Fluid Mechanics Final Project

MET330

Group 3

Robert Morris, Trey Ward, Gavin Cotton, Naftaly Gichunga

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Abstract

The purpose of this report is to detail a piping system that will move coolant through various tanks and ensure machines continue to run at a manufacturing site. A rail car arrives to renew the facility with fresh coolant. The site requires coolant for the machines to operate, however over the course of a week the coolant becomes contaminated and must be set to a waste tank. The waste tank is emptied monthly by truck. The piping system that was designed for this facility had many variables that needed to be accounted for, such as head loss, pressure, flow rate, pipe diameter, water hammer, and cavitation.

Table of contents

List of figures and Tables

Report Body

Job site location

The location of this manufacturing facility is in Dayton, Ohio and is owned by Continental AG. The building has a railway on the right side of the building where the railcar will drop off fresh coolant, and a driveway connecting to a road in front of the building.

Specifications and design philosophy

The design philosophy of this piping system wanted to account for a wide variety of situations. There are everyday variables that cannot be accounted for in a report, such as time to fill or empty. While a system can be designed to fill or empty in a set amount of time, it does not take into account the labor and set up required before the process can start. The system described in the report is designed to have room for error, so that even with minor scheduling problems, the manufacturing facility can continue to operate.

Sources

Mott & Utener. Applied Fluid Mechanics. 7th edition. Pearson. 2015

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Low-Pressure Stainless Steel Unthreaded Pipe Flanges. (n.d.). Retrieved from Mcmaster-carr: https://www.mcmaster.com/blank-flanges/low-pressure-stainless-steel-unthreaded-pipe-flanges/

n.d.). Retrieved from Zoro: https://www.zoro.com/uei-test-instruments-dual-differential-input-manometer-9v-em152/i/G4594926/?utm_source=google&utm_medium=surfaces&utm_campaign=shopping%20feed&utm_content=free%20google%20shopping%20clicks&gclid=Cj0KCQiA4uCcBhDdARIsAH5jyUlKum7Xcq71Xyr

3/8" MPT Paddlewheel Flow Meter With Sensor Mounted And Molded In-Line Body (.8-8 GPM), RTS138M1GM1. (n.d.). Retrieved from PVC Pipe Supplies: https://pvcpipesupplies.com/f-2000-

Materials and Specifications

Establish the pipe and tank material use

The pipe and tanks will be made of steel. These materials will be used to develop a piping system that will efficiently move coolant from one tank to another.

Fluid characteristics

The fluid that will be used to cool the system will be primarily water with soluble oil in it. This coolant has the same corrosiveness as water, has a freezing point at 0°F, and a specific gravity of 0.94. The viscosity and vapor pressure of the coolant are 1.5 times that of water.

Preliminary drawings and sketches

Plot plan

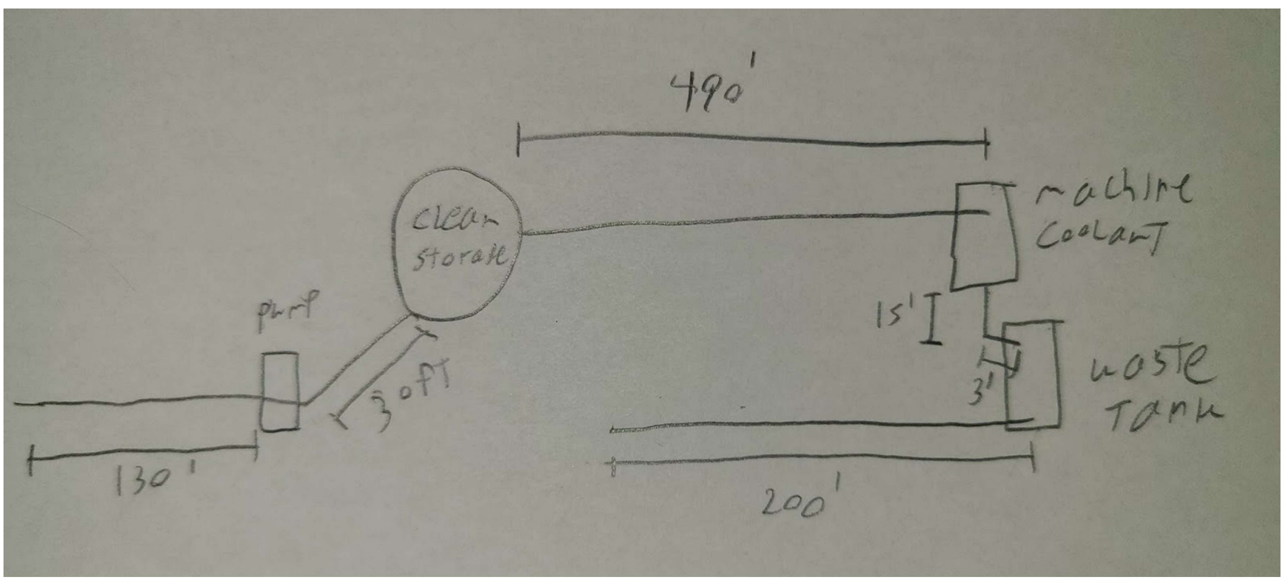


Figure 1: Initial Drawn plot plan

Elevations

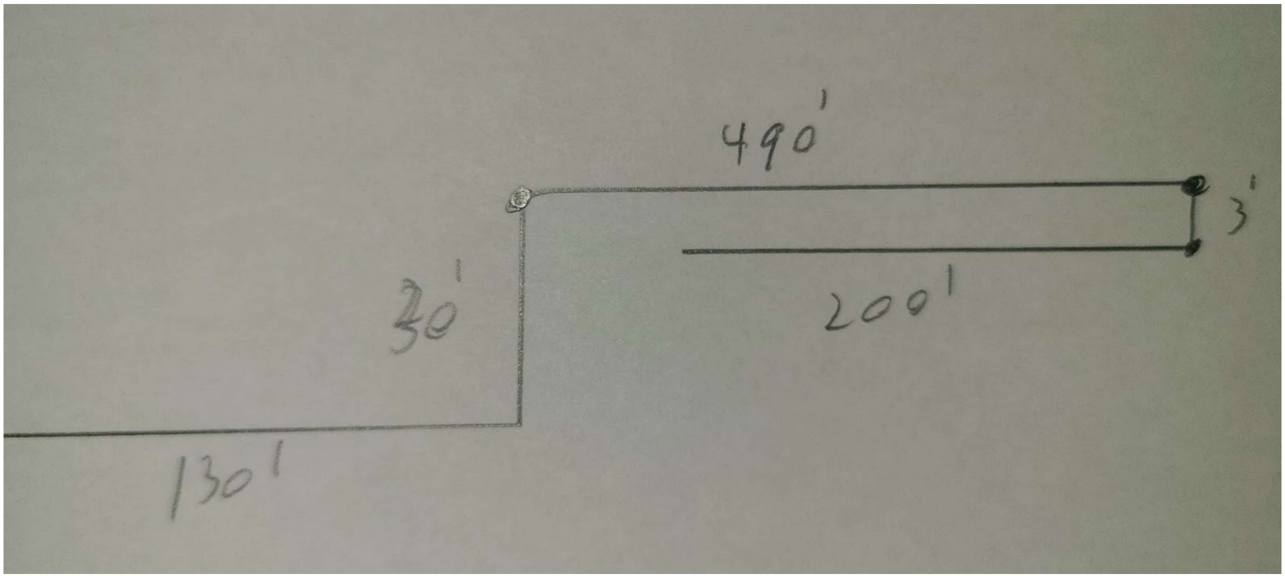


Figure 2: Initial Drawn Elevations

Design calculations

Tank specifications

Location (task 1)

This section will detail the location of the tanks for the proposed system.

<u>Drawings and Diagrams</u>

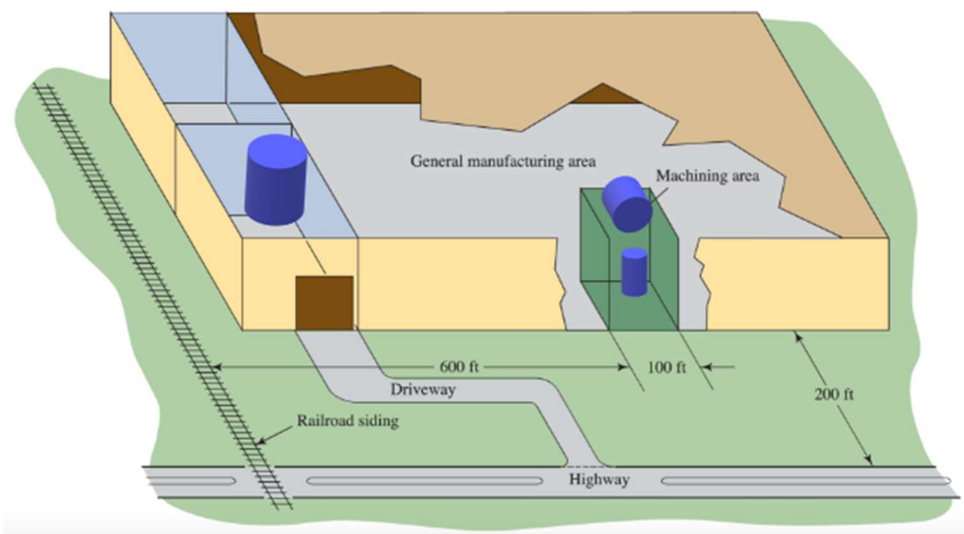


Figure 3: Tank locations on building

The Tank above the garage is the 20000-Gallon tank that will hold the coolant from the rail car. This will then connect to the 1000-gallon tank above the machine area. The last tank will be the waste tank that will be on the front side and will connect to a pipe that dumps the waste into a truck.

Size design (task 1)

This section will detail the design and specifications of the tanks that will be used in the proposed project.

The storage tank for the clean coolant will have a volume of 20000 gallons each. This will allow the manufacturing facility to have some extra space and prevent overflow of the storage tank. The railroad car only carries about 15000 gallons, with the machines going through 1000 gallons of coolant a week, so while the size is slightly excessive, if the rail cars are able to carry more coolant in the future, the system will not need to be redone. As for the waste storage tank, a smaller 5000-gallon tank will be used. This is because the dirty coolant is taken away from the facility on a monthly basis. The size of the tanks were determined by looking through an online catalog on the website "National Tank outlet" and finding tank sizes that had the same volume as what we required. The clean coolant storage tank will have a height of 193" with a diameter of 216", the waste storage tank will have a height of 159" with a diameter of 102", and the reservoir tank will have a height of 80" with a diameter of 64".

Tank thickness (task 2)

This section will focus on the wall thickness of the tanks being used.

All three of the tanks used will be made out of galvanized steel with a wall thickness of 0.9mm. There are no calculations for this section as the wall thickness of galvanized steel is a standard measurement.

Future drain connection – blank flange design (task 3)

The Future drain connection will be on the waste storage tank. This was chosen because in the future there may be situations where the coolant cannot be dumped on a monthly basis; this would allow the facility to continue operating for long periods without overflowing the waste tank. The flange will have four bolts sized at 2.75in. This is because each bolt will need to withstand a force of 0.4225 lb. This was calculated by these steps

$$1155000in^3 = \frac{\pi}{4}(159n)^2 * h$$

With h= 58.1698" the pressure could be calculated

$$0.94 * 62.4\frac{lb}{ft^3} * \frac{113}{12} = 284.3339\frac{lb}{ft^2}$$

$$284.3339\frac{lb}{ft^2} * \frac{\pi}{4}\left(\frac{1}{12}\right) = 18.60\ lb$$

With this value for force on the bolts, each bolt would need to stand 4.65lb of force. Looking at blank flanges on the website "mcmaster.com" a blank flange for a 1" pipe has four bolts with a diameter of ½" and the flange itself has an outer diameter of 4.25".

Wind load and weight (task 11)

Purpose:

Determine wind load and weight of storage tanks.

Drawings and Diagrams:

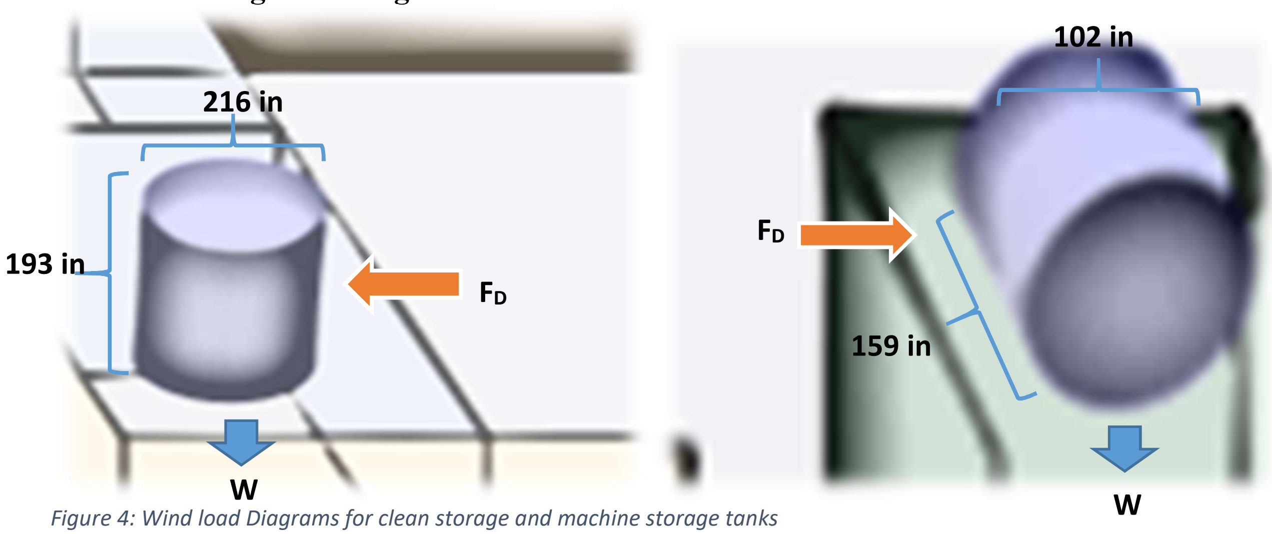


Figure 4: Wind load Diagrams for clean storage and machine storage tanks

Design Considerations:

- Location: Dayton, Ohio
- Outdoor temperature ranges from -20F to +105F
- Maximum wind (gust wind) is 48 mph in December. We will use 50 mph for additional tolerance.
- A cylinder's cross-sectional area is treated as a rectangle.

Data and variables:

v_{max} = 50 mph = 73.3 ft/s

$\nu_{coolant} = \nu_{water} \times 1.5 = \left[1.05 \times 10^{-5}\frac{ft^2}{s}\right] \times 1.5 = 1.575 \times 10^{-5}\frac{ft^2}{s}$

$\rho_{coolant} = SG \times \rho_{water} = 0.94 \times 1.94\frac{slugs}{ft^3} = 1.82\frac{slugs}{ft^3}$

$\rho_{steel} = 15.15\frac{slugs}{ft^3}$

$g = 32.2\frac{ft}{s^2}$

Calculations:

Large Clean Storage Tank

Wind

$$A = lb = 193\ in \times\ 216\ in = 41{,}688 \times \frac{1}{144} = 289.5\ ft^2$$

$$N_R = \frac{vL}{\nu} = \frac{73.3\ \frac{ft}{s} \times 16.08\ ft}{1.575 \times 10^{-5}\ \frac{ft^2}{s}} = 7.48 \times 10^7$$

Reynolds number was calculated in conjunction with the chart shown to find C_D. However, the drag coefficient is further to the right of the graph based on the computed figures. Therefore, a drag coefficient estimate of 0.3 was determined.

$$F_D = C_D\left(\frac{\rho v^2}{2}\right)A = 0.3 \times \left(\frac{1.82\ \frac{slugs}{ft^3} \times [73.3\ \frac{ft}{s}]^2}{2}\right) \times 289.5\ ft^2 = 424638.3\ lb$$

Weight:

$W = mg;\ \ m = \rho V;\ \ W = \rho V g$

Tank thickness = 0.9mm or 0.00295 ft

$V_{total} = \pi r^2 h = \ \pi \times (9\ ft)^2 \times 16.1\ ft = 4096.9\ ft^3$

$V_{empty} = \pi(r - 0.00295\ ft)^2 h = \pi \times (9\ ft - 0.00295\ ft)^2 \times (16.1\ ft - 0.00295\ ft)$
$= 4093.5\ ft^3$

$V_{tank} = V_{total} - V_{empty}\ ;\ \ V_{tank} = 4096.9\ ft^3 - 4093.5\ ft^3 = 3.4\ ft^3$

$W_{tank} = \left(15.15\ \frac{slugs}{ft^3}\right)(3.4\ ft^3)\left(32.2\ \frac{ft}{s^2}\right) = \ 1658.6\ lb$

$W_{coolant} = \rho V g\ \ ;\ \ V_{empty} = V_{coolant}\ \ ;\ \ \rho = 1.82\ \frac{slugs}{ft^3}$

$W_{coolant} = \left(1.82\ \frac{slugs}{ft^3}\right)(\ 4093.5\ ft^3)\left(32.2\ \frac{ft}{s^2}\right) = 239{,}895.5\ lb$

$W = W_{tank} + W_{coolant} = 1658.6\ lb\ + 239{,}895.5\ lb = 241{,}554.1\ lb$

Machine Reservoir Tank

$$A = lb = 159\ in \times\ 102\ in = 16{,}218 \times \frac{1}{144} = 112.6\ ft^2$$

$$N_R = \frac{vL}{\nu} = \frac{73.3\ \frac{ft}{s} \times 13.25\ ft}{1.575 \times 10^{-5}\ \frac{ft^2}{s}} = 6.17 \times 10^7$$

Again, the drag coefficient is further to the right of the graph based on the computed figures. Therefore, a drag coefficient estimate of 0.3 was determined.

$$F_D = C_D\left(\frac{\rho v^2}{2}\right)A = 0.3 \times \left(\frac{1.82\ \frac{slugs}{ft^3} \times [73.3\ \frac{ft}{s}]^2}{2}\right) \times 112.6\ ft^2 = 165161.6\ lb$$

Weight:

$W = mg;\ \ m = \rho V;\ \ W = \rho V g$

Tank thickness = 0.9mm or 0.00295 ft

$V_{total} = \pi r^2 h = \ \pi \times (4.25\ ft)^2 \times 13.25\ ft = 751.9\ ft^3$

$V_{empty} = \pi(r - 0.00295\ ft)^2 h = \pi \times (4.25\ ft - 0.00295\ ft)^2 \times (13.25\ ft - 0.00295\ ft)$
$= 750.7\ ft^3$

$V_{tank} = V_{total} - V_{empty}\ ;\ \ V_{tank} = 751.9\ ft^3 - 750.7\ ft^3 = 1.2\ ft^3$

$W_{tank} = \left(15.15\ \frac{slugs}{ft^3}\right)(1.2\ ft^3)\left(32.2\ \frac{ft}{s^2}\right) = \ 585.4\ lb$

$W_{coolant} = \rho V g$; $V_{empty} = V_{coolant}$; $\rho = 1.82 \frac{slugs}{ft^3}$
$W_{coolant} = \left(1.82 \frac{slugs}{ft^3}\right)(750.7\, ft^3)\left(32.2 \frac{ft}{s^2}\right) = 43{,}994\, lb$
$W = W_{tank} + W_{coolant} = 585.4\, lb + 43{,}994\, lb = 44579.4\, lb$

Waste Storage Tank

Note: Wind force is neglected for this tank due to its location (inside)

<u>Weight:</u>

$W = mg;\ m = \rho V;\ W = \rho V g$

Tank thickness = 0.9mm or 0.00295 ft

$V_{total} = \pi r^2 h = \pi \times (2.67\, ft)^2 \times 6.67\, ft = 149.4\, ft^3$
$V_{empty} = \pi(r - 0.00295\, ft)^2 h = \pi \times (2.67\, ft - 0.00295\, ft)^2 \times (6.67\, ft - 0.00295\, ft)$
$= 148.9\, ft^3$
$V_{tank} = V_{total} - V_{empty}$; $V_{tank} = 149.4\, ft^3 - 148.9\, ft^3 = 0.5\, ft^3$
$W_{tank} = \left(15.15 \frac{slugs}{ft^3}\right)(0.5\, ft^3)\left(32.2 \frac{ft}{s^2}\right) = 243.9\, lb$
$W_{coolant} = \rho V g$; $V_{empty} = V_{coolant}$; $\rho = 1.82 \frac{slugs}{ft^3}$
$W_{coolant} = \left(1.82 \frac{slugs}{ft^3}\right)(148.9\, ft^3)\left(32.2 \frac{ft}{s^2}\right) = 8726.1\, lb$
$W = W_{tank} + W_{coolant} = 243.9\, lb + 8726.1\, lb = 8970\, lb$

Open channel for drainage (task 12)

Purpose

This section is focused on designing and calculating open channel flow. The open channel flow is important because there may be situations in the future where the coolant of a tank may need to be drained.

Drawings and diagrams

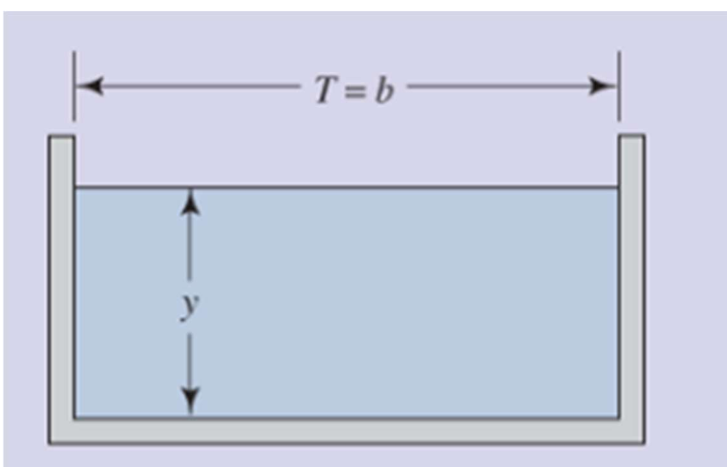


Figure 5: Open channel diagram

Design consideration

- Incompressible fluid
- Steady-state
- Isothermal

Materials

- Float-finished concrete
- Coolant (sg=0.94)

Data and variables

- Q = 50 GPM = 0.1114 ft^3/s
- Manning's constant, n=0.015
- 1-percent slope

Procedure

Using the open channel flow equation, we shall determine the dimension of the open channel. We shall use the suggested ratios for the most efficient sections.

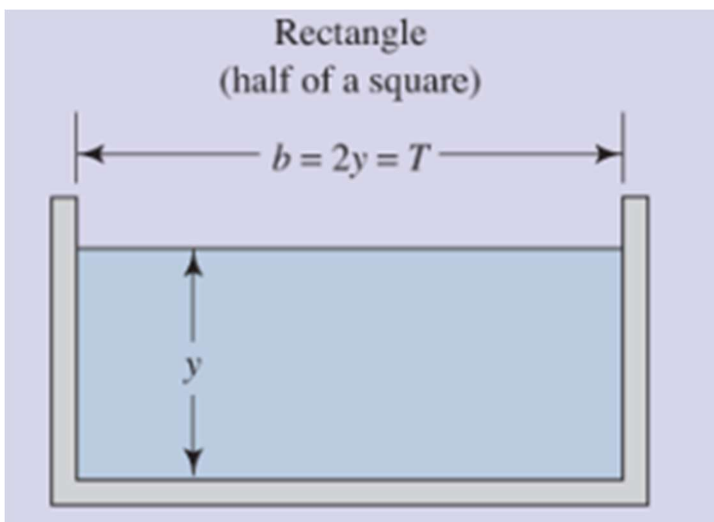


Figure 6: Open channel diagram for calculations

Calculations

$$AR^{2/3} = \frac{nQ}{1.49S^{1/2}} = \frac{0.015*0.1114\,ft^3/s}{1.49*0.01^{1/2}} = 0.01121$$

For a rectangular channel, $A = 2y^2$ and $R = y/2$

$$AR^{2/3} = (2y^2)(y/2)^{2/3} = 0.01121$$
$$1.26y^{8/3} = 0.01121$$
$$y = 0.17$$
$$b = 2y = 2*0.17 = 0.34$$

Summary

The height of the channel is 0.17’, and the width is 0.34’.

Analysis

For a flow rate of 50 GPM, a rectangular open channel would be 0.17’ deep and 0.34’ wide with a slope of 0.01. This will allow the coolant to be dumped in the event of an emergency drainage.

Flow rate

Tank fill/empty times (task 4)

This section will go into detail about the time to fill and empty the tanks and the rate of flow.

Location	Flow Rate	Time
Railcar to storage	50 GPM	5 Hours
Storage to machine	5.56 GPM	3 Hours
Machine to waste	5.56 GPM	3 Hours
Waste to truck	20.83 GPM	4 Hours

Table 1: Flow rates and times

This section will go into detail about the time to fill and empty the tanks and the rate of flow. The Fill rate for the clean coolant tank will be 50 GPM and will fill in 5 hours. This was done by specifying the time and dividing the amount of fluid by the time, then converting the rate into minutes.

$$\frac{15000\ gallons}{5\ hours} = \frac{3000\ gallons}{1\ hour} * \frac{1\ hour}{60\ minutes} = 50\ GPM$$

The fill and empty rate of the reservoir will be 5.56 GPM and will empty and fill itself in 3 hours. The waste coolant tank will fill at a rate of 5.56 GPM and take 3 hours, it will then empty into a truck at a rate of 20.83 GPM and empty in about 4 hours.

Desired flow rate (task 4)

The desired flow rate is a critical part of our system design, and must be correctly selected.

This piping system uses a flow velocity of 10 ft/s and has a variable flow rate. The flowrate from the railcar to the clean coolant storage tank was 50 gallons per minute. The flowrate in the pipes connected to the reservoir were at 5.56 gallons per minute. Finally, the flowrate in the pipe connection between the waste storage tank and the truck was 20.83 gallons per minute.

Pipe sizing

Piping layout (task 5)

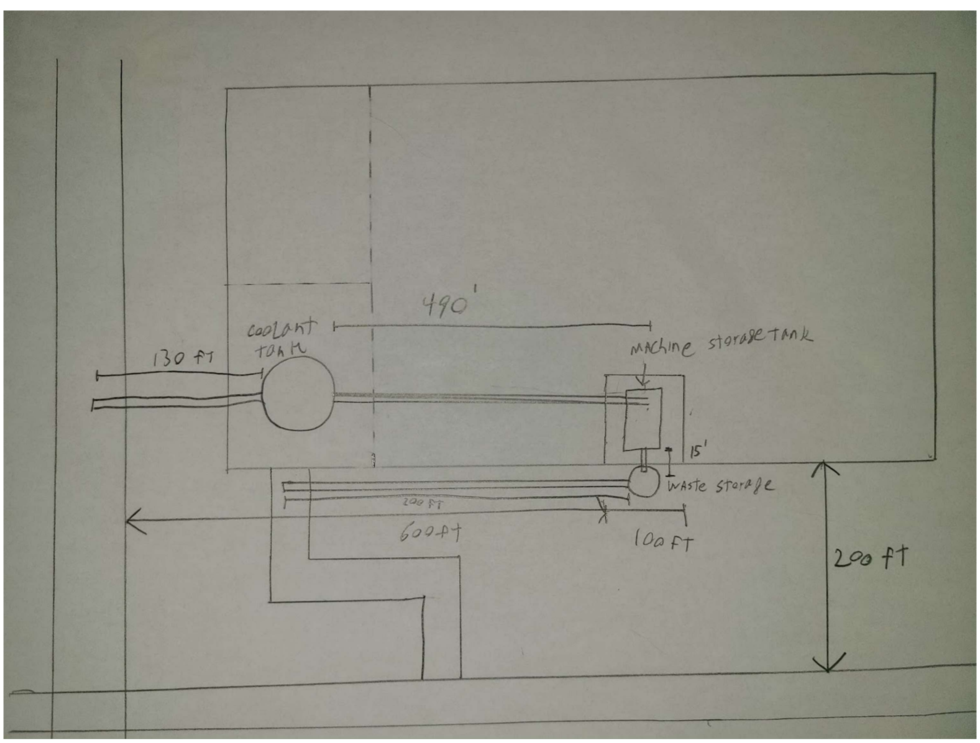


Figure 7: Piping layout

Pipe diameter and lengths (task 5)

The purpose of this task is to determine the sizes of all pipes and the lengths required.

Pipe	Pipe size	Diameter	Length
To clean storage from rail car	1½" Schedule 40	1.9"	164'
To machine tank	⅜" Schedule 40	0.675"	490'
To waste tank	⅜" Schedule 40	0.675"	15'
To truck from waste storage	1" Schedule 40	1.050"	200'

Table 2: Pipe information for system

The pipe going from the railcar to the clean coolant storage tank will be a 112" schedule 40 pipe with an outer diameter of 1.9" and have a length of 182'. This diameter was found using the following equation:

$$\frac{50GPM * 0.002228\frac{ft^3}{s}}{10\frac{ft^2}{s}} = 0.01414ft^2$$

to find the flow area required then finding the matching pipe size in the textbook *Applied Fluid Mechanics, 7th Edition*. The pipes connecting the clean coolant storage tank, the reservoir, and the dirty storage tank will all be 38" schedule 40 pipes with an outer diameter of 0.675" and a length of 490' going from the clean coolant storage tank, and a length of 15' going from the reservoir to the waste storage tank. The Pipe going from the waste coolant tank to the truck will be a 1" schedule 40 pipe with an outer diameter of 1.315" and a length of 200'.

Pipe thickness (task 9)

The purpose of this section is to determine the wall thickness (schedule).

The pipes going from the railcar to the clean coolant storage tank will have a thickness of 0.145" because it is a 1 ½ "schedule 40 pipe. The pipes connecting to the reservoir are ⅜ "schedule 40 pipes and have a thickness of 0.091". Lastly, the pipes going from the waste storage tank to the truck will have a thickness of 0.133" because it is a 1" schedule 40 pipe. The piping wall thickness was sourced from *Applied Fluid Mechanics, 7th edition.*

Fittings (task 6)

This section will give the fittings, the size, and material, number of required fittings, elbows, T-Bracket and valves.

Section	Size of Components	Elbows	Valves	Fittings	T-Bracket
Clean Storage	1.5 NPS	2	1	8	0
Machine Tank	0.375 NPS	2	1	6	0
Waste Storage	0.375 NPS	2	2	8	1
To Truck	1 NPS	2	0	5	0

Table 3: Pipe size and amount.

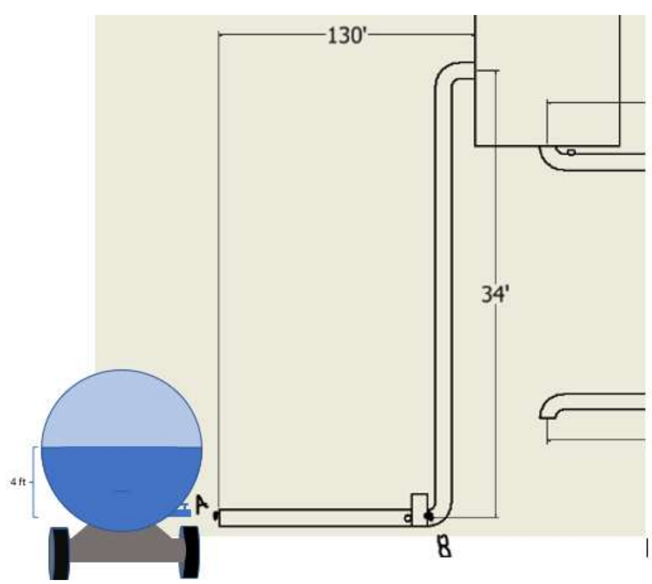
Component	Material	Total Required
Elbow	304L Stainless Steel	8
Valves	316 Stainless Steel	4
Fitting	304L Stainless Steel	27
T-Bracket	304L Stainless Steel	1

Table 4: Pipe material and total required

Water hammer (task 10)

Check design for concerns regarding water hammer. Check to see if the pipe you choose can withstand this excess pressure. If not, suggest using a water hammer arrestor by stating the maximum pressure it can withstand.

Drawings and Diagrams:



Design Considerations:

- The specific gravity of the coolant is .94
- Pressure is maximum at outlet of each pump

Data and variables:

$$\rho_{coolant} = \left(940\,\frac{kg}{m^3}\right)$$

$$E_{steel} = 2.0 * 10^{11}\frac{N}{m^2}$$

$$E_0 = 2.179 * 10^9\,\frac{N}{m^2}$$

$$\delta = 0.00368\,m$$

Calculations:

$$C = \frac{\sqrt{\frac{E_o}{\rho}}}{\sqrt{1 + \frac{E_o D}{E\delta}}}$$

$$C = \frac{\sqrt{\frac{2.179 * 10^9\,\frac{N}{m^2}}{940\,\frac{kg}{m^3}}}}{\sqrt{1 + \frac{\left(2.179 * 10^9\,\frac{N}{m^2}\right) * 0.04826\,m}{2.0 * 10^{11}\frac{N}{m^2} * 0.00368\,m}}}$$

$$C = 1424.18$$

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

$$\Delta P = \left(940\,\frac{kg}{m^3}\right) * (1424.18) * (3.048\,\frac{m}{s})$$

$$\Delta P = 632.52\,\frac{lb}{in^2}$$

$$P_{max} = 632.52\,\frac{lb}{in^2} + 1.63\,\frac{lb}{in^2} = 634.15\,\frac{lb}{in^2}$$

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

Where:

t = Basic wall thickness
p = design pressure (Pmax)
D = pipe diameter
S = allowable stress in tension (20.0 ksi)
E = longitudinal joint quality factor (1.00)
Y = correction factor (0.4)

$$t = \frac{634.15\,\frac{lb}{in^2} * 1.9\ in}{2(20000\frac{lb}{in^2} * 1.00 + 634.15\,\frac{lb}{in^2} * 0.4)}$$

$$t = 0.0297\ in$$

Summary:

The system needs a pipe thickness of.0297 inches when water hammer is taken into consideration, according to the calculations stated previously. The pipe chosen for this part of the system has a wall thickness of 0.145 in. No water hammer arrestors are required.

Provide pipeline support info

Type of supports (task 13)

The type of supports that will hold up the pipes will be a simple steel rod with a 1in cross sectional area.

Distance between supports (task 13)

The distance between supports varies between each section. The number that is required was found by calculating the total weight of the pipe with fluid and then dividing it by the compressive and tensile strength of steel. The weight was found by distributive analysis and multiplying the length of the pipe by the sum of weight of the pipe and the fluid per square feet.

For the pipe connecting the machine tank to the waste tank:

$$\text{weight} = 15 * (490 * (0.015 * 1) + (58.882 * (0.00133 * 1)$$
$$= 111.4246\text{lbs}$$

then

$$\text{Compression supports} = \frac{111.4246\text{lbs}}{25000\text{lbs}} = 0.00446$$

and

$$\text{Tension Supports} = \frac{111.4245\text{lbs}}{60900\text{lbs}} = 0.00183$$

Steel is a very durable and stable material, so according to our calculations not many supports would be required. However, since safety and reliability were a concern, supports were placed in reasonable spacing along the longer pipes, with one support for the shorter pipes.

Section	Compression	Tension	Number of Supports	Locations
Rail car to Pump	0.0654	0.0268	3	43' Apart
Pump to Tank	0.0102	0.0042	1	At Bottom
Storage to Machines	0.1456	0.0598	4	98' Apart

Machines to Waste	0.0045	0.0018	1	At Middle
Waste to Truck	0.0762	0.0313	2	Center and End

Table 5: Support information

Forces on supports (task 13)

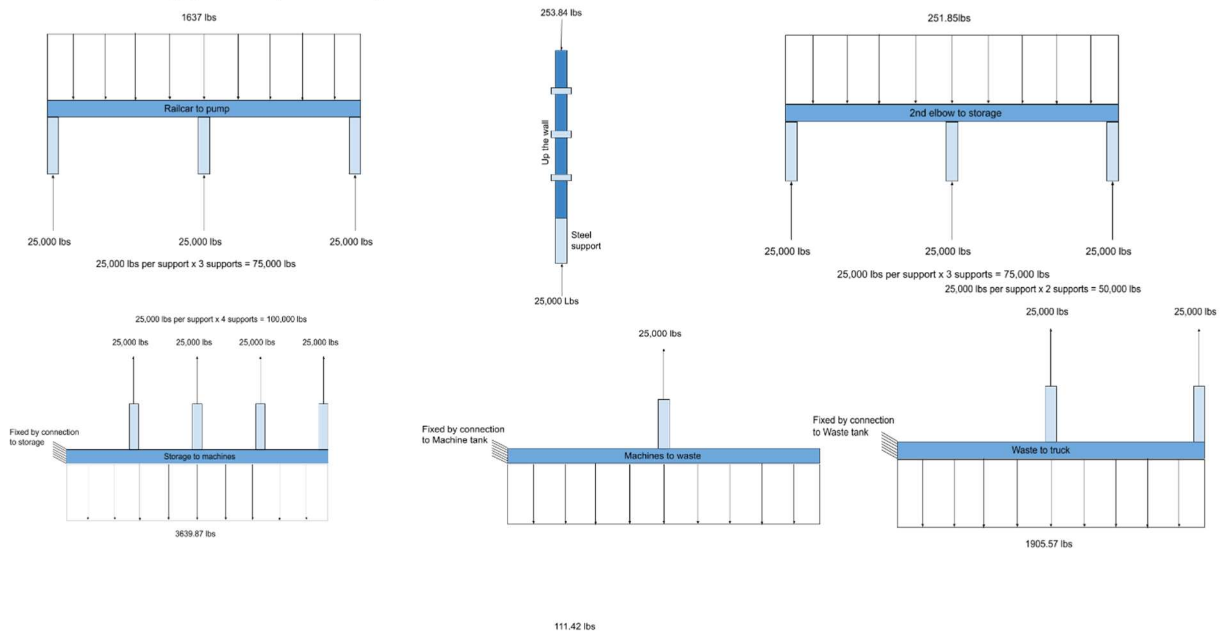


Figure 8: Forces on supports

Energy losses (task 7) (make a table of energy losses, analyze, which has the highest loss?)

Pipe	Energy Loss
Railcar to Storage	34.7467 ft
Storage to Reservoir	7082.9253 ft
Reservoir to Waste	244.2742 ft
Waste to Truck	544.6765 ft
Total	7906.6228 ft

Table 6: Energy losses

The focus of this section is to calculate the energy losses through the system. These values will later be used to determine the type of pump that will be used for the system. First step was to calculate the Reynolds number and then the friction factor. Then the friction of the pipes and add the resistance of the elbows and gate valves to determine total energy losses. For example, the equations for the Reservoir to Waste tank will be demonstrated.

$$\mathrm{NR} = \frac{2.8317 * 0.0125 * 9.2496}{0.00255} = 145.5124$$

Then to find the friction factor,

$$\frac{64}{145.5124} = 0.4398$$

We also need to know the velocity head of the pipes

$$\frac{2.8317^2}{2 * 9.81} = 0.4091m$$

With these three values, the friction of the system could be calculated. For the pipes:

$$0.4398 * \left(\frac{4.572}{0.0125}\right) * 0.4091 = 65.8141\mathrm{m}$$

Gate valve:

$$(8 * 0.4398) * 0.4091 = 1.4395\mathrm{m}$$

Elbows:

$$2 * ((20 * 0.4398) * 0.4091) = 7.1975\mathrm{m}$$

These values were then added up and converted back into feet.

The highest loss is in the pipe connecting the clean storage tank to the machine tank. This is because the pipe is 490' long and has significant friction losses and there is a lot of liquid that needs to be moved.

Pump selection

Pump requirements (task 8 and 15)

For this piping system, only one pump will be required. The pump will be located before the elbow on the pipeline loading coolant from the railcar into the clean coolant storage tank. This pump will need to move the material at 50 GPM, and have a pump head of 42.8ft.

$$\left(\left(0.028 * \left(\frac{55.4736m - 39.624m}{0.0409m}\right) * 0.2659\right) + 9.7536 + 0.2979 + 0.1329\right) * 3.281 = 42.8\,ft$$

Selection of pump type (task 15)

The best pump for a flow rate of 50 gpm and a pump head of 42.8 ft is 1x2x7.5A operating at 60Hz and 3520 rpm.

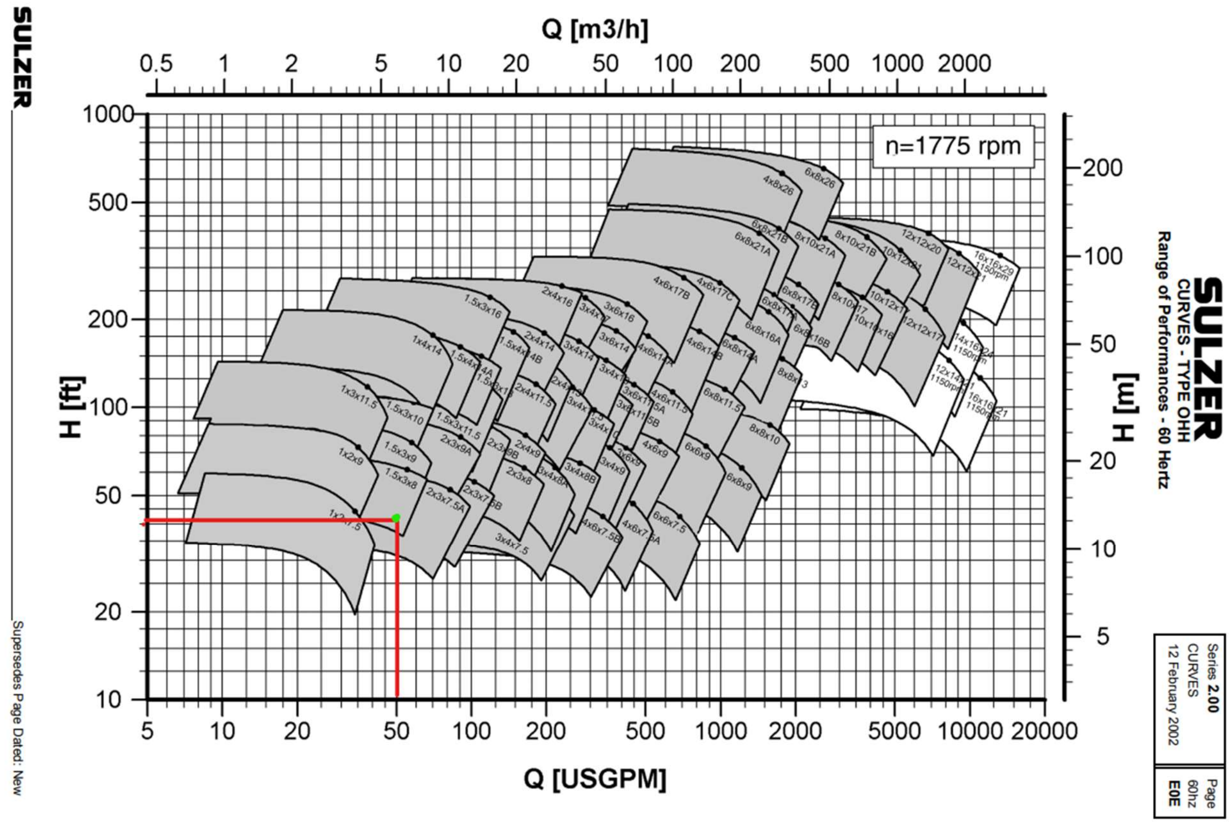


Figure 9: Pump selection chart

Pump curves and system curves with operating point (task 16)

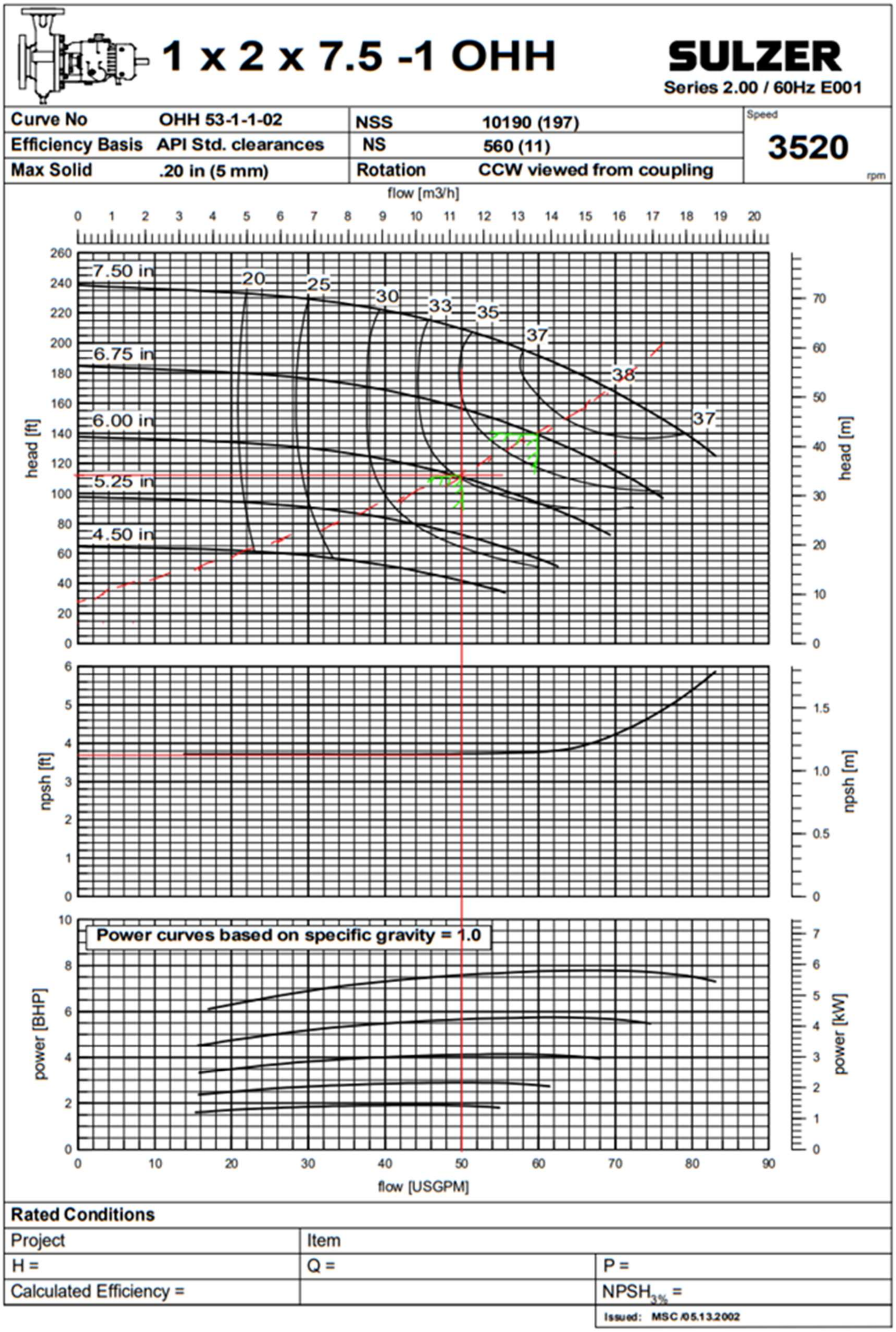


Figure 10: Pump curves

Cavitation (task 18)

The selected pump has a required NSPH of 3.7 feet.

$$\text{NSPH average} = \frac{\text{Psuc} - \text{Pv}}{\gamma}$$

$\text{Psuc} = \gamma(\text{water}) * \text{sg} * \text{h}$ (Assuming that the tank is 10 feet in diameter and 4 feet above the pump)

$= 62.4 * 0.94 * 14$

$= 5.703$ psi $+ 14.7$psi(atm) $= 20.403$ psi

P_v (from thermodynamics) =0.35psi

$\text{NSPH average} = (20.403 - 0.35) * 144/62.4 = 46.2$ feet

The NSPH that was calculated was more than that required for the pump, resulting in no cavitation.

Summary of pumps (task 16 and 17)

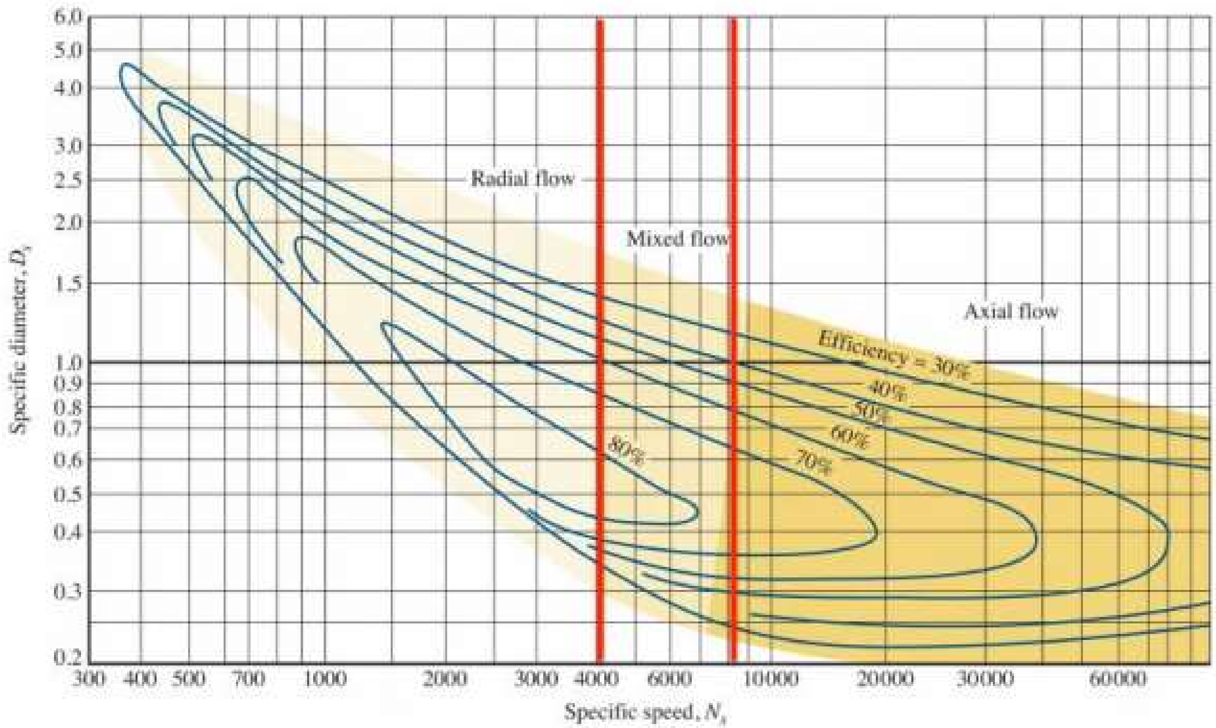
The pump will be a Sulzer 1x2x7.5A pump with a weight of 141kg. The pump will be located at the side of the building, before the elbow going up the building into the clean storage tank.

We will need to choose from three variants of kinetic pumps based on their specialties. Radial flow, axial flow, and mixed flow are some of these alternatives. We can determine which classification our pump requires by solving the equation for specific speed.

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

$$N_s = \frac{3520\ RPM\sqrt{50\ GPM}}{(42.8\ ft)^{3/4}}$$

$$N_s = 1487.46\ RPM$$



With our values of specific speed, N_s, falling under 4000 RPM, we use the graph above to validate our selection of a radial flow pump.

Instrumentation selection

The pipe where pressure and flow rate are most relevant is the pipe from the machine tank, to the machines themselves. The flow rate and pressure is most important in this section of pipe as the section is in use most often; additionally we must ensure that the machines are receiving the appropriate amount of oil at a reasonable pressure.

Flow rate (task 14)

In order to ensure that the volumetric flow rate is stable and as close as possible to 5.5 gallons per minute as possible, a flow rate sensor was selected. This flow rate sensor uses paddles to collect data regarding the velocity of the fluid with an upper limit of 8 gallons per minute. It is a small component, with dimensions of 5.875” x 5.875” x 4.75”. The collected velocity information is then used to derive the flow rate within the pipe. If flow rate were ever to drop unexpectedly, the machines may overheat from the lack of lubrication. If it ever increases unexpectedly, there may be a risk of flooding. Regardless of the reason, a flow rate monitor ensures that any irregularity in the delivery of lubricant is easy to detect.

Pressure (task 14)

To ensure that pressure within the pipes maintain a reasonable level, a manometer must be used to monitor the data point. A digital manometer is the simplest solution to this issue. However, where the manometer probes are mounted is important, as it would only monitor pressure drop between the two probes. Therefore the probes shall be placed at the very beginning and end of the section of pipe using ¼" hose barb and tube. By doing so we ensure that, any increase in pressure drop along the length of the pipe will be detected. In the event that the operator notices a drop in pressure, they should immediately begin the process of attempting to locate a leak in the pipe between the two probes. In the event that the pressure drop decreases, the operator should inspect the condition of the pipe. An increase in pressure is likely due to the accumulation of debris within the pipe.

Final drawings

Plot plan (task 19)

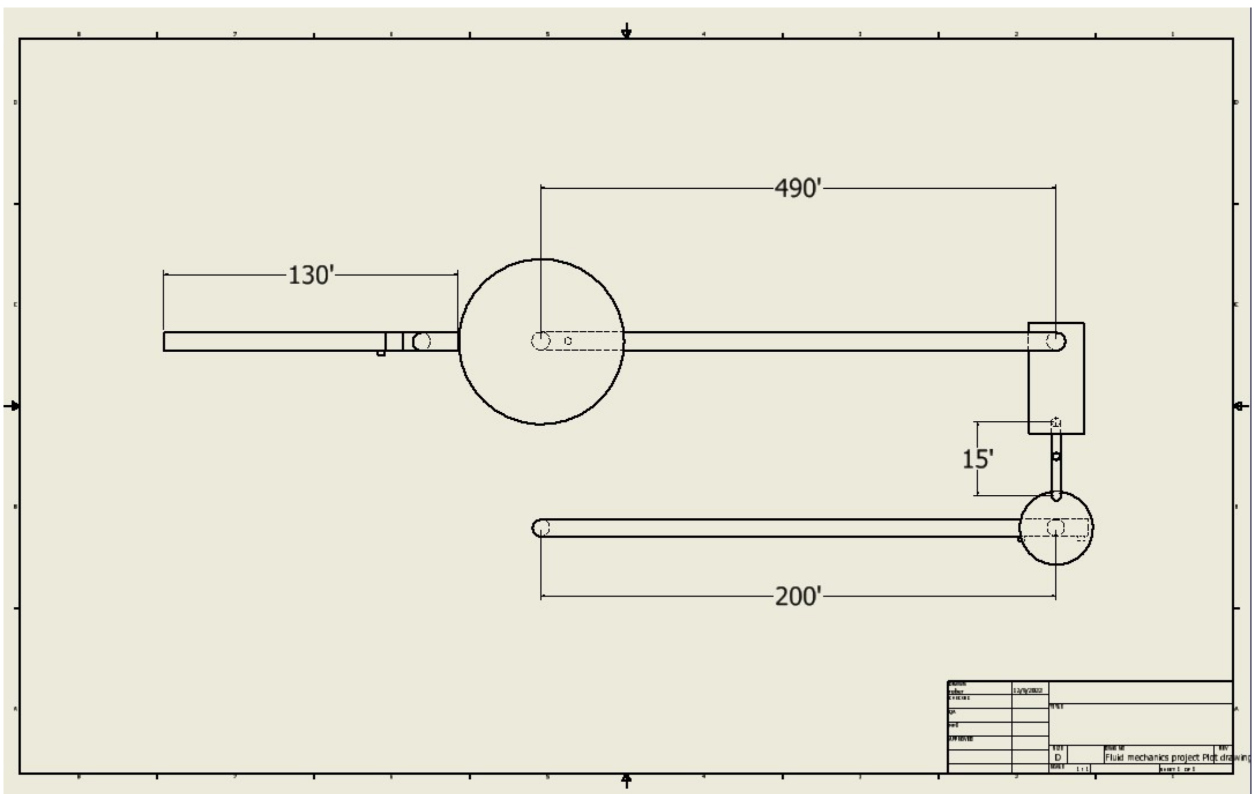


Figure 11: Final Plot Plan

Elevations (task 19)

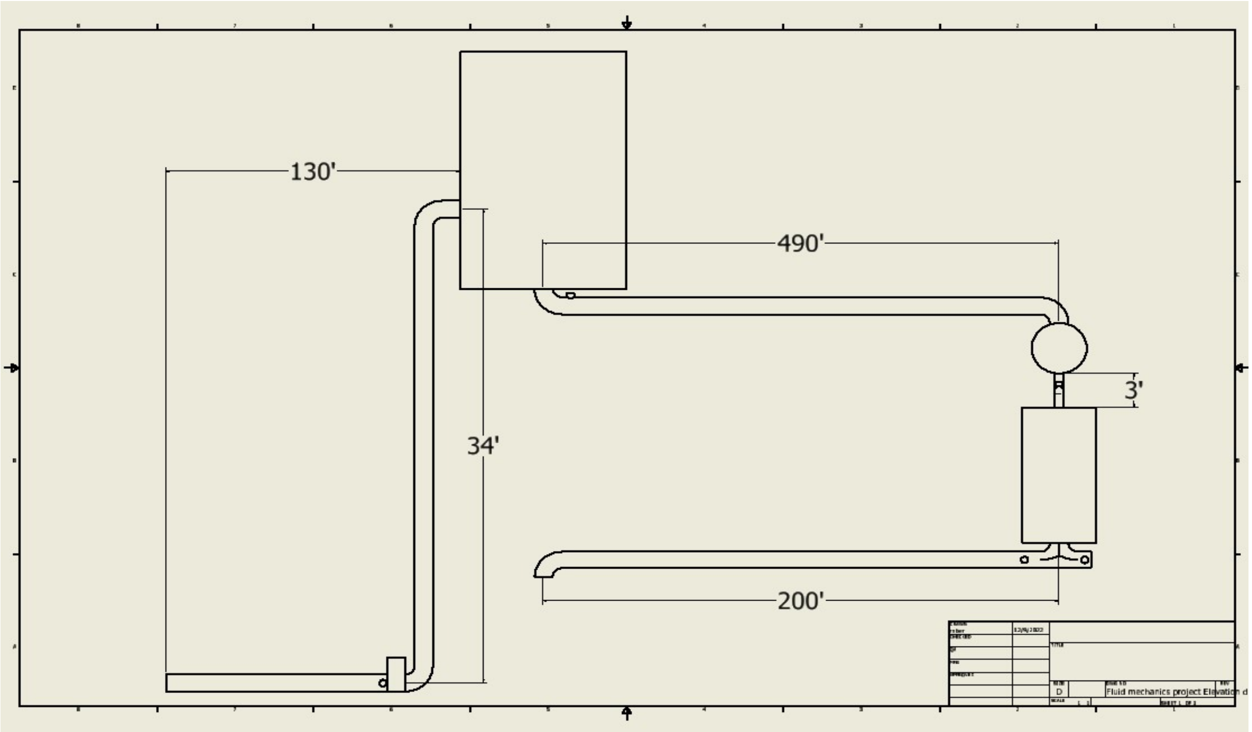


Figure 12: Final Elevations

Isometrics (task 19)

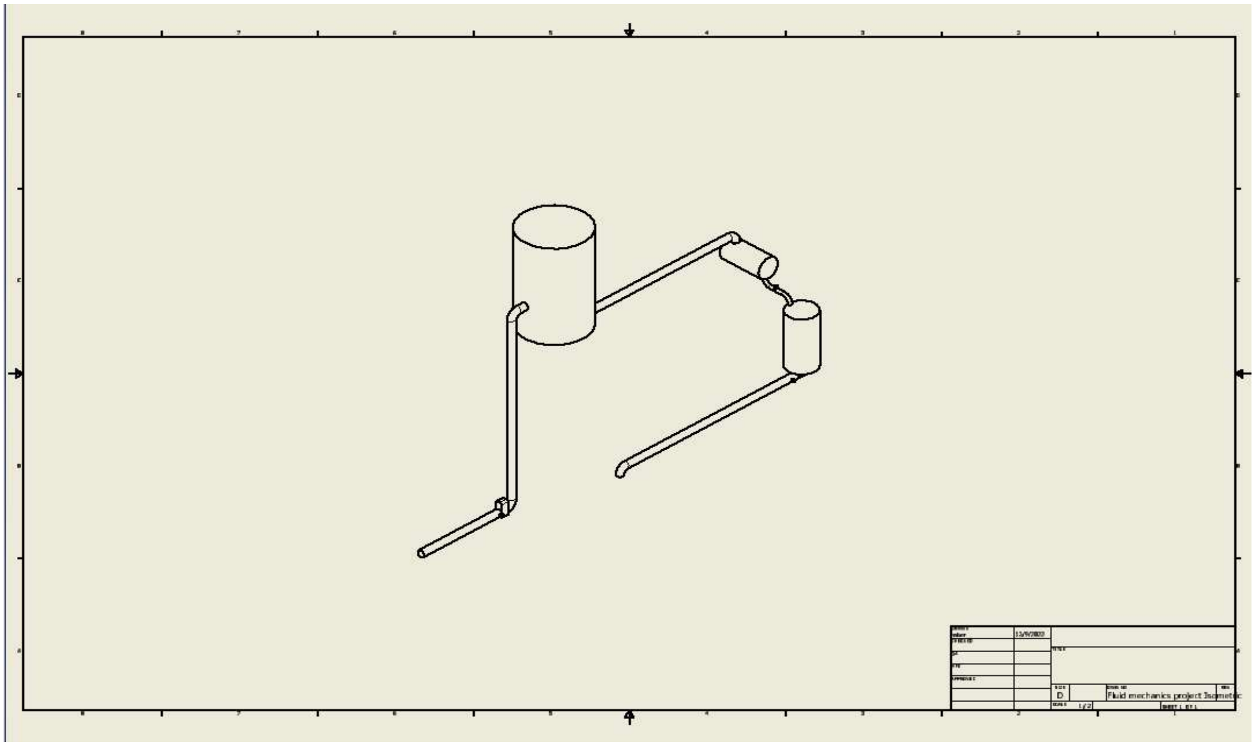


Figure 13: Isometric drawing

Bill of Materials and equipment list (task 20)

Item	Quantity
1x2x7.5A Sulzer Pump	1
20000-Gallon Tank	1
1000-Gallon Tank	1
5000-Gallon tank	1
1.5 NPS Elbow	2
1.5 NPS Valve	1
1.5 NPS Fitting	8
0.375 NPS Elbow	4
0.375 NPS Valve	3
0.375 NPS Fitting	14
0.375 NPS T-Bracket	1
0.375 NPS Blank Flange	1
Bolts for Blank Flange	4
1 NPS Elbow	2
1 NPS Fitting	5
3/8" MPT Paddlewheel Flow Meter	1
Dual Differential Input Manometer, 9V	1

Final Remarks (task 21)

Our design may be a little unorthodox, but we are confident in its functionality. There were more than a few difficulties faced with the designing of this project, but we are confident that it will function fully and reliably. Throughout this report we have detailed certain aspects like flow rate, material requirements, water hammer and energy losses. We are sure that we have looked at every necessary variable in designing this piping system for safety and reliability.

Appendix

Calculations

Flow rate

$$\frac{1000\ gallons}{3\ hours} = \frac{333.33\ gallons}{1\ hour} * \frac{1\ hour}{60\ minutes} = 5.56\ GPM$$

$$\frac{5000\ gallons}{4\ hours} = \frac{1250\ gallons}{1\ hour} * \frac{1\ hour}{60\ minutes} = 20.83\ GPM$$

Pipe sizes

$$\frac{5.56GPM * 0.002228\frac{ft^3}{s}}{10\frac{ft^2}{s}} = 0.00123ft^2$$

$$\frac{20.83GPM * 0.002228\frac{ft^3}{s}}{10\frac{ft^2}{s}} = 0.00464ft^2$$

Energy Losses

To clean storage from railcar

$$\mathrm{NR} = \frac{2.28 * 0.0409 * 9.2496}{0.00255} = 384$$

friction factor

$$\text{Moody chart} = 0.028$$

Velocity head

$$\frac{2.28^2}{2 * 9.81} = 0.2659m$$

Pipes:

$$0.028 * (\frac{55.4736}{0.0409}) * 0.2659 = 65.8141\mathrm{m}$$

Gate valve:

$$(8 * 0.028) * 0.2659 = 1.4395\mathrm{m}$$

Elbows:

$$2 * ((20 * 0.028) * 0.2659) = 7.1975\mathrm{m}$$

Entrance

$$0.5 * 0.2659 = 0.1329m$$

To machine tank from clean storage

$$\mathrm{NR} = \frac{2.8317 * 0.00125 * 9.2496}{0.00255} = 145.5124$$

friction factor

$$\frac{64}{145.5124} = 0.4398$$

Velocity head

$$\frac{2.8317^2}{2 * 9.81} = 0.4091m$$

Pipes:

$$0.4398 * (\frac{149.352}{0.0125}) * 0.4091 = 2149.9287\text{m}$$

Gate valve:

$$(8 * 0.4398) * 0.4091 = 1.4395\text{m}$$

Elbows:

$$2 * ((20 * 0.4398) * 0.4091) = 7.1975\text{m}$$

Entrance

$$0.5 * 0.2659 = 0.2045m$$

To truck from waste storage

$$\text{NR} = \frac{2.3322 * 0.0266 * 9.2496}{0.00255} = 255.0342$$

friction factor

$$\frac{64}{255.0342} = 0.2509$$

Velocity head

$$\frac{2.3322^2}{2 * 9.81} = 0.2775m$$

Pipes:

$$0.2509 * (\frac{60.96}{0.0266}) * 0.2775 = 159.6031\text{m}$$

Tee:

$$(60 * 0.2509) * 0.2775 = 4.1785m$$

Gate valve:

$$(8 * 0.2509) * 0.2775 = 0.5571\text{m}$$

Elbows:

$$(20 * 0.2509) * 0.2775 = 7.1975\text{m}$$

Exit

$$exit = 0.2775$$

Static Analysis

Railcar to storage

Weight

$$\text{Railcar to pump} = 130 * (490 * (0.024 * 1) + \big(58.882 * (0.01414 * 1)\big))$$
$$= 1637.0368\text{lbs}$$

$$\text{Up building} = 20.158 * (490 * (0.024 * 1) + \big(58.882 * (0.01414 * 1)\big))$$
$$= 253.8414\text{lbs}$$

$$\text{Elbow to tank} = 20 * (490 * (0.024 * 1) + (58.882 * (0.01414 * 1) = 251.8518\text{lbs}$$

Compression

$$\text{Railcar to pump} = \frac{1637.0368}{25000} = 0.0654$$

$$\text{Up building} = \frac{253.8414}{25000} = 0.0101$$

$$\text{Elbow to tank} = \frac{251.8518}{25000} = 0.01$$

Tension

$$\text{Railcar to pump} = \frac{1637.0368}{60900} = 0.0268$$

$$\text{Up building} = \frac{253.8414}{60900} = 0.0041$$

$$\text{Elbow to tank} = \frac{251.8518}{60900} = 0.0041$$

Storage to machines

Weight

$$490 * (490 * (0.015 * 1) + (58.882 * (0.00133 * 1))) = 3639.8733\text{lbs}$$

Compression

$$\frac{3639.8733}{25000} = 0.1455$$

Tension

$$\frac{3639.8733}{60900} = 0.0597$$

Waste to Truck

Weight

$$200 * (490 * (0.019 * 1) + (58.882 * (0.0037 * 1))) = 1905.5726\text{lbs}$$

Compression

$$\frac{1905.5726}{25000} = 0.0762$$

Tension

$$\frac{1905.5726}{60900} = 0.0312$$