MET 330 Fluid Mechanics

Final Project Report

Full Pipeline System Design of a Manufacturing Plant for

CONTINENTAL AG

Group 5

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Abstract

Continental AG is planning for a new manufacturing facility. As part of the new plant, there will be an automated machining line in which five machines will be supplied with coolant from the same reservoir. As the plant engineer, we have provided a design of the system to handle the coolant from the time it reaches the plant in railroad tank cars until the dirty coolant is removed from the premises by a contract firm for reclaim. Using the data, design requirements, and limitations provided; this document is a virtual walkthrough on how our design uses resources effectively in order to maximize production and energy efficiency while minimizing customer costs.

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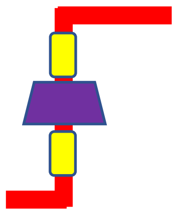
Job site location

Continental AG Manufacturing Plant in Dayton, Ohio.

Using our Fill time to justify pipe dimensions.



This is the section from the side of the building where the train will fill the large tank. There are 2 valves, 2 elbows, 1 pump. Calculations:

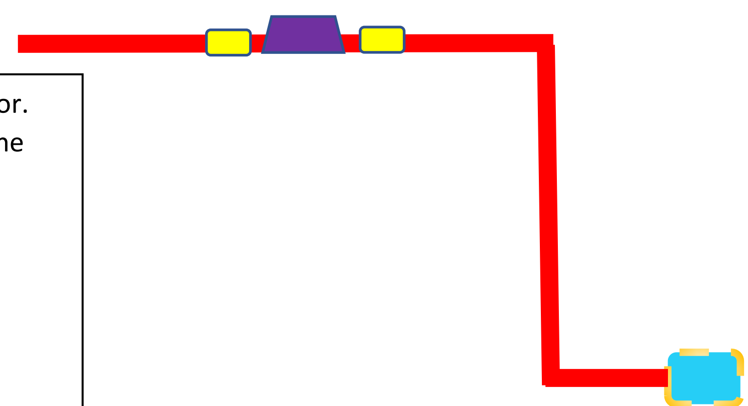
Pipe: Schedule 40 4 inch

Flow rate: .497 ft3/s and a velocity of 5.7 ft/s

Time to fill: 4.5 hrs

Pipe Area: .0884 ft2   Pipe Length: Horizontal 20ft, Vertical 36ft, Horizontal 100ft.

Notes: The horizontal length starts right next to the rail track so that we do not have to estimate any distances. The vertical distance is taken with the valve for the rail car being at about 4ft from ground level up to the center distance of our large tank.



This is the section from the side of the large tank to the small reservoir under the floor. There are s valves a pump and 2 elbows, with the possibility of needing a flange on the tank.

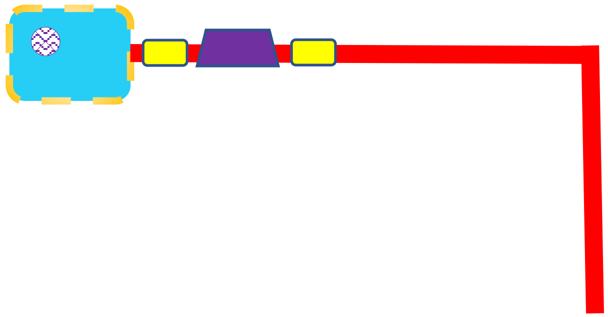
Pipe: Schedule 40 2.5 inch   Diameter:.208 ft

Flow rate: .222 ft3/s and a velocity of 6.54 ft/s (critical velocity)

Time to fill: 10 minutes

Pipe Area:.034 ft2   Pipe Length: Horizontal 490 ft, Vertical 44ft, Horizontal: 85 ft

Notes: The length of pipe going down is 44 feet so that the tank will be below the frost line. The location back from the front of the building must be estimated due to lack of dimensions. The room appears to be 100x150. The tank will be placed directly in the center. This means it will be 75 ft back from the front of the building.



This is the section that starts from the collection of used coolant from the machines and runs to the trash tank. After reading the task again I think that Ayala wants us to put the drain and blind flange on the same tank. I may be incorrect about this. There are 2 pumps, 4 valves 2 elbows and possibly 2 flanges for the tank.

Pipe: Schedule 40 2.5 inch Diameter: .208 ft

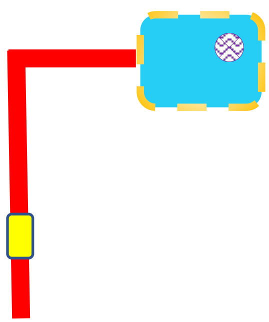
Flow rate: .2 ft3/s at a velocity of 5.89 ft/s (critical velocity)

Time to fill: 100 minutes (This is if we were dumping as much coolant as possible.)

Pipe Area: .034 ft2

Pipe Length: Vertical 44 ft out of the ground, Horizontal 75 ft towards front of building, Horizontal: 435ft parallel to front of building.

Notes: The distance to the driveway is estimated to be 455 ft from center of machining area.



This is the section that moves coolant from the trash tank to the removal truck near the drive way. There a 2 valves and 1 pump.

Pipe: Schedule 40 3inch Diameter: .25 ft

Flow rate: .334 ft3/s at a velocity of 6.81 ft/s (critical velocity)

Time to fill: 1 hour (This is if we were dumping as much coolant as possible.)

Pipe Area: .049 ft2

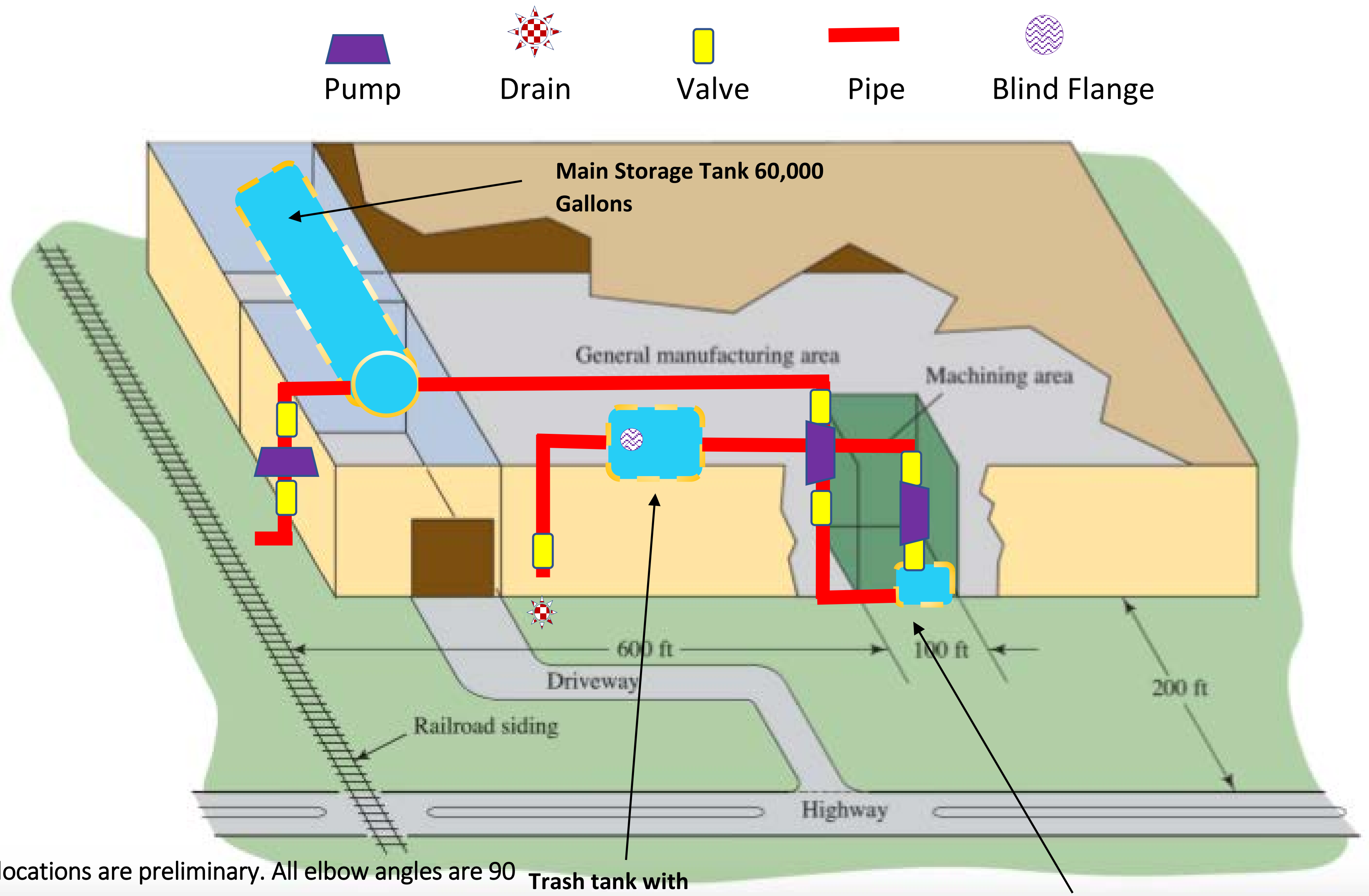
Pipe Length: Horizontal: 20ft to drive way for truck removal, Vertical 40 feet down.

Materials and Specifications

Pipe material: Galvanized Steel

Tank material: Galvanized Steel

Fluid Characteristics: Low Viscosity Fluid(1.5 x that of water) with similar corrosion characteristics. The specific gravity is .94 and the freezing point is 0 degrees F.



All locations are preliminary. All elbow angles are 90 degrees. The valves next to the railroad and drive way are threaded/ coupled for hook ups to supply and remove coolant. Flange location is not marked.

Purpose:

The purpose was to determine the size and location of all three storage tanks needed for the system.

Drawings and Diagrams:

See attached below.

Sources:

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

Design Considerations:

The roof can be designed to hold one storage tank.
Coolant is delivered by railcar to the left (west) of the building.
Used coolant is picked up by truck at the front, left side of the building.
Coolant is used at a rate of about 1000 gallons per week.
The coolant has similar flow, expansion, and contraction properties to water.
The area has outside temperature ranges of -20°F to 105°F.
Tanks will be cylindrical, oriented horizontally.

Data and Variables:

Temperature variance: -20°F to 105°F
1000 gallon reservoir established, 1000 gallons used weekly
Truck pickup used coolant monthly
Railcars carry 15,000 gallons each

Procedure:

The first need was to evaluate the simplest and easiest way to facilitate new coolant delivery and used coolant pickup. Using the amount used each week, the occasional need for new coolant in the middle of the week, and monthly pickup times for used coolant, a determination for how much each tank needed to hold was made. Then, temperature variances were taken into consideration and tank sizes were increased to account for expansion of the fluid.

Calculations:

Coolant delivery times of twice per year were chosen.
1000 gallons used each week, occasionally more if needing to be dumped early.

Assumed a worst case scenario of 2000 gallons needed per week: 52,000 gallons used in 6 months. To account for expansion due to temperature changes, a 60,000 gallon storage tank was chosen.
The tank used to store used coolant until the trucks pick it up was evaluated similarly. Estimated worst case scenario would require an 8,000 gallon capacity plus an extra 1,000 gallons to account for expansion.
Finally, the reservoir used in the machining area was previously established to hold 1.000 gallons.
All tanks will be cylindrical, and all tanks are to be placed horizontally.

Pi*r^2 gives the area for a circle. The number of gallons can be converted to feet cubed then a length for the tank can be chosen. From the remaining number, radius can be solved for.

60,000 gal x (0.133681 ft^3/1 gal) = 8020.86 ft^3
45.5 ft long → 8020.86 ft^3/45.5 ft = 176.28 ft^2
Now radius or diameter can be solved for. → 176.28/pi = 56.11 → square root = 7.49 ft (radius)

Summary:

Tank	Shape/Orientation	Capacity (gal)	Dimensions
Reservoir	Cylindrical/Horizontal	1,000	4.6 ft diameter x 8 ft long
Used Coolant	Cylindrical/Horizontal	9,000	10.4 ft diameter x 14 ft long
Storage	Cylindrical/Horizontal	60,000	15 ft diameter x 45.5 ft long

Tank volumes, sizes, and materials

1. The volume of our tanks is currently:
    a. Main storage: 60,000 gallons (horizontal cylinder)
    b. Machine reservoir: 1000 gallons (horizontal cylinder)
    c. Trash Tank: 9000 gallons (horizontal cylinder)

2. The shape of each tank will be cylindrical.
    a. Area = Pi(radius)^2
    b. Volume= Area x Height (or length)

3. Figuring out what radius and length our storage tank should be.
    a. 1 Gallon = .13368 ft^3
    b. Total capacity= about 8020 ft^3
    c. Pi(radius)^2 X Length= about 8020 ft^3
    d. Infinite possible dimensions
    e. Suggested dimensions are 15ft in diameter and 45 ft 6” long.
    f. For 60,000 gallons our liquid will be 12 feet high in the tank.
    g. Suggested material is steel.

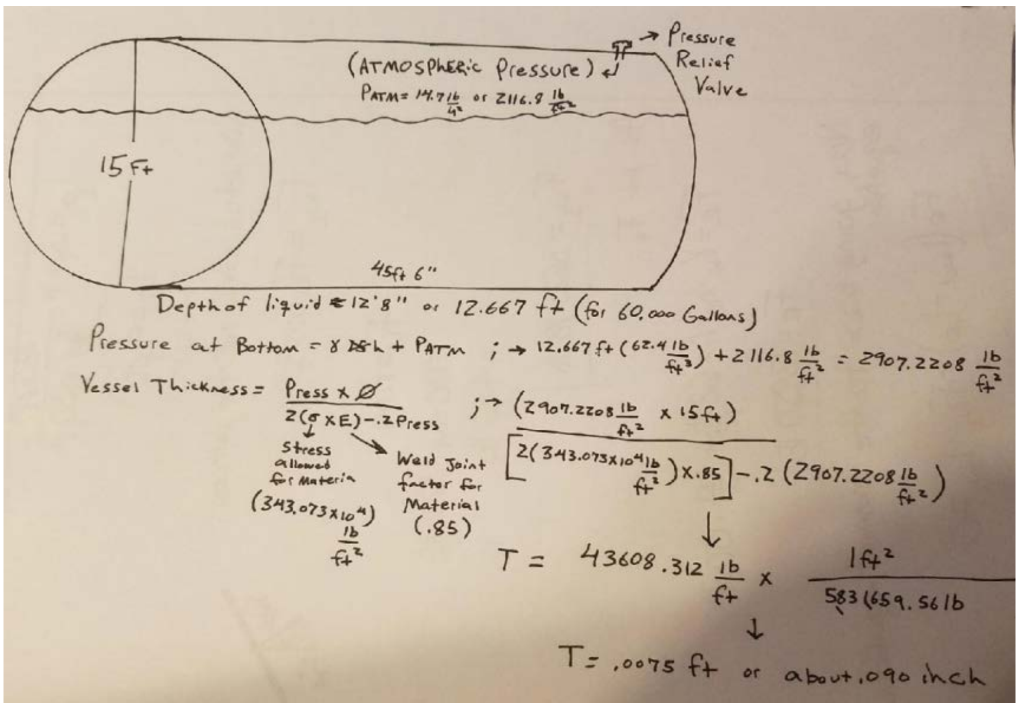
4. Figuring out what radius and length our reservoir tank should be.
    a. Using same basic information as previous tank
    b. Suggested dimensions are 6ft long and 6 feet in diameter.
    c. Liquid height will be 4ft 9in.
    d. Suggested material is coated steel.

5. Figuring out what radius and length our trash tank should be.
    a. Using the same basic information as the last 2 tanks
    b. Suggested dimensions are 14 feet 1 inch in length and 11 feet in diameter.
    c. The liquid will be 9 feet 4 inches high.
    d. Suggested material is coated steel.

Specifying tank material and determining tank wall thickness

1. Purpose:
    a. We need to determine the wall thickness required to support the maximum pressure and volume of the tank. We will also need to specify the type of material used, as this will be a determining factor in the tank wall thickness.

2. Drawing and diagrams:
    a.



3. Sources: Mott, R ,Untener, J.A., "Applied fluid mechanics" 7th edition, Pearson education INC, (2015)

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    N.H. Yates and Co. Inc. – Engineering Design Team(Expansion Tank and Water Specialties)

4. Design Considerations:
    a. The selected tank for calculations will be the 60,000 gallon storage tank
    b. The tank will only be filled to a max of 80% at any time
    c. The specific gravity of the water/oil coolant is .94
    d. The tank will never be filled with a compressible gas/liquid
    e. All tank materials will be brand new

5. Data and variables:
    a. The corrosion factor of stainless steel is .125 and the weld joint factor is .85
    b. The specific weight of water is 62.4 lb/ft^3
    c. The selected tank is 15' in height(round) and has a cylinder length of 45' 6"

6. Procedure:
    a. First we must specify which material we will be using for the tank. We choose stainless steel due to the size of the tanks and to eliminate future possible corrosion concerns of regular steel.
    b. Next, we were tasked with determining the force on the bottom of the tank.
    c. With this force now being determined we now have all required data and variables to solve for the necessary wall thickness

7. Calculations:

    P(at bottom of the tank= gamma*sg*h + Patm

    P = 12.6777ft(62.4 lb/ft^3)+2116.8lb/ft^2 = 2907.2208 lb/ft^2

    WT= (P * I.D.) / 2 (oE-.2P)

    WT = (2907.2208lb/ft^2*15ft) / 2(343.07*10^4 lb/ft^2 * .85 - .2*2907.2208lb/ft^2)

    WT= 43608.312 lb/ft * (1ft^2/ 5,831,659.56lb)

    WT= .0075ft or .09in

    WT= .09in + corrosion factor of .125 = .215 inches

8. Summary:
    a. Our calculations and results were verified by an industry proven tank manufacturer and were right on line with the ASME standards for a tank that size(.200 – .250 inches)

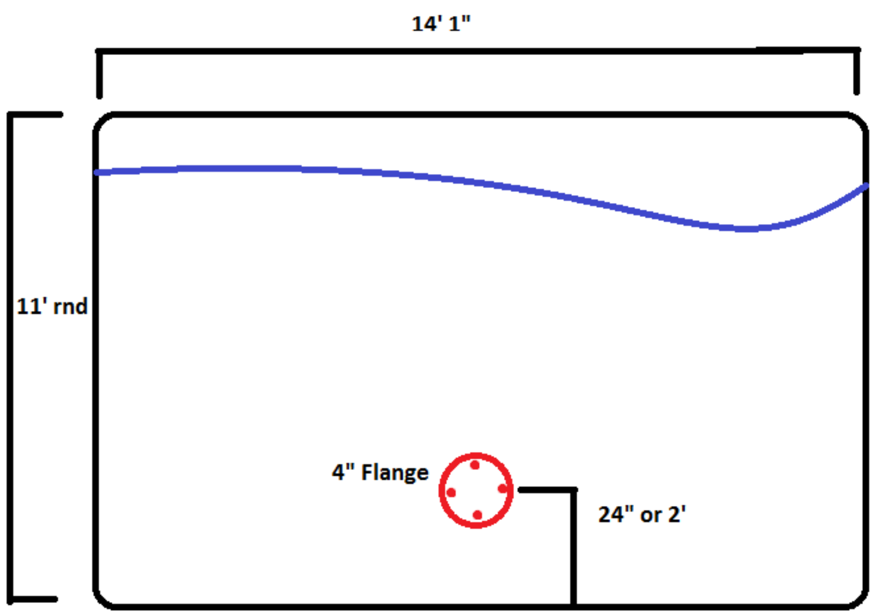
	I.D.(ft)	Height of Fluid(ft)	SG of Water(lb/ft^3)	PressureATM(lb/ft^2)	Pressure(lb/ft^2	Stress Allowed(lb/ft^2)	Weld Factor
Storage Tank	15	12.68	62.4	2116.8	2907.89	3430730	0.85
Reservoir Tank	6	4.75	62.4	2116.8	2413.20	3430730	0.85
Trash Tank	14	7.83	62.4	2116.8	2605.60	3430730	0.85

Wall Thickness(inches)	(Pressure*I.D)/2(Stress Allowed*Weld Factor -.2Pressure) +Corrosion factor
Storage Tank	0.214763973
Reservoir Tank	0.154796293
Trash Tank	0.200068749

Determining pressure requirements of a blind flange connection

1. Purpose:
    a. We need to determine the pressure of the fluid acting on the area of potential flange location. We also need to determine a size, thickness, and style of bolt that will safely hold the flange intact.

2. Drawing and diagrams:



3. Sources: Mott, R ,Untener, J.A., "Applied fluid mechanics" 7th edition, Pearson education INC, (2015)

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    Coastal Precision Engineered Flanges – Cut Sheet/Submittal

4. Design Considerations:
    a. The selected tank will be the 9,000 gallon trash tank
    b. The tank will only be filled to a max of 80% at any time
    c. The specific gravity of the water/oil coolant is .94
    d. The tank will never be filled with a compressible gas/liquid

5. Data and variables:
    a. We know that the blind flange will only be installed on one of the tanks
    b. The specific weight of water is 62.4 lb/ft^3
    c. The selected tank is 14' 1" in length and has a diameter width of 11'

6. Procedure:
    a. First we must determine the size of the blind flange the customer would like to use. With this flange being installed for future use, there are no flow requirements that need to be met. Due to the size of the tank, we determined to use a common 4 inch size.
    b. Next, a height on the tank is set with the thought of accessibility in mind.
    c. We then incorporate the dimensions of the selected flange into a resultant force equation and determine the maximum pressure acting on the blind flange.

7. Calculations:

Fr=gammaCoolant*h*Area of the circle
gammaCoolant = 62.4 lb/ft^3 * .94
gammaCoolant = 58.656 lb/ft^3
gammaCoolant = .03394444lb/in^3
h=94in-24in – 70 inches
Acircle= 12.57in^2

Fr = .03394444lb/in^3*70in*12.57in^2

Fr=29.86 lbs

Using a cutsheet/submittal of the closest corresponding pressured rated blind flange, we specify that a class 150(150 max psi) flange be used. This flange shall be made with a thickness of atleast .94 inches and be secured by 4----5/8" x 3---1/2" bolts.

The use of 4 bolts would result in a force of 7.465 lbs on each bolt. Based on the ASME standards posted below for a 5/8" bolt the 7.465 lbs per bolt load falls safely under the stated max of 1210 psi.

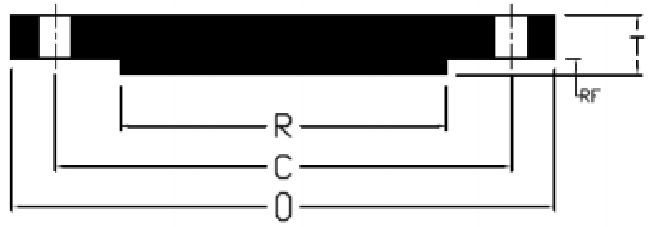
TENSILE STRENGTH (WORKING LOAD) CHART FOR SAE BOLTS BOLT SAFE WORKING LOADS (LBS)			
SAFE TENSILE LOAD AT 6,000 PSI LOAD *SAFE SHEAR STRENGTH*			
BOLT DIA (IN)	**SHEAR AT THREAD ROOT**	**SHEAR (FULL BOOT)**	**TENSILE (AT THREAD ROOT)**
1/4"	200	370	160
5/16"	340	575	270
3/8"	510	830	410
7/16"	700	1130	560
1/2"	940	1470	760
9/16"			
5/8"	1510	2300	1210

When determining the required thickness of the flange, the calculations are fairly similar to the one used to derive the thickness of the tank. However in this case, the height/location of the blind flange must be taken into account.

P(at flange)= gamma*sg*h + Patm
P = 5.83ft(62.4 lb/ft^3)+2116.8lb/ft^2 = 2480.59 lb/ft^2
T= (P * I.D.) / 2 (oE-.2P)
T = (2480.59lb/ft^2*15ft) / 2(343.07*10^4 lb/ft^2 * .85 - .2*2480.59lb/ft^2)
Thickness of flange= .071in + corrosion factor of .125 = .196 inches

8. Summary:
    a. With the coolant being non-compressed and the flange coming from the side of the tank, the weight of the coolant is primarily the only force acting against the blind flange.
    b. A class 150 blind flange(submittal below) will easily accommodate all forces coming from inside the tank.

COASTAL
Precision Engineered Flanges
11906 FM 529
Houston, TX 77041
USA
Phone: 713.937.3333
Fax: 713.937.3471
1.800.643.9063
www.coastalflange.com



All dimensions are in inches
These flanges will be furnished with a 1/16" raised face unless otherwise specified.

ANSI B16.5 CLASS 150 BLIND FLANGES

Nominal Pipe Size	Outside Diameter (O)	Thickness (T)	Raised Face Diameter (R)	Number of Holes	Diameter of Holes	Bolt Circle (C)	Approximate Weight (lbs)
1/2	3.50	0.44	1.38	4	0.63	2.38	1
3/4	3.88	0.50	1.69	4	0.63	2.75	2
1	4.25	0.56	2.00	4	0.63	3.13	2
1 1/4	4.63	0.63	2.50	4	0.63	3.50	3
1 1/2	5.00	0.69	2.88	4	0.63	3.88	4
2	6.00	0.75	3.63	4	0.75	4.75	5
2 1/2	7.00	0.88	4.13	4	0.75	5.50	7
3	7.50	0.94	5.00	4	0.75	6.00	9
3 1/2	8.50	0.94	5.50	8	0.75	7.00	13
4	9.00	0.94	6.19	8	0.75	7.50	17

Sources:

Mott, R., Untener, J.A. “Applied Fluid Mechanics.” 7th edition, Pearson Education, Inc. (2015).
National Renewable Energy Laboratory. “Ohio - Annual Average Wind Speed Estimates at 100-m Height.” U.S. Department of Energy. (2007). http://www.greenenergyoh.org/wp-content/uploads/2015/02/Ohio-Wind-Map-2007.pdf
Dayton (45416) Monthly Climate Averages. (n.d.). Retrieved November 27, 2017, from https://www.worldweatheronline.com/lang/en-us/v2/weather-averages.aspx?q=45416.

Equation:

$F_D=C_D(½)(□)(v^2)(A)$

Design Considerations:
□ for air at -20 degrees Fahrenheit = $2.80X10^{-3}$
□ for air at 105 degrees Fahrenheit = $2.20X10^{-3}$
v ranges from 88ft/s to 12.5ft/s
The cross-sectional area used for a cylinder is a rectangle.
A maximum wind velocity of 60mph (88ft/s) was used to find the maximum wind force. The highest velocity found to be recorded was 56mph in 1967.

Drag Coefficient of Large Storage Tank (Diameter=15ft)
C_D was found by calculating Reynolds numbers and using the chart pictured. Based on the numbers calculated, though, the drag coefficient is off the graph to the far right. As a result, drag coefficient was estimated to be 0.3 for all values of density (relating to temperature) and wind velocity.

Drag Coefficient of Trash Tank (Diameter=10.4ft)
The same problem with the Reynolds numbers’ location outside the range of the chart to find the drag coefficient occurred for the tank with the used coolant. The drag coefficient of 0.3 was used again, resulting in the same numbers for drag force.

The reservoir tank is not susceptible to air drag due to its location under the floor inside the factory.

Calculations:

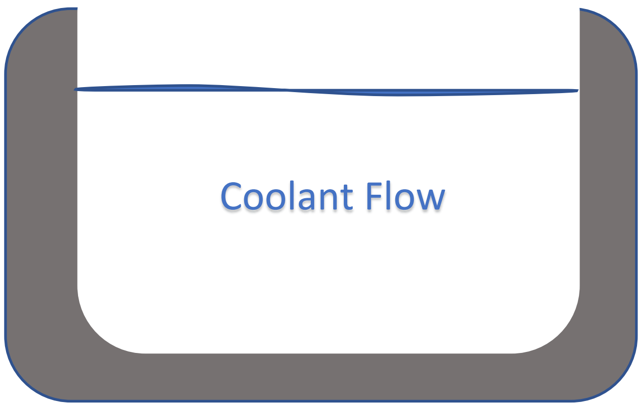
At -20 degrees, $F_D=(0.3)(½)(2.80X10^{-3})(88^2)(682.5) = 2219.82$ lb
This will be the maximum force of the wind because the density is higher at the coldest temperature.

Open Channel System for coolant coming from Trash Tank

1. Purpose:
    a. Develop an open channel system to move coolant from one of the storage tanks to an offsite location that is to be specified.

2. Drawings and diagrams:

Cross Section of Asphalt Channel



3. Sources: Mott, R ,Untener, J.A., "Applied fluid mechanics" 7th edition, Pearson education INC, (2015)

4. Design Considerations:

    a. The channel will have to start from the closest adjacent part of the building from the tank we decide to empty.

b. The channel will be outside, so it must be made of a material that is capable of withstanding not only the coolant but also environmental factors such as sunlight and ice.
c. The channel will most likely run parallel to the building in the front which means it will be long.
d. The site chosen to hold the coolant after it has flowed will need to be below the channel so that gravity will allow it to fill.
e. The slope and shape of the channel as well as the width of the channel will be key factors in the height of the fluid.
f. We do not know the velocity, width or height of fluid so iteration will have to be used.
g. The flow needs to be subcritical, so the Froude number will have to be calculated.

5. Data and variables:
   a. The tank chosen to drain is the trash tank in the front of the building.
   b. The flowrate is .3342 ft3/s
   c. The Slope will be .00008 since the channel will be at least 400 feet long.
   d. The iteration spread sheet was used to find a possible size of the channel.
      i. The internal width of the channel is 1.5 feet wide.
      ii. The fluid will have a height of .72 feet or 8.64 inches
      iii. The velocity of the fluid will be .525 ft/s
      iv. n for smooth asphalt is .013
      v. The channel will have a rectangular cross section

6. Procedure:
   a. First, we will come up with an equation that allows us to iterate our width and height of fluid given the flowrate.
   b. Next, we will iterate on a spread sheet to find an acceptable width and height of fluid.
   c. Then, we will have to calculate the hydraulic radius to get the velocity.
   d. Finally, we will solve for the Froude number to verify that with the given size that our flow is subcritical.

Open Channel System for coolant coming from Trash Tank

7. Calculations:

Height	Value Found from Height	Value to Equal from height	n	Slope	Width	Fr#	Velocity	R	Area of channel	Hydraulic Depth
0	0	0.551693497	0.013	0.00008	1.5	0.109	0.525315	0.367	1.08	0.72
0.5	0.336040366									
0.7	0.533272966									
0.72	0.553824968									

Open Channel System for coolant coming from Trash Tank

NF needs to be < 1.00

$$NF = \frac{V}{\sqrt{g(y_h)}} \rightarrow \qquad \text{Veloc} = \frac{1.49}{n}(R^{2/3})(S^{.5})$$

$$Y_h = \frac{\text{Area}}{\text{Width}} \begin{array}{l} \rightarrow \text{of Chanel} \\ \rightarrow \text{Water Surface} \end{array}$$

To find h

$$\hookrightarrow \frac{\left[\left(\left(\text{Width}^{2/3}\right) \times \text{width}\right) \text{height}^{5/3}\right]}{(2h + w)^{(2/3)}}$$

Iterate with excel to find a height and Width that gives a Froude # < 1

A slope of .0008 was Chosen

The Channel will be Made of Smooth Asphault
$n = .013$

Q for System is .3342 ft^3/s

A Width of 1.5 ft was Chosen, A depth of .72 ft.

$$R = \frac{A}{W_p} \rightarrow \left(\frac{(1.5 \times .72)\ ft^2}{(.72 \times 2) + 1.5\ ft}\right) = .367\ ft$$

$$V = \left(\frac{1.49}{.013}\right)(.367\ ft)^{2/3}(.0008^{.5})$$

Velocity = .525 ft/s

$$Y_h = \frac{1.5 \times .72}{1.5} = .72$$

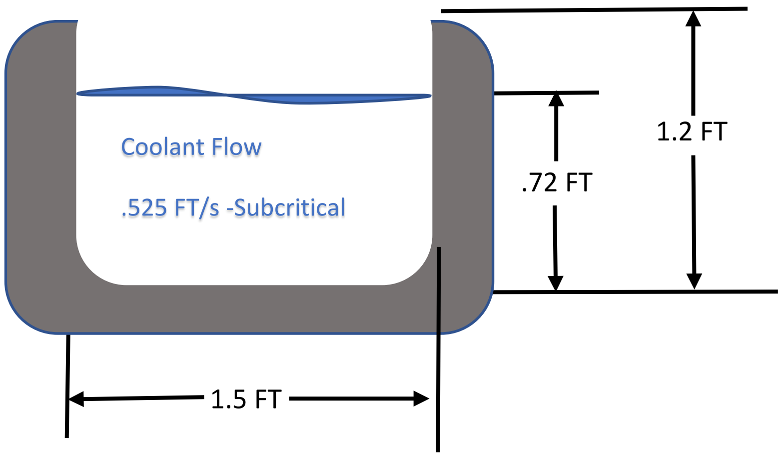
$$Fr\# = \frac{.525}{\sqrt{32.2 \times y_h}}$$

$Fr\# \rightarrow .109$ (Sub critical)

Open Channel System for coolant coming from Trash Tank

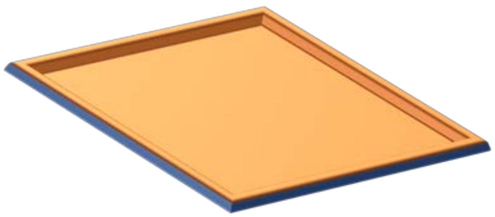
8. Summary:
    a. The size of the channel is 1.5 feet wide by 1.2 feet tall with the fluid only reaching .72 feet high on the channel.

    b. The length of our channel is 450 feet where it opens into an open-air pool for storage.

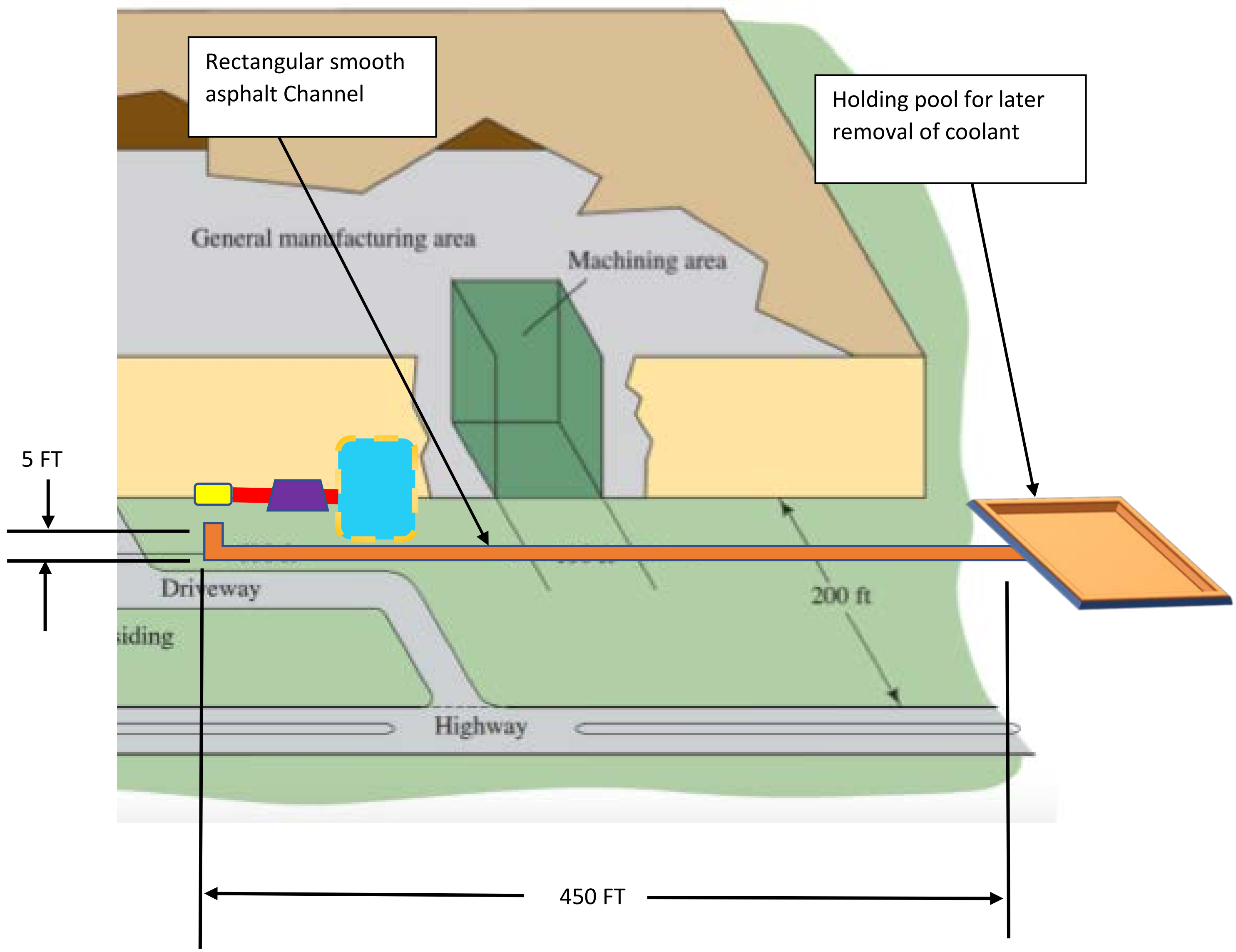


The cross section of the channel is shown above. The channel is made of smooth asphalt and has a slope of .00008. The dimensions shown were calculated by iteration.

The open-air pool is recessed into the ground since it is gravity fed. The pool is 10 feet wide, 20 feet long, and 8 feet deep. The total amount of fluid it needs to hold is only 9000 gallons; however, it is capable e of holding 11,960 gallons in case of rain fall or if additional fluid is required to be dumped for any reason.



Open Channel System for coolant coming from Trash Tank



Time required to Fill Tanks

1. Purpose:
    a. Determine the flow rate of the system based on how quickly we wish to fill up our tanks in a way that is efficient and practical.

2. Drawing Diagrams:
    a. Please see document 1A as a visual aid for location of the tanks.

3. Sources: Mott, R ,Untener, J.A., "Applied fluid mechanics" 7th edition, Pearson education INC, (2015)

4. Design Considerations:
    a. The low rate must be fast enough to be efficient but not so fast that it is not practical or cost effective.
    b. It should be done in a way that it causes turbulent flow so that the oil/ water mixture has less of a chance arriving at the machining area separated.
    c. The critical velocity should not be violated, if this does occur we will need to increase the pipe diameter or increase the fill time.

5. Data and variables:
    a. The liquid we are pumping through the building is very similar to water as it has a specific gravity of .94 .
    b. The tanks we are using are made of stainless steel and the pipes we are going to use are going to be steel schedule 40.
    c. The critical velocity was given to us. Flow rate will be adjusted to create turbulent flow as well as an efficient fill time for each tank.

6. Procedure:
    a. We will do research to find an acceptable range of time to move our amount of fluid.
    b. This time will be fixed once an acceptable value is agreed upon, this will then drive many of our design decisions.

7. Calculations:
    a. No true calculations are necessary at this point since we are using our "common sense" to justify how quickly we need to fill our tanks.

b. Achieving a velocity under the critical velocity while maintain a turbulent flow will be achieved by adjusting pipe size.

8. Summary:

Tank Name	Fluid transfer amount	Fill Time	Flow Rate GPM
Rail car to Large Storage tank	60000 Gallons	4.5 Hours	222.22
Storage tank to Reservoir tank	1000 Gallons	10 Minutes	100
Reservoir tank to trash tank	9000 Gallons	100 Minutes	90
Trash tank to removal truck	9000 Gallons	60 minutes	150

9. Analysis:
   a. If we increase the flow rate we must increase the pipe diameter, to avoid the critical flow rate, which leads to faster fill times but requires much bigger pumps and power requirements.
   b. Finding an industry standard for how many gallons an hour a normal pump can handle was rather difficult, so we chose custom flow rates that fall in the spectrum of what we believe should be acceptable.

Pipe Layout for coolant system

1. Purpose: Determine the layout of the pipping system and complete calculations for variables involving flow and material size. Calculate lengths as well as this will be needed for future calculations.

2. Drawings/Diagrams:
    a. See attached diagram 1A. This is the general layout of the tanks, pipes, elbows, pumps, and drain.
    b. See document 1B for individual segments as well as calculations for lengths of pipe.

3. Sources: Mott, R ,Untener, J.A., "Applied fluid mechanics" 7^{th} edition, Pearson education INC, (2015)

4. Design considerations:
    a. The pipes will run in straight lines where applicable to reduce the amount of energy loss as well as reduce cost.
    b. The diameter of the pipe will be calculated by using the specified critical velocity of 9.84 ft/s^2 and the desired flow rate we have agreed upon.
    c. The pipe for the large storage tank will be at roof level to avoid consuming storage space on the roof.
    d. The 1000-gallon reservoir tank will be placed far enough underground that it will be below the frost line, which means that the pipe leading to/from this location will have an appropriate length.
    e. The Pipe removing contaminated coolant will come from the center of the room along the ceiling.
    f. Some lengths will have to be estimated not all necessary dimensions regarding the building are included. Every attempt will be made to accurately estimate these lengths.
    g. Piping will run along the ceiling or walls as an attempt to avoid the creation of tripping hazards or obstacles for other systems.
    h. There should be a valve before and after each pump for maintenance reasons.
    i. The depth of the room is estimated to be 150 ft. To place the tank in the center of the room would place it a total of 675 feet from the track and 50 feet back from the front of the building.
    j. The estimated distance of the pipe starting from the center of the machining area to the trash tank is estimated to be 455ft.

5. Data and variables:
    a. The length from the tracks to the 1000-gallon reservoir tank is given as 600ft.

b. The roof is 32ft above the floor.
c. The machining area is 100 feet wide.
d. The liquid we are using is like water but has a viscosity that is 150% that of water for any given temperature.
e. Critical velocity is 9.84 ft/s.

6. Procedure:
    a. Using "Common Sense" and our best judgment we will find the best possible location for the piping by making it as short as possible.
        i. Find the closest locations for the pipe to be run regarding the storage tanks while not violating any of the design considerations mentioned above.
        ii. Verify that the locations and lengths chosen reflect the best viable options through group review.
    b. Design the diagram mentioned previously so that it can be used for future design considerations. This will be a living document capable of changing as we find/ learn better practices for a system such as this.

7. Calculations:
    a. The flow rate is found by dividing the tank volume by the amount of time we have fixed to fill/empty the tank.
    b. The area of the pipe is calculated as the flow rate divided by the velocity.
    c. The diameter is found by manipulating the equation Area=(Pi*Diameter^2)/4 .
    d. After the initial calculation an excel spread sheet was used.
    e. Flow rate and velocity were chosen using common sense, while attempting to maintain turbulent flow so that the coolant does not arrive separated.
    f. Example of solving for the main storage tank:
        i. 8058.185 ft^3/16200 seconds = .497 ft^3/second
        ii. .497ft^3/(5.70 ft/s) = .0872 ft^2
        iii. SQRT(4*.0872ft^2/Pi)=.333 ft or 4 inches in diameter

Q ft3/s	V ft/s	A ft2	Diameter Ft	Time to fill	Tank Volume ft3
0.49742	5.703019	0.08722	0.33333	4.5 Hours/16200 Seconds	8058.185
0.22236	6.547271	0.033962	0.208	10 Minutes/600 Seconds	133.68
0.20012	5.892426	0.033962	0.208	100 Minutes/ 6000 seconds	1203.125
0.3342	6.81172	0.049063	0.25	1hour/3600 seconds	1203.125

8. Summary:

a. The best option for getting coolant to and from the machining area is to use as much straight pipe as possible. By eliminating the number of elbows and bends in the pipe.
b. The fill time of the tanks allowed us to choose a pipe diameter that gave us a fluid velocity below the critical velocity. This then yielded the flow rate.

Pipe/System	Material	Total Length	Size- Internal diameter
Rail car to Storage Tank	Steel	156 feet	3.75 inch
Storage tank to Reservoir	Steel	619 feet	2.25 inch
Reservoir to trash Tank	Steel	546 feet	2.25 inch
Trash Tank to removal truck	Steel	60 feet	3 Inch

9. Analysis:
    a. Our system design meets all the design considerations we came up with during the planning phase.
    b. It has a turbulent flow which means that the drag forces acting on our liquid are minimized and the oil/water solution that makes up our coolant has less of a chance of being separated when it reaches the machines as a turbulent flow will mix the solution up.
    c. If we increased the pipe diameter or decreased the flow rate we would possibly cause laminar flow and violate the critical velocity requirement.

Calculating Pressure of fluid exiting pumps

1. Purpose: The purpose of this task is to calculate the required minimum wall thickness of the pipe we are using to transport the coolant. By proving that the standard pipe chosen has thick enough walls we can prove that a rupture will not occur. These numbers and equations can be used for later tasks such as calculating water hammer forces.

2. Drawing and diagrams:
    a. See the pipe Lay out Diagram on document 1B.
    b. See table 2A for additional detailed information.

3. Sources:
    a. Mott, R ,Untener, J.A., "Applied fluid mechanics" 7^{th} edition, Pearson education INC, (2015)
    b. http://engstandards.lanl.gov/esm/pressure_safety/process_piping_guide_R2.pdf

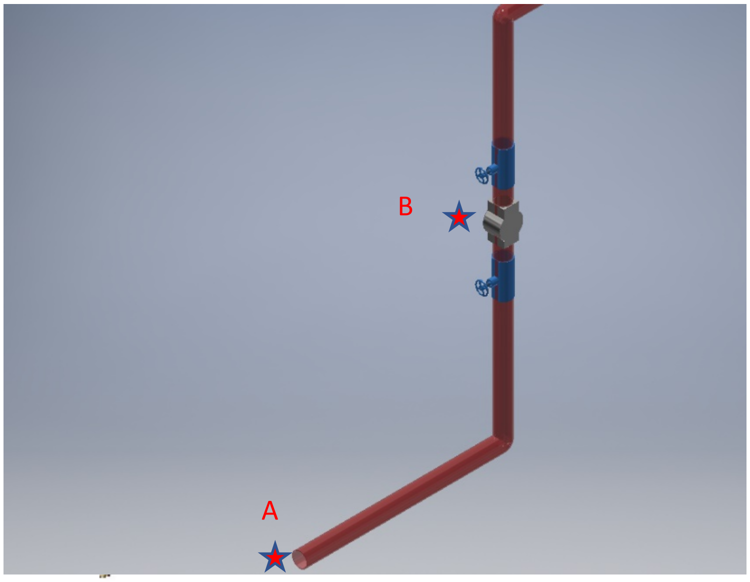
4. Design Considerations:
    a. Components chosen for our system are schedule 40 standard size pieces.
    b. Standard values for allowable stress and other factors for steel pipe are available through ASME.
    c. Care must be taken with units and assumptions.

5. Data and variables:
    a. The outside diameter of chosen pipe is given to us from Appendix F of our book.
    b. The allowable stress for steel pipe is 20ksi.
    c. The corrosion factor is .08 inches.
    d. The joint quality factor is 1.00
    e. The correction factor is .4
    f. Values for pressure will be calculated in lb/ft2 and then converted to ksi.
    g. The gamma for our liquid was chosen to be 62lb/ft^3.
    h. Values from previous tasks will be used, such as pump head and lengths for energy loss calculations.

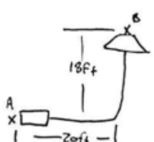
6. Procedure:
    a. We need to find the maximum pressure that will exist in our pipes to verify there is no chance of failure.
    b. A calculation for each pipe system will be done finding the pressure at the outlet of the pump.
    c. The energy losses will be found at the outlet of each pump. Lengths of pipe used will be noted in calculations.

7. Calculations:

From the rail car to the large storage tank:



Rail Car to Roof Mounted Storage Tank



$$\left[h_A - \frac{V_B^2}{2g} - Z_B - h_L\right]\gamma = P_B \quad \rightarrow \quad \left[53.26ft - \left(\frac{5.704^2}{2g}\right) - 18ft - 1.53ft\right]\frac{62}{ft}$$

$\hookrightarrow 2059.93\ lb/ft^2$

$\downarrow$

$.0143\ Kips/in^2$

$P_A = 0$

$V_A = 0$

(Being fed from A Rail car.)

Total pipe Length = 38 ft

$Z_B = 18$ ft

h_L for pipe

Using Table for an elevation of 18ft.

$h_{L_{Pipe}} = 1.15ft$

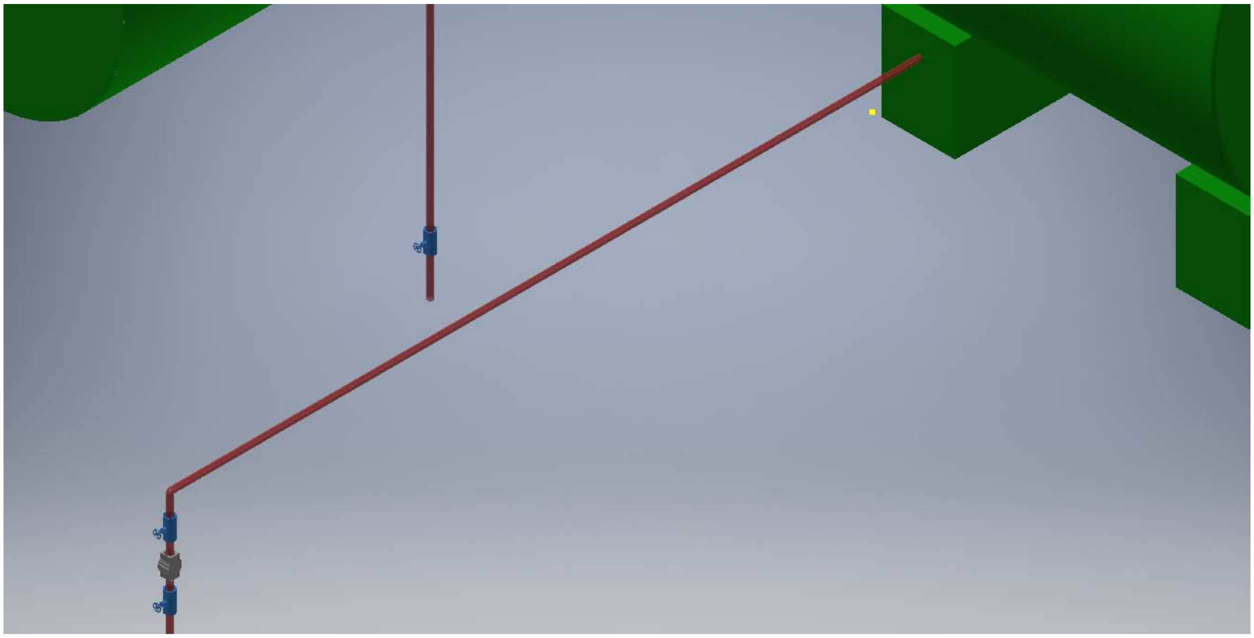
Elbow $= .02(\cancel{8}30) = .6\left(\frac{5.704^2}{2g}\right) = .30$

Valve $= .02(8) = .16\left(\frac{5.704^2}{2g}\right) = .08$

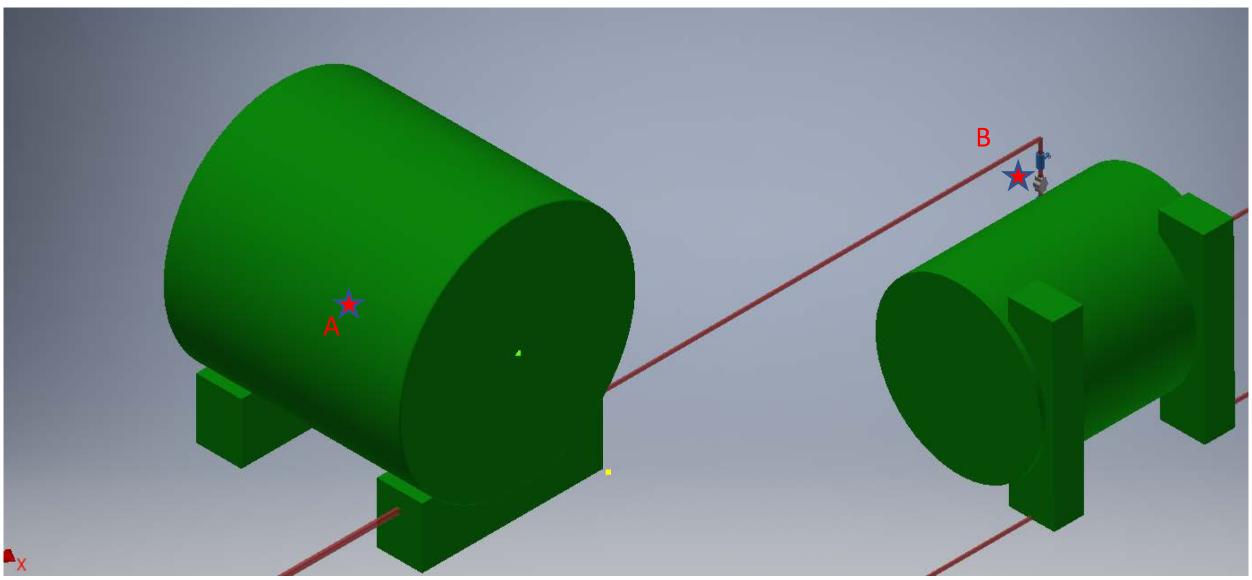
Total $= 1.53$

Large storage tank to reservoir under machines:

Back View of the system shown for clarification



Isometric view of analysis points



Storage Tank To Reservoir   Pipe Length = 247 ft

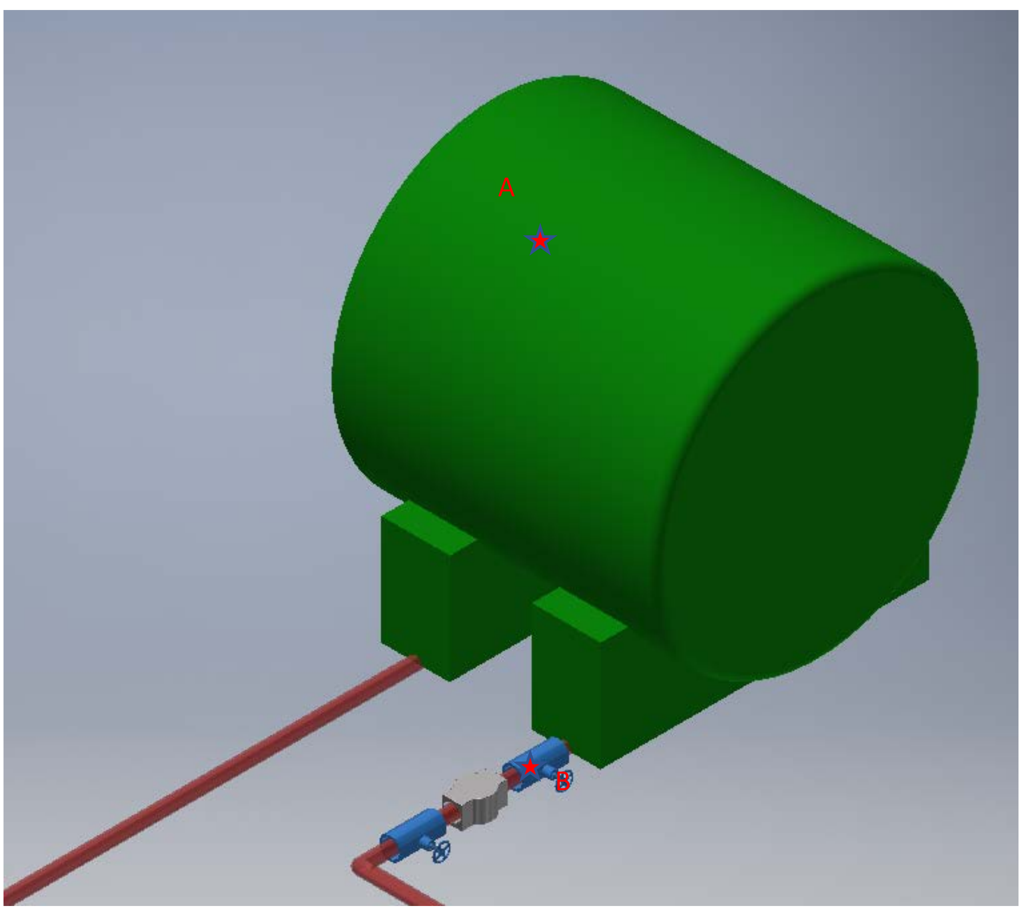
$$P_B = \left[(Z_A - Z_B) + h_A - \frac{V_B^2}{2g} - h_L\right]\gamma \qquad Z_A = 4.2\text{ ft} \quad Z_B = -2\text{ ft}$$

h_L = Pipe + Valve $\rightarrow$ 17.373 + .106 = 17.479 ft

$$P_B = \left[6.2\text{ft} + 110.86\text{ ft} - \left(\frac{6.547^2}{2g}\right) - 17.479\right]\gamma$$

$$P_B = (133.87)\,62 = 8300 \text{ lb/ft}^2 \rightarrow .058 \text{ Ksi}$$

Reservoir to trash tank:



Reservoir to Trash Tank Pipe Length = 2 ft

$$P_B = \left[H_A - \frac{V_B^2}{2g} - h_L\right]\gamma \qquad Z_A - Z_B = 0$$

h_L of pipe = .116
h_L of Valve = .095

$$P_B = \left[62.42 - \frac{(5.892)^2}{2g} - .211\right]\gamma$$

$$P_B = (62.09)62 \rightarrow 3849.7\ \text{lb/ft}^2$$

$$P_B = .027\ \text{Ksi}$$

Pipe	Pressure-ksi	Out Dia-inch	Allowable Stress-ksi	Joint Factor	Correct Factor	Thickness Required
1	0.015	4.5	20	1	0.4	0.081928234
2	0.058	2.875	20	1	0.4	0.08475936
3	0.027	2.875	20	1	0.4	0.082216937

See table 2A for calculations for energy loss and additional details for thickness calculations.

8. Summary:

System/ Pipe Size	Pressure-ksi	Min thickness required-inch	Standard thickness-inch
Rail to Roof/ SCH 40 4inch	.014	.082	.237
Roof to Reservoir/ SCH 40 2.5 inch	.058	.084	.203
Reservoir to Trash/ SCH 40 2.5 inch	.027	.082	.203

Values found in Appendix F, tables F.1 and F.2 of source A.

9. Analysis:
   a. Schedule 40 pipe is being used for all parts of the system, and provide thick enough pipe for the pressures found in our system.
   b. The pressure experienced after each pump is the remainder of what is left once the pump over comes friction forces, the difference in elevation and, the velocity divided by gravity.
   c. Increasing the pump head will increase the pressure and may require a thicker pipe to be used.
   d. Knowing the stress that a certain pipe can withstand is key here.
   e. Values for HL and lengths are based on pump location. Please see document 1B.
   f. Most of our pipe thickness comes from corrosion considerations since we are using steel.

g. Water hammer calculations will require the pipes to be thicker than calculated here.

Determining the number, types, materials, and sizes of the valves and elbows

Purpose: To determine specifications of the valves and elbows in the system.

Diagrams and Drawings:

See Document 1B for the locations of valves and elbows (attached at end of section).

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

Design Considerations:

a. Tanks are steel
b. Pipes are Schedule 40 steel

Data and Variables:

a. Pipes are 4 inches, 2.5 inches, and 3 inches.

Procedure:

The choice of gate valves was made to allow for control of flow. 90° short radius elbows were chosen to eliminate some space. There are six elbows, in the system to be placed at each bend needed in the pipes. Common standard sizes for valves and elbows were chosen.

Summary:

Systems →

From railcar to storage tank on roof:

2 elbows, 90° short radius, 4 inch Schedule 40
2 valves, also 4 inch Schedule 80

From storage tank to reservoir tank:

2 elbows, 90° short radius, 2.5 inch Schedule 40
2 valves, 2.5 inch Schedule 40

From reservoir tank to trash tank:

2 elbows, 90° short radius, 2.5 inch Schedule 40
4 valves, 2.5 inch Schedule 40
2 flanges - drain and blind flange specified from task 3

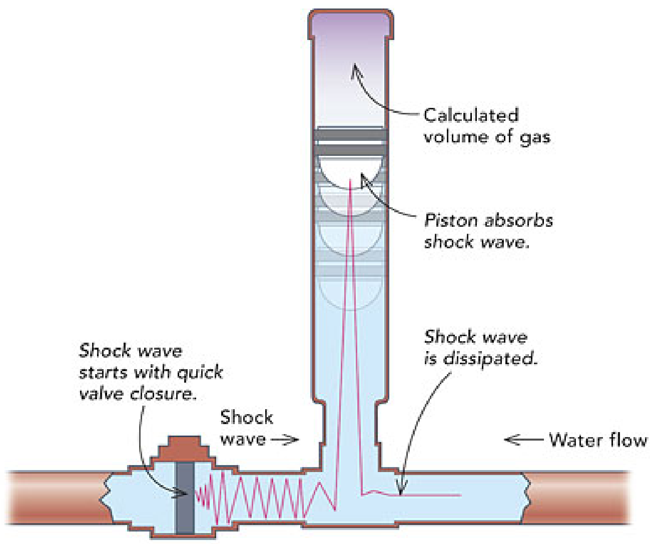
From trash tank to removal truck:

1 valve, 3 inch Schedule 40

Water Hammer Arrestors

1. Purpose:
    a. To calculate the amount of pressure the selected pipe can withhold, thus determining the best fit water hammer arrestor to handle the over-pressure.

2. Drawing and diagrams:
    a.



3. Sources: Mott, R ,Untener, J.A., "Applied fluid mechanics" 7th edition, Pearson education INC, (2015)

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    Sioux Chief – Professional Manufacturer (Water Products and Water Specialties)

4. Design Considerations:
    a. Pressure is maximum at outlet of each pump
    b. The specific gravity of the water/oil coolant is .94
    c. Thickness of schedule 40 steel pipe will be used rather than the minimum thickness required derived in Task 9.
    d. Worst case scenarios taken into account

5. Data and variables:

    P(Pressure) = .0143 ksi = 14.3 psi
    p(Density) = 940 kg/m^3
    Eo=343,000 psi = 2.36 x 10^9 N/m^2
    V(Velocity) = 5.7 ft/s = 1.74 m/s
    I.D(Inner Diameter) = 4.026 inches = .1023 meters
    T(Thickness) = .006 meters
    Esteel = 2.9 x 10^7 psi = 1.99 x 10^11 N/m^2

6. Procedure:
    a. First we must derive all variables/values required to solve for C as specified in the data and variables section. Most of these equations/values were used in Task 9 and can be plugged directly in.
    b. Next we must solve for C, which will give us the remaining value required to determine the change in pressure due to water hammer
    c. Then having solved for that change in pressure, we are then able to plug-in the pipe pressure value from task 9 and sum it with the pressure value due to water hammer. Thus resulting in a new Pmax.
    d. Finally, we will plug these values into a new thickness calculation(taking worst case scenario into effect) and will be able to determine if a water hammer arrestor is necessary.

7. Calculations:

$$C = \frac{\sqrt{\frac{E_o}{\rho}}}{\sqrt{1 + \frac{E_o D}{E_{steel}\,\delta(T)}}}$$

$$= \frac{\sqrt{\frac{2.36 \cdot 10^{\wedge 9}\ N/m^2}{940\ Kg/m^3}}}{\sqrt{1 + \frac{(2.36 \cdot 10^{\wedge 9}\ N/m^2)(.1025\,m)}{(1.99 \cdot 10^{\wedge 11}\ N/m^2)(.006\,m)}}}$$

$$C = \frac{1584.50}{1.096630}$$

$$C = 1{,}444.88$$

$$\Delta P = \rho C V$$

$$\Delta P = (940 Kg/m^{\wedge}3) \cdot (1{,}444.88) \cdot (1.74\ m/s)$$

$$\Delta P = 2{,}363{,}245.73\ N/m^2$$

$$\Delta P = 342.76\ psi$$

$$P_{max} = P(\text{water hammer}) + P(\text{pipe})$$

$$P_{max} = 342.76\ psi + 14.3\ psi$$

$$P_{max} = 357.06\ psi$$

$$t = \left[\frac{P_{max}(D)}{2(S)(E) + P_{max}(.4)}\right]$$

$$t = \left[\frac{(357.06 psi)(4.5_{in})}{2(20{,}000\ psi)(.80) + 357.06 psi(.4)}\right] = .0498\ \text{inches}$$

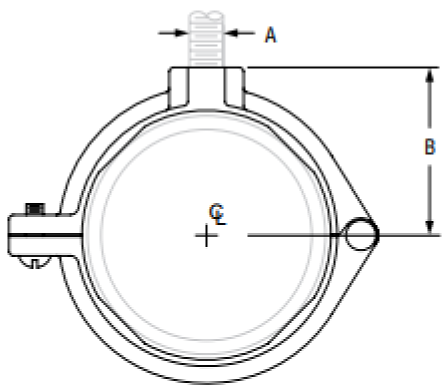
8. Summary:

   Based on the calculations listed above, the system requires a pipe wall thickness of .0498 inches when water hammer is taken into account. The pipe selected for this section of the system has a wall thickness of .237 inches. Therefore, a water hammer arrestor will not be necessary in this section of the system. Please see the table below for the pipe thickness requirements of the other systems.

Pipe Supports

1. Purpose:
    a. To determine the type of supports and determine the force acting upon each support. This value will need to be used to regulate the distance between supports.

2. Drawing and diagrams:
    a.



3. Sources: Mott, R ,Untener, J.A., “Applied fluid mechanics” 7th edition, Pearson education INC, (2015)

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    Anvil – Professional Manufacturer (Pipe Hanger and Supports)

4. Design Considerations:
    a. Pipes are completely filled at all times
    b. New pipe and pipe age is not taken into account
    c. 10% diameter maximum deflection ratio taken into account
    d. No objects will be hanging on supported from the pipes
    e. Split ring hangers will be used.

5. Data and variables:

   Outside Diameter = 4.5 inches

   Inside Diameter = 4.026 inches

   Density of Coolant = 1.8236 slug/ft^3 = 1.055 x10^-3 slug/in^3

   Density of Steel = .284 lb/in^3 = 8.82 x 10^-3 slug/in^3

   Esteel= 29,000,000 PSI

   g = 32.2 ft/s^2 = 386.4 in/s^2

   Deflection of Pipe/Beam Equation = Y = -((PL^3)/48EI)

6. Procedure:
    a. First we must derive all variables/values required to solve for the mass, volume, and density of the pipe and coolant
    b. Next we must solve for L length of pipe between hanger, which we will do so by manipulating the deflection equation.
    c. Then we will used the necessary length between pipe to solve the force between each support.
    d. The force between the hangers will be solved by using a manipulation of the F = M * G formula

7. Calculations:

$\boxed{\text{Steel Pipe}}$

ρ = Density V = Volume = $A \cdot L$

$$M_{pipe} = \rho \cdot V$$

$$= 8.82 \cdot 10^{-3} \cdot \left(\frac{\pi (4.5)^2}{4} - \frac{\pi (4.026)^2}{4} \right) \cdot L$$

$$m_{pipe} = .0279\ L$$

$$W_{pipe} = m_{pipe} \cdot g$$

$$Weight_{pipe} = W_{pipe} = .0279\ L\ (386.4)$$

$$W_{pipe} = 10.808$$

$\boxed{\text{Coolant} =}$

$$M_C = \rho \cdot V$$

$$= 1.055 \cdot 10^{-3} \cdot \left(\frac{\pi (4.026)^2}{4} \right) L$$

$$M_C = .0134236 L$$

$$W_c = .0134236 L \cdot (386.4)$$

$$W_c = 5.1868867 L$$

$W_{total} = W_{Pipe} + W_{coolant}$

$W_{total} = 15.99L$

$$I_{nterior} = \pi \frac{(O.D^4 - I.D.^4)}{64}$$

$I_{nterior} = 7.23 \ in^4$

Plugging back into the deflection formula we find;

$$Y = -\frac{PL^3}{48EI}$$

Y = amount of deflection

Through sources, I have seen both 1% + 25% of pipe diameter as max allowed deflection. I will use 10% to be safe.

$.4 = 10\%$ of 4 inch pipe

$$.4 = \frac{(15.99L)L^3}{48(29{,}000{,}000)(7.23)}$$

$$L = \sqrt[4]{\frac{.4}{1.5937 \cdot 10^{-9}}}$$

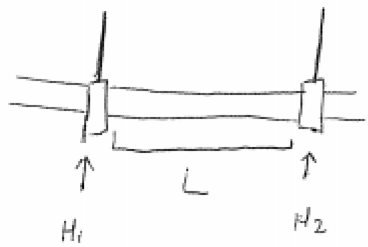
$L = 125.966$ inches $\boxed{L = 10.497 \text{ ft}}$ - Length between each hanger

Forces on hanger

$$F = W \cdot L$$

$$= 15.99\,\tfrac{lb}{ft} \cdot 10.497\,ft$$

$$\boxed{F = 167.84\ lbf}$$ Force on hanger



8. Summary:

Based on the calculations listed above, this system requires the use of split ring hangers. Due to the need of vertical and horizontal supports, these split ring hangers serve as the best multi-purpose hanger/support option.

Support Type	Pipe Diameter(inches)	Distance between Hanger	Force on Hangers	Distance between Hangers Used
Split-ring hanger	4	10.5 feet	167.84 lbf	8 feet
Split-ring hanger	2.5	12.3 feet	82.6 lbf	8 feet
Split-ring hanger	2.5	12.3 feet	82.6 lbf	8 feet
				* Safety Factor and Uniformity

Minor and Friction Losses

1. Purpose:
    a. To perform a detailed hydraulic analysis on all parts of the system. This will be done by determining the minor losses per section due to friction.

2. Drawing and diagrams:
    a. N/a

3. Sources: Mott, R ,Untener, J.A., “Applied fluid mechanics” 7th edition, Pearson education INC, (2015)

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4. Design Considerations:
    a. The only fittings and valves in the system are the ones specified
    b. The piping in the system is all brand new
    c. The type of coolant has no effect on the friction

5. Data and variables:
    a. We know our pipe lengths, sizes, valves, and elbows as specified in the pipe layout
    b. Data and variables incorporated into calculations below.

6. Procedure:
    a. To begin this hydraulic analysis process, we must first begin by incorporating the values of Qft/s^3, Vft/s, and Aft/s as solved for earlier in the layout process when determining pipe size and time to fill.
    b. These values will be useful in helping us determine Reynold's number and the Friction factor. Having solved for these variables, we will then be able to solve the equation for head loss.

7. Calculations:

Qft3/s= Tank Volume/Time to fill
Aft/s = .0799 (value determined due to diameter of pipe)
Vft/s= (Qft3/s) / (Aft/s)
Viscosity = .000018 (Derived from table in book)
Reynolds number = (Vft/s * Diameter(internal-.3192ft)) / Viscosity
Reynolds number = 174,477.78
Epsilon = .00015

$$f = \frac{0.25}{\left[\log\left(\frac{1}{3.7\,(D/\varepsilon)} + \frac{5.74}{N_R^{0.9}}\right)\right]^2}$$

Plugging in values we determine that f=.0189706

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

The remaining step is to plug all solved values in the formula above while accounting for all valves and elbows. This is completed by using the fT and Le/D in the tables below.

hL= f *(L/D) *(V^2/2g) + (Number of valves*Le/D*fT) + (Number of elbows*Le/D*fT)

hL of pump 1 = 6.91 ft
hL of pump 2= 54.37 ft
hL of pump 3= 47.92 ft

TABLE 10.4 Resistance in valves and fittings expressed as equivalent length in pipe diameters, L_e/D

Type	Equivalent Length in Pipe Diameters L_e/D
Globe valve—fully open	340
Angle valve—fully open	150
Gate valve—fully open	8
—¾ open	35
—½ open	160
—¼ open	900
Check valve—swing type	100
Check valve—ball type	150
Butterfly valve—fully open, 2–8 in	45
—10–14 in	35
—16–24 in	25
Foot valve—poppet disc type	420
Foot valve—hinged disc type	75
90° standard elbow	30
90° long radius elbow	20
90° street elbow	50
45° standard elbow	16
45° street elbow	26
Close return bend	50
Standard tee—with flow through run	20
—with flow through branch	60

(Reprinted with permission from "Flow of Fluids Through Valves, Fittings and Pipe, Technical Paper 410" 2011. Crane Co. All Rights Reserved.)

TABLE 10.5 Friction factor in zone of complete turbulence for new, clean, commercial Schedule 40 steel pipe

Nominal Pipe Size		Friction factor, f_T	Nominal Pipe Size		Friction factor, f_T
U.S. (in)	Metric (mm)		U.S. (in)	Metric (mm)	
½	DN 15	0.026	3, 3½	DN 80, DN 90	0.017
¾	DN 20	0.024	4	DN 100	0.016
1	DN 25	0.022	5, 6	DN 125, DN 150	0.015
1¼	DN 32	0.021	8	DN 200	0.014
1½	DN 40	0.020	10–14	DN 250 to DN 350	0.013
2	DN 50	0.019	16–22	DN 400 to DN 550	0.012
2½	DN 65	0.018	24–36	DN 600 to DN 900	0.011

8. Summary:
    a. Analyzing our calculations, we can determine that the length of the pipe run has the greatest impact on head loss. Pipe runs one and two had similar valve and elbow layouts however differed in hL values drastically.

Q ft3/s	V ft/s	A ft2	Pipe type Diameter in inches	Tank Volume ft3	Time to fill s	Time to fill in hrs	Q in gph	Diameter	v= kin. Viscos ft2/s @60 degre	Reynolds Number
0.5	6.4935	0.0799	Sch 80 4	8058.185	16116.37	4.476769444	13465	0.31917	0.000018	115139.4811
0.2	7.247	0.0294	Sch 40 2.5	133.68	668.4	0.185666667	5386	0.20583	0.000018	82870.68214
0.2	7.247	0.0294	Sch 40 2.5	1203.125	6015.625	1.671006944	5386	0.2058	0.000018	82857.36667

Epsilon	Roughness	FF Step1	FF step2	ff step3	FF step4	Friction Factor step5-Final Number	Length(ft)	Energy Loss(ft)	Valves	Elbows
0.00015	2127.778	0.0001243	0.00016	-3.546	12.577	0.0198782	150	6.912958354	2	2
0.00015	1372.222	0.0001928	0.00021	-3.39	11.489	0.021759083	615	54.36927007	4	2
0.00015	1372	0.0001928	0.00021	-3.39	11.489	0.021759935	553	47.91835431	2	0

Determining Pump Head and Flowrate

1. Purpose:
    a. To determine the amount of pumps required to make the pipe system run properly at a maximum efficiency. To ensure complete functionality of the system we will also need to calculate pump head and flowrate.

2. Drawing and diagrams:
    a. N/a

3. Sources: Mott, R ,Untener, J.A., "Applied fluid mechanics" 7th edition, Pearson education INC, (2015)

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4. Design Considerations:
    a. The only fittings and valves in the system are the ones specified
    b. The piping in the system is all brand new
    c. The type of coolant has no effect on the friction
    d. No additional piping specialties in system besides valves and elbows

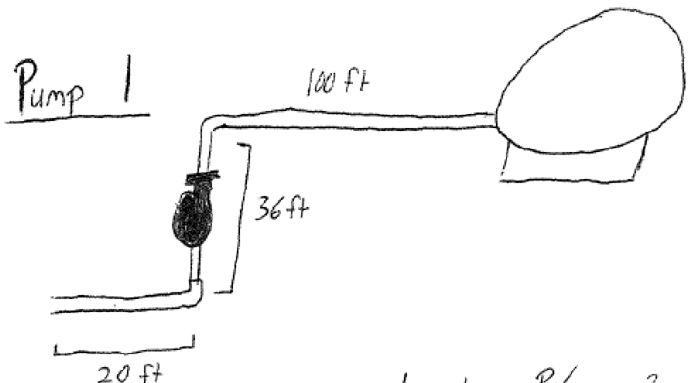
5. Data and variables:
    a. We know our pipe lengths, sizes, valves, and elbows as specified in the pipe layout
    b. Data and variables incorporated into calculations below.
    c. Head loss values/calculations were derived in Task 7

6. Procedure:

   a. The procedure of this task will be a continuation of the efforts of the last task.
   b. To continue this hydraulic analysis process, we must first begin by incorporating the head loss values and the pipe layout dimensions into Bernoulli's equation.
   c. To solve Bernoulli's equation, the variables must be manipulated to fit the tested part of the system.
   d. Once the arrangement of the equation correlates the system in test, the corresponding values are plugged in to solve for the pump head.

7. Calculations:

hL of pump 1 = 6.91 ft
hL of pump 2= 54.37 ft
hL of pump 3= 47.92 ft



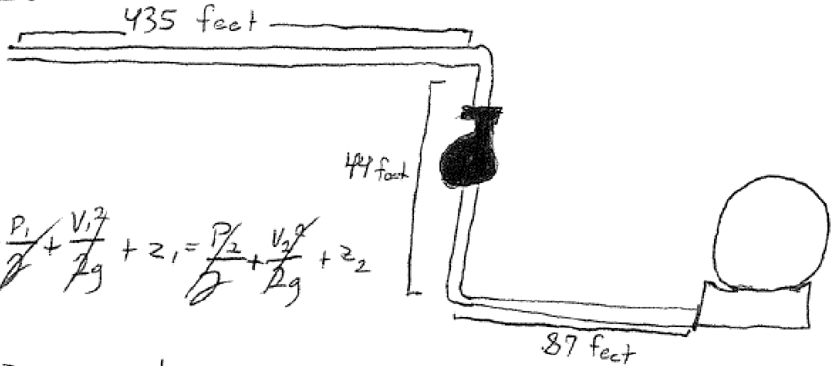
$$h_A - h_L + \cancel{\frac{P_1}{\gamma}} + \frac{v_1^2}{2g} + z_1 = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{v_2^2}{2g}} + z_2$$

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

$$h_A = 6.913 + 51 - 4 - \frac{(6.4935)^2}{2g}$$

$$\boxed{h_A = 53.26 \text{ ft}}$$

Pump 2



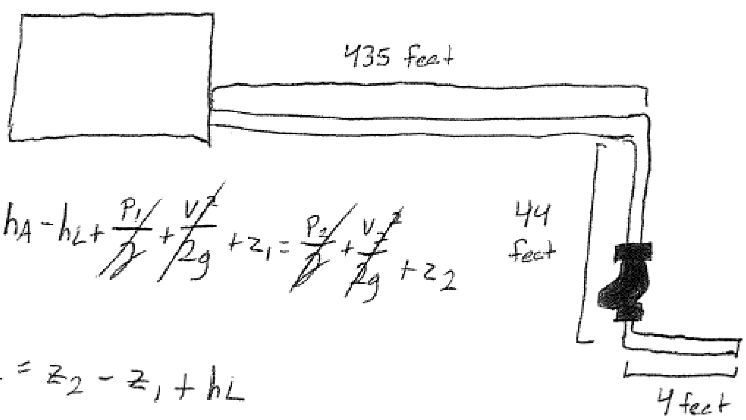
$$h_A - h_L + \cancel{\frac{P_1}{\gamma}} + \cancel{\frac{V_1^2}{2g}} + z_1 = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + z_2$$

$$h_A = z_2 - z_1 + h_L$$

$$h_A = 51 - (-5.5) + 54.36$$

$$\boxed{h_A = 110.86 \text{ feet}}$$

Pump 3



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

$$h_A = z_2 - z_1 + h_L$$

$$h_A = 9 + 5.5 + 47.92$$

$$\boxed{h_A = 62.42 \text{ ft}}$$

Flow rate = Q(GPM's)

Q=A *V
Flow rate in GPM's of pump 1= 224.42
Flow rate in GPM's of pump 2= 89.76
Flow rate in GPM's of pump 3= 89.76

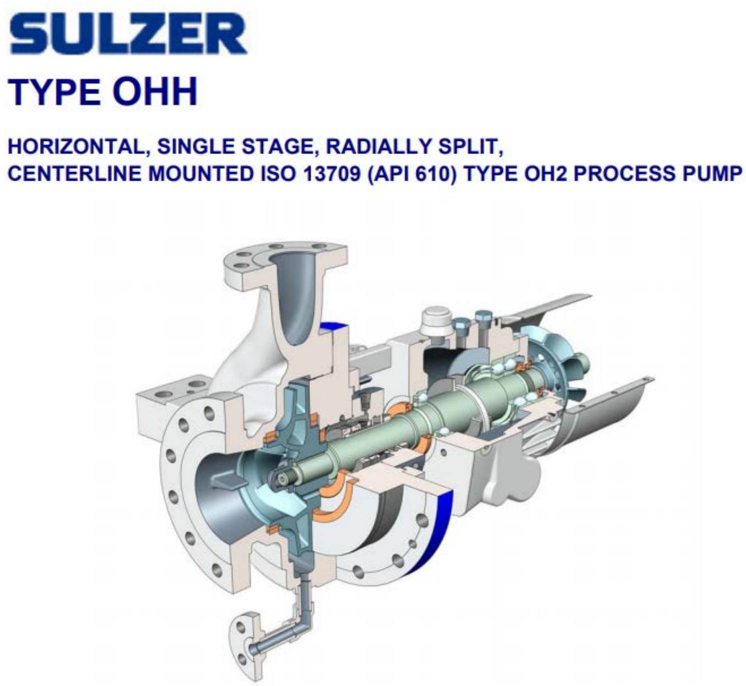
8. Summary:
   a. Analyzing our calculations, we get a better understanding of the similarities between the values of pump head and head loss. We see that pump head doesn't go as hand in hand with the flow rate as expected.

	Energy Loss(ft)	Valves	Elbows	Pump Head(ft)	Flow Rate(GPMs)
Pump 1	6.912958354	2	2	53.26	224.4155845
Pump 2	54.36927007	4	2	110.86	89.7662338
Pump 3	47.91835431	2	0	62.42	89.7662338
Pump 4	1.402077515	2	0	2.122573024	149.9998255

Pump Selection

1. Purpose:
    a. To determine the number of pumps required to operate the designed system and select the best fit pumps based on the specifications calculated. These specifications include flow capacities, head requirements, and power required. Through this selection process the customer will be informed the reasoning behind using a kinetic, radial pump and it's benefits in this system over the other options.

2. Drawing and diagrams:
    a.



3. Sources: Mott, R ,Untener, J.A., "Applied fluid mechanics" 7th edition, Pearson education INC, (2015)

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    Sulzer Pump Catalog – Professional Pump Manufacturer

4. Design Considerations:
    a. Pump selection limited to Sulzer pump catalog
    b. Pressure is maximum at outlet of each pump
    c. The specific gravity of the water/oil coolant is .94
    d. Values for coolant flow and pump head were determined in previous task
    e. Worst case(maximum/minimum) scenarios taken into account
    f. Liquid coolant has a low viscosity
    g. Pump aging will not be taken into account

5. Data and variables:

    Q1 = 223.25 gpms or 50.7 m^3/h

    Q2 = 99.79 gpms or 22.7 m^3/h

    Q3 = 89.82 gpms or 20.4 m^3/h

    H1 = 53.26 ft or 16.23 m

    H2 = 110.86 ft or 33.79 m

    H3 = 62.42 ft or 19.03 m

6. Procedure:
    a. We need to select three Sulzer pumps that can ensure the proper function of our system while maintaining maximum efficiency. Before these pumps can be selected, we must decide whether a kinetic/ radial pump is necessary.
    b. Using flow requirements and pump head values that we previously solved for in earlier task, we will then begin by carefully examining Sulzer Range of Performance Charts and pump schematic cut sheets/schematics. Once a range has been established, we will need to solve for n, the required rpms.
    c. After analyzing all information, we will accurately be able to choose the pump of best fit. This selection will lay the foundation in determining impeller size, efficiency, etc.
    d. Finally, we will plug these values into equations and will be able to use the graphs below to determine the power required and NPSH required.

7. Calculations:

We chose to use a kinetic pump on this project for various reasons. The main reason including the low-viscosity of the coolant fluid. With the simplicity of the lower flow and head demand, we are able to save the energy and resources a positive displacement pump would of required. The smaller single phase kinetic pump will give the warehouse a better control of flow than the multi-phase positive displacement pump would. Choosing a kinetic pumps gives us three additional options of specialization. These options include radial flow, axial flow, and mixed flow. Solving for the equation for specific speed will allow us to pinpoint which category our pumps will need to fall under.

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

N = Rotational speed of impeller (
Q = Flow rate (gpm)
H = Total head of pump (ft)

$$\frac{3520\sqrt{223.25}}{53.26^{3/4}}$$

Ns for Pump 1 =   2667.70 RPMs

$$\frac{3520\sqrt{99.79}}{110.86^{3/4}}$$

Ns for Pump 2 = 1029 RPM's

$$\frac{3520\sqrt{89.82}}{62.42^{3/4}}$$

Ns for Pump 3 = 1502.23 RPM's

$$D_s = \frac{DH^{1/4}}{\sqrt{Q}} \qquad N = \text{Rev/min} \qquad H = \text{Head, ft}$$
$$Q = \text{Flow, U.S. gpm} \qquad D = \text{Diameter, in}$$

Ds of Pump 1 = .72

$$\frac{4\sqrt[4]{53.26}}{\sqrt{223.25}}$$

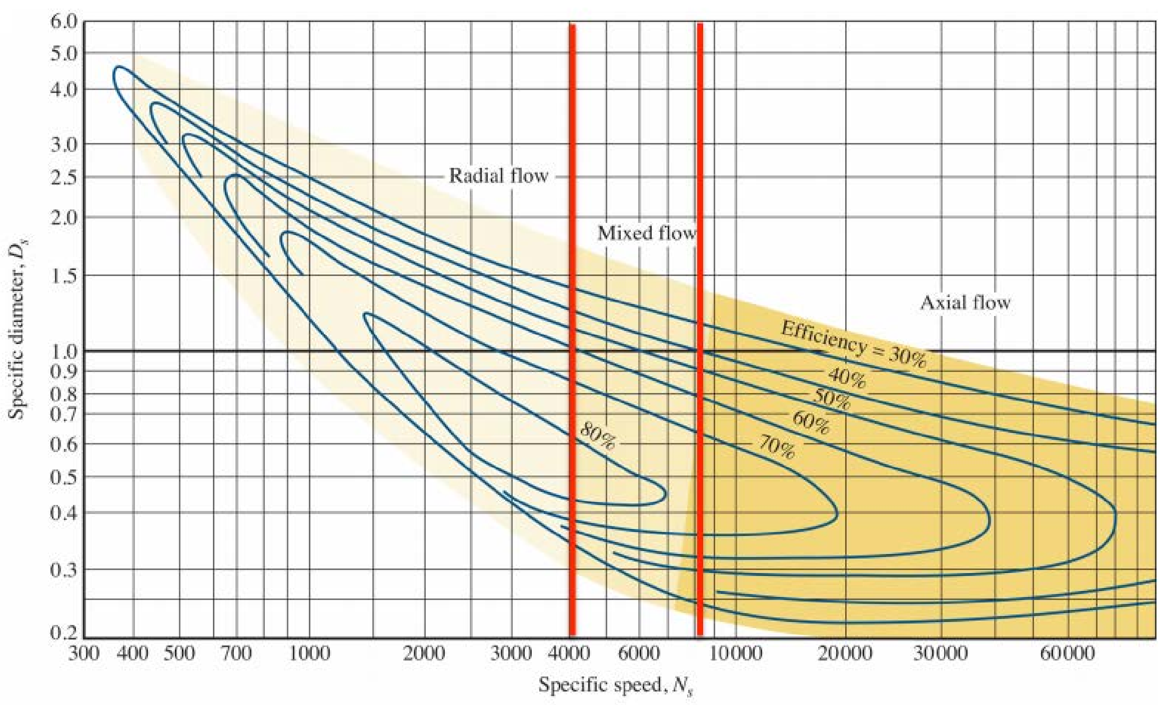
Ds of Pump 2 = 1.29

$$\frac{4\sqrt[4]{110.86}}{\sqrt{99.79}}$$

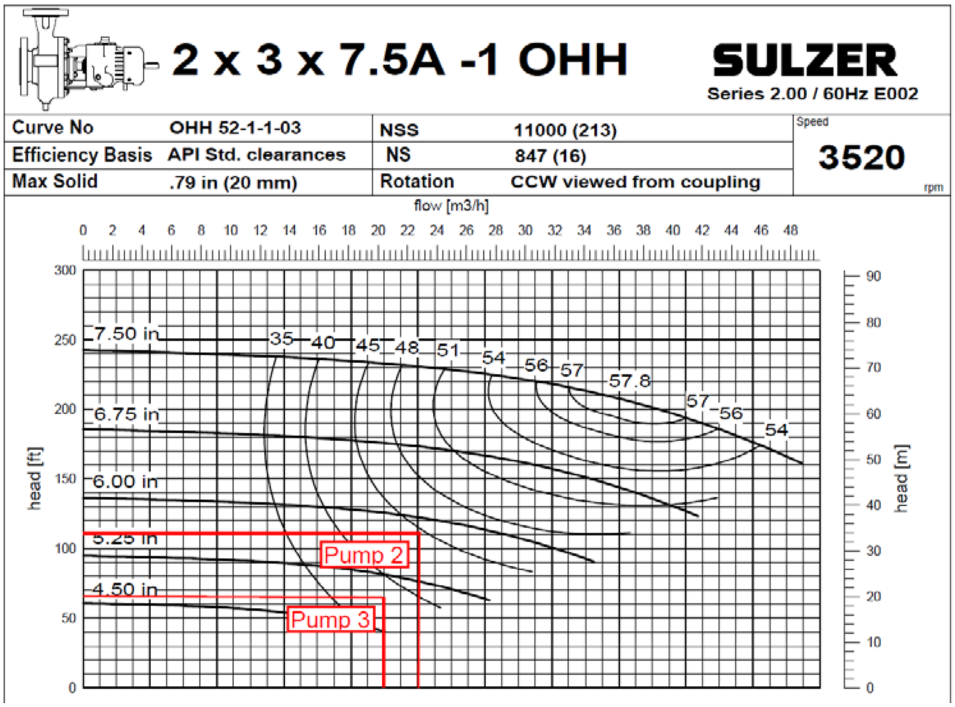
Ds of Pump 3 = 1.19

$$\frac{4\sqrt[4]{62.42}}{\sqrt{89.82}}$$

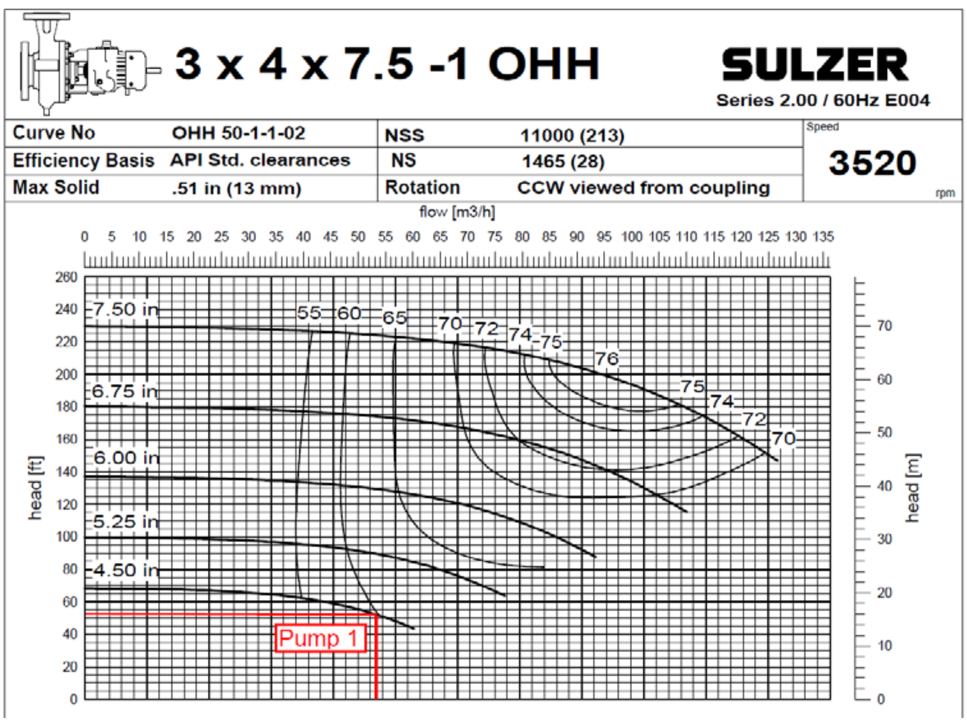
With our values of specific speed, Ns falling safely under 4000 and our specific diameter ranging between 1.29 - .72, we use the graph below to demonstrate our choice of using a radial flow pump.



8. Summary:



2 x 3 x 7.5A -1 OHH
SULZER
Series 2.00 / 60Hz E002
Curve No OHH 52-1-1-03
Efficiency Basis API Std. clearances
Max Solid .79 in (20 mm)
NSS 11000 (213)
NS 847 (16)
Rotation CCW viewed from coupling
Speed 3520 rpm
flow [m3/h]
head [ft]
head [m]
7.50 in
6.75 in
6.00 in
5.25 in
4.50 in
Pump 2
Pump 3



3 x 4 x 7.5 -1 OHH
SULZER
Series 2.00 / 60Hz E004
Curve No OHH 50-1-1-02
Efficiency Basis API Std. clearances
Max Solid .51 in (13 mm)
NSS 11000 (213)
NS 1465 (28)
Rotation CCW viewed from coupling
Speed 3520 rpm
flow [m3/h]
head [ft]
head [m]
7.50 in
6.75 in
6.00 in
5.25 in
4.50 in
Pump 1

Through the calculations and analysis, we were able to pinpoint the pumps of best fit, and determine the modifications we needed to select to make these pumps most suitable for our system. The pumps and modifications our values selected for us were as follows;

Pump 1 ----3 x 4 x 7.5 -1 -Impeller size 4.5 inches @ 60% efficiency rate
Pump 2 ----2 x 3 x 7.5A -1 -Impeller size 5.25 inches @ 45% efficiency rate
Pump 3----2 x 3 x 7.5A -1 -Impeller size 6.00 inches @ 38% efficiency rate

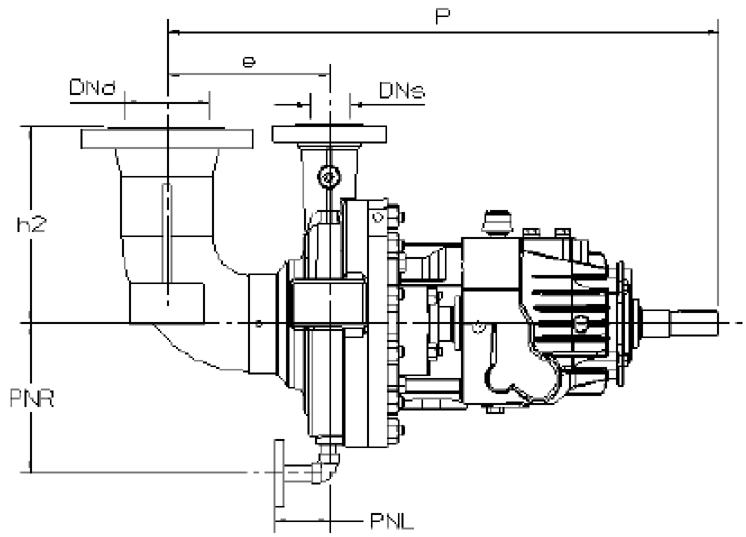
9. Summary:

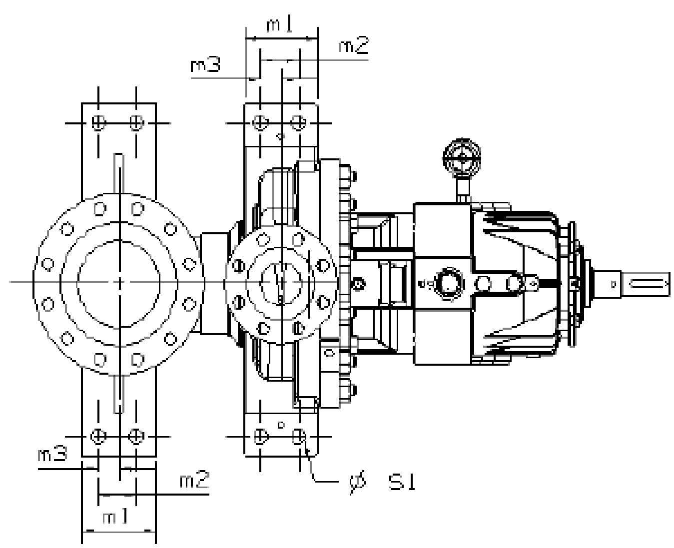
	Head Requirement	Flow Capacity	Pump Size	Impeller size	Efficiency Rating
Pump 1	53.26 ft	223.25 gpm	3 x 4 x 7.5-1	4.5 in	60%
Pump 2	110.86 ft	99.79 gpm	2 x 3 x 7.5A-1	5.25 in	45%
Pump 3	62.42 ft	89.82 gpm	2 x 3 x 7.5A-1	6.00 in	38%

Pump Characteristics

1. Purpose:
    a. To determine the characteristics of the pumps; including the point of operation, actual pump size, and weight. Provide cut-sheets and specifications for the selected pumps.

2. Drawing and diagrams:
    a.





3. Sources: Mott, R ,Untener, J.A., “Applied fluid mechanics” 7th edition, Pearson education INC, (2015)

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   Sulzer Pump Catalog – Professional Pump Manufacturer

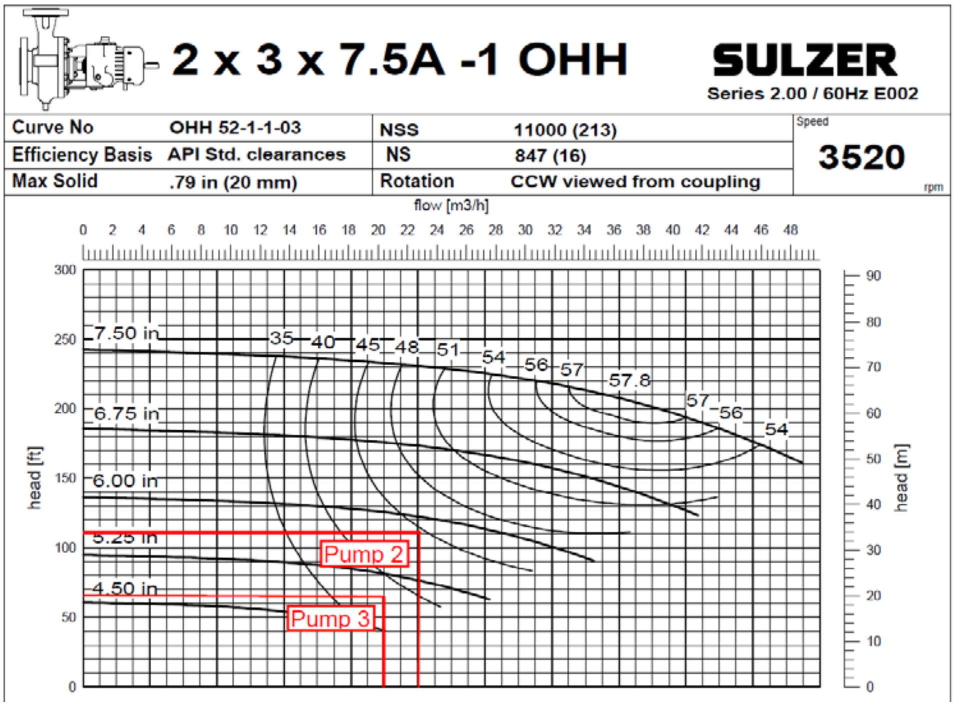
4. Design Considerations:
   a. Pump selection limited to Sulzer pump catalog
   b. Pressure is maximum at outlet of each pump
   c. The specific gravity of the water/oil coolant is .94
   d. Values for coolant flow and pump head were determined in previous task
   e. Worst case(maximum/minimum) scenarios taken into account
   f. Liquid coolant has a low viscosity
   g. Pump aging will not be taken into account

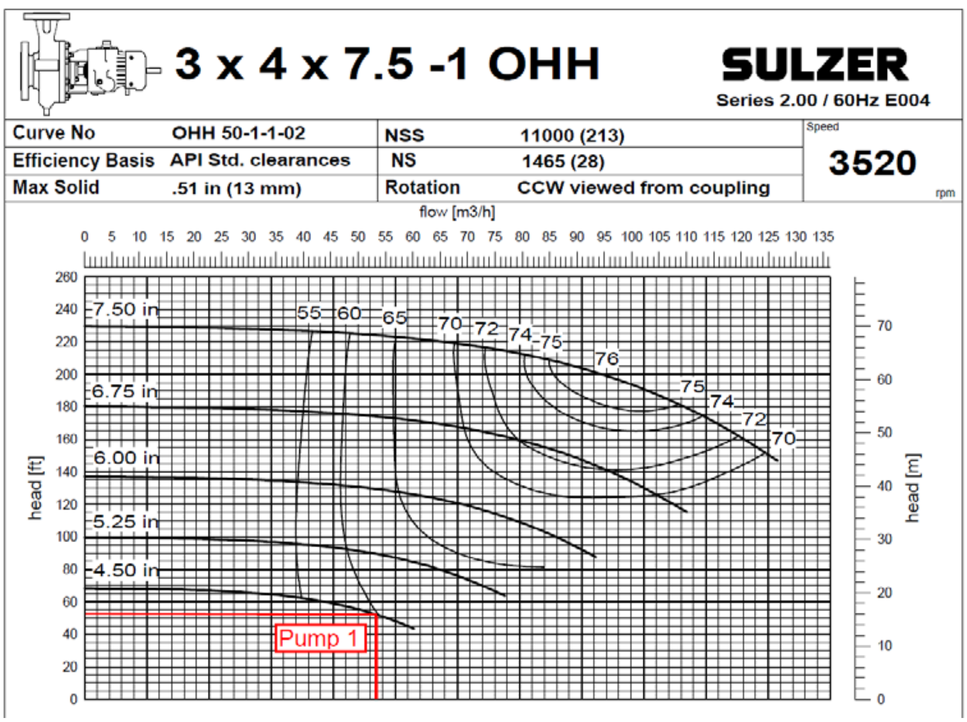
5. Data and variables:

   Q1 = 223.25 gpms or 50.7 m^3/h
   Q2 = 99.79 gpms or 22.7 m^3/h
   Q3 = 89.82 gpms or 20.4 m^3/h
   H1 = 53.26 ft or 16.23 m
   H2 = 110.86 ft or 33.79 m
   H3 = 62.42 ft or 19.03 m

6. Procedure:
   a. We will use Sulzer cut-sheets and submittal specifications to display the characteristics of the pumps; including the point of operation, actual pump size, and weight.

7. Calculations:

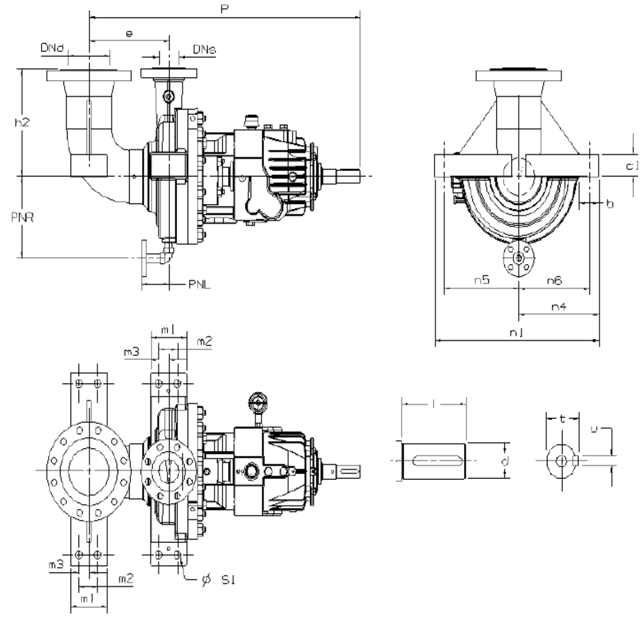




SULZER

DIMENSIONAL DATA - TYPE OHH

General Arrangement – Bare Shaft Top Suction – US Customary Units



Certified by : ________________________**date:**__________
Ref No. : ____
Project Name : ____
Project Item No.: ______________________________________

All dimensions are nominal inches and for guidance only. Certified Drawings will be issued for actual construction.
Rotation is counterclockwise –H.I. looking from Drive End.

Pumps 2 & 3
Pump 1

PUMP SIZE	PUMP wt lbs	DNs	DNd	h2	e	P	n1	n4	n5	n6	b	c1	m1	m2	m3	S1	l	d	t	u	PNR	PNL
		in																				
1x2x7.5-1	362	2	1	9.06	6.89	33.03	18.90	9.45	8.46	8.46	3	1.97	3.94	1.97	0.71	0.94	3.54	1.26	1.38	0.39	7.48	3.94
2x3x7.5A-1	409	3	2	9.06	9.84	36.10	18.90	9.45	8.46	8.46	3	2.36	4.33	1.97	0.79	0.94	3.54	1.26	1.38	0.39	7.87	3.94
2x3x7.5B-1	408	3	2	9.06	9.84	36.10	18.90	9.45	8.46	8.46	3	2.36	4.33	1.97	0.79	0.94	3.54	1.26	1.38	0.39	7.87	3.94
3x4x7.5-1	443	4	3	9.06	11.61	37.95	18.90	9.45	8.46	8.46	3	2.56	4.33	1.97	0.71	0.94	3.54	1.26	1.38	0.39	8.07	3.94
4x6x7.5B-1	545	6	4	10.04	13.78	40.47	20.47	10.24	9.06	9.06	3	2.76	4.92	2.76	1.14	1.10	3.54	1.26	1.38	0.39	8.62	3.94
4x6x7.5A-1	545	6	4	10.04	13.78	40.47	20.47	10.24	9.06	9.06	3	2.76	4.92	2.76	1.14	1.10	3.54	1.26	1.38	0.39	8.46	3.94
6x6x7.5-1	722	6	6	12.60	13.98	41.57	24.41	11.22	11.81	10.04	3	2.56	7.48	5.51	3.03	0.94	3.54	1.26	1.38	0.39	10.04	3.94
1.5x3x8-1	409	3	1	9.06	8.46	34.96	18.11	9.06	8.07	8.07	3	1.97	5.12	3.15	1.59	0.94	3.54	1.26	1.38	0.39	8.86	3.94
2x3x8-1	410	3	2	9.06	8.86	35.51	18.11	9.06	8.07	8.07	3	1.97	5.12	3.15	1.57	0.94	3.54	1.26	1.38	0.39	8.66	3.94
3x4x8A-1	445	4	3	9.45	10.24	36.77	18.31	9.06	8.27	8.07	3	1.97	5.12	3.15	1.57	0.94	3.54	1.26	1.38	0.39	8.66	3.94
3x4x8B-1	456	4	3	9.45	10.24	36.97	18.90	9.25	8.66	7.87	3	1.97	5.12	3.15	1.89	0.94	3.54	1.26	1.38	0.39	8.86	3.94
3x4x8B-2	456	4	3	9.45	10.24	36.97	18.90	9.25	8.66	7.87	3	1.97	5.12	3.15	1.89	0.94	3.54	1.26	1.38	0.39	8.86	3.94
1x2x9-1	366	2	1	9.06	7.48	33.62	18.90	9.45	8.46	8.46	3	1.77	3.94	1.97	0.71	0.94	3.54	1.26	1.38	0.39	7.87	3.94
1.5x3x9-1	403	3	1	9.06	8.46	34.65	18.90	9.45	8.46	8.46	3	2.36	3.74	2.17	0.67	0.94	3.54	1.26	1.38	0.39	7.87	3.94
2x3x9A-1	410	3	2	9.45	8.46	34.69	18.90	9.45	8.46	8.46	3	2.36	3.94	2.36	1.02	0.94	3.54	1.26	1.38	0.39	8.27	3.94
2x3x9B-1	406	3	2	9.45	8.46	34.76	18.90	9.45	8.46	8.46	3	2.36	3.94	2.36	1.06	0.94	3.54	1.26	1.38	0.39	8.27	3.94
2x4x9-1	452	4	2	10.04	9.45	35.71	20.47	10.24	9.06	9.06	3	2.36	4.33	1.97	0.79	1.10	3.54	1.26	1.38	0.39	8.86	3.94
3x4x9-1	473	4	3	10.43	11.61	37.95	20.47	10.24	9.06	9.06	3	2.36	4.92	2.95	1.50	1.10	3.54	1.26	1.38	0.39	9.17	3.94
3x4x9-2	473	4	3	10.43	11.61	37.95	20.47	10.24	9.06	9.06	3	2.36	4.92	2.95	1.50	1.10	3.54	1.26	1.38	0.39	9.17	3.94
3x6x9-1	474	6	3	11.02	11.81	38.23	21.46	10.24	10.04	9.06	3	2.56	5.31	2.76	1.42	1.10	3.54	1.26	1.38	0.39	9.37	3.94
3x6x9-2	474	6	3	11.02	11.81	38.23	21.46	10.24	10.04	9.06	3	2.56	5.31	2.76	1.42	1.10	3.54	1.26	1.38	0.39	9.37	3.94
4x6x9-1	557	6	4	12.99	11.81	38.39	23.03	10.24	11.42	9.06	3	2.56	5.31	2.76	1.46	1.10	3.54	1.26	1.38	0.39	10.63	3.94
4x6x9-2	557	6	4	12.99	11.81	38.39	23.03	10.24	11.42	9.06	3	2.56	5.31	2.76	1.46	1.10	3.54	1.26	1.38	0.39	10.63	3.94

8. Summary:

	Pump Size	Impeller size	Efficiency Rating	Pump Weight	Pump Length	Pump Height	Pump Width
Pump 1	3 x 4 x 7.5-1	4.5 in	60%	443 lbs	37.95 in	18.12 in	18.9 in
Pump 2	2 x 3 x 7.5A-1	5.25 in	45%	409 lbs	36.10 in	18.12 in	18.9 in
Pump 3	2 x 3 x 7.5A-1	6.00 in	38%	409 lbs	36.10 in	18.12 in	18.9 in

Analysis:

In all projects it is important to run all heavy/large equipment by the structural and civil engineers. This will allow them to account for any additional structural reinforcements that may be required and verify that the mechanical equipment is not hindering any other trades or possible uses of that real estate. The more information shared will lead to less problems during construction.

Purpose: Determine if the NPSH available in the system is greater than the NPSH needed for each pump.

Sources: Mott, R ,Untener, J.A., “Applied fluid mechanics” 7 th edition, Pearson education INC, (2015)
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Data and Variables:

γ=62 lb/ft^3
Losses (h_L) pump$_1$=6.91 ft → for the purposes of NPSH, use ½ of energy losses = 3.455 ft
Losses (h_L) pump$_2$=54.37 ft → for the purposes of NPSH, use ½ of energy losses = 27.185 ft
Losses (h_L) pump$_3$=47.92 ft → for the purposes of NPSH, use ½ of energy losses = 23.96 ft
p_1=14 psia
p_v=0.949 psia
□z pump$_1$= -18 ft (pump is located above fluid level)
□z pump$_2$= +2 ft (pump is located below fluid level)
□z pump$_3$= 0 ft (pump is located level with worst case fluid level)

Procedure and Calculations:

$(p_{IN}-p_v)/\gamma = (p_1-p_v)/\gamma +$ □z $- h_L$
NPSH
Available

<u>Pump 1</u>

(14 lb/in^2 - 0.949 lb/in^2)/62 lb/ft^3 * (12 in/1 ft) * (12 in/1 ft) + (-18 ft) - 3.455
= 30.312 ft - 18 ft - 3.455 ft
= 8.857 ft
NPSH needed = 6 ft
Pump 1 is sufficient for the needs of the system.

<u>Pump 2</u>

(14 lb/in^2 - 0.949 lb/in^2)/62 lb/ft^3 * (12 in/1 ft) * (12 in/1 ft) + (2 ft) - 27.185
= 30.312 ft + 2ft - 27.185 ft
= 5.127 ft
NPSH needed = 3.5 ft
Pump 2 is sufficient for the needs of the system.

<u>Pump 3</u>

$(14\ lb/in^2 - 0.949\ lb/in^2)/62\ lb/ft^3 * (12\ in/1\ ft) * (12\ in/1\ ft) + (0\ ft) - 23.96$
$= 30.312\ ft + 0\ ft - 23.96\ ft$
$= 6.352\ ft$
NPSH needed = 3.25 ft
Pump 3 is sufficient for the needs of the system.

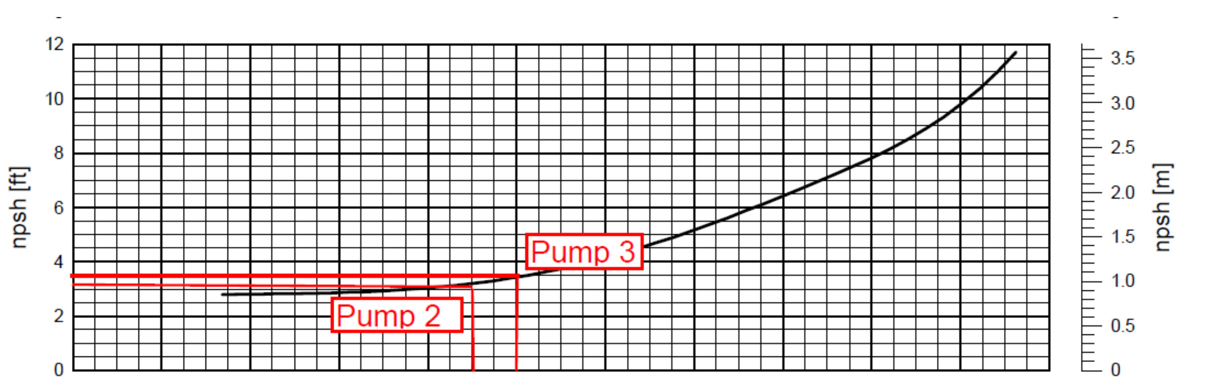
NPSH values necessary were found from the following charts pertaining to the pumps used.

Summary and Analysis:

The pumps selected for each part of the coolant delivery system are acceptable choices based on the net positive suction head analysis.

Pump 1 will be a Sulzer 3 x 4 x 7.5 -1 OHH with an impeller size of 4.50 inches. It will direct the fluid from the railcars to the storage tank on the roof. Pump 2 will be a Sulzer 2 x 3 x 7.5A -1 OHH with an impeller size of 5.25 inches. It will direct fluid from the storage tank to the reservoir tank. Finally, pump 3 will be a Sulzer 2 x 3 x 7.5A -1 OHH with an impeller size of 6.00 inches. It will direct fluid from the reservoir tank to the used coolant tank to be stored for removal.

NPSH values necessary were found from the following charts pertaining to the pumps used.



Electrical requirements for Pumps

1. Purpose: The purpose of this task is to find the electrical requirements for the pumps we selected so that the civil engineers also working on this project will know what kind of motor is necessary, which power cables to run and electrical boxes to install. There is often a code associated with electrical components especially if high voltage or current exist, so it is important that this information is shared correctly.

2. Drawings and diagrams:

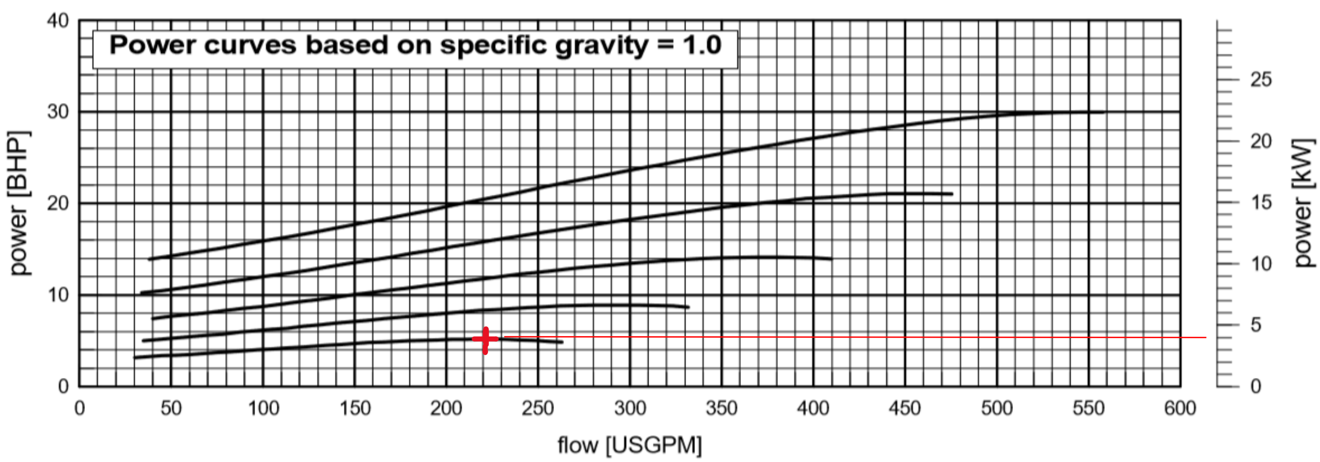
3. Sources:
    a. Mott, R ,Untener, J.A., “Applied fluid mechanics” 7th edition, Pearson education INC, (2015)
    b. Sulzer Catalog

4. Design considerations:
    a. The pumps selected have power requirements, we will ask for an electrical motor that can provide 110% of that requirement.
    b. This is done to ensure the motor is not running near its upper limit which would cause the pumps to operate poorly if a sudden need for extra power exists.
    c. It is most likely that the power needed by the pumps will not be exactly as advertised but rather with in a close specified tolerance, so having extra power available is necessary.
    d. Having a pump that is too big will be costly and take up more room than the suggested pump.
    e. Having a pump that is too small will result in a flow rate that is too small which can jeopardize the effectiveness of the entire coolant system.

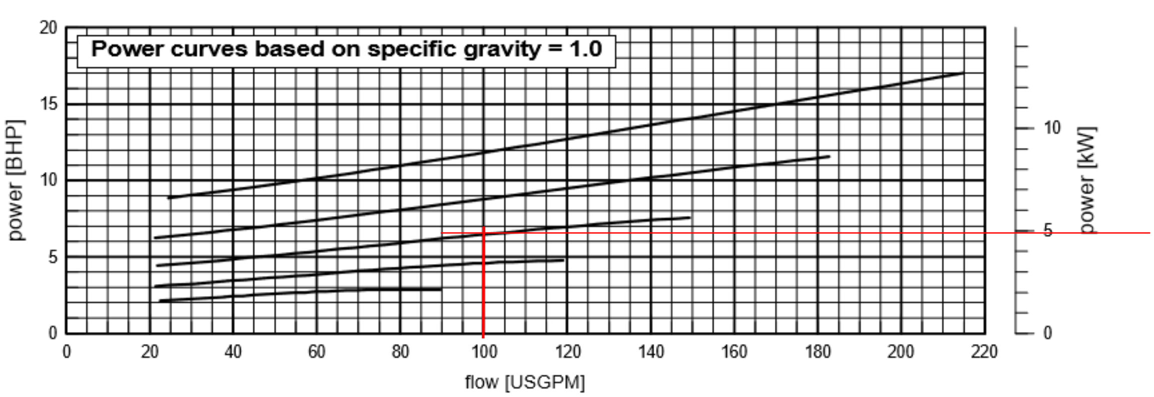
5. Data and Variables:
    a. The flow rates of our systems are as follows: .497 ft3/s, .222 ft3/s, .200ft3/s, and .334 ft3/s.
    b. The specific gravity of our coolant is .94 which means that the power curves on the given graph will not be exactly correct.
    c. The pump head of pump 1 is 53.26 ft, pump 2 is 110.86 ft, and pump 3 is 62.42 ft.
    d. Pump 1 is a 3X4X7.5-1 OHH
    e. Pumps 2 and 3 are 2X3X7.5A-1 OHH

6. Procedure
    a. We can use the supplied graphs from the brochure for our pumps to find the power requirements.
    b. I will first look at the head/ flow diagram to see what size impeller was selected.
    c. Next, I will go down to the power/flow diagram to find the power requirements for this pump with this impeller at this flow rate.
    d. Once I have found the power needed in Kilowatts I will multiply that number by 1.1.
    e. Finally, I will make a table showing the electrical needs for our pumps so that it can be easily communicated to electrical engineering.

7. Calculations
    a. The graph for pump 1 shows us that we will need at least 4Kw of power.

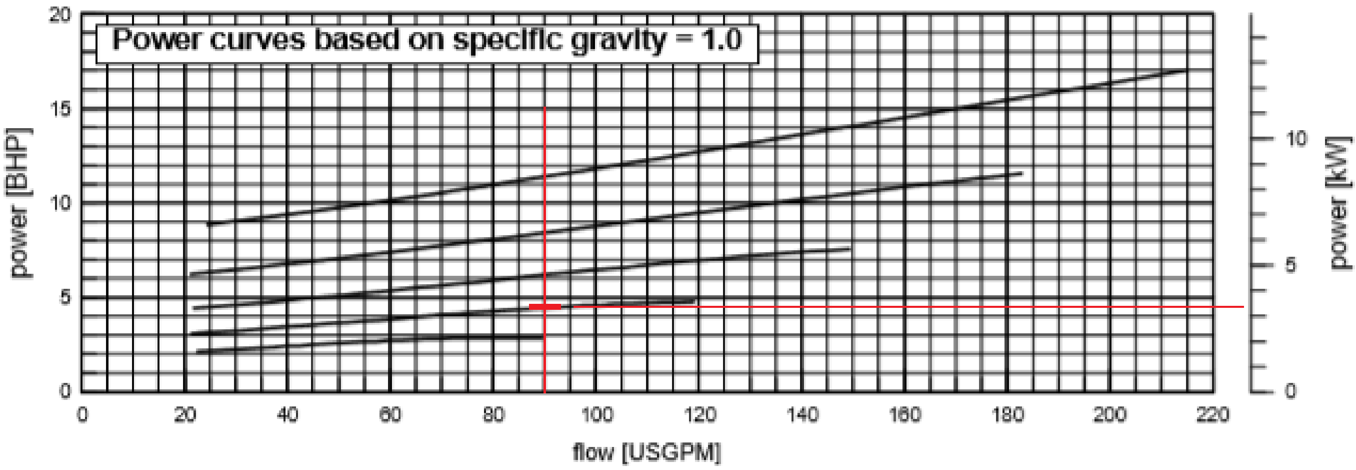


    b. The graph for pump 2 shows us that we will need at least 5 kW of power.



Electrical requirements for Pumps

c. The graph for pump 3 shows us that we will need at least 3.5 kW of power.



d. We will now multiply these requirements by 1.1 and then communicate these values to electrical engineering.
   i. 4kW* 1.1= 4.4 kW
   ii. 4.5kW * 1.1= 4.95 kW
   iii. 3.5 kW * 1.1 = 3.85 kW

8. Summary:

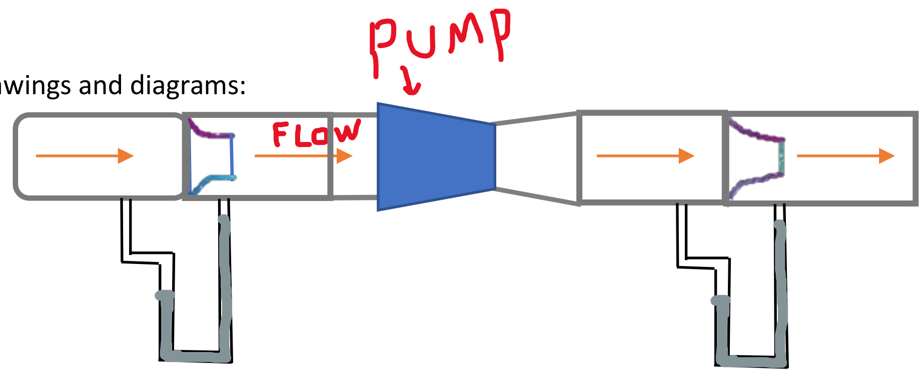
Pump	Power Required	Adjusted Power Requirement
1	4kW	4.4kW
2	5kW	5.5 kW
3	3.5kW	3.85kW

9. Analysis:
   a. The power for our pumps is not very high meaning that all our requirements for flow will be met without costing a lot.
   b. If we ever need to increase our flow rate we will need to reevaluate our power needs, and possibly choose a different impeller.
   c. Since our SG is below 1 our calculations will be slightly above what we will need.
   d. The values communicated to electrical engineering are minimum values, so a system will most likely be designed with the nearest standard value that is above what has been calculated.

The pumps selected all have power requirements for proper operation, the supplied graphs tell us these values.

Flow meter design

1. Purpose: The purpose of this task is to design pressure differential devices to check the flow rate in our pipe lines to verify that the system is operating normally. Being able to custom build our devices gives us the ultimate freedom to design convenience and efficiency.

2. Drawings and diagrams:
   a. 

3. Sources: Mott, R ,Untener, J.A., "Applied fluid mechanics" 7th edition, Pearson education INC, (2015)

4. Design considerations:
   a. The system chosen to analyze is the pump that is adding pressure to the fluid going from the storage tank on the roof to the reservoir that feeds the machines.
   b. A manometer that I am familiar with is the mercury manometer that measures pressure differential.
   c. The gamma of mercury is much higher than the gamma of our coolant so the diameter of the nozzle or orifice will need to be somewhat smaller than our pipe diameter.
   d. A flow measurement device needs to go on each side of the pump to verify correct operation and that the pump head is what is advertised.

5. Data and variables
   a. The specific gravity of our coolant is .94
   b. This means that the gamma of our coolant is 58.656 lb/ft3
   c. The flow rate of this system is .222 ft3/s
   d. The area of our pipe is .0333 ft2
   e. The chosen size of our nozzle diameter is 1.25 inches
   f. The area of the nozzle diameter is .0085 ft2
   g. The discharge coefficient is .98 and was found by using figure 15.5 and since the Reynolds number is 7.57 * 10^4.
   h. The pump head is 110.86 ft and was found from previous tasks.

6. Procedure:
   a. First, I have decided that the nozzle diameter will be 1.25 inches so that our mercury reading will be at a convenient range.

Flow meter design

b. The equation used is like what was used in chapter 15 when solving for the H value of a manometer.
c. Solving for H will tell us if the orifice is too big or too small because the range needed to do a reading will be too long.
d. Then, we will solve to see what the required range is for the system after the pump. We will have to add the pump head to the pressure difference that already exists.
e. In this case the pump head is enough to cause the need for a long manometer.
f. An alternative measurement device should be chosen for convenience reasons.

7. Calculations:

$Q = .222 \ ft^3/s$ $\qquad A_2 = .0333 \ ft^2$

$\gamma = .94(62.4 \ lb/ft^3)$ $\qquad R_N = 7.57 \times 10^4$

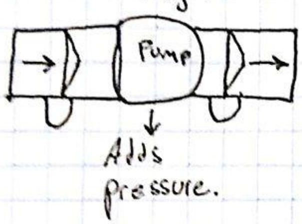
$\gamma = 58.656 \ lb/ft^3$ $\qquad C = .98 \rightarrow (15.5)$ Figure

$P_1 - P_2$ will give h ; $P_1 - P_2 = \dfrac{\gamma Q^2 [(A_1/A_2) - 1]}{2 g C^2 A_1}$

$$P_1 - P_2 = \frac{58.656(.222^2)[(.0333/.0085) - 1]}{2(32.2)(.98^2)(.0333^2)}$$

$$P_1 - P_2 = \frac{41.477}{.0686} \ \frac{ft^3 \cdot lb/s}{ft^3/s^2} = 604.623 \ lb/ft^2 \ \text{or} \ 4.199 \ lb/in^2$$

$$h = \frac{P_1 - P_2}{\gamma_{Hg} - \gamma} \ ; \ h = \frac{604.623}{(844.9 - 58.656)} = .769 \ ft \ \text{or} \ 9.23 \ inch$$



Same nozzle, Q, and γ.

Pressure after both nozzles and pump is higher.

Pump head = 110.86 ft

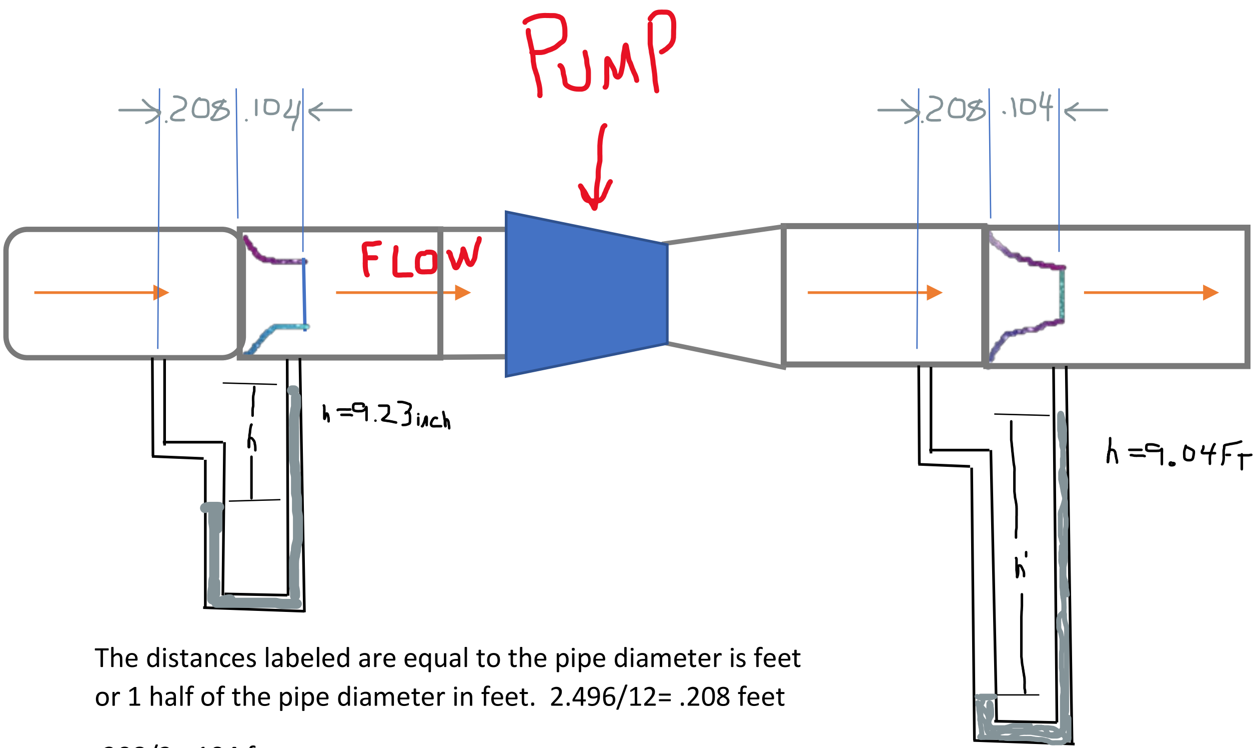
$110.86 \times 58.656 = 6505.93$

$P_1' - P_2' = P_1 - P_2$

$$h = \frac{604.623 + 6505.93}{\gamma_{Hg} - \gamma} = \frac{7110.553}{\gamma_h - \gamma}$$

$h = 9.04 \ ft$

Flow meter design



The distances labeled are equal to the pipe diameter is feet or 1 half of the pipe diameter in feet. 2.496/12= .208 feet

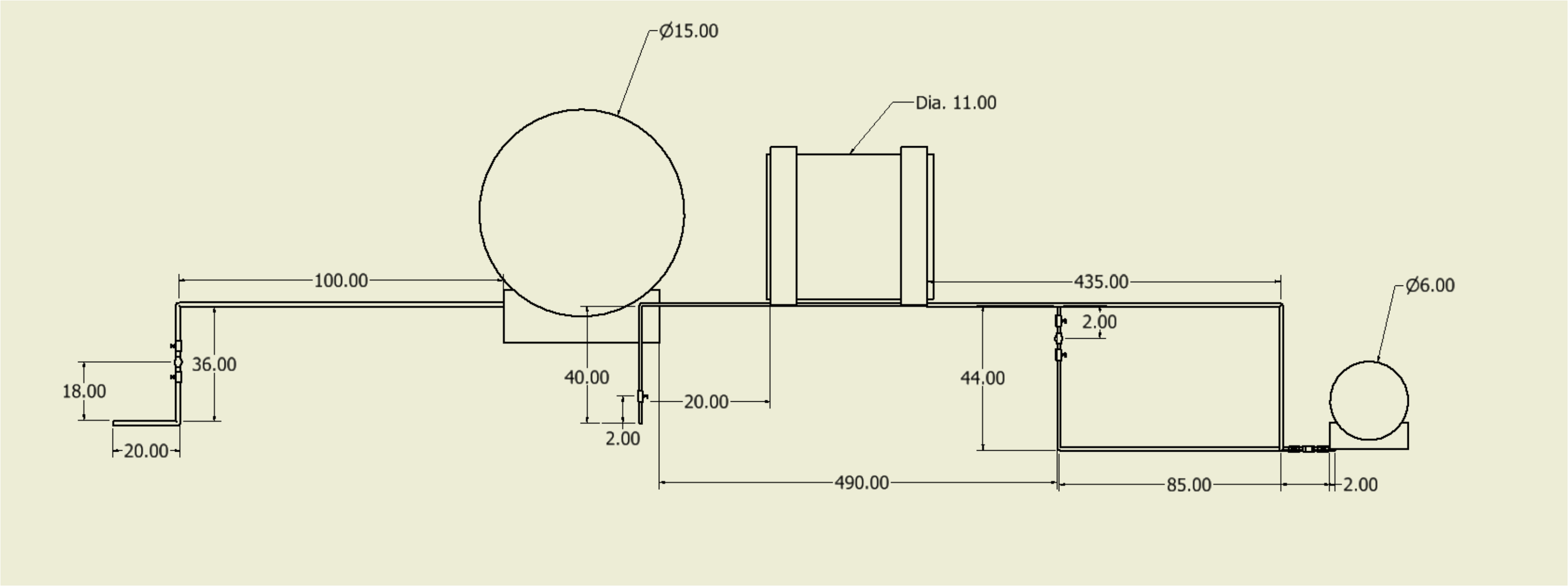
.208/2=.104 feet

8. Summary:
   a. We have attached to devices to our system, one before and one after the pump that supplies pressure to the fluid coming from the storage tank and going to the reservoir.
   b. The nozzles installed have a diameter of 1.25 inches while the manometer installed before the pump will have to have over 9.23 inches of linear space for readings. I would suggest at least 12 inches for reading room.
   c. The manometer after the pump would have to be quite long at least 9.04 feet due to the amount of pressure.
   d. I would suggest using a digital device such as a Coriolis meter to measure the pressure drop to get the flow rate of the fluid. This would eliminate the need for such a long manometer as well as reducing the possibility of a misreading due to the digital output. Unfortunately, this type of meter requires an electrical source to work.

9. Analysis:
   a. The flow nozzles have been designed so that the pressure drop is of sufficient size to be measured by a manometer even if it must be a long one. I would suggest using a digital gage before and after the pump since electrical lines will most likely be near by since there will be heating devices located on the piping to prevent freezing.
   b. To reduce the H value in the manometer a larger orifice could be used, however due to the pressure that exists after the pump it would require a long manometer.

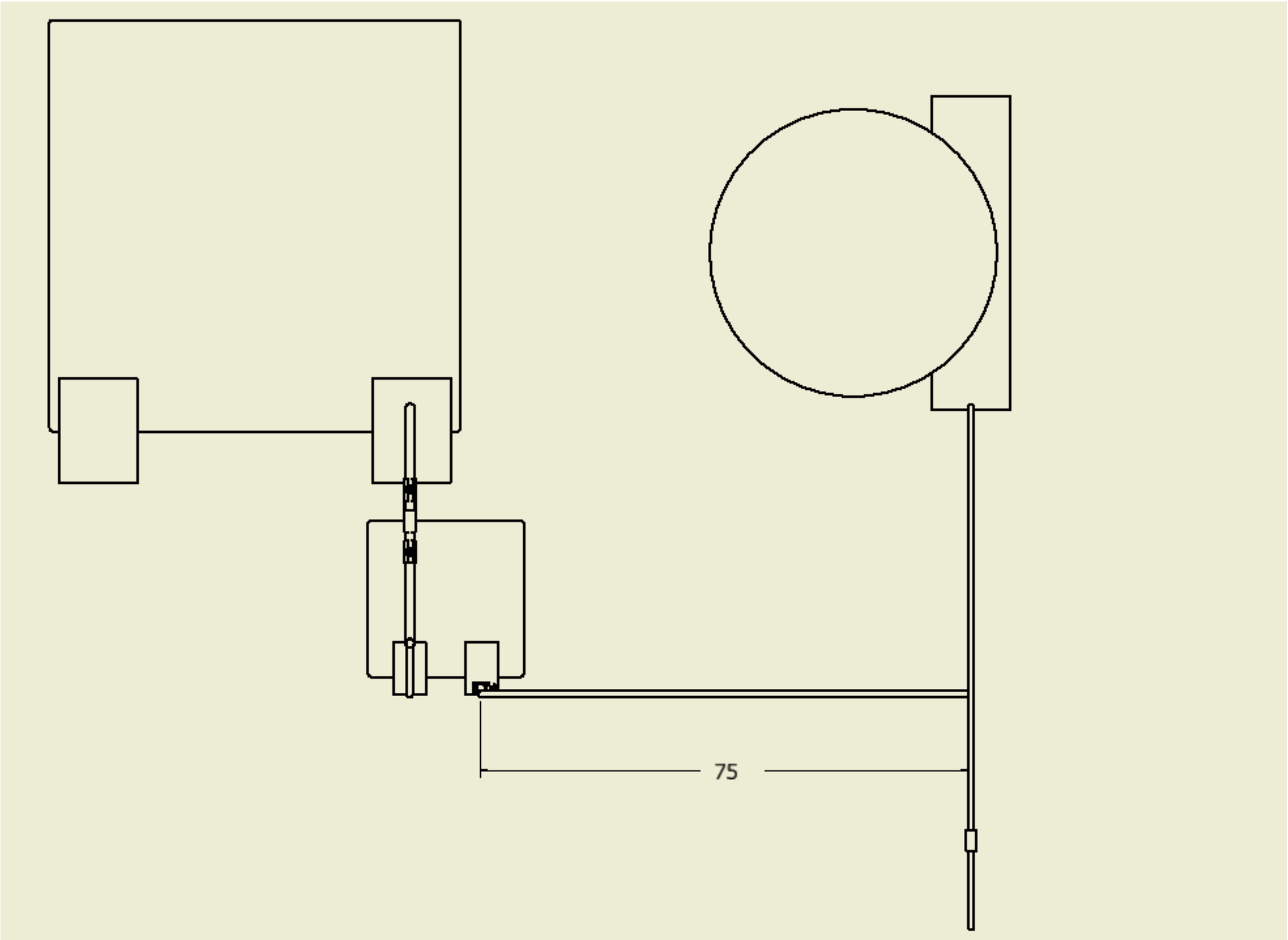
Top, Side, and Isometric view of pipe layout

Front View of pipping system



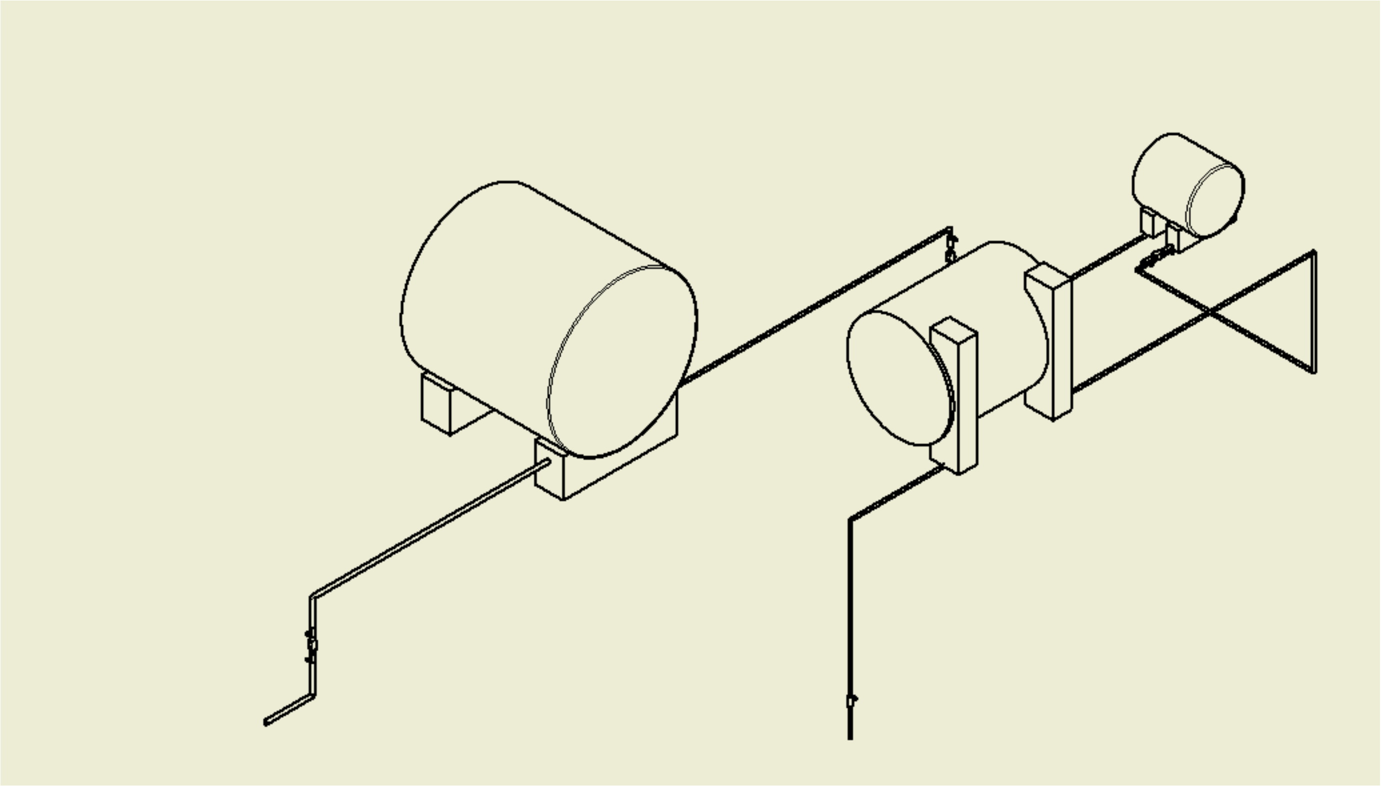
The drawing is not to scale as the lengths of pipe were shortened visually so that they can be viewed. This is looking at the system from the front of the building.

Top, Side, and Isometric view of pipe layout



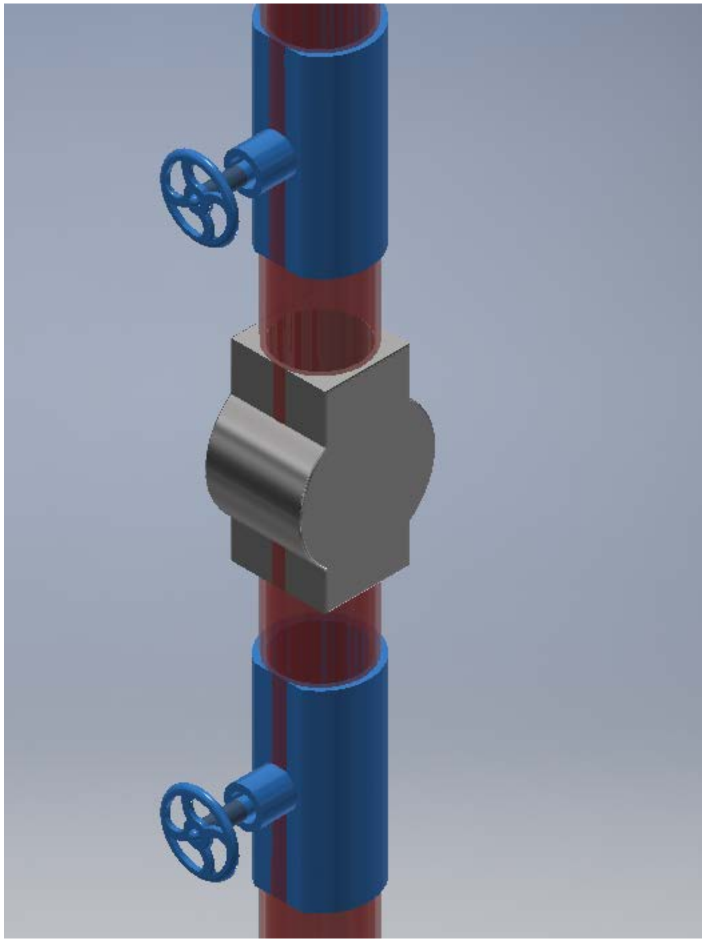
This is a side view of the coolant system as it is viewed from the side nearest to the railroad tracks.

Top, Side, and Isometric view of pipe layout



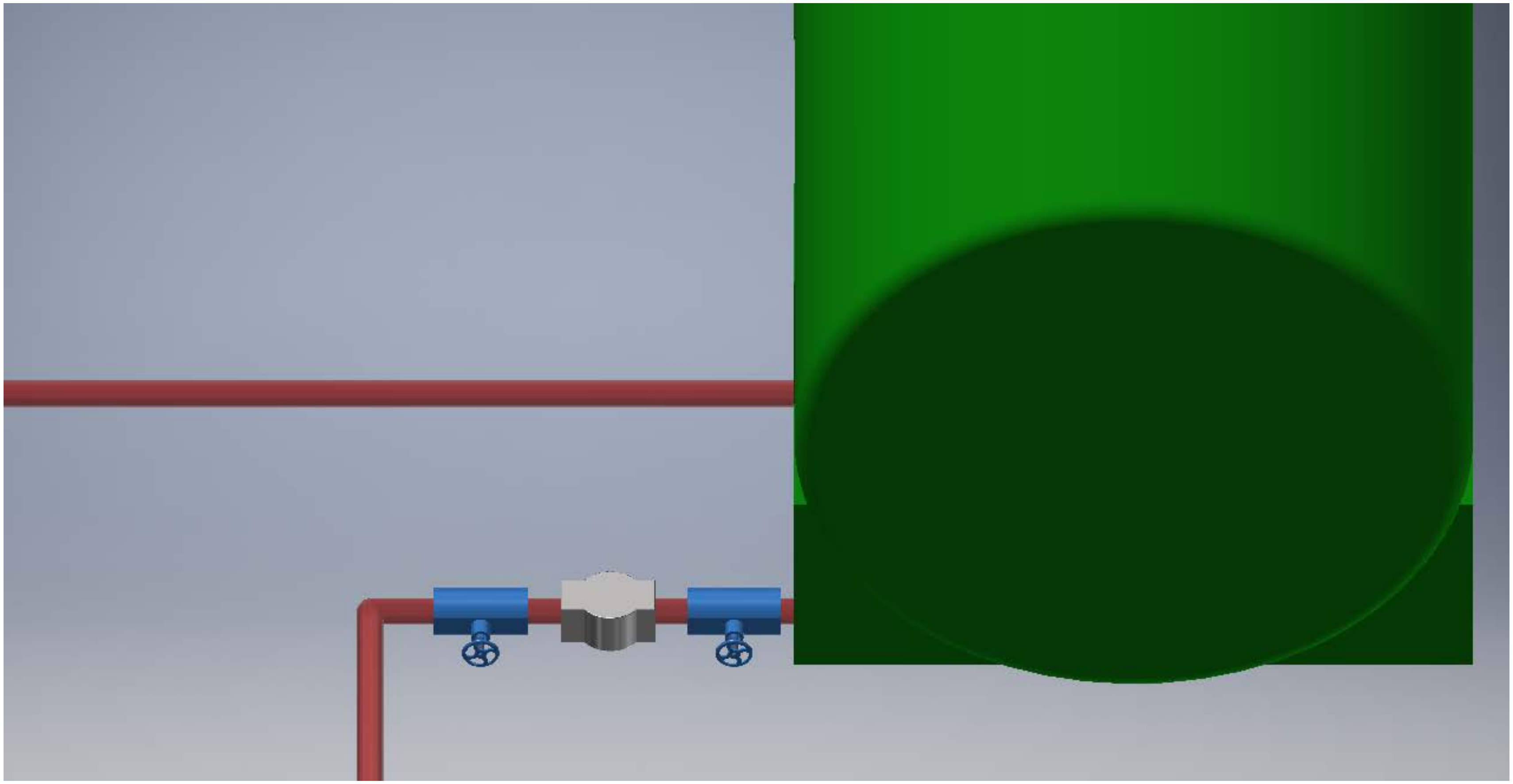
This is the isometric view of our design, as viewed from the front corner that is adjacent to the side view wall.

Top, Side, and Isometric view of pipe layout



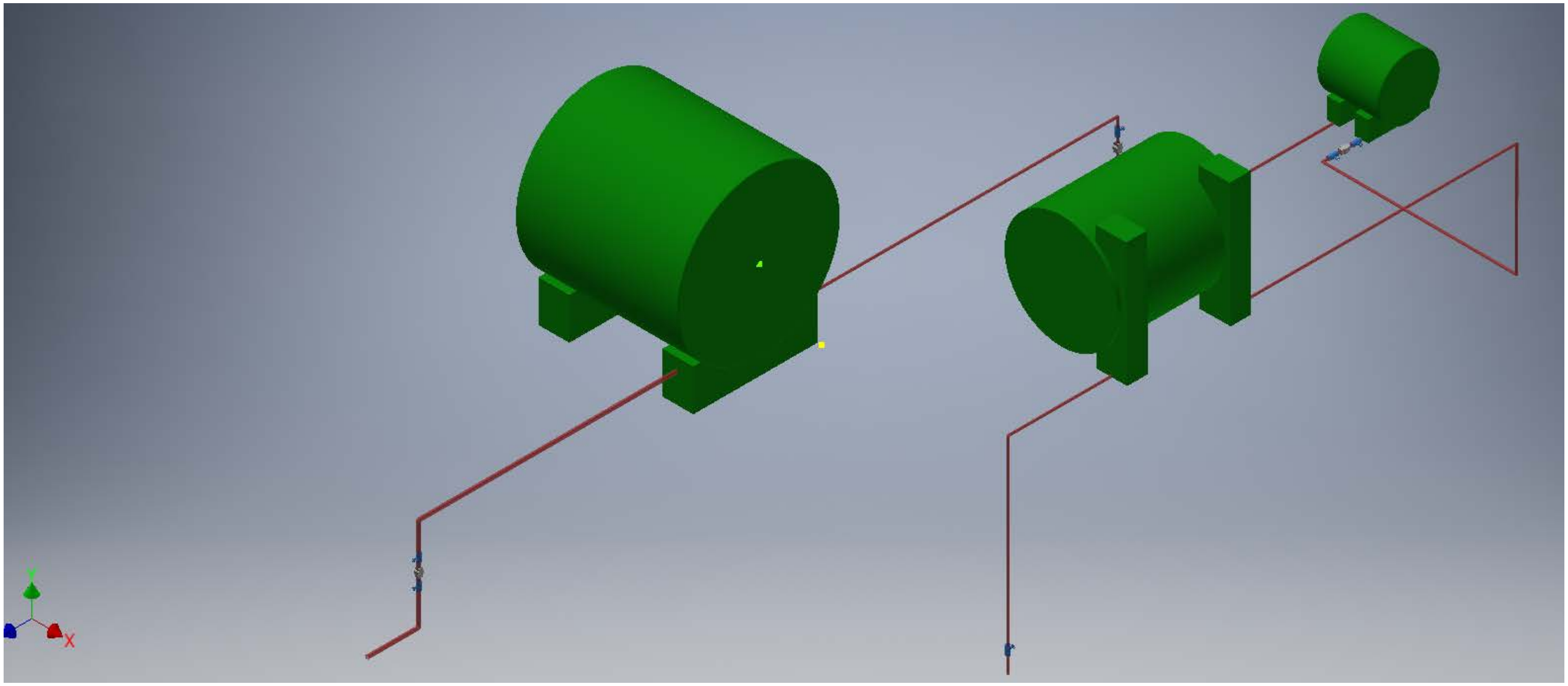
This better shows the features of our system such as the gate valves and the symbol for a pump in the middle.

Top, Side, and Isometric view of pipe layout



A view again better showing our valves and pump.
These are connected to the reservoir beneath the
machines.

Top, Side, and Isometric view of pipe layout



An isometric 3D view of our system, again viewed from the front/left corner.

Item	Material	Size	Number	Other Details
Storage Tank	Steel	60,000 gal 45.5’x15’Dia	1	Cylindrical, Horizontal
Reservoir Tank	Coated Steel	1,000 gal 6’x6’Dia	1	Cylindrical, Horizontal
Used Coolant Tank	Coated Steel	9,000 gal 14.083’x11’Dia	1	Cylindrical, Horizontal
Pipe	Steel	Schedule 40, 4 inch diameter	156 ft	
Pipe	Steel	Schedule 40, 2.5 inch diameter	1,196 ft	
Pipe	Steel	Schedule 40, 3 inch diameter	60 ft	
Valves	Steel	Schedule 40, 4 inch diameter	2	For layout from railcar to storage tank
Valves	Steel	Schedule 40, 2.5 inch diameter	6	For layouts from storage to reservoir and reservoir to used coolant tank
Valves	Steel	Schedule 40, 3 inch diameter	1	For layout from used coolant tank to removal truck
Flange	Steel		1	For drain
Blind Flange	Steel		1	For later possible connection
Flange	Steel	3 inch diameter	6	
Flange	Steel	4 inch diameter	16	
Elbows	Steel	Schedule 40, 4 inch diameter	2	90° radius
Elbows	Steel	Schedule 40, 2.5 inch diameter	4	90° radius
Elbows	Steel	Schedule 40, 3 inch diameter		90° radius
Bolts	Steel	⅝” x 3 ½”	88	24 for 3” flanges, 64 for

				4”flanges
Couplings	Steel	2 inch	58	
Hangers	Steel		87	To support pipes
Supports	Steel	4 feet	67	To support pipes
Sulzer Pump		3 x 4 x 7.5 - 1 OHH	2	4.50 inch impeller; one for use, one back-up
Sulzer Pump		2 x 3 x 7.5A -1 OHH	2	6.00 inch impeller, one for use, one back-up
Sulzer Pump		2 x 3 x 7.5A -1 OHH	2	5.25 inch impeller, one for use, one back-up

Rebecca Sopher –Personal Reflection

I do believe I will be using the skills I learned in this course professionally. I do not know how much I will be using these concepts, because I'd like to work with the Virginia Department of Transportation, perhaps. However, I do know that fluids and how they flow and interact with structures will be important in that work. Roads and bridges need to have drainage systems and how wind and water flow affect the structures will be important to determine while designing them.

As for the project, I would describe it as developing a coolant delivery system for a factory. All aspects of the system had to be solved for, including tanks, pipes, supports, fittings, and some external forces as well (such as air drag). I had no experience with these topics prior to this class. As a result, I was learning from my group members and as I was completing tasks. I learned more through completion of this project than I would have if I had simply taken the final exam. I believe my strengths lay in my time management and organization. Time management was not always apparent because there were definitely tasks I struggled with completing, but I had devoted the time necessary and more to completing them. Because our group was an online group, I felt it was important that we meet over video conferencing every week to discuss what we had done and what we were doing next. This class caused a lot of confusion for me, and my ability to complete some of the tasks was compromised as a result. My group members helped walk me through the process of multiple of them, but I do feel I was the least experienced, so needed more coaching. I continually asked questions in an attempt to understand better and complete the tasks I was assigned. I also watched many of the lecture videos multiple times to observe the process of solving similar problems. I think we have completed the tasks to specifications, but it would have been nice to devote more time to enhancing our designs and finding places for more improvement. I don't know how practical our design is, but we were told cost was not a factor, so our designs are acceptable. I believe we found how to solve each problem for our particular design and we made corrections where necessary. In the future, I think I would start watching the lecture videos a second or third time sooner into the semester. I did not start re-watching the lectures until about a third of the way through the semester. I would also try to do more than just the required number of homework questions.

Jeff Vincent –Personal Reflection

The information learned in this fluids class, more specially the class project, was extremely important in jump starting my professional career. With this project in my portfolio, I will have supporting documents that display my ability to work as a team and design an entire fluid system. This project focused on calculations and equations that we will run into in our everyday engineering lives. In hopes of eventually working in engineering design, I believe I will face these same tasks/equations/situations when presenting my ideas to the lead designer engineer. I would explain this project as a time-consuming investment that requires attention to detail at all parts. This project requires complete team cooperation and communication due to everyone's tasks affecting each other. I believe my strengths to this project was my field experience having worked for a mechanical contractor for the past five years. Working this this equipment everyday gave me great first hand knowledge when applying all these different parts into the system. My weakness was my organization skills in this project. I wasted a lot of time working on this project by having to rework my calculations since I couldn't decipher my previous notes and calculations or forgetting what I originally did when I had to go back and chance something. If I could go back to the being of the project, I would choose a smaller system to make the calculations easier and tell myself to start on Day 1!

Reflection – Joshua Dillon

1. What I have learned in this class by working on this project is that perseverance and devotion to practice can be the difference between a failure and success. This has been by far the most intricate, and challenging project I have ever worked on however, after repeatedly exercising my abilities to solve complex equations after interrogating multipart systems I feel more ready to take on the engineering world. These skills will serve me going forward as I want to pursue a career that will require critical thinking.

2. I am currently employed in the nuclear industry as a software technologist and wish to move up to engineering after earning my degree. This is where I will be using what I have learned as we often design components to meet a flow requirement.

3. I would explain our project to someone as a web of detail orientated technical decisions that grew over the course of an entire semester. I call it a web since any decision made directly affected the entire system due to the nature of fluids. If a valve were added or a pipe length increased past decisions would have to be reevaluated and possibly altered which would then cause a chain reaction of design modification to occur. This has increased my ability to think critically and to consider my options in a design by considering both the future and the past.

4. I would tell the person interviewing me that my strengths were in keeping the group on schedule, verifying that changes made were accounted for in earlier tasks, and by helping my team mates to think through problems we did not understand.

5. My weakness in this project was communication. I would often change a parameter of a previous task and then verify what other design aspects would then be affected. I would alert the person in charge of that task about the change but would often forget to be specific about what change was made. This weakness was eventually exercised out of my habits since complete chaos would ensue when we were trying to look over what numbers were used across the several tasks. My team mate's kindness and patience were what helped me to defeat my inability to communicate well.

6. The strengths in our project resides in the strength of the materials we used such as steel and pipes and tanks as well as our considerations for safety when it comes to conditions such as water hammer and pipe thickness requirements. The only weakness I am aware of would be the estimates used to place certain components or when justifying pipe lengths as we only had one picture to pull information from.

7. The advice I would carry if I had to redo the class would be to focus more on the lecture notes rather than the book as the tests revolve around the teachers notes. I would remember to place my pumps in better locations so that cavitation and energy losses would be minimized. Finally, I would not take Thermodynamics or any other high-level math at the same time. Not only was I

constantly swapping ideas and equations but I also would run out of time on test weeks since the class's timelines paralleled each other.