac{lb}{in^2} \times 0.85\right) + \left(2.8518\frac{lb}{in^2} \times 0.4\right)\right)} = 0.00677in$$

$$t_{min} = t + A = 0.00677in + 0.08in = 0.08677in$$

Dirty Coolant tank:

$$p_d = \left(0.03395\frac{lb}{in^3}\right)(132in) = 4.4814\ lb/in^2$$

$$t_d = \frac{\left(4.4814\frac{lb}{in^2}\right)(108in)}{2\left(\left(14{,}866.5\frac{lb}{in^2} \times 0.85\right) + \left(4.4814\frac{lb}{in^2} \times 0.4\right)\right)} = 0.01915in$$

$$t_{min} = t + A = 0.01915in + 0.08in = 0.09915in$$

<u>Summary:</u>

- The needed wall thickness for the clean coolant tank would be 0.11094 in.
- The needed wall thickness for the reservoir tank would be 0.08677 in.
- The needed wall thickness for the dirty coolant tank would be 0.09915 in.

<u>Material:</u>

Stainless steel 304

<u>Analysis:</u>

The wall thicknesses were a bit thinner than expected. Perhaps a higher factor of safety would have given thicker walls.

Task 3 - Blind Flange

<u>Purpose:</u>

The blind flange will be used at the drain connection for the reservoir tank.

Drawings:

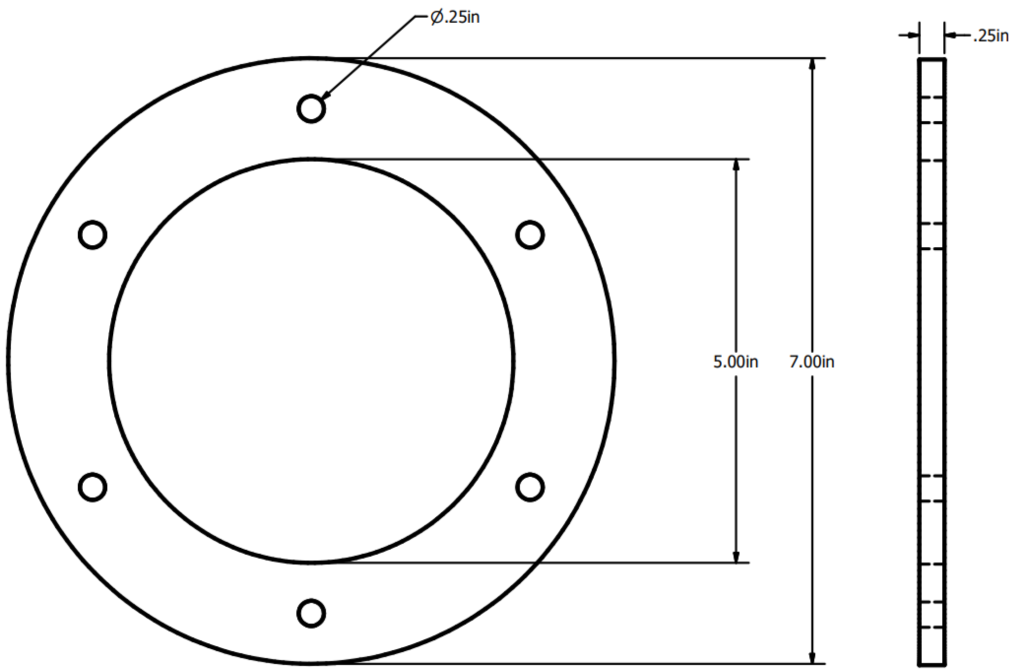


Figure 2 – Dimensions of Blind Flange

Figure 3 – Blind Flange

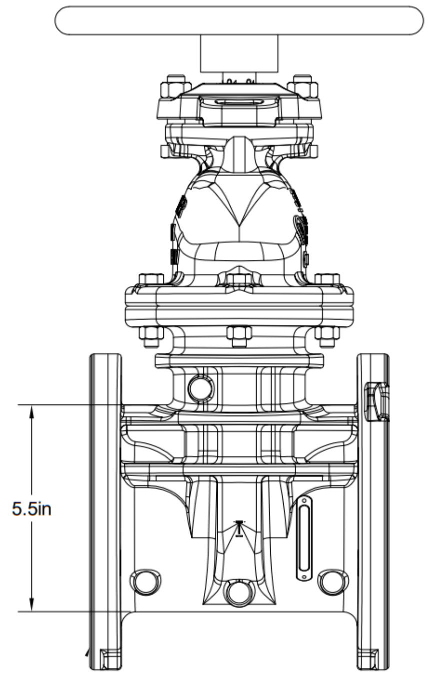


Figure 4 – Blind Flange Layout

Sources:

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

Design considerations:

This blind flange uses 6 bolts to ensure that a proper seal is established so that leakage will not occur, and that it can withstand pressure during operation

Procedure:

The blind flange is located at the reservoir tank and allows for the tank to be drained. The blind flange will be attached to a gate valve.

Materials:

Bolts	
Material	ASTM A307 steel
Strength	60000 psi
length	1.5 in
diameter	0.25 in
Flange	
Material	ASTM A36 steel
Strength	36000 psi
Inside Diameter	7 in
Outside Diameter	5 in
Thickness	0.25 in

Table 1 – Blind Flange Specifications

Variables:

Specific Gravity, SG = 0.94

Outside Diameter, OD = 5.5in = 0.458ft

Diameter, D = 5in

H_c = 7ft – (0.458 / 2) = 6.771ft

Bolts = 6

Force per bolt, F_{bolt}

Area of Flange, A_{flange}

Thickness of Flange, T_{flange}

Calculations:

Pressure:

Aflange = $(\pi D^2/4)$ = 19.6 in^2

γ = SG * γ_{water} = 0.94 * 62.4 lb/ft^3 = 58.656 lb/ft^3

P = Y * Hc = 58.656 * 6.771 = 397.2 lb/ft^2 = 2.75 Psi

F = P * A = (2.75Psi)(19.6 in^2) = 53.9 lb

Bolts:

F_{bolt} = (F / Bolts) = 53.9 / 6 = 8.98 lb per bolt

A_{bolt} = F_{bolt} / 60000psi = 0.00014 in^2

Minimum bolt diameter, D_{bolt} = Square root ((4* A_{bolt}) / (π)) = 0.0133in

Flange Thickness:

$$T_{flange} = 5.5\sqrt{\frac{0.3 \times 2.75}{36000 \times 1} + \frac{1.9 \times 53.9 \times 0.458}{36000 \times 5.5^3}} = 0.03in$$

Summary:

The blind flange designed for the system will have a thickness of 0.25 inches and use six 0.25-inch bolts to ensure that a proper watertight seal is established at the flange connection. This flange will be attached to a gate valve.

Task 11 – Wind Load and Weight

Purpose:

The purpose is to determine the wind load experienced by each tank for civil engineers

Drawings:

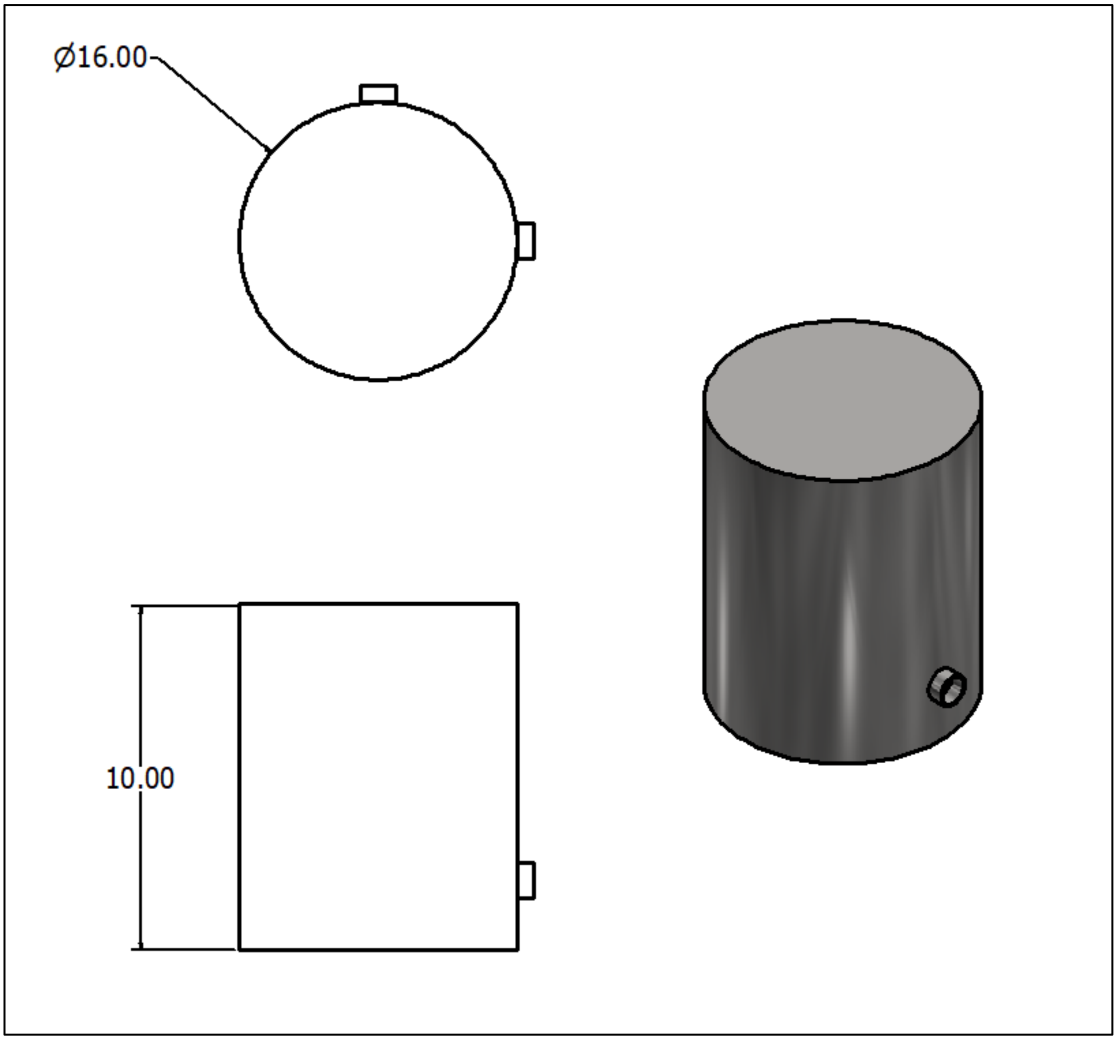


Figure 5 – Tank 1

Sources:

Mott, Robert L. and Joseph A. Untener. "Applied Fluid Mechanics." 7th ed.

https://weatherspark.com/h/y/15863/2021/Historical-Weather-during-2021-in-Dayton-Ohio-United-States#Figures-WindSpeed

Design Considerations:

Reservoir tank is located inside the building

Wind velocity is based on highest recorded wind speed during the 2021 year

Data & Variables:
v = 51mph = 81ft/s

Cd = 1.1

Pair = 2.8 x 10^{-3} slug/ft^3

Psteel = 15.5 slug/ft^3

Pcoolant = 1.82 slug/ft^3

G = 32.3 ft/s^2

D = outside diameter

d = inside diameter

H = outside height

h = inside height

<u>Procedure:</u>

1. Calculate the force of the wind using the drag force equation
2. Calculate the weight of each tank
3. Calculate the weight of the coolant in each tank

<u>Calculations:</u>

Tank 1

$$F_{wind} = 1.1 * 905ft^2 * \frac{2.8 * 10^{-3} * 81ft/s^2}{2} = 9144lb$$

$$W_{tank} = \rho_{steel} \left(\frac{\pi D^2 H}{4} - \frac{\pi d^2 h}{4}\right) \mathrm{g}$$

$$W_{tank} = \rho_{steel} \left(\frac{\pi 16^2 10}{4} - \frac{\pi 15.77^2 9.77}{4}\right) * 32.2$$

$$W_{tank} = 51223lb$$

$$W_{coolant} = \rho_{coolant} V_{tank} g$$

$$W_{coolant} = 1.8 * 1908 * 32.2$$

$$W_{coolant} = 110587lb$$

$$W_{tank1} = W_{coolant} + W_{tank}$$

$$W_{tank1} = 161810lb$$

Tank 3

$$F_{wind} = 1.1 * 439ft^2 * \frac{2.8 * 10^{-3} * 75ft/s^2}{2} = 4435lb$$

$$W_{tank} = \rho_{steel} \left(\frac{\pi D^2 H}{4} - \frac{\pi d^2 h}{4}\right)g$$

$$W_{tank} = 15.5 \left(\frac{\pi 9^2 11}{4} - \frac{\pi 8.8^2 10.8}{4}\right) * 32.2$$

$$W_{tank} = 21488lb$$

$$W_{coolant} = \rho_{coolant} V_{tank} g$$

$$W_{coolant} = 1.8 * 656 * 32.2$$

$$W_{coolant} = 38021lb$$

$$W_{tank3} = W_{coolant} + W_{tank}$$

$$W_{tank3} = 59509lb$$

Materials:

1. Coolant
2. Stainless Steel 304 tanks

Summary:

Tank	Wind load	Weight
1	9144lb	161810lb
3	4435lb	59509lb

Table 2 – Wind load and weight

Analysis:

If the civil engineers were concerned for the need to build a bracket to hold the tanks, the difference between when the tanks are empty or full should have no impact

Task 12 – Open channel

Purpose:

Design an open channel for the possibility of a tank failure.

Diagrams:

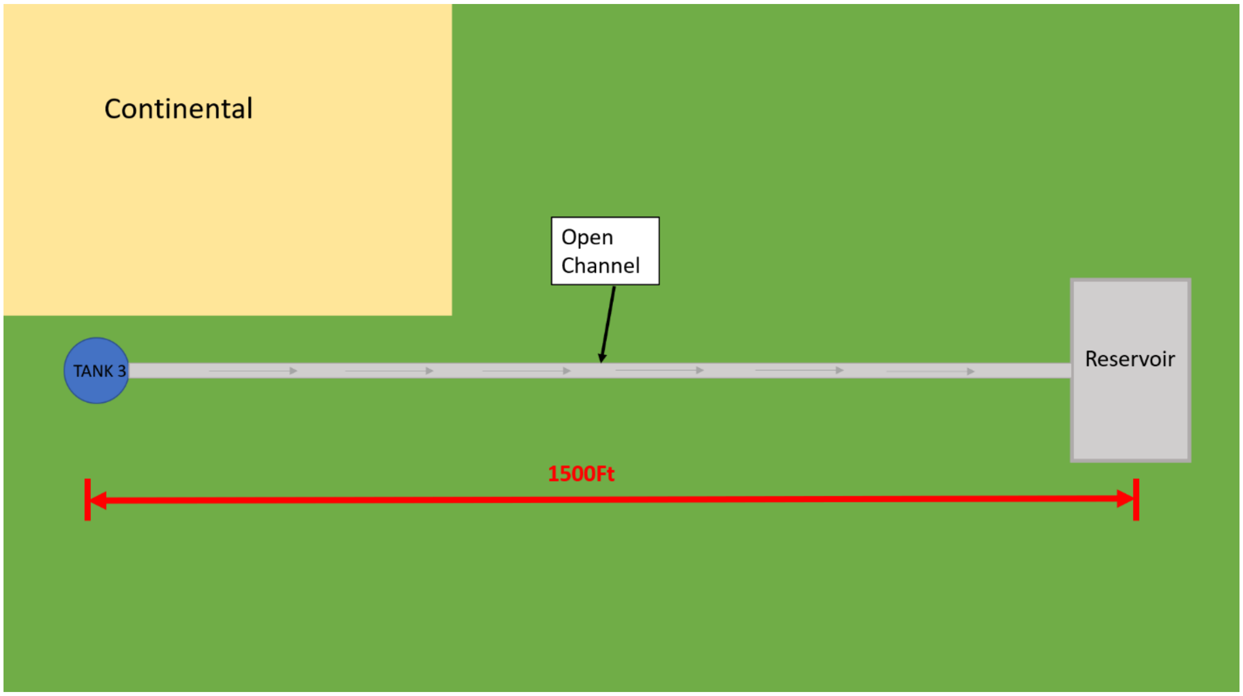


Figure 6 – Coolant Open Channel

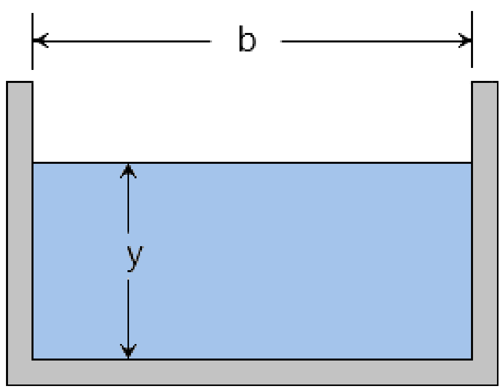


Figure 7 – Cross-section of Open Channel

Sources:

Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7^{th} ed. Pearson Edu. (2015)

Design Considerations:

The dirty coolant tank's (tank 3) variables will be used in the calculations. The fluid is incompressible.

Variables:

Q=0.097 ft^3/s v=9.84 ft/s

Procedure:

Start by calculating the area. Once the area is found the height and base of the channel can be found.

Calculations:

$$A = \frac{Q}{v} = \frac{0.097ft^3/s}{9.84ft/s} = 0.00986ft^2$$

$$A = by \rightarrow y = \sqrt{A/2} \rightarrow y = \sqrt{0.00986ft^2/2} = 0.0702ft$$

$$b = 2y = 2(0.0702ft) = 0.1404$$

$$WP = b + 2y = 0.1404ft + 2(0.0702ft) = 0.2808ft$$

$$R = \frac{A}{WP} = \frac{0.00986ft^2}{0.2808ft} = 0.0351ft$$

Summary:

The dimensions of the open channel are y = 0.0702ft, b = 0.1404ft, WP = 0.2808ft, and R = 0.0351ft.

Materials:

Coolant and unpainted steel.

Analysis:

If tank 3 were to fail, there would be a rectangular open channel to take it to a location that is 1500ft away from the plant safely.

5.f.ii. Flow Rate

Task 4 - Flow Rate

Purpose:
Estimate the time required to fill and empty each tank. Decide on a desired flow rate for each sub-system.

Sources:
Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7th ed. Pearson Edu. (2015)

Design Considerations:
Time required to fill or empty any single tank must be between 1 and 8 hours.

Variables:
Tank 1 volume: 2010.6 ft^3
Tank 2 volume: 137.4 ft^3
Tank 3 volume: 699.8 ft^3

Procedure:
The desired time required to fill each tank must be decided first. The volume of the tank in cubic feet can be divided by the desired fill time in seconds to obtain a flow rate. This must be done for the clean storage tank, the reservoir tank, and the dirty storage tank.

Calculations:
It is decided it will take 4 hours to fill the clean storage tank from the railcar.
Converting hours to seconds: $\frac{4\ hr}{1} * \frac{3600\ s}{1\ hr} = 14400\ s$
Solving for flow rate: $Q = \frac{V}{t} = \frac{2010.6\ ft^3}{14400\ s} = 0.140\ \frac{ft^3}{s}$

It is decided it will take 1 hour to fill or empty the reservoir tank from the clean storage tank.
Converting hours to seconds: $\frac{1\ hr}{1} * \frac{3600\ s}{1\ hr} = 3600\ s$
Solving for flow rate: $Q = \frac{V}{t} = \frac{137.4\ ft^3}{3600\ s} = 0.0382\ \frac{ft^3}{s}$

It is decided it will take 2 hours to empty the dirty storage tank into the truck.
Converting hours to seconds: $\frac{2\ hr}{1} * \frac{3600\ s}{1\ hr} = 7200\ s$
Solving for flow rate: $Q = \frac{V}{t} = \frac{699.8\ ft^3}{7200\ s} = 0.097\ \frac{ft^3}{s}$

Summary:
There will be four flow rates in the system:
System 1 (from railcar to clean storage): Q = 0.140 ft^3/s
System 2 (from clean storage to reservoir): Q = 0.0382 ft^3/s
System 3 (from reservoir to dirty storage): Q = 0.0382 ft^3/s
System 4 (from dirty storage to truck): Q = 0.097 ft^3/s

Materials:
The tanks are made of 304 Stainless Steel.

Analysis:
The times required to empty the clean storage tank and fill the dirty storage tank are assuming a constant flow rate with no stopping. This is the case for filling or emptying the reservoir tank. However, the clean storage tank will only be emptied long enough to fill the reservoir tank and the dirty storage tank will only be filled long enough so as to empty the reservoir tank.

5.f.iii. Pipe Sizing

Task 5 - Piping Layout, Material, and Sizes

Purpose:
Specify the overall layout of the piping system in relation to the tanks, the building, and other landmarks. Also determine the inside pipe diameter and pipe material.

Drawings:

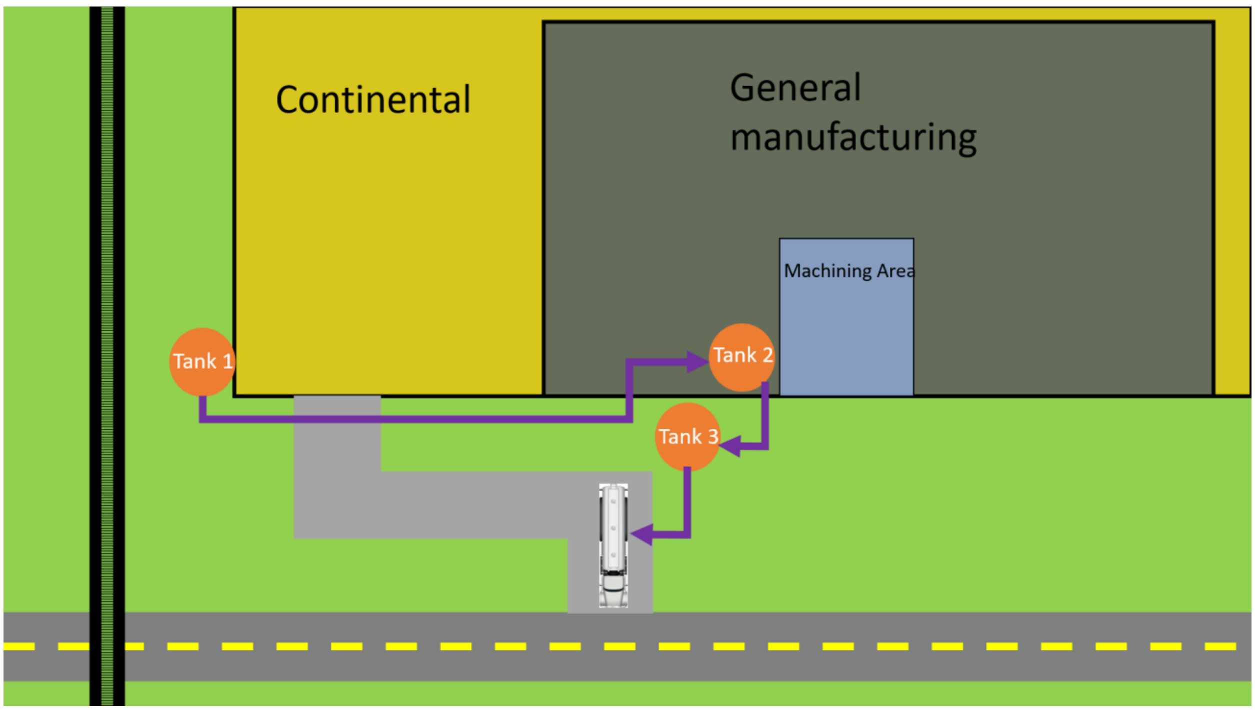


Figure 8 – General layout of system

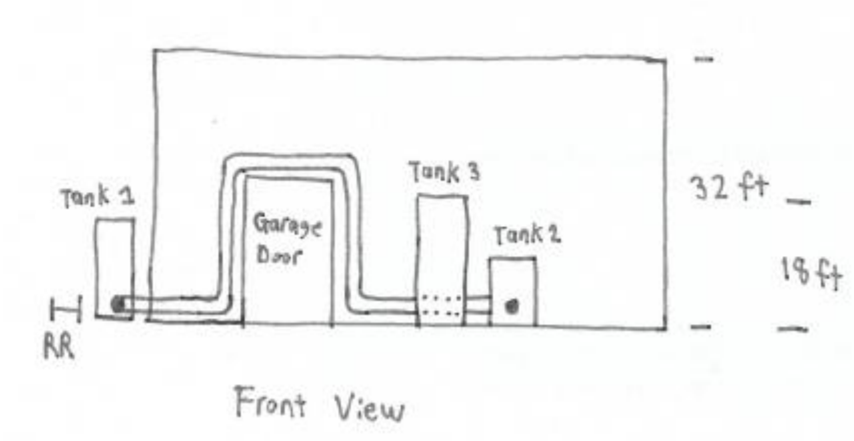


Figure 9 – Front view of pipe layout

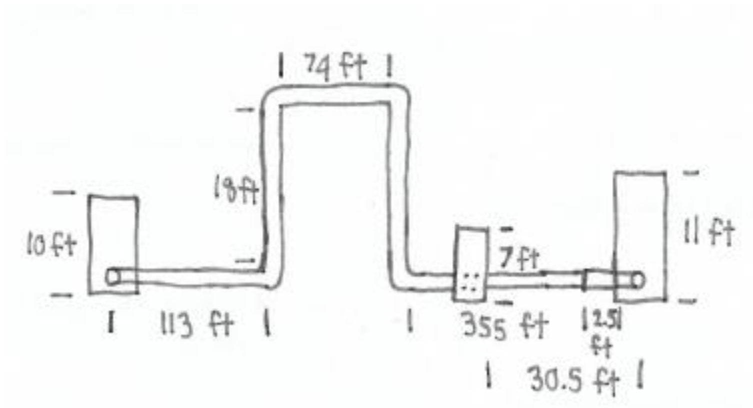


Figure 10 – Elevations of pipe layout

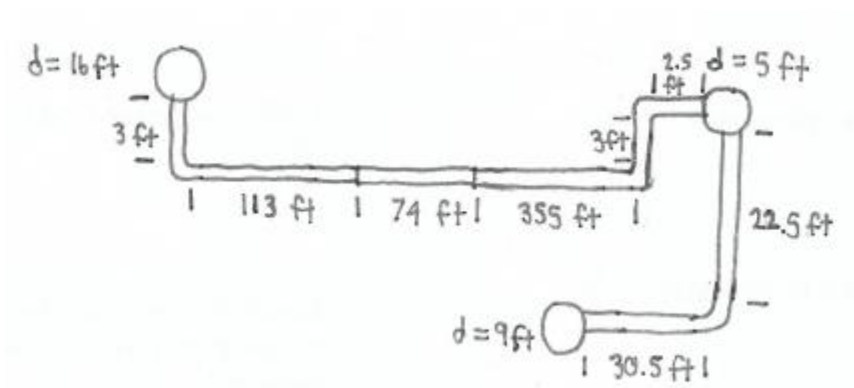


Figure 11 – Dimensions of pipe layout

<u>Sources:</u>

Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7th ed. Pearson Edu. (2015)

<u>Design Considerations:</u>

Pipe length should be minimized in order to cut down on friction losses and reduce pump requirements. Pipes must not interfere with the operation of the railroad, highway, or driveway.

The pipes will be kept one foot away from the building, the garage door, and the ground. The inside pipe diameter must be determined from the desired velocity and flow rate.

Variables:
Distance from the railroad tracks to the machining area is 600 ft.
Distance from the highway to the front side of the building is 200 ft.
The machining area is 100 ft. wide.
The roof is 32 ft. above the floor and the garage door is half the height of the roof.
Flow rate from Railcar to Tank 1 is 0.140 ft^3/s.
Flow rate inside the pipes between Tank 1 and Tank 3 is 0.0382 ft^3/s.
Flow rate from Tank 3 to Truck is 0.097 ft^3/s.
Desired velocity is approximately 9.84 ft/s.

Procedure:
The tank locations have been previously determined. The optimal piping route will be found by taking the shortest path between the tanks, minimizing pipe length and elbows where possible. The inside pipe diameter can be found from the flow rate equation since the desired velocity is known.

Calculations:
Distance from the railroad to the machining area: $76\ ft + 76\ ft + 72\ ft + 376\ ft = 600\ ft$
Tank 1 is halfway between the railroad and the left side of the building: $\frac{76\ ft}{2} = 38\ ft$
Distance from tank 1 to the left side of the garage door: $38\ ft + 76\ ft - 1\ ft = 113\ ft$
Distance across the top of the garage door: $72\ ft + 2\ ft = 74\ ft$
Height of the garage door: $\frac{32\ ft}{2} = 18\ ft$
Distance from the right side of the garage door to tank 2: $376\ ft - 15\ ft - 5\ ft - 1\ ft = 355\ ft$
Tank 2 is 25 ft. behind tank 3, so that pipe length is 25 ft. minus the radius of tank 2: $25\ ft - 2.5\ ft = 22.5\ ft$
Tank 3 is 35 ft. to the left of tanks 2, so that pipe length is 35 ft. minus the radius of tank 3:$35\ ft - 4.5\ ft = 30.5\ ft$
The Truck will be 30 ft in front of tank 3, and 15 feet to the left of tank 3.
$30\ ft + 15\ ft = 45\ ft$

From Railcar to Tank 1:

Inside pipe diameter: $A = \frac{Q}{V} = \frac{0.140\,\frac{ft^3}{s}}{9.84\,\frac{ft}{s}} = 0.0142\ ft^2$

The flow area of 1.5 inch Schedule 40 pipe is 0.01414 ft^2. This is what we will use.

Actual velocity becomes: $V = \frac{Q}{A} = \frac{0.140\,\frac{ft^3}{s}}{0.01414\ ft^2} = 9.90\ \frac{ft}{s}$

Between Tank 1 and Tank 3:

Inside pipe diameter: $A = \frac{Q}{V} = \frac{0.0382\,\frac{ft^3}{s}}{9.84\,\frac{ft}{s}} = 0.00388\ ft^2$

The flow area of 0.75 inch Schedule 40 pipe is 0.0037 ft^2. This is what we will use.

Actual velocity becomes: $V = \frac{Q}{A} = \frac{0.0382 \frac{ft^3}{s}}{0.0037\, ft^2} = 10.32\ \frac{ft}{s}$

From Tank 3 to Truck:

Inside pipe diameter: $A = \frac{Q}{V} = \frac{0.097 \frac{ft^3}{s}}{9.84 \frac{ft}{s}} = 0.00986\ ft^2$

The flow rea of 1.25 inch Schedule 40 pipe is 0.01039 ft^2. This is what we will use.

Actual velocity becomes: $V = \frac{Q}{A} = \frac{0.097 \frac{ft^3}{s}}{0.01039\, ft^2} = 9.34\ \frac{ft}{s}$

<u>Summary:</u>
In total, there is 684.5 feet of pipe and 9 elbows will be required.
Three-quarter inch Schedule 40 pipe will be used between Tank 1 and Tank 2, and between Tank 2 and Tank 3. One and a quarter inch Schedule 40 pipe will be used from Tank 3 to the Truck.

<u>Materials:</u>
Steel pipe and coolant.

<u>Analysis:</u>
The pipes stay close to the building to minimize length. However, the pipes are routed over the garage door so as not to interfere with the driveway. The pipe area solved for here is optimal, not necessarily the exact value. Calculations must be performed to determine the required pipe wall thickness before picking an exact pipe size and schedule.

Task 6 - Number, types, material, and size of all valves, elbows, and fittings

<u>Purpose:</u>

To specify the pipes and the fittings that will be used throughout each system uses in the cooling system.

<u>Drawings:</u>

Figures 8, 9, 10, and 11.

<u>Sources:</u>

Mott, R.L., Untener, J.A., “Applied Fluid Mechanics” 7th ed. Pearson Edu. (2015)

<u>Variables:</u>

Pipe length from tank 1 to tank 2 = 586.5ft

Pipe length from tank 2 to tank 3 = 53ft

Pipe length from tank 3 to disposal truck = 45ft

Materials:

Materials		
System	Description	Quantity
Tank 1 to Tank 2	0.75" Carbon Steel Schedule 40 Pipe	586.5 ft
	90° 0.75" Long Radius Elbow Schedule 40 Carbon Steel	7
	Class 150 312 Stainless Steel 0.75" Slip-On Flange	28
	Class 150 Slip-On Flange Gasket, Nuts, and Bolts Kit	28
	Gate Valve	1
	Swing-Type Check Valve	1
Tank 2 to Tank 3	0.75" Carbon Steel Schedule 40 Pipe	53 ft
	90° 0.75" Long Radius Elbow Schedule 40 Carbon Steel	1
	Class 150 312 Stainless Steel 0.75" Slip-On Flange	3
	Class 150 Slip-On Flange Gasket, Nuts, and Bolts Kit	3
	Gate Valve	1
	Swing-Type Check Valve	1
Tank 3 to Truck	1.25" Carbon Steel Schedule 40 Pipe	45 ft
	90° 1.25" Long Radius Elbow Schedule 40 Carbon Steel	1
	Class 150 312 Stainless Steel 1.25" Slip-On Flange	3
	Class 150 Slip-On Flange Gasket, Nuts, and Bolts Kit	3
	Gate Valve	1
	Swing-Type Check Valve	1

Table 3 – Bill of materials

Summary:

In total, there is 684.5 feet of pipe and 9 elbows will be required along with 34 slip on flanges. The design also calls for 3 gate valves and 3 swing-type check valves.

Analysis:

The pipe system will be going over the garage door. If a design change were to occur, such as burying the pipe, it will allow for less pipe to be used and allow for better flow rates through the system.

Task 9 - Pipe Wall Thickness

Purpose:

Specify the wall thickness for the pipes.

Drawings and Diagrams:

Figures 8, 9, 10, and 11.

Sources:

Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7th ed. Pearson Edu. (2015)

Variables:

V=10.32 ft/s E= 0.85 Y=0.40 γ=58.66 lb/ft^3 D=0.2982in

Allowable stress= 25,400 psi h_L=398.08 ft h_A=399.73 ft

Procedure:

Calculate wall thickness

Calculations:

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

$$10ft + 399.73ft - 398.08ft = \frac{p_2}{58.66lb/ft^3} + \frac{(10.32ft/s)^2}{2(32.2ft/s^2)}$$

$$p_2 = 586.38lb/ft^2 = 4.072psi$$

$$t = \frac{(4.072psi)(0.2982in)}{2((25{,}400psi)(0.85) + (4.072psi)(0.40))} = 0.000028in$$

$$t_{min} = 0.000023 + 0.08 = 0.080028in$$

Summary:

The wall thickness of the pipes should be about 0.080028in, schedule 40.

Materials:

The pipes are made out of steel

Analysis:

It seems that with the coolant we are using for this system schedule 40 pipes with a wall thickness of 0.080028in would work best.

Task 10 – Water Hammer

Purpose:
Check the system design for structural integrity in the case of water hammer.

Diagrams:
See Figures 10 and 11.

Sources:
Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7th ed. Pearson Edu. (2015)

Design Considerations:
These calculations will be done considering point 1 to be at the surface of the fluid inside Tank 1 and point 2 to be between the pump and the gate valve. The working fluid is assumed to be incompressible. Steady state operation and constant temperature are also assumed.

Variables:

Z_1 = 10 ft.	P_1 = 0 psig	Q = 0.0382 ft^3/s	Y = 0.4
Z_2 = 1 ft.	V_1 = 0 ft/s	V_2 = 10.32 ft/s	E_L = 1
γ = 58.66 lb/ft^3	ρ = 1.82 slug/ft^3	S = 14866.5 psi	OD = 1.05 in
h_a = 398.08 ft.	δ = 0.113 in	ID = 0.824 in	E_0 = 316000 psi
S.F. = 2	E = 29733 psi		

Procedure:
Calculate the speed of the wave generated by water hammer. The maximum pressure spike is then speed of the wave times normal operating velocity times density of the working fluid. The maximum pressure spike will be added to the normal operating pressure and the result will be used in the pipe thickness equation. If the pipe thickness required to withstand water hammer is less than the pipe thickness chosen for the system, then the pipes will not fail due to water hammer.

Calculations:
Speed of the wave caused by water hammer:

$$c = \frac{\sqrt{\frac{E_0}{\rho}}}{\sqrt{1 + \frac{E_0 * ID}{E * \delta}}} = \frac{\sqrt{\frac{45504000\ \frac{lb}{ft^2}}{1.82\ \frac{slug}{ft^3}}}}{\sqrt{1 + \frac{45504000\ \frac{lb}{ft^2} * 0.0687\ ft}{4281552\ \frac{lb}{ft^2} *\ 0.00942\ ft}}} = 564.32\ \frac{ft}{s}$$

Maximum pressure spike:

$$\Delta P_{max} = V_2 * \rho * c = 10.32 \frac{ft}{s} * 1.82 \frac{slug}{ft^3} * 564.32 \frac{ft}{s} = 10599.28 \frac{lb}{ft^2} = 73.61\, psi$$

Bernoulli's equation from point 1 to point 2:

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

Pressure and velocity at point 1 are zero. Because the pipe length is so short (less than 3 ft.), energy losses will also be neglected.

$$398.08\, ft + 10\, ft = \frac{P_2}{58.66 \frac{lb}{ft^3}} + \frac{10.32^2 \frac{ft}{s}}{2 * 32.17 \frac{ft}{s^2}} + 1\, ft$$

Normal operating pressure at point 2: $P_2 = 23782.21 \frac{lb}{ft^2} = 165.15\, psig$

Maximum pressure inside the pipe:

$$P_{max} = P_2 + \Delta P_{max} = 165.15\, psig + 73.61\, psi = 238.76\, psig$$

Pipe thickness equation:

$$t = \frac{P_{max} * OD}{2(S * E_L + P_{max} * Y)} = \frac{238.76\, psig * 1.05\, in}{2(14866.5\, psi * 1 + 238.76\, psig * 0.4)} = 0.00838\, in$$

Summary:

The minimum pipe thickness required to withstand water hammer is 0.00838 in. The actual thickness of 0.75 in Schedule 40 steel pipe is 0.113 in. Therefore, the system will not fail due to water hammer.

Materials:

Coolant and 0.75 inch Schedule 40 steel pipe.

Analysis:

The strongest pump in the system is located after Tank 1, therefore the highest pressure in the system is immediately after this pump. Adding the pressure spike due to water hammer to the highest operating pressure in the system should ensure the entire system is structurally sound. If the size or the material of the pipe were to change, this would change the speed of the wave and affect the pressure spike caused by water hammer.

5.f.iv. Provide pipeline support info

Task 13 - Supports

Purpose:
Determine the type of pipe supports to be used for one system. Also calculate the load these supports must hold and the maximum allowable distance between the supports.

Diagrams:

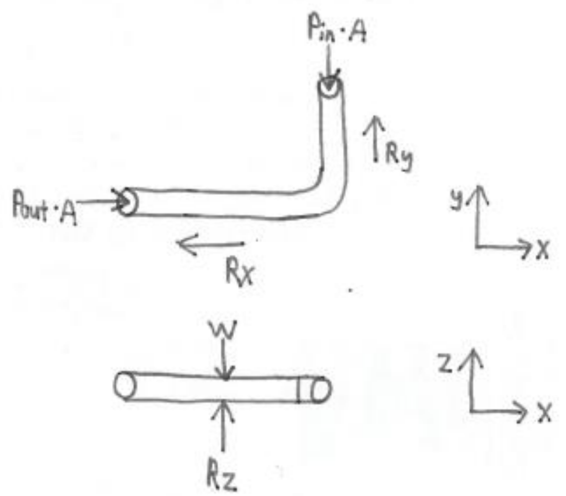


Figure 12 – Forces acting on the pipes

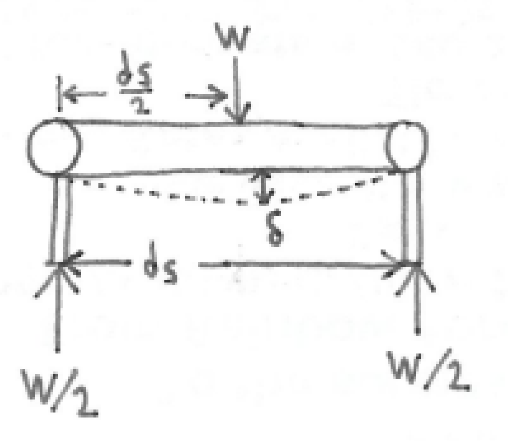


Figure 13 – Dimensions of the pipes

Figure 14 – The supports

Sources:
Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7th ed. Pearson Edu. (2015)
Spotts, M.F., Shoup, T.E., "Design of Machine Elements" 8th ed. Pearson Edu. (2004)

Design Considerations:
These calculations are for the system between the reservoir tank and the dirty storage tank. Flow rate and all properties are assumed to be constant. The Y-axis will be considered parallel to the railroad tracks, the X-axis parallel to the highway, and the Z-axis perpendicular to the ground. For the beam deflection equation, the pipe will be modelled as a hollow cylinder.

Variables:

S.G. = 0.94	$Q = 0.0382\ ft^3/s$	L = 53 ft	$A = 0.0037\ ft^2$
ID = 0.0687 ft	V = 10.32 ft/s	$\gamma = 58.66\ lb/ft^3$	$\rho = 1.824\ slug/ft^3$
$h_L = 40.21$ ft	$h_a = 398.08$ ft	$g = 32.17\ ft/s^2$	h = 7 ft
$E = 4281552\ lb/ft^2$	$\rho_{steel} = 15.33\ slug/ft^3$	OD = 0.0875 ft	

Procedure:
Calculate the pressure at the pipe inlet and exit for the system. Then determine the reaction forces exerted on the fluid by the pipes, assuming static equilibrium. These are the forces the supports must provide to keep the pipes from moving. A maximum allowable pipe deflection will be decided, then the maximum distance between the pipe supports will be calculated using a beam deflection equation.

Calculations:
Pressure at the pipe inlet is equal to the pressure due to fluid elevation in Tank 2:

$$P_{in} = \gamma * h = 58.66\ \frac{lb}{ft^3} * 7\ ft = 410.62\ \frac{lb}{ft^2} = 2.85\ psig$$

Pressure at the pipe outlet must be found with Bernoulli's equation between the pipe inlet and outlet:

$$h_a + \frac{P_{in}}{\gamma} + \frac{V_{in}^2}{2g} + Z_{in} = h_L + \frac{P_{out}}{\gamma} + \frac{V_{out}^2}{2g} + Z_{out}$$

Velocity at the inlet is zero. The inlet and outlet elevations are also equal. Pump head and energy loss were solved for in earlier tasks. Bernoulli's equation becomes the following:

$$P_{out} = \gamma * \left(h_a + \frac{P_{in}}{\gamma} - h_L - \frac{V_{out}^2}{2g}\right)$$

$$P_{out} = 58.66\ \frac{lb}{ft^3} * \left(398.09\ ft + \frac{410.62\ \frac{lb}{ft^2}}{58.66\ \frac{lb}{ft^3}} - 40.21\ ft - \frac{10.32^2\ \frac{ft}{s}}{2 * 32.17\ \frac{ft}{s^2}}\right) = 21306.24\ \frac{lb}{ft^2}$$

Forces in the x direction:

$$\Sigma F_x = (P_{out} * A) - R_x = \rho * Q * (V_{out,x} - V_{in,x})$$

There is no velocity in the x direction at the inlet. Solving for Rx:

$$R_x = (P_{out} * A) - (\rho * Q * V_{out})$$

$$R_x = \left(21306.24\ \frac{lb}{ft^2} * 0.0037\ ft^2\right) - \left(1.824\ \frac{slug}{ft^3} * 0.0382\ \frac{ft^3}{s} * -10.32\ \frac{ft}{s}\right) = 79.55\ lb$$

Forces in the y direction:

$$\Sigma F_y = R_y - (P_{in} * A) = \rho * Q * (V_{out,y} - V_{in,y})$$

There is no velocity in the y direction at the exit. Solving for Ry:

$$R_y = \rho * Q * -V_{in,y} + (P_{in} * A)$$

$$R_y = \left(1.824\ \frac{slug}{ft^3} * 0.0382\ \frac{ft^3}{s} * 10.32\ \frac{ft}{s}\right) + \left(410.62\ \frac{lb}{ft^2} * 0.0037\ ft^2\right) = 2.24\ lb$$

Forces in the z direction:

There is no velocity acting in the z direction, therefore Rz is equal to the weight of the fluid:

$$R_z = W = \gamma * V = \gamma * A * L = 58.66\ \frac{lb}{ft^3} * 0.0037\ ft^2 * 53\ ft = 11.5\ lb$$

It is decided the allowable pipe deflection will be 5% of the pipe diameter:

$$\delta = 0.0687\ ft * 0.05 = 0.003435\ ft$$

Cross sectional area of the steel pipe:

$$A_p = \frac{\pi * OD^2}{4} - \frac{\pi * ID^2}{4} = \frac{\pi(0.0875^2\ ft - 0.0687^2\ ft)}{4} = 0.00231\ ft^2$$

Moment of inertia for pipe cross section:

$$I = \frac{\pi(OD^4 - ID^4)}{64} = \frac{\pi(0.0875^4\ ft - 0.0687^4\ ft)}{64} = 1.784 * 10^{-6}\ ft^4$$

Deflection equation for a beam with two simple supports:

$$\delta = \frac{W * d_s^3}{48 * E * I}$$

W is the weight of the pipe plus the weight of the fluid in the pipe.

Weight of the fluid:

$W_f = \gamma * A * d_s$

Weight of the pipe:

$W_p = \rho_{steel} * g * A_p * d_s$

$$W = W_f + W_p = d_s\left(\gamma * A + \rho_{steel} * A_p * g\right) = 1.356 d_s$$

The deflection equation becomes:

$$0.003435\ ft = \frac{1.356 * d_s^4}{48 * 4281552\ \frac{lb}{ft^2} * 1.784 * 10^{-6}\ ft^4}$$

Solving for d_s:

$$d_s = \sqrt[4]{\frac{0.003435\ ft * 48 * 4281552\ \frac{lb}{ft^2} * 1.784 * 10^{-6}\ ft^4}{1.356}} = 0.98\ ft$$

Summary:

The supports must provide 79.55 lb in the negative x direction, 2.24 lb in the positive y direction, and 11.5 lb in the positive z direction. The maximum distance between supports must be 0.98 ft or 11.75 in. Rigid pipe supports similar to those shown in the figure will be used.

Materials:

0.75 in Schedule 40 steel pipe

Analysis:

If the maximum pipe deflection is 5% of the pipe diameter, or 0.041 in, this requires one support for every foot of pipe. This seems excessive, which could incur unnecessary expenses. Perhaps the allowable deflection could be greater.

5.f.v. Energy losses

Task 7 - Hydraulic Analysis

Purpose:

Conduct a hydraulic analysis of the piping system. Determine the losses due to friction and minor losses due to elbows, valves, and other fittings.

Drawings:

Figures 8, 9, 10, and 11.

Sources:

Mott, R.L., Untener, J.A., “Applied Fluid Mechanics” 7th ed. Pearson Edu. (2015)

Design Considerations:
The major and minor losses will be calculated for each section of the piping system.
Section 1 contains 586.5 ft. of pipe, 7 elbows, 1 gate valve, and 1 check valve.
Section 2 contains 53 ft. of pipe, 1 elbow, 1 gate valve, and 1 check valve.
Section 3 contains 45 ft. of pipe, 1 gate valve, and 1 check valve.

Variables:

$Q_1 = 0.0382\ ft^3/s$	$A_1 = 0.0037\ ft^2$	$V_1 = 10.32\ ft/s$	$D_1 = 0.0687\ ft.$
$Q_2 = 0.0382\ ft^3/s$	$A_2 = 0.0037\ ft^2$	$V_2 = 10.32\ ft/s$	$D_2 = 0.0687\ ft.$
$Q_3 = 0.097\ ft^3/s$	$A_3 = 0.0104\ ft^2$	$V_3 = 9.34\ ft/s$	$D_3 = 0.115\ ft.$
$L_1 = 586.5\ ft.$	$L_2 = 53\ ft.$	$L_3 = 45\ ft.$	
$f_{T1} = 0.024$	$f_{T2} = 0.024$	$f_{T3} = 0.021$	
$g = 32.17\ ft/s^2$	$\varepsilon = 1.5 * 10^{-4}\ ft.$		

Le/D = 20 for 90° long radius elbow
Le/D = 8 for fully open gate valve
Le/D = 100 for swing type check valve

Procedure:
For each section of pipeline, Reynold's number will be calculated to determine if the flow is laminar or turbulent. Then the friction factor must be determined before using Darcy's energy loss equation to solve for the friction loss in the pipes. Next, the resistance coefficient will be found for the elbows and valves to calculate minor losses.

Calculations:
Kinematic viscosity of the coolant is 1.5 times that of water:

$$\nu = 1.5 * (1.05 * 10^{-5})\frac{ft^2}{s} = 1.575 * 10^{-5}\ \frac{ft^2}{s}$$

Section 1:
Reynold's number:

$$Re_1 = \frac{V_1 * D_1}{\nu} = \frac{10.32\ \frac{ft}{s} * 0.0687\ ft}{1.575 * 10^{-5}\ \frac{ft^2}{s}} = 45{,}015$$

Friction factor for turbulent flow:

$$f_1 = \frac{0.25}{(\log\left(\frac{1}{3.7 * \frac{D_1}{\varepsilon}} + \frac{5.74}{Re_1^{0.9}}\right))^2} = \frac{0.25}{(\log(\frac{1}{3.7 * \frac{0.0687\ ft}{1.5 * 10^{-4}\ ft}} + \frac{5.74}{45015^{0.9}}))^2} = 0.0275$$

Darcy's equation for friction loss in section 1:

$$h_{Lp} = f_1 * \frac{L_1}{D_1} * \frac{V_1^2}{2 * g} = 0.0275 * \frac{586.5\ ft}{0.0687\ ft} * \frac{10.32^2\ \frac{ft}{s}}{2 * 32.17\ \frac{ft}{s^2}} = 388.22\ ft$$

Minor energy loss in each elbow:

$$h_{Le} = \frac{Le}{D} * f_{T1} * \frac{V_1^2}{2 * g} = 20 * 0.024 * \frac{10.32^2 \ \frac{ft}{s}}{2 * 32.17 \ \frac{ft}{s^2}} = 0.795 \ ft$$

Minor energy loss in each gate valve:

$$h_{Lgv} = \frac{Le}{D} * f_{T1} * \frac{V_1^2}{2 * g} = 8 * 0.024 * \frac{10.32^2 \ \frac{ft}{s}}{2 * 32.17 \ \frac{ft}{s^2}} = 0.318 \ ft$$

Minor energy loss in each check valve:

$$h_{Lcv} = \frac{Le}{D} * \ f_{T1} * \frac{V_1^2}{2 * g} = \ 100 \ * 0.024 * \frac{10.32^2 \ \frac{ft}{s}}{2 * 32.17 \ \frac{ft}{s^2}} = \ 3.973 ft$$

Total energy loss for section 1:

$$h_{L1} = h_{Lp} + 7 * h_{Le} + \ h_{Lgv} + h_{Lcv} = 398.08 \ ft$$

Section 2:

Reynold's number:

$$Re_2 = \frac{V_2 \ * \ D_2}{\nu} = \frac{10.32 \ \frac{ft}{s} \ * \ 0.0687 \ ft}{1.575 \ * \ 10^{-5} \ \frac{ft^2}{s}} = 45{,}015$$

Friction factor for turbulent flow:

$$f_2 = \frac{0.25}{(\log\left(\frac{1}{3.7 * \frac{D_2}{\varepsilon}} + \frac{5.74}{Re_2^{0.9}}\right))^2} = \frac{0.25}{(\log (\frac{1}{3.7 * \frac{0.0687 \ ft}{1.5 * \ 10^{-4} \ ft}} + \frac{5.74}{45015^{0.9}}))^2} = 0.0275$$

Darcy's equation for friction loss in section 2:

$$h_{Lp} = f_2 * \frac{L_2}{D_2} * \frac{V_2^2}{2 * g} = 0.0275 * \frac{53 \ ft}{0.0687 \ ft} * \frac{10.32^2 \ \frac{ft}{s}}{2 * 32.17 \ \frac{ft}{s^2}} = 35.12 \ ft$$

Minor energy loss in each elbow:

$$h_{Le} = \frac{Le}{D} * f_{T2} * \frac{V_2^2}{2 * g} = 20 * 0.024 * \frac{10.32^2 \ \frac{ft}{s}}{2 * 32.17 \ \frac{ft}{s^2}} = 0.795 \ ft$$

Minor energy loss in each gate valve:

$$h_{Lgv} = \frac{Le}{D} * f_{T2} * \frac{V_2^2}{2 * g} = 8 * 0.024 * \frac{10.32^2 \frac{ft}{s}}{2 * 32.17 \frac{ft}{s^2}} = 0.318\ ft$$

Minor energy loss in each check valve:

$$h_{Lcv} = \frac{Le}{D} * f_{T2} * \frac{V_2^2}{2 * g} = 100 * 0.024 * \frac{10.32^2 \frac{ft}{s}}{2 * 32.17 \frac{ft}{s^2}} = 3.973\ ft$$

Total energy loss for section 2:

$$h_{L2} = h_{Lp} + h_{Le} + h_{Lgv} + h_{Lcv} = 40.21\ ft$$

Section 3:

Reynold’s number:

$$Re_3 = \frac{V_3 * D_3}{\nu} = \frac{9.34 \frac{ft}{s} * 0.115\ ft}{1.575 * 10^{-5} \frac{ft^2}{s}} = 68{,}197$$

Friction factor for turbulent flow:

$$f_3 = \frac{0.25}{(\log\left(\frac{1}{3.7 * \frac{D_3}{\varepsilon}} + \frac{5.74}{Re_3^{0.9}}\right))^2} = \frac{0.25}{(\log(\frac{1}{3.7 * \frac{0.115\ ft}{1.5 * 10^{-4}\ ft}} + \frac{5.74}{68197^{0.9}}))^2} = 0.0242$$

Darcy’s equation for friction loss in section 2:

$$h_{Lp} = f_3 * \frac{L_3}{D_3} * \frac{V_3^2}{2 * g} = 0.0242 * \frac{45\ ft}{0.115\ ft} * \frac{9.34^2 \frac{ft}{s}}{2 * 32.17 \frac{ft}{s^2}} = 12.84\ ft$$

Minor energy loss in each gate valve:

$$h_{Lgv} = \frac{Le}{D} * f_{T3} * \frac{V_2^2}{2 * g} = 8 * 0.021 * \frac{9.34^2 \frac{ft}{s}}{2 * 32.17 \frac{ft}{s^2}} = 0.228\ ft$$

Minor energy loss in each check valve:

$$h_{Lcv} = \frac{Le}{D} * f_{T3} * \frac{V_3^2}{2 * g} = 100 * 0.021 * \frac{9{,}34^2 \frac{ft}{s}}{2 * 32.17 \frac{ft}{s^2}} = 2.847\ ft$$

Total energy loss for section 3:

$$h_{L2} = h_{Lp} + h_{Lgv} + h_{Lcv} = 15.92\ ft$$

Total energy loss for the entire system:
$h_L = h_{L1} + h_{L2} + h_{L3} = 454.21\ ft$

Summary:
Energy loss in section 1 is 398.08 ft. Energy loss in section 2 is 40.21 ft. Energy loss in section 3 is 15.92 ft. Total energy loss of the whole system is 454.21 ft.

Materials:
All pipes are made of welded steel. The working fluid is a mixture of water and oil with a specific gravity of 0.94.

Analysis:
The energy loss for section 1 seems quite large. This is due to the extensive length of pipe the fluid must travel through. A large pump will be required to overcome this friction loss. Friction loss could possibly be reduced by decreasing the velocity, decreasing pipe length, or increasing the pipe diameter.

5.f.vi. Pump Selection

Task 8 - Pump Requirements

Purpose:

To determine the minimum number of pumps required for system operation and to layout pump placement

Sources:
Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7th ed. Pearson Edu. (2015)

Drawings:

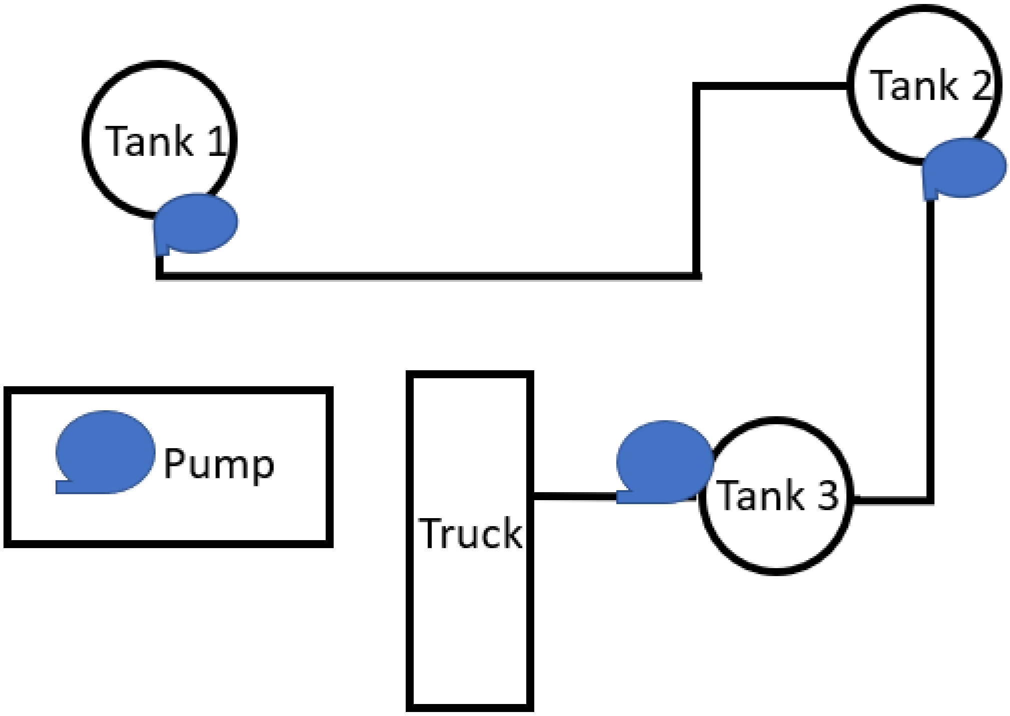


Figure 15 – Pump Layout

Design Considerations:

1. The pipes from tank 1 to tank 2 have more energy loss
2. The pipes from tank 2 to tank 3 will have less energy loss
3. 2" Schedule 40 steel pipe

If we calculate for pump 1, which has the most h_L and will require a higher h_a, then we could theoretically use the same type of pump throughout the other systems

Variables:

$Q = 0.097\ ft^3/s$

$V = 10.32\ ft/s$

$h_L = 398.08\ ft$

$Y = 0.94$

Procedure:

Using the previously calculated flow rate and energy loss from tasks 4 & 7 we can determine requirements for the pumps used in the system. Using these numbers, we can plug numbers from Bernoulli's equation and then calculate the minimum for the pumps.

Calculations:

Pump 1: After plugging in 0's from Bernoulli's equation we can see that all that is left for calculating pump minimums is:

$$h_a = \frac{v^2}{2g} + h_L$$

$$h_a = 399.73\ ft$$

Materials:

1. 2" schedule 40 pipe
2. 2" 90-degree elbows
3. Pumps

Summary:

In conclusion the system will require pumps with a minimum spec of:

Q = 0.097 Ft^3/min

h_a= 399.73 ft

Task 15 – Pump Selection

Purpose:

To specify the number of pumps, their types, head requirements, flow capacities, and power required.

<u>Drawings:</u>

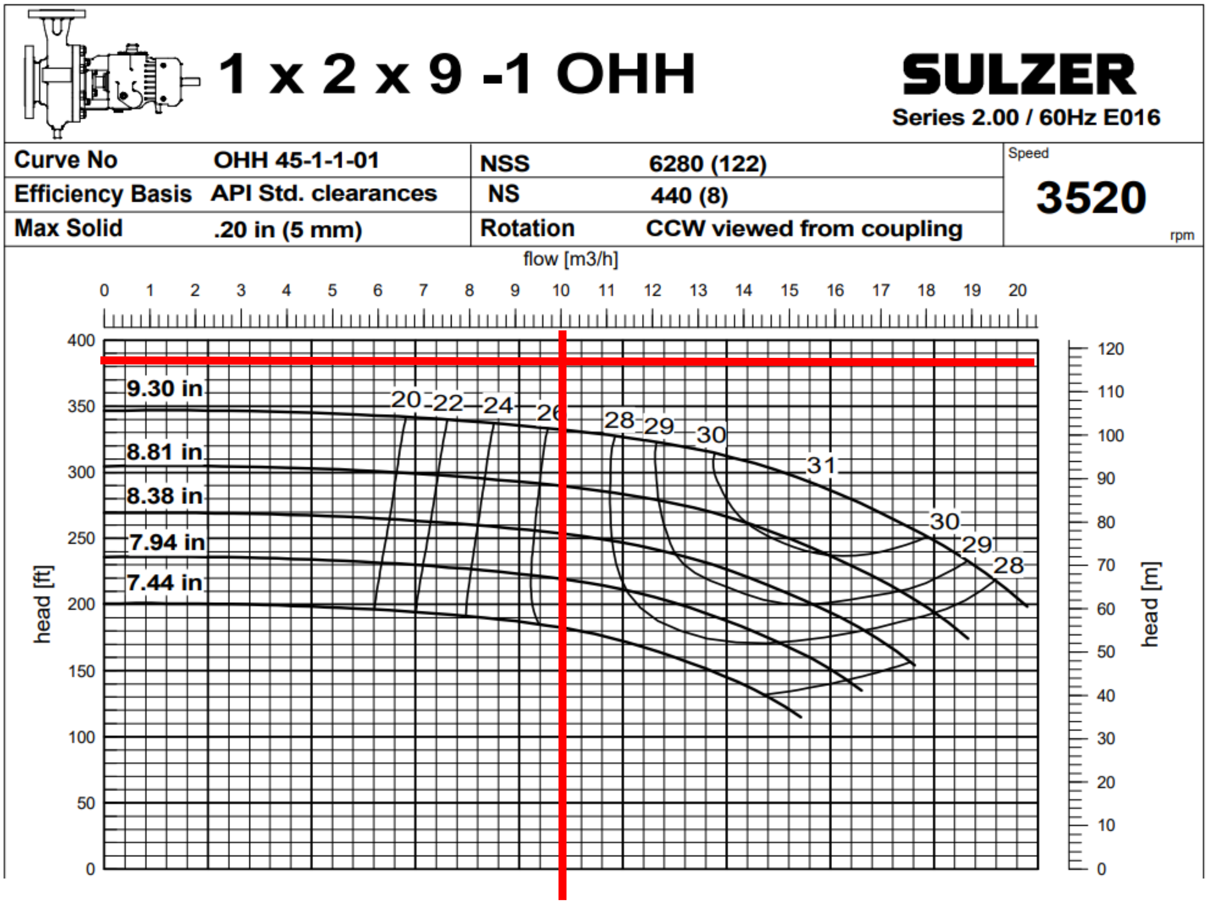


Figure 16 – Impeller diameter

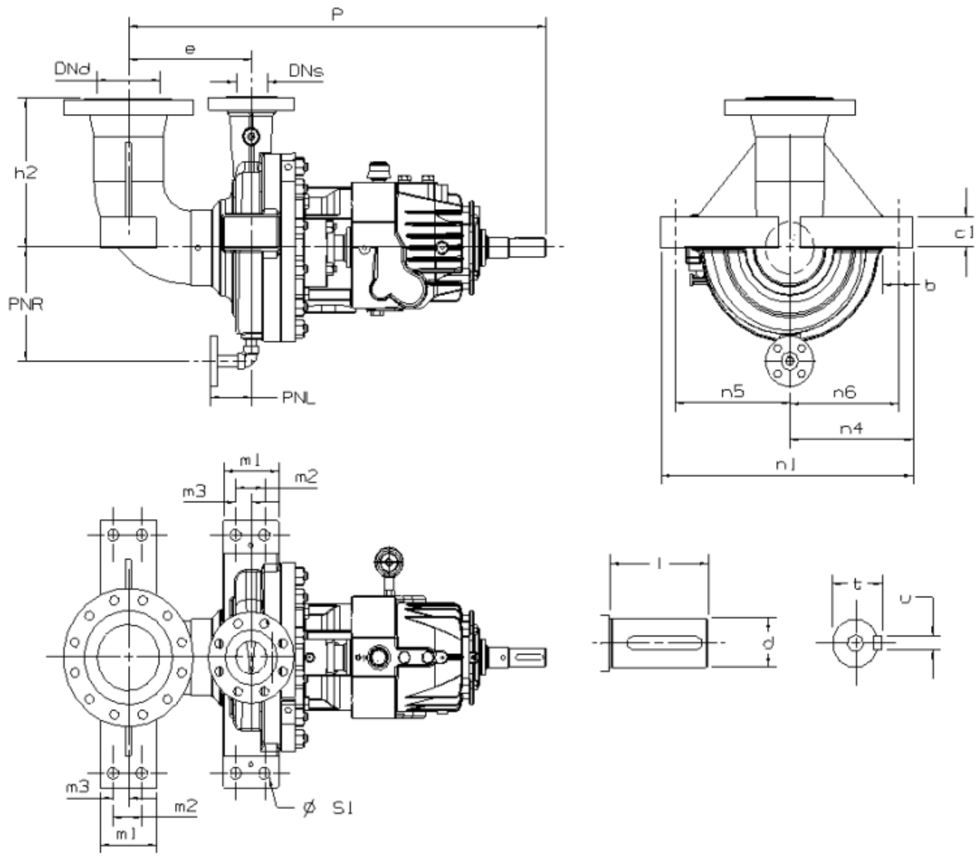


Figure 17 – Pump diagram

Sources:

Robert L. Mott. and Joseph A. Untener. (2014), Applied Fluid Mechanics (7th Edition)

Design Considerations:

Only using Sulzer pumps

Data:

Q = 0.0382 ft^3/s

Ha = 398.08 ft

Procedure:

The system will use 3 pumps in total. The pump with the most head will be used for all applications in the system, as it will work in every location. The specific speed needs to be calculated first, then the power requirements.

Calculations:

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

$$N_s = \frac{3570rpm\sqrt{43.53}}{398.08^{3/4}}$$

$$N_s = 264.29$$

$$P = H_a Y Q$$

$$P = \frac{398.08 * 58.66 * 2.292}{33{,}000}$$

$$P = 1.62hp$$

Materials:

- 1 x 2 x 9 -1 OHH Pumps, Quantity: 3
- Coolant

Summary:

Pump type	Quantity	Efficiency	Power Required
1 x 2 x 9 -1 OHH	3	26%	1.62 hp

Table 4 – Pump information

Analysis:

Three of the 1x2x9-1OHH pumps are required for the system, if we were to decrease the required head by changing the losses in the system then a smaller impeller size would be more viable, and the required power would decrease.

Task 16 – Pump characteristics

Purpose:

To provide pump characteristics from the Sulzer catalog

Drawings:

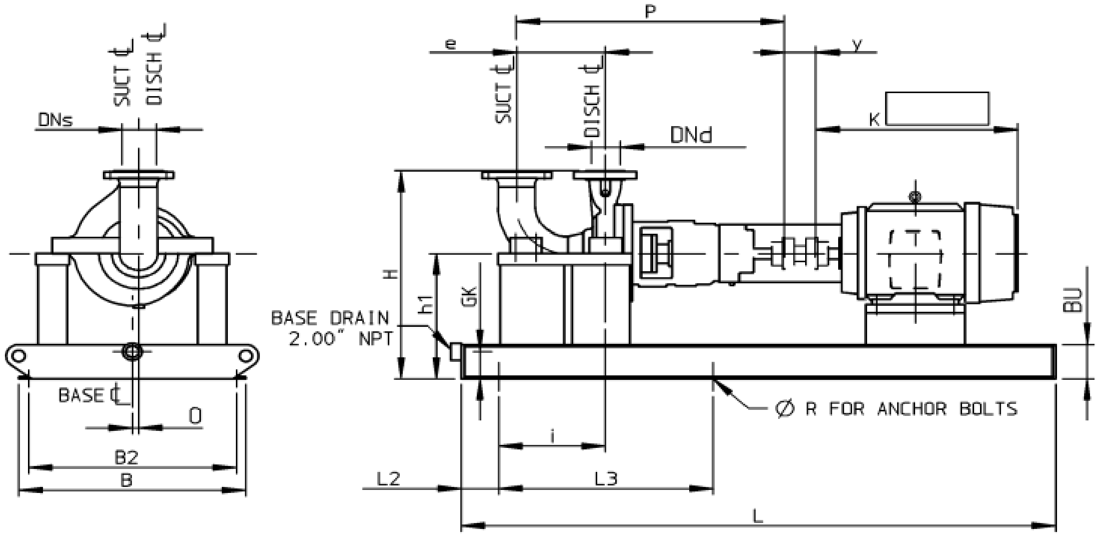
Figure 17 as well as:

SULZER

DIMENSIONAL DATA - TYPE OHH

General Arrangement Dimensions – Top Suction – US Customary Units

Series **2.00**	Page
DIMENSIONS	US
October - 02	**D09**



Certified by :____________________
Date: ______________ Certified for Nozzle &
Anchor Bolt locations only when signed above
Ref No. : ________________________________
Project Name : ______________________________
Project Item No.: ____________________________

HH -- Number of Base Hold Down Holes each side, equally spaced.

L3 -- Distance between holes.

GH -- Minimum Number of Grout Holes.

API No.	Base wt lbs	B	B2	BU	L	L2	L3	R	GK	HH	GH
1.5	800	30	27	6	72.5	6	30.25	1	4.75	3	4
2.0	930	30	27	6	84.5	6	24.16	1	4.75	4	4
13	Non API Baseplate. Used when the standard API baseplates are too small to accommodate the required driver										

Dimension K is derived from NEMA standards or motor supplier catalogue The rotation is counterclockwise – H.I. looking from Drive End. All dimensions are nominal inches and for guidance only. Certified Drawings will be issued for actual construction.

WP-XXX

When Available 'TS" frame should be used to minimize coupling size, there is no price difference on drivers.

PUMP SIZE	PUMP wt lbs	DNs	DNd	O	B	e	P	h1	i	H	y	BASE REFERENCE (Electric Driver - NEMA Frame)
		in										
1x2x7.5-1	362	2	1	0	30	6.89	33.03	18	**5.83**	27.06	5	1.5 (143T-215T)
2x3x7.5A-1	409	3	2	0	30	9.84	36.10	18	**9.28**	27.06	5	2.0 (254T-286T) (284TS-326TS)
2x3x7.5B-1	408	3	2	0	30	9.84	36.10	18	**9.28**	27.06	5	13 (324T-405T) (364TS-405TS)
3x4x7.5-1	443	4	3	0	30	11.61	37.95	18	**11.60**	27.06	5	
4x6x7.5B-1	545	6	4	0	30	13.78	40.47	18	**15.01**	28.04	5	
4x6x7.5A-1	545	6	4	0	30	13.78	40.47	18	**15.01**	28.04	5	
6x6x7.5-1	722	6	6	1	30	13.98	41.57	18	**15.21**	30.60	7	13 (284T-365T) (284TS-365TS)
1.5x3x8-1	409	3	1.5	0	30	8.46	34.96	18	**6.90**	27.06	5	1.5 (143T-254T)
2x3x8-1	410	3	2	0	30	8.86	35.51	18	**8.30**	27.06	5	2.0 (256T-365T) (324TS-365TS)
3x4x8A-1	445	4	3	0	30	10.24	36.77	18	**10.22**	27.45	5	13 (404T-405T) (404TS-405TS)
3x4x8B-1	456	4	3	0	30	10.24	36.97	18	**10.22**	27.45	5	
3x4x8B-2	456	4	3	0	30	10.24	36.97	18	**10.22**	27.45	5	
1x2x9-1	366	2	1	0	30	7.48	33.62	18	**16.42**	27.06	5	
1.5x3x9-1	403	3	1.5	0	30	8.46	34.65	18	**7.90**	27.06	5	
2x3x9A-1	410	3	2	0	30	8.46	34.69	18	**7.90**	27.45	5	
2x3x9B-1	406	3	2	0	30	8.46	34.76	18	**7.90**	27.45	5	
2x4x9-1	452	4	2	0	30	9.45	35.71	18	**9.43**	28.04	5	
3x4x9-1	473	4	3	0	30	11.61	37.95	20	**11.60**	30.43	5	
3x4x9-2	473	4	3	0	30	11.61	37.95	20	**11.60**	30.43	5	
3x6x9-1	474	6	3	0.5	30	11.81	38.23	20	**13.05**	31.02	5	
3x6x9-2	474	6	3	0.5	30	11.81	38.23	20	**13.05**	31.02	5	

Figure 18 – Pump selection

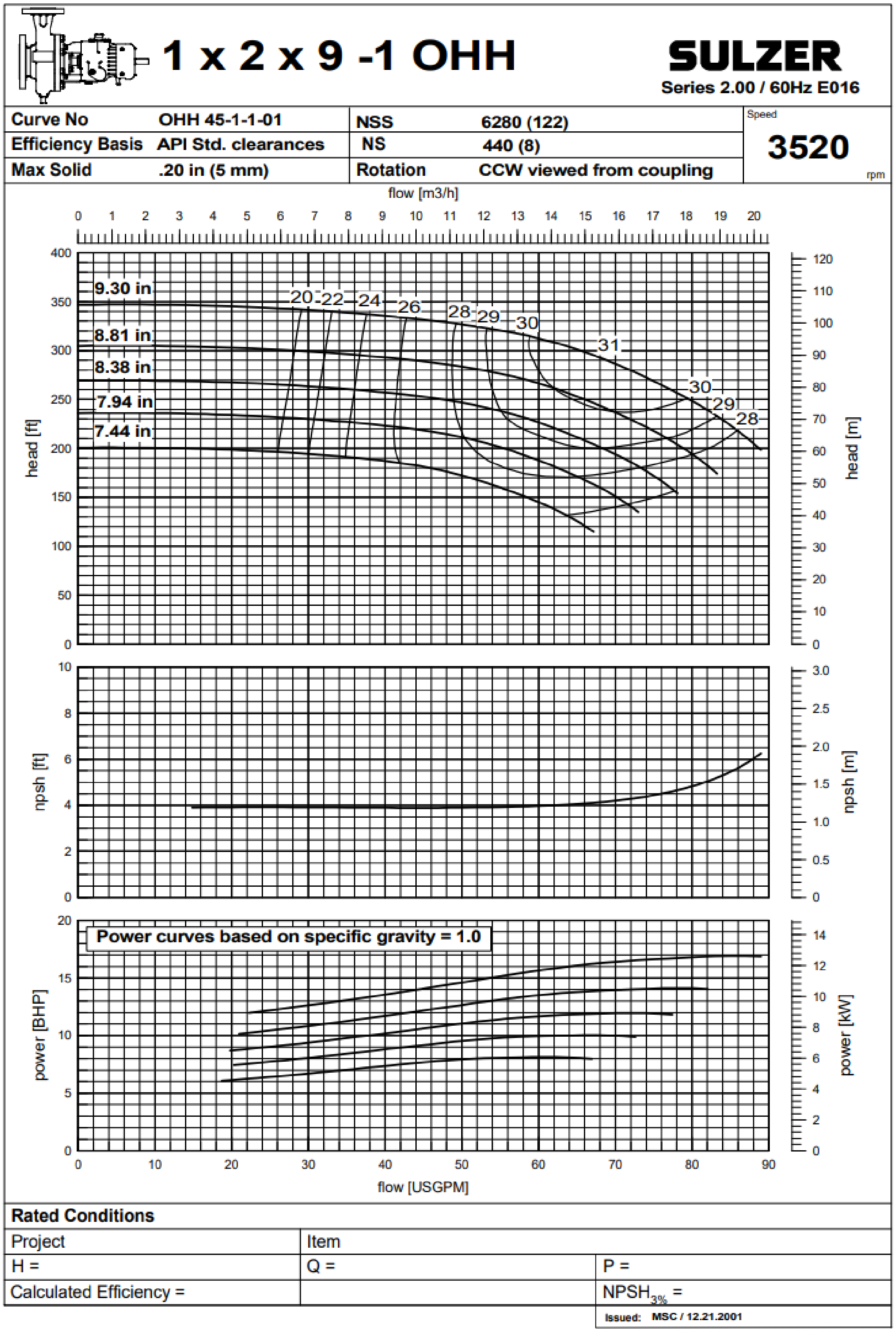


Figure 19 – Pump information

Sources:

Robert L. Mott. and Joseph A. Untener. (2014), Applied Fluid Mechanics (7th Edition)

Data:

N = 3520 rpm

Materials:

- 1x2x9-1OHH Pump

Summary:

Quantity	3
Type	1x2x9-1OHH
Impeller Diameter	5.63 inches
Pump Height	27.06 inches
Pump Weight	320 lbs

Table 5 – Pump dimensions

Analysis:

The pump selected comes from the Sulzer catalog and lists the characteristics of the pump.

Task 17 – Electrical motor requirements

Purpose:

To specify the electric motor requirements, which need to be 110% of the pump power requirements

Drawings:

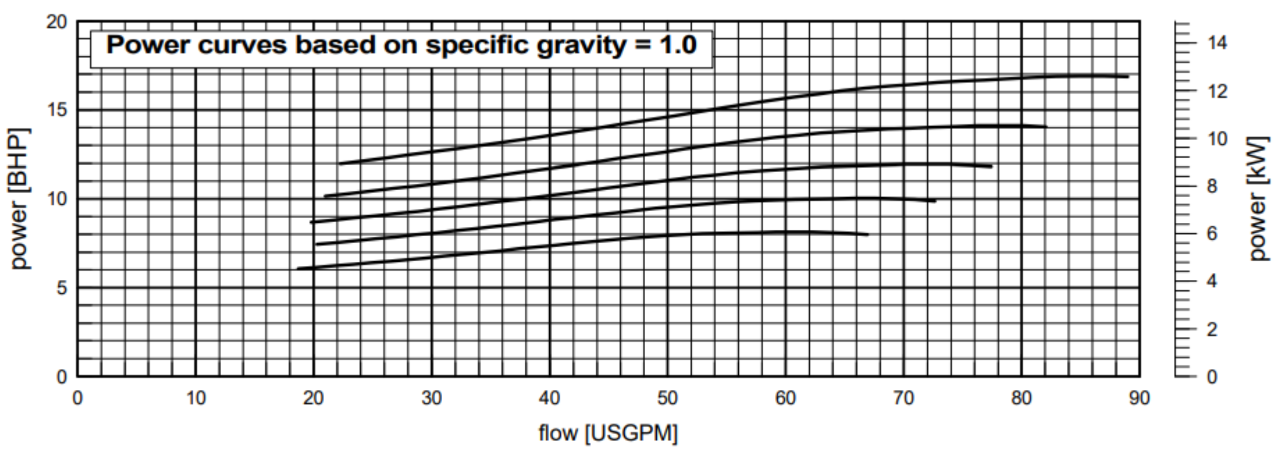


Figure 20 – Electrical motor power

Sources:

Robert L. Mott. and Joseph A. Untener. (2014), Applied Fluid Mechanics (7th Edition).

Design Considerations:

- Sulzer pumps only

Data:

- Q = 0.0382 ft^3/2

Procedure:

Calculate the required power for the pump and then multiply by 1.10 to find the actual power needed.

Calculations:

$$P = \frac{398.08 * 58.66 * 0.0382}{0.26}$$

$$P = 3.4hp$$

$$P_m = 1.1 * 3.4hp$$

$$P_m = 3.74hp$$

Materials:

- Coolant
- Sulzer 1x2x9-1OHH Pumps

Summary:

Type	1x2x9-1OHH
Quantity	3
HP	3.4hp
Motor 1.10 Requirement	3.74hp

Table 6 – Electrical motor information

Analysis:

The pumps will require 3.74hp so we will go with 4hp for the pumps.

Task 18 – NPSH

Purpose:

Evaluate the net positive suction head available and verify the system against cavitation.

Drawings and Diagrams:

Figure 17 and 19.

Sources:

Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7^{th} ed. Pearson Edu. (2015)

Design Considerations:

We will be using 1 x 2 x 9 -1 OHH Pumps in the calculations against cavitation.

Variables:

p_{atm} = 14.7psi = 2116.80lb/ft^2 p_{sat} = 0.3631psi = 52.29lb/ft^2 Z_1 = 9ft

Z_2 = 6ft Z_3 = 10ft h_{L1} = 1.99ft h_{L2} = 3.31ft h_{L3} = 0.855ft

γ = 58.66lb/ft^3

Procedure:

Start by manipulating Bernoulli's equation to get the proper equation for NPSH available. Using the gathered energy losses and elevation changes, calculate the NPSH available for each of the systems. Once calculated, compare them to the NPSH required to find out if they will cavitate.

Calculations:

$$NPSH_A = \left(\frac{p_{atm} + p_{saturation}}{\gamma}\right) \pm \Delta z - h_{L,suction\ pipe}$$

$$NPSH_{A1} = \left(\frac{2116.8lb/ft^2 + 52.29lb/ft^2}{58.66lb/ft^3}\right) + 9ft - 1.99ft = 42.20ft$$

$$NPSH_{A2} = \left(\frac{2116.8lb/ft^2 + 52.29lb/ft^2}{58.66lb/ft^3}\right) + 6ft - 3.31ft = 37.88ft$$

$$NPSH_{A3} = \left(\frac{2116.8lb/ft^2 + 52.29lb/ft^2}{58.66lb/ft^3}\right) + 10ft - 0.855ft = 44.34ft$$

From figure 19 we can see that the NPSH required is 4 feet. All $NPSH_A$'s are greater than the required therefore they will not cavitate.

Summary:

- The NPSH available for the pump right after tank 1 is 42.20ft
- The NPSH available for the pump right after tank 2 is 37.88ft
- The NPSH available for the pump right after tank 3 is 44.34 ft
- System will not cavitate

Materials:

- 1 x 2 x 9 -1 OHH Pumps
- ¾ inch schedule 40 steel pipes

Analysis:

The NPSH is supposed to be greater than the NPSH required in order for the system to not cavitate. In our case we were able to avoid it.

5.f.vii. Instrument Selection

Task 14 – Required Instruments

Purpose:

Specify the required instruments to measure the flow and calculate the drop in pressure across it.

Drawings and Diagrams:

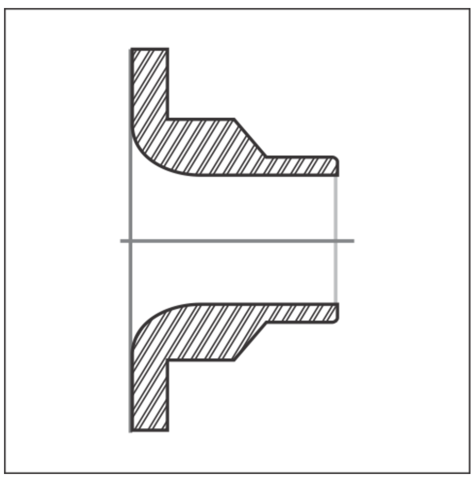


Figure 21 – Flow Nozzle

Sources:

Mott, R.L., Untener, J.A., "Applied Fluid Mechanics" 7th ed. Pearson Edu. (2015)

Design Considerations:

Specifying the flowmeter instrument for the pipe that goes from tank 1 to tank 2. The instrument chosen is a flow nozzle that has a diameter of 0.412in.

Variables:

D = 0.824in = 0.0687ft   d = 0.412in = 0.0343ft γ=58.66lb/ft^3

v=1.575x10^{-5}ft^2/s V_1=10.32ft/s A_1=0.0037ft^2

<u>Procedure:</u>

Start by finding the area of the nozzle. Then find Reynolds number and the diameter ratio to be able to calculate the discharge coefficient. Use all the found values and plug them into the equation to find the pressure difference.

<u>Calculations:</u>

$$A_2 = \frac{\pi(0.0343ft)^2}{4} = 0.000924ft^2$$

$$N_R = \frac{V_1 D}{v} = \frac{\left(\frac{10.32ft}{s}\right)(0.0687ft)}{1.575 \times 10^{-5} ft^2/s} = 4.5014 \times 10^4$$

$$\beta = \frac{d}{D} = \frac{0.0343ft}{0.0687ft} = 0.50$$

$$C = 0.9975 - 6.53\sqrt{\beta/N_R} = 0.9975 - 6.53\sqrt{0.50/4.5014} = 0.9757$$

$$\Delta p = (\frac{V_1}{C})^2 \frac{\gamma((A_1/A_2)^2 - 1)}{2g}$$

$$\Delta p = (\frac{10.32ft/s}{0.9757})^2 \frac{58.66lb/ft^3((0.0037ft^2/0.000924ft^2)^2 - 1)}{2(32.2ft/s^2)} = 1532.06lb/ft^2$$

$$\Delta p = 10.64psi$$

<u>Summary:</u>

Instrument being used is a flow nozzle. The pressure difference is 10.64 psi.

<u>Materials:</u>

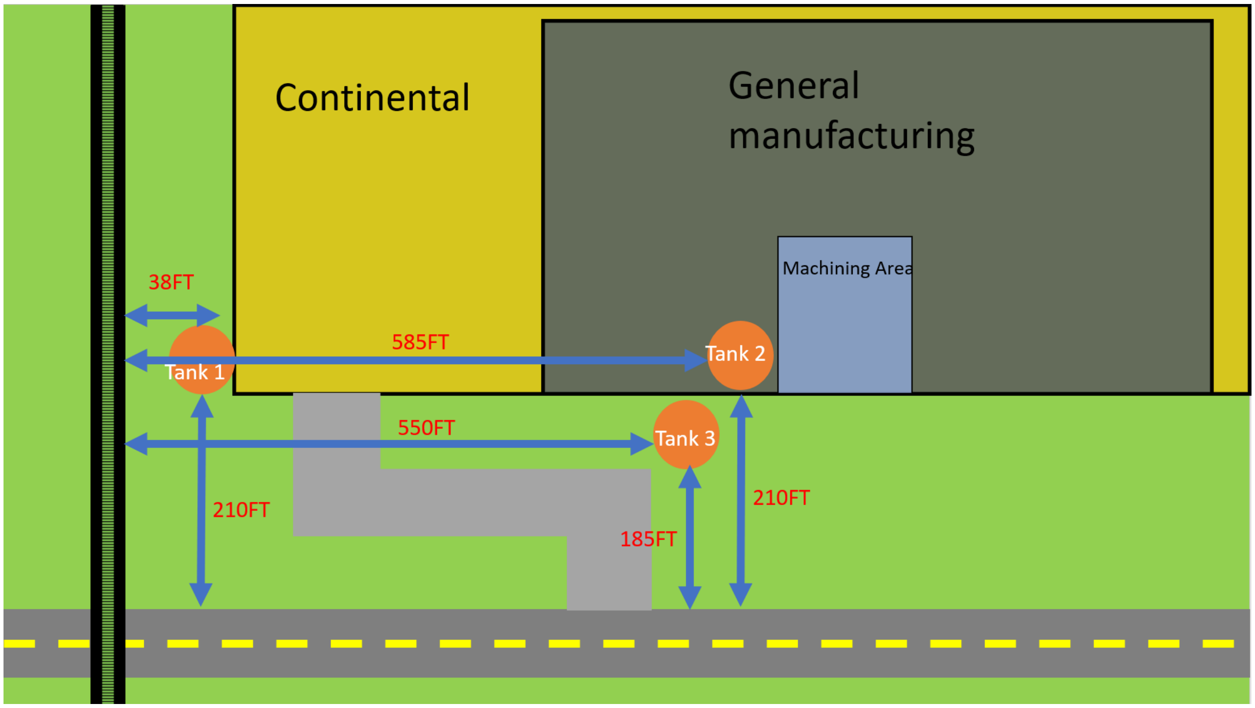
Flow nozzle and schedule ¾ inch 40 steel pipes.

<u>Analysis:</u>

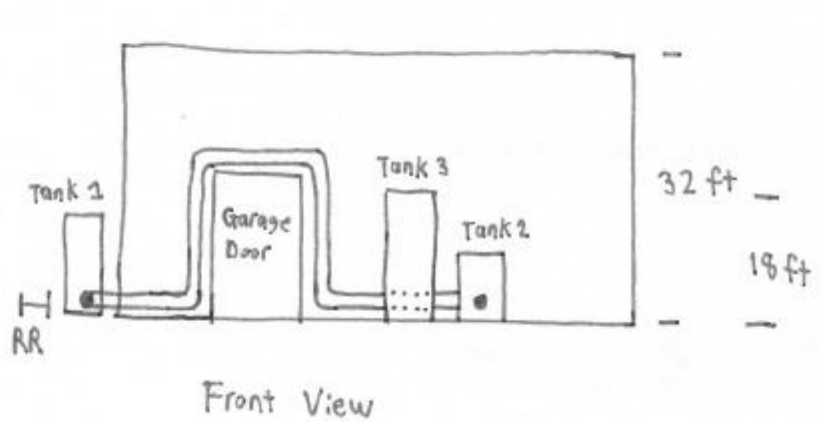
Since flow nozzle have a gradual decrease in diameter there is less energy loss and doesn't affect the flow rate as much as other instruments might.

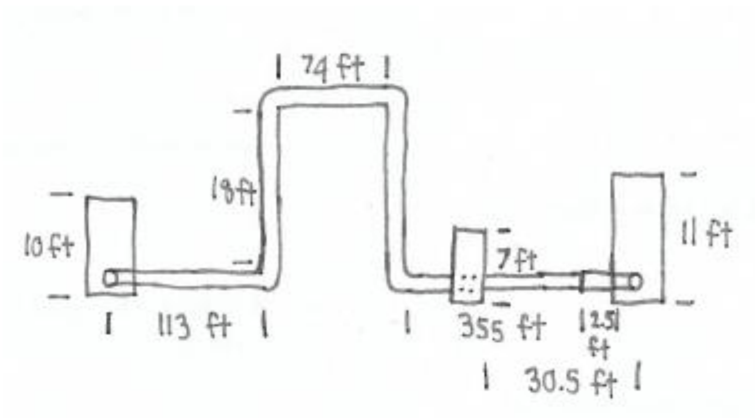
<u>**6. Final Drawing:**</u>

6.g. Plot Plan

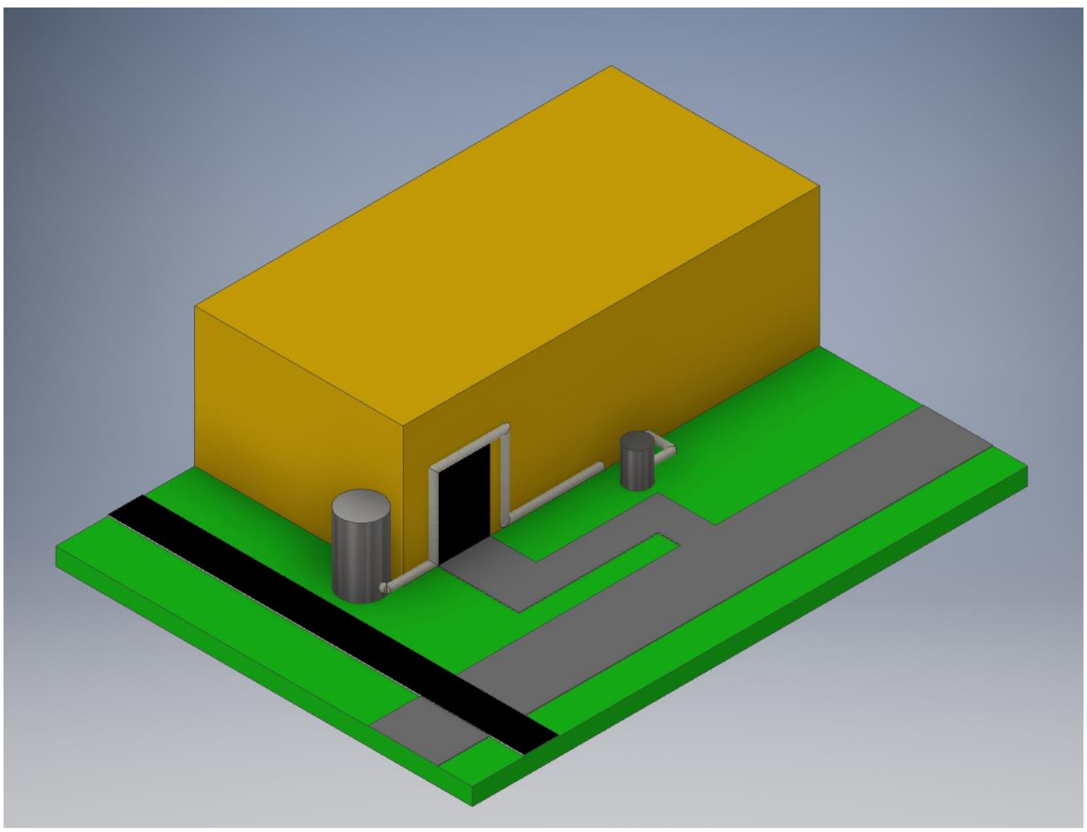


6.h. Elevation View





6.i. Isometric



7. Bill of Materials and Equipment List:

Bill of Materials		
Item	Description	Quantity
Pipes	0.75" Schedule 40 Steel Pipe	640 ft
	1.25" Schedule 40 Steel Pipe	45 ft
	1.5" Schedule 40 Steel Pipe	30 ft
Pumps	Kinetic Pump, Radial Flow, 1 x 2 x 9 - 1 OHH	3
Tanks	Cylindrical, Stainless Steel, 16' x 10' (D x h)	1
	Cylindrical, Stainless Steel, 5' x 7' (D x h)	1
	Cylindrical, Stainless Steel, 9' x 11' (D x h)	1
Fittings	90° 0.75" Long Radius Elbow Schedule 40 Carbon Steel	8
	90° 1.25" Long Radius Elbow Schedule 40 Carbon Steel	1
	Class 150 312 Stainless Steel 0.75" Slip-On Flange	31
	Class 150 312 Stainless Steel 1.25" Slip-On Flange	3
	Class 150 312 Stainless Steel 1.5" Slip-On Flange	3
	Class 150 Slip-On Flange Gasket, Nuts, and Bolts Kit	37
Valves	Gate Valve	4
	Check Valve, Swing-Type	4
Instruments	Flow Nozzle, 0.412" Minimum Diameter	1
Supports	Rigid Supports, Dual-Clamp, 2-Bolts	675

8. Final Remarks:

When designing a new facilities' coolant system, there are a lot of things to consider. In this case we had to consider three tanks that hold coolant and how the coolant should be transferred in and out of each tank. There is a railroad car that brings clean coolant, which is then transferred to tank 1, it then passes through a pipe system to go to tank 2, this supplies the coolant to the machining room, this coolant then goes to tank 3 where the dirty coolant is held and finally gets transferred to the truck that removes the dirty coolant from the facility. There were a lot of calculations that had to be made to make sure that the system would function properly. Since there are multiple different shifts, we calculated separate flow rates to empty and fill each tank so they could be completed in one shift, therefore, eliminating possible error from shift changes. We also wanted to ensure the pipes, tanks, and pumps could handle various situations and problems by calculating for worst case scenarios and creating backup plans in case a system might fail. We believe our design is cost effective because we chose appropriate material that is acceptable and functional that wouldn't cost an unreasonable amount.

9. Appendix:

Nathan Snead:

I think what was learned from this class and the project is very important to my career as a mechanical engineer. Fluids are utilized in countless engineering applications and it is vitally important how fluids behave and how to control them. I have learned a great deal in this class and I find the material most interesting; I am even considering finding a fluid mechanics job when I graduate.

In a hypothetical job interview, I would explain the project as a semester-long group project requiring the complete design of a pipeline system for a manufacturing plant. My role as technical leader was to ensure my teammates understood the requirements of each project task; I also did my share of the design work and calculations. I am a very detail-oriented person with a drive to do things correctly. These strengths assisted me in the project by keeping my calculations neat and consistent as well as making sure nothing was overlooked. A weakness of mine is that when I see something that needs correcting, I want to do it myself rather than wait for someone else to do it. This project gave me the opportunity to work with my teammates on revisions, instead of doing everything myself.

I feel like our system design is simplistic and fairly efficient. It is not over-complicated and it should accomplish its purpose. However, there are a few weaknesses I notice in hindsight. Firstly, if the pipes had been routed underneath the driveway instead of over it, the pipe length in that system could have been approximately 30 feet shorter. This would have decreased the energy losses and a smaller pump could have been used. Secondly, each system only contains one gate valve; this will make maintenance difficult in the case of pump failure. The last weakness in the design is that the systems outside the building are vulnerable to the fluid freezing. The freezing point of the working fluid is $0^{\circ F}$ and the outside temperature at the site location may reach $-20^{\circ F}$.

If I were to retake this class, I would advise myself to do all the homework problems and check the work of my teammates. The homework problems effectively prepared me for the tests and the tests were very much geared towards preparing us for the project. I would also do my best to make communication with my teammates clear and frequent.

Dustin Jones:

Yes, I know that what I have learned in this class will certainly be useful to me once I begin my career. I do not know if in the future I will be required to do the calculations that we learned, but I know that if I understand the concepts then that will be useful

Probably on a construction job like the one I have currently. The flow of fluids is pretty important on a Tunnel Boring Machine, as the fluid being transported is the spoils from the excavating. Also, the machine uses many pumps for systems such as lubrication and ground treatment. The flow of fluids is important in these instances as they are vital to the function.

I would explain that the project was to design a system that transported coolant for a manufacturing facility. I would explain that my contributions to the project involved designing blind flanges, selecting pumps and their layout, and using design software to make drawings.

I would say my strengths were that I understood the material and design. As well as having a good work ethic. My understanding helped me complete the tasks I was given, and my work ethic allowed me to complete them in a timely manner.

My weakness was that in the beginning of the project I had bad communication with my group, but what helped me fix this was to reach out and help coordinate meeting times.

The technical strengths of the project are that my group had a good understanding of the project so the generally I believe it is technically strong. I think if there is any weakness, it comes from my group being down a member resulting in everyone having to pick up more work than they intended.

I would do more practice problems and reach out to the professor if I needed help.

Stephanie Broussard:

After completing this project, I feel that I have learned a lot of useful techniques and information. I think a lot of what I learned could definitely be used and is important for my professional career. I would imagine that I will be using what I have learned in future classes, as well as if I ever have to design a system in a job. If I were to describe this project in a job interview, I would tell them that I completed a group project where we had to design a system to transfer coolant throughout a manufacturing facility. I would mention that we had to calculate for various scenarios to ensure the functionality of the system. I would tell them that I had contributed to the project by doing my portion of the project as well as gathering everyone else's portions and putting them into a document displaying the work we had done in a clear and concise manner. I think a good strength of mine is that I am organized and like to get things done a little early when it comes to schoolwork. I think this played a role in the project to help be able to stay on time with the tasks. With a project this big, it is very important to not get behind and overwhelmed by what needs to be done, so I think my organization helped with that as well. A weakness of mine would be my lack of experience with working on large projects with a group. It seems most of the semester long projects I have done were completed individually, so it took some getting used to, but as the semester went on I got a better grasp on how they work and how to work together. I believe a technical strength in this project would be the uniform way we did the tasks. It makes it clear and easy to read through the report. I don't believe there were really any technical weaknesses in the project. If I were able to start the class over again, I would probably tell myself to give myself plenty of time to complete each task or homework assignment in order to really grasp each concept.