# MET 330 Pipeline Design Project

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# Abstract

In response to a contract from Continental AG, our Engineering Consulting Firm is leading the design of a cutting-edge coolant processing system for their upcoming manufacturing facility located in Dayton, Oh. This project includes the careful handling of coolant, from its initial delivery from railroad tank until it is finally extracted by a third-party reclamation company. Our design's fundamental component is the steady coolant delivery to a highly automated machining line with five machines that share a reservoir inside the new facility. Our goal is to maintain sustainability and regulatory compliance throughout the coolant's lifecycle in the manufacturing facility, in addition to optimizing operational and cost efficiency.

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## a. Building Location

Dayton, OH

## b. Specifications and design philosophy

The new manufacturing facility for Continental AG focuses on optimizing efficiency, reliability, and environmental responsibility. Key considerations include the size of the storage tanks. A 15,000-gallon holding tank for new coolant, a 1000-gallon reservoir for the machining system, and a 6,000-gallon dirty tank will provide a steady supply of coolant to the machining area and will also allow for scheduled maintenance. A designated holding tank for the disposal of dirty fluid and a plan for an open channel system for the safe transportation of drained fluid away from the plant reduce the environmental impact. With two shifts every day, daily maintenance during the third shift, and emergency procedures for contaminated coolant, operational efficiency is a priority. The design also factors in the climate conditions of Dayton, Ohio, with materials and specifications addressing temperature extremes, freezing points of the coolant, and frost line considerations.

The engineering method includes detailed calculations for the thickness of the tank wall, fluid analysis, pipe sizing, pump selection, and water hammer effects. Collaboration with civil and electrical engineering colleagues is emphasized, addressing concerns such as wind loads, tank failures, and electrical motor requirements. The design philosophy emphasizes cost-effectiveness, ensuring that the proposed system meets specifications while optimizing resources and minimizing unnecessary expenses.

## c. Sources


1. *Used Process Equipment* (2023) *Phoenix Equipment*. Available at: https://www.phxequip.com/equipment.aspx (Accessed: 23 September 2023).
2. Baker, M. (2009, September 11). *NISTM - National Institute for Storage Tank Management*. Nistm.org. https://www.nistm.org/houstonSept2009/docs/2009_HoustonConf_Pres/Basic_API650.pdf
3. Mott, R. Untener, J.A., "Applied Fluid Mechanics" 7th edition, Pearson Ed. (2015).
4. ASME B31.3
5. *Dayton climate: Temperature Dayton & Weather By Month*. (n.d.). https://en.climate-data.org/north-america/united-states-of-america/ohio/dayton-1663/
6. www.mcmaster.com


## d. Materials and Specifications

The materials selected for this pipeline system are determined by standards in the industry and their availability. The components throughout the system include tanks, valves, fittings, and piping which are made using corrosion-resistant stainless steel 304. For pipeline systems, stainless steel 304 offers corrosion resistance, durability, and low maintenance requirements. The material's low maintenance requirements and compatibility with various substances contribute to cost-effectiveness and versatility in different applications and because of its strength, it can withstand extreme temperatures and pressures. When choosing the pumps, the Sulzer catalog is used to ensure dependability and performance.

## e. Preliminary Drawings and Sketches

### I. Plot Plans

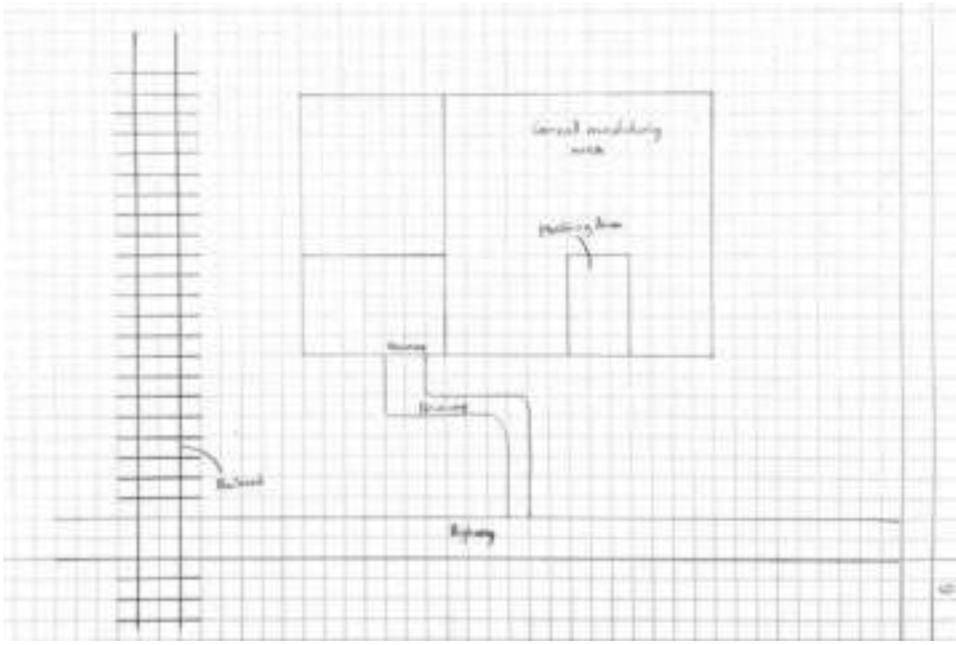

*Figure 1.1 Preliminary Plot Plan*

### II. Elevations

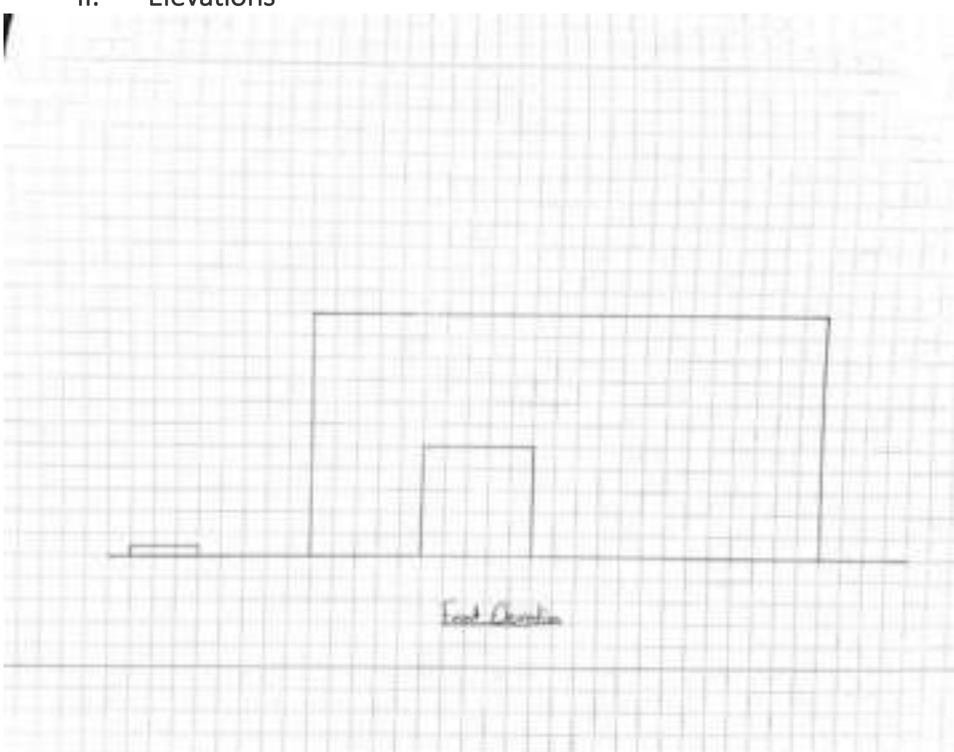

*Figure 1.2 Preliminary Front Elevation*

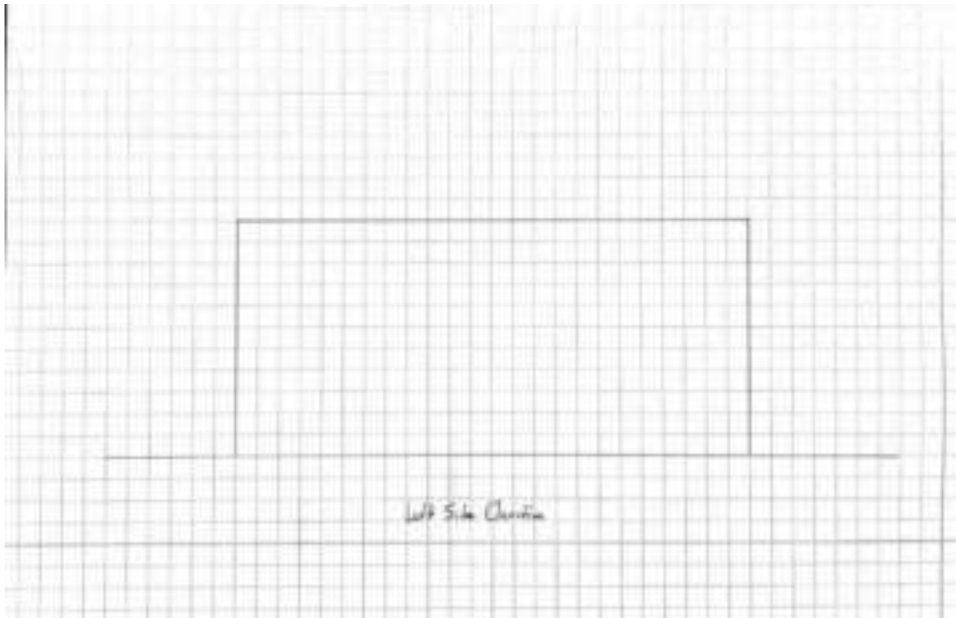


*Figure 1.3 Preliminary Left Side Elevation*

## f. Design Calculations

### I. Tank Specifications

- *Location and Size Design*

**Purpose:**
Establish the location and size of each coolant tank.

**Drawings & Diagrams:**

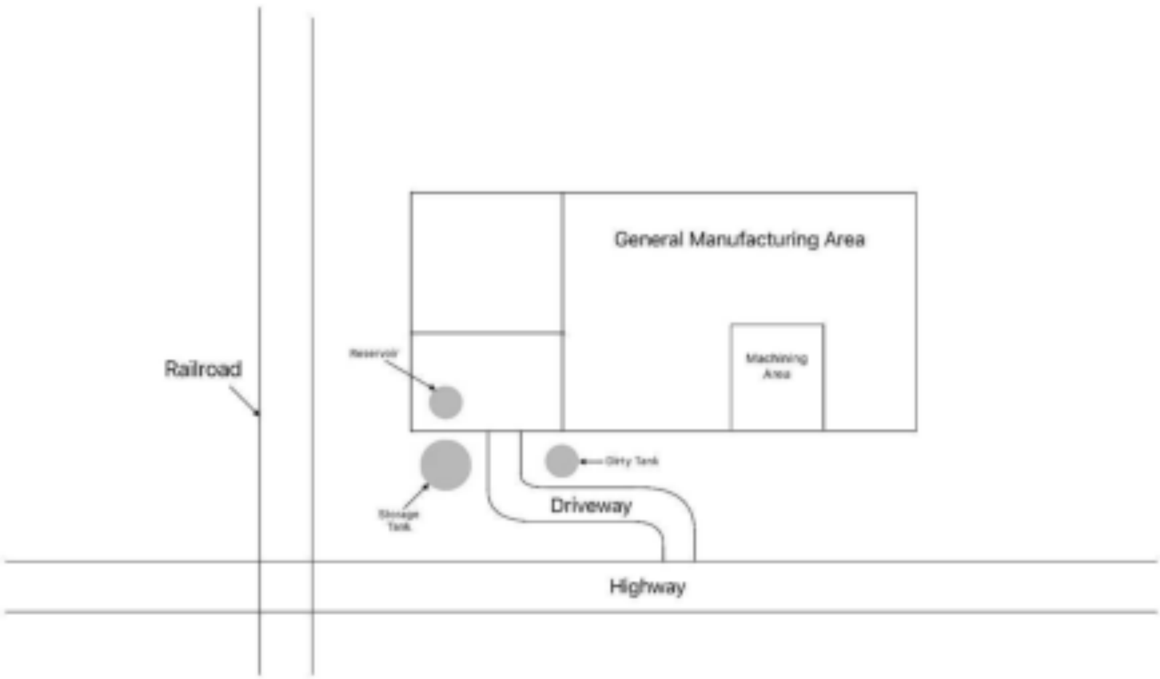


*Figure 2.1 Tank Layout*

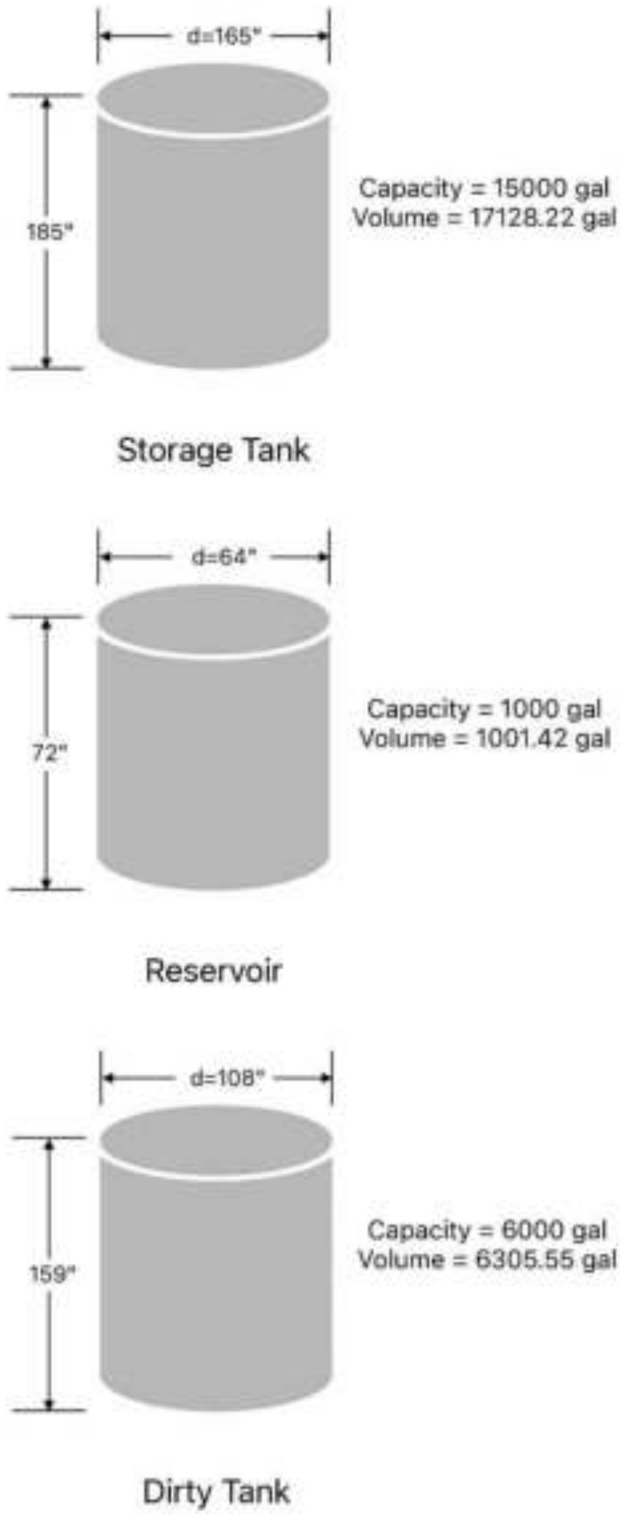


*Figure 2.2 Tank Design*

**Sources:**

*Used Process Equipment* (2023) *Phoenix Equipment*. Available at: https://www.phxequip.com/equipment.aspx (Accessed: 23 September 2023).

**Design Considerations:**

- Incompressible Fluid
- Stainless steel tank
- Three separate tank sizes

**Procedure:**

A website selling and buying used tanks was used as a reference for what typical dimensions of stainless-steel storage tanks of various sizes look like and similar tank sizes and dimensions were chosen accordingly. The chosen values were then converted to liters from gallons for ease of future calculation.

**Variables:**

| Storage Tank | | | |
|---|---|---|---|
| Description | Symbol | Value | Units |
| Capacity | c1 | 15000 (2005.20) | Gal (ft^3) |

| Reservoir Tank | | | |
|---|---|---|---|
| Description | Symbol | Value | Units |
| Capacity | c2 | 1000 (1001.42) | Gal (ft^3) |

| Dirty Tank | | | |
|---|---|---|---|
| Description | Symbol | Value | Units |
| Capacity | c3 | 6000 (802.08) | Gal (ft^3) |

**Calculations:**

| Storage Tank | | | | |
|---|---|---|---|---|
| Description | Symbol | Equation | Value | Units |
| Capacity | c1 | Given | 15000 (2005.20) | Gal (ft^3) |
| Height Minimum | h_min1 | $h_{min1} = \frac{C_1}{\pi r^2}$ | 162 (13.5) | in (ft) |
| Height Chosen | h_1 | Chosen | 185 (15.42) | in (ft) |
| Actual Volume | v1 | $V = \pi r^2 h_1$ | 3955756.03 (2289.71) | in^3 (ft^3) |
| Diameter | d1 | Chosen | 165 (13.75) | in (ft) |

| Reservoir Tank | | | | |
|---|---|---|---|---|
| Description | Symbol | Equation | Value | Units |
| Capacity | c2 | Given | 1000 (133.68) | Gal (ft^3) |
| Height Minimum | h_min2 | $h_{min2} = \frac{C_2}{\pi r^2}$ | 71.88 (5.99) | in (ft) |
| Height Chosen | h_2 | Chosen | 72 (6) | in (ft) |

| | | | | |
|---|---|---|---|---|
| Actual Volume | v2 | $V = \pi r^2 h_2$ | 231327.36 (133.87) | in^3 (ft^3) |
| Diameter | d2 | Chosen | 64(5.33) | in (ft) |

| Dirty Tank | | | | |
|---|---|---|---|---|
| Description | Symbol | Equation | Value | Units |
| Capacity | c3 | Given | 6000 (802.08) | Gal (ft^3) |
| Height Minimum | h_min3 | $h_{min3} = \frac{C_3}{\pi r^2}$ | 151.32 (12.61) | in (ft) |
| Height Chosen | h_3 | Chosen | 159 (13.25) | in (ft) |
| Actual Volume | v3 | $V = \pi r^2 h_3$ | 1456583.04 (842.93) | in^3 (ft^3) |
| Diameter | d3 | Chosen | 108(9) | in (ft) |

Storage Tank: *Note: Final values are adjusted from calculations to fit standard dimensions; calculations ensure appropriate sizing to accommodate needed capacity*

$$h_1 = \frac{c_1}{\pi r^2} = \frac{2005.2}{\pi(6.875)^2} = 13.5ft = 162\, in.$$
$$v_1 = \pi r^2 h_1 = \pi(6.875)^2(15.42) = 2289.71\, ft^3 = 17128.22\, gal$$

Reservoir Tank:

$$h_2 = \frac{c_2}{\pi r^2} = \frac{133.68}{\pi(2.665)^2} = 5.99\, ft = 71.88\, in.$$
$$v_2 = \pi r^2 h = \pi(2.665)^2(6) = 133.87\, ft^3 = 1001.42\, gal$$

Dirty Tank:

$$h_3 = \frac{c_3}{\pi r^2} = \frac{802.08}{\pi(4.5)^2} = 12.61\, ft = 151.32\, in.$$
$$v_3 = \pi r^2 h = \pi(4.5)^2(13.25) = 842.93\, ft^3 = 6305.55\, gal$$

**Summary:**

| | **Height:** | **Diameter:** | **Volume:** |
|---|---|---|---|
| **Storage Tank:** | 185 in. | 165 in. | 3955756.03 in.^3 |
| **Reservoir Tank:** | 72 in. | 64 in. | 231327.36 in.^3 |
| **Dirty Tank:** | 159 in. | 108 in. | 1456583.04 in.^3 |

Table 1.1.1 Tank Location and Size

**Analysis:**

The most essential element of any storage and distribution system is making sure there is ample space at each stage for all the materials needed. Even if the storage tank is big enough to hold all the necessary coolant, if the reservoir tank or dirty tank is too small, then the size of the storage tank doesn't matter. The dirty tank would fill too quickly, making the reservoir unable to drain and the machining unit would have no access to clean coolant. In the other case, the reservoir tank would run out of coolant too fast, and the machines would overheat. Having tanks that are too big is unacceptable as well. They'd be too expensive and would take up more space than is necessary that could be used for other appliances, machines, etc. It is of utmost importance to make sure that the size of each tank is appropriate for its workload.

- *Tank Thickness*

**Purpose:**
Determine the tank wall thickness for our 15,000gal storage tank, dirty tank, and the reservoir tank.

**Sources:**
Baker, M. (2009, September 11). *NISTM - National Institute for Storage Tank Management*. Nistm.org. https://www.nistm.org/houstonSept2009/docs/2009_HoustonConf_Pres/Basic_API650.pdf

**Design Considerations:**
- Our storage tanks are built out of stainless steel which the standard API 650 must be used to calculate storage tank wall thickness.
- A weld efficiency of 85% was assumed
- Fluid has a specific gravity of 0.94

**Procedure:**
- Determined tank material based on specifications of coolant used and preferences provided by client and group members
- Using the "One foot method" Calculated minimum tank wall thickness
- Referenced API 650 to determine a safe wall thickness for each of the storage tanks

**Variables:**
D = Diameter in ft
H = Height in ft
Sg = Specific gravity
Sp = Maximum allowable stress
Wn = Weld efficiency

**Calculations:**

$$T_d = \frac{\left(2.6(D)(H-1)\left(S_g\right)\right)}{S_p \cdot W\eta}$$

$$T_d = \frac{(2.6(13.75)(15.4167-1)(0.94))}{20000 \cdot 0.85}$$

$$T_d = 0.0285in$$

$$T_d = 0.0285in < 0.1875in$$

$$T_d = 0.1875in\ must\ be\ used\ per\ API\ 650$$

**Summary:**
Tank wall thickness was calculated using industry standard safety protocols and considerations. Since our largest tank was already calculated below the minimum requirements set by API 650 and the same coolant is used throughout the system the minimum wall thickness of 3/16" was used for all the tanks.

| Tank Wall Thickness | |
|---|---|
| Storage Tank (15,000 gal) | 3/16” |
| Reservoir Tank | 3/16” |
| Dirty Tank | 3”16” |

Table 1.1.2 Tank Wall Thickness

**Analysis:**
Wall thickness is crucial to designing a safe and effective tank. With a storage tank wall too thin, the risk of the system failing is drastically increased, without the supply of coolant to the rest of the system it cannot function. With a storage tank wall thickness too large, while it may be extremely safe and effective, it would be wasteful and more costly than using an appropriately sized wall thickness.

- *Future Drain Connection – blind flange design*

**Purpose:**
Design blind flange for connection to drain located on the storage tank.

**Sources:**
Mott, R. Untener, J.A., “Applied Fluid Mechanics” 7th edition, Pearson Ed. (2015).
ASME B31.3

**Design Considerations:**
- Constant Properties
- Isothermal Conditions
- Incompressible Fluid

**Data and Variables:**
Tank Capacity = 15,000gal
Sg = 0.94
h = 160in = 4.064m
dg = 2.38in
s = 30ksi = 30000psi
E = 1
W = 1
P = 466.2 psi
C = 0

**Procedure:**
Use specific gravity to determine specific weight of the coolant to find the pressure located at the point of the blind flange. The resultant force formula will be used to determine the force acting upon the blind flange. The minimum thickness of the flange will be found using an equation found online and then the force on each bolt will be calculated using F=PxA.
**Calculation:**
<u>Coolant:</u>

$$sg = \frac{\delta_{coolant}}{\delta_w @ 4^\circ C}$$

$$.94 = \frac{\delta_{coolant}}{9.81 \frac{kN}{m^3}}$$

$$\delta_{coolant} = 9.22 \frac{kN}{m^3}$$

$$\Delta p = \delta h$$

$$\Delta p = \left(9.22 \frac{kN}{m^3}\right)(4.064m)$$

$$\Delta p = 37.47kPa$$

<u>Pressure on blind flange:</u>

$$A_{flange} = \pi r^2 = 28.27 \text{in}^2$$

$$\text{P} = 37.47\text{kPa} = 5.43\text{psi}$$

$$\delta = 9.22 \frac{\text{kN}}{\text{m}^3} = .034 \frac{\text{lb}}{\text{in}^3}$$

$$\text{I}_c = \frac{\pi \text{D}^4}{64}$$

$$\text{I}_c = \frac{\pi (6)^4}{64}$$

$$\text{I}_c = 63.62 \text{in}^4$$

$$\text{h}_c = 160 \text{in}$$

$$\text{F}_{coolant} = \text{P}_{avg} \text{A}$$

$$\text{F}_{coolant} = \delta \text{h}_c \text{A}$$

$$\text{F}_{coolant} = \left(.034 \frac{\text{lb}}{\text{in}^3}\right)(160\text{in})\left(28.27\text{in}^2\right)$$

$$\text{F}_{coolant} = 153.8\text{lb} = 69.76\text{kg}$$

Blind Flange Thickness:

$$T_m = dg\sqrt{\frac{3P}{16(SEW)}} + C$$

$$T_m = \sqrt{\frac{3(466.2psi)}{16(30000psi)}}$$

$$T_m = .128in$$

Blind Flange Selected:
2 NPS Blind Class 150 RF
OD = 6in
B.C. = 4.75in
Thickness = .69in
Gasket ID = 2.38in
Material: Stainless Steel 304

Bolts:
F.S. = 5
Yield Strength for Stainless Steel = 31200psi

$$F_{bolt} = \frac{153.8lb}{4}$$

$$F_{bolt} = 38.45lb = 17.44kg$$

$$\sigma_{max} = \frac{\sigma_y}{F.S.}$$

$$\sigma_{max} = \frac{31200psi}{5}$$

$$\sigma_{max} = 6240psi$$

$$\sigma_{bolt} > \frac{F_{bolt}}{A_{bolt}}$$

$$6240psi > \frac{153.8lb}{A_{bolt}}$$

$$A_{bolt} = .025in^2$$

Hardware Selected:
Hex Head Cap Screw, 5/8-16 UNC
Material: Stainless Steel
Qty: 4
Hex Nut, 5/8-16 UNC
Material: Stainless Steel
Qty: 4

Cross-sectional area of 5/8-16 UNC bolt is 0.226$in^2$.

**Summary:**
To withstand the pressure of the coolant exerted on the blind flange and hardware the material chosen is stainless steel 304, and according to ASME B31.3 the blind flange will be class 150 which has a maximum pressure rating of 230psi. The hardware will consist of 4 5/8-16 UNC bolts and nuts.

| Item | Material | Quantity | Size |
|---|---|---|---|
| Flange | Stainless Steel 304 | 1 | 2 NPS Class 150 |
| Hex Head Cap Screws | Stainless Steel 316 | 4 | 5/8-11 UNC |
| Washer | Stainless Steel 316 | 4 | Screw size 5/8 |
| Hex Nut | Stainless Steel 316 | 4 | 5/8-11 UNC |

Table 1.1.3 Blind Flange Hardware

**Materials:**
Blind Flange and Hardware – Stainless Steel 304

**Analysis:**
The design of a blind flange involves a flat, solid plate with no opening, used to block or seal the end of a pipeline. The process involved calculating the force applied to the bolts, the minimum flange thickness, and the force caused by the coolant pressure on the blind flange. Specifications for pipe flanges and hardware within pressure ratings are specified by the ASME B31.3 standard. It was found that the blind flange is subjected to a strain of 153.9lbs and that its minimum thickness is.128 in. The selected 2NPS Class 150 RF flange is within the necessary criteria when compared to typical size flanges.

When selecting bolt sizes for blind flanges, it is essential to consider factors such as flange material, pressure, and temperature requirements. Proper bolt size and spacing are critical to maintaining a secure and leak-free seal and ensuring the flange can withstand the internal pressure without deformation or failure. The minimum cross-sectional area of the bolt was calculated after it was calculated that each bolt needed to withstand a force of 38.45 lbs. This information was used to estimate the necessary bolt sizes. Again, standard size bolts with the matching flange were used. The bolts used are 5/8-16 UNC, which have a cross-sectional area of.226$in^2$ and are greater than the required minimum of .025$in^2$.

- *Wind load and Weight*

**Purpose:**
To determine the force of wind on the storage tanks and the weight of the tanks empty and full

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

**Considerations:**
Energy is conserved
Isothermal Fluid

**Materials:**
Stainless steel 304 Storage tank
Stainless steel 304 Reservoir tank
Stainless steel 304 Dirty tank

**Data & Variables:**
All tanks have a thickness of 3/16”
Storage tank: 165” x 185”
Reservoir: 64” x 72”
Dirty tank: 108” x 159”
Wind Velocity: 68.9ft/s, taken from 1% of wind speed in Dayton Ohio (Riskfactor.com)
Cd: 1.22 (Table 17.6)
Density of Cold air (-20F): $2.94x10^{-3}$slugs/ft3
Density of stainless steel: $\frac{0.283lb}{in^3}$
Specific gravity of fluid: 0.94

**Procedure for Wind Force:**
1. Wind load was calculated by using the equation for drag force.
2. The Density of cold air was found in tables since cold air is the densest thus will create more force.
3. Cd was found in the tables for a cylindrical shape.
4. Area was calculated perpendicular to the wind force.

**Calculations for Wind Force:**

$$F_D = C_D\left(\frac{\rho V2}{2}\right)A$$

Storage Tank:

$$F_D = 1.22\left(\frac{(2.94x10^{\,-3})(68.9)^2}{2}\right)13.75x14.42 = 1805lbf$$

Dirty tank:

$$F_D = 1.22\left(\frac{(2.94x10^{\,-3})(68.9)^2}{2}\right)9x13.25 = 1015lbf$$

Reservoir:
Is not located in the open so

$$F_D = 0lbf$$

**Summary for Wind force:**

| | Wind Velocity (ft/s) | Wind Force (lbf) |
|---|---|---|
| **Storage Tank** | 68.9 | 1805 |
| **Reservoir** | 0 | 0 |
| **Dirty Tank** | 68.9 | 1015 |

Table 1.1.4 Wind Load

**Procedure for Weight of Storage Tanks:**

1. Amount of stainless steel was found by calculating surface area and multiplying it by thickness
2. Fluid density was multiplied by the volume of fluid in each storage tank to find the weight if the tank was filled
3. Weight of the tank and weight of the fluid was added to get total weight.

**Calculations for weight of Storage Tanks:**

Weight of tanks:

2(D x 3/16) + 2(H x 3/16) x ($\rho$ ) + $Gal \cdot 8.15 \cdot Sg$

Storage Tank w/Fluid:

$$2\left(165 \cdot \frac{3}{16}\right) + 2\left(185 \cdot \frac{3}{16}\right)(0.283) + (15{,}000 \cdot 8.15 \cdot 0.94) \ = 117{,}772lb$$

Reservoir w/Fluid:

$$2\left(64 \cdot \frac{3}{16}\right) + 2\left(72 \cdot \frac{3}{16}\right)(0.283) + (1{,}000 \cdot 8.15 \cdot 0.94) \ = 7{,}863lb$$

Dirty Tank w/Fluid:

$$2\left(108 \cdot \frac{3}{16}\right) + 2\left(159 \cdot \frac{3}{16}\right)(0.283) + (6{,}000 \cdot 8.15 \cdot 0.94) \ = 47{,}122lb$$

Storage Tank w/o Fluid:

$$2\left(165 \cdot \frac{3}{16}\right) + 2\left(185 \cdot \frac{3}{16}\right)(0.283) = \ 37.14lb$$

Reservoir w/o Fluid:

$$2\left(64 \cdot \frac{3}{16}\right) + 2\left(72 \cdot \frac{3}{16}\right)(0.283) = \ 14.43lb$$

Dirty Tank w/o Fluid:

$$2\left(108 \cdot \frac{3}{16}\right) + 2\left(159 \cdot \frac{3}{16}\right)(0.283) = \ 28.34lb$$

**Summary of Weight of Storage Tanks:**

| | Dimensions | Weight Empty (lb) | Weight Filled (lb) |
|---|---|---|---|
| **Storage Tank** | 165” x 185” | 37.14 | 117,772 |
| **Reservoir** | 64” x 72” | 14.43 | 7,863 |
| **Dirty Tank** | 108” x 159” | 28.34 | 47,122 |

Table 1.1.5 Tank Weights

**Analysis:**
By Calculating the Wind load and the weight of the storage tanks, our team can give this information to our civil engineer colleagues to make sure the supporting system for the tanks is safe. Using a decently conservative wind estimate, we can be sure our design will last under nearly all conditions. If we were to plan around the worst feasible scenario, we would be wasting money on designing the supporting system for the worst possible situation which might never happen. By using 1% of the wind conditions, we get the benefits of safety and cost efficiency.

- *Open Channel for Drainage*

**Purpose:**
Design a backup system to implement if one of our storage tanks fails by using an open channel to drain the fluid.

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

**Considerations:**
Incompressible fluid
Isothermal fluid
Open channel surface is smooth

**Data & Variables:**
Semicircle open Channel Shape
Q= 33.3 gal/min
N=0.010
A=$\frac{1}{2}\pi y^2$
S=0.01 = 1%
R=$\frac{y}{2}$
y= height of fluid level from bottom of open channel

**Solution:**

Open Channel Design

$$Q = \frac{1.0}{N} A S^{\frac{1}{2}} R^{\frac{2}{3}}$$

$$33.3 = \frac{1.0}{0.010}\left(\frac{1}{2}\pi(y)^2\right)(0.01)^{\frac{1}{2}}\left(\frac{y}{2}\right)^{\frac{2}{3}}$$

$$y = 0.653ft \ = 7.839in$$

Semicircle open channel

D= y*2 = 15.678in $\approx 16"NPS$

**Summary:**

| | Height of Fluid | Diameter of Pipe | NPS |
|---|---|---|---|
| **Open Channel** | 7.839” | 15.678” | 16” |

Table 1.1.6 Open Channel

**Diagram:**

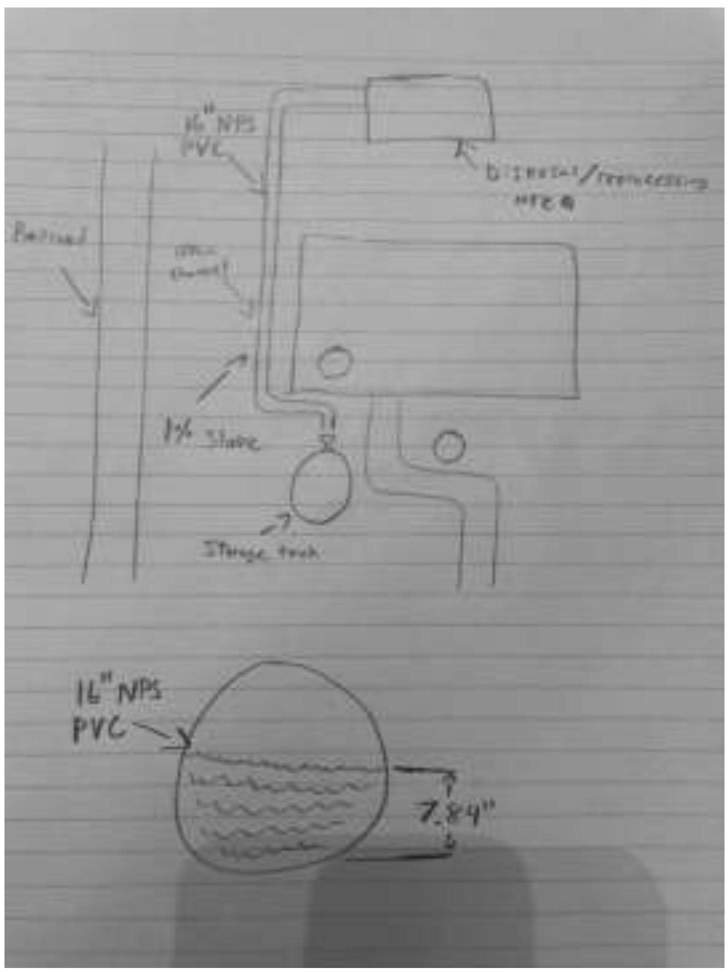


*Figure 2.3 Open Channel*

**Analysis:**
We designed an open channel that could move all the fluid from the 15,000gal Storage tank. This open channel was designed with cost saving measures in mind as this separate system would only be used in case an emergency repair was needed on the reservoir. The open channel has the capaciaty to move 33.3gal/min of fluid, which was the flow rate coming out of the storage tank. With efficiency in mind the open channel uses a semicircle design (which is one of the most efficient because of the ratio of the wetted perimeter to the area) In the equation that was used above. This design allows this piece to easily be made from 16" NPS PVC pipe cut in half only at the beginning section to allow the fluid to flow in. A slope of 1% was used in the calculations which is standard for open channel design. The open channel will run along the left side of the building and further away behind the back of the building to be reprocessed or disposed of at a later date.

## II. Flow Rate

**Purpose:**
Establish the timeframe to fill and empty all three tanks as well as the desired flow rate for each tank.

**Sources:**
Mott, R. Untener, J.A., "Applied Fluid Mechanics" 7th edition, Pearson Ed. (2015).

**Considerations:**
Incompressible fluid
Isothermal fluid

**Data & Variables:**
Storage tank capacity= 15,000 gal
Reservoir tank capacity= 1,000 gal
Dirty tank capacity= 6,000 gal

**Procedure:**
1. The fill/empty time for each tank was selected based off the shift time frame, taking careful consideration regarding down time of the machines using the coolant system.
2. The storage tank fill/empty timeframe was chosen to be 5 hours, the reservoir tank fill/empty time frame was chosen to be 30 minutes, and the dirty tank fill/empty timeframe was chosen to be 2 hours.
3. Each tank capacity was divided by the desired time to give the flow rate in gallons per minute.

- *Tank Fill/Empty Times*

| | |
|---|---|
| Storage Tank | 5 hours (300 min) |
| Reservoir Tank | 30 min |
| Dirty Tank | 2 hours (120 min) |

- *Desired Flow Rate*

**Calculations:**

<u>Storage Tank:</u>

$$\frac{15000gal}{300min} = 50.0\ \frac{gal}{min}$$

<u>Reservoir Tank:</u>

$$\frac{1000gal}{30min} = 33.333\ \frac{gal}{min}$$

<u>Dirty Tank:</u>

$$\frac{6000gal}{120min} = 50.0\ \frac{gal}{min}$$

**Summary:**

| | Fill/ Empty Time (min) | Flow Rate (gal/min) |
|---|---|---|
| **Storage Tank** | 300 minutes | 50.0 |
| **Reservoir Tank** | 30 minutes | 33.333 |
| **Dirty Tank** | 120 minutes | 50.0 |

Table 2.1.1 Flow Rate

**Materials:**
Stainless steel 304 Storage tank
Stainless steel 304 Reservoir tank
Stainless steel 304 Dirty tank

**Analysis:**
The group decided the fill/empty time of the storage tank to be 5 hours, the fill/empty time of the reservoir tank to be 30 minutes, and the fill/empty time for the dirty tank to be 120. Dividing the volume capacity of each tank by its desired fill/empty time gave us the flow rate for each tank. This gave a flow rate of 50 gal/min for the storage tank, 33.333 gal/min for the Reservoir tank, and 50 gal/min for the dirty tank. All time frames were selected based off of the total time allotted for maintenance (8 hours, a single operating shift) and the amount of coolant that needs to be moved.

## III. Pipe Sizing

- *Piping Layout*

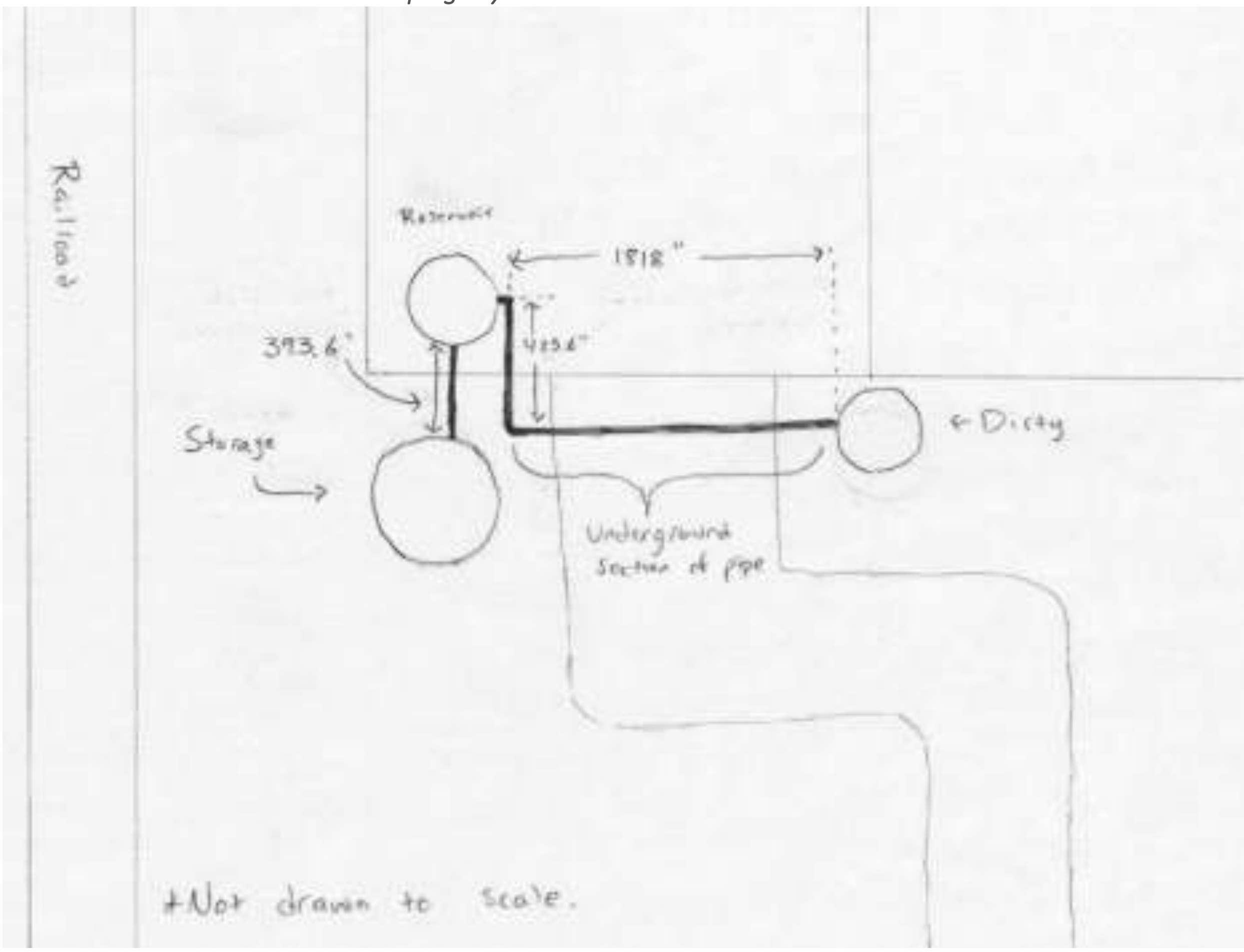


*Figure 3.1 Piping Layout Plan View*

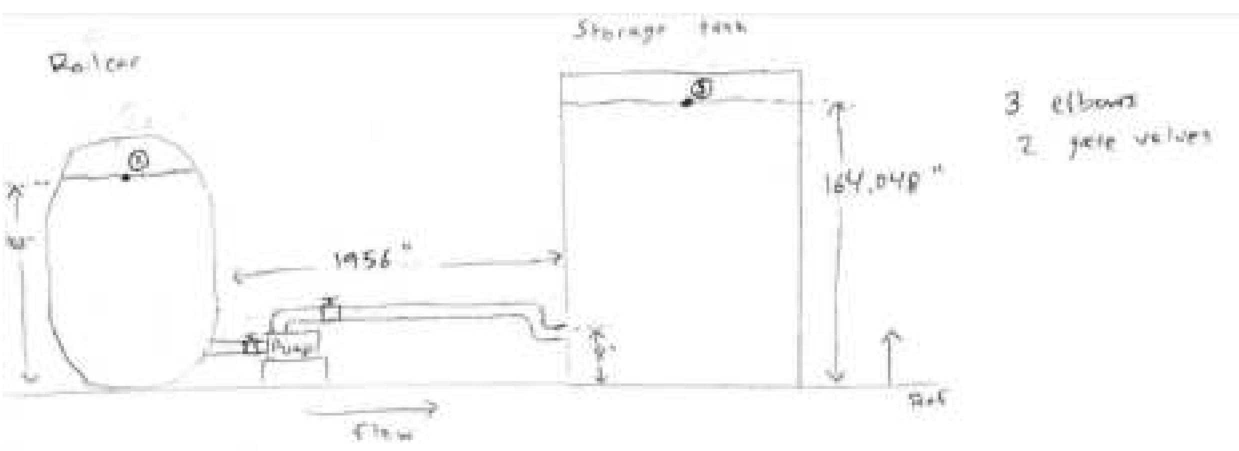


*Figure 3.2 Piping Layout Railcar to Storage*

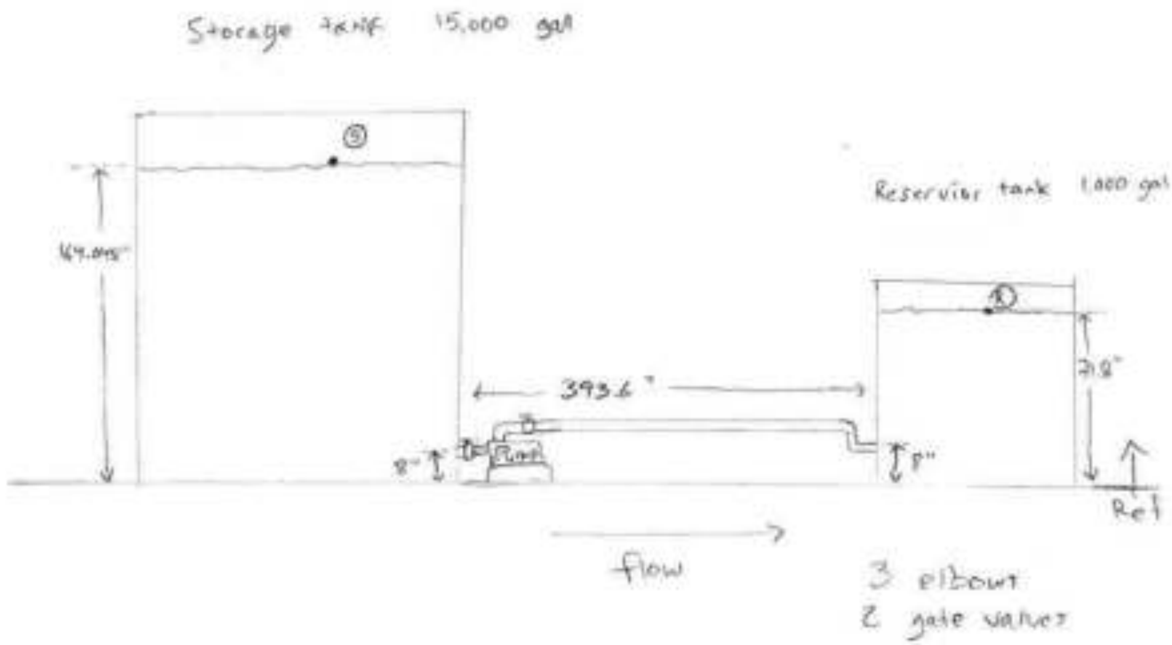


*Figure 3.3 Piping Layout Storage to Reservoir*

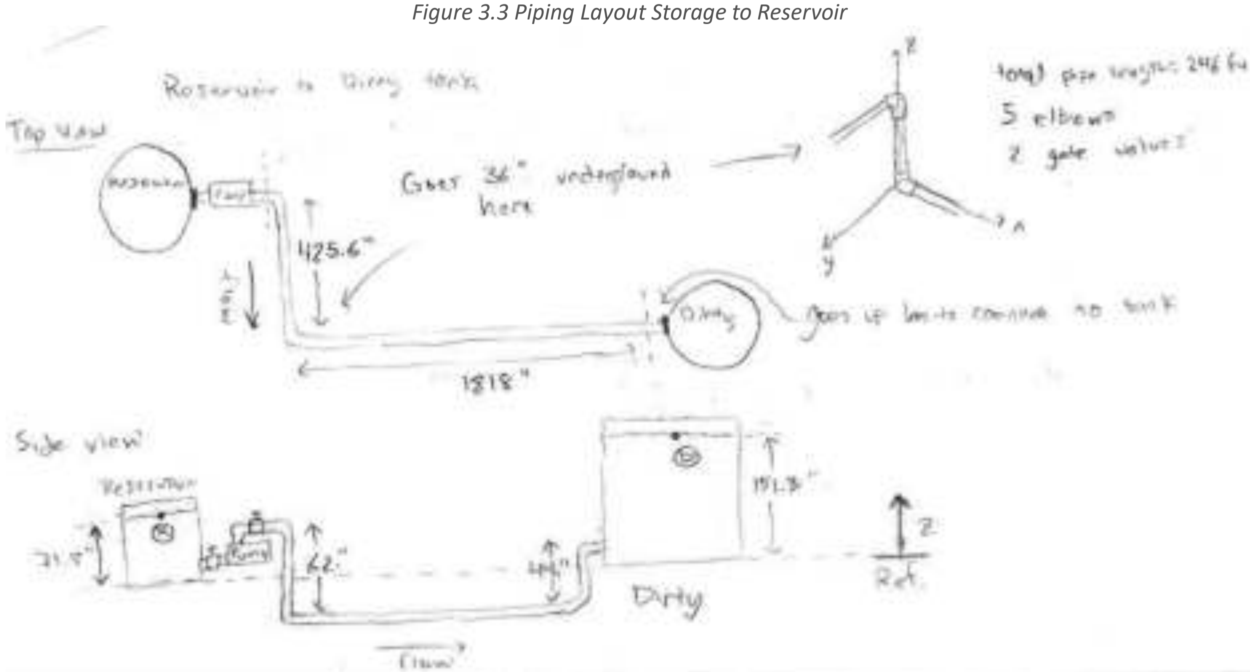


*Figure 3.4 Piping Layout Reservoir to Dirty*

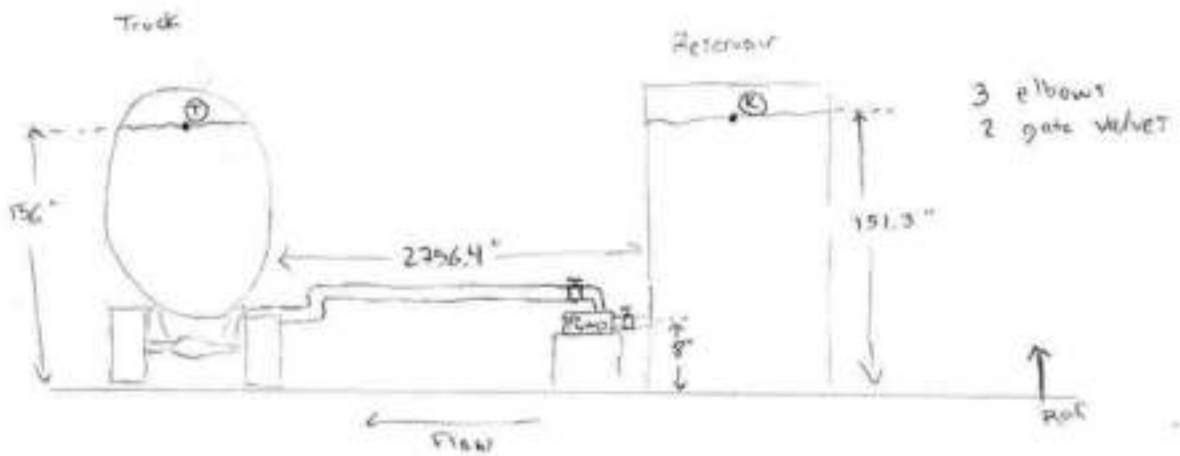


*Figure 3.2 Piping Layout Dirty to Truck*

- *Pipe Diameter and Lengths*

**Purpose:**
Specify the layout of the piping system and the material type, size, and length of all pipes within the system.

**Drawings and diagrams:**
Shown in Section 3.f.iii.

**Sources:**
Mott, R. Untener, J.A., "Applied Fluid Mechanics" 7th edition, Pearson Ed. (2015).

**Considerations:**
Incompressible fluid
Isothermal fluid

**Data and Variables:**

$$V_{desired} = 590.551 \frac{ft}{min}$$
$$Q_{CtS} = 50 \frac{gal}{min} = 6.68403 \frac{ft^3}{min}$$
$$Q_{StR} = 33.3 \frac{gal}{min} = 4.4516 \frac{ft^3}{min}$$
$$Q_{RtD} = 33.3 \frac{gal}{min} = 4.4516 \frac{ft^3}{min}$$
$$Q_{DtT} = 50 \frac{gal}{min} = 6.68403 \frac{ft^3}{min}$$

**Procedure:**
1. The material of the pipe was chosen to be 304 Stainless Steel Schedule 40
2. The chosen flow rates of each system were divided by the assumed velocity of the fluid were to determine an estimate of the area of the pipe.

3. The estimated flow area of each pipe system was used to find the actual area from Table F.1 in the textbook, by selecting the pipe size with the closest area.
4. Using the map of the manufacturing plant and the placement of the coolant tanks, the piping was drawn out.
5. Based off the placement of the tanks, the total pipe length needed for each system was decided.

**Calculations:**

Railcar to Storage Tank & Dirty Tank to Truck:

$$Q = VA$$

$$Q = 50 \, {}^{gal}\!/\!_{\min} = 6.684 \, {}^{ft^3}\!/\!_{\min}$$

$$A = \frac{Q}{V} = \frac{6.684 \, {}^{ft^3}\!/\!_{\min}}{590.551 \, {}^{ft}\!/\!_{\min}} = 0.011318 \, ft^2$$

From table F.1 Schedule 40:

Nominal Pipe Size= 1 ½"

Actual flow area= 0.01414 $ft^2$

OD= 1.9”

Wall thickness= 0.145”

ID= 1.61”

$$V_{actual} = \frac{Q}{A} = \frac{6.684 \, {}^{ft^3}\!/\!_{\min}}{0.01414 \, ft^2} = 472.7016 \, {}^{ft}\!/\!_{\min}$$

Storage Tank to Reservoir Tank & Reservoir Tank to Dirty Tank:

$$Q = VA$$

$$Q = 33.333 \, {}^{gal}\!/\!_{\min} = 4.452 \, {}^{ft^3}\!/\!_{\min}$$

$$A = \frac{Q}{V} = \frac{4.452 \, {}^{ft^3}\!/\!_{\min}}{590.551 \, {}^{ft}\!/\!_{\min}} = 0.007539 \, ft^2$$

From table F.1 Schedule 40:

Nominal Pipe Size= 1 ¼"

Actual flow area= 0.01039 $ft^2$

OD= 1.66”

Wall thickness= 0.14”

ID= 1.38”

$$V_{actual} = \frac{Q}{A} = \frac{4.452 \, {}^{ft^3}\!/\!_{\min}}{0.01039 \, ft^2} = 428.4889 \, {}^{ft}\!/\!_{\min}$$

**Summary:**

| | Material Type | NPS (*in*) | Flow Area ($ft^2$) | Total Section Length (ft) |
|---|---|---|---|---|
| Railcar to Storage | 304 Stainless Steel Schedule 40 | 1 ½" | 0.01414 | 163 |
| Storage to Reservoir | 304 Stainless Steel Schedule 40 | 1 ¼" | 0.01039 | 32.8 |
| Reservoir to Dirty | 304 Stainless Steel Schedule 40 | 1 ¼" | 0.01039 | 195.8 |
| Dirty Tank | 304 Stainless Steel Schedule 40 | 1 ½" | 0.01414 | 229.7 |
| Total length of all pipes: 621.3 ft | | | | |

Table 3.1.1 Pipe Diameter

**Materials:**
1 ¼" NPS Stainless Steel pipe 304
1 ½" NPS Stainless Steel pipe 304
Pipe elbows 316 (qty. 9)

**Analysis:**
The diameter of the pipe was selected based on the desired flow rate. 304 stainless steel was chosen as the material for the pipe so that rust would not be an issue within the system. The pipe coming from the railcar to the storage tank is 1 ¼" NPT. The pipe leaving the storage tank and entering the reservoir tank is 1 ¼" NPT. There is an outlet on the reservoir tank that allows for piping to the machines at 1 ¼" NPT. The pipe size from the reservoir to the dirty tank is 1 ¼" NPT. The pipe size from the dirty tank to the truck is 1 ½". These pipe sizes allow for the desired flow rate within the system. The locations of all the tanks were placed in such a way that they are efficient and cost-effective for running the pipe to each tank. To counteract the effects of cold weather on the coolant during winter, the pipe that routes from the reservoir to the dirty tank drops down 36" into the earth. This counteracts the 30" frost line. If it were decided not to put the pipes underground, the project would save money. However, this would also create problems with the coolant during the winter. To counteract this problem, the piping could be insulated throughout the system so that the coolant does not get cold enough to damage the machines or freeze. The reservoir tank is placed far away from the machining area to keep that space clear for machine expansion and allow for more work area. The tank and pipe layout are thoughtfully placed so that the least amount of pipe is used, while keeping the storage tank close to the railroad and the dirty tank close to the road where the truck will pick it up.

- *Pipe Thickness*

**Purpose:**
Determine the thickness of pipes used throughout the system.

**Drawings:**

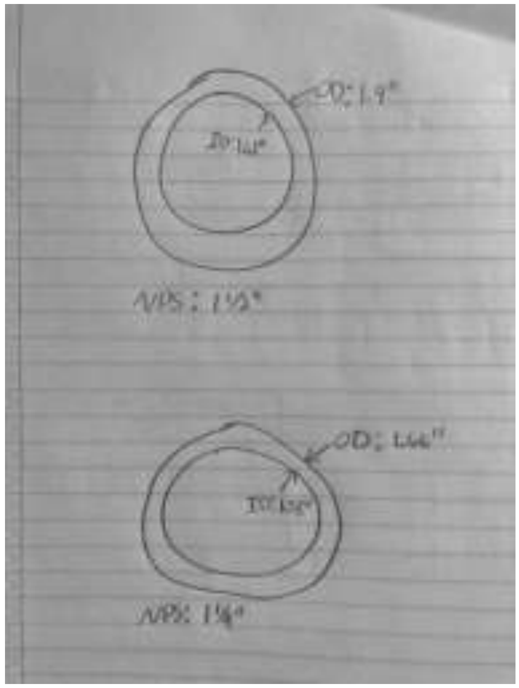


*Figure 3.6 Pipe Thickness*

**Sources:**

Mott, R. Untener, J.A., "Applied Fluid Mechanics" 7th edition, Pearson Ed. (2015).

**Design Considerations:**

Nominal pipe size was chosen based on the calculated inner diameter. The inner diameter was selected so that the flow rate and velocity matched the desired flow rate.

**Procedure:**

- Based on a desired flow rate and velocity the inner diameter of the pipe was calculated.
- Knowing the inner diameter, material of the pipe and what schedule pipe was desired nominal pipe size was selected to best reflect the same results.
- Knowing the Nominal pipe size an outer diameter is given.
- Bernoulli's is used to find design pressure.
- The pipe wall thickness was then calculated by subtracting the outer diameter from the inner diameter.

**Variables:**

| **Variable:** | **1 ¼" NPS** | **1 ½" NPS** |
|---|---|---|
| t | 0.14 in. | 0.145 in. |
| D | 1.66" | 1.9" |
| ID | 1.38" | 1.61" |
| S | 20000 | 20000 |
| E | 0.85 | 0.85 |
| Y | 0.4 | 0.4 |
| A | 0.08 in | 0.08 in |

t = Pipe wall thickness
ID = Inner pipe diameter
D = Outer diameter
S = Yield Strength
E= Weld Quality (Accepted as 85%)
Y = Corrosion Factor (Accepted as 0.40 for stainless steel)
A = Corrosion Allowance (Accepted as 0.08in)

**Calculations:**

$$t = \frac{(OD - ID)}{2}$$

$$\frac{P1}{\gamma} + \frac{v1^2}{2g} + Z1 + Ha = \frac{P2}{\gamma} + \frac{v2^2}{2g} + z2 + HL_{1-2}$$

$$0 + 0 + 13.574 + 19.23 = \frac{P2}{60.536} + \frac{(7.14)^2}{64.4} + 2.17 + 21.53$$

$$P2 = 3.57 psi$$

$$t = \frac{(1.66 - 1.38)}{2} = 0.14\ in. \text{ for 1 ¼ NPS}$$

$$t = \frac{(1.9 - 1.61)}{2} = 0.145 in \text{ for 1 ½ NPS}$$

$$t_{nom} = 1.143\left[\frac{\rho D}{2(SE + \rho Y)} + A\right]$$

Storage to Reservoir

$$t_{nom} = 1.143\left[\frac{3.57 \cdot 1.66}{2(22000 \cdot 0.85 + 3.57 \cdot 0.4)} + 0.08\right] = 0.081 in$$

Reservoir to Dirty tank

$$t_{nom} = 1.143\left[\frac{0.86 \cdot 1.66}{2(22000 \cdot 0.85 + 0.86 \cdot 0.4)} + 0.08\right] = 0.08 in$$

Dirty tank to Truck

$$t_{nom} = 1.143\left[\frac{4.15 \cdot 1.9}{2(22000 \cdot 0.85 + 4.15 \cdot 0.4)} + 0.08\right] = 0.08 in$$

**Summary:**

Pipe wall thickness was calculated by taking the outer diameter of the pipe, given by the table, and subtracting it from the inner diameter calculated from the desired flow rate and velocities specified in section 3.f.iii. To calculate theoretical minimum pipe thickness Bernoulli's equation was used where pressure was the greatest which was after the pump between the Reservoir and the dirty tank. By knowing the velocity, pump head, pipe losses, change in elevation, and the water's temperature I was able to solve the pressure after the pump. By using the equation for minimum pipe wall thickness I was able to determine that our standard 1.5” and 1.25” schedule 40 steel pipe has a great enough pipe thickness to withstand the pressure for our system (0.14”>0.081”) Was the closest.

**Analysis:**
By knowing pipe wall thickness calculations can be run to determine heat loss/gain and future design considerations can be considered.

- *Fittings*

**Purpose:**
Specify number, type, material, and size of valves, elbows, and fittings.

**Drawing:**

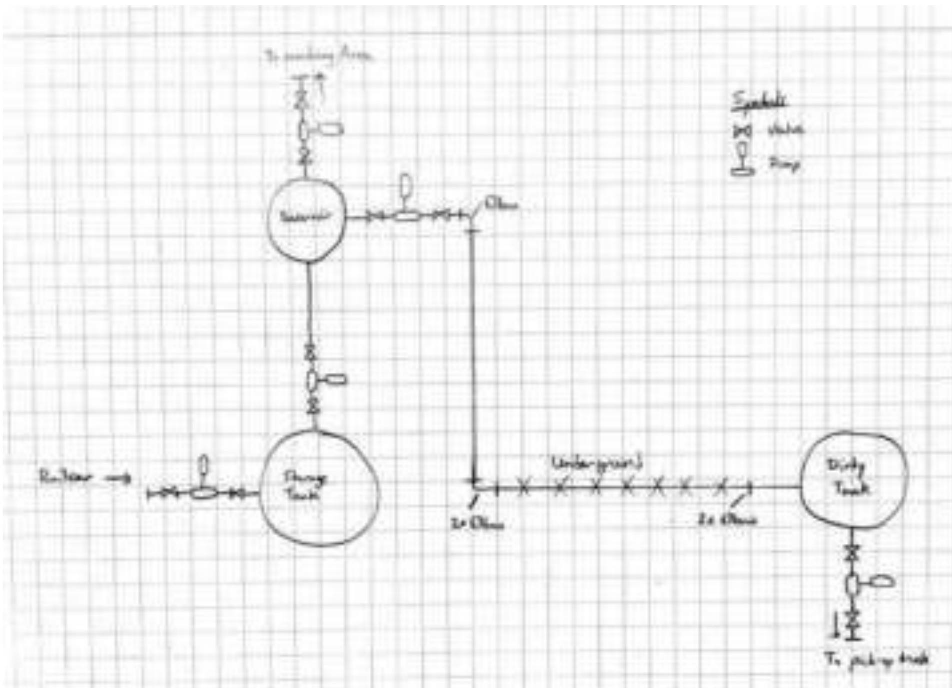


*Figure 3.7 Fittings Top View*

**Sources:**
www.mcmaster.com

**Calculation:**
Elbows:
Qty: 5
Size: 1-1/4 NPS, Sch 40
Material: Stainless Steel 304
Flange Size: 1-1/4 NPS, 4.62in OD

Reducers:
QTY: 8
Size:
1-½ - 1-½"
1-½” - 2”

1-½ “- 3”
1-¼” - 1”
1-¼ - 2”
Material: Stainless Steel 304

<u>Valves:</u>
Type: Butterfly
Size: 1-1/4 pipe size
Material: Stainless Steel 316
Qty: 10
Pressure Class: 150psi

<u>Pumps:</u>
Qty: 5
2x3x7.5A 1775 RPM
1x2x9 1775 RPM
1.5x3x8 1775 RPM

**Summary:**
Using calculations shown in previous sections the selection of elbows and valves were based on pipe diameter.

| System | Number of Elbows | Number of Valves | Number of Reducers | Number of Pumps |
|---|---|---|---|---|
| Railcar to Storage Tank | 1 | 2 | 2 | 1 |
| Storage Tank to Reservoir | 3 | 2 | 2 | 1 |
| Reservoir to Dirty Tank | 5 | 2 | 2 | 1 |
| Dirty Tank to Pick-up Truck | 1 | 2 | 2 | 1 |

Table 3.1.3 Fittings

**Materials:**
Elbows: Stainless Steel 304
Reducers: Stainless Steel 304
Valves: Stainless Steel 316

**Analysis:**
The calculations presented in sections 3.f.iii and 3.f.iii were used to select pipe elbows and valves. 10 elbows, 8 valves, 5 pumps and 8 reducers were discovered to be necessary where 2 of the 5 pumps will be used directly in our system and the other 3 will be supplied if the fluid distributer, manufacturing company or pick-up truck require the use of a pump for their operations. The valves will be installed before and after each pump to shut off flow and allow maintenance to be performed on the pumps. The correct valve for a piping system is critical since it has a direct impact on the system's efficiency, safety, and overall performance. The valve type, size, and material must be compatible with the specific fluid,

pressure, and temperature requirements to enable effective control, prevent leaks, and minimize maintenance, eventually adding to the overall system's longevity and reliability.

- *Water Hammer*

**Purpose:** Ensure the safety of all systems from water hammer to avoid pipeline system failure.

**Drawings & Diagrams:**

<u>Railcar to Storage:</u>

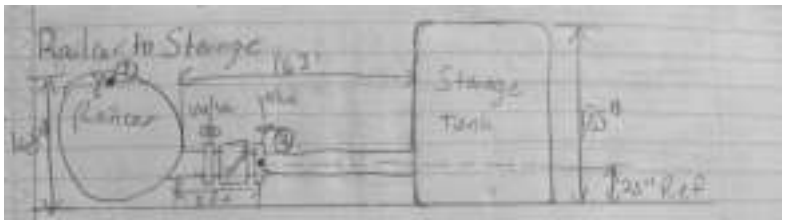


*Figure 3.8 Water Hammer Railcar to Storage*

<u>Storage to Reservoir:</u>

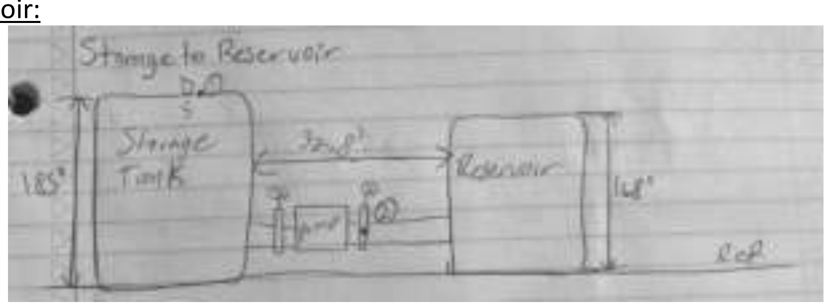


*Figure 3.9 Water Hammer Storage to Reservoir*

<u>Reservoir to Dirty:</u>

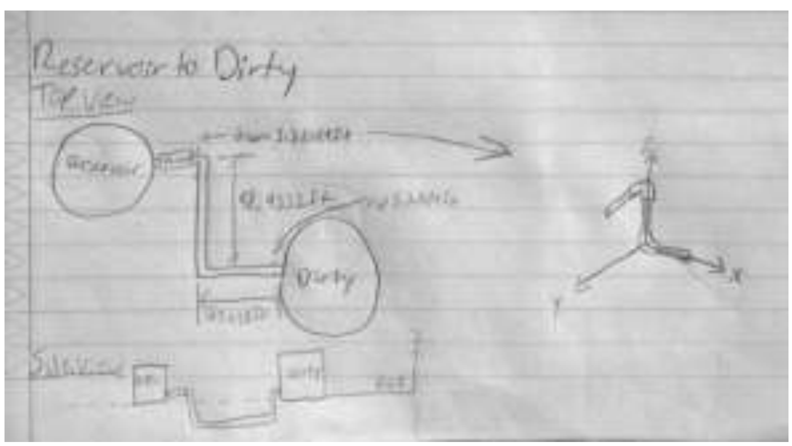


*Figure 3.10 Water Hammer Reservoir to Dirty*

Dirty to Truck:

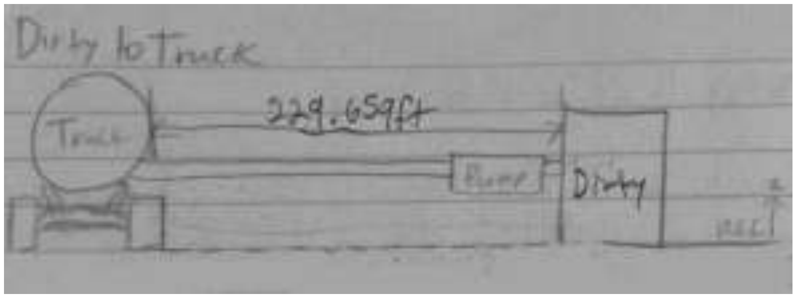


*Figure 3.11 Water Hammer Dirty to Truck*

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

**Design Considerations:**
Incompressible Fluid
Constant Properties

**Data & Variables:**
Bulk Modulus, $E_o = 2.2212 \cdot 10^8 \ \frac{kg}{ms^2}$
Density, $\rho = 99.8349 \ \frac{kg}{m^3}$
Outside Pipe Diameter (NPS 1 ¼"), $D = 0.042164 \, m \ = 1.66 \ in.$
Original Pipe Thickness (NPS 1 ¼"), $\delta = 0.003556 \, m \ = 0.14 \ in.$
Modulus of Elasticity (steel), $E = 200 \ GPa$
Fluid Velocity (NPS 1 ¼"), $V = 2.40132 \ \frac{m}{s}$
Specific Weight, $\gamma = 9.81 \ \frac{kN}{m^3}$
Pump Head, $h_{A_{(X \to S)}} = 9.3086 \, m$
Height of Railcar Fluid Surface, $z_{1_{(X \to S)}} = 4.2672 \, m$
Height of Pump Outlet, $z_{2_{(X \to S)}} = 0.2032 \, m$
Gravitational Constant, $g = 9.81 \ \frac{m}{s^2}$
Energy Losses from z_1 to z_2, $h_{L_{XtS(1 \to 2)}} = 0.9011 \, m$
Outside Pipe Diameter (NPS 1 ½"), $D = 0.04826 \, m = 1.9 \ in.$
Original Pipe Thickness (NPS 1 ½"), $\delta = 0.003683 \, m \ = 0.145 \ in.$
Fluid Velocity (NPS 1 ½"), $V = 2.1767 \ \frac{m}{s}$
Pump Head, $h_{A_{(S \to R)}} = 19.23529 \, m$
Height of Storage Fluid Surface, $z_{1_{(S \to R)}} = 4.116 \, m$
Height of Pump Outlet, $z_{2_{(S \to R)}} = 0.2032 \, m$
Energy Losses from z_1 to z_2, $h_{L_{StR(1 \to 2)}} = 6.4824 \, m$
Pump Head, $h_{A_{(R \to D)}} = 13.83041 \, m$
Height of Reservoir Fluid Surface, $z_{1_{(R \to D)}} = 1.824 \, m$
Height of Pump Outlet, $z_{2_{(R \to D)}} = 0.2032 \, m$
Energy Losses from z_1 to z_2, $h_{L_{RtS(1 \to 2)}} = 0.6947 \, m$
Pump Head, $h_{A_{(D \to T)}} = 13.51411 \, m$
Height of Dirty Fluid Surface, $z_{1_{(D \to T)}} = 3.843 \, m$

Height of Pump Outlet, $z_{2_{(D\to T)}} = 0.2032\,m$
Energy Losses from z_1 to z_2, $h_{L_{DtT(1\to 2)}} = 0.7229\,m$

**Procedure:**
I will compute water hammer overpressure, then maximum pressure, and use equation 11-9 to compute the pipe thickness necessary to withstand water hammer, comparing it to our original pipe thickness.

**Calculations:**
Railcar to Storage:

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

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

$$C = \frac{\sqrt{\frac{2.179 \cdot 10^8}{99.8349}}}{\sqrt{\left(1 + \frac{(2.179)(0.042164)}{(200)(0.003683)}\right)}} = \frac{1477.363692}{1.060532397} = 1393.039662\,\frac{m}{s}$$

$$\Delta P = (99.8349)(1393.039662)(2.40132) = 333961.1185\,Pa = 48.436965\,psi$$

$$P_2 = \gamma\left(h_A + (z_1 - z_2) - \frac{V^2}{2g} - h_L\right)$$

$$P_2 = (9.81)\left(9.308579 + (4.2672 - 0.2032) - \frac{2.40132^2}{2(9.81)} - 0.9011\right)$$

$$P_2 = 119.4620401\,\frac{kN}{m^2} = 119462.0401\,Pa = 17.3265040\,psi$$
$$P_{max} = P_2 + \Delta P = 17.3265040 + 48.436965 = 65.763469\,psi$$

$$t_{(S\to R)} = \frac{P_{max} D}{2(SE + P_{max} Y)} = \frac{(65.763469)(1.9)}{2\big((20000)(0.85) + (65.763469)(0.4)\big)} = 0.00366934\,in.$$

$t_{(X\to S)} < 0.145\,in.$, ∴ the system from Railcar to Storage is safe from water hammer.

Storage to Reservoir:

$$C = \frac{\sqrt{\frac{2.179 \cdot 10^8}{99.8349}}}{\sqrt{1 + \frac{(2.179)(0.04826)}{(200)(0.003683)}}} = \frac{1477.363692}{1.0690005} = 1382.004678\,\frac{m}{s}$$

$$\Delta P = (99.8349)(1382.004678)(2.1767) = 300324.3029\,Pa = 43.5583574\,psi$$

$$P_2 = (9.81)\left(19.23529 + (4.116 - 0.2032) - \frac{2.1767^2}{2(9.81)} - 6.4824\right)$$

$$P_2 = 161.1214075\ \frac{kN}{m^2} = 161121.4075\ Pa = 23.3686844\ psi$$

$$P_{max} = P_2 + \Delta P = 23.3686844 + 43.5583574 = 66.9270418\ psi$$

$$t_{(S \to R)} = \frac{(66.9270414)(1.66)}{2\big((20000)(0.85) + (66.9270418)(0.4)\big)} = 0.003262477\ in.$$

$t_{(S \to R)} < 0.14\ in.$, $\therefore$ The system from Storage to Reservoir is safe from water hammer.

Reservoir to Dirty:

$$C = \frac{\sqrt{\frac{2.179 \cdot 10^8}{99.8349}}}{\sqrt{\left(1 + \frac{(2.179)(0.04826)}{(200)(0.003683)}\right)}} = \frac{1477.363692}{1.0690005} = 1382.004678\ \frac{m}{s}$$

$$\Delta P = (99.8349)(1382.004678)(2.1767) = 300324.3029\ Pa = 43.5583574\ psi$$

$$P_2 = (9.81)\left(13.83041 + (1.824 - 0.2032) - \frac{2.1767^2}{2(9.81)} - 0.6947\right)$$

$$P_2 = 142.3923517\ \frac{kN}{m^2} = 142392.3517\ Pa = 20.652264\ psi$$

$$P_{max} = P_2 + \Delta P = 20.652264 + 43.5583574 = 64.2106214\ psi$$

$$t_{(R \to D)} = \frac{(64.2106214)(1.66)}{2\big((20000)(0.85) + (64.2106214)(0.4)\big)} = 0.00313026\ in.$$

$t_{(R \to D)} < 0.14\ in.$, $\therefore$ The system from Reservoir to Dirty is Safe from water hammer.

Dirty to Truck:

$$C = \frac{\sqrt{\frac{2.179 \cdot 10^8}{99.8349}}}{\sqrt{\left(1 + \frac{(2.179)(0.042164)}{(200)(0.003683)}\right)}} = \frac{1477.363692}{1.060532397} = 1393.039662\ \frac{m}{s}$$

$$\Delta P = (99.8349)(1393.039662)(2.40132) = 333961.1185\ Pa = 48.436965\ psi$$

$$P_2 = (9.81)\left(13.51411 + (3.843 - 0.2032) - \frac{2.40132^2}{2(9.81)} - 0.7229\right)$$

$$P_2 = 158.3050392 \frac{kN}{m^2} = 158305.0392\ Pa = 22.9602047\ psi$$

$$P_{max} = P_2 + \Delta P = 22.9602047 + 48.436965 = 71.3971697\ psi$$

$$t_{(D\to T)} = \frac{(71.3971697)(1.9)}{2\big((20000)(0.85) + (71.3971697)(0.4)\big)} = 0.00398315\ in.$$

$t_{(D\to T)} < 0.145\ in.$, ∴ The system from Dirty to Truck is safe from water hammer.

**Summary:**

| System | Thickness (in.) | Safe? (Y/N) |
|---|---|---|
| $X \to S$ | 0.00366934 | Y |
| $S \to R$ | 0.00326248 | Y |
| $R \to D$ | 0.00313026 | Y |
| $D \to T$ | 0.00398315 | Y |

**Materials:**
Coolant
Sch. 40 Stainless Steel

**Analysis:** Given that throughout the four systems, there were only two nominal pipe sizes, the systems from the Railcar to the Storage Tank and the Dirty Tank to the Truck had the same C values and change in pressure, as did the systems from the Storage Tank to the Reservoir Tank and the Reservoir to the Dirty Tank. In these cases, the only variables setting each system apart were P_2, pump head, energy losses, and elevation changes. As a result, while each system's minimum thickness to be safe from water hammer was different from the rest, they were all within the same thousandth of an inch, and all systems were deemed safe.

## IV. Pipeline Supports

- *Types of Supports*
- *Distance between supports*
- *Forces on supports*

**Purpose:**
Decide the type of support, distance between supports, and determine the force acting upon each support for a particular system.

**Drawings and diagrams:**

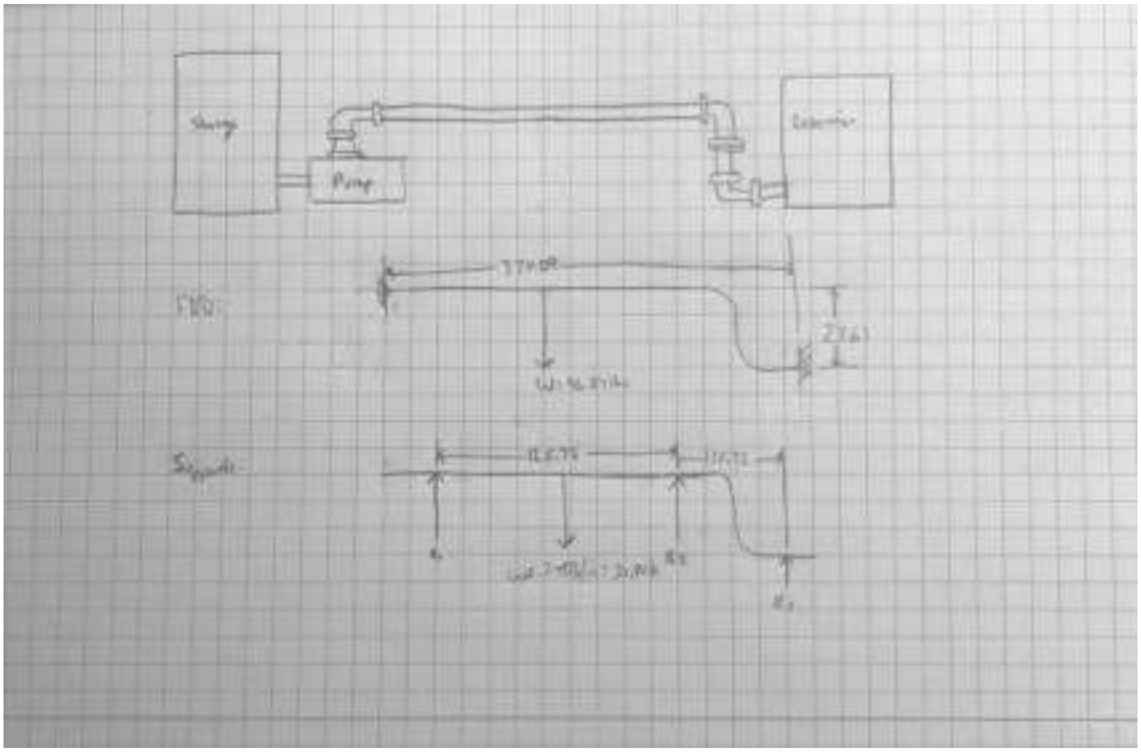

*Figure 4.1 Piping Supports*

**Sources:**

Mott, R. Untener, J.A., “Applied Fluid Mechanics” 7th edition, Pearson Ed. (2015).
https://www.amardeepsteel.com/blog/density-of-stainless-steel-304.html
ASME B31.3 Power Piping
www.mcmaster.com

**Considerations:**

Total weight of the fluid in the piping and total length of the piping. Neglecting weight of the valve.

**Data and Variables:**

L= 393.7” (32.8’)
E = 28,000,000 psi
 = 1.660”
 = 1.380”
 = .036 lb/in^3
 = .286 lb/in^3
**=** 1.496 in^2 (0.01039 ft^2)

**Procedure:**

I will begin by calculating the combined weight of the pipe and the fluid. I will next compute the pipe's deflection using the equation for a fixed beam with a uniformly distributed load. Following a predetermined standard, the allowable deviation between supports is limited to 1% of the outside diameter of the pipe. Using the same formula for uniformly distributed load, I will calculate the maximum distance between each support to make sure the specified deflection limit is met. I'll compute the force in the y-direction and the moments using the length between each support and the distributed load to determine the forces acting on each support. I will then choose an item from a manufacturer's catalog based on the determined forces at each support.

**Calculations:**

Weight of pipe (Wp):

$$V=\pi\left[\left(\frac{D_0}{2}\right)^2-\left(\frac{D_1}{2}\right)^2\right]\times L$$

$$V=\pi\left[\left(\frac{1.66}{2}\right)^2-\left(\frac{1.38}{2}\right)^2\right]\times 393.7$$

$$V=263.20 in^3$$

$$W_{p-V\rho}$$

$$W_{p-263.2\times .286}$$

$$W=75.28 lbs$$

Weight of the Coolant (Wf):

$$W_f=\rho A$$

$$W_f=.036\times 1.496$$

$$W_f=.054\ lb/in$$

$$W_f=.054\times 393.7$$

$$W_f=21.26\ lbs$$

Total Weight:

$$W_{T=}W_{p+}W_F$$

$$W_{T=}75.28+21.26$$

$$W_{T=}96.54\ lbs$$

Deflection:

$$Distributed\ weight:$$

$$w = \frac{96.54lbs}{393.7"}$$

$$w = .245lb/in$$

$$Moment\ of\ Inertia:$$

$$I = \frac{\pi}{64}\left(D_0^4 - D_1^4\right)$$

$$I = \frac{\pi}{64}\left(1.66^4 - 1.38^4\right)$$

$$I = .198in^4$$

$$y = \frac{wL^4}{384EI}$$

$$y = \frac{.245 \times 393.7^4}{384 \times 28,000,000 \times .198}$$

$$y = -2.764in$$

$$y = \frac{wL^4}{384EI}$$

$$.02875 = \frac{.245L^4}{384 \times 28,000,000 \times .198}$$

$$L = 125.72in$$

$$Distance\ between\ supports:$$

$$R_1 = R_2 = R_3 = 125.72"$$

$$Weight\ equally\ distributed\ on\ each\ support:$$

$$.245lb/in \times 125.72" = 30.8lb$$

**Summary:**

With the use of the uniform distributed load equation and the fixed beam, the calculated overall deflection of the fluid-filled pipe came out to be -2.764 inches. Per the client's requirements, the maximum distance between supports could not be greater than 1% of the pipe's outer diameter. As a result, the maximum distance between supports is 125.72 inches, which means that three supports must be installed between the storage tank and reservoir tank. After calculating the forces acting on each support, a force of 30.8 pounds was determined. The pipe supports that were chosen are the McMaster-Carr 8487T15 Floor-mount support strut-style supports, which have a 100-pound load capacity.

| Part Number | Qty | Load Supported (lbs) | Maximum Load (lbs) |
|---|---|---|---|
| McMaster-Carr 8487T15 | 3 | 30.8 | 100 |

Table 4.1.1 - Supports

**Materials:**
1-1/4 Sch 40 Stainless Steel 304 Pipe
McMaster-Carr 8487T15

**Analysis:**
The procedure used was to calculate the force acting on the piping between the storage tank and the reservoir tank and to determine the deflection of the piping with the fluid. Note that there is an ASME standard that focuses on process piping systems that provides guidelines for design, installation and supports of piping. When determining the spacing of pipe supports, factors such as pipe size, material, operating temperature, fluid characteristics, and the specific requirements of the piping system are considered. One of the most important steps in minimizing excessive pipe deflection is calculating the distance between piping supports. Unrestrained deflection can result in a variety of problems, such as reduced flow rate, higher energy usage, fluid stagnation, and more strain on the pipe supports. The maximum distance between supports was calculated to be 125.72 inches and shall be kept within 1% of the pipe diameter to minimize deflection. According to the ASME B31.1 standard from Table 121.5, there is not a suggested pipe support spacing for 1-1/4 NPS pipe, therefor the pipe size used for this comparison will be 2 NPS which gives a span of 10 ft (120 in) for water. By comparison, the distance between supports is just above the suggested span provided in the ASME standard. The selected pipe supports, have a temperature rating spanning from -30°C to 180°C, making them well-suited for Ohio's range of weather conditions. Designed using a strut channel, pipe clamps can easily be installed to hold the pipe in place and their height adjustability provides the adaptability to different installation requirements.

## V. Energy Losses

**Purpose:**
Determine energy losses of each sub-system of piping between the tanks using software. Complete at least one calculation by hand and compare it to the software results.

**Drawings & Diagrams:**

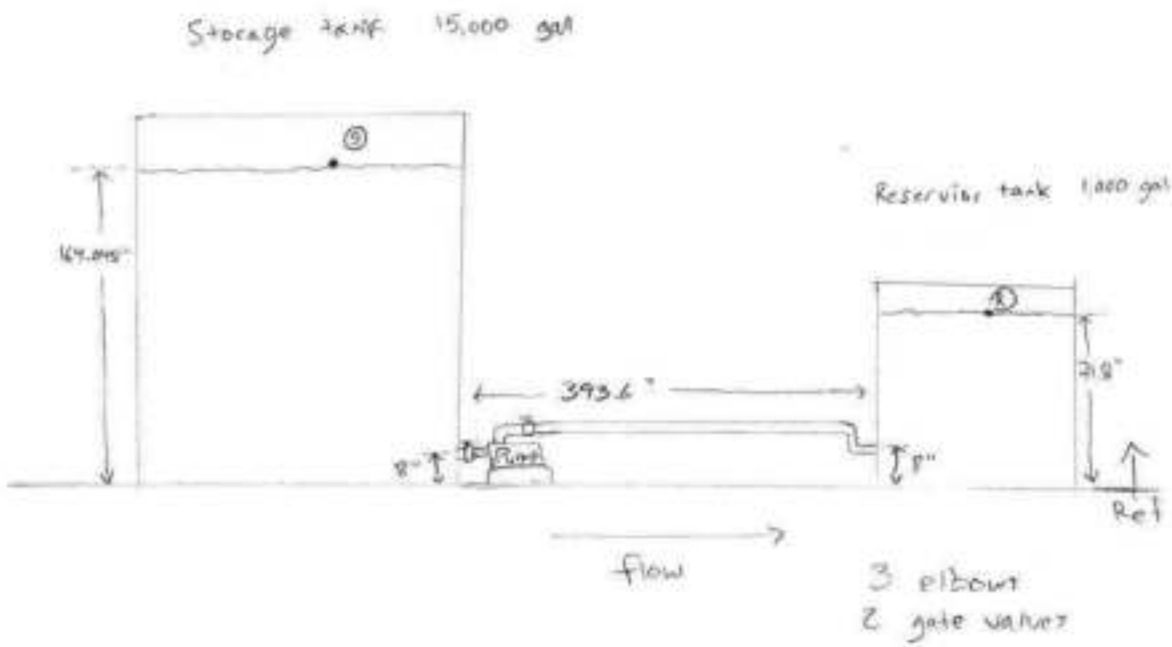


*Figure 5.1 Energy Losses*

**Sources:**
Mott, R. Untener, J.A., "Applied Fluid Mechanics" 7th edition, Pearson Ed. (2015).

**Design Considerations:**
- Incompressible Fluid

**Data and Variables:**

$$L_{X\rightarrow S} = 49.6824m$$
$$V_{X\rightarrow S} = 2.0132\ \frac{m}{s}$$
$$D_{X\rightarrow S} = 0.0409m$$
$$g = 9.81\ \frac{m}{s^2}$$
$$\upsilon = 1.95E-6\ \frac{m^2}{s}$$
$$\epsilon = 4.6E-5\ m$$
$$No.\ of\ elbows\ =\ 1$$
$$K_{elbow} = 30f_T$$
$$K_{gate\,valve} = 8f_T$$
$$K_{inlet} = 0.5$$
$$K_{outlet} = 1$$
$$f_T = 0.02$$

**Procedure:**
Use Bernoulli's equation to find that total energy losses are equal to the pump head. Solve for energy losses due to friction. Solve for minor energy losses in the elbows of the pipes, multiply by the number of

elbows before adding with friction losses to find the total energy losses. Use excel to find the same for the rest.

**Calculations:**

From Railcar to Storage ($X \rightarrow S$ ):

$$h_L = f\frac{L}{D}\frac{V^2}{2g} + K_{elbow}\frac{V^2}{2g} + 2\left(K_{gate\,valve}\frac{V^2}{2g}\right) + K_{inlet}\frac{V^2}{2g} + K_{outlet}\frac{V^2}{2g}$$

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

$$Re = \frac{VD}{\upsilon} = \frac{(2.40132)(0.0409)}{(1.95E-6)} = 50366.15$$

$$f = \frac{0.25}{\left(\log\left(\frac{1}{3.7\left(\frac{0.0409}{4.6E-5}\right)} + \frac{5.74}{50366.15^{0.9}}\right)\right)^2} = \frac{0.25}{(\log(0.000303971 + 0.000336502))^2} = 0.024514$$

$$h_L = \left(\frac{V^2}{2g}\right)\left(f\frac{L}{D} + K_{elbow} + 2K_{gate\,valve} + K_{inlet} + K_{outlet}\right)$$

$$h_L = \left(\frac{2.40132^2}{2(9.81)}\right)\left(0.024514\left(\frac{163}{0.1342}\right) + 30(0.02) + 2\big(8(0.02)\big) + 0.5 + 1\right)$$

$$h_L = (0.293901006)(29.77482861 + 0.6 + 0.32 + 0.5 + 1)$$

$$h_{L_{X\rightarrow S}} = 9.4621\,m$$

Data & Variables in Excel:

| | | | | |
|---|---|---|---|---|
| g | 32.174 | ft/s^2 | 9.81 | m/s^2 |
| Rel. Rough | 0.000046 | m | | |
| Kinematic \ | 1.95E-06 | m^2/s | | |
| | | | | |
| Storage | | | | |
| h_storage | 162.048 | in | 4.116 | m |
| | | | | |
| Reservior | | | | |
| h_res | 71.8 | in | 1.824 | m |
| | | | | |
| Dirty | | | | |
| h_dirty | 151.3 | in | 3.843 | m |
| | | | | |
| Train | | | | |
| h_train | 168 | in | 4.2672 | m |
| | | | | |
| Truck | | | | |
| h_truck | 156 | in | 3.962 | m |

Calculations in Excel:

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Train to Storage (1 1/2 NPS) | | | | | | f | fT | | h_length | h_elbow | h_gate | h_inlet | h_outlet | | h_X1:X27A |
| v | 472.7016 | ft/min | 2.40132 | m/s | | 0.02451356 | 0.02020943 | | 8.75158509 | 0.1781871 | 0.04751657 | 0.1469505 | 0.28802299 | | 9.308579 |
| Q | 50 | gal/min | 0.003155 | m^3/s | | | | | | | | k=0.5 | k=0.98 | | |
| D | 0.1342 | ft | 0.0409 | m | | Contains: | 3 elbows | | | h_total_x-s | | | | | GPM |
| l | 163 | ft | 49.6824 | m | | | 2 gate valves | | | 9.4597788 | | | | | 50 |
| Re | 50366.1477 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| Storage to Reservior (1 1/4 NPS) | | | | | | f | fT | | h_length | h_elbow | h_gate | h_inlet | h_outlet | | h_A |
| v | 428.4889 | ft/min | 2.1767 | m/s | | 0.02584562 | 0.02099485 | | 1.77765578 | 0.152101 | 0.04056028 | 0.12074472 | 0.23665966 | | 19.23529 |
| Q | 33.333 | gal/min | 0.002103 | m^3/s | | | | | | | | k=0.5 | k=0.98 | | |
| D | 0.115 | ft | 0.0351 | m | | Contains: | 3 elbows | | | h_total_s-r | | | | | GPM |
| l | 32.8 | ft | 9.997 | m | | | 2 gate valves | | | 21.527288 | | | | | 33.333 |
| Re | 39180.6 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| Reservior to Dirty (1 1/4 NPS) | | | | | | f | fT | | h_length | h_elbow | h_gate | h_inlet | h_outlet | | h_A |
| v | 428.4889 | ft/min | 2.1767 | m/s | | 0.02584562 | 0.02099485 | | 10.6123756 | 0.152101 | 0.04056028 | 0.12074472 | 0.23665966 | | 13.83041 |
| Q | 33.333 | gal/min | 0.002103 | m^3/s | | | | | | | | k=0.5 | k=0.98 | | |
| D | 0.115 | ft | 0.0351 | m | | Contains: | 5 elbows | | | h_total_r-d | | | | | GPM |
| l | 195.8025 | ft | 59.6808 | m | | | 2 gate valves | | | 11.811406 | | | | | 33.333 |
| Re | 39180.6 | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | |
| Dirty to Truck (1 1/2 NPS) | | | | | | f | fT | | h_length | h_elbow | h_gate | h_inlet | h_outlet | | h_A |
| v | 472.7016 | ft/min | 2.40132 | m/s | | 0.02451356 | 0.02020943 | | 12.3305427 | 0.1781871 | 0.04751657 | 0.1469505 | 0.28802299 | | 13.51411 |
| Q | 50 | gal/min | 0.003155 | m^3/s | | | | | | | | k=0.5 | k=0.98 | | |
| D | 0.1342 | ft | 0.0409 | m | | Contains: | 1 elbow | | | h_total_d-t | | | | | GPM |
| l | 229.6599.9 | ft | 70 | m | | | 2 gate valves | | | 13.395111 | | | | | 50 |
| Re | 50366.1477 | | | | | | | | | | | | | | |

**Summary:**

| | |
|---|---|
| $h_{L(X \to S)}$ | 9.4598 m |
| $h_{L(S \to R)}$ | 21.5273 m |
| $h_{L(R \to D)}$ | 11.8114 m |
| $h_{L(D \to T)}$ | 13.5141 m |

Table 5.1.1 - Energy Losses

**Materials:**
Stainless steel schedule 40 pipes, coolant

**Analysis:**
Energy losses in a system must be calculated to select the proper equipment needed to get a job done. If energy losses were not factored, then the motor in the pump selected for a sub-system would not have the necessary power to push the fluid where it needs to go, as it was only based on how much fluid it must move, rather than that as well as the resistance the fluid would face. Ensure that the pump is not going to cause cavitation between the pump inlet and the impeller by finding the NPSH required and NPSH available and comparing the two.

## VI. Pump Selection

**Purpose:**
Determine how many pumps are needed in the coolant system and calculate the pump head and flow rate for each pump. Use this information to specify the type of pumps needed as well as their flow capacity, head requirements, and power requirements. Using the selected pumps, specify their characteristics, point of operation, size, and weight. Specify the electrical power required for each pump. Determine the NPSH available for this design and demonstrate that the pump has an acceptable NPSH required.

**Drawing:**

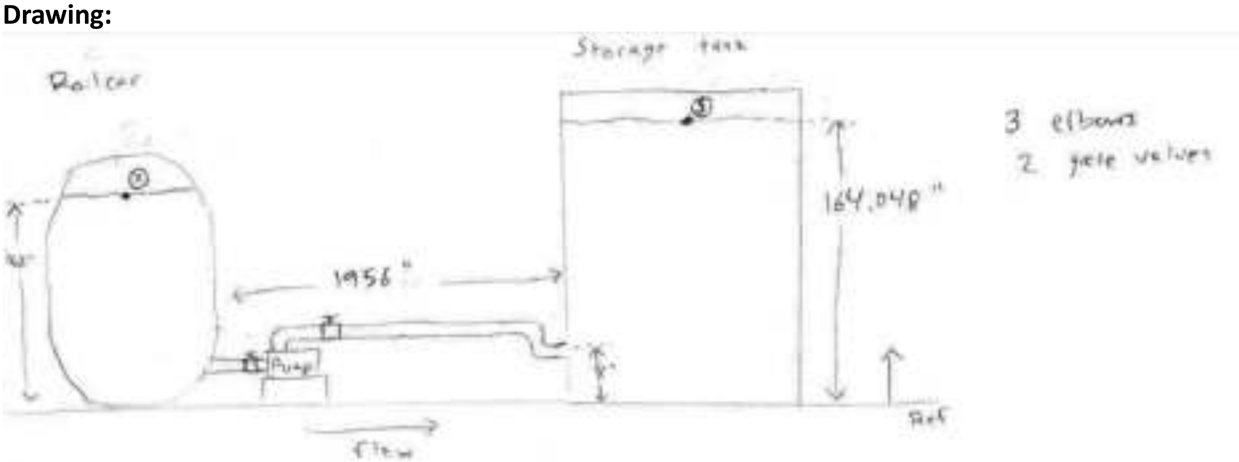


*Figure 6.1 Pump Selection Railcar to Storage*

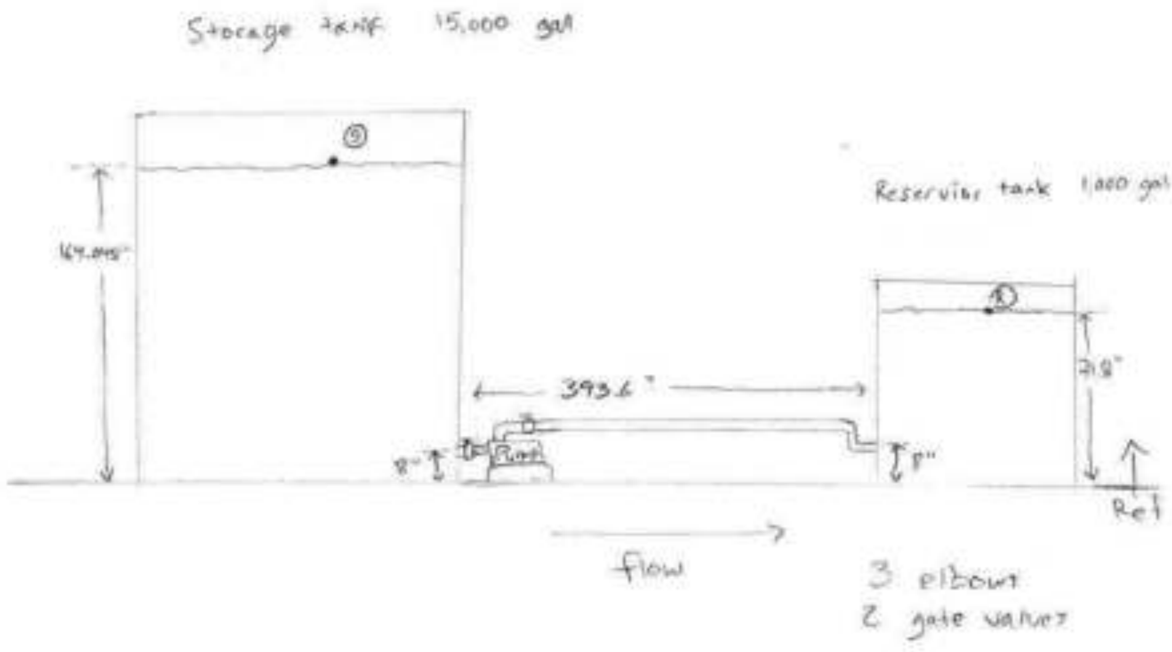


*Figure 6.2 Pump Selection Storage to Reservoir*

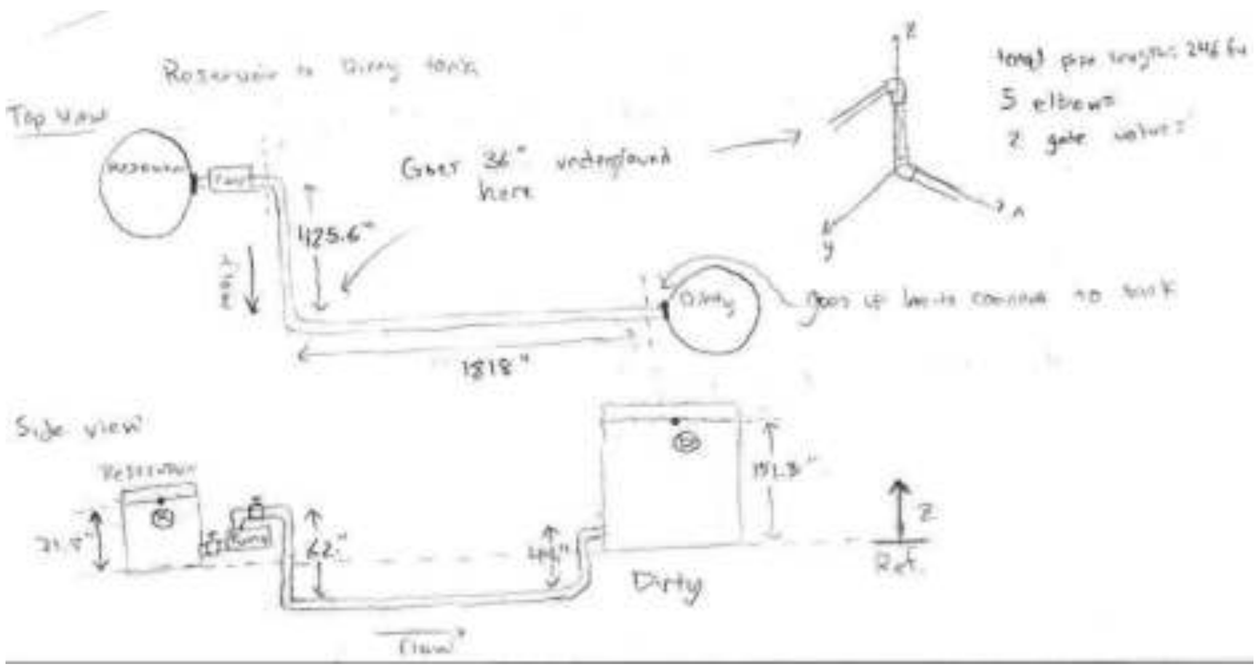


*Figure 6.3 Pump Selection Reservoir to Dirty*

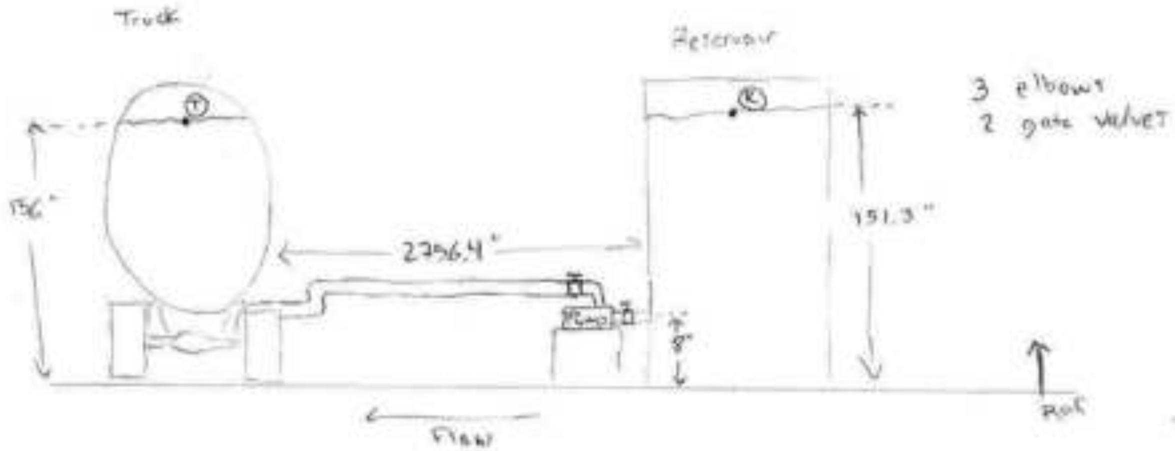


*Figure 6.4 Pump Selection Reservoir to Truck*

**Sources:**

Mott, R. Untener, J.A., "Applied Fluid Mechanics" 7th edition, Pearson Ed. (2015).

*Dayton climate: Temperature Dayton & Weather By Month*. (n.d.). https://en.climate-data.org/north-america/united-states-of-america/ohio/dayton-1663/

*Sulzer Product Manual Series 2.00*. Series 2.00, Sulzer, October 2020.

**Considerations:**

Incompressible fluid
Isothermal fluid

- *Pump Requirements*

*Pump Head calculations and number of pumps*

**Data and Variables:**

$$h_{L_{X-S}} = 9.4598m$$
$$h_{L_{S-R}} = 21.5273m$$
$$h_{L_{R-D}} = 11.8114m$$
$$h_{L_{D-T}} = 13.5141m$$
$$z_X = 4.2672m$$
$$z_S = 4.116m$$
$$z_R = 1.824m$$
$$z_T = 3.962m$$
$$V_{X-S} = 6.684\, {}^{ft^3}\!/_{\min}$$
$$V_{S-R} = 4.452\, {}^{ft^3}\!/_{\min}$$
$$V_{R-D} = 4.452\, {}^{ft^3}\!/_{\min}$$
$$V_{D-T} = 6.684\, {}^{ft^3}\!/_{\min}$$

**Procedure:**

1. The layout of the coolant system was analyzed to determine the number of pumps needed.
2. 4 pumps were decided necessary.
3. The pump head was calculated for each pump using the head loss calculated above and Bernoulli's equation.
4. The velocity of each pump was calculated based off the area of the pipe and the desired flow rate.

**Calculations:**

Pump from railcar to storage tank

Assuming: 163ft pipe between them & Railcar fluid level height of 168"

$$h_{a_{X-S}} + \frac{P_X}{\gamma} + \frac{v_X^2}{2g} + z_X = \frac{P_S}{\gamma} + \frac{v_S^2}{2g} + z_S + h_{L_{X-S}}$$
$$h_{a_{X-S}} = z_S + h_{L_{X-S}} - z_X$$
$$h_{a_{X-S}} = 4.116m + 9.4598m - 4.2672m$$
$$h_{a_{X-S}} = 9.3086m$$

$$v_{X-S} = \frac{6.684\, {}^{ft^3}\!/_{\min}}{0.01414\, ft^2} = 472.702\, {}^{ft}\!/_{\min} = 2.4013\, {}^{m}\!/_{s}$$

Pump from storage tank to reservoir

$$h_{a_{S-R}} = +\frac{P_S}{\gamma} + \frac{v_S^2}{2g} + z_S = \frac{P_R}{\gamma} + \frac{v_R^2}{2g} + z_R + h_{L_{S-R}}$$

$$h_{a_{S-R}} = z_R + h_{L_{S-R}} - z_S$$

$$h_{a_{S-R}} = 1.824m + 21.5273m - 4.116m$$

$$h_{a_{S-R}} = 19.235m$$

$$v_{S-R} = \frac{4.452\, {}^{ft^3}\!/_{\min}}{0.01309\, ft^2} = 428.489\, {}^{ft}\!/_{\min} = 2.1767\, {}^{m}\!/_{s}$$

<u>Pump from reservoir to dirty tank</u>

$$h_{a_{R-D}} + \frac{P_R}{\gamma} + \frac{v_R^2}{2g} + z_R = \frac{P_D}{\gamma} + \frac{v_D^2}{2g} + z_D + h_{L_{R-D}}$$

$$h_{a_{R-D}} = z_D + h_{L_{R-D}} - z_R$$

$$h_{a_{R-D}} = 3.843m + 11.8114m - 1.824m$$

$$h_{a_{R-D}} = 13.830m$$

$$v_{R-D} = \frac{4.452\, {}^{ft^3}\!/_{\min}}{0.01309\, ft^2} = 428.489\, {}^{ft}\!/_{\min} = 2.1767\, {}^{m}\!/_{s}$$

<u>Pump from dirty tank to truck</u>
Assuming: 229.7 ft pipe between them & truck tank fluid level height of 156”

$$h_{a_{D-T}} + \frac{P_D}{\gamma} + \frac{v_D^2}{2g} + z_D = \frac{P_T}{\gamma} + \frac{v_T^2}{2g} + z_T + h_{L_{D-T}}$$

$$h_{a_{D-T}} = z_D + h_{L_{D-T}} - z_T$$

$$h_{a_{D-T}} = 3.843m + 13.395m - 3.962m$$

$$h_{a_{D-T}} = 13.514m$$

$$v_{D-T} = \frac{6.684\, {}^{ft^3}\!/_{\min}}{0.01414\, ft^2} = 472.702\, {}^{ft}\!/_{\min} = 2.4013\, {}^{m}\!/_{s}$$

- *Selection of Pump Type*

**Data and Variables:**

$N_1 = 1775 rpm$

$N_2 = 3520 rpm$

$Q_{X-S} = 50 gpm$

$Q_{S-R} = 33.333 gpm$

$Q_{R-D} = 33.333 gpm$

$Q_{D-T} = 50 gpm$

$h_{a_{X-S}} = 9.309 m$

$h_{a_{S-R}} = 19.235 m$

$h_{a_{R-D}} = 13.830 m$

$h_{a_{D-T}} = 13.514 m$

**Procedure:**

1. Based off the system diagrams, the number of pumps required was discerned.
2. The "Range of Performance" charts in the Sulzer OHH product manual were used to find the correct pump needed for each system by taking the pump head and the GPM of each system and intersecting them with the pump types.
3. The affinity equations were used with each pump to find the Q and hA values of the pumps at 3520 rpm.
4. If the point found was not on one of the pump curves, then the Q valve for each pump was changed in order to give 3 different points on the pump curve chart. These points were joined together to plot the system curve.
5. The spot where the pump curve and the system curve intersect was chosen as the point of operation for each pump.
6. Using this point of operation, a new flow rate and pump head were found.
7. The weight and dimensions of each pump was recorded from the Sulzer pump catalog.

**Calculations:**

Train to Storage

$$\frac{Q_{1775}}{Q_{3520}} = \frac{N_1}{N_2}$$

$$Q_{3520} = {50 gpm}/{\tfrac{1775}{3520}} = 99.15 gpm$$

$$\frac{h_{a,1775}}{h_{a,3520}} = \left(\frac{N_1}{N_2}\right)^2$$

$$h_{a,3520} = {9.89327 m}/{\left(1775/3520\right)^2} = 38.907 m$$

Storage to Reservoir

$$\frac{Q_{1775}}{Q_{3520}} = \frac{N_1}{N_2}$$

$$Q_{3520} = {33.333gpm}\Big/{\tfrac{1775}{3520}} = 66.103gpm$$

$$\frac{h_{a,1775}}{h_{a,3520}} = \left(\frac{N_1}{N_2}\right)^2$$

$$h_{a,3520} = {19.3627m}\Big/{\left(1775/3520\right)^2} = 76.147m$$

Reservoir to Dirty

$$\frac{Q_{1775}}{Q_{3520}} = \frac{N_1}{N_2}$$

$$Q_{3520} = {33.333gpm}\Big/{\tfrac{1775}{3520}} = 66.103gpm$$

$$\frac{h_{a,1775}}{h_{a,3520}} = \left(\frac{N_1}{N_2}\right)^2$$

$$h_{a,3520} = {14.0852m}\Big/{\left(1775/3520\right)^2} = 55.3926m$$

Dirty to Truck

$$\frac{Q_{1775}}{Q_{3520}} = \frac{N_1}{N_2}$$

$$Q_{3520} = {50gpm}\Big/{\tfrac{1775}{3520}} = 99.15gpm$$

$$\frac{h_{a,1775}}{h_{a,3520}} = \left(\frac{N_1}{N_2}\right)^2$$

$$h_{a,3520} = {13.7424m}\Big/{\left(1775/3520\right)^2} = 54.044m$$

- *Pump Curves and System Curves with Operating Point*

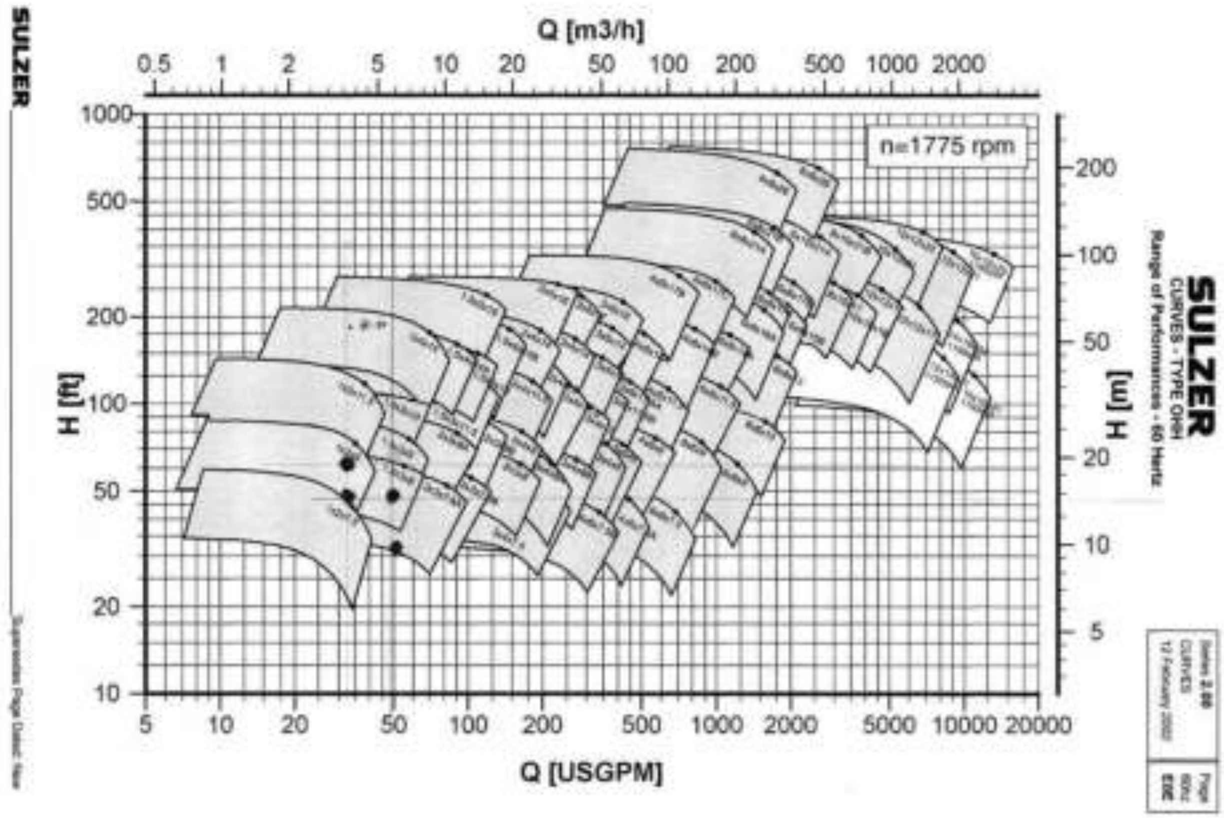


*Figure 6.5 Pump Curves*

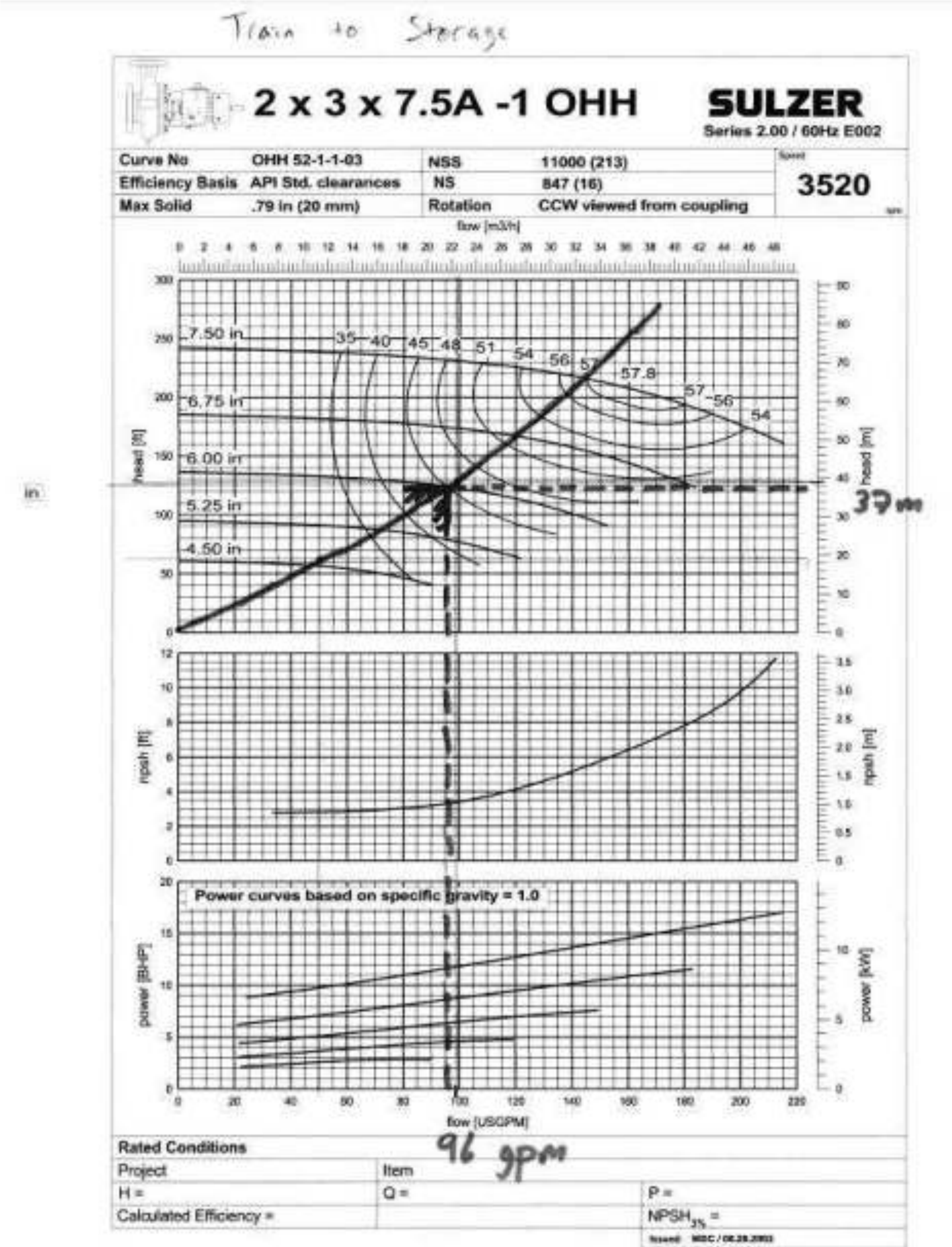


*Figure 6.6 Pump Curves Train to Storage*

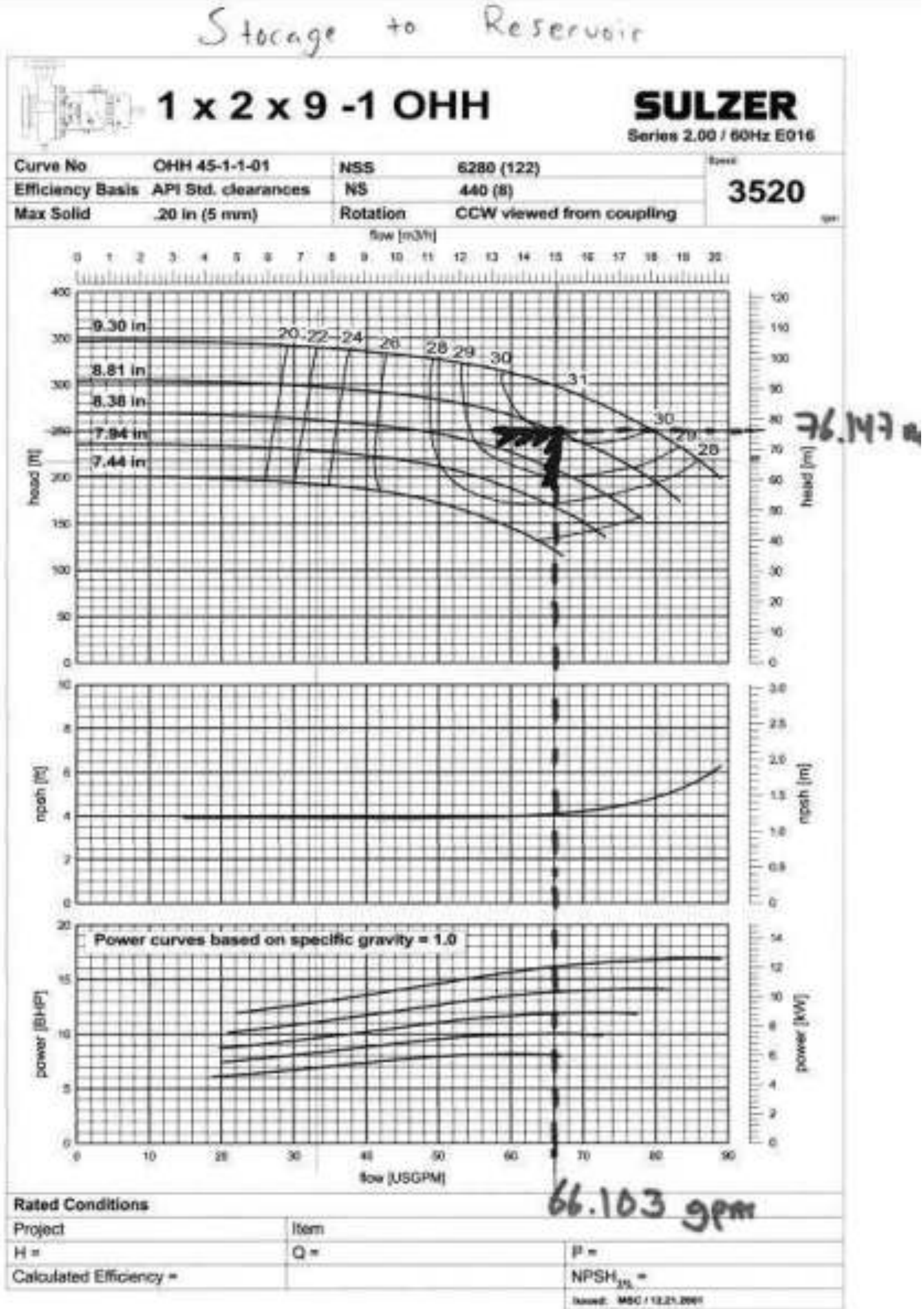


*Figure 6.7 Pump Curves Storage to Reservoir*

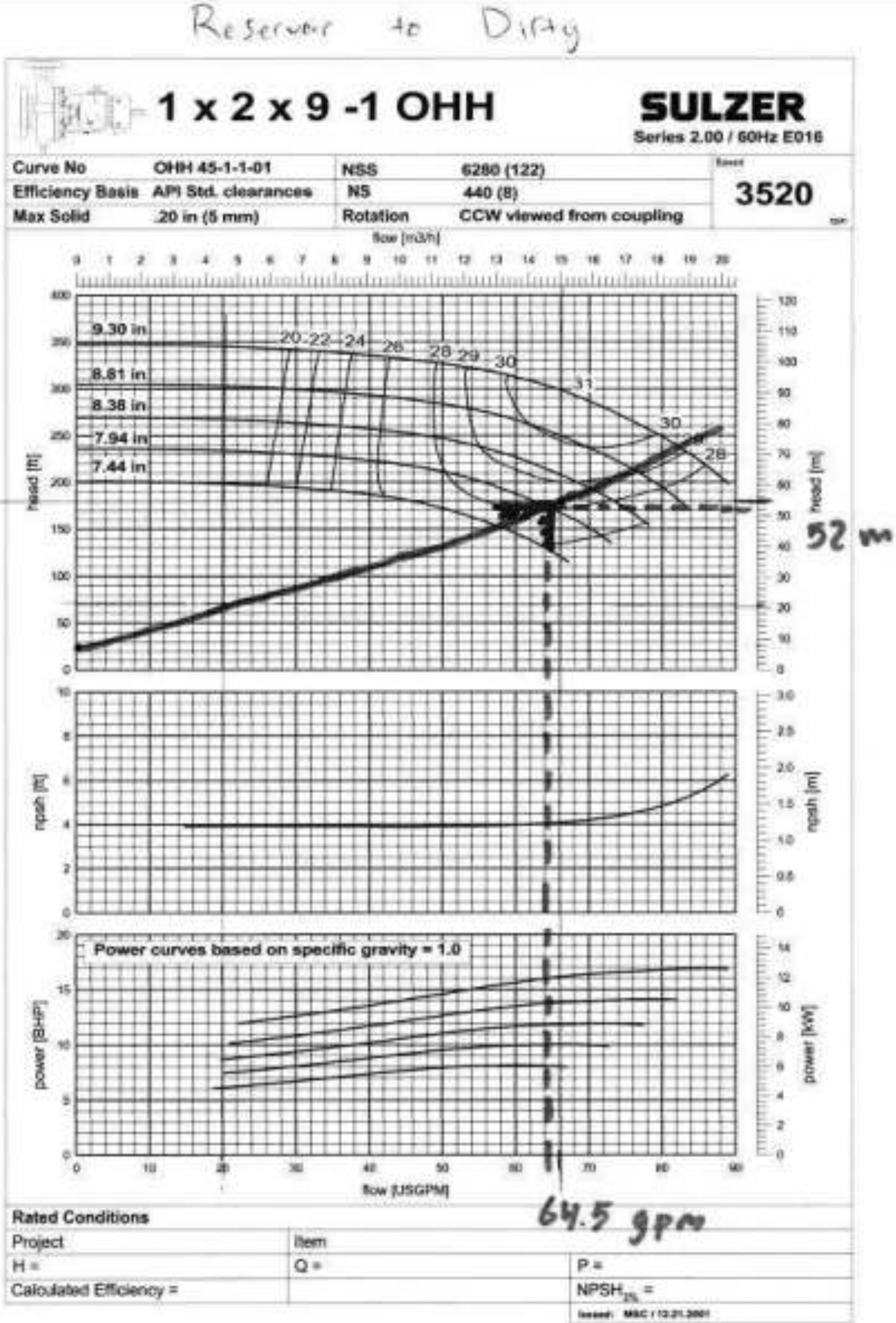


*Figure 6.8 Pump Curves Reservoir to Dirty*

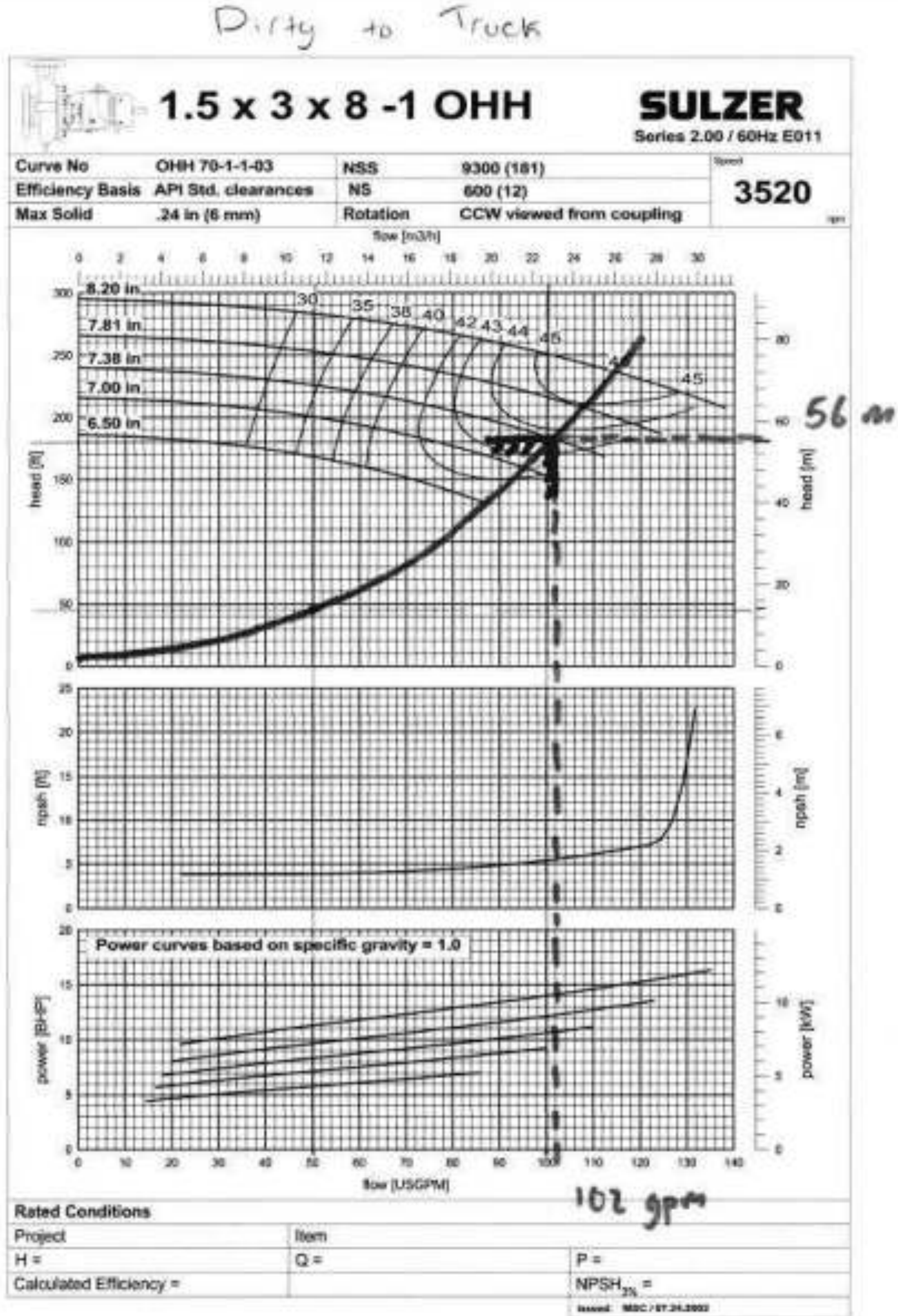


*Figure 6.9 Pump Curves Dirty to Truck*

*Type of Kinetic pump selection*

**Diagram**

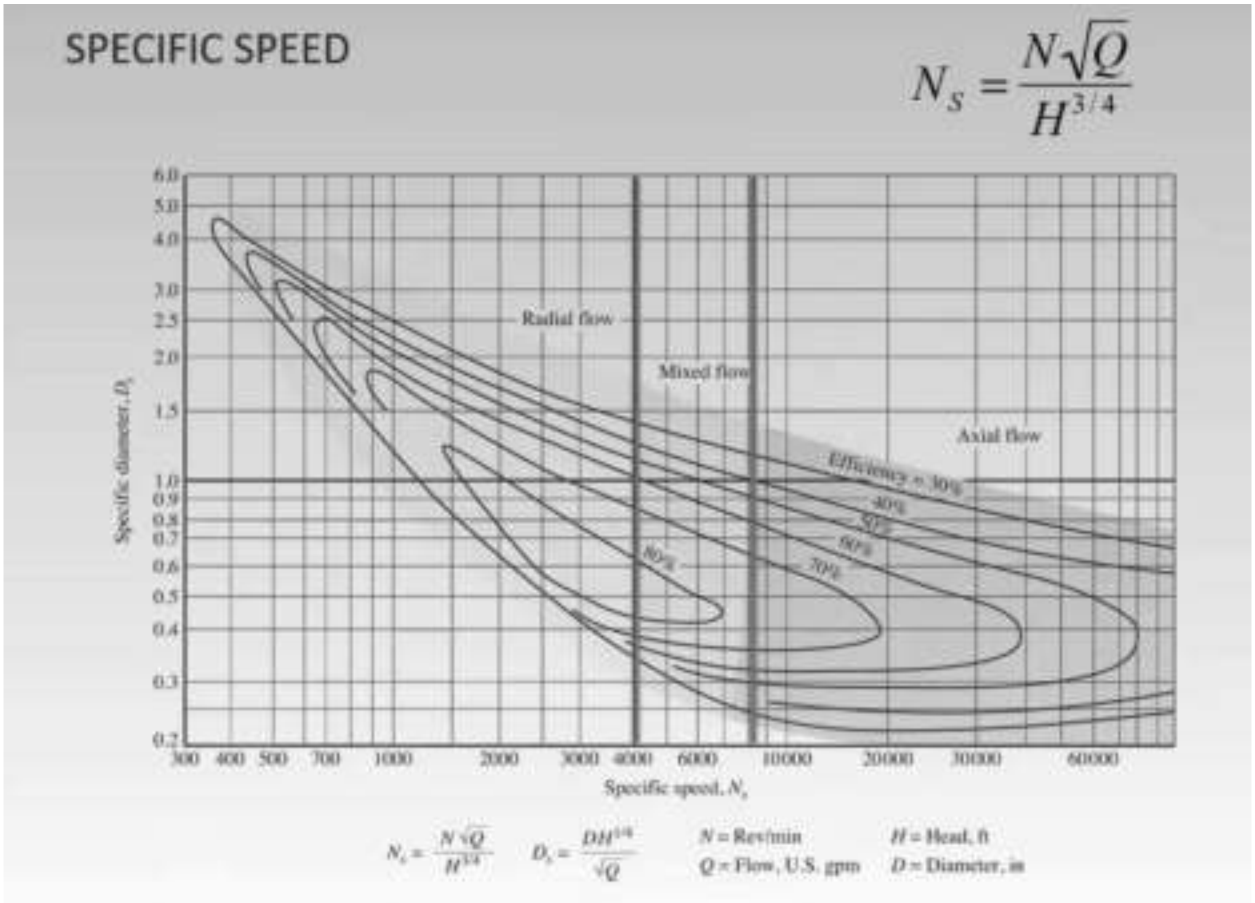


*Figure 6.10 Kinetic Pump Selection*

**Procedure**

1. To decide which type of kinetic pump is needed, the specific speed equation was used.
2. The RPM, flow rate, and pump head of each pump was inputted into the equation.
3. The value from the specific speed equation was compared against the specific speed chart, determining which type of kinetic pump is needed.
4. The chosen kinetic pump for each system was inputted in the summary table.

**Calculations**

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

$$N_{s_{X-S}} = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1775rpm\sqrt{50gpm}}{30.541ft^{3/4}} = 966.1$$

$$N_{s_{S-R}} = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1775rpm\sqrt{33.333gpm}}{19.235ft^{3/4}} = 1115.7$$

$$N_{s_{R-D}} = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1775rpm\sqrt{33.333gpm}}{13.830ft^{3/4}} = 1429.0$$

$$N_{s_{D-T}} = \frac{N\sqrt{Q}}{H^{3/4}} = \frac{1775rpm\sqrt{50gpm}}{13.514ft^{3/4}} = 1780.7$$

- *Cavitation*

**Drawings & Diagrams:**

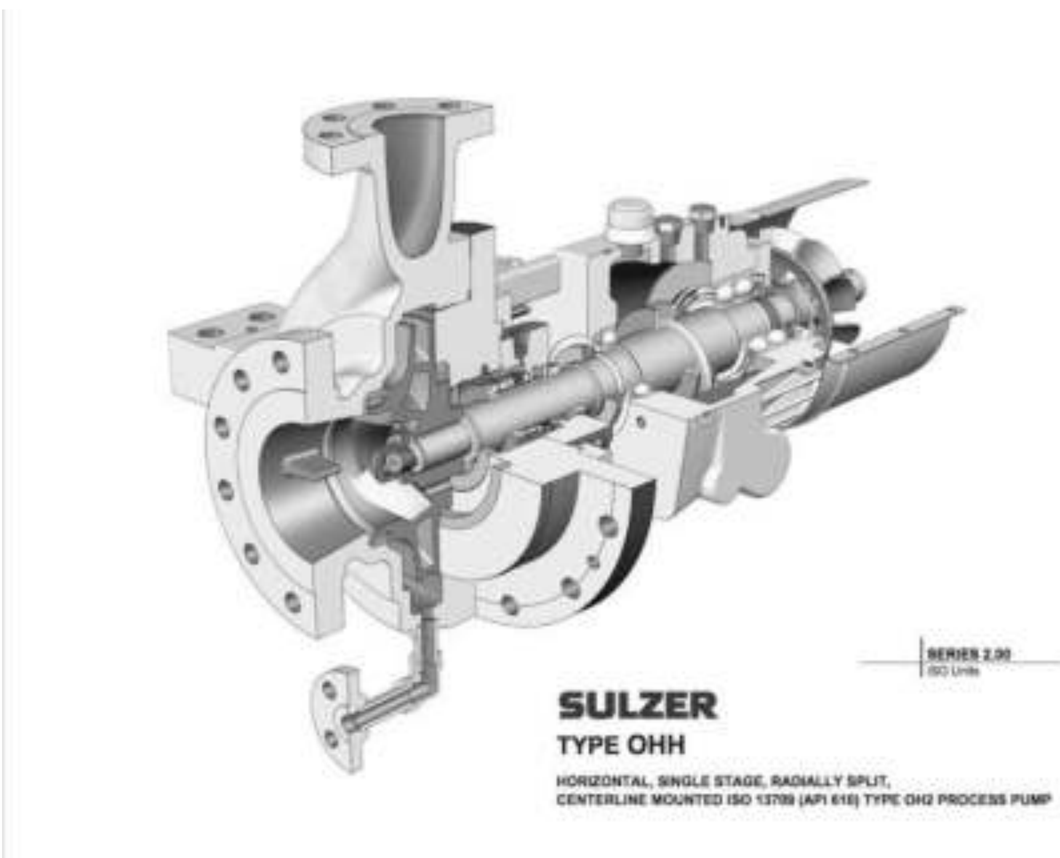


*Figure 6.11 Sulzer Pump*

**Design Considerations:**
T= 50 degrees F = 10 degrees C
Incompressible Fluid

**Data & Variables:**
Q1 = 50 GPM
Q2 = 33.33 GPM
Q3 = 33.33 GPM
Q4 = 50 GPM
h_L(1) = 0.9011 m = 2.9564 ft
h_L(2) = 6.4824 m = 21.2677 ft
h_L(3) = 0.6947 m = 2.2792 ft
h_L(4) = 0.7229 m = 2.3717 ft

$$\Delta z_1 = 4.064\ ft$$
$$\Delta z_2 = 3.9128\ ft$$
$$\Delta z_3 = 1.6208\ ft$$
$$\Delta z_4 = 3.6398\ ft$$

Psat head=0.4109 ft

**Calculations:**
Required NPSH pulled from pump graphs:

NPSHreq(1)=3.25 ft
NPSHreq(2)=4.1 ft
NPSHreq(3)=4 ft
NPSHreq(4)=5.5 ft

Available NPSH calculated using Bernoulli's:
NPSHavail(1):

$$\frac{P_{suct}}{\gamma} - \frac{P_{sat}}{\gamma} = \Delta z + \frac{P_1}{\gamma} + h_L - \frac{P_{sat}}{\gamma}$$

$$NPSH_{avail(1)} = \Delta z + 0 + h_L - \frac{P_{sat}}{\gamma}$$

$$NPSH_{avail(1)} = 4.064 + 0.9011 - 0.4109 = 4.5542\ ft$$

$$NPSH_{avail(1)} > NPSH_{req(1)}\ \therefore\ system\ 1\ is\ safe\ from\ cavitation$$

NPSHavail(2):

$$NPSH_{avail(2)} = \Delta z + 0 + h_L - \frac{P_{sat}}{\gamma}$$

$$NPSH_{avail(2)} = 3.9128 + 21.2677 - 0.4109 = 24.7696\ ft$$

$$NPSH_{avail(2)} > NPSH_{req(2)} \;\therefore\; system\ 2\ is\ safe\ from\ cavitation$$

NPSHavail(3):

$$NPSH_{avail(3)} = \Delta z + 0 + h_L - \frac{P_{sat}}{\gamma}$$

$$NPSH_{avail(3)} = 1.6208 + 0.6947 - 0.4109 = 1.9046\ ft$$

$$NPSH_{avail(3)} < NPSH_{req(3)} \;\therefore\; system\ 3\ is\ subject\ to\ cavitation$$

NPSHavail(4):

$$NPSH_{avail(4)} = \Delta z + 0 + h_L - \frac{P_{sat}}{\gamma}$$

$$NPSH_{avail(4)} = 3.6398 + 2.3717 - 0.4109 = 5.6006\ ft$$

$$NPSH_{avail(4)} > NPSH_{req(4)} \;\therefore\; system\ 4\ is\ safe\ from\ cavitation$$

- *Summary of Selected Pumps*

**Purpose:**

Determine electrical motor requirements for pumps.

**Calculations:**

<u>Railcar to Storage Tank</u>

$Q = 50\ gpm$

$\gamma = 58.69\ lb/ft^3$

$h_A = 31.69\ ft$

$\eta = .83$

$$P = \frac{\gamma Q h_a}{3960\eta}$$

$$P = \frac{(58.69)(50)(31.69)}{(3960)(.83)}$$

$P = 28.29 hp$

Storage Tank to Reservoir

$Q = 33.33\ gpm$

$\gamma = 58.69\ lb/ft^3$

$h_A = 63.12\ ft$

$\eta = .83$

$$P = \frac{\gamma Q h_a}{3960\eta}$$

$$P = \frac{(58.69)(33.33)(63.12)}{(3960)(.83)}$$

$P = 37.57hp$

Reservoir to Dirty

$Q = 33.33\ gpm$

$\gamma = 58.69\ lb/ft^3$

$h_A = 45.37\ ft$

$\eta = .83$

$$P = \frac{\gamma Q h_a}{3960\eta}$$

$$P = \frac{(58.69)(33.33)(45.37)}{(3960)(.83)}$$

$P = 27hp$

Dirty to Truck

$Q = 50\ gpm$

$\gamma = 58.69\ lb/ft^3$

$h_A = 44.32\ ft$

$\eta = .83$

$$P = \frac{\gamma Q h_a}{3960\eta}$$

$$P = \frac{(58.69)(50)(44.32)}{(3960)(.83)}$$

$P = 39.6hp$

**Summary:**
Total Number of Pumps: 4

| Pump Location | Pump Head (m) | Velocity (m/s) |
|---|---|---|
| Railcar to Storage | 9.309 | 2.4013 |
| Storage to Reservoir | 19.235 | 2.1767 |
| Reservoir to Dirty tank | 13.830 | 2.1767 |
| Dirty tank to truck | 13.514 | 2.4013 |

Table 6.1.2 Pump Requirements

| Location | Selected pump | Pump RPM | Type of Pump | Flow Capacity | Head Requirement |
|---|---|---|---|---|---|
| Train to Storage | 2x3x7.5A | 1775 | Kinetic Radial | 48 | 9.41 |
| Storage to Reservoir | 1x2x9 | 1775 | Kinetic Radial | 33.333 | 19.36 |
| Reservoir to Dirty | 1x2x9 | 1775 | Kinetic Radial | 32.25 | 13.22 |
| Dirty to Truck | 1.5x3x8 | 1775 | Kinetic Radial | 51 | 14.24 |

Table 6.1.3 Selection of Pump Type

| Location | Selected pump | Pump Power (hp) | Impeller size (in) | Weight (lbs) |
|---|---|---|---|---|
| Train to Storage | 2x3x7.5A | 28.29 | 6.00 | 332 |
| Storage to Reservoir | 1x2x9 | 37.57 | 8.81 | 320 |
| Reservoir to Dirty | 1x2x9 | 27 | 7.94 | 320 |
| Dirty to Truck | 1.5x3x8 | 39.6 | 7.38 | 336 |

Table 6.1.4 Pump Motor Requirements

| Characteristics and Dimensions of Pumps | | | |
|---|---|---|---|
| | **2x3x7.5A** | **1x2x9** | **1.5x3x8** |
| **Size of Casing Drain Construction NPT** | 0.75 | 0.75 | 0.75 |
| **Bearing Housing No.** | 3 | 3 | 3 |
| **Shaft Dia. between bearings (in)** | 2.56 | 2.56 | 2.56 |
| **Span between bearings (in)** | 7.34 | 7.34 | 7.34 |
| **Span CL Rad Brg to CL Imp (in)** | 10.28 | 10.16 | 10.51 |
| **Shaft Dia. at Seal Chamber (in)** | 1.89 | 1.89 | 1.89 |
| **Shaft Dia. at coupling (in)** | 1.26 | 1.26 | 1.26 |
| **Typical API Baseplate #** | 1.5 | 1.5 | 1.5 |
| **Radial Bearing Number** | 6310 | 6310 | 6310 |

| | | | |
|---|---|---|---|
| **Thrust Bearing Number** | 7311 | 7311 | 7311 |
| **Typical API Baseplate weight (lb)** | 802 | 802 | 802 |
| **Wear Ring Diameter - Eye (in)** | 4.53 | 4.13 | 4.13 |
| **Wear Ring Diameter - Hub (in)** | 4.53 | 4.13 | 4.13 |
| **Clearance Below 500°F - Eye (in)** | 0.016 | 0.015 | 0.015 |
| **Clearance Below 500°F - Hub (in)** | 0.016 (8) | 0.015 (8) | 0.015 (8) |
| **Mass Moment of Inertia (lb-ft2) WR2** | 0.52 | 0.89 | 0.63 |
| **Shaft Stiffness Factor L3/D4** | 85 | 82 | 91 |
| **Critical Speed (Dry) (cpm)** | 10557 | 9806 | 9685 |

Table 6.1.5 Characteristics and Dimensions of Pumps

| **Cavitation** | | |
|---|---|---|
| **System** | **NPSHavail (ft)** | **NPSHreq (ft)** |
| **1 (X-S)** | 4.5542 | 3.25 |
| **2 (S-R)** | 24.7696 | 4.1 |
| **3 (R-D)** | 1.9046 | 4 |
| **4 (D-T)** | 5.6006 | 5.5 |

Table 6.1.6 Cavitation

**Materials:**

392.7 ft – 1.5” NPS Stainless Steel pipe 304
228.6 ft – 1.25” NPS Stainless Steel pipe 304
6 – 1.5” NPS stainless steel pipe elbows 316
8 – 1.25” NPS Stainless Steel pipe elbows 316
(1) 2x3x7.5A Kinetic Radial Pump
(2) 1x2x9 Kinetic Radial pump
(1) 1.5x3x8 Kinetic Radial pump

**Analysis:**

There are a total of 4 pumps in the coolant system. Each pump is placed on a cement block 8” above the ground. The first pump brings fluid from the train car to the storage tank. The pump head required for this system is 9.309m and the velocity of the fluid is 2.4013 m/s. The next pump in the system brings the fluid from the storage tank to the reservoir. The pump head of this section is 19.235 and the velocity is 2.1767 m/s. This is the shortest pipe length in our system and unfortunately, we didn’t realize this was going to be a problem during pump selection until it was too late to change our layout. To finish the project and provide a working system for the client, the gate valve right after the pump is only open ¼ of the way. Wize this is horrible engineering and if we had realized that such a short pipe would create an issue when choosing a pump, we would have redesigned the system so this wasn’t an issue. Unfortunately, we didn’t understand this until there were only a few days left until the project’s due date. The next pump in this coolant system is between the reservoir and the dirty tank. The pump head in this system is 13.830m and the velocity is 2.1767 m/s. The last pump in the system brings the coolant from the dirty tank to the truck that picks up the dirty fluid once a month. The pump head in this system is 13.514m and the velocity is 2.4013 m/s. The highest pump head in the entire coolant system is between the storage and reservoir. This is due to the energy losses caused by closing the gate valve. In all the other systems, the pump head is mostly caused by the length of the pipes.

The pump between the train and the storage tank is a 2x3x7.5A Kinetic Radial Pump. The power requirement for this pump is 28.29 HP. The pump between the storage tank and the reservoir is a 1x2x9 Kinetic Radial pump. The power requirement for this pump is 37.57 HP. The pump between the reservoir tank and the dirty tank is a 1x2x9 Kinetic Radial pump. The power requirement for this pump is 27 HP. And the pump between the dirty tank and the truck is a 1.5x3x8 Kinetic Radial pump. The power requirement for this pump is 39.6 HP. A kinetic pump was chosen over a positive displacement pump for a few reasons. First is that the fluid we are dealing with is not very viscous, therefore a positive displacement pump is not necessary. Second it that kinetic pumps are cheaper which will be a benefit to the client. Third is that a kinetic pump allows for the control of Q. Although we are dealing with a constant flow rate in this system, having a pump that gives you the ability to control Q if you want to which could be an advantage to the client. Out of the 3 types of Kinetic pumps, radial pumps were chosen based off the specific speed equation and chart. This is proven because all 4 pumps are inside the radial pump area on the chart. After doing cavitation calculations, all systems are safe from cavitation except for system 3 (Reservoir to Dirty). System 3 is subject to damage and should be monitored for cavitation and cavitation-related issues.

## VII. Instrumental Selection

**Purpose:** Select a flow measurement tool to pair with a manometer, select an appropriate manometer scale range as well as an indicating fluid, and specify the dimensions of the measurement tool for a single system.

**Drawings & Diagrams:**

<u>Railcar to Storage:</u>

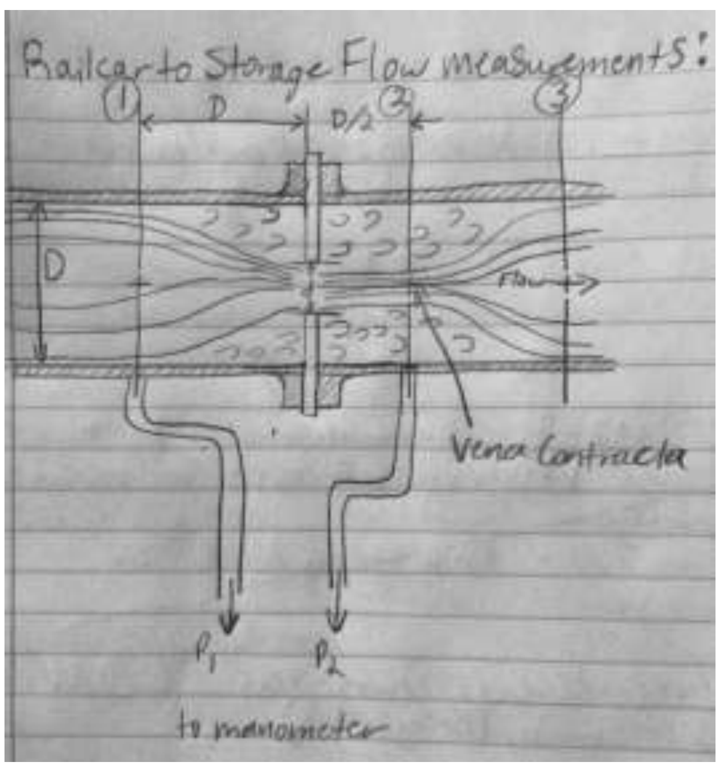

*Figure 7.1 Instrumentation Selection*

**Sources:**

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

**Design Considerations:**

T= 50 degrees F = 10 degrees C
Incompressible Fluid

**Data & Variables:**

Q range = 34GPM-63 GPM = 4.54514 GPM – 8.42188 GPM
Range of Manometer: 0-12 in.= 0-1 ft
A_1 = 0.01414 ft^2
D = 0.1342 ft
V = 7.8784 ft/s
v = 1.4*10^-5 ft^2/s
C(assumed)=0.6

**Procedure:**

Use the equation for an orifice plate flow meter and apply it to the flow rate, assume C, and check later, iterating until the change in values is negligible. Find the diameter of the orifice and use it to find the range of pressures measured.

- *Flow Rate*

*The range of flow rate values for this section was determined arbitrarily and each extreme was calculated about 37% away from the expected flow rate (50 GPM) in both directions, modeled after practice problems done in class.

- *Pressure*

**Calculations:**

<u>Railcar to Storage:</u>

$$Q = A_1 C \sqrt{\frac{2gh\left(\frac{\gamma_m}{\gamma_w} - 1\right)}{\left(\frac{A_1}{A_2}\right) - 1}}$$

$$A_2 = \frac{A_1}{\sqrt{\frac{2gh\left(\frac{\gamma_m}{\gamma_w} - 1\right)}{\left(\frac{Q}{A_1 C}\right)^2} + 1}}$$

*We assume C=0.6, and iterate

$$A_2 = \frac{0.01414}{\sqrt{\frac{2 \cdot 32.2 \cdot 1\left(\frac{844.9}{62.4} - 1\right)}{\left(\frac{8.82292}{(0.01414)(0.6)}\right)^2} + 1}} = 0.01413\ ft^2$$

$$d = 2\sqrt{\frac{0.01413}{\pi}} = 0.1341\ ft$$

$$Re = \frac{VD}{\upsilon} = \frac{(7.8784)(0.1342)}{1.4E-5} = 7.55E04$$

$$\frac{d}{D} = 0.999 \rightarrow C \approx 0.625$$

*Our new C value is less than a 5% difference from the old one. It is acceptable.

$$h = \frac{\left(\frac{Q}{A_1 C}\right)^2 + \left[\left(\frac{A_1}{A_2}\right)^2 - 1\right]}{2g\left(\frac{\gamma_m}{\gamma_w} - 1\right)}$$

*We plug in our lowest flow rate value to find the lowest pressure value.

$$h = \frac{\left(\frac{4.54514}{(0.01414)(0.625)}\right)^2 + \left[\left(\frac{0.01414}{0.01413}\right)^2 - 1\right]}{2(32.2)\left(\frac{844.9}{62.4} - 1\right)} = \frac{(2.64506.0904)(0.001415929)}{807.5801282} = 0.463758131\ ft$$
$$= 5.5651\ in.$$

**Summary:**

| | |
|---|---|
| **Type of Flow Meter** | Orifice Plate |
| **A_2** | 0.01413 ft^2 |
| **Pressure Range** | 5.5651in-12in. Of mercury |

Table 7.1.1 Instrumentation Selection

**Materials:**
Mercury U-tube manometer (12in.)
Sch. 40 Stainless Steel Pipe
Orifice plate

**Analysis:** It is important to notice the minimal difference between A_1 and A_2. We infer this is because the pipe is already small and the flow rate is relatively low. A dramatic change in pressure does not need to be facilitated to read it accurately.

# 4. Final Drawings

## a. Plot Plan

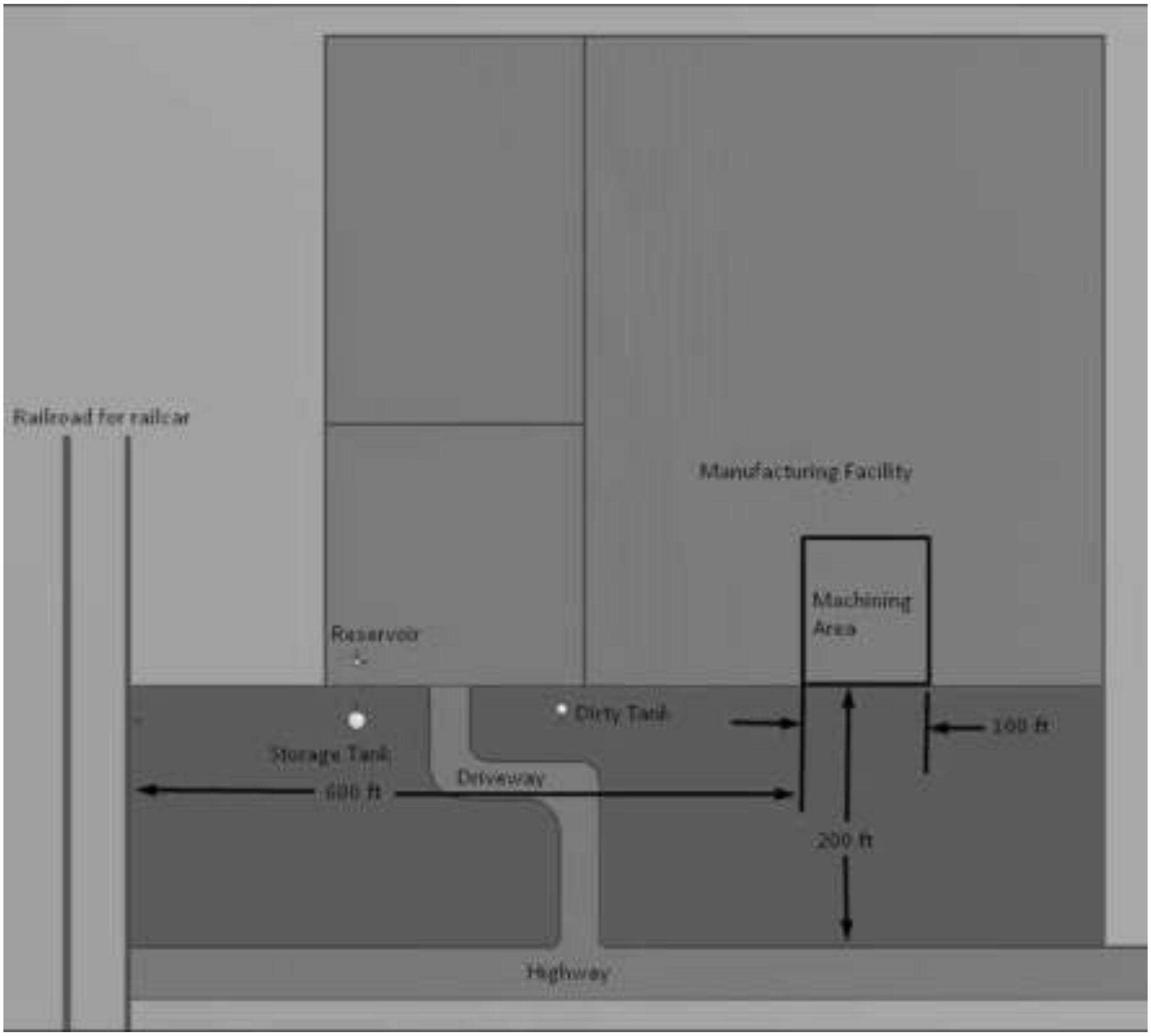


*Figure 8.1 Final Plot Plan*

*Figure 8.2 Final Piping Layout*

## b. Elevations View

*Figure 8.3 Final Front Elevation*

*Figure 8.4 Final Side Elevation*

## c. Isometric View

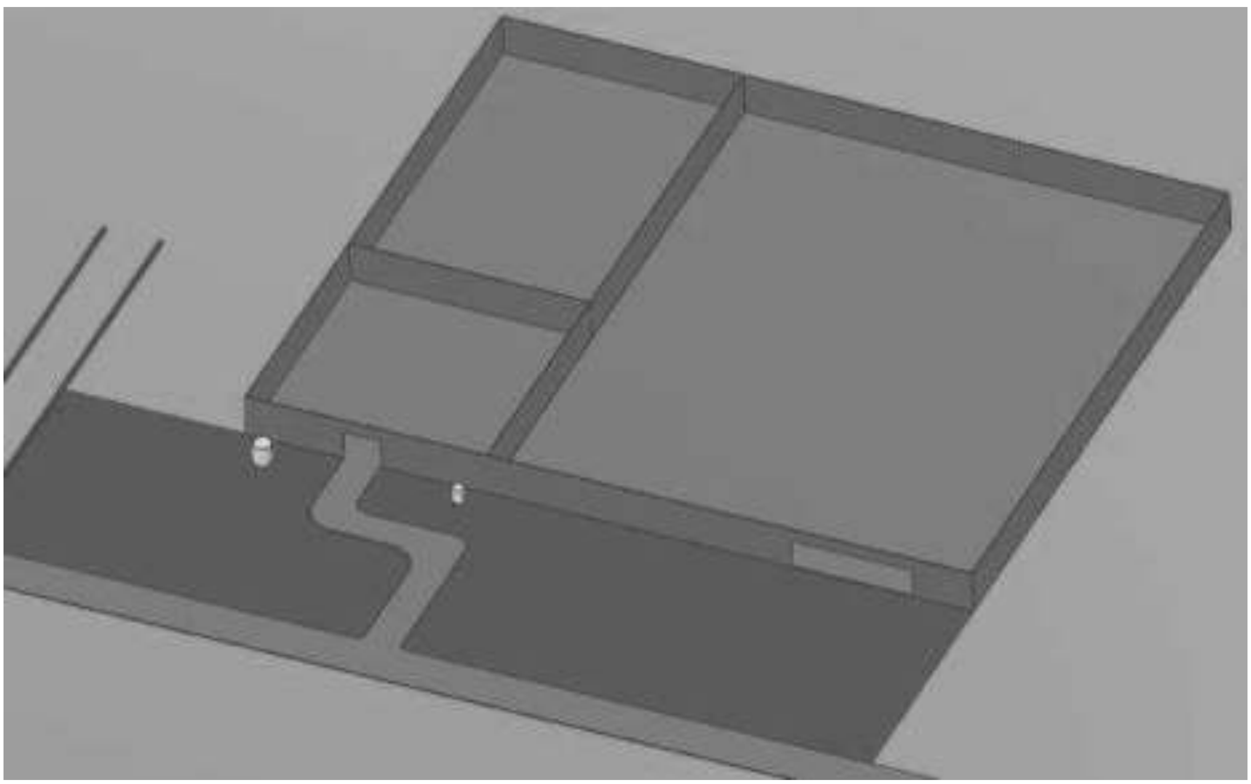

*Figure 8.5 Isometric View*

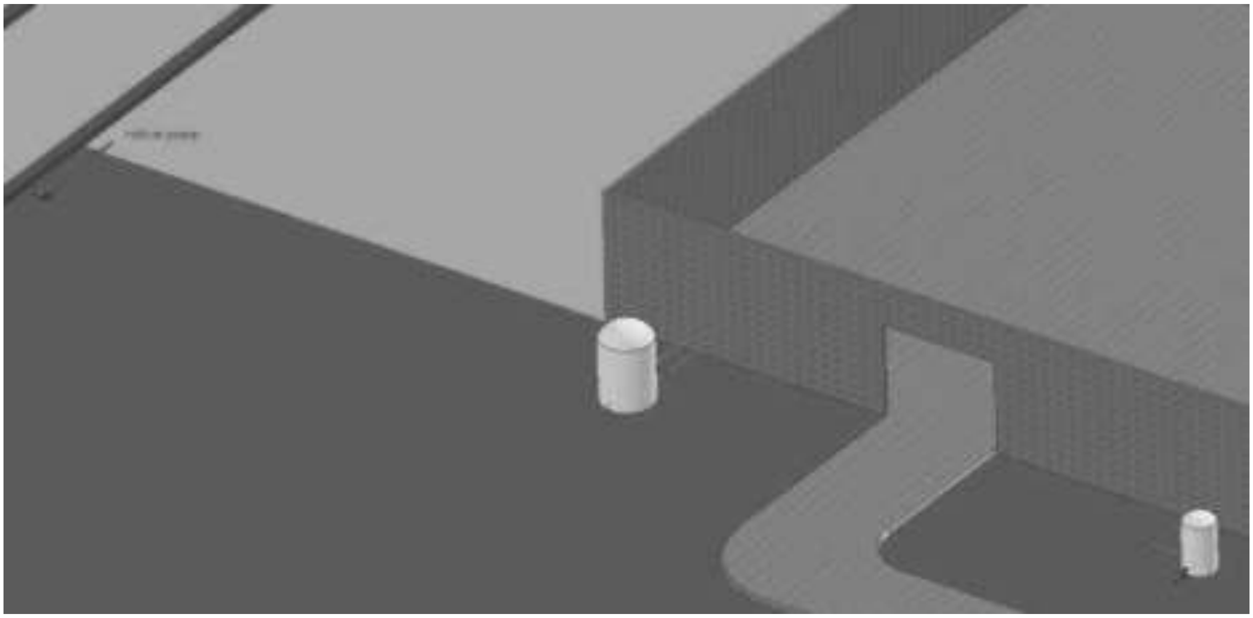

*Figure 8.6 Isometric View 2*

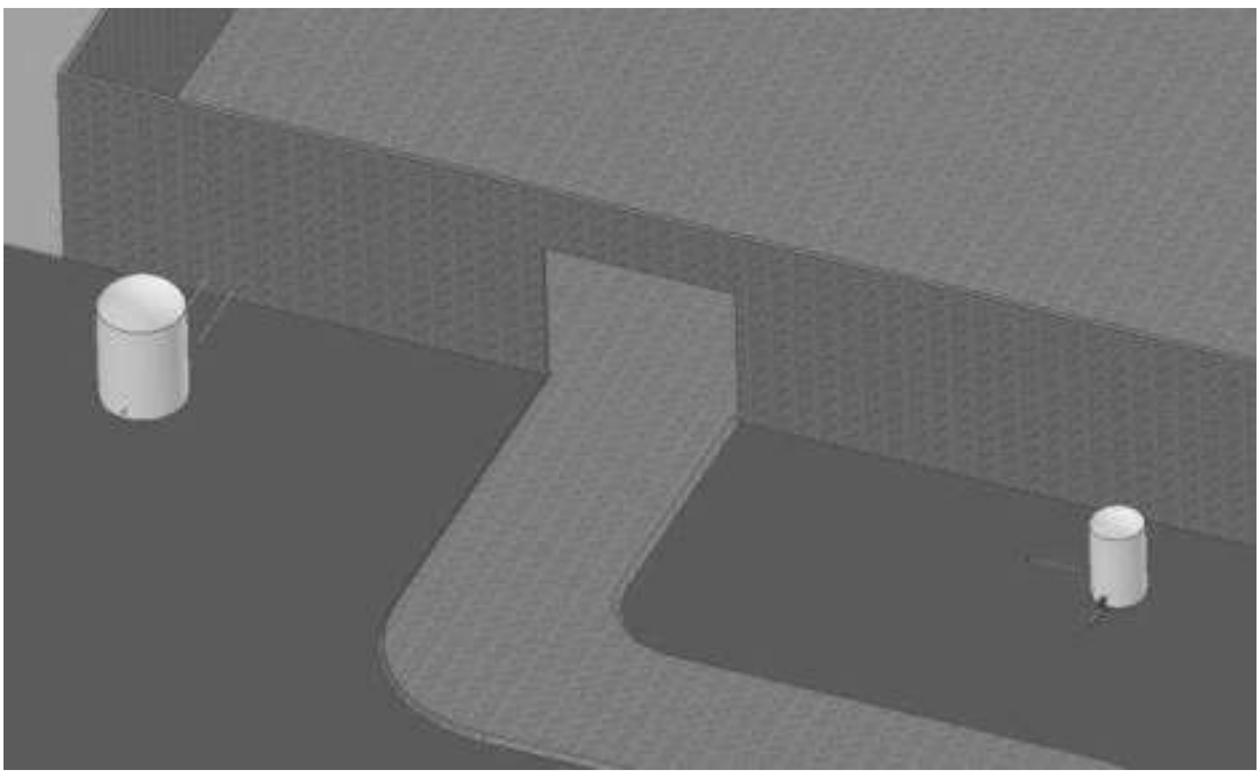

*Figure 8.7 Isometric View Storage Tank and Dirty Tank*

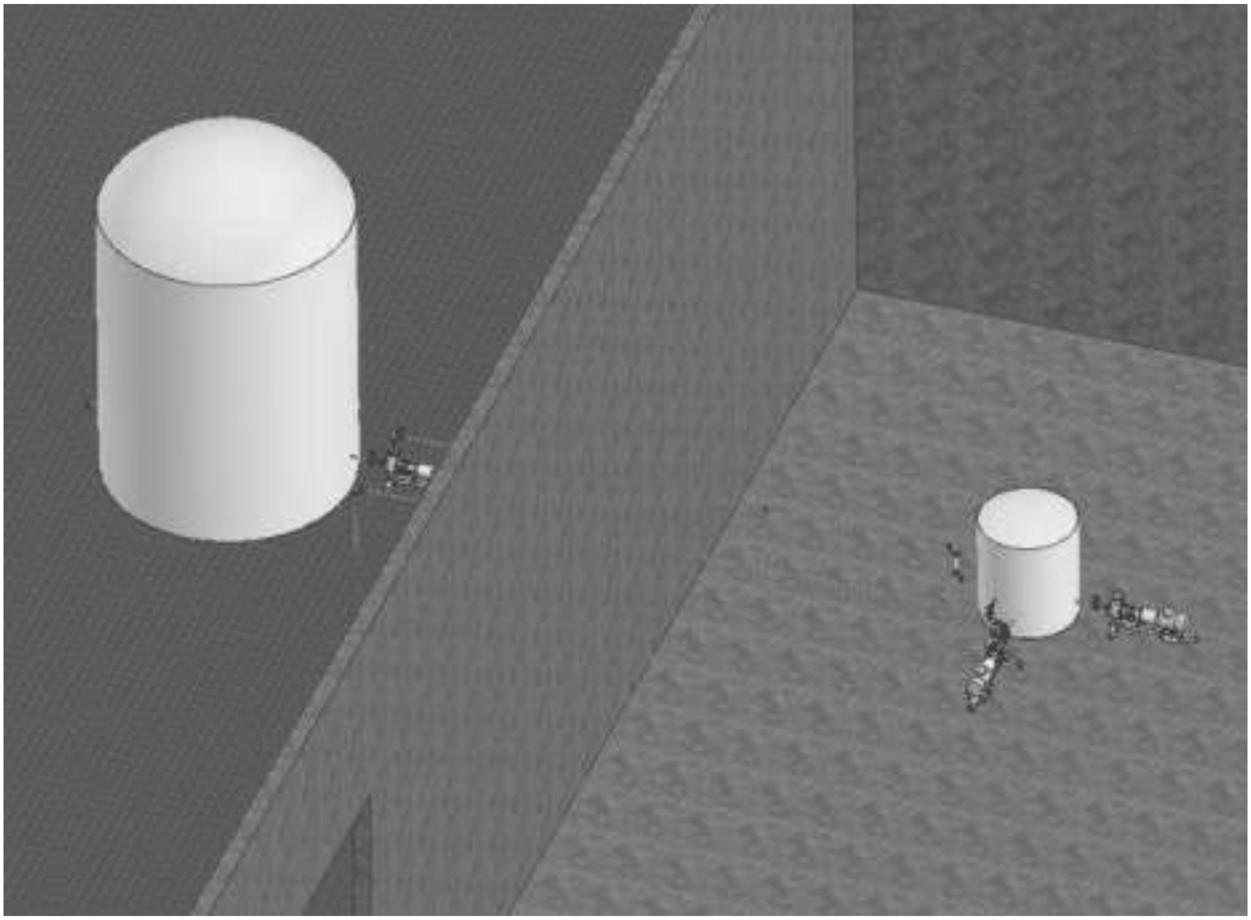
*Figure 8.8 Isometric View Storage Tank and Reservoir*

## 5. Bill of Materials and Equipment List

| QTY | PART NUMBER | DESCRIPTION | MATERIAL |
|---|---|---|---|
| 1 | - | STORAGE TANK, 165" DIA X 185" H X 3/16" WALL | STAINLESS STEEL 304 |
| 1 | - | RESERVIOR, 64" DIA X 72" H X 3/16" WALL | STAINLESS STEEL 304 |
| 1 | - | DIRTY TANK, 108" DIA X 159" H X 3/16" WALL | STAINLESS STEEL 304 |
| 5 | - | SPOOL ASSEMBLY, 1-1/4 NPS SCH 40 X 10 OAL, 1-1/4 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 2 | - | SPOOL ASSEMBLY, 1-1/2 NPS SCH 40 X 10 OAL, 1-1/2 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 8 | - | SPOOL ASSEMBLY, 1-1/4 NPS SCH 40 X 240 OAL, 2-1/2 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 1 | - | SPOOL ASSEMBLY, 1-1/4 NPS SCH 40 X 115.67 OAL, 1-1/4 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 1 | - | SPOOL ASSEMBLY, 1-1/4 NPS SCH 40 X 122.71 OAL, 1-1/4 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 1 | - | SPOOL ASSEMBLY, 1-1/4 NPS SCH 40 X 15.40 OAL, 1-1/4 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 1 | - | SPOOL ASSEMBLY, 1-1/4 NPS SCH 40 X 55.70 OAL, 1-1/4 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 2 | - | SPOOL ASSEMBLY, 1-1/4 NPS SCH 40 X 177.00 OAL, 1-1/4 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 1 | - | SPOOL ASSEMBLY, 1-1/4 NPS SCH 40 X 79.29 OAL, 1-1/4 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 1 | - | SPOOL ASSEMBLY, 2 NPS SCH 40 X 12.50 OAL, 2 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 1 | - | 2 NPS RF BLIND FLANGE | STAINLESS STEEL 304 |
| 8 | - | ELBOW ASSEMBLY, 1-1/4 NPS SCH 40, 1-1/4 RF WELD NECK FLANGE (2) | STAINLESS STEEL 304 |
| 1 | - | REDUCER, 1-1/2 NPS SCH 40 TO 2 NPS SCH 40 | STAINLESS STEEL 304 |
| 2 | - | REDUCER, 1-1/2 NPS SCH 40 TO 3 NPS SCH 40 | STAINLESS STEEL 304 |
| 2 | - | REDUCER, 1-1/4 NPS SCH 40 TO 1 NPS SCH 40 | STAINLESS STEEL 304 |
| 2 | - | REDUCER, 1-1/4 NPS SCH 40 TO 2 NPS SCH 40 | STAINLESS STEEL 304 |
| 1 | - | SULZER PUMP, 2 X 3 X 7.5A | - |
| 2 | - | SULZER PUMP, 1 X 2 X 9 | - |
| 1 | - | SULZER PUMP, 1.5 X 3 X 8 | - |
| 7 | - | BUTTERFLY VALVE, 1-1/4 NPS | STAINLESS STEEL |
| 1 | - | BUTTERFLY VALVE, 1-1/2 NPS | STAINLESS STEEL |
| 3 | MCMASTER-CARR 8487T15 | ADJUSTABLE HEIGHT FLOOR MOUNT STRUT STYLE SUPPORT | - |

Table 8.1.1 Bill of Materials

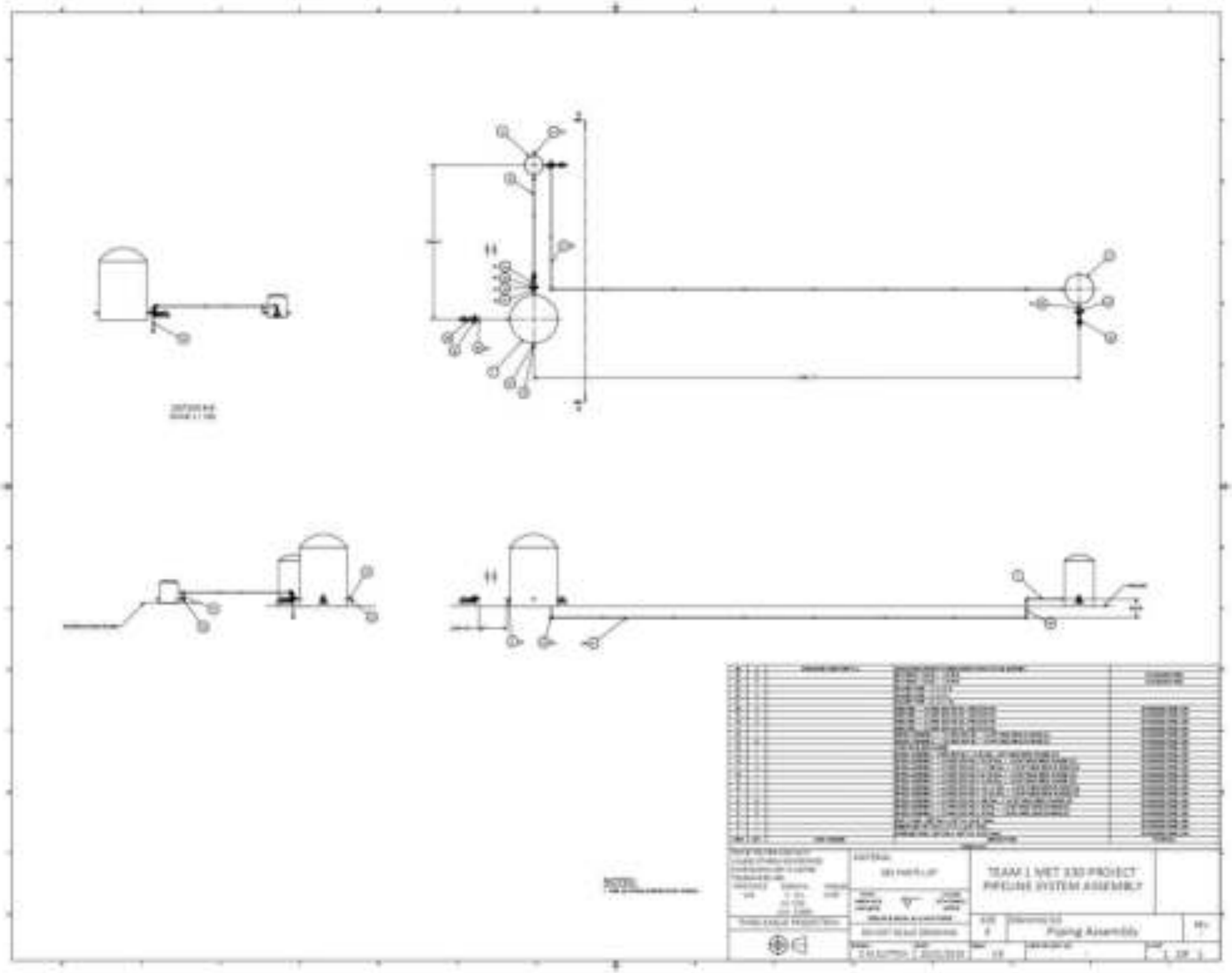


*Figure 8.9 Final Assembly Drawing*

## 6. Final Remarks

In concluding this project, we have all combined our efforts that led to the successful completion of the pipeline system of a manufacturing plant. The skills and knowledge gained throughout this endeavor have undoubtedly enriched our capabilities in designing piping systems. While we navigated through challenges such as initial coordination hurdles and occasional communication gaps, these experiences served as valuable lessons for continuous improvement. Many factors led to the design and performance of the system which include materials selected, type of fluid, equipment, temperature, and facility layout. As we neared the completion of the project, some hiccups were encountered when selecting the pumps for each system. Prior knowledge of the situation would have allowed us to make appropriate design changes to ensure that we would not have any issues. Even though it went against our better judgment as engineers, we improvised to save time rather than having to redesign our entire piping layout. To make it possible to supply the proper pump head for the specified pump, it was decided to restrict the flow of fluid through gate valves in a few of the systems. Even though we all agree that this is poor engineering, the experience has taught us many important lessons. It is now evident to us that, to provide the most effective and economical design, we must think about the needs of the client and not just our own convenience when making design decisions.

On regular occasions, a railcar will arrive on-site and offload 15,000 gallons of coolant into a stainless-steel storage tank at 50 gallons per minute, from which approximately 1,000 gallons will be pumped weekly into a reservoir tank at 33.33 gallons per minute, also stainless, through Sch 40 steel pipes. The reservoir tank will circulate the coolant throughout the machining area during the week and will be emptied at the end of each week into a 6,000-gallon tank, which is stainless steel as well, and also being pumped at 33.33 gallons per minute through identical pipes, marked dirty for collection by truck once every month. At the end of each month, the truck will pause on the street while coolant is pumped into it at 50 gallons per minute. The filling process for the storage tank will take 5 hours, filling/emptying the reservoir will take 30 minutes, and emptying the dirty tank will take 2 hours. Each of these processes will occur during the third shift, finishing before the start of the first shift.

Our teams design implements cost effectiveness through its use of selecting an appropriate pump for our application and the selection of pipe material. While the upfront cost of our choice of stainless steel would be considerably more than going with a plastic alternative the client would save money in the form of repairs and maintenance in the long run from our systems increased reliability, this was our goal in mind. We felt the need for our design to go underground and move the reservoir inside of the building. This will also allow the reservoir to be isolated from the outside conditions, reducing the possibility of damage even further. The choice of stainless-steel shines in this type of application because of the material properties allow it to be very corrosion resistant. If a plastic option was chosen the risk of the system needing repaired would be increased because of corrosion. Our team did see a good use of PVC to be implemented in the open channel design. The choice to have the open channel designed out of a 16” NPS PVC pipe allows for the open channel system to be easily repaired because of the simplicity of the open channel and if needed replaced its readily available. Our cost savings were balanced in our goal to design a system that would last a long time, while saving money in our design where we saw applicable.

# 7. Appendix

**Cameron Sutton:**

The skills and concepts acquired in this project significantly contribute to my ongoing success in my current career, particularly in the design of piping systems. As the group leader, I demonstrated competence in project management, collaboration, and leadership by effectively overseeing and organizing every aspect of the project to satisfy client requirements. Making use of my design background, I modeled the pipeline layout using 3D CAD software, which improved our ability to visualize how the system works. I used the Team Charter and other tools well to stay organized and meet project milestones, even though there were times when things were difficult. Through thorough system specifications, calculations and analysis as well as the use of 3D CAD modeling, the project demonstrated its technical strengths. Initial coordination challenges and occasional communication gaps in conveying technical concepts were identified as weaknesses. Recognizing these areas for improvement emphasized the importance of continuous learning and refinement for future projects. If I could give myself advice, I would emphasize how important it is to carefully go over each assignment, comprehend how they are dependent on one another, and consider how changes to the design will affect the project as a whole. This kind of insight would enable more effective planning and the anticipation of any potential repercussions throughout the project.

**Daryn Patrick:**

I believe that everything I've learned in this class and during this project will contribute immensely to my future professional career. While the focus of what I learned is specific to fluid mechanics, I also gained a broader understanding of the industry, as well as how to think like an engineer. Therefore, while I will be able to apply equations that I learned if I happen to be a part of designing any fluid-related systems, I will be able to apply much of what I learned otherwise to my craft regardless of where I land in the workforce. If I were to describe this project and my contribution during a job interview, I would do so as follows:

"I was matched with a group of my classmates to design a pipeline system that would store and organize coolant in a manufacturing facility. We were tasked with designing tanks and determining their material, size, shape, and location before we fixed the timing for the fill schedule. This opened a pathway for us to conclude our piping layout complete with pipe sizes, pumps, and other hardware including elbows, gate valves, and other things that cause minor losses. We completed calculations to determine the safety of each of our sub-systems before submitting the project. My role was that of a planner. I made myself responsible for laying out appropriate timelines for milestones of completion. As someone who had had plenty of experience working as a part of a team, a well-oiled machine, be it as one of three sisters, as a girl scout, as a fry cook in the back of a restaurant, a service worker in the front, or just a student who works in groups frequently, I was happy to step up and take responsibility for most of our communication with the professor, who was acting as our client for the duration of this project. Not only have I been part of a team before, but I also spent years as an adolescent building my leadership skills. I made a point to keep meetings on task and informative, gathering any questions the group may have had to facilitate clear and concise correspondence with the "client", prioritizing communication and clarity throughout the semester. We as a group wanted to make sure that the client was receiving a design that fit their needs appropriately, and I made sure to extract as much information as I could to be certain that their expectations were known to everyone in our group so that we all had an opportunity to do our best work. Just like everybody else, I have weaknesses, mainly in time management. Dealing with ADHD can make it challenging to manage time wisely, stick to plans, and meet deadlines. However, I have found that the best way to improve at anything at all is to practice consistently and get comfortable with being uncomfortable. I have found over the years that if I expose myself to as many situations as I can, as early as I can, I will notice patterns that allow me to adapt more and more quickly, making myself able to apply lessons and strategies in every situation, familiar or not. This is the logic I applied when I decided to volunteer for the planning role in my group. It was a difficult task to complete, but I was able to do better because I knew that I wasn't the only person affected by my actions. Being a part of a group makes me push harder to do better, and I saw more success fulfilling my role in this project than I had in any assignment prior."

I would identify our drawings, diagrams, and visualizations as a technical strength in this project. We all did our best to make the most accurate and precise calculations possible and if there were any gaps we managed to overlook despite looking over the report again and again, I would like to think that the drawings we created (and especially Cameron's CAD models) are enough perspective to bring clarity to any readers of this report. If I were to start the class over again, I would learn everything I can about pumps as soon in the semester as possible, much earlier than they were covered in class. Truthfully, I feel like we started the project too early. We had no clue what we were doing, and our placement of the tanks shows that. Our group agreed that had we known when we started what we know now, this project would have looked drastically different. We wanted to minimize energy losses, but the project would have been more convenient for the client and ourselves had we placed the tanks further apart. We also thought at the beginning that it would be easier to complete the project in metric units, hence the switching back and forth between metric and imperial. Because we lacked knowledge, we made decisions that we didn't even know were mistakes, realizing too late to rectify them and still finish the project on time.

**Tyler Gray:**

Going into this project I really did not know what to expect, this was by far the largest group project I have ever worked on. It required a lot of communication between all of us to tackle these problems and come up with the solutions and refine our design to meet our expectations but was very successful. I'm very thankful for the group I was assigned as it turned out to be an amazing group with some awesome people! All of us had a similar mindset of how to tackle any problems that came up and we handled them quickly and discussed everything. I absolutely think this project will be beneficial in making me a better engineer. It taught me how to effectively communicate on a project with such a wide scope which a traditional assignment just can't offer. All the skills I have learned will be used in the field. I felt that my strengths came more from the problem-solving standpoint and being open to new ideas and discussions. My weakness I felt in the project came simply from my availability, my schedule runs tight with juggling working full time having another part time job and being a 15-credit hour student. I felt I was lacking in the sense that some of my portions of the project could have been done a little quicker. I felt our project was very technically sound, as Cameron created 3-d models of the project and

Josh and Daryn created multiple spreadsheets to organize the data which was very helpful. We ran into a few hiccups regarding pump selection and energy losses but resolved them very quickly. If I were to take this class over again, I would tell myself to focus tasks that rely heavily on each other earlier because when running into issues down the line it is very difficult to go back and correct just one thing, it pretty much turns into doing the entire project twice.

**Josh Jonasson:**

Throughout this project I learned many things that will be important to my professional career. The biggest, and probably most important would be working as a team. Throughout this entire project, it was crucial to be in constant communication with the other team members and make sure we were all on the same page. The times that we weren't on the same page, we paid for it by having to re-do parts of the project. This is a really important skill to have in my professional career because I will most likely be working with a team on projects. Being able to effectively communicate, discuss, and bounce ideas off of you team can make or break the success of a project. The other thing I learned was how to go about a big project and work on it step by step. It can be very daunting when first looking at this project, so it is important that you focus on specific tasks and work through the project step by step. Both the skills of teamwork and being able to overcome a big project will be used throughout my entire professional career as well as currently as I finish up school.

If I was explaining this project to a job interviewer and my contributions in it, I would say that it is a full design project where all the calculations built off the ones before it. My team and I split the tasks equally while also be willing to help each other out with tasks that weren't ours. My main contributions in this project revolved around calculating the flow rate, velocity, and pipe layout/sizing for the entire system. As well as choosing the correct size and type of pump for each system by calculating each systems energy losses, pump head, flow capacity, and point of operation. I also used Excel extensively when calculating these value so if something needed to be changed it could be changed quickly and effectively. My strengths in this project revolved around hard work and constant questioning about how something should be done. My weakness in this project revolved around my lack of time. Dealing with other classes and working full time, it was difficult to pour the amount of time required into this project. It was a constant battle for me to find time to complete this project. This will be addressed in my professional career because I will not have a million other things to do while also completing the project at the same time. The work I do for this employer will be my job, so I will be able to give them my full attention.

My technical strengths in this project revolved around the use of excel. Throughout this project I had to really familiarize myself with Excel and how to use it efficiently and quickly. Being able to put all the calculations, from multiple sections, into one Excel file allowed the group to change values of things easily so we could quickly determine if a change would work or not. My technical weakness in this project revolved around the correct way to use equations. At the beginning of the project, I attempted to figure out how to solve problems based on the equations and my own thought process. This created incorrect processes and values. Having to re-do entire sections of the project caused me to be more mindful about how I calculate different values and ensure that I was relying on the lectures for technical knowhow. If I was starting this class over, the advice I would give myself to ensure I had a successful semester and successful final project would be to take my time and plan things out. Throughout the semester I attempted to quickly solve problems that were given to me, due to lack of time, but usually this ended up biting me in the butt because I would have to re-do work. For the project specifically, I would tell myself to look at the big picture of the project and plan things out accordingly. Focusing on a single problem without realizing the impact it has on later parts can create a lot of issues. Understanding what I am solving and why I am solving something can save me a lot of time and stress.