MET 330 – Group 13

Final Project

Full Pipeline System Design of a Manufacturing Plant for CONTINENTAL AG

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2. Abstract

Continental AG is planning construction on a new manufacturing facility to be located in Dayton, Ohio. This project is to be developed on a new construction site and is to be incorporated into the current construction plans. The project will include the design and specifications for the delivery, storage, usage, and disposal of the machining coolant fluid for the automated machining line in the manufacturing facilities. All characteristics of the fluid, facility location, type of use and schedule will be incorporated into the design to allow a safe and efficient coolant use and transferring from arrival at the facility to disposal of the used fluid.

2. Table of Contents

3. List of Figures

4. List of Tables

5. Project

5.a. Job site location:

The piping system will be located at continental Maritime new construction location in Dayton, Ohio.

The temperature range for this location is: -20°F to +105°F

5.b. Specifications and design philosophy

The piping system was designed to offload, store, and transfer coolant, from the arrival via railcar to disposal via tanker truck. The cooling fluid is to arrive via railroad tank cars carrying 15,000 gallons each. This system will hold the newly delivered coolant, store the coolant that is used and transferred to the dirty holding tank at rate of 1000 gallons per week. The system will then hold the dirty coolant until it is picked up once a month. The plant will operate 2 shifts per day, 7 days a week with maintenance being performed during 3rd shift. Any transferring of the coolant that will impact the normal production hours will have to be accomplished within the 8-hour third shift window.

5.c. Sources

Robert L. Mott. and Joseph A. Untener. (2014), Applied Fluid Mechanics (7th Edition).
Beer, Johnston, DeWolf, Mazurek (2015), Mechanics of Materials (7th Edition).
Milwaukee Valve Co. http://www.milwaukeevalve.com
Global Spec Valves https://www.globalspec.com/
Sulzer Pumps https://www.sulzer.com
McMaster-Carr Supply Co. https://www.mcmaster.com
Stanwade Metal Products, Inc. http://www.stanwade.com/default.htm

5.d. Materials and specifications

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

The material that will be used in the piping system and tank is galvanized carbon steel. Carbon steel piping is available in a wide range of wall thicknesses and can vary in carbon content making it a suitable option for this design.

5.d.ii Fluid characteristics

The liquid coolant will flow through the piping system from the storage tank to the holding tank during usage. The coolant is a solution of water and soluble oil with a specific gravity of 0.94 and a freezing point of 0F. Its corrosiveness is approximately the same as that of water. The viscosity and vapor pressure of the coolant are 1.50 times that of water at any temperature.

5.e. Preliminary drawings and sketches

5.e.i. Plot plan

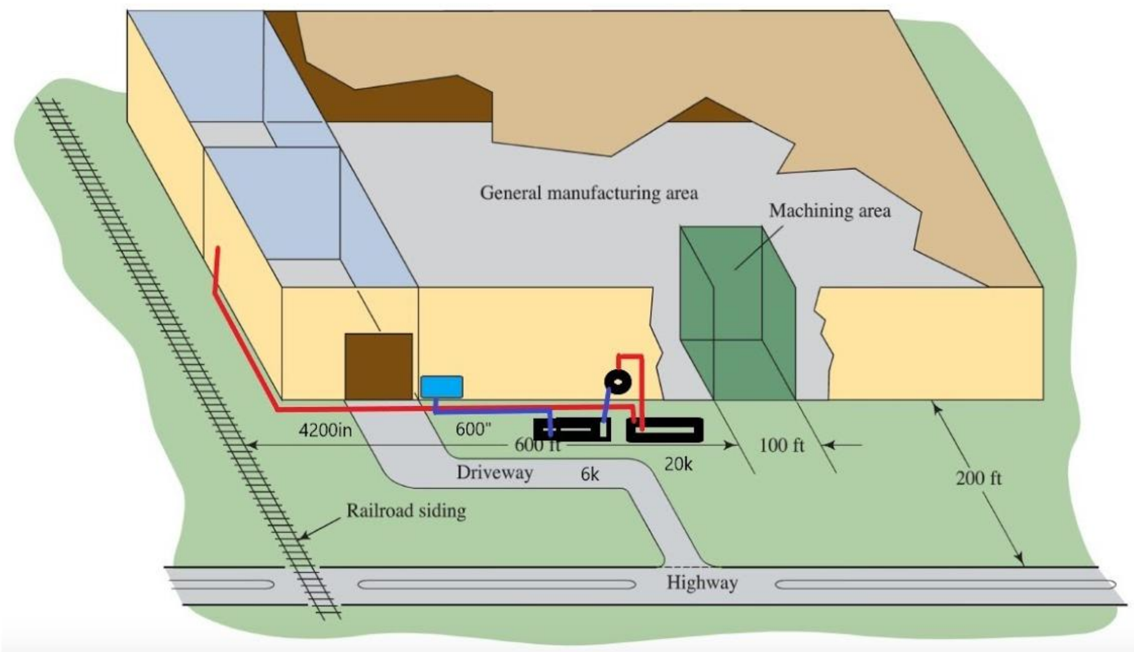


Figure P-1

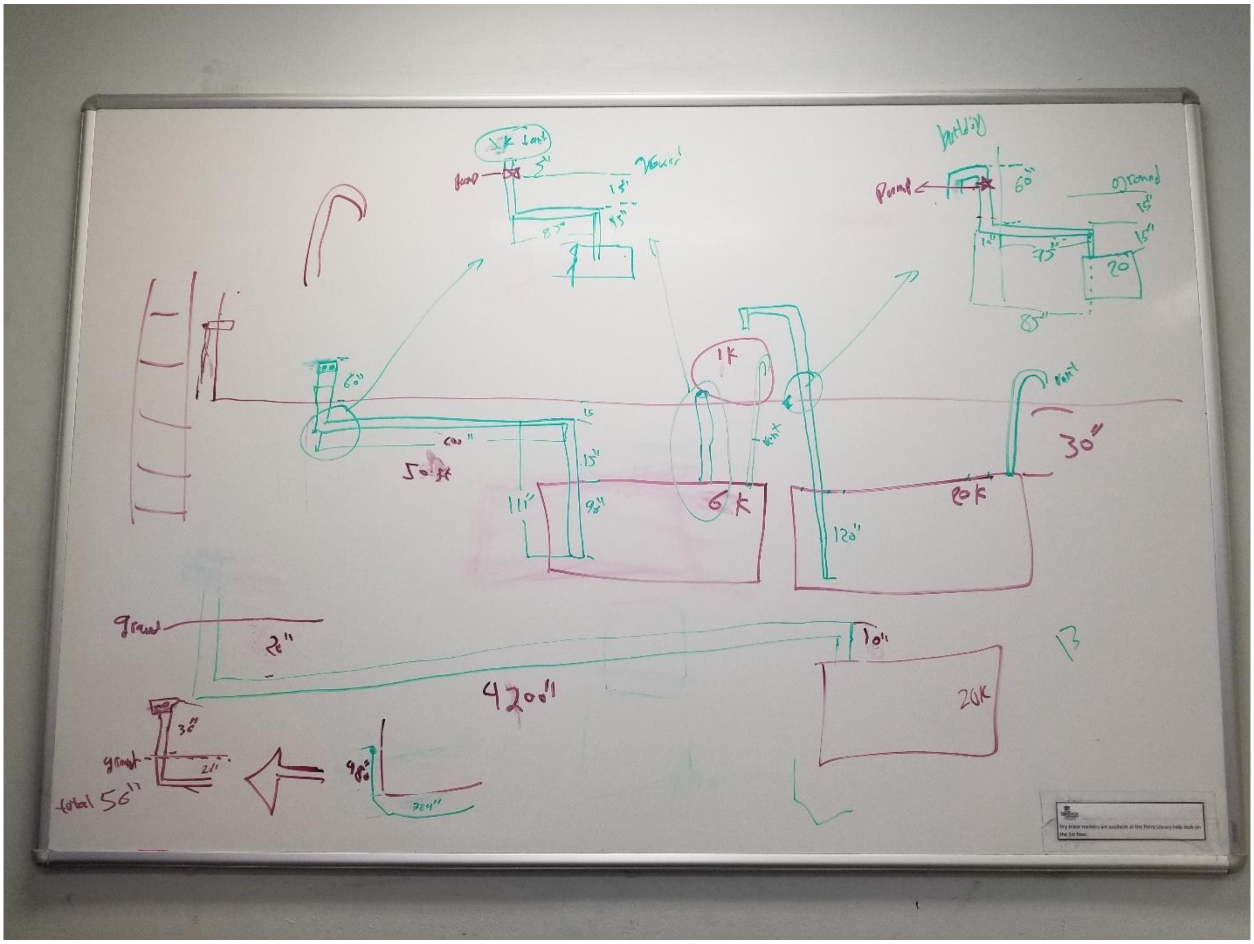


Figure P-2

5.e.ii. Elevations

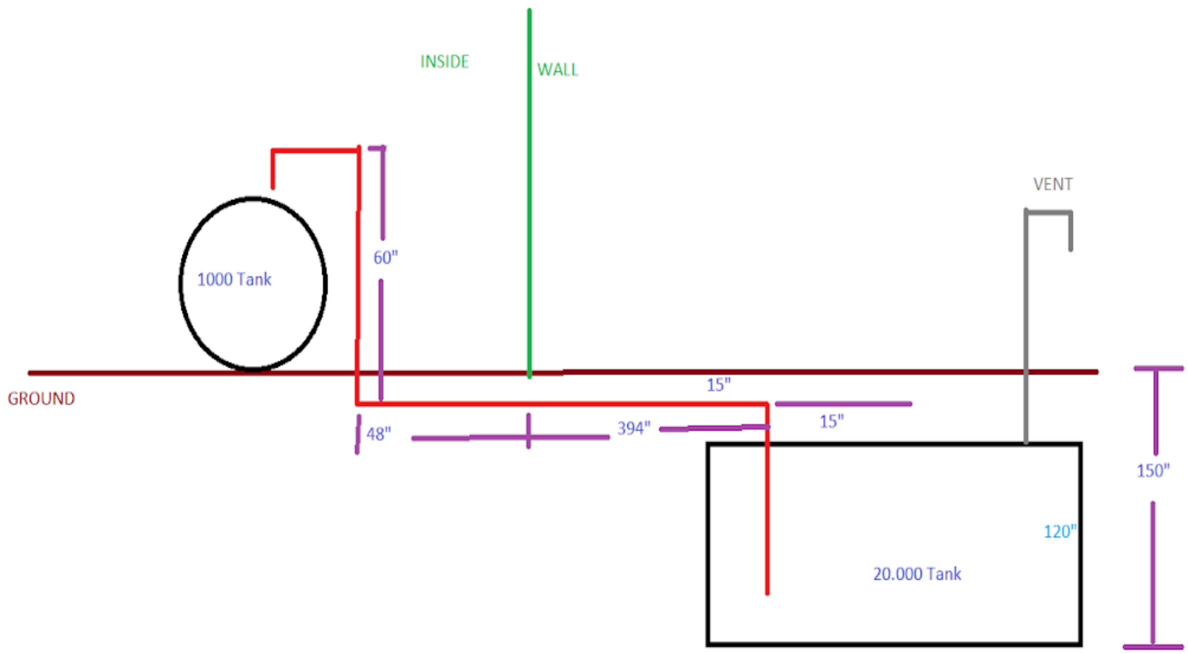


Figure P-3

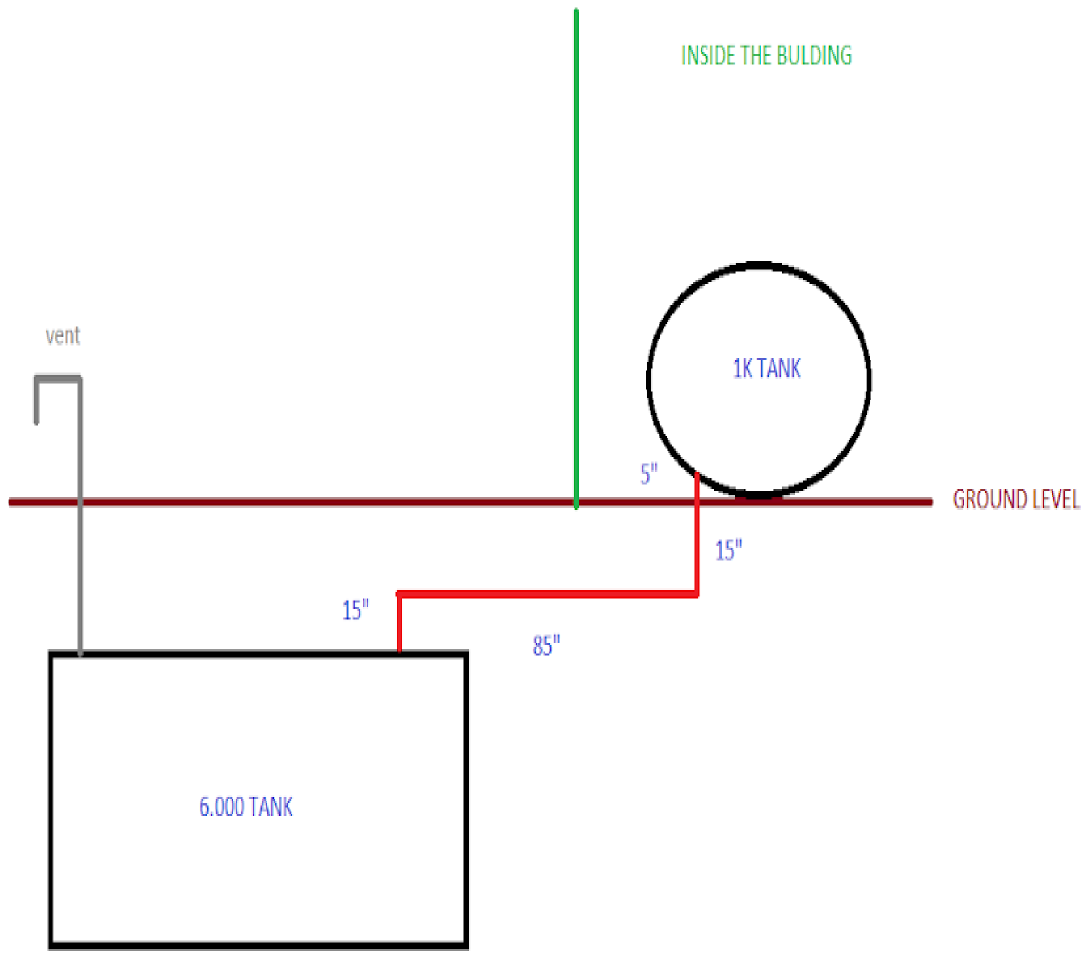

INSIDE THE BULDING
vent
1K TANK
5"
GROUND LEVEL
15"
15"
85"
6.000 TANK

Figure P-4

5.f. Design calculations

5.f.i. Tank specifications

- Tank location and size

Purpose:

Specify the size and location of all storage tanks.

Drawings & Diagrams:

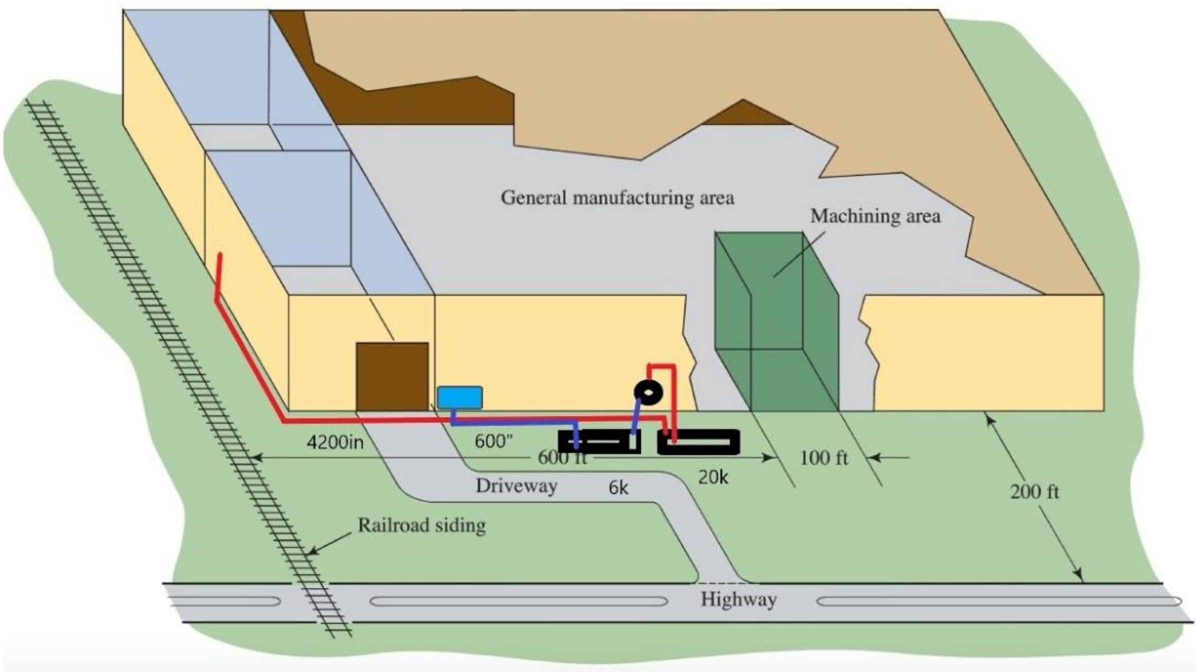


Figure 1-1

Design Considerations:

The design of both the clean 20,000gal and dirty 6,000 gal storage tanks chosen are to be in ground horizontal type storage tanks. The 1,000 gallon daily use reservoir will be a single wall above ground tank that will be located inside the facility.

Data and variables

$$Length_{\ clean\ tank} = 34.2\ ft$$

$$Diameter_{\ clean\ tank} = 10.0\ ft$$

$$Length_{\ Dirty\ tank} = 16\ ft$$

$$Diameter_{\ Dirty\ tank} = 8\ ft$$

$$Length_{\ Resvior\ tank} = 10.67\ ft$$

$$Diameter_{\ Reservoir\ tank} = 4\ ft$$

Materials:

The tanks will be constructed of painted double wall carbon steel.

Calculations:

Volume of a tank = 20,000 gallons

$$V = \pi \cdot r^2 \cdot L = \pi \cdot (60)^2 \cdot (408) =$$

$$= \underline{4614371.3 \text{ inches}^3}$$

convert it to gallons

$$\boxed{= 19{,}975.6} \text{ gallons}$$

Figure 1-2

Summary:

The tanks sizes were chosen based on the needed extra capacity to support the fluid being placed into each tank. The weekly holding tank was placed at approximately 270 feet from the railroad tracks, ideally in between the dirty and clean tanks, in order to make the circulation of the fluid more efficient between the three tanks. The clean and dirty fluid tanks were placed outside and underground to avoid protect the coolant from freezing due to local winter temperatures.

Location of 20k Gal Tank:

The centroid of the tank would be located 30 feet off the south side building wall and 350 feet to the right of the railroad tracks, and 30 inches below ground.

So, as the charts shown when the clean coolant dump into the tank; the height will be *85 inches* with capacity of *15,129 gallons.*

Location of 6k Gal Tank:

The centroid of the tank would be located 30 feet off the Southside building wall and 300 feet to the right of the railroad tracks, and 30 inches below ground.

So, as the charts shown when the clean coolant dump into the tank; the height will be *61 inches* with capacity of *4,033 gallons.*

Location of 1k Gal Tank:

The tank will be inside of the central manufacturing area, 4 feet from south side wall. The tank will sit 5 inches off of the floor. The tank would sit 270 feet west of the machining area.

	Required Capacity (gallon)	Actual Capacity (gallon)	Capacity (ft^3)
Clean Tank	20,000	19,976	2,683
Dirty Tank	6,000	6,016	804
In Use Tank	1,000	1,003	134

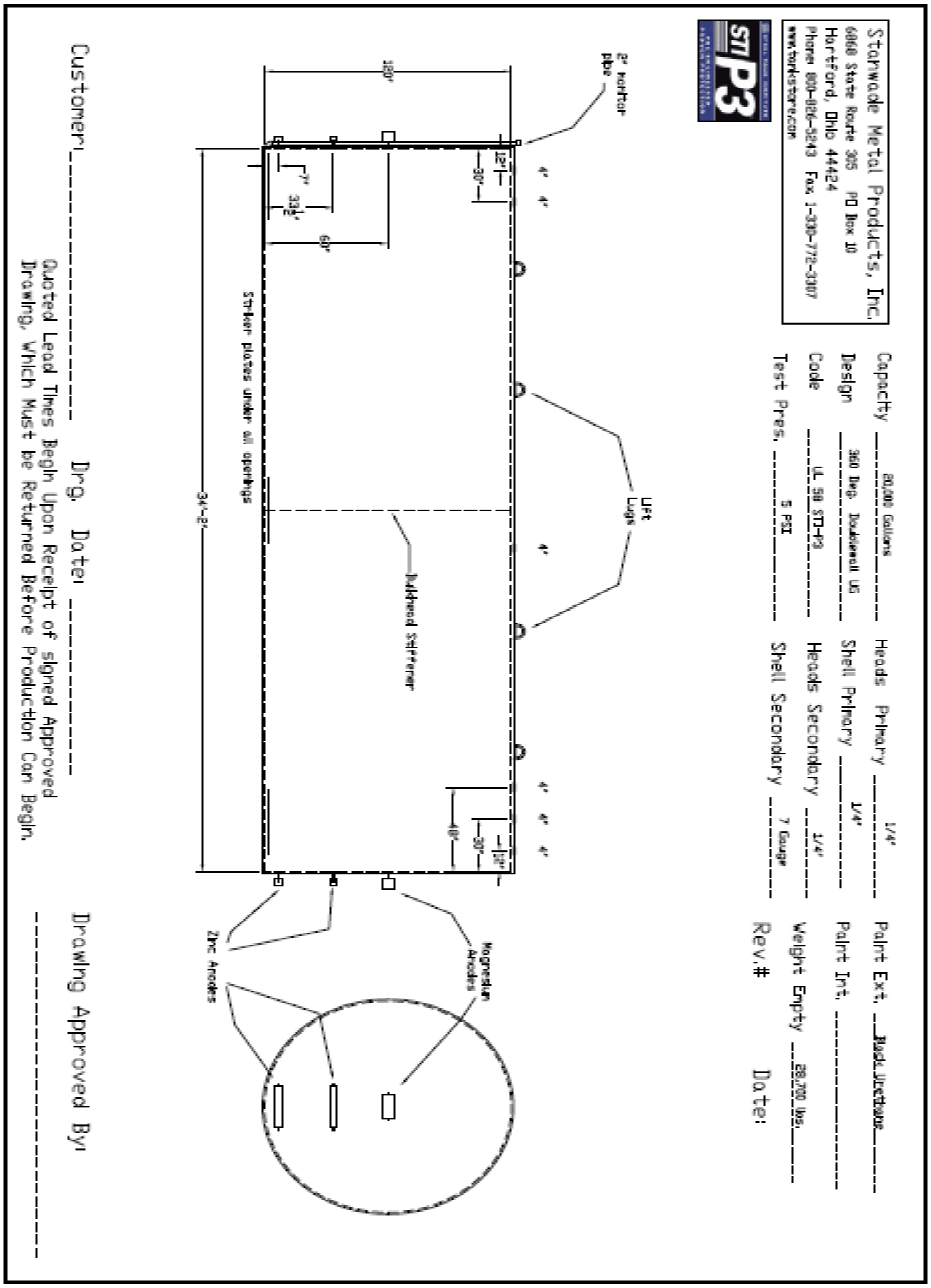
Table 1-1

Analysis:

The sizes and locations of our tanks were determined based on a new construction site. Tank dimensions were assumed to be industry standards. The depth of the two underground tanks were determined based on a 30 inch frost line in the state of Ohio. Furthermore, these tanks are provided form Stanwade Metal Products, INC that located on Ohio state as well which their manufacture some of their tanks to be located underground and can handle the weather temperature change during the year.

The tanks material and thickness were chosen based on a predesigned tank from Stanwade Metal Products. Each tank is double walled and made of standard grade steel. The tanks are coated with black urethane paint in order to meet regulations for code: 4L 58 STI.P3.

20,000 Gallon Tank:

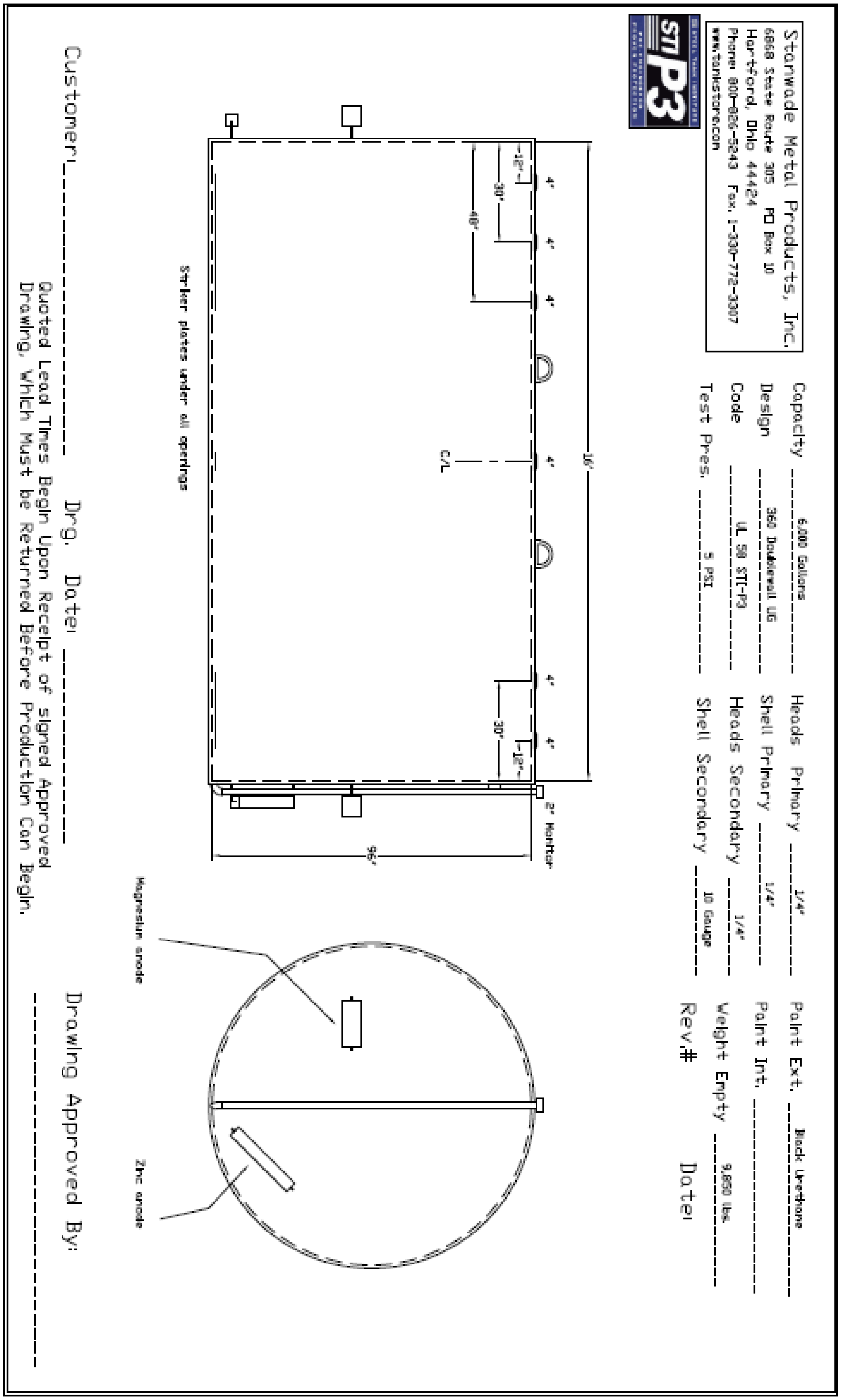


Stanwade Metal Products, Inc.

Horizontal tank of diameter 120 and length 408

INCHES	GALLONS	INCHES	GALLONS	INCHES	GALLONS	INCHES	GALLONS
1	25.733	2	72.6	3	133.038	4	204.304
5	284.792	6	373.405	7	469.326	8	571.913
9	680.644	10	795.08	11	914.845	12	1039.612
13	1169.092	14	1303.025	15	1441.178	16	1583.338
17	1729.31	18	1878.912	19	2031.978	20	2188.351
21	2347.884	22	2510.439	23	2675.886	24	2844.101
25	3014.965	26	3188.366	27	3364.198	28	3542.356
29	3722.741	30	3905.258	31	4089.816	32	4276.323
33	4464.695	34	4654.847	35	4846.698	36	5040.168
37	5235.179	38	5431.657	39	5629.528	40	5828.718
41	6029.157	42	6230.776	43	6433.506	44	6637.279
45	6842.03	46	7047.693	47	7254.204	48	7461.499
49	7669.515	50	7878.19	51	8087.462	52	8297.27
53	8507.553	54	8718.251	55	8929.304	56	9140.653
57	9352.238	58	9563.999	59	9775.878	60	9987.817
61	10199.755	62	10411.634	63	10623.396	64	10834.98
65	11046.329	66	11257.382	67	11468.08	68	11678.364
69	11888.172	70	12097.443	71	12306.118	72	12514.134
73	12721.429	74	12927.94	75	13133.603	76	13338.354
77	13542.127	78	13744.857	79	13946.476	80	14146.915
81	14346.105	82	14543.976	83	14740.454	84	14935.466
85	15128.936	86	15320.786	87	15510.938	88	15699.31
89	15885.818	90	16070.375	91	16252.892	92	16433.278

6,000 Gallon Tank:

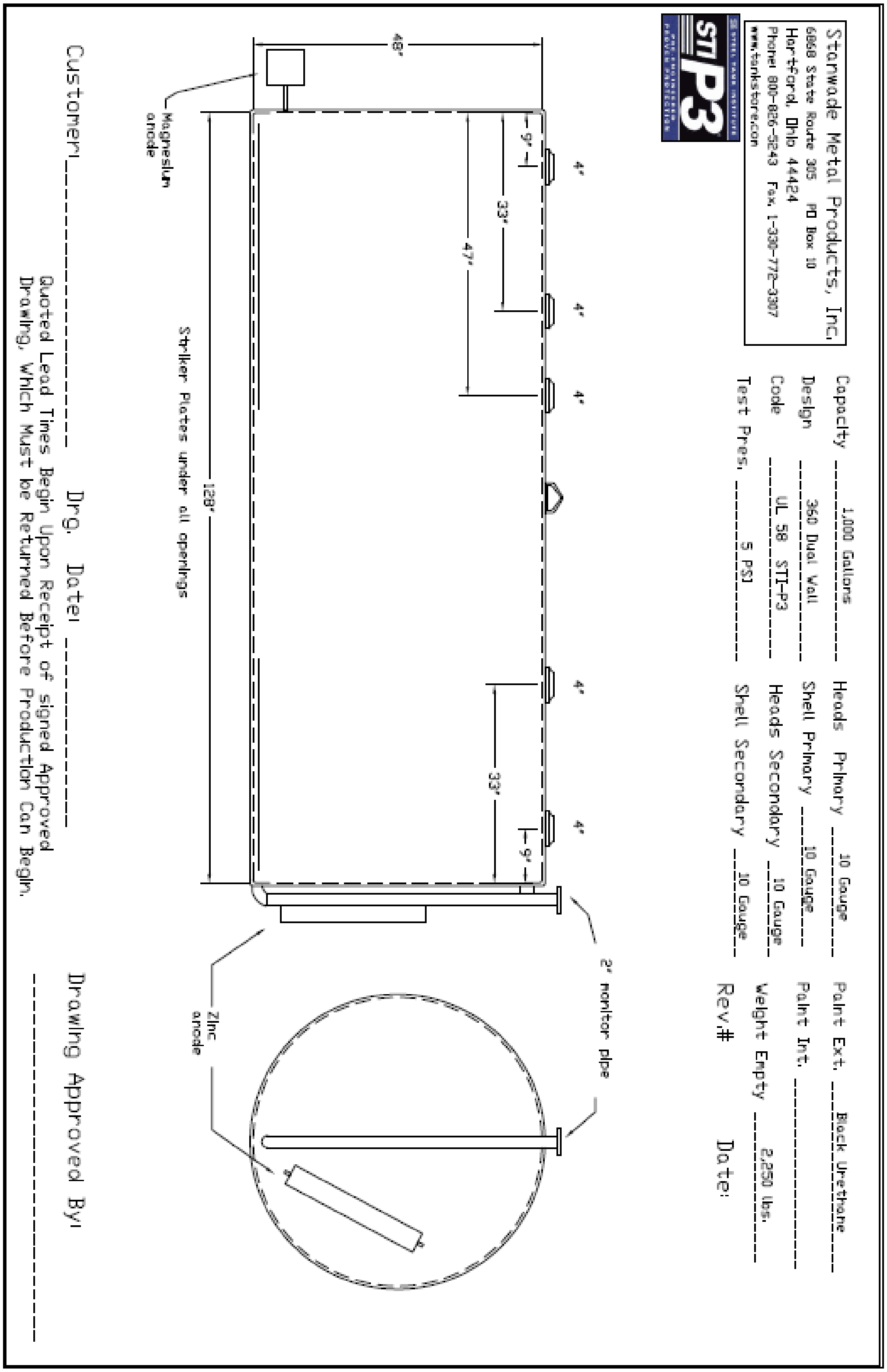


Stanwade Metal Products, Inc.

Horizontal tank of diameter 96 and length 192

INCHES	GALLONS	INCHES	GALLONS	INCHES	GALLONS	INCHES	GALLONS
1	10.824	2	30.519	3	55.89	4	85.773
5	119.485	6	156.558	7	196.641	8	239.459
9	284.786	10	332.433	11	382.234	12	434.049
13	487.75	14	543.222	15	600.364	16	659.08
17	719.283	18	780.893	19	843.834	20	908.036
21	973.433	22	1039.96	23	1107.559	24	1176.172
25	1245.745	26	1316.226	27	1387.564	28	1459.711
29	1532.621	30	1606.246	31	1680.545	32	1755.473
33	1830.989	34	1907.051	35	1983.621	36	2060.659
37	2138.125	38	2215.983	39	2294.196	40	2372.725
41	2451.536	42	2530.592	43	2609.857	44	2689.296
45	2768.875	46	2848.557	47	2928.309	48	3008.095
49	3087.882	50	3167.634	51	3247.316	52	3326.894
53	3406.334	54	3485.599	55	3564.655	56	3643.465
57	3721.995	58	3800.207	59	3878.065	60	3955.532
61	4032.57	62	4109.139	63	4185.202	64	4260.718
65	4335.646	66	4409.944	67	4483.57	68	4556.479
69	4628.627	70	4699.965	71	4770.446	72	4840.019
73	4908.632	74	4976.231	75	5042.758	76	5108.154
77	5172.356	78	5235.298	79	5296.908	80	5357.111
81	5415.827	82	5472.968	83	5528.441	84	5582.142
85	5633.956	86	5683.758	87	5731.404	88	5776.731
89	5819.549	90	5859.633	91	5896.706	92	5930.418
93	5960.301	94	5985.671	95	6005.366	96	6016.191

1,000 Gallon Tank:



Stanwade Metal Products, Inc.

Horizontal tank of diameter 48 and length 128

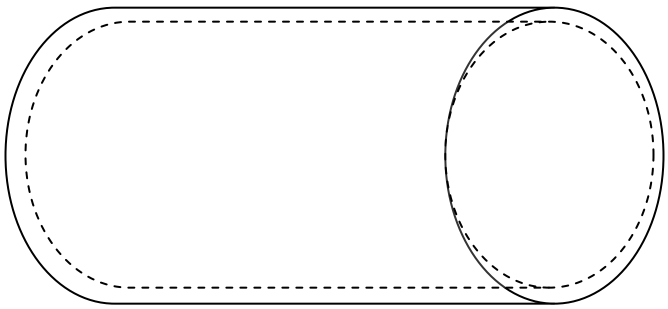
INCHES	GALLONS	INCHES	GALLONS	INCHES	GALLONS	INCHES	GALLONS
1	5.087	2	14.295	3	26.093	4	39.91
5	55.405	6	72.341	7	90.537	8	109.847
9	130.149	10	151.339	11	173.327	12	196.029
13	219.371	14	243.285	15	267.708	16	292.579
17	317.842	18	343.443	19	369.331	20	395.454
21	421.765	22	448.216	23	474.76	24	501.349
25	527.939	26	554.482	27	580.933	28	607.244
29	633.368	30	659.255	31	684.857	32	710.12
33	734.991	34	759.413	35	783.327	36	806.67
37	829.372	38	851.359	39	872.55	40	892.852
41	912.161	42	930.357	43	947.293	44	962.789
45	976.605	46	988.403	47	997.612	48	1002.698

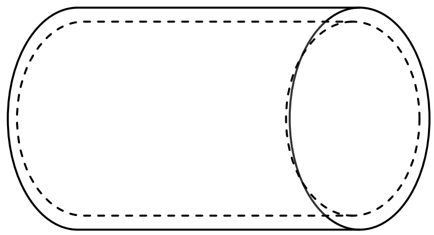
- Tank thickness

Purpose:

Select the tank material and specify required wall thickness of each storage tank.

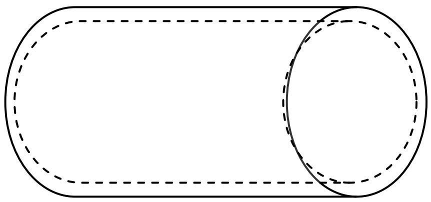
Drawings & Diagrams:





Dirty tank: Thickness = ¼"

Clean tank: Thickness = ¼"



Daily use tank: Thickness = ¼"

Figure 1-9

Materials: Painted Carbon steel

Variables:

W1 = interior tank thickness

W2 = exterior tank thickness

P = design pressure

Di = Inside Diameter

σ = Allowable Design Stress of tank material

E = weld joint factor = .85

Design Considerations:

1. Temperature of local area
2. Pressure of fluid inside tank
3. Incompressible Fluid

Procedure:

We will use the formula: $t = \frac{P\,D}{2(SE+PY)}$ to determine the required wall thickness for each tank.

Calculations:

Calculations for 20,000 Gal Tank Material Thickness

$$Thickness, t = \frac{P * Di}{2\sigma E - 0.2P} = \frac{5psi * 12in}{2*140MPa*.85 - 0.2*5psi} = 0.253in = 0.25in$$

Calculations for 6,000 Gal Tank Material Thickness

$$Thickness, t = \frac{P * Di}{2\sigma E - 0.2P} = \frac{5psi * 12in}{2*250MPa*.85 - 0.2*5psi} = 0.1415in = 0.14in$$

Calculations for 1,000 Gal Tank Material Thickness

$$Thickness, t = \frac{P * Di}{2\sigma E - 0.2P} = \frac{5psi * 12in}{2*250MPa*.85 - 0.2*5psi} = 0.1415in = 0.14in$$

Summary:

The tank material of all three tanks is standard grade steel. Each tank is double walled and coated in black urethane paint. The 20k gallon tank is 1/4" steel. The 6k gallon tank and 1k gallon tank are both 10 gauge steel. Tanks selected are commercially available tanks that have been designed to last 20 years in the ground.

- Future drain connection - blind flange design (task 3)

Purpose:

To determine a future additional connection to drain one of the tanks and design a blind flange. Provide the amount needed and the dimensions of the blind flange, bolts and nuts.

Drawings and Diagrams:

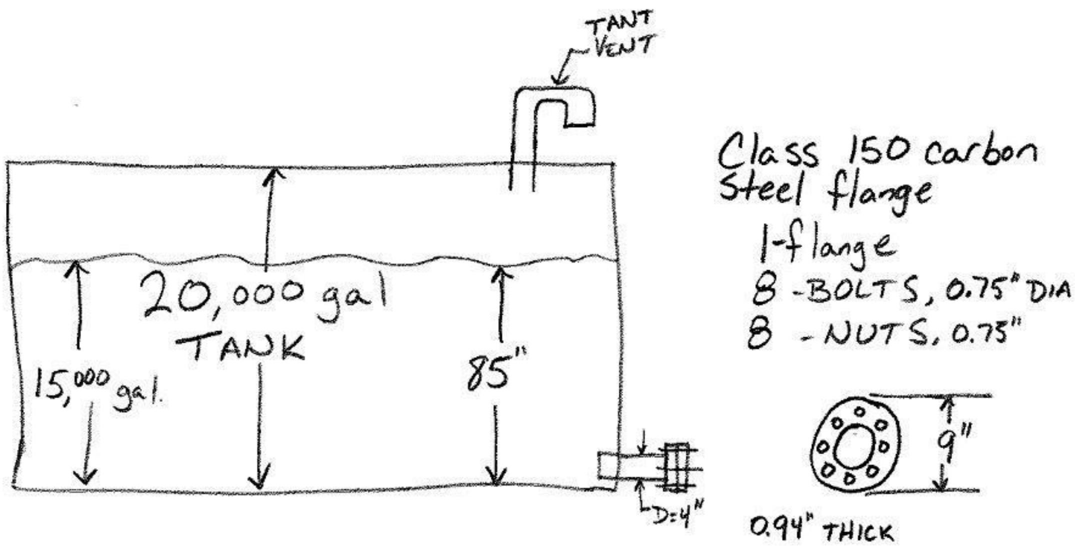


Figure 1-10

Variables:

A = Area of pipe

Sg = Specific Gravity

F=Force

P = Pressure

Design Considerations:

The smallest blind flange available for 4” pipe is 150 class carbon steel flange. It comes with standard 8 bolt holes at 0.75” each. The standard flange is 0.94” thick. The calculations will show that this flange is adequate to resist the pressure from the tank fluid.

Procedure:

We will first calculate the pressure on the flange using, $F_{flange} = P \times A$, once we have the force on the flange face, we can then calculate the force on the bolts using . We can then compare the force to the strength of the bolts to determine whether they will hold the flange securely.

Data and variables:

- $P_{tank} = pressure\ at\ the\ tank$
- $A_{flange} = Area\ of\ flange$
- $F_{bolt} = Force\ on\ the\ bolts$
- $F_{flange} = Force\ on\ the\ flange$

Calculations:

$$P_{max} = P_{tank} + P_{ATM} \qquad P_{atm} = 101.325\ kPa$$

PRESSURE AT BOTTOM OF TANK $= \gamma h$

$$\gamma = 9.81\left(kN/m^3\right), \quad h = 10\ ft = 3.05\ m$$

$$P_{tank} = 9.81\left(kN/m^3\right) \cdot (3.05\ m) + 101.325\ kPa$$

$$P_{max} = 131.25\ kPa = 1.31\ bar = 19\ psi$$

$$Area = \frac{\pi}{4}(4")^2 = 12.57\ in^2$$

$$F_{Flange} = P \cdot A$$

$$F_{flange} = 19\ psi \cdot 12.57\ in^2$$

$$\boxed{F_{flange} = 238.8\ lbs}$$

$$F_{bolt} = \frac{238.8\ lbs}{8\ bolts} = \boxed{29.85\ lbs/bolt}$$

Figure 1-11

Summary:

The tank with the largest capacity was used to calculate the force on the flange. The maximum pressure on the flange at its full 20,000 gallon capacity is 19 pounds per square inch. With an area of 12.57 square inches the total force on the 4” diameter flange is 238.8 lbs. Each bolt will experience 29.85 lbs of force.

Materials:

- Class 150 carbon steel flange
- Steel bolts and nuts
- Flange gasket

Analysis:

Industry standard blind flange is class 150 carbon steel flange that is 0.94” thick. The standard flange is supplied with 8 bolt holes that are 0.75” diameter. The minimum available flange will be more than adequate to maintain the fluid inside the tank.

- Wind load and weight

Purpose:

Determine wind load and weight of storage tanks

Drawings and Diagrams:

Design Considerations:

- Both Clean and dirty tanks will be located underground, wind load will be neglected
- Daily use tank will be located indoors, wind load will be neglected
- Location: Dayton, Ohio
- Outdoor temperature ranges from -20F to +105F

Procedure:

Weight of the tanks

1. The basic equation for the weight,

$$W = m\ g$$

2. Knowing that $m = \rho \forall$, we substitute the values and we get

$$W = \rho \forall g$$

3. Weight of the tank will be calculated twice empty tank and filled tank

4. After that we sum up the two values in order to get the total weight of the tank, by using the following equation

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

Data and variables:

Variables

$\rho_{coolant} = density\ of\ coolant$

$W_{steel} = weight\ of\ an\ empty\ tank$ (from manufacturer)

$W_{coolant} = weight\ of\ fluid$

$W_{total} = total\ weight\ of\ the\ tank$

$\forall = Volume\ of\ the\ tank$

$g = gravity$

Data

	$\forall$ (gal)	$\rho_{steel}\ (\frac{lb}{ft^3})$	$\rho_{coolant}\ (\frac{lb}{ft^3})$	g $(\frac{ft}{s^2})$
Clean Tank	20,000	490	62.43	32.2
Dirty Tank	6,000	490	62.43	32.2
Daily Use Tank	1,000	490	62.43	32.2

Table 1-2

Note: Wind force is neglected for all tanks due to their location (underground and inside)

Calculations:

• Weight of tanks

1) Empty tank

$$m = \rho$$

$$W = mg$$

$$\Rightarrow W = \rho \forall g$$

$$\rho_{carbon\ steel} \approx 490 \frac{lb}{ft^3}$$

$$\forall_{tank} = 10{,}731.68\ ft^3$$

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

$$W_{steel} = \left(490 \frac{lb}{ft^3}\right)\left(10{,}731.68\ ft^3\right)\left(32.2\ ft/s^2\right) = \boxed{28{,}400\ lb}$$

• Coolant weight

$$W_{coolant} = \rho_{coolant} \cdot \forall_{tank} \cdot g$$

$$\rho_{coolant} = 62.43 \frac{lb}{ft^3} \quad ; \quad \forall_{tank} = 10{,}731.68\ ft^3$$

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

$$W_{coolant} = \left(62.43 \frac{lb}{ft^3}\right) \cdot \left(10{,}731.68\ ft^3\right)\left(32.2 \frac{ft}{s^2}\right) \approx \boxed{166{,}908\ lbs}$$

• filled tank

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

$$= 28{,}400\ lb + 166{,}908\ lb$$

$$\boxed{W_{total} = 195{,}308\ lb}$$

Figure 1-12

Materials:

- Coolant
- Tanks

Summary:

	$F_{wind}\ (lbf)$	$W_{steel}\ (lb)$	$W_{coolant}\ (lb)$	$W_{total}\ (kN)$
Clean Tank	Neglected	28,400	166,908	195,308
Dirty Tank	Neglected	10,100	50,072	60,172
Daily Use Tank	Neglected	2,350	8,345	10,695

Table 1-3

Note: Weight of tanks given by tank manufacturer

- Open channel for drainage

Purpose:

Determine the size, location, and destination of a channel used to empty a tank that has failed in the system

Design Consideration:

We need to consider the land area around the tanks, the most efficient channel shape, each tanks capacities and the desired flow rate the channel will need to sustain.

Data and variables

$Q = flowrate$

$A = area$

$S\ = slope$

$n = Manning$ value

$WP = wetted\ perimeter$

$R = hydraulic\ radius$

Materials:

Rough unfinished concrete, pump, galvanized steel pipe

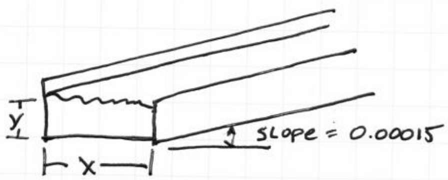
Procedure:

We will design the channel to be able to handle the volume of the 20,000 gallon tank since this would be the largest volume of coolant the channel would have to accommodate. In this case the piping coming from the train rail car to the clean coolant storage tank would be in the concrete trough. The trough will lead to the concrete lined underground tank enclosure. If the tank should leak all coolant would remain in the concrete enclosure until it could be properly disposed. These calculations will be used to properly size the piping trough to ensure that any piping leaks will also drain into the concrete tank enclosure.

Calculations:

DRAINAGE TROUGH FOR LEAKING PIPE

GIVEN: $Q = 8.35 \text{ scfm} = 0.139 \frac{ft^3}{s}$ (FROM STEP TASK 4)



SOLVE USING MANNING EQUATION FOR CHANNEL DIMENSIONS

$$Q = \frac{1.49}{n} A S^{1/2} R^{2/3} \Rightarrow \frac{Qn}{1.49 S^{1/2}} = A R^{2/3}$$

FROM TABLE IN TXT BOOK:

$Q = 0.139 \frac{ft^3}{s}$

$n = 0.04$

$S = 0.00015$

$A = 2y^2 \Rightarrow y = \sqrt{\frac{A}{2}}$

$A = xy \Rightarrow x = \frac{A}{y}$

$WP = 4y$

$R = \frac{y}{2}$

$$\frac{(0.139)(0.04)}{1.49(0.00015)^{1/2}} = AR^{2/3} \Rightarrow \frac{.00556}{0.01825} = AR^{2/3} \Rightarrow 0.30467 = AR^{2/3}$$

Results:

Flowrate Q=	0.139	ft^3/s						
n=	0.04							
s=	0.00015							
Area (Guess)								
A (ft^2)	WP (ft) = 4Y	Y (ft) = sqrt(A/2)	X (ft) = A/Y	R = Y/2	(Qn)/(1.49*S^1/2)	A*R^2/3	Difference	
0.689	2.34776489	0.586941224	1.1738824	0.2935	0.304679	0.304272	-0.133776	
0.6891	2.34793526	0.586983816	1.1739676	0.2935	0.304679	0.304331	-0.1144017	
0.6892	2.34810562	0.587026405	1.1740528	0.2935	0.304679	0.304390	-0.0950339	
0.6893	2.34827596	0.587068991	1.174138	0.2935	0.304679	0.304449	-0.0756727	
0.6894	2.34844629	0.587111574	1.1742231	0.2936	0.304679	0.304508	-0.056318	
0.6895	2.34861661	0.587154154	1.1743083	0.2936	0.304679	0.304567	-0.0369699	
0.6896	2.34878692	0.58719673	1.1743935	0.2936	0.304679	0.304626	-0.0176284	
0.6897	2.34895722	0.587239304	1.1744786	0.2936	0.304679	0.304684	0.0017067	
0.6898	2.3491275	0.587281874	1.1745637	0.2936	0.304679	0.304743	0.0210351	
0.6899	2.34929777	0.587324442	1.1746489	0.2937	0.304679	0.304802	0.0403571	
0.69	2.34946802	0.587367006	1.174734	0.2937	0.304679	0.304861	0.0596725	
0.6901	2.34963827	0.587409568	1.1748191	0.2937	0.304679	0.304920	0.0789814	
0.6902	2.3498085	0.587452126	1.1749043	0.2937	0.304679	0.304979	0.0982837	
0.6903	2.34997872	0.587494681	1.1749894	0.2937	0.304679	0.305038	0.1175795	
0.6904	2.35014893	0.587537233	1.1750745	0.2938	0.304679	0.305097	0.1368688	
0.6905	2.35031913	0.587579782	1.1751596	0.2938	0.304679	0.305156	0.1561516	
0.6906	2.35048931	0.587622328	1.1752447	0.2938	0.304679	0.305215	0.1754279	
0.6907	2.35065948	0.58766487	1.1753297	0.2938	0.304679	0.305274	0.1946977	
0.6908	2.35082964	0.58770741	1.1754148	0.2939	0.304679	0.305333	0.2139609	
0.6909	2.35099979	0.587749947	1.1754999	0.2939	0.304679	0.305391	0.2332176	

Table 1-4

Analysis:

The area that best suits our required flow rate is 0.6897 square feet. The trough should be 1.17 ft wide by 0.587 ft high. The wetted perimeter for a rectangular trough would be 2.34 ft. This shape and size of the trough would allow any coolant that may leak from the piping system at the maximum flow rate to flow safely to the tank containment area.

5.f.ii. Flow rate

- Tank fill/empty times and desired flow rate (Task 4)

Purpose:

Estimate the time and flow rate required to fill and empty all tanks.

Design Consideration:

The design was based on a complete fill of the 15,000 gallon clean fluid tank within one 8-hour shift. Time to fill the tank will be based on completion within 3-4 hours to allow time for hooking up, disconnecting and cleanup.

Drawings and Diagrams:

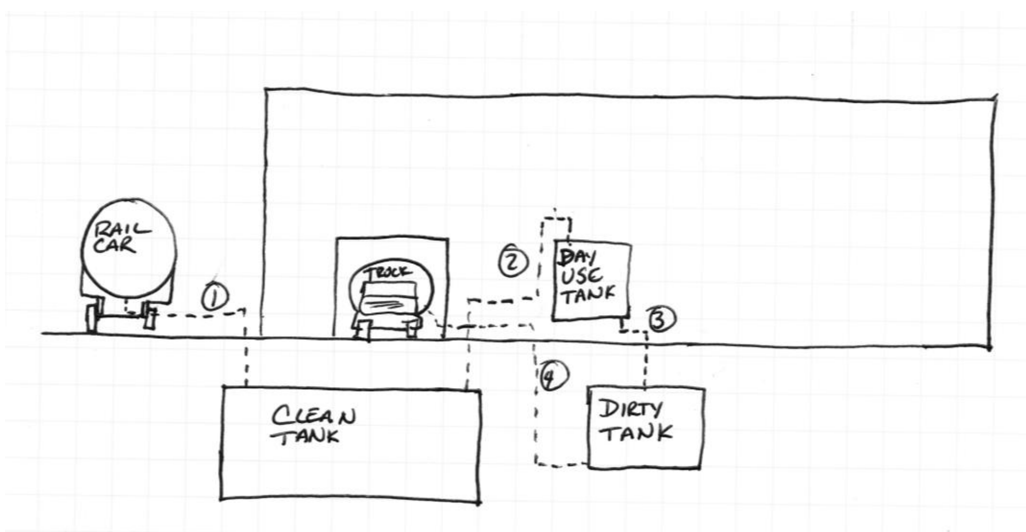


Figure 2-1

Data and variables:

$\text{Volume}_{\text{Train to Clean Tank}} = 15{,}000\ \text{Gal.}$

$\text{Volume}_{\text{Clean Tank to Day use tank}} = 1{,}000\ \text{Gal.}$

$\text{Volume}_{\text{Day use tank to Dirty Tank}} = 1{,}000\ \text{Gal.}$

$\text{Volume}_{\text{Dirty Tank to Truck}} = 4{,}000\ \text{Gal.}$

$\text{Time}_{\text{Train to Clean Tank}} = 240\ \text{min.}$

$\text{Time}_{\text{Clean Tank to Day use tank}} = 20\ \text{min.}$

$\text{Time}_{\text{Day use tank to Dirty Tank}} = 20\ \text{min.}$

$\text{Time}_{\text{Dirty Tank to Disposal Truck}} = 60\ \text{min.}$

Materials:

No materials used in this step.

Procedure:

Flow rates will be calculated using the equation: Flow rate = Volume/Time. Each flow rate can be calculated separately since all operations can be conducted simultaneously. The flow rates will be broken down into 4 separate functions:

1. Rail car to clean holding tank
2. Clean holding tank to day use tank
3. Day use tank to dirty coolant tank
4. Dirty coolant holding tank to disposal truck

Calculations:

TRAIN TO CLEAN TANK

GIVEN: Volume = 15,000 gallons (V)
time = 240 MIN. (T)

$$\text{FLOW RATE} = Q = \frac{V}{T} = \frac{15{,}000\ \text{gal.}}{240\ \text{min}} = \underline{\underline{62.5\ \text{gpm}}}$$

$$\frac{1\ \frac{ft^3}{s}}{449\ \text{gpm}} \cdot 62.5\ \text{gpm} = \underline{0.139\ \frac{ft^3}{s}} \cdot \frac{60\ s}{1\ \text{min}} = \boxed{8.35\ \frac{ft^3}{\text{min}}}$$

Figure 2-2

Summary:

Stage	Sub-systems	Volume (gallons)	Time (minutes)	Flowrate (gpm)	Flowrate (scfm)
1	Train to Clean Tank	15000	240	62.5	8.35
2	Clean Tank to Day use tank	1000	20	50	6.68
3	Day use tank to Dirty Tank	1000	20	50	6.68
4	Dirty Tank to Truck	4000	60	66.67	8.91

Table 1-5

5.f.iii. Pipe sizing

- Piping layout & pipe diameter and lengths (task 5)

Purpose:

Specify the layout of the piping system, material type, sizes and lengths of all pipes.

Data and variables:

$V = Velcoity$

$Q\ = Flowrate$

$D = Diameter\ (ID)$

$L = Overall\ length\ of\ pipe$

$Z = Height\ of\ tank$

$h_L = Energy\ losses$

$Vcrt = Critical\ Veloctiy$

Analysis:

Pipe diameters were calculated and then estimated into standard sizes based Bernoulli's equation for the gravity driven systems and the volumetric flow rate equation (based on critical velocity) for the pump driven systems. The appropriate fittings and piping system components were selected based on the pipe diameter. Below is a list of the subsystems and the method of delivery that is used will be used.

Calculations:

Pumped coolant piping system:
Clean fluid from Railcar to clean tank

<u>Given Values:</u> $Q = 8.35 \frac{ft^3}{m} = 0.139167 \frac{ft^3}{s}$

$V_{crt} = 10 \frac{ft}{s}$

We need to find pipe diameter (D) Based on the critical velocity.

<u>Solution:</u> $Q = VA \Rightarrow \frac{Q}{V_{crt}} = \frac{\pi D^2}{4}$

$$\sqrt{\frac{4\left(\frac{Q}{V_{crt}}\right)}{\pi}} = D = \sqrt{\frac{4\frac{(0.139167)}{10}}{\pi}} = 0.133\ ft$$

$$\boxed{D = 0.133\ ft = 1.597''}$$

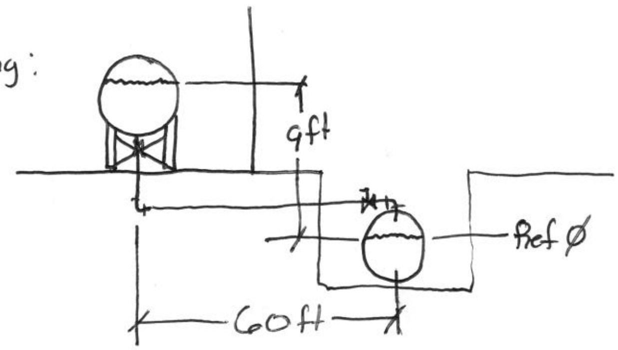
WE HAVE CHOSEN TO USE COMMERCIALLY AVAILABLE 2" PIPE SIZE WITH SCH 40 WALL THICKNESS. THIS PIPING HAS AN INSIDE DIAMETER OF 2.067 in

Figure 2-3

Gravity drained piping system:

Used fluid from day use tank to dirty tank

Drawing:



$Q = 6.68 \frac{ft^3}{m} = 0.1113 \frac{ft^3}{s}$

$\varepsilon = 0.00015\ ft$

$\eta = 0.00003525\ \frac{lb \cdot s}{ft^2}$

$\rho = 1.8236\ \frac{slug}{ft^3}$

USE Bernoullis eqn to find pipe diameter.

Solution:

$$\cancel{\frac{P_1}{\gamma}}^{0} + \cancel{\frac{V_1^2}{2g}}^{0} + Z_1 = \cancel{\frac{P_2}{\gamma}} + \cancel{\frac{V_2^2}{2g}} + \cancel{Z_2} + h_{L1\text{-}2}$$

$$Z_1 = h_{L1\text{-}2} \Rightarrow Z_1 = f\frac{L}{D}\frac{V_{1\text{-}2}^2}{2g} + K\frac{V_{1\text{-}2}^2}{2g}$$

$$Z_1 = \frac{V_{1\text{-}2}^2}{2g}\left(f\frac{L}{D} + \Sigma K\right) \Rightarrow V_{1\text{-}2} = \sqrt{\frac{(Z_1)(2g)}{\left(f\frac{L}{D} + \Sigma K\right)}}$$

find K Values:

$$\Sigma K = \left(4K_{elbow} + 2K_{valve} + K_{in} + K_{out}\right)$$

$K_{elbow} = 30\ ft \qquad K_{in} = 0.5$

$K_{valve} = 8ft \qquad K_{out} = 1.0$

$$\Sigma K = (f_T \cdot ((2 \cdot 30) + (2 \cdot 8)) = (f_T\,76) + 1.5$$

We are planning to use 2" sch 40 pipe so I.D. will be 0.17225 ft

$$D/\varepsilon = \frac{0.17225\ ft}{0.00015} = 1148.33 \Rightarrow f_T = 0.020$$

$$R_N = \frac{VD\rho}{\eta} = \frac{4Q}{\pi D^2}\left(\frac{D\rho}{\eta}\right) = \frac{4(0.1113)}{\pi(0.17225)^2}\left(\frac{0.17225\ (1.8236)}{\pi\ (0.00003525)}\right) \Rightarrow \boxed{R_n = 13{,}547.73}$$

Figure 2-4

$$f = \frac{0.25}{\left(\text{Log}\left(\frac{1}{3.7 D/\varepsilon} + \frac{5.74}{R_N^{0.9}}\right)\right)^2} = \frac{0.25}{\left(\text{Log}\left(\frac{1}{3.7(1148)} + \frac{5.74}{13{,}547.73}\right)\right)^2} \Rightarrow \underline{f_i = 0.0403}$$

$$V_{1\text{-}2_i} = \sqrt{\frac{(z_i)(2g)}{\left(f\frac{L}{D} + \Sigma K\right)}} = \sqrt{\frac{5(2\cdot 32.2)}{\left(\left(0.0403\frac{60}{0.17225}\right) + \left(\left(0.020\cdot 76\right) + 1.5\right)\right)}}$$

$$\underline{V_{1\text{-}2} = 4.345\ ft/s}$$

$$A = \frac{Q}{V} \Rightarrow \frac{0.1113}{4.345} = 0.0256\ ft^2$$

$$A = \frac{\pi D^2}{4} \Rightarrow D = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4(0.0256)}{\pi}} = 0.1805\ ft$$

$$\frac{D}{\varepsilon} = \frac{0.1805}{0.00015} = 1203.6 \qquad \underline{D = 2.166''}$$

We will still choose 2" sch. 40 pipe size.

Figure 2-5

pump driven system pipe diameter calculations					
Diameter clean tank to reservoir tank(ft)		ft to inches	given Vcrt (ft/s)	Q	velosity
0.168427364		2.021128372	10	0.2228	0.008416737
diameter pipe from train to cleen tank (ft)		ft to inches	given Vcrt (ft/s)	Q	Velosity
0.142345826		1.708149909	10	0.15914	0.006011847
diameter pipe durty tank to truck (ft)		ft to inches	given Vcrt (ft/s)	Q	Velosity
0.158777023		1.905324274	10	0.198	0.007479865
Diameter pipe resevoir to durty tank (ft)		ft to inches	given Vcrt (ft/s)	Q	Velosity
0.137504935		1.650059224	10	0.1485	0.005609899
summary	delivery method	normail pipe D (2")	calculated pipe inside D	Pipe length (ft)	enrgy losses
train to clean tank	pump	2.067	1.708"	375	8.32417E-05
clean to resevoir tank	cravity	2.067	2.021 "	54.33	0.000150273
reservior to durty tan	pump	2.067	1.650 "	10	5.18548E-05
durty tank to truck	pump	2.067	1.905 "	285	0.000101815

Table 1-6

Summary:

Sub-systems	Delivery Method	Calculated Pipe Inside	Nominal Pipe Dia. / Inside	Overall Length of Pipe
Train to Clean tank	Pump	1.948”	2” / 2.067”	350 ft.
Clean tank to Day use tank	Pump	2.131”	2” / 2.067”	60 ft.
Day use tank to Dirty tank	Gravity	2.166”	2” / 2.067”	80 ft.
Dirty tank to Truck	Pump	1.823”	2” / 2.067”	50 ft.

Table 1-7

Clean Tank to Day use tank Layout:

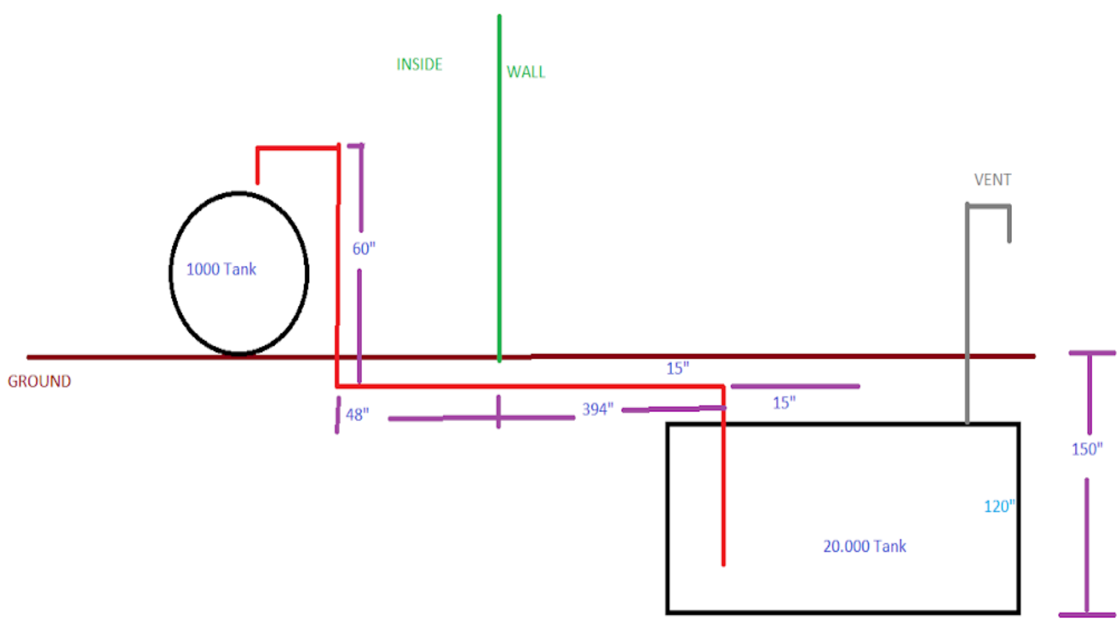


Figure 2-6

Day use tank to Dirty Tank Layout:

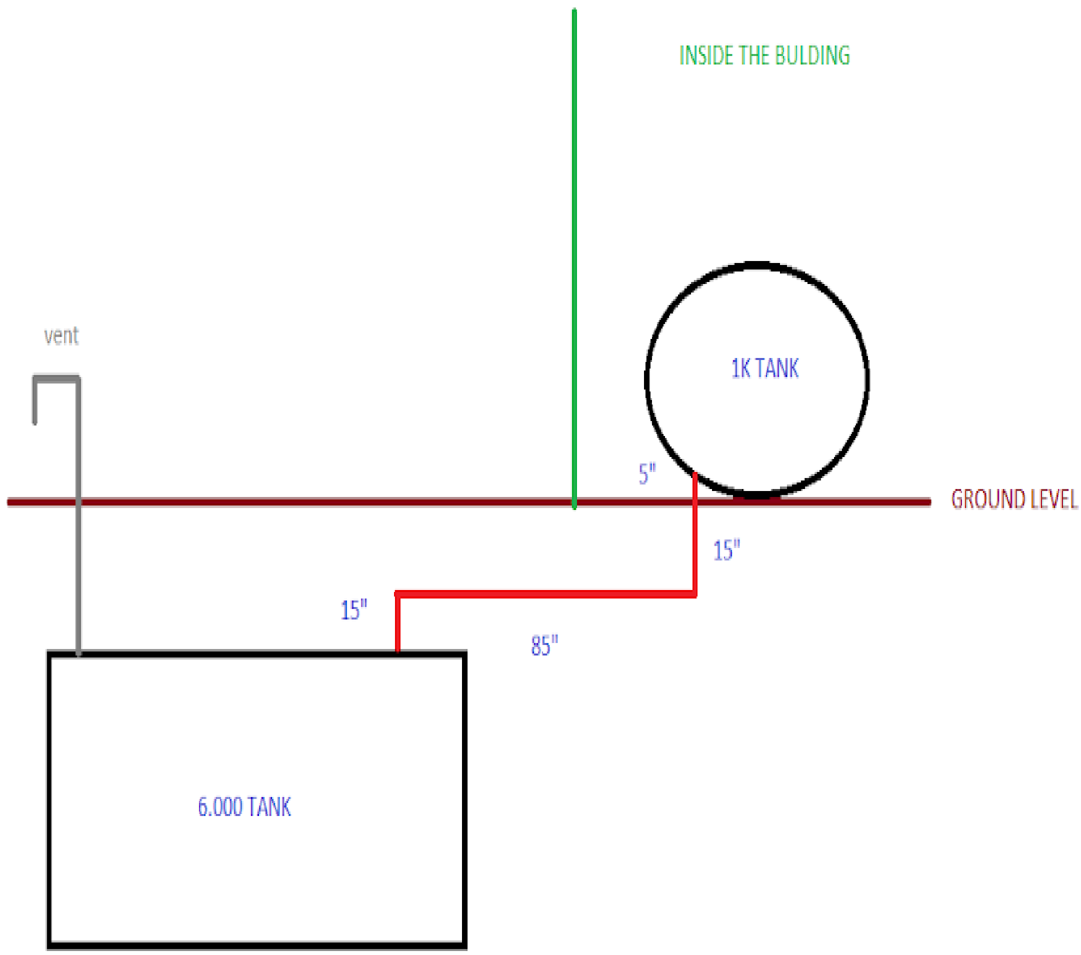


Figure 2-7

- Pipe thickness (task 9)

Purpose:

Calculate the max operating pressure in the pump line in order to determine the thickness or schedule of the pipe necessary.

Drawings & Diagrams:

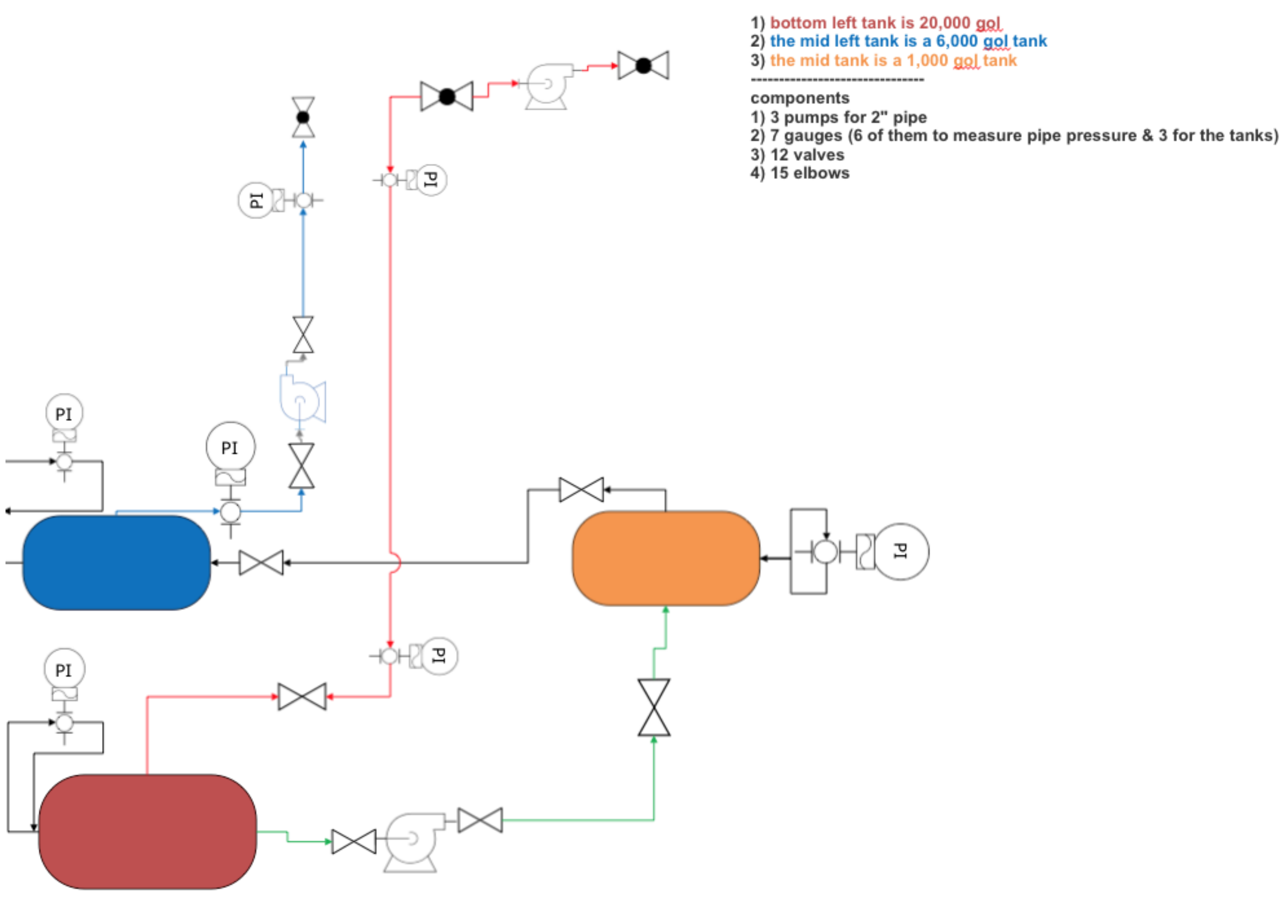


Figure 2-8

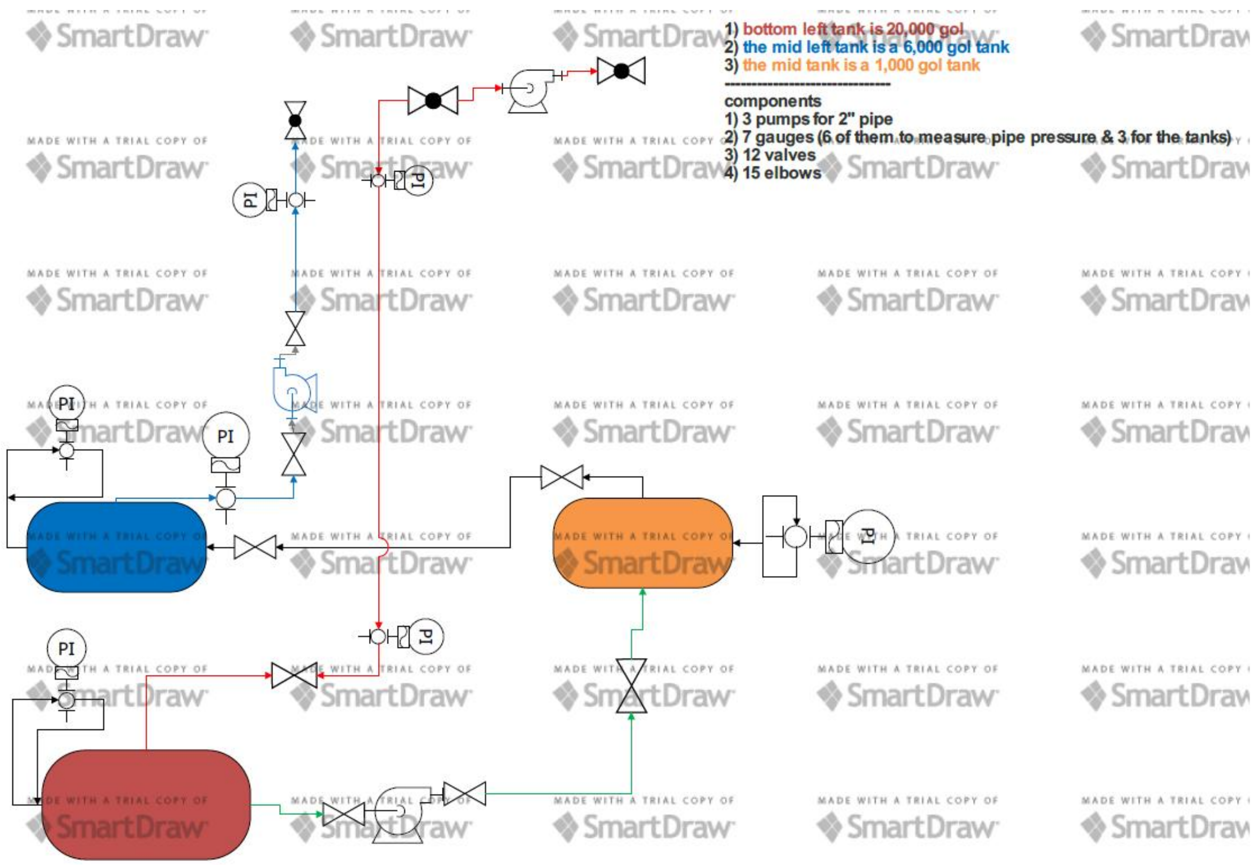


Figure 2-9

Design Considerations:

- Pump will pump from clean cylindrical tank to day-use tank a total of 1,000 gallons in 20 minutes
- Vb will be zero
- 2” Galvanized Steel Pipe
- Tank is filled with coolant
- Pressure is greatest at outlet of pump

Data & Variables:

- $Q = 6.68\ ft^3/min$ or $Q = 50\ gpm$
- $V_B = 0\ ft/s$
- $V_A = 9.55\ ft/s$
- $Z_A = 0\ ft$
- $Z_B = 3\ ft$
- $Total\ Pipeline\ Length\ (L) = 350\ ft$
- $\gamma = 58.66 \frac{lb}{ft^3}$
- $h_L = 65\ ft$

Procedure:

We will use Bernoulli's Equation to calculate the pressure at Point A which is located right at the outlet of the pump. We will take variables that were previously calculated for the pump line after the pump. Once we find Pa, we will know that this is the maximum pressure at which the pipeline will ever have to deal with. Using a pipe thickness equation from Chapter 11, we will be able to find the nominal thickness needed for the pipe line.

Calculations:

Bernoulli's Equation

$$\left(\frac{P_a}{\gamma}\right) + \left(\frac{V_a^2}{2g}\right) + z_a = \left(\frac{P_b}{\gamma}\right) + \left(\frac{V_b^2}{2g}\right) + z_b + h_L$$

We know: Pb = 0, Vb = 0, and Za = 0, Therefore we are left with:

$$P_a = [z_b + \ h_L - \left(\frac{V_a^2}{2g}\right)]\gamma$$

$$P_a = \left[3\ ft + 65\ ft - \left(\frac{\left(9.55 \frac{ft}{s}\right)^2}{2\left(32.2 \frac{ft}{s^2}\right)}\right)\right] * (58.66 \frac{lb}{ft^3})$$

$P_a = 3{,}905.8\ psf$ or $P_a = 27.1\ psi$

Now that we know the maximum pressure that will be generated by the pump, we can use the Basic Wall Thickness Calculation to find the needed nominal thickness for the pipe.

Basic Wall Thickness Calculation

$$t = [\frac{PD}{2(SE + PY)}]$$

We know for 2” Galvanized Steel Pipe:

- Y = 0.4
- P = 57.4 psi
- E = 0.80
- S = 20,000 psi
- A = 0.08

$$t = [\frac{(27.1psi)(2.375in)}{2((20{,}000psi)(0.80) + (27.1psi)(0.4))}]$$

$$t = 0.002005 \text{ in}$$

Summary:

By looking at the above calculations, we can see that the maximum pipe pressure will be 27.1 psi. In order to design a reliable and working system, we need to make sure that all of the pipes and components in the system are capable to withstand that pressure. Using the calculated pressure, we found that the thickness of the pipe required is 0.002005 in. Using schedule 40 pipe the pipe will have a thickness of 0.154 in. which means we are far above the required pipe thickness of the pressure generated.

Materials:

- 2” Galvanized Pipe (Sch. 40)
- 2” Pump
- Cylindrical tank
- Coolant

Analysis:

Since we calculated the max pressure in the pipeline to be 27.1 psi, we can see that we are far below the limit of the pressure rating in the pipe. This means we can safely continue with our design.

- Fittings (task 6)

Purpose:

Specify the number, types, material, and size of all valves, fittings, and associated components of the piping lines.

Drawings & Diagrams:

No Drawings or Diagrams used in this section

Design Consideration:

Considerations were made to accommodate the piping run layout, Tank inlet/outlet connections, valve connections, as well as future pressure indication and water hammer arrestors.

Data and variables

No varaiables used in this section

Materials:

Materials to be used are galvanized steel pipe and fittings, steel valves, flanges, and hardware, and flange gaskets. The materials are compatible and recommended for water, which holds similar corrosive properties as the coolant used in this piping system.

Calculations:

No Calculations made in this section

Summary:

Train to Clean Tank (Pumped)

Before Pump		
Qty.	**Material**	**Description**
1	Galvanized Steel	2” Galvanized Steel Welded Pipe ASTM A-53, 21ft. Lengths
2	Galvanized Steel	2” 90 Degree Elbow FNPT ends
2	Galvanized Steel	Class 150 2” Threaded Pipe Flange
2	Buna – N / Steel	2” Flange Gasket w/ Hardware
1	Steel	Class 150 4” Threaded Pipe Flange
1	Buna – N / Steel	4” Flange Gasket w/ Hardware
1	Galvanized Steel	3” x 4” Reducing Bushing
1	Cast Steel	2” Gate Valve, Class 150 Flanged ends
After Pump		
Qty.	**Material**	**Description**
17	Galvanized Steel	2” Galvanized Steel Welded Pipe ASTM A-53, 21ft. Lengths
20	Galvanized Steel	2” Pipe Coupling FNPT ends
6	Galvanized Steel	2” 90 Degree Elbow FNPT ends
1	Galvanized Steel	2” x 2” x 1/2” Reducing Tee FNPT ends
1	Galvanized Steel	2” x 2” x 1” Reducing Tee FNPT ends
1	Steel	Class 150 1” Threaded Pipe Flange
1	Buna – N / Steel	1” Flange Gasket w/ Hardware
5	Galvanized Steel	Class 150 2” Threaded Pipe Flange
5	Buna – N / Steel	2” Flange Gasket w/ Hardware
1	Galvanized Steel	1” x 2” Reducing Adapter
2	Cast Steel	2” Gate Valve, Class 150 Flanged ends
1	Steel	2” Check Valve, FNPT ends

Table 1-8

Clean Tank to Day Use Tank (Pumped)

Before Pump		
Qty.	**Material**	**Description**
1	Galvanized Steel	2” Galvanized Steel Welded Pipe ASTM A-53, 21ft. Lengths
1	Galvanized Steel	2” 90 Degree Elbow FNPT ends
2	Galvanized Steel	Class 150 2” Threaded Pipe Flange
2	Buna – N / Steel	2” Flange Gasket w/ Hardware
1	Steel	Class 150 4” Threaded Pipe Flange
1	Buna – N / Steel	4” Flange Gasket w/ Hardware
1	Galvanized Steel	3” x 4” Reducing Bushing
1	Cast Steel	2” Gate Valve, Class 150 Flanged ends
After Pump		
Qty.	**Material**	**Description**
3	Galvanized Steel	2” Galvanized Steel Welded Pipe ASTM A-53, 21ft. Lengths
2	Galvanized Steel	2” Pipe Coupling FNPT ends
3	Galvanized Steel	2” 90 Degree Elbow FNPT ends
1	Galvanized Steel	2” x 2” x 1/2” Reducing Tee FNPT ends
1	Galvanized Steel	2” x 2” x 1” Reducing Tee FNPT ends
1	Steel	Class 150 1” Threaded Pipe Flange
1	Buna – N / Steel	1” Flange Gasket w/ Hardware
5	Galvanized Steel	Class 150 2” Threaded Pipe Flange
5	Buna – N / Steel	2” Flange Gasket w/ Hardware
1	Galvanized Steel	1” x 2” Reducing Adapter
2	Cast Steel	2” Gate Valve, Class 150 Flanged ends
1	Steel	2” Check Valve, FNPT ends

Table 1-9

Day Use Tank to Dirty Tank (Gravity)

Qty.	Material	Description
3	Galvanized Steel	2” Galvanized Steel Welded Pipe ASTM A-53, 21ft. Lengths
4	Galvanized Steel	2” Pipe Coupling FNPT ends
4	Galvanized Steel	2” 90 Degree Elbow FNPT ends
1	Galvanized Steel	2” x 2” x 1/2” Reducing Tee FNPT ends
1	Galvanized Steel	2” x 1” x 2” Reducing Tee FNPT ends
4	Galvanized Steel	Class 150 2” Threaded Pipe Flange
4	Buna – N / Steel	2” Flange Gasket w/ Hardware
2	Cast Steel	2” Gate Valve, Class 150 Flanged ends

Table 1-10

Analysis:

Elbows were used for bends, couplings were used for lengths of pipe, and tees were uses for connecting other associated components. ANSI flanges were used to make connections to the tanks and valves. Accommodations were also made for the flange gasket and hardware material

- Water hammer (task 10)

Purpose:

Check your design for water hammer problems. Check if the pipe you selected can hold such over-pressure, if not, propose the use of a water-hammer arrestor by specifying the pressure that it will handle.

Design Considerations:

- Pump will pump from clean cylindrical tank to reservoir a total of 1,000 gallons in 10 minutes
- Vb will be zero since we are assuming it is a large tank
- 2" Galvanized Steel Pipe
- Tank is filled with coolant
- Pressure is greatest at oulet of pump
- Pressure in the pump line will be the greatest of all the sub-systems of the system

Data & Variables:

- E_{steel} = 2.90075 x 10^7 psi or **2.0 x 10^{11} N/m^2**
- E_o = 316,000 psi or **2.179 x 10^9 N/m^2**
- I.D. = 2.067 in or **0.0525 m**
- δ = 0.154 in or **0.003912 m**
- ρ = 1.824 slugs/ft^3 or **940.45 kg/m^3**
- Pa = 27.1 psi or **186,847.9 N/m^2**
- Va = 9.55 ft/s or **2.913 m/s**

Procedure

First we will calculate C given the variables listed above. Then we calculate the change in pressure due to the water hammer. Once we have found this change in pressure, we will add the max pressure that was calculated in Task 9. This will then give us Pmax in the pipe due to water hammer. Once we find the Pmax we will need to find the thickness of the pipe required to handle the overpressure, if it is over 0.154.

Calculations

Equation for C Factor

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

$$C = \frac{\sqrt{\frac{(2.179 \text{ x } 10^9 \text{N/m2})}{940.45 \text{ kg/m3}}}}{\sqrt{1 + \frac{(2.179 \text{ x } 10^9 \text{ N/m2})(0.0525 \text{ m})}{(2.0 \text{ x } 10^{11} \text{ N/m2})(0.003912 \text{ m})}}}$$

$$C = \frac{1{,}522.06}{1.0706} = 1{,}421.7$$

Now we can calculate the change in pressure due to the water hammer,

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

$$\Delta P = (940.45 \text{ kg/m3})(1{,}421.7)(2.913 \text{ m/s})$$

$$\Delta P = 3{,}894{,}750 \text{ N/m}^2 \text{ or } \mathbf{564.9 \text{ psi}}$$

Now that we know the change in pressure due to water-hammer, we need to find the max pressure by incorporating the pressure from Task 9.

$$P_{max} = 564.9\,psi + 27.1\,psi$$

$$P_{max} = 592 \text{ psi}$$

Now we will find the pipe thickness required to hold this over pressure,
We know for 2" Galvanized Steel Pipe:

- $Y = 0.4$
- $P_{max} = 622.29$ psi
- $E = 0.80$
- $S = 20{,}000$ psi

$$t = \left[\frac{(592 \text{ psi})(2.375in)}{2((20{,}000psi)(0.80) + (592 \text{ psi})(0.4))}\right]$$

$$t = 0.0433 \text{ in}$$

We can see that the thickness required to withhold the overpressure from the water hammer needs to be 0.0433 inches thick which is still less than our selected pipe thickness at 0.154 inches thick.

Materials:

- 2" Galvanized Pipe (Sch. 40)
- 2" Pump
- Cylindrical tank
- Coolant

Summary:

By looking at the above calculations, we can see that the over pressure caused by water-hammer in the pipe will be 592 psi. This only requires a pipe thickness of 0.0433 inches which is still less than the thickness of our pipe selection at 0.154 inches. We will not need to install a water-hammer arrestor because our pipe will be able to withstand the overpressure caused by water-hammer.

Analysis:

We would not need a water-hammer arrestor since our pipe selection is able to withstand the overpressure.

5.f.iv. Provide pipeline support info.

- Type of supports
- Distance between supports
- Forces on the supports

Purpose:

Decide the type of supports, the force acting upon each support, and the maximum distance apart the supports should be placed.

Design Consideration:

Considerations were made in regards to the supports based on the surfaces which the pipe will be running above. The maximum deflection of the pipe cannot exceed 1% of the diameter of the pipe. The supports will also have to be rated to withstand the forces acting upon them.

Data and variables

$D_o = outside\ diamter\ of\ pipe$
$d_i = inside\ diameter\ of\ pipe$
$g\ = gravity$
$\rho_{cool} = density\ of\ coolant$
$\rho_{stl} = density\ of\ galvanized\ steel$
$E_{stl} = modulus\ of\ elasticity\ of\ galvanized\ steel$
$I\ = moment\ of\ inertia$
$V = volume$
$m = mass$
$W = weight$

Materials:

Galvanized steel, coolant, tube supports, and beam deflection equations.

Analysis:

The piping support selected will be a bolt down adjustable pipe support suitable for 2" pipe. The maximum spacing of the supports will be calculated using the weight of the pipe and coolant using the beam defection equation.

Drawings & Diagrams:

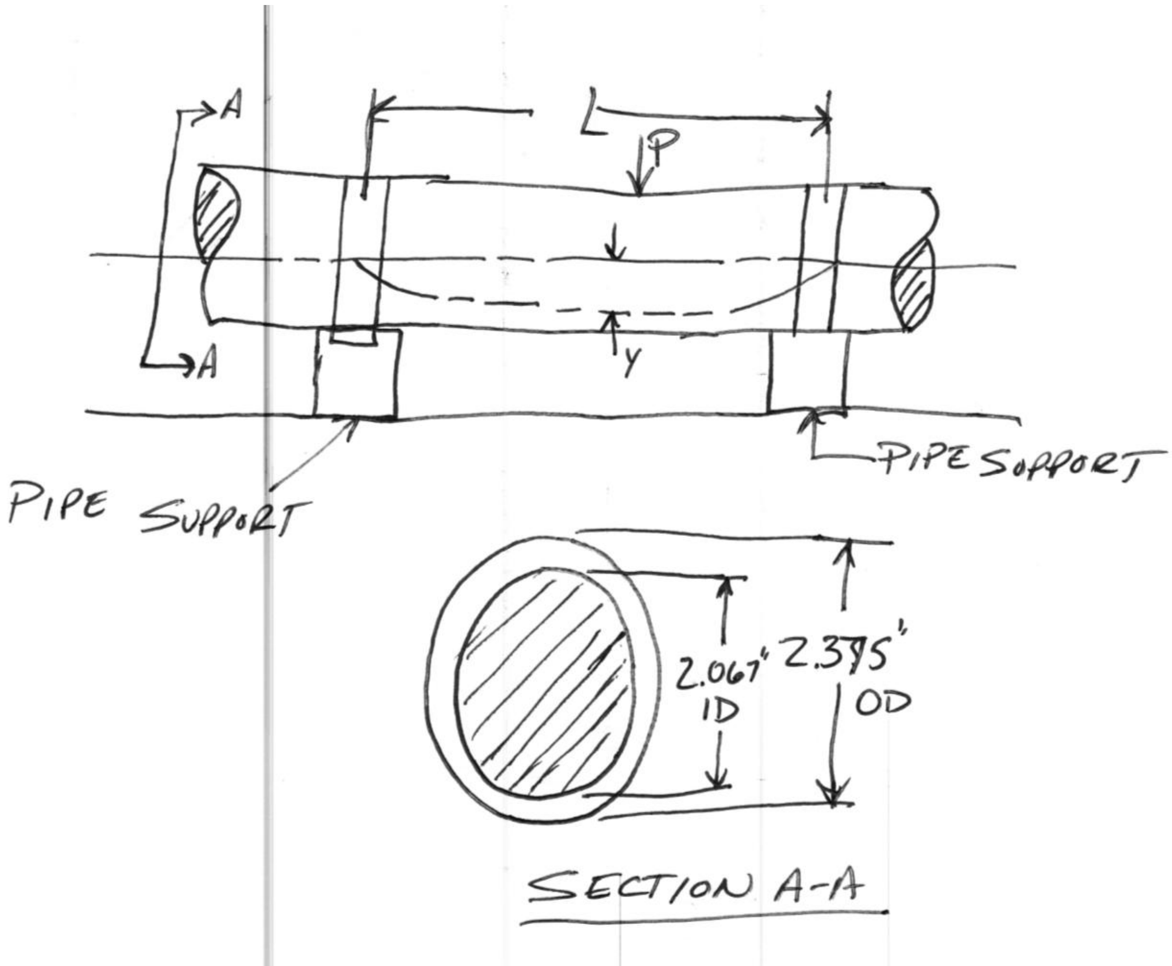


Figure 2-10

A calculation will also be done to determine the force acting on each support.

Calculations:

PIPE SUPPORTS

GIVEN: $D_o = 2.375$ in

$d_i = 2.067$ in

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

$\rho_{coolant} = 1.8236\ \frac{slug}{ft^3} = 1.055 \times 10^{-3}\ slug/in^3$

$\rho_{steel} = 0.284\ lb/in^2 = 8.82 \times 10^{-3}\ slug/in^3$

$E_{steel} = 2{,}900{,}000.\ lb/in^2$

FIND: DISTANCE BETWEEN SUPPORTS (L)

Solution:

WEIGHT OF STEEL & COOLANT

$W = mg \; ; \quad m = \frac{\rho}{V}$

STEEL:

$$m = \frac{\rho_{stl}}{V} = \frac{8.82 \times 10^{-3}}{A_o L - A_i L} = \frac{8.82 \times 10^{-3}}{\frac{\pi (2.375)^2}{4} L - \frac{\pi (2.067)^2}{4} L}$$

$$m = 0.00821 L \Rightarrow W = mg = (0.00821)(386.4)(L)$$

$$W_{stl} = 3.1716 L$$

COOLANT:

$$m = \frac{\rho}{V} = \frac{1.055 \times 10^{-3}}{A_o L - A_i L} = \frac{1.055 \times 10^{-3}}{\frac{\pi (2.375)^2}{4} - \frac{\pi (2.067)^2}{4}}$$

$$m = 9.818 \times 10^{-4} L \Rightarrow W = mg = (9.818 \times 10^{-4})(386.4)(L)$$

$$W_{coolant} = 0.3794 L$$

$$W_{total} = P = W_{stl} + W_{coolant} = (3.1716 L) + (0.3794 L)$$

$$P = 3.551 L$$

Figure 2-11

MOMENT OF INERTIA:

$$I = \frac{\pi\left(D_o^4 - d_i^4\right)}{64} = \frac{\pi\left(2.375^4 - 2.067^4\right)}{64}$$

$$I = 0.6657 \text{ in}^4$$

STANDARD ALLOWABLE DEFLECTION IS 1% PIPE DIAMETER

$$Y = 1\%\,OD = 0.01(2.375") = 0.02375"$$

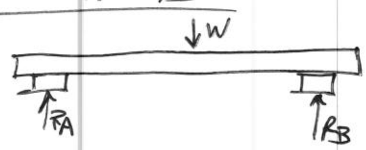
$$y = -\frac{PL^3}{48EI}$$

$$0.02375 = -\frac{(3.551L)L^3}{48(29\times10^6)(0.6657)}$$

$$0.02375 = 383\times10^{-9}L^4$$

$$L = \left(\frac{0.02375}{3.83\times10^{-9}}\right)^{1/4} = 49.90" = 4.16\text{ ft}$$

FORCE ON SUPPORTS



$W = 3.551(L)$ $\quad L = 49.9"$

$W = 3.551(49.9) = 177.195 \text{ lbf}$

$\Sigma F_x = W - R_A - R_B = 177.195 - R_A - R_B$

$R_A + R_B = 177.195$ $\quad R_A = R_B$

$R_A = 88.59 \text{ lb}\uparrow$

$R_B = 88.59 \text{ lb}\uparrow$

Figure 2-12

Summary:

Maximum distance between supports: 4.16 ft.

Maximum weight on each support: 88.6 lbf.

Support type: 2” Bolt Down Adjustable Support (10,000 lb. max)

5.f.v. Energy losses. (task 7)

Purpose:

Develop the hydraulic analysis of all parts of the system, including energy losses due to friction and minor losses for each subsystem.

Design Consideration:

The design considerations made pertained to the piping routes and trying to minimize the amount of losses yet provide an installation that met the design requirements. Piping routes conform to the building layout yet maintain a professional installation.

Calculations:

GIVEN:

FROM PREVIOUS SECTIONS

D (PIPE ID) $= 0.17225$ ft

$\varepsilon = 0.00015$ ft

$\eta = 0.00003525 \ \frac{lb \cdot s}{ft^2}$

$\rho = 1.8236 \ \frac{slug}{ft^3}$

$L = 350$ ft

$V = 5.81$ ft/s

FIND: ENERGY LOSSES IN SUB-SYSTEM (h_{LA-B})

Solution: USE SIMPLIFIED BERNOULLI'S EQUATION

$$\cancel{\frac{P_A}{\gamma}}^{0} + \cancel{\frac{V_A^2}{2g}}^{0} + Z_A = \cancel{\frac{P_B}{\gamma}}^{0} + \cancel{\frac{V_B^2}{2g}}^{0} + Z_B + h_{LA-B}$$

$$Z_A = h_{LA-B}$$

$$R_N = \frac{VD\rho}{\eta} = \frac{(5.81)(0.17225)(1.8236)}{0.00003525} = 51{,}759.9$$

$$D/\varepsilon = \frac{0.17225}{0.00015} = 1148.33 \Rightarrow f_T = 0.020 \text{ from Moody's curve}$$

$$f = \frac{0.25}{\left(\operatorname{Log}\left(\frac{1}{3.7\,D/\varepsilon} + \frac{5.74}{R_N^{0.9}}\right)\right)^2} = \frac{0.25}{\left(\operatorname{Log}\left(\frac{1}{3.7(1148.33)} + \frac{5.74}{(51{,}759.9)^{0.9}}\right)\right)}$$

$$f = 0.0237$$

K-VALUES (FOR MINOR LOSSES): $K_{elbow} = 30 f_T = 30(0.20) = 0.60$

$K_{TR} = 20 f_T = 20(0.20) = 0.40$

$K_{TB} = 60 f_T = 60(0.20) = 1.20$

$K_{VLV} = 8 f_T = 8(0.020)\ 0.16$

$K_{EXIT} = 1.0$

$K_{Enter} = 0.5$

Figure 3-1

$$h_{L\,PIPE} = f\frac{L}{D}\frac{V^2}{2g}$$

$$h_{L\,\substack{MINOR\\LOSSES}} = K\frac{V^2}{2g}$$

$$h_{L_{A-B}} = h_{L\,PIPE} + h_{L_{EL}} + h_{L_{TR}} + h_{L_{TB}} + h_{L_{VLV}} + h_{L_{ENT}} + h_{L_{EXIT}}$$

$$h_{L_{A-B}} = f\frac{L}{D}\frac{V^2}{2g} + \frac{V^2}{2g}\left(4K_{EL} + K_{TR} + K_{TB} + 2K_{VLV} + K_{ENT} + K_{EXIT}\right)$$

$$h_{L_{A-B}} = (0.0237)\left(\frac{118.77}{0.17225}\right)\left(\frac{5.8085^2}{2(32.2)}\right) + \left(\frac{5.8085^2}{2(32.2)}\right)\Big(4(0.60) + 0.40 + 1.20 +$$

$$\hookrightarrow 2(0.16) + 0.5 + 1.0\Big)$$

$$h_{L_{A-B}} = 8.5612 + 0.524(5.82)$$

$$\boxed{h_{L_{A-B}} = 11.61\ ft}$$

$$h_a = 11.604\ ft$$

Figure 3-2

5.f.vi. Pump selection

- Pump requirements

Purpose:

Calculate head and flow rate to determine minimal requirements for pump(s) needed in order to properly supply coolant from the 15,000 gallon clean tank to the 1,000 gallon reservoir in the desired

Drawings & Diagrams:

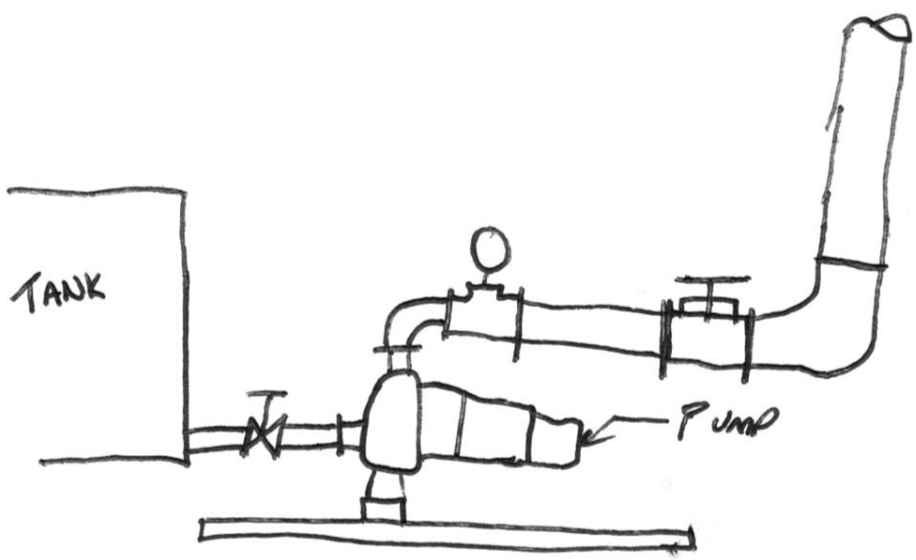


Figure 3-4

Design Considerations:

- Pressured System
- Pump will pump from clean cylindrical tank to reservoir a total of 1,000 gallons in 10 minutes
- 2” Galvanized Steel Pipe
- Clean tank has air vent (no vacuum)

Data & Variables:

- $Q = 6.68\ ft^3/min$ or $Q = 50\ gpm$
- $V_B = 9.55\ ft/s$
- $Z_A = 0\ ft$
- $Z_B = 3\ ft$
- $Total\ Pipeline\ Length\ (L) = 350\ ft$

Procedure:

First , we will need to find flow rate for the pump line. We can use the Q that was calculated in task 4. We can then use Bernoulli's Equation to calculate the total head for the sub-system. This will consist of calculating the energy losses in all the components of the pump line and the friction losses in the pipe. We can also use friction losses and energy losses for the pump system in Task 7. Once total head is calculated we will have the head that is required allowing us to select the proper pump for the system.

Calculations:

Flow Rate from Task 4

$$Q = 50\ \frac{gal}{min}$$

Bernoulli's Equation

$$h_a + \left(\frac{P_a}{\gamma}\right) + \left(\frac{V_a^2}{2g}\right) + z_a = \left(\frac{P_b}{\gamma}\right) + \left(\frac{V_b^2}{2g}\right) + z_b + h_L$$

We know that since Za = 0, Va = 0, Vb = 0, Pa = 0, and Pb = 0.

We have:

$$h_a = z_b + h_L$$

We know from Task 7: $z_b = 3\ ft$ and $h_L = 65\ ft$

$h_a = 3\ ft + 65\ ft$

$$h_a = 68\ ft$$

Summary:

Minimum Pump Requirements	
Q	**6.68 ft^3/min**
h_A	**68 ft**

Table 1-11

Materials:

- 2” Galvanized Pipe/Fittings
- 2” Pump
- Storage tank

Analysis:

We calculated the values at which it would be the toughest for the pump to keep the system working. Therefore to avoid failure of the supply, or a slower flow rate, we need a pump that meets the above requirements.

- Selection of pump type (task 15)

Purpose:

Specify the number of pumps, their types, flow capacities, head requirements, and power required. Prove that you need a kinetic pump (instead of a positive displacement) and also prove that the radial pump is the type of kinetic pump you need.

Drawings & Diagrams:

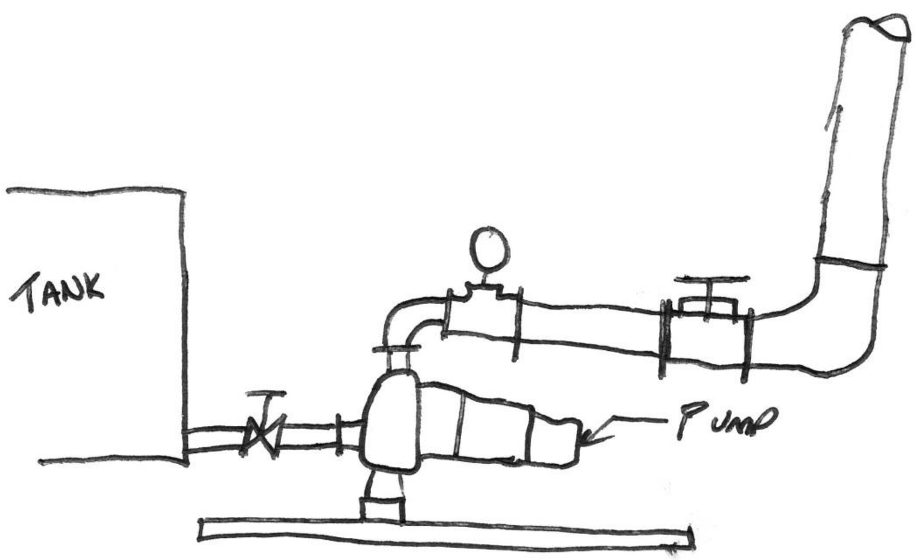


Figure 3-5

Design Considerations:

- Pump will pump from clean cylindrical tank to reservoir a total of 1,000 gallons in 20 minutes
- 2” Galvanized Steel Pipe
- Will pump a coolant with low viscosity similar to water
- Sulzer pumps only

Data & Variables:

- Q =50 gpm
- Ha = 65 ft
- N = 3570 rpm (industry standard)

Procedure

Our system will contain 3 pumps. First we will pick the type of pump that is most suitable for the sub-system. We know we will be pumping low viscosity and always liquid state coolant. Now we need to find the Specific Speed of the pump in order to specify if the pump will be radial flow, axial flow, or mixed flow. To do this, we will use Q and H from Task 8 and use the specific speed formula. Then we will use Q and H from Task 8 and find the size pump we will need. Using the Sulzer graph for the specified pump size we will select an impeller diameter that best suits our system. Then we will calculate the pumps flow capacities and head requirements with new impeller. After that we will find the power using the pump power equation.

Calculation

We will be using a kinetic pump since we are pumping low-viscosity and always liquid coolant. To specify if the pump will be radial flow, axial flow, or mixed flow, we will use the specific speed equation:

Equation for Specific Speed

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

$$N_s = \frac{3570\ \mathrm{rpm}\sqrt{50\ \mathrm{gpm}}}{(65\ \mathrm{ft})^{\frac{3}{4}}}$$

$$N_s = 1102.73$$

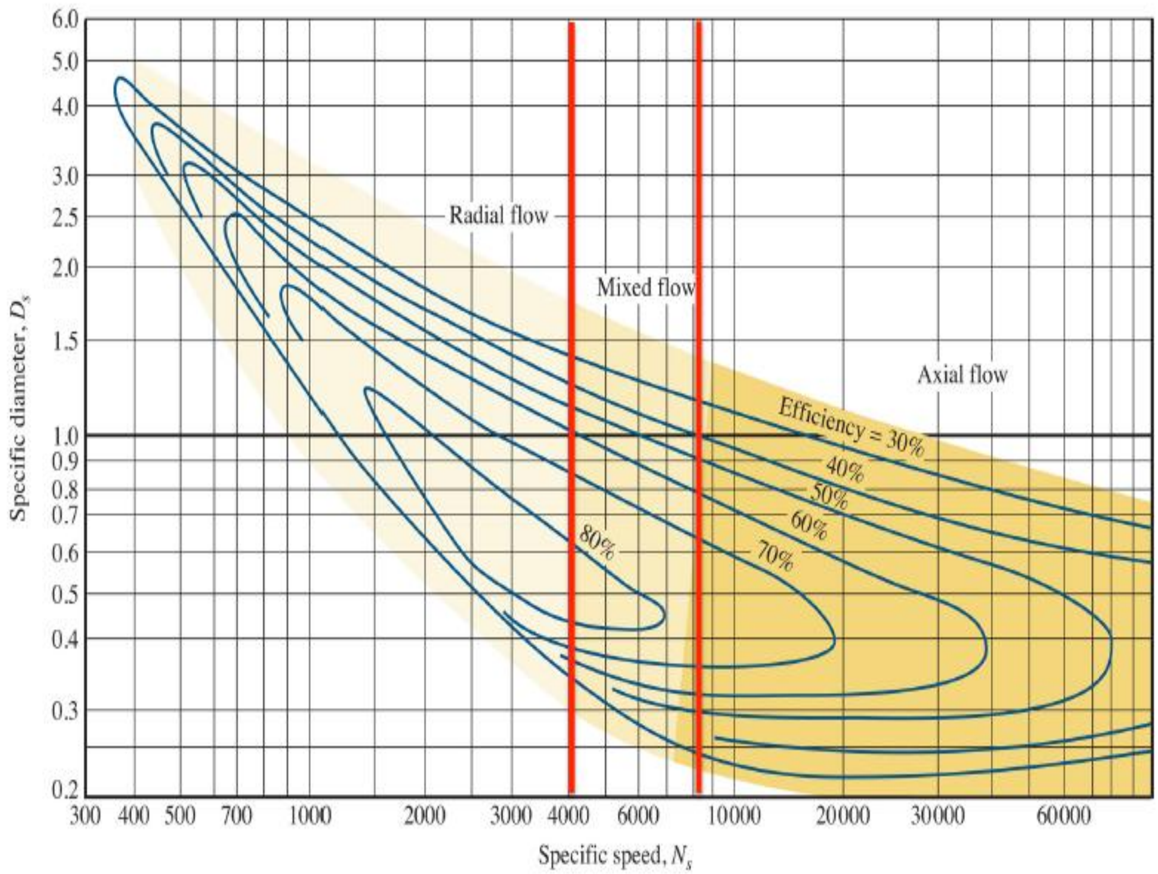


Figure 3-6

We know that N_s < 4,000 is radial flow therefore we will be dealing with a radial (centrifugal) pump.

Now we will use Q and H from Task 8 and find the size pump we will need to find the pump size that is capable of handing our system Q and H. The graph on the following page is how we chose the size of the pump needed. We chose the pump with the closest operating speeds to what we used for the N_s calculation, therefore we will be dealing with pump speeds of N = 3520 rpm.

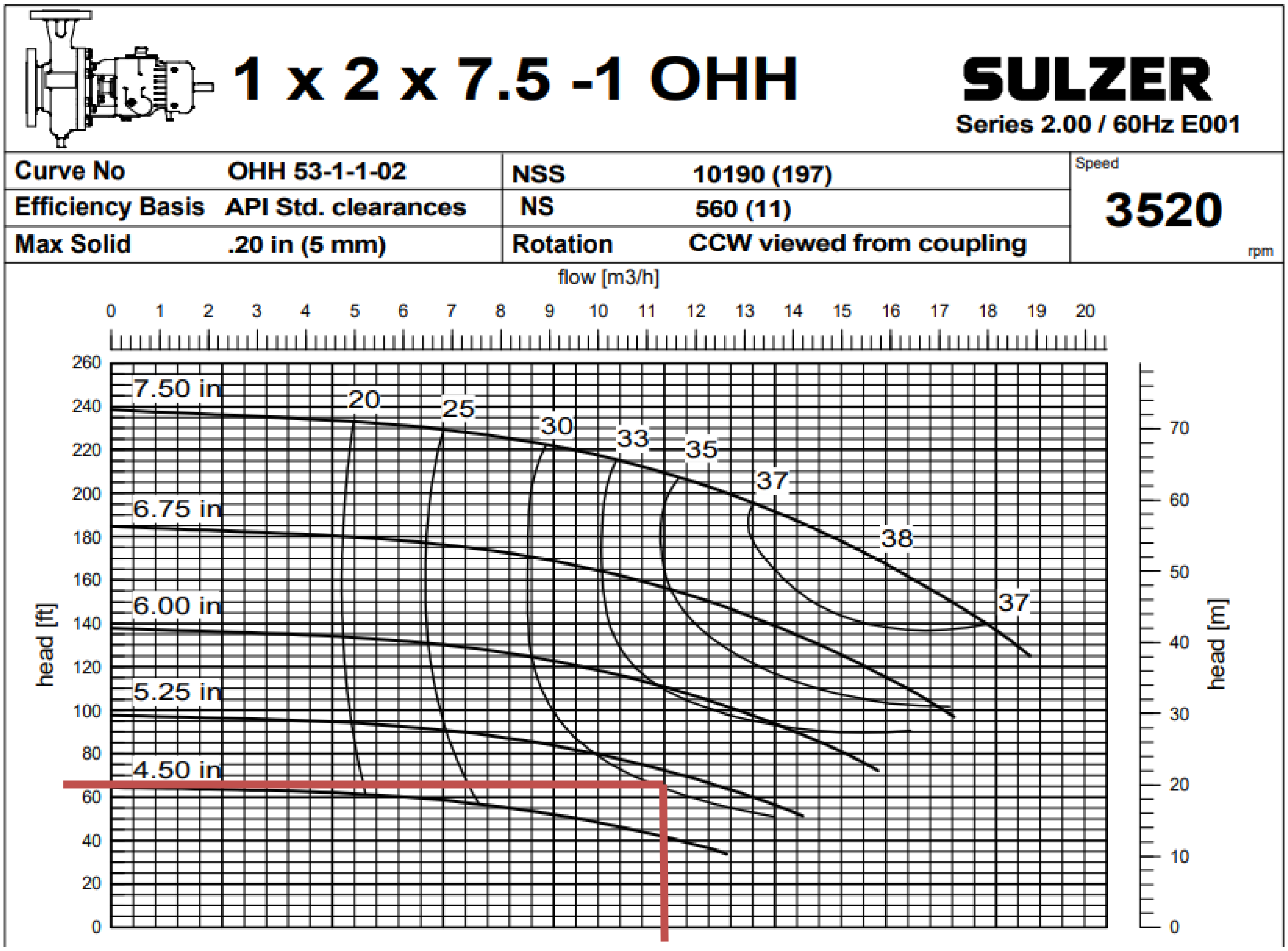


Figure 3-7

From the chart we can see we need a pump size of **1 x 2 x 7.5A-1 0HH**

From the graph we see that we need to go with a 4.50 in impeller in order to meet the head requirement of our system.

Based on the new pump and impeller size, we selected a operation point on the previous graph. Since the operation point does not land on a specific efficient line we will need to select an approximate efficiency value. This value will be approximately **34% efficiency**.

Now we can calculate the power required for the pump using the new values from the Sulzer pump curve graph.

$$P = H_a \gamma Q$$

$$P = (65\ ft)\left(58.66\frac{lb}{ft^3}\right)(8.35\ scfm)$$

$$P = 31{,}837.72\ \frac{lbft}{min} \quad \text{or} \quad P = 0.96\ hp$$

Summary:

Quantity	Type	Impeller Diameter	Flow Capacity	Head Requirement	Power Required
1	**1 x 1 x 7.5-1 0HH**	**4.50 inches**	**52 gpm**	**65 ft**	**0.96 hp**

Table 1-12

- Pump curves, and system curves with operating point

Purpose:

Specify the characteristics of the chosen pumps, point of operation, and actual pump size and weight. Include pump curves with the system curve, and point of operation.

Drawings & Diagrams:

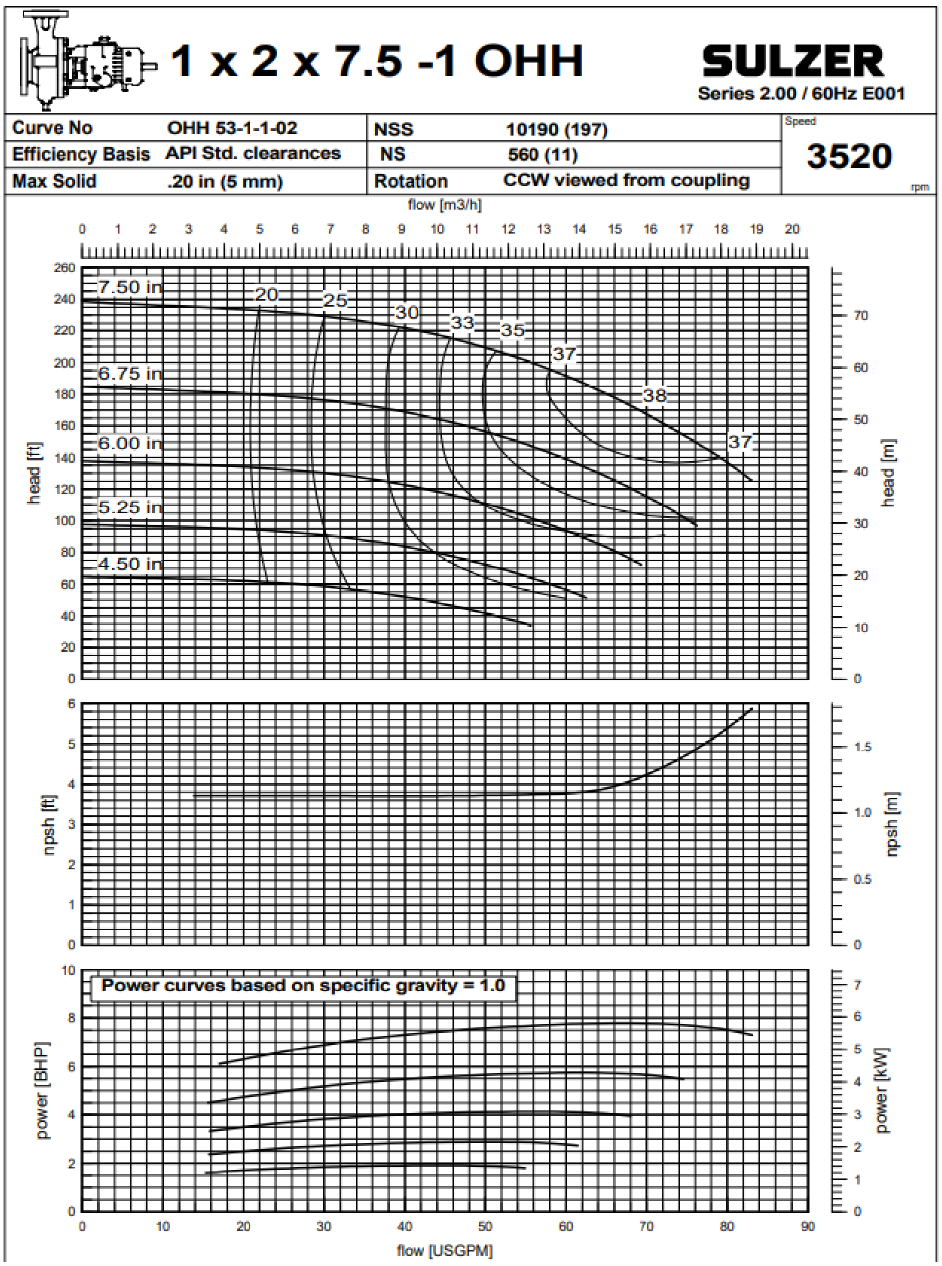


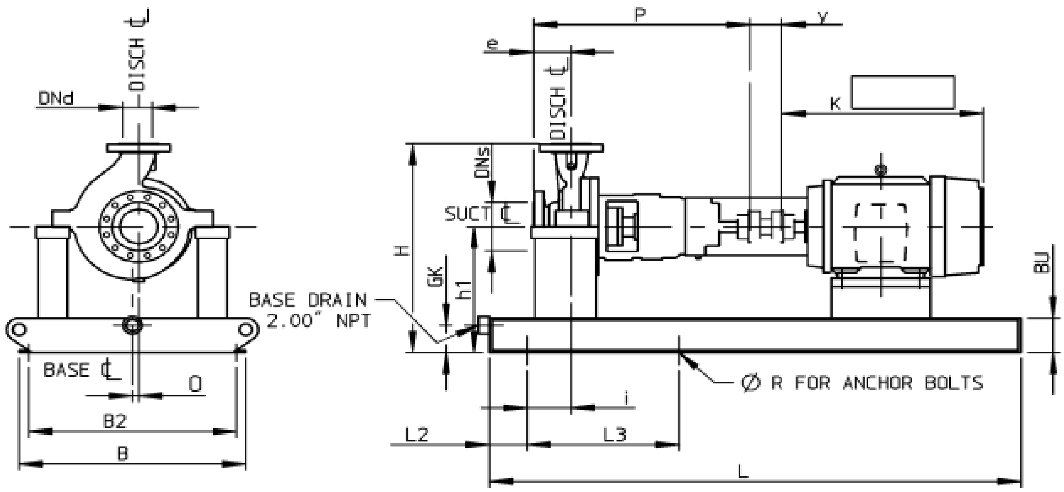
Figure 3-8

SULZER

DIMENSIONAL DATA - TYPE OHH

General Arrangement Dimensions – End Suction – US Customary Units

Series **2.00**	Page
DIMENSIONS	US
October - 02	**D01**



Certified by :________________________

Date: ______________ Certified for Nozzle & Anchor Bolt locations only when signed above

Ref No. : ____________________________

Project Name : ___________________________

Project Item No.: _________________________

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

L3 -- Distance between holes.

GH -- # of Grout Holes

API No.	Base wt lbs	B	B2	BU	L	L2	L3	R	GK	HH	GH
1.5	800	30	27	6	72.5	6	30.25	1	4.75	3	4
2.0	930	30	27	6	84.5	6	24.16	1	4.75	4	4

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

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

PUMP SIZE	PUMP wt lbs	DNs	DNd	O	B	e	P	h1	i	H	y	BASE REFERENCE (Electric Driver - NEMA Frame)
		in										
1x2x7.5-1	[illegible]	[illegible]	1	0	30	4.92	[illegible]	18	[illegible]	27.06	5	1.5 (143T-286T) (284TS-286TS)
2x3x7.5A-1	[illegible]	[illegible]	[illegible]	[illegible]	30	4.92	[illegible]	18	[illegible]	27.06	5	2.0 (324T-405T) (324TS-405TS)
2x3x7.5B-1	331	3	2	0	30	4.92	31.18	18	**5.38**	27.06	5	
3x4x7.5-1	352	4	3	0	30	4.92	31.26	18	**5.36**	27.06	5	
4x6x7.5B-1	398	6	4	0	30	5.51	32.20	18	**5**	28.04	5	
4x6x7.5A-1	399	6	4	0	30	5.51	32.20	18	**5**	28.04	5	
6x6x7.5-1	522	6	6	1	30	8.07	35.67	18	**5.63**	30.60	7	2.0 (284T-365T) (284TS-365TS)
1.5x3x8-1	335	3	1.5	0	30	5.51	32.01	18	**5.65**	27.06	5	1.5 (143T-286T) (284TS-286TS)
2x3x8-1	336	3	2	0	30	5.91	32.56	18	**5.63**	27.06	5	2.0 (324T-405T) (324TS-405TS)
3x4x8A-1	360	4	3	0	30	6.30	32.83	18	**5.38**	27.45	5	
3x4x8B-1	370	4	3	0	30	6.30	33.03	18	**5.63**	27.45	5	
3x4x8B-2	370	4	3	0	30	6.30	33.03	18	**5.63**	27.45	5	
1x2x9-1	320	2	1	0	30	5.51	31.65	18	**5.63**	27.06	5	
1.5x3x9-1	334	3	1.5	0	30	5.51	31.69	18	**5.63**	27.06	5	
2x3x9A-1	338	3	2	0	30	5.51	31.73	18	**5.5**	27.45	5	
2x3x9B-1	334	3	2	0	30	5.51	31.81	18	**5.63**	27.45	5	
2x4x9-1	360	4	2	0	30	5.51	31.77	18	**5.38**	28.04	5	
3x4x9-1	374	4	3	0	30	5.51	31.85	20	**7.38**	30.43	5	
3x4x9-2	374	4	3	0	30	5.51	31.85	20	**7.38**	30.43	5	
3x6x9-1	406	6	3	0.5	30	5.91	32.32	20	**7.25**	31.02	5	
3x6x9-2	406	6	3	0.5	30	5.91	32.32	20	**7.25**	31.02	5	

SULZER Supersedes Page Dated: 22 March 2002

Figure 3-9

Design Considerations:

- Will pump a low viscosity coolant (always liquid state)
- Sulzer pumps only

Data & Variables:

- Q = 52 gpm
- Ha = 65 ft
- N = 3520 rpm (highest typical in U.S.)

Procedure

From the attached Sulzer Catalog pages under the Drawings & Diagrams heading, we will specify the dimensions, weight, pump curve, and point of operation of the selected pump. We have already generated a system curve along with the operation point in Task 15.

Calculations

For specific sizes and weight of the selected pump, see drawing Page: D01 the specific pump information is outlined

As for the pump curves, system curve, and point of operation, this was calculated in Task 15 please refer to the Calculation section of Task 15 for specifics. Below will be the plotted system curve generated in Task 15.

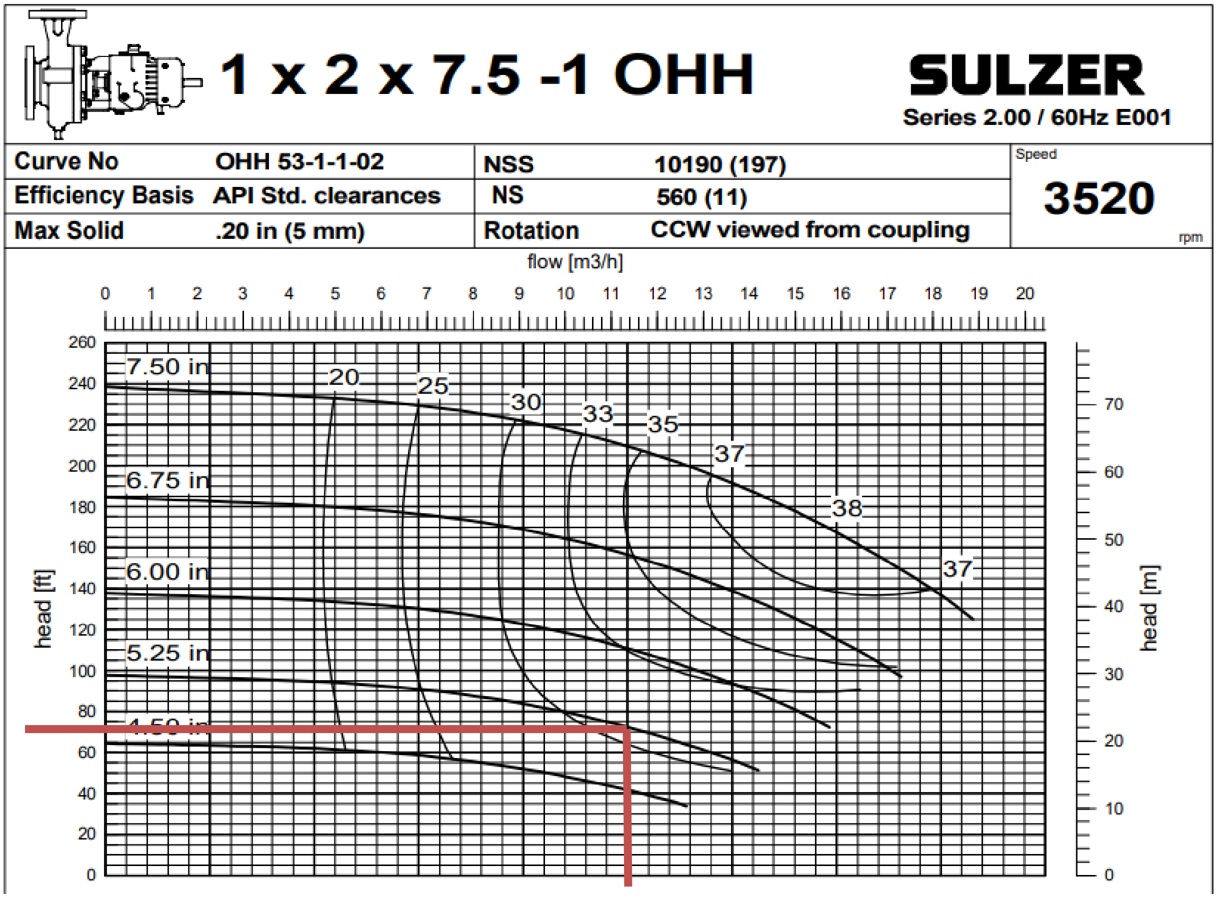


Figure 3-10

Summary:

Quantity	**1**
Type	**1 x 2 x 7.5-1 0HH**
Impeller Diameter	**4.50 inches**
Flow Capacity	**52 gpm**
Head Requirement	**65 ft**
Pump Size	**See Drawings & Diagrams drawing**
Pump Weight	**See Drawings & Diagrams drawing**

Table 1-13

Materials:

- 1 x 2 x 7.5-1 0HH Pump
- 4.50 inch diameter impeller
- Coolant

Analysis:

We selected a pump using the Sulzer Catalog that satisfied our system requirements and listed specific characteristics of the pump. This needed for the civil engineers as well as anyone who is reviewing the project.

- *Electrical motor requirement*

Purpose:

Electrical motor requirement for our pump

Drawings & Diagrams:

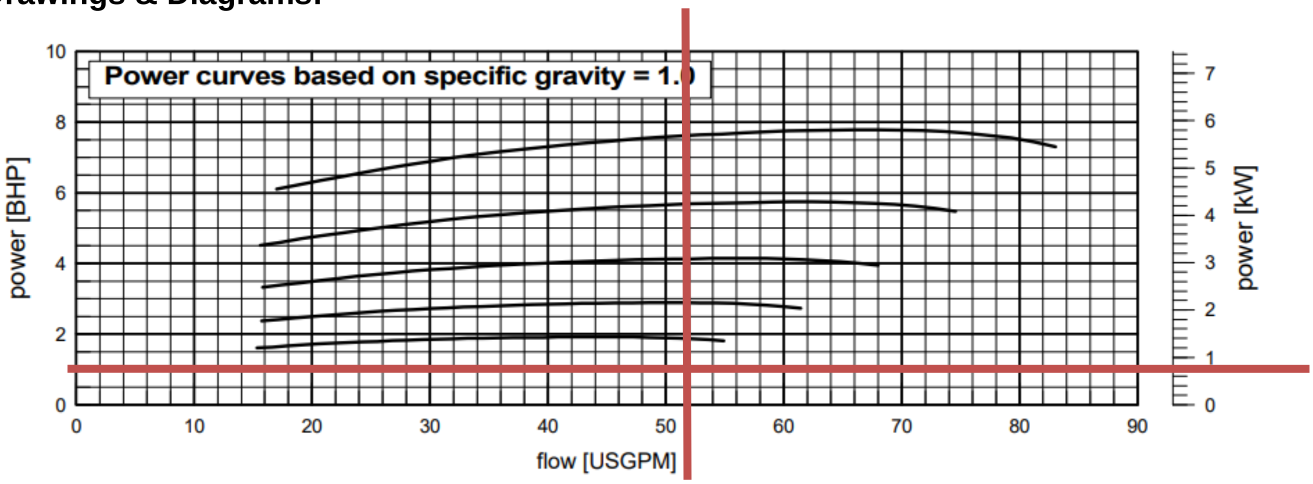


Figure 3-11

Design Consideration:

An electrical motor

Materials:

A standard electrical motor

Procedure:

1- To compute the required power for the pump we could use either of the two methods.
   a. Reading the power value from the above diagram
   b. Calculated the actual power needed.
2- By using the following equation, we calculate the required power.

$$P = \frac{\gamma\, Q\, h_A}{\eta}$$

3- Multiplying the result by (1.10) we need to make sure that,

$$P_{motor} > P_{required}$$

Data and variables:

$\gamma_{coolant} = specific\ weight\ of\ the\ coolant$

$Q = flow\ rate$

$h_a = pump\ head$

$\eta = pump\ effeciency$

$P\ \ = power\ needed\ for\ the\ pump$

$P_{\ motor} = electrical\ motor\ power$

Data

$\gamma_{coolant}(\frac{lb}{ft^3})$	$Q\ (\frac{lb}{ft^3})$	h_A	η
58.66	0.2361	65	34%

Table 1-14

Calculations:

Electrical Motor Requirement

$$P = \frac{\gamma Q h_A}{\eta}$$

$$\gamma_{coolant} = 58.66\ lb/ft^3$$

$$Q = 52\ gpm = 0.1159\ lb/ft^3$$

$$h_A = 65\ ft$$

$$\eta = 34\% = 0.34$$

$$P = \frac{\left(58.66\frac{lb}{ft^3}\right)\left(0.1159\frac{lb}{ft^3}\right)(65\,ft)}{0.34}$$

$$P = 1299.75\,\frac{lb * f}{s}\,(0.001818\,hp)$$

$$P = 2.36$$

$$P_{motor} = 2.36\,hp\,(1.10)$$

$$P_{motor} = 2.6\,hp$$

Summary:

$\gamma_{coolant}(\frac{lb}{ft^3})$	$Q\,(\frac{lb}{ft^3})$	h_A	η	$P\,(HP)$	$P_{\,motor}(HP)$
58.66	0.1159	65	34%	2.36	2.6

Table 1-15

Analysis:

At least 2.6 hp needed to pump the coolant from the bottom of the tank to the day use tank.

- Cavitation & Summary of the selected pump

Purpose:
Evaluate the NPSH available for the design, and demonstrate the pump has an acceptable NPSH required. Specify installation requirements for the pump, including suction line.

Design Consideration:

Considerations were made in regards to the pump installation keeping the suction line near the pump suction inlet. This will reduce the possibility of cavitation. In addition, straight and direct piping routes will be considered to reduce the amount of energy losses in the upstream portion of the system.

Materials:
Galvanized steel pipe and fittings, Pump, Coolant

Analysis:
The NPSH available will be calculated by determining the pressure of the pump suction inlet. Once determined it will be compared with the NPSH required that was found in the Sulzer pump catalog. The Pump (base) should be installed at the same level as the tank approximately 13’ underground in the enclosed concrete tank area. The pump will be mounted on a concrete pad base The Suction line will be 2” galvanized steel pipe measuring approximately 5’ from the pump into the tank, then 12’ down to the suction point.

5.f.vii. Instrumentation selection.

- Flow rate and pressure

Purpose:

Determine flow meter and pressure gauge type for one of the pipeline systems.

Design Consideration:

The pipeline that was chosen to select the flow meter and gauge for was the dirty tank to truck since this is the highest flow rate and that is also uses a pump.

Data and variables

$Q = flowrate$

$D = inside\ diameter\ of\ pipe$

$d = diameter\ of orifice$

$g\ = gravity$

$\rho_{cool} = density\ of\ coolant$

$\gamma_{cool} = specific\ weight\ of\ coolant$

$\gamma_{Hg} = specific\ weight\ of\ mercury$

$\beta = ratio\ of\ orifice\ diamter\ and\ inside\ diameter\ (d/D)$

$h\ = manometer\ reading$

$\eta = dynamic\ viscosity$

Materials:

Galvanized steel, stainless steel gauge, coolant, manometer.

Analysis:

The flow meter selected for measurement will be a differential head-type flow meter. We will also use a mercury manometer with a scale of 0-3 in. of Hg will be used to show the pressure difference on either side of the orifice. It will be desired to have the normal operating conditions (8.91 scfm) read at the center of this scale. The pressure gauge will be selected based on the maximum pressure in the line which was determined in task 9. The selected gauge range will be selected to have the working pressure read within the 2/3rd portion of the gauge scale. The maximum pressure is 27.1 psig, therefore the scale of the gauge will be 0-50 psig.

Summary:

Flowmeter: Differential Head-Type	Specifications
Sharp-edged Orifice	d = 1.0 in.
β (actual) = d/D	0.523

Table

Manometer: Mercury	Specifications
Scale Range	0-3 in. of Hg.
Normal Operation Reading	1.5 in. of Hg (@ 8.91 scfm)

Table

Gauge: Round Face	Specifications
Type	Bourdon Tube
Range	0-50 PSIG
End Connection	1/2” Male NPT

Table 1-16

6. Final drawings

a. Plot plan (task 19)

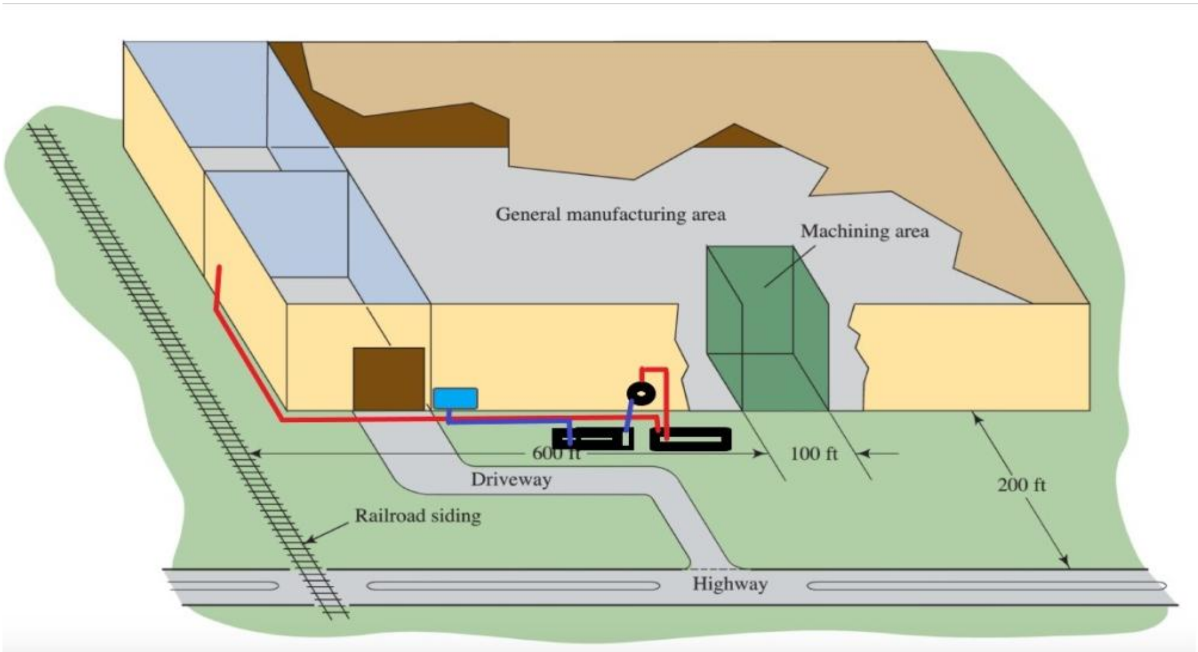


Figure 3-12

6.b. Elevations view (task 19)

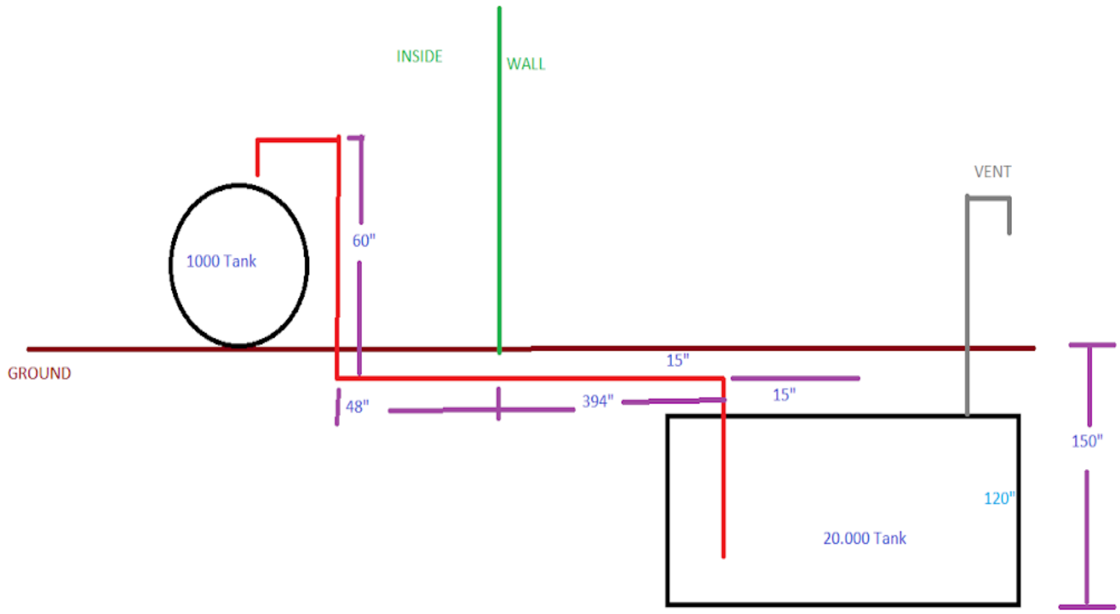


Figure 3-13

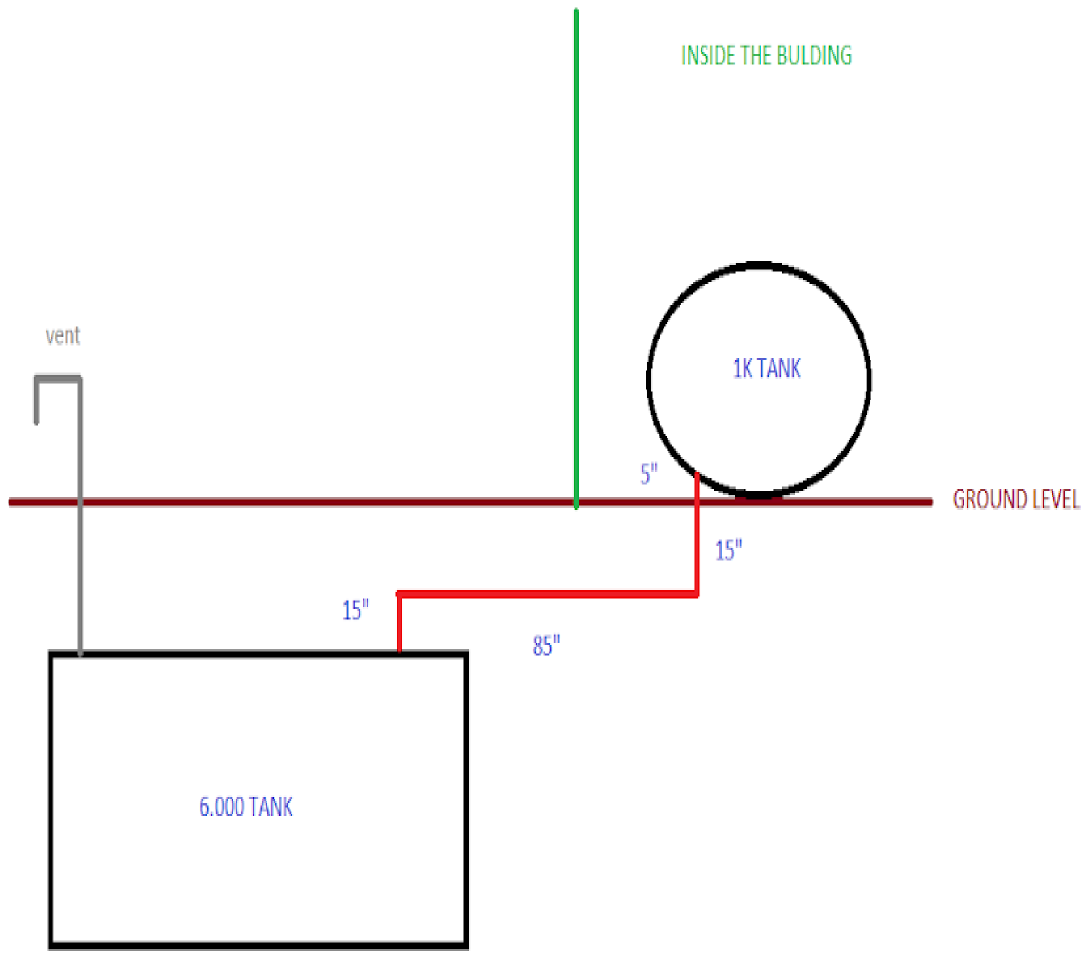

INSIDE THE BULDING
vent
1K TANK
5"
GROUND LEVEL
15"
15"
85"
6.000 TANK

Figure 3-14

7. Bill of materials and equipment list (task 20)

Bill of Materials:

Item #	Qty. Total	Material	Description	Part number	Supplier
1	1	Carbon Steel	20,000-gal Tank, 19.33' x 11.6'	20K	Stanwade Metal Products
2	1	Carbon Steel	6,000-gal Tank, 3.17' x 4'	6K	Stanwade Metal Products
3	1	Carbon Steel	1,000-gal Tank, 12' x 6.07'	1K	Stanwade Metal Products
4	25	Galv. Steel	2" Galvanized Steel Welded Pipe ASTM A-53, 21ft. Lengths	T52G	Metals Depot
5	26	Galv. Steel	2" Pipe Coupling FNPT ends	4638K119	McMaster-Carr
6	16	Galv. Steel	2" 90 Degree Elbow FNPT ends	4638K138	McMaster-Carr
7	4	Galv. Steel	2" x 2" x 1/2" Reducing Tee FNPT ends	4638K276	McMaster-Carr
8	1	Galv. Steel	3" x 4" Reducing Bushing	4638K247	McMaster-Carr
9	18	Galv. Steel	Class 150 2" Threaded Pipe Flange	7551K125	McMaster-Carr
10	18	Buna / Steel	2" Flange Gasket w/ Hardware	9166K66	McMaster-Carr
11	1	Forged Steel	4" Blind Class 150 Flange, 8 Bolt		McMaster-Carr
12	1	Buna / Steel	4" Flange Gasket w/ Hardware		McMaster-Carr
13	4	Stainless Stl.	6" Pressure Gauge, 1/2" MNPT lower mount 0-50 PSI Range		Swagelok
14	8	Cast Steel	2" Gate Valve, Class 150 Flanged ends	1550CB2-020-O	Milwaukee Valve Co.
15	2	Steel	2" Check Valve, FNPT ends	4895K68	McMaster-Carr
16	65	Galv. Steel	2" Floor Mount Clamp Style Pipe Support	8427T69	McMaster-Carr
17	3	Steel	Sulzer Radial Centrifugal Pump, 3520 rpm, 1.0 HP, 4.50" Impeller	1x2x7.5-1 0HH	Sulzer

18	1	Stainless Stl.	Sharp-edge Type Universal Orifice Plate, 2.437" OD x 0.987" Orifice	Custom	Kelley
19	1	Various	Flex-Tube U-Tube Manometer Range 3-0-3, Hg Filled	458-303	Lowes
20	60	Concrete	Concrete for tank enclosure (cubic yards) 2" thick sides	N/A	

Table 1-15

8. Final remarks

This piping system was designed to use commercially available products that are cost effective and easily acquired. Changes in pipe direction were minimized to reduce extra head pressure for the pumps. The tanks were placed below grade at a depth of 30” to reduce the chances of the coolant freezing. The pump was selected to be the smallest pump available while still being able to overcome the required resistance. Schedule 40 galvanized pipe and matching fittings are available anywhere and are relatively inexpensive.

9. Appendix

Steven Blea

This class was very easily one of the most time consuming classes I have taken this far. I have learned that there are many factors in designing a piping system and all decisions are important to the final project. After taking this class I am more familiar with many of the processes and calculations that are required to solve fluid problems. Every section of this project required a hands on approach to gather the needed data and apply it to what was needed.

Abdullah Fahad A Alruwaished

On this project, as students, we learned how the real design system is not difficult and how the equations use on real life. Moreover, the first important thing is the pipe system layout because all the calculations based on it, such as the pipes length and how many elbow and valves do we need to be able to calculate the energy losses and minor losses as well. As future engineers, we are looking forward to design incurable system and more efficient with low cost. Furthermore, communication between partner and I or with Clint is so important to have easy successful work and to overcome the issues.