Full Pipeline System Design of a Manufacturing Plant

Group #8

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Abstract

Continental AG requires a pipeline system for their new manufacturing facility. This system will consist of three tanks: one for new coolant, a reservoir for the machining area, and a dirty coolant tank. The new coolant tank will be underground to provide natural insulation. Also, two pumps will be required in this system. The system is designed to fulfill the minimum requirements for the project yet be efficient. In this way, the system will be cost efficient.

Table of Contents

List of Figures and Tables

Figures:

Tables (All tables except tables 15.1 and 20.1 are summaries)

Job Site Location

The plant belongs to Continental AG and is located in Dayton Ohio where temperatures outside can be as low as -20^{o}F or as high as 105^{o}F. The frost line is also thirty inches underground. Additionally, the roof of the plant is 32 feet above the floor. Other details can be seen in later drawings.

Specifications and Job Philosophy

The units given in the project description were all English units. In order to keep a simple and uniform flow of calculations, English units were used throughout the rest of the project. The system was designed so that the new coolant tank would be filled in 150 minutes, the clean coolant tank in 10, and the dirty coolant tank in 60 minutes.

Overall, the goal in this project was effective simplicity. The design was made to be easy to manufacture and set up while still completing the required tasks without lacking anything.

Sources

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

http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-14392015000601372

https://coolconversion.com/pressure/lbf/ft2-to-psi
http://www.wermac.org/flanges/flanges_pressure-temperature-ratings_astm_asme.html

https://www.texasflange.com/index.php/component/layeredfinder/

https://www.texasflange.com/index.php/ansi-b16-1-2/class150-flanges

https://sciencing.com/calculate-pipe-size-flow-rate-5595865.html

https://www.saylor.org/site/wp-content/uploads/2011/07/ME303-4.1.1.pdf

https://www.pipeflowcalculations.net/pipediameter.xhtml

PVC Properties. (2016). Retrieved from Vinidex: https://www.vinidex.com.au/technical/material-properties/pvc-properties

https://www.saylor.org/site/wp-content/uploads/2011/04/Viscosity.pdf

https://www.sulzer.com/en/shared/products/2017/03/28/12/42/gsg-diffuser-style-barrel-pump#stacked-tab__4c33cd19-c4b0-4be5-bd40-28eee219829a

Materials and Specifications

Pipe and tank material

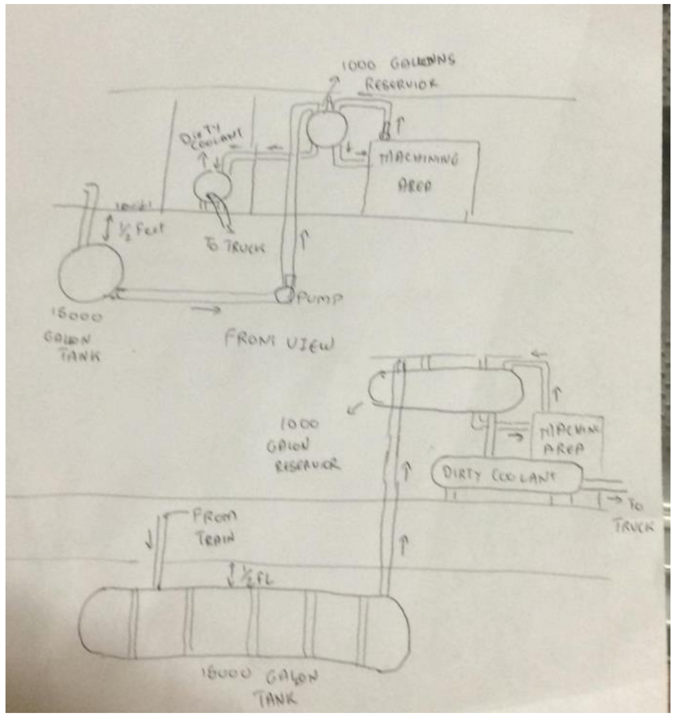
The tanks will be made of fiberglass. More detail is on pages 12-15

The pipes will be made of Schedule 30 PVC. More detail is on pages

Fluid Characteristics

The fluid is a solution of water and soluble oil. It has a specific gravity of 0.94 and freezes and 0^{o}F. It is about as corrosive as water and has a viscosity and vapor pressure 1.5 times that of water.

Preliminary Drawings and Sketches



Plot Plan

No physical drawings were made including elevation, only those listed further in the report.

- Location and Size design (task 1)

Task 1:

Purpose:

Specify the size and location of all storage tanks.

Drawings & Diagrams

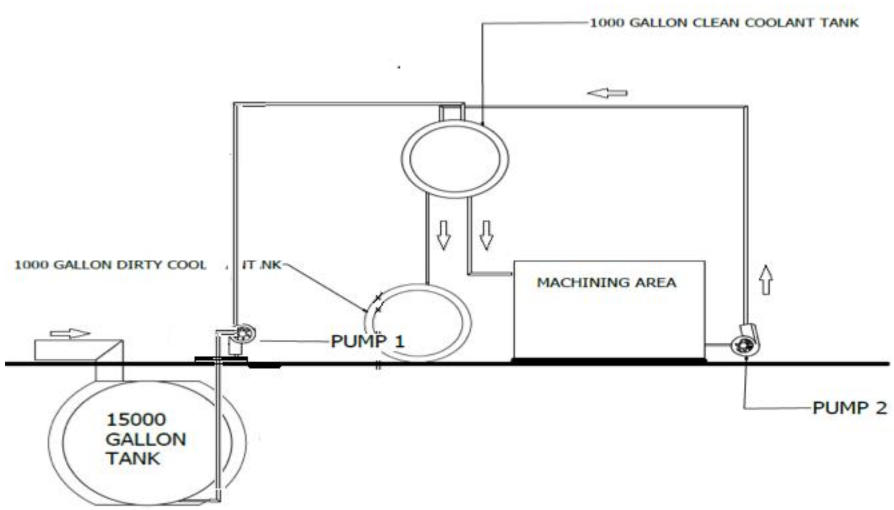


Figure 1.1 DRAWING AND ISOMETRIC VIEW

Sources

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

Design considerations
Designing for lesser cot’
Considering factor of safety 20%
2 pumps

Calculations & Procedure-
For Tank 1 that is 15000-gallon tank

15000-gallon tank will be stored ½ ft. inside the ground that is almost 44 inch as the frost line is below 30 inches and we don’t want that the temperature affects the coolant

For safety purpose we will be using tank of 18000 gallon, taking 20% safety into consideration

Considering its height as 15 ft

So the tank diameter will be

18000 gal = 2406.25ft^3

So □ = □□ $^2 * h$

2406.25=□* □^{2}*15

r = 7.1 ft

For the 1000-gallon clean coolant

The tank with clean coolant will be close to the machine and attached to the roof while

For safety purpose, we will be using tank of 1100 gallon, taking 10% safety into consideration

Considering its height to be 5 ft

So the tank diameter will be

1100 gal = 147.0486ft^3

So □ = □□ $^2 * h$

147.0486=□* □^{2}*5

r = 3.1 ft

For the 4000-gallon dirty coolant

The Dirty coolant tank will be on the floor near to drive way

we will be using tank of 4000 gallons, so that tank can be emptied any time in a month

Considering its height to be 11 ft

So the tank diameter will be

4000 gal = 534.72ft^3

So □ = □□ $^2 * h$

534.72=□* □^{2}*11

r = 3.93 ft

Summary

	Volume (gal)	Volume (ft^3)	Radius (ft)	Diameter (ft)	Height (ft)
Tank 1	18000	2406.25	7.1	14.2	14
Tank 2	1100	147.04	3.1	6.2	5
Tank 3	4000	534.72	3.93	7.86	11

Table 1.1

Analysis

We believe that the locations we have chosen will be the most efficient way to set up the tanks. As it is using the least amount of piping and pumps and mostly using gravity so we have huge saving in cost

- Tank thickness (task 2)

Task 2

Purpose:

Select tank material and specify wall thickness of storage tanks.

Drawings & Diagrams

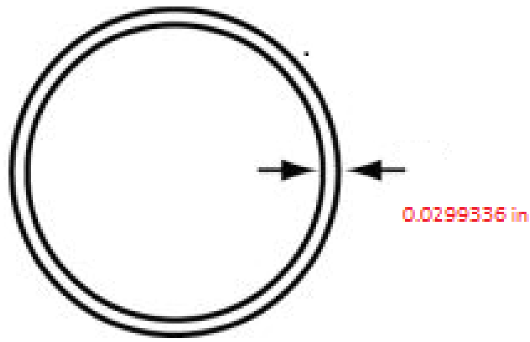


Figure 2.1 Thickness for 18000-gallon tank

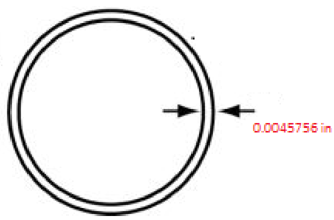


Figure 2.2 Thickness for 1100-gallon tank

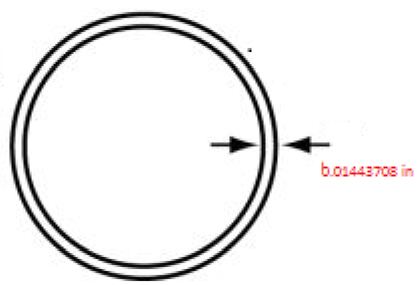


Figure 2.3 Thickness for 4000-gallon tank

Sources

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

http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1516-14392015000601372

Data and Variables

Diameter of tank 1=14.2 ft. =170.4 in
Diameter of tank 2=6.2 ft. = 74.4 in
Diameter of tank 3=7.86 ft. = 94.32 in
Specific Gravity of coolant =0.94
(□□□□□□ $_{@4\,0□}$)=62.43 lb. /ft3
Specific weight: □□□□□□□ = (□□□□□□ $_{@4\,0□}$) * Specific Gravity of coolant
62.43*0.84
□coolant = 59 lb./ft3

Design considerations
We will be taking factor of safety as 2 as we know one of the tank is under the ground and pump are also used which will create pressure in the system and we will also assume the tanks are full at all time and it under maximum pressure

Procedure

We will be choosing fiber glass as a material and we found out that the yield strength of fiber glass is 30000 psi
So allowable stress will be 15000 psi
we a know that □ = □h
And t = P R/FS* S (http://faculty.washington.edu/vkumar/me356/pv_rules.pdf)
Where
t = Minimum required thickness (in.)
P = Design pressure (psi)
R = Inside radius (in.)
S = Allowable stress (psi)
FS = factor of safety
Calculations

Tank 1
We know in first tank 15000 gallons of coolant will be there

15,000 □□□ = 2005.2 □□^{3}

2,005.2 □□ ^{3} = □ ∗ 7.1^2 ∗ h

h = 12.66 □□

□ = □h

= 59*12.66

□ = 759.6□□/□□ ^{2}

□ = 5.27 psi (https://coolconversion.com/pressure/lbf/ft2-to-psi)

t =P R/FS* S
t = (5.27*85.2)/15000
t = 0.0299336 in

Tank 2
We know in second tank 1000 gallon of coolant will be there

1000 □□□ = 133.681□□^{3}

133.681□□ ^{3} = □ ∗ $3.1^2 * h$

h = 4.430 □□

□ = □h

= 59*4.430

□ = 265.8 □□/□□ ^{2}

□ = 1.845 psi (https://coolconversion.com/pressure/lbf/ft2-to-psi)

t =P R/FS* S
t = (1.8 45*37.2)/15000
t = 0.0045756 in

Tank 3
We know in third tank 4000 gallon of coolant will be there at max

4000 □□□ = 534.7222□□^{3}

534.7222 □□ ^{3} = □ ∗ $3.93^2 * h$

h = 11.0258 □□

□ = □h

= 59*11.0258

□ = 661.55 □□/□□ ^{2}

□ = 4.59 psi (https://coolconversion.com/pressure/lbf/ft2-to-psi)

t =P R/FS* S
t = (4.59*47.18)/15000
t = 0.01443708 in

Summary

Tank	Maximum Pressure (psi)	Minimum Tank Thickness (in)
1	5.27	0.0299336
2	7.84	0.0045756
3	4.59	0.01443708

Table 2.1

Material

Fiberglass

Analysis

We have used fiberglass as I have high yield strength and the cost is too low compared to steel tanks
So this material with less thickness will make our design cost effective.

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

Task 3

Purpose:

To provide a future additional connection to drain ONE OF THE TANKS. Design the blind flange required to hold the pressure for such connection (size, thickness, etc.). This should include the number of bolts and nuts and the size of them. (to final report section 5.f.i)

Drawings & Diagrams

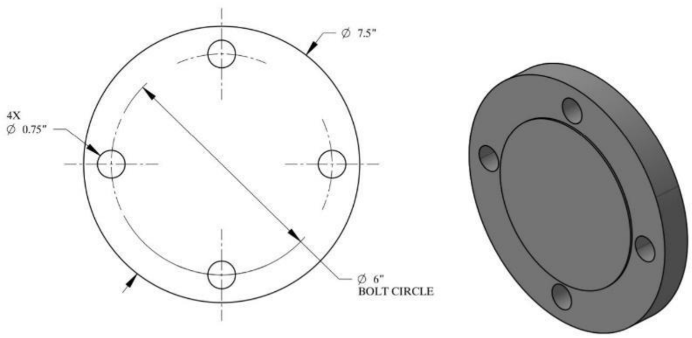


Figure 3.1 Flange

Sources

http://www.wermac.org/flanges/flanges_pressure-temperature-ratings_astm_asme.html
https://www.texasflange.com/index.php/component/layeredfinder/
https://www.texasflange.com/index.php/ansi-b16-1-2/class150-flanges

Data and variable

P1=759.6□□ /□□ ^{2}

□coolant = 59 lb/ft^3

Z=14.2 ft
D = 7.86 ft

σ =Allowable stress for forged steel 3430669.536 □□ /□□ ^{2}

E= weld joint factor=0.85

Design considerations

The flange will be on the side, to the bottom of the tank
Assuming the tank is full of coolant
The pipe size will be 3 inch
Number of bolts are set at 4 for the flange
The material of the flange will be steel

Procedure

We know that the specific weight of coolant is 59 lb/ft^3 (from task 2) and it is at the bottom of tank 1 so the height difference between coolant and flange will be equal to diameter that is 14.2 ft. so the suing this pressure we will be calculating the pressure at the bottom using Bernoulli's and then from the bottom pressure we will be calculating the force and the thickness of the flange which will yield as the size of bolt and nut.

Where fr =resultant force = $\square h \square$A

Calculations

$$\frac{\square 1}{\square} + \frac{\square 1}{2\square} + Z_1 = \frac{\square 2}{\square} + \frac{\square 2}{2\square} + Z_2$$

$$\frac{\square 1}{\square} + Z_1 = \frac{\square 2}{\square}$$

$$P_2 = 1594.18\square\square\ /\square\square^{2}$$

Force on the flange

F= P*A

$1594.18 * \frac{\pi}{4} * 7.86$

= 775.83 lb

Maximum force on each bolt

F_{max}= 775.83/4 (As number of bolt are 4)

$F_{max=}$193.95 lb

Thickness of the flange

$$T_{min} = D * \sqrt{\frac{3\square}{16 * \square * \square}}$$

$$T_{min} = 7.86 * \sqrt{\frac{3 * 1594.18}{16 * 0.85 * 3430669.53}}$$

$$T_{min} = 0.0795 \text{ ft}$$

Diameter of bolt

A =f/ $\square$

A= 193.65/ 3430669.53

A= 0.0000564ft

A= 0.0006768 in

D=0.0293 in

Summary

PRESSURE	FORCE	NUMBER OF BOLT	THICKNESS OF FLANGE	DIA OF BOLT
1594.18□□ /□□ ^{2}	193.95 lb	4	0.0795 ft	0.0293 in

Table 3.1

Material

Forged steel

Analysis

The flange size was calculated using ASTM GROUP 2-1.1 from which we found the thickness of the flange to be 0.0795 ft and the force acting on the flange to be 193.95 lb for this we will be using CL 150 flange manufactured by Texas flange company which will be a good option as this can withstand the force obtained and from the above table of CL 150 flange in summary we know that 4 bolts are used and the hole diameter with diameter 0.0293 in each.

- Wind load and weight (task 11)

Task 11

<u>Purpose</u>: Specify wind load and weight of storage tanks.

<u>Drawings and Diagrams:</u>

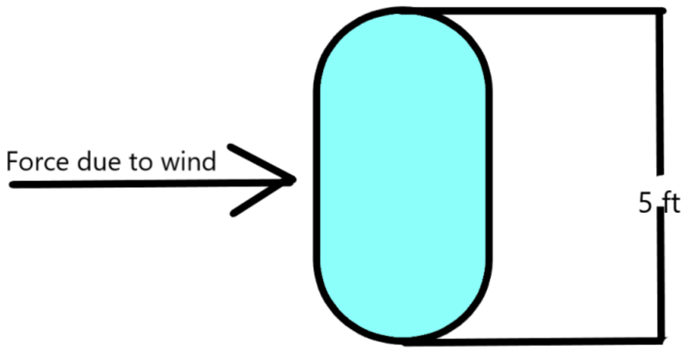


Figure 11.1 Tank wind load

Data and Variables:

Mass of fiber glass =159.19lb/ft^3

Average Temperature = 60℉

Density of air at 60 ℉=0.0878 lb/ft3

Kinematic viscosity of air 60 ℉ = 1.57*10^-4 lb/ft3

Volume of the clean coolant tank= 147.0486 ft3

Design Considerations:

Vertical and horizontal forces on tank

Temperature effect

Procedure:

The initial step is to ascertain the volume of the shell of the perfect coolant stockpiling tank. This is finished by taking the known external range of the tank and subtracting the figured thickness from it to locate the inward sweep of the tank. The external span, internal range, and stature of the tank are then connected to the recipe for volume of an empty chamber. The mass of the shell of the coolant tank is then ascertained utilizing the known estimation of thickness of fiber strengthened plastic and the discovered estimation of volume of the shell of the tank. This yields the estimation of the mass of the tank in pound mass units, which are then changed weight by multiplying it by gravity.

The key on this step is to realize that the tank moves due to wind is mathematically a moment. Thus, the moving of tank is when the algebraic sum of moments is equal to zero M = 0

We select a point to apply the moment balance equation. I prefer to use the pivoting point at the end that is the total height of the tank

Thus, the moment balance equation becomes

Fd *Dd- w*Dw

So, we will be calculating velocity using this equation and the calculate the total drag force.

Calculations:

Rin= (3.1 ft) -(0.0045756 ft) = 3.0954244ft

V= □*h*Rout-Rin

V= π(5) ((3.1) ^2 -(3.095) ^2 = 0.4866 ft^3

m = 159.1913*0.4866= 77.5 lb

w= m*g

w= 32.2 * 77.5 =2495.5 lb ft/s^2

The key on this problem is to realize that the mobile home overturn is mathematically a moment. Thus, the mobile home is on the verge of turning when the algebraic sum of moments is equal to zero.

And,

$Fd=C_D (\rho*v^2/2)A$

$C_D (\rho*v^2/2)A-w*Dw$

Where A $=2\pi rh+2\pi r2\approx157.77078$

$0=(1.12(0.0878*V^2 /2)157.77*5 –(2495.5*5)$

V= 17.97 ft/s

F_D=2496.4 lb

Summary:

The wind which will be acting upon the clean coolant cylinder will be have following.

Drag force due to wind	Weight of the tank	Velocity of the wind
2496.4 lb	2495.5 lb ft/s^2	17.97 ft/s

Table 11.1

Materials:

Air

Fiberglass tank

Analysis:

Twist speeds in the zone are regularly higher than this most extreme esteem, however our tank will be appended to a help which is additionally connected to the top of the assembling plant. This gives the tank additional steadiness and will enable it to withstand wind speeds a lot higher than this ascertained esteem.

- Open channel for drainage (task 12)

Task 12

Purpose:

To design an open channel for fluid to flow through in the event of a tank rupture.

Drawings and Diagrams:

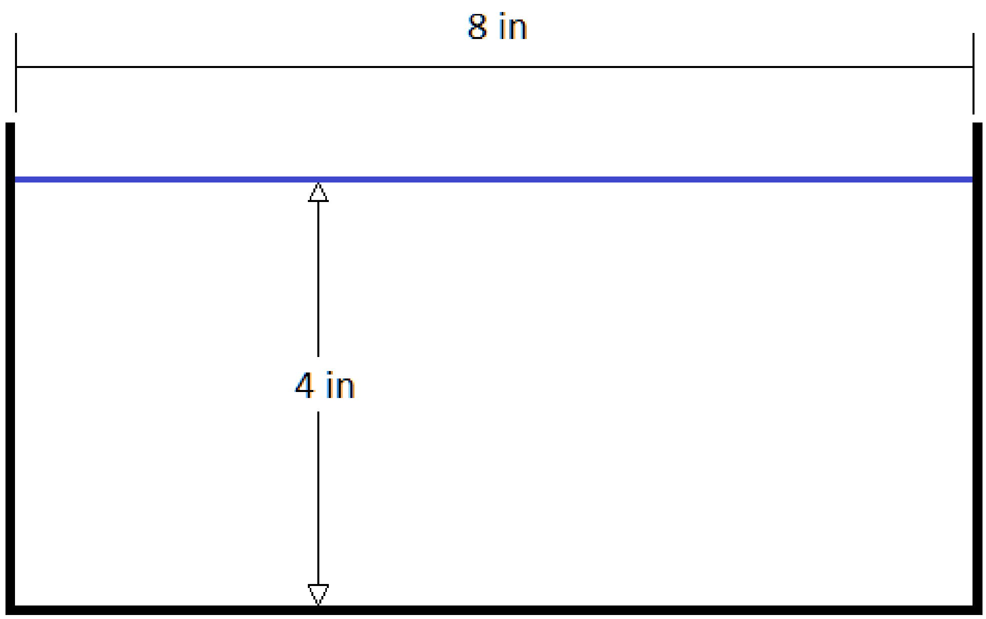


Figure 12.1 Open Channel

Sources:

Robert L. Mott, J. A. (2015). *Applied Fluid Mechanics, Seventh Edition.* London: Pearson Education Limited.

Design Considerations:

Incompressible fluid, unpainted steel channel

Data and Variables:

n = 0.01, Q = 0.222 ft^3/s, A = 0.222 ft^2

Procedure:

First, the value of R must be calculated for the channel. Next, using the given values, the slope (S) can be solved for.

Calculations:

$$\square = \frac{\square}{2} = \frac{0.333\square\square}{2} = 0.166\square\square$$

$$\square = \left(\frac{\square\square}{1.49\square\square^{\frac{2}{3}}}\right)^2 = \left(\frac{0.222\ \square\square^3/\square(0.01)}{1.49(0.222\square\square^2)(0.166\square\square)^{\frac{2}{3}}}\right)^2 = 0.022$$

Summary:

Distance traveled by liquid in channel	1000 ft
Height dropped	22 ft

Materials:

Steel, coolant

Analysis:

In order to keep the same flow rate as in the pipes of the system, this channel requires a slope of 0.022 or 22 feet per every thousand feet traveled. The most likely storage tank to rupture appears to be the 18,000-gallon tank. Since this tank is at the edge of the facility and near ground level, the open channel can easily be installed next to it running away from the facility.

i. Flow rate
   - Tank fill/empty times (task 4)
   - Desired flow rate (task 4)

Task 4

Purpose:

Estimate the time required to fill and empty all tanks (you are supposed to fix them). Specify the desired flow rate to fill and empty all tanks)

Sources

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

Design considerations

Constant fluid properties
Incompressible fluid

Data and Variables:

Fill and empty Times

Tank no 1: Reservoir Tank= 150 minutes

Tank no 2: Clean Coolant (CC) Tank =10 minutes

Tank no 3: Dirty Coolant (DC) Tank= 60 minutes

TANKER =50 minutes

Procedure

As specified in the lecture we have to use the flow rate equation with volume and time to find the flow rate

Calculations &

Rail to Tank no 1

V = 15000 gal (Tank no 1)

Q_1=V/t

Q1=15000/150

Q_1=100 gal/min

Q_1=13.3681ft ^{3}/min

Tank 1 to Tank no 2 (USING PUMP)

V = 1000 gal (Tank no 2)

Q_2=V/t

Q_2=1000/50

Q_2=200 gal/min

Q_2= 26.72 ft ^{3}/min

Tank 2 to Tank no 3

V = 4000 gal (Tank no 3)

Q_3=V/t

Q_3= 4000/60

Q_3=66.66 gal/min

Q_3= 8.9111458 ft^3/min

Tank 3 to Tanker.

(We will consider the capacity of the tank as 4000 gal)

Q_3= 4000/50

Q_3=80 gal/min

Q_3= 10.694 ft^3/min

Summary

	Flow rate in gal/min	**Flow rate in** ft^3/min
Rail to Tank no 1	100	13.3681
Tank 1 to Tank no 2	50	26.72
Machining area to Clean tank	50	26.72
Tank 2 to Tank no 3	66.66	8.9111458
Tank 3 To Tanker	80	10.69

Table 4.1

The machining circulation tank will be filled in approximately 150 minutes at a rate of 100 gal/min. as it is filled with the help of pump the coolant tank will be filled in approximately 10 min at a rate of 100 gal/min. The dirty coolant tank will be filled in approximately 50 min at a rate of 66.66 gal/min

Analysis

The flow rates make sense, because the larger the tank the more time is required to fill/empty it and the smaller the tank the less time is required to fill/empty it. It is also depending upon the pipe size.

iii. Pipe sizing
- Piping layout (task 5)
- Pipe diameter and lengths (task 5)

Task 5

Purpose:

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

Diagrams:

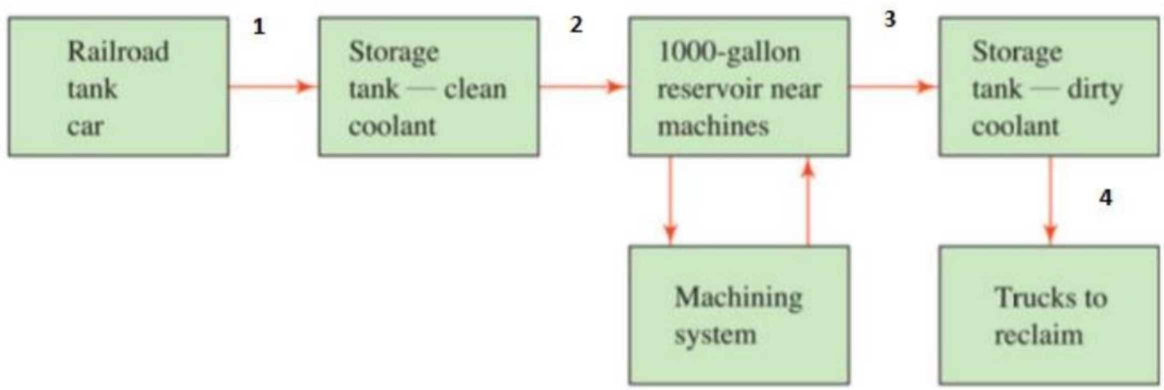


Figure 5.1 Fluid Process

Sources

https://sciencing.com/calculate-pipe-size-flow-rate-5595865.html

https://www.saylor.org/site/wp-content/uploads/2011/07/ME303-4.1.1.pdf

http://www.pipeflowcalculations.net/pipediameter.xhtml

Design considerations

1. Two pumps are needed one at the ground level near the reservoir to pump fluid to the clean coolant storage tank which is height of 37ft from the floor
2. Coolant from clean tank will flow to machining area and then back to clean tank
3. Coolant from clean tank will flow to dirty tank with the help of gravity

.

Procedure

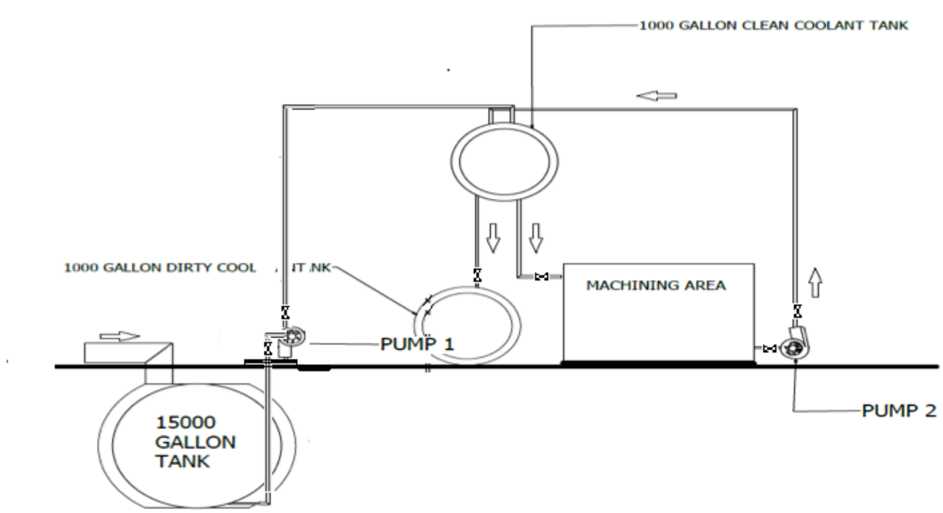


Figure 5.2 System Drawing

As seen in the diagram above we will be distribute each system in to section for ease of calculation. And will be using Schedule 30 PVC 3 in nominal pipe The first section of system will run from the ground level 15000 gallon tank up to the 1000 gallon clean tank and will have a pump to move the coolant, the second section will run from the clean tank to machining area third section will run from machining area back to the clean coolant tank and the fourth section will run from clean coolant tank to 4000 gallon dirty coolant tank section 1 will be having 200 ft. long pipe under the ground and then there is pump and it will go to clean coolant tank from ground with 39ft height and 380ft pipe to the tank Section 2 will be having 15ft pipe and 5ft with an elbow section 3 will be having 5ft pipe and 30ft pipe with a pump and section 4 will be having 17ft pipe from clean coolant tank to dirt tank we will also be finding the pipe diameter using the critical velocity and the volume flow rate found we found out in section 5

Calculations

(Diameter of the pipe (gravity driven)

Q=AV

$13.368=\frac{\pi}{4}*D^2*9.8425$

D=3.2256 1inches

Q=AV

$8.912=\frac{\pi}{4}*D^2*9.8425$

D=3.151 inches

Diameter of the pipe (pump driven)

Q=AV

$26.73=\frac{\square}{4}*D^2*9.8425$

D= 1.10 inches

Storage tank to clean coolant tank Section that is 1-2= 39+580 = 619ft

Clean coolant tank to machining area that is Section 2-3= 15+5 =25ft

Machining area to clean coolant tank Section 3-4 = 30+5 =40ft

Clean coolant tank to dirty coolant tank Section 4-5 = 17 ft

Dirty coolant tank to Truck section 5-6 = 5 ft

Material

PVC pipe

Summary

Schedule 30 PVC pipe clean coolant tank will be feed using a pump and coolant from machining area will be back to the clean coolant tank using a pump

section	Length	No of Pump	No of elbow
Section 1-2	619	1	4
Section 2-3	25	0	1
Section 3-4	40	1	3
Section 4-5	17	0	0
Section 4-5	5	0	0

Table 5.1

Analysis

The total length of the pipe used will be 702ft and will be using 2 pumps with and total of 6 and schedule 30 PVC pipe of 3.5 for gravity driven and 1.5 inch for pump driven as per our calculation taking critical velocity into consideration for its durability and strength.

- Pipe thickness (task 9)

Task 9

Purpose:

Find the required wall thickness for the piping system using the coolant process.

Diagrams

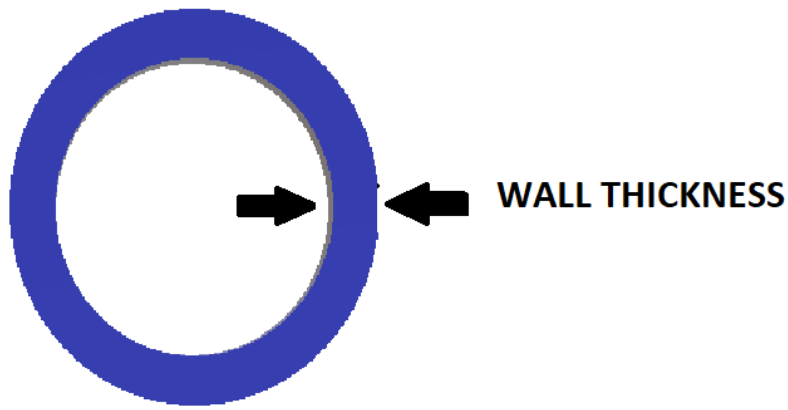


Figure 9.1 Pipe thickness

Sources

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

https://www.pipeflowcalculations.com/tables/schedule-30.php

Design Considerations

Maximum pressure acting on the pipe wall

Data & Variables:

Pipe size = 30 PVC pipe
Yield strength of PVC =7541 PSI =1085904 lbf/ft^2
Outside dia of 3.5 in Schedule 30 PVC pipe= 4 in = 0.3333 ft
Outside dia of 1.5 in Schedule 30 PVC pipe= 2 in = 0.190 ft

Procedure

As we are using two pipes sizes, we 3.5 for gravity driven and 1.5 for the pump driven we will be calculating pressure for both and then thickness using Hoop stress equation for maximum pressure from the textbook to find the thickness of the pipe.
Max pressure to be found applying Bernoulli's between storage tank 1 and 2 and similarly from section 2 and 3 for 3.5- and 1.5-inch pipe.

Calculations

For pipe of 3.5-inch thickness

$$\frac{\square 4}{\square} + \frac{\square 4}{2\square} + Z_4 = \frac{\square 3}{\square} + \frac{\square 3}{2\square} + Z_3$$

$P_3 = 2257.895\ lbf/ft^2$

$\square = (\frac{\square\square}{2(\square - 0.2 * \square})$

$\square = \frac{2257.895 * 0.333}{2(1085904 - 0.2 * 2257.895)}$

$\square$ = 0.134 in

For pipe of 3.5-inch thickness

$$\frac{\square 1}{\square} + \frac{\square 1}{2\square} + Z_1 = \frac{\square 2}{\square} + \frac{\square 2}{2\square} + Z_2$$

$P_1 = 859.36$ lbf/ft^2

$\square = (\frac{\square\square}{2(\square - 0.2 * \square})$

$\square = \frac{859.36 * 0.190}{2(1085904 - 0.2 * 859.36)}$

$\square$ = 0.1163 in

Summary

So, using a Schedule 30 PVC pipe which is cheap and strong enough for our use the wall thickness will be 0.0464 in

Schedule 30 diameter pipe size	Max pressure	Thickness	Thickness specified by manufacturer
3.5	2257.895 lbf/ft^2	0.134 in	0.188 in
1.5	859.36 lbf/ft^2	0.116 in	0.124 in

Table 9.1

Material

PVC Pipe

Analysis

We have got the thickness using Hoops equation and it came out to be less then the thickness specified by the manufacturer which is better, we will be using the thickness specified by the manufacturer that is for 3.5 inch pipe the thickness will be 0.188 in and for 1.5 inch pipe the thickness will be 0.124 in.

▪ Fittings (task 6)

Task 6

Purpose

Specify the number, types, material, and size of all valves, elbows, and fittings

Source

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

Drawing

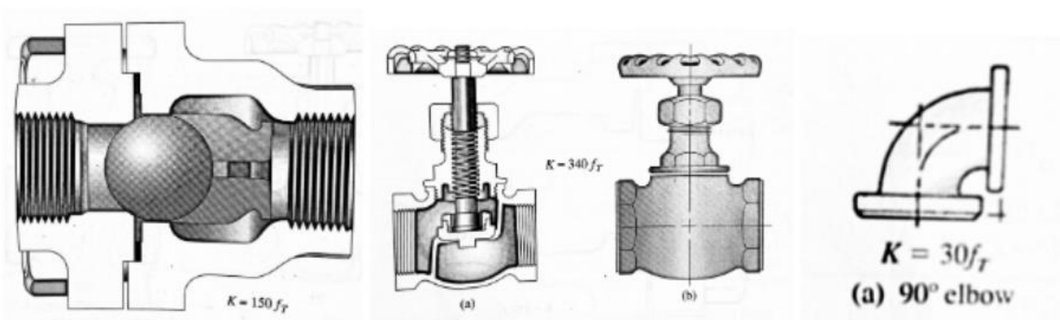


Figure: Common Pipe Fittings

Figure 6.1 Common Pipe Fittings

Design Considerations

The piping used in the system is PVC pipe.
Two valves per pump will be used.

Data and Variables

Schedule 30 PVC with 3.5 and 1.5 in nominal diameter is used in all the system

Procedure

The figure in task 5 represent the layout of the piping system shows where elbows and valves will be needed to make the system operate. The number of valves needed for the system is dependent upon the number of pumps

Material

PVC pipe
PVC 90 degree elbow
Steel gate valve

Summary

section	Material	No of Gate valve	No of 90 degree elbow
Section 1-2	PVC, Steel	**2**	**4**
Section 2-3	PVC, Steel	**1**	**1**
Section 3-4	PVC, Steel	**2**	**3**
Section 4-5	PVC, Steel	**1**	**0**
Section 5-6	PVC, Steel	**1**	**0**

Table 6.1

Analysis:

Our system has attest on gate vale at the exit of each tank and one valve at the exit of pump and other two at the at the entry and exit of pump a section 3, elbow is of same material but valve are made up of steel as PVC can withstand such extreme pressure, the size of the elbow and the gate valve will be 3.5 and 1.5 schedule PVC.

▪ Water hammer (task 10)

Task 10

Purpose:

To determine if the design requires adjustment for water hammer, and if so, what changes need to be implemented.

Drawings and Diagrams:

Refer to previous project drawings.

Sources:

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

PVC Properties. (2016). Retrieved from Vinidex: http://www.vinidex.com.au/technical/material-properties/pvc-properties

Design Considerations:

Incompressible fluid, assume same pressure going into pump as used in task 9 for thickness equation

Data and Variables:

T=70°C E_o=474000 psi (assume 1.5 x water) E(PVC)≈3 GPa=435 psi δ=0.188 (Task 9) ρ=2.91slugs/ft^3 (assume 1.5 x water) D=3.312 in=0.276 ft A=0.239 ft^2 Q=0.222 ft^3/s

Procedure:

First, the points must be set, and a reference plotted. The first point will be at the top of the 18,000-gallon tank and the second right before the first pump. This seems like the most common place for water hammer should the pump be cut off swiftly. Next, velocity can be calculated by dividing the flow rate from previous tasks. Continuing, the equations from the water hammer lecture can be used to determine a maximum pressure and this pressure can be tested against current project limits.

Calculations:

$P_{max} = P + \Delta P$

$\Delta P = \rho C v$

v = Q/A = (0.222 ft^3/s)/(0.239 ft^2) = 0.93 ft/s

$$C = \frac{\sqrt{\frac{E_O}{\rho}}}{\sqrt{\frac{E_O D}{E\delta}}} = \frac{\sqrt{\frac{3291.67\ lb/ft^2}{2.91\ slugs/ft^3}}}{\sqrt{\frac{3291.67\ lb/ft^2(0.276\ ft)}{3.02\ lb/ft^2(0.188\ ft)}}} = 0.84$$

$$\Delta P = 2.91\frac{slugs}{ft^3}(0.84)\left(0.93\frac{ft}{s}\right) = 2.28\ psi$$

so, P_{max} = 6.5 psi + 2.28 psi = 8.78 psi

Summary:

Velocity	**Pressure**	**Maximum Pressure**
0.93 ft/s	6.5 psi	8.78 psi

Table 10.1

Materials:

PVC pipe, coolant

Analysis:

Since the velocity is so low and the original pressure is also low, the pressure added by water hammer would only be about a third of the original pressure. Since this is so small, it seems unnecessary to calculate for breakage since our system is already well over the safety recommendations determined by previous tasks.

iv. Provide pipeline support info.
- Type of supports (task 13)
- Distance between supports (task 13)
- Forces on supports (task 13)

Task 13

Purpose:

Each of the tanks have support to keep them in place to avoid any damage when fluid is in them. The same applies to the pipes going to and from the tanks. Supports need to be placed along the piping path to avoid deflection due to the fluid and pipes weight, which could break the pipe. The lengths between each support would be found to control these forces.

Drawings:

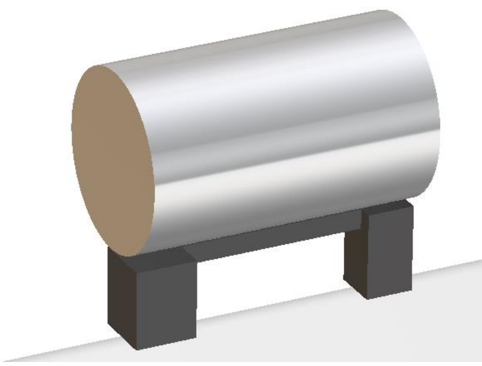


Figure 13.1 Dirty coolant tank on stand

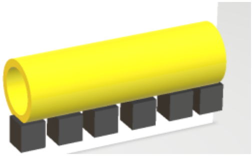


Figure 13.2 Pipe with support

Design Considerations:

- Constant properties
- Fluid
- Deflection should be less than 0.1 inches

Data and Variables:

- E = Modulus of Elasticity for PVC pipe = 2.9 Gpa = 420609 psi
- I = moment of inertia
- ɗ = pipe deflection
- Di=inner diameter=2.5in
- Do = outside diameter = 2.65in
- R = Reactional forces of supports

I =0.5032 IN^4

Procedure:

From the redirection outlines of a pillar, the conditions to discover max diversion and snapshot of dormancy is found, for two equivalent response powers at the two closures of the shaft and resultant power specifically in the middle. The power connected on the pipe is then found by including the heaviness of the pipe to the heaviness of the liquid. This is then utilized in the redirection condition for a diversion under 0.1 in, which will then outcome in a length L being given.

Calculations:

F= Wpvc + Wfluid

Wpvc = 1.07 ib/ft

W fluid =Y COOLANT* $\frac{\pi \square^2}{4} \square$

F=1.07*L+59*$\frac{\pi * 0,2233^2}{4} \square$ =3.38L

=Deflection d= $\frac{\square(\square)^2}{48 * \square * \square}$ $= \frac{3.38\ \square * (\square)^2}{48 * 420609 * 0.5032}$

L= 100in

d=0.332

Summary:

A	B	C	D	E	F
d	E	L	I	F	
0.332703	420609	100	0.5032	338	

Materials:

PVC piping

Coolant

Analysis:

On the off chance that the pipe diverted excessively because of its and the liquids weight, it could blast and cause all the liquid to spill out of the tanks, causing genuine harm and costs.

v. Energy losses. (task 7)

Task 7

Purpose:

Develop the hydraulic analysis of all parts of the system; includes energy losses due to friction and minor losses.

Source

https://www.saylor.org/site/wp-content/uploads/2011/04/Viscosity.pdf

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

Design Considerations:

There are energy losses in pipe, elbows, and valves
Two pumps are used one in section 1 and one in section 3
Remaining two system works on gravitational forces
The pipe sizes are assumed to be Schedule 30 PVC 3.5 and 1.5 in nominal.
Viscosity of water = $8.90*10^{-4}$
Viscosity of coolant = $8.90*10^{-4*1.5}$ $13.35*10^{4}$
Diameter of pipe (all section) = 0.25ft
□coolant = 59 lb/ft3
Velocity all section = 9.8 ft/s
K for gate valve = 0.313
K for elbow=0.256

Data and Variables:

Section 1 = length 609ft, 1 pump 2 gate valve 4 elbows

Section 2 =length 25ft, 1 gate valve 1 elbows

Section 3 = length 40ft, 1 pump 2 gate valve 3 elbows

Section 4 = length 17ft, 1 gate valve

Procedure:

To calculate the head loss of each section we should find out the Reynolds number of that section this is done by dividing the product of density, velocity, and diameter by the viscosity. Then, the next step is to calculate the friction factor for turbulent flow as we know that mostly the flow will be turbulent after that we should calculate head loss due to valve pump and elbow and add them up to find the total heal loss.

Calculations:

Reynolds number =Re = pVD/u

$= (59) (9.81) (0.4)/ (13.35*10^{4})$

=4.03*10^3

f= (0.25)/ [(log (1/ (3.7)) ((D)/ (K)) + (5.74)/ (RE)] ^2

$f = (0.25)/[(log(1/(3.7))((0.4)/(5*10^{-6}))+(5.74)/(4.03*10^{3})]$^2

f= 0.01045

Head loss pipe (section 1) = (f) (L/D) ((V^2)/ (2g))

Head loss pipe (section 1) = (0.01045) ((609)/ (0.4)) ((9.83^2)/ ((2) (32.18))

Head loss pipe (section 1) = 16.19

Head loss valve (section 1) = (2) (0.256) (9.83^2) (2*32.18)

Head loss valve (section 1) = 0.0084

Head loss elbow (section 1) = (4) (0.313) ((9.83^2) (2*32.18))

Head loss elbow (section 1) =0.0061

Head loss (section 1) = 16.219

Summary

	Reynolds number	Friction Factor	Head loss pipe	Head loss valve	Head loss elbow	Total head loss
section 1-2	4.03*10^3	0.01045	16.2045	0.0084	0.0061	16.219
section 2-3	4.03*103	0.00965	11.25	0.0042	0.0016	11.2558
section 3-4	4.03*103	0.00825	9.03	0.0084	0.0045	9.0429
section 4-5	4.03*103	0.00912	8.15	0.0042	0	8.1542

Table 7.1

Material

PVC pipe

PVC 90 degree elbow

Steel gate valve

Analysis

The total lengths calculated of each system are dependent upon the elbows and pumps necessary to make the overall system functional. These numbers will be used for future design and calculation purposes. The desired flow rates must be obtained through the preliminary design phase in order to ensure the right velocity is being used in calculations.

vi. Pump selection

▪Pump requirements (tasks 8 and 15)

Task 8

Purpose

Determine the number of pumps required for the system. Provide requirements (pump head, flow rate) for each pump.

Sources

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

Design Considerations

Pump 1 from Tank 1 to clean tank (Section 1)
Pump 2 from machine center to clean coolant tank (system 3)

Data and Variables

Height of clean coolant tank to pump from section 1 to 2 = 39ft
Height of clean coolant tank to pump from machine area = 30 ft.
Flow rate from section 1-2 = 13.3681□□ 3 /□in
Flow rate from machining area to clean coolant tank =13.3681□□ 3 /□in
Head loss (section 1) = 16.2045
Head loss (section 3) = 9.0352

Procedure

To figure out what pump we need we must calculate the pump head requirement using a Bernoulli’s equation □□ = □ + *h*□.

Calculations

For Pump 1 □□ = □ + *h*□

= 39 □□ + 16.204□□ = 55.219□□

For Pump 2 □□ = □ + *h*□

= 30□□ + 9.03□□ = 39.035□t

Summary

Pump	Pump Head Requirement (ft.)
1	55.219
2	39.035

Table 8.1

Materials

Coolant
Pump
PVC Pipe

Analysis
We got the head of both the pump which are having value close to each other so we will be using same type of pump for both places except one should can work under the ground

- ▪ Selection of pump type (task 15)

Task 15

Purpose:

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

Sources:

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

Drawing

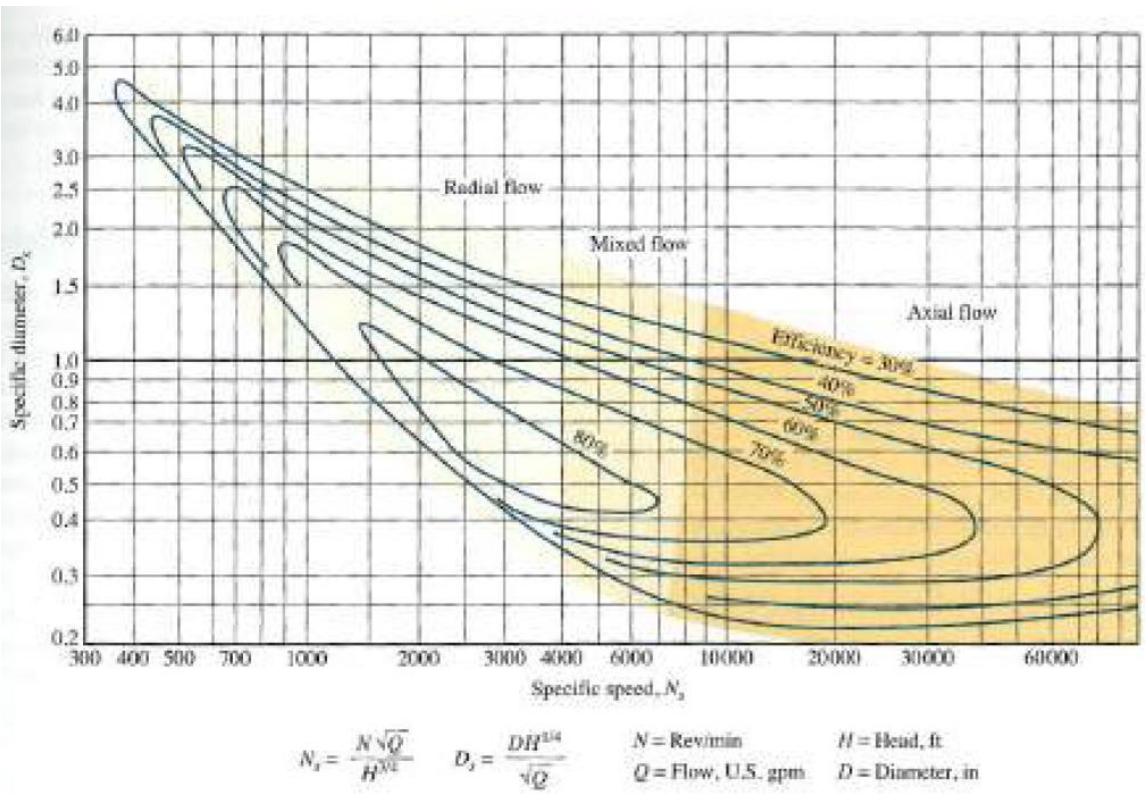


Figure 15.1 Selecting pump as per above speciation

Considerations:

Constant Properties
Incompressible fluid
Flow from clean coolant tank to dirty coolant is gravity driven
Radial pump selected to use above figure

Data and variable

□coolant = 59 lb/ft3

Head requirement for pump 1=55.219
Head requirement for pump 1= 39.035
Flow rate for pump 1 =26.72 ft^3/min
Flow rate for pump 2 =26.72 ft^3/min
Diameter of the pipe =1.5 inch

Procedure

As we are using radial pump for now we will consider RPM as 3500 rev/min and will find out specific speed and the specific diameter and then we will be using flow rate and the head to select one of the pump from sulzer chart and then will be find out the efficiency from the graph and using that we can find out the power requirement of the pump

Calculation:

	N(rpm)	Q(gmp)	H(ft)	Ns	Ds
Pump in section 1	3500	50	55.219	1814.78	1.15653
Pump in section 2	3300	50	39.035	1893.58	1.06047

Figure 15.2 Pump Calculations

Now calculating power

But before that we will choose the efficiency from the diagram above

So, the efficiency is 0.59 and 0.74 respectively.

	Power calculation				
Specific gravity	H(ft)	Q(ft^2/sec)	Efficiency	Power (lbft/s)	Power (hp)
59	55.219	0.445	0.59	2457.2455	4.467719091
59	39.035	0.445	0.74	1384.95125	2.518093182

Table 15.1 Pump Calculations

Summary

	Number Of pump	Type of pump	Ds	H(ft)	Power(HP)	Efficiency
Pump in section 1	1	Radial	1.156	55.219	4.467719091	0.59
Pump in	1	Radial	1.0604	39.035	2.518093182	0.74

section 2						

Table 15.2

Material

Coolant

Radial kinetic pump

Analysis

We are using radial pump because the its rotating impeller to create a vacuum in order to move fluid. The pump's impeller rotates within the housing and reduces pressure at the inlet. This motion then drives fluid to the outside of the pump's housing, which increases the pressure enough to send it out the discharge.

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

▪ Summary of selected pumps (includes values at operating point, NPSH_req, pump size, pump weight, pump required power, electrical motor power) (tasks 16 and 17)

Task 16

Purpose:

Specify the characteristics of the chosen pumps, point of operation, and actual pump size and weight.

Sources:

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

https://www.sulzer.com/en/shared/products/2017/03/28/12/42/gsg-diffuser-style-barrel-pump#stacked-tab__4c33cd19-c4b0-4be5-bd40-28eee219829a

Drawing

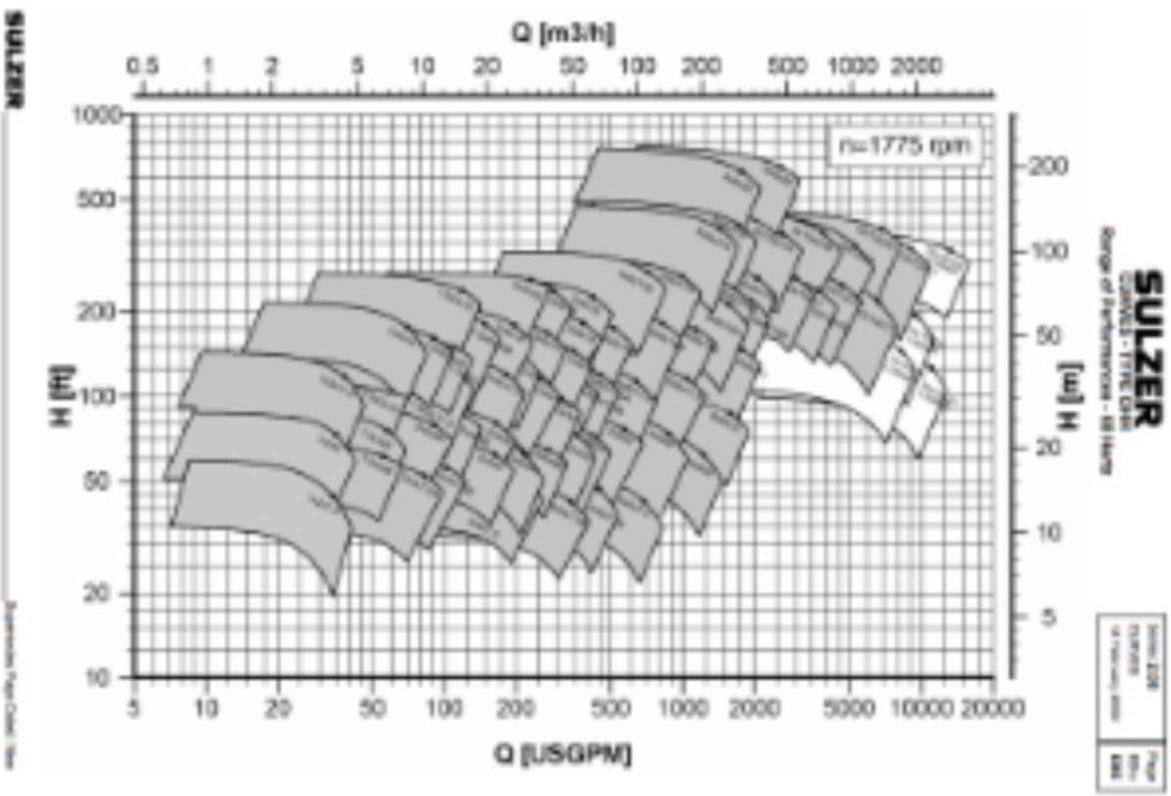


Figure 16.1 Sulzer Chart

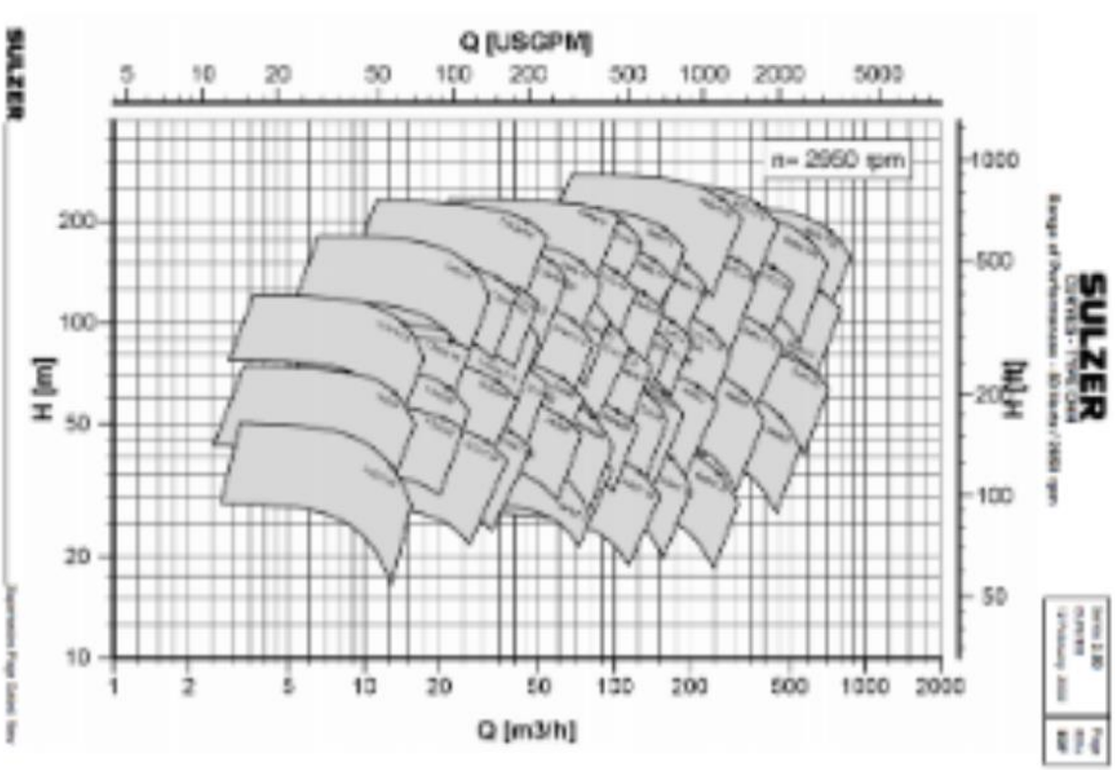


Figure 16.2 Sulzer chart for section 1 and 2

Design consideration

Incompressible fluid

Constant Properties

Kinetic Radial pump used

Data and variables

Head requirement for pump 1=55.219
Head requirement for pump 1= 39.035
Flow rate for pump 1 =26.72 ft^3/min
Flow rate for pump2 =26.72 ft^3/min
Hz for pump 1 and 2 =50

Procedure

We will be using the pump head flow rate and place of operation to select the pump the impeller size and power will be determined after selecting the pump size.

Calculation

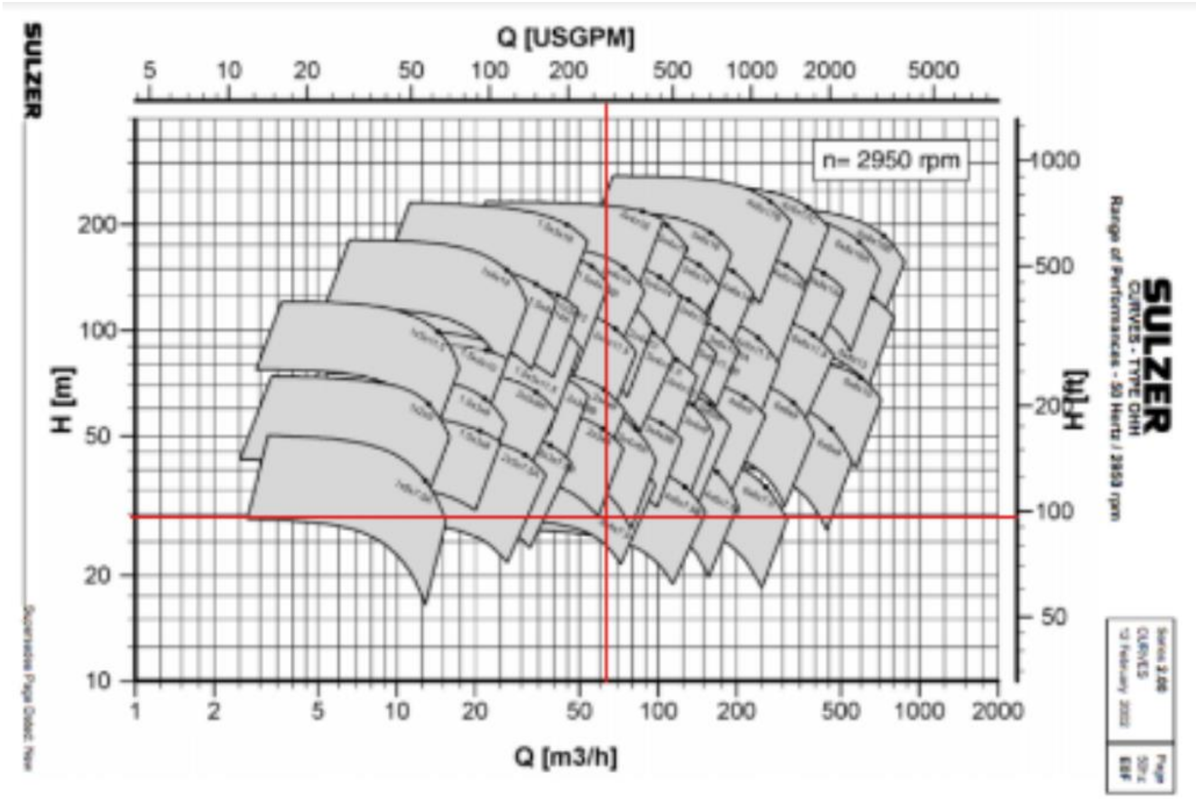


Figure 16.3 Pump no 1 3x4x7.5 Sulzer pump

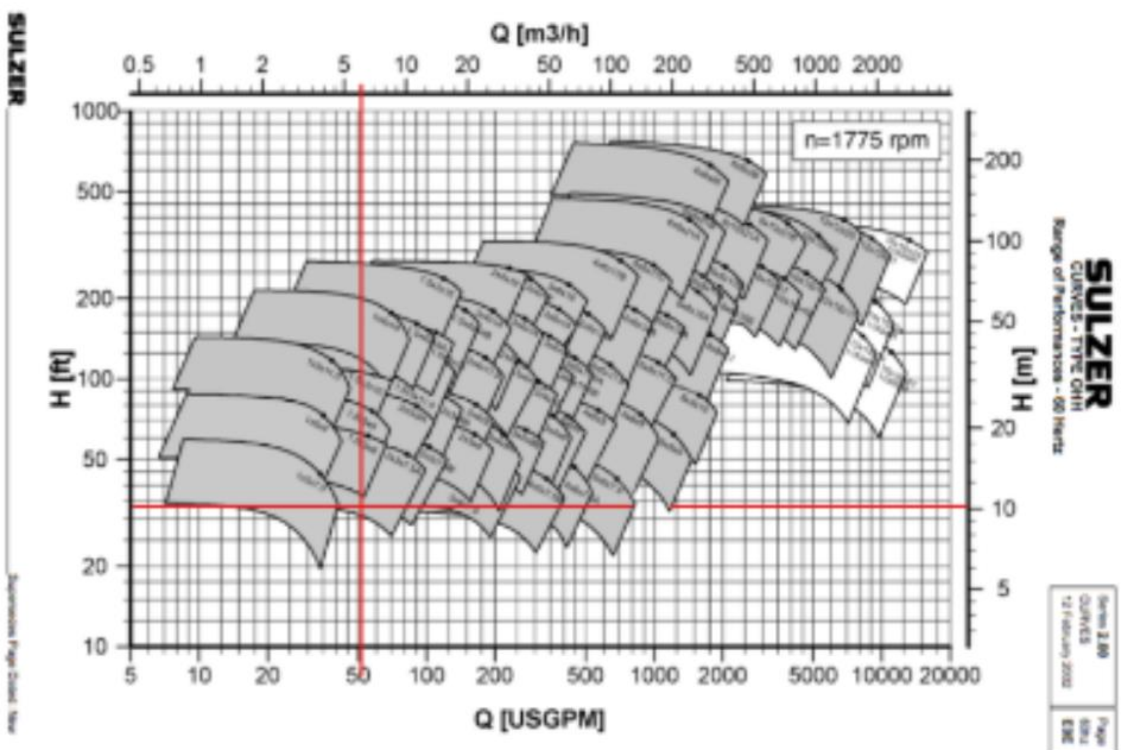


Figure 16.4 Pump no2 3x4x7.5 A Sulzer pump

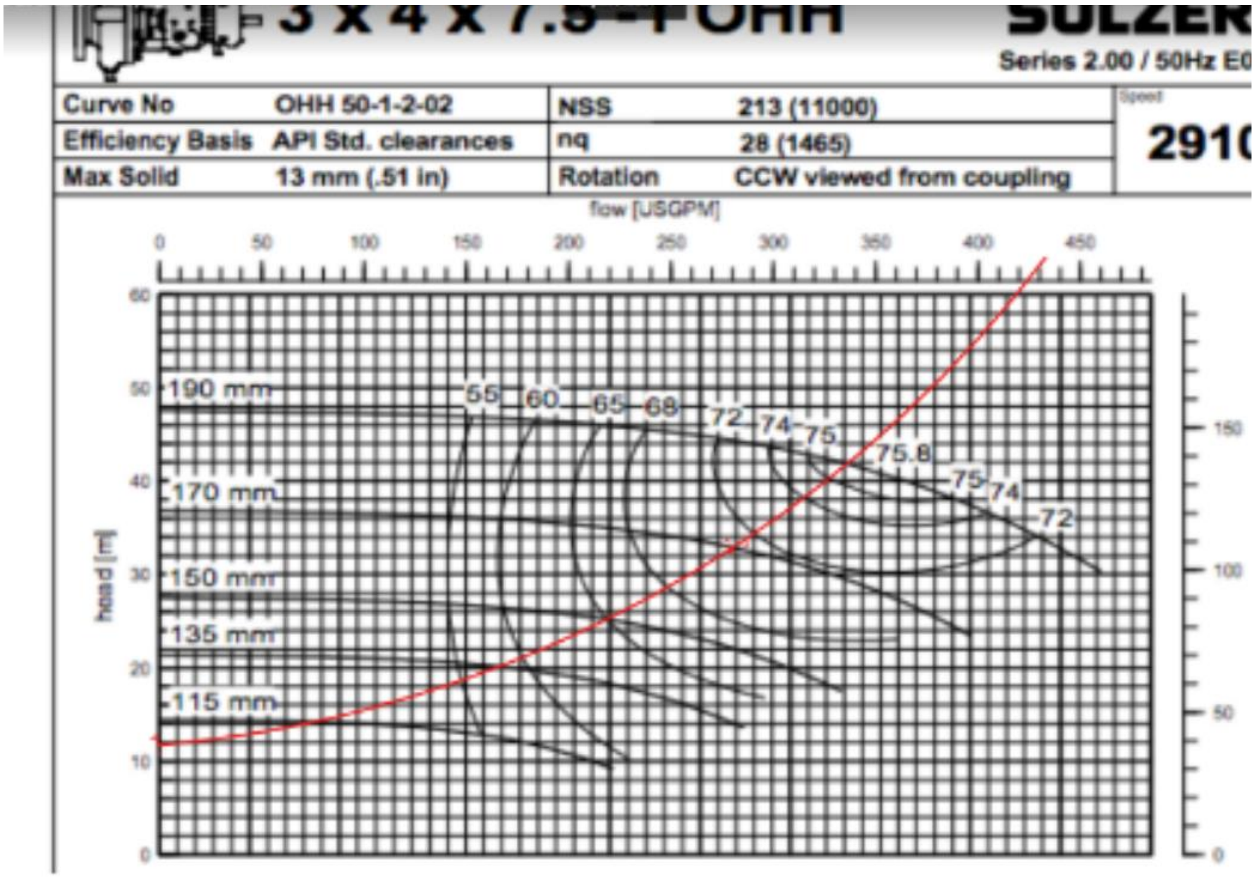


Figure 16.5 Impeller size for pump 1 = 170mm = 6.7 inches

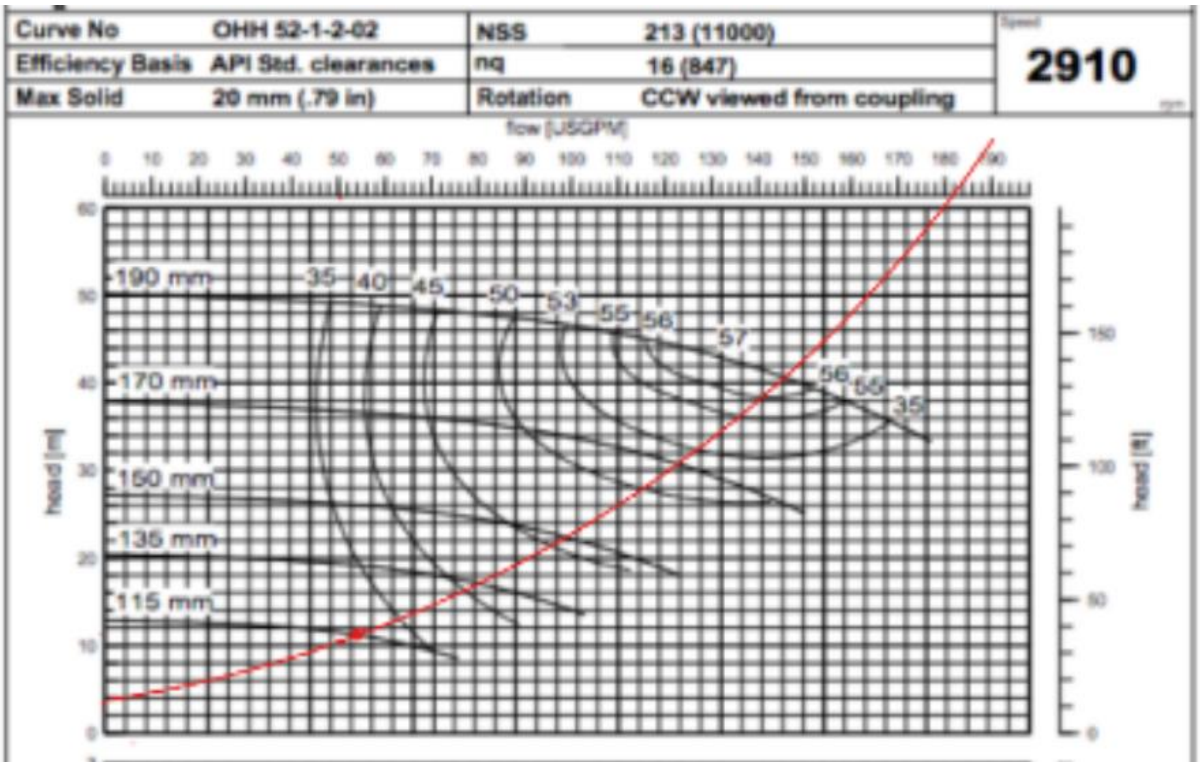


Figure 16.6 Impeller size for pump 2 = 115mm = 4.5 inches

Summary

	Pump type	Impeller size (in)
Pump no 1	3x4x7.5 Sulzer pump	6.7
Pump no 2	3x4x7.5 A Sulzer pump	4.5

Table 16.1

Material

Coolant

Pump

Radial Impellers

Analysis

There are two pump needed in the system 1 to transfer fluid from storage tank to clean coolant tank and the second one from machining area back to clean coolant tank. We could determine the type of pump we will be using in the system using the graph and the size of the impeller.

Task 17

Purpose:

To determine the electrical motor requirements for each of our system's pumps.

Drawing

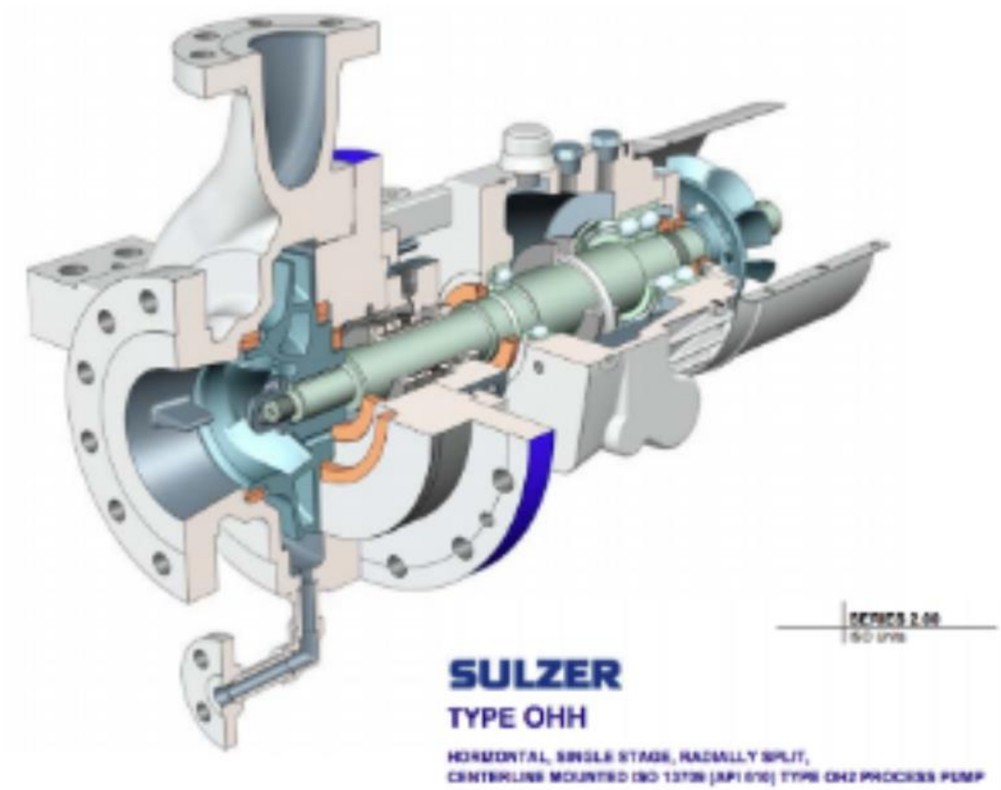


Figure 17.1 Sulzer pump with electric motor

Design Considerations:

Coolant has identical properties of water
Incompressible fluid
Pumps from Sulzer are used
Constant properties
Two pumps being used
60 Hz, Radial pumps are being used

Data and Variables:
Pump 1 head = 55.219 ft
Efficiency pump 1 = 0.59
Flow pump 1 = 0.445 Ft/s^2
Flow pump 2 = 0.445 Ft/s^2
Efficiency pump 2 = 0.74
Pump 2 head = 39.035 ft

□coolant = 59 lb/ft3

Procedure:

We will be calculating required power of the pump using the flow rate head and efficiency and them we will multiply it by 1.10 to determine the power input of electrical motor

Calculations:
For pump 1

$$P_1=\frac{\square\square\square}{\cap}$$

$$P_1=\frac{59*0.445*55.21}{0.59} = 14.5 \text{ hp}$$

Motor power =4.5*1.1= 14.95 hp

For pump 2

$$P_2=\frac{\square\square\square}{\cap}$$

$$P_1=\frac{59*0.445*39.035}{0.75} = 12.5 \text{ hp}$$

Motor power =2.5*1.1= 12.76 hp

Summary

	Power	Electric motor power
Pump 1	14.5	14.91
Pump 2	12.518	12.76

Table 17.1

Material:
Sulzer pumps

Coolant

Analysis:

These calculations give us the electrical motor requirements for the pumps in our design. The calculated values will allow us to ensure that the pumps we select for the pipeline system are powerful enough to propel the system properly.

- ▪ Cavitation (task 18)

Task 18

Purpose:

Evaluate the NPSH available for your design, and demonstrate that your pump has an acceptable NPSH required. Specify the installation requirements for the pumps, including the complete suction line system.

Sources:

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

Design Considerations:

Coolant has identical properties of water
Incompressible fluid
Pumps from Sulzer are used
Constant properties
Two pumps being used

Data and Variables:

Psat= 14.7 psi= 2116.8 psf
hL= 55.219 ft
Vs= 8.5 ft/s
Vimp= 1775 7.76 ft/s

Procedure:

To analyze the NPSH for our design, we had to display that the NPSH available in our design was indeed greater than the NPSH required. we will be using Bernoulli equation to derive actual NPHS for each pump the NPHS required will be found using the Sulzer chart
.

Calculations:

NPSH available= $\square_{1}/\square \pm \square\square - h_{\square} - \square\square/\square$
= (2829.6 psf - 2116.8 psf)/(58.6892 lbf/ft^3)= 12.1464 ft
NPSH actual=

$$\frac{\square 1}{\square} + \frac{\square 1}{2\square} + Z_1 = \frac{\square 2}{\square} + \frac{\square 2}{2\square} + Z_2 + h_l$$

$$\frac{\square 1}{\square}+Z_1=\frac{\square 2}{\square}+\frac{\square 2}{2\square}+Z_2+h_l$$

$$NPHS = Z_1 - \frac{\square 2}{2\square} - h_l + \frac{\square 2 - \square}{\square}$$

$$NPHS = 55.21 - \frac{8.5^2}{2*32.714} - 6.78 - + \frac{2018.40-904.33}{59}$$

NPHS= 45.78 ft

NPHS act > NPHS req
Similarly, for Pump 2
NPSH available= 3 ft

NPSH actual=

$$\frac{\square 1}{\square}+\frac{\square 1}{2\square}+Z_1=\frac{\square 2}{\square}+\frac{\square 2}{2\square}+Z_2+h_l$$

$$\frac{\square 1}{\square}+Z_1=\frac{\square 2}{\square}+\frac{\square 2}{2\square}+Z_2+h_l$$

$$NPHS = Z_1 - \frac{\square 2}{2\square} - h_l + \frac{\square 2 - \square}{\square}$$

$$NPHS = 39.035 - - \frac{7.87^2}{2*32.714} - 4.1 - + \frac{2018.40-904.33}{59}$$

NPHS= 34.69 ft

NPHS act > NPHS req
Summary:

	NPHS req	NPHS act
Pump 1	12.14	45.78
Pump 2	3	34.69

Table 18.1

Materials:
Sulzer pumps
PVC pipes

Coolant

Analysis:

The value of NPSH available was significantly higher than that of the NPSH required.
Therefore, our pump has an acceptable NPSH requirement. There will be gate valves, installed on either side of the pump, before the inlet and after the outlet.

vii. Instrumentation selection.

- Flow rate (task 14)
- Pressure (task 14)

Task 14

Purpose:

Decide the instruments for one pipeline framework. This incorporates an instrument to quantify the stream of the weight and stream rate going through the framework.

Sources:

- Mott R., Untener A. "Applied Fluid Mechanics," 7th Edition, Pearson Education

Inc.,

Drawings and Diagrams:

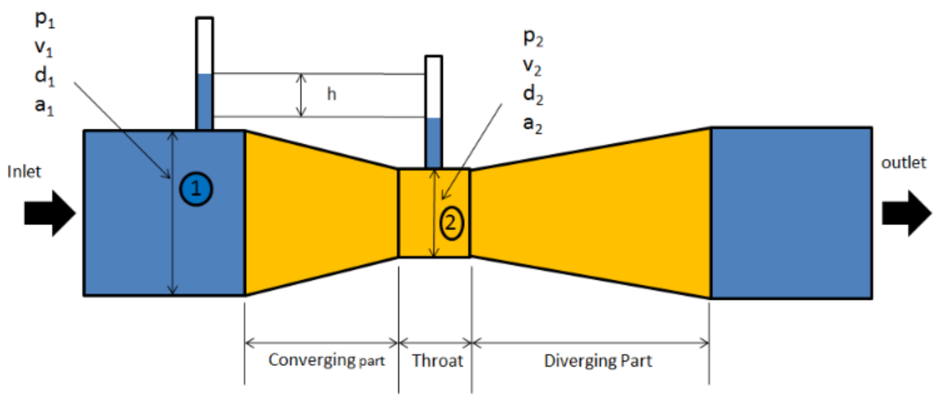


Figure 14.1 Venturi

Design Considerations:

- Pressure change
- Steady flow
- Incompressible Fluids

- Mercury is the fluid for Manometer
- Constant properties Data and Variables: ●
- Venturi Pressure: P2
- Venturi Velocity: V2
- Venturi flow Area: A2
- Manometer Flow Height: h in.
- Venturi Discharge Coefficient: C

Data and variable

Specific weight of coolant Yf: 58.56 lbm/ft3

Mercury Specific Weight: 844.9 lbm/ft^3

flow through pipe=13.3681 ft^2/min =0.22280 ft^2/sec

p1=5.27 psf

v1 =9.8 ft/s

Re= 4.03*10^3

Area of the pipe = 0.0409ft*@

Procedure:

Utilizing the Venturi Discharge Coefficient in the reading material, the release coefficient is discovered utilizing the Reynolds number. The condition for stream rate through a pipe with a venturi connected will at that point be utilized to locate the required venturi weight, stream zone, and speed. The Manometer stature appended to a venturi condition is then used to discover its tallness with mercury as its estimation liquid. The equivalent exceeds expectations work is then used to discover the range from the venturi properties found in the main capacity.

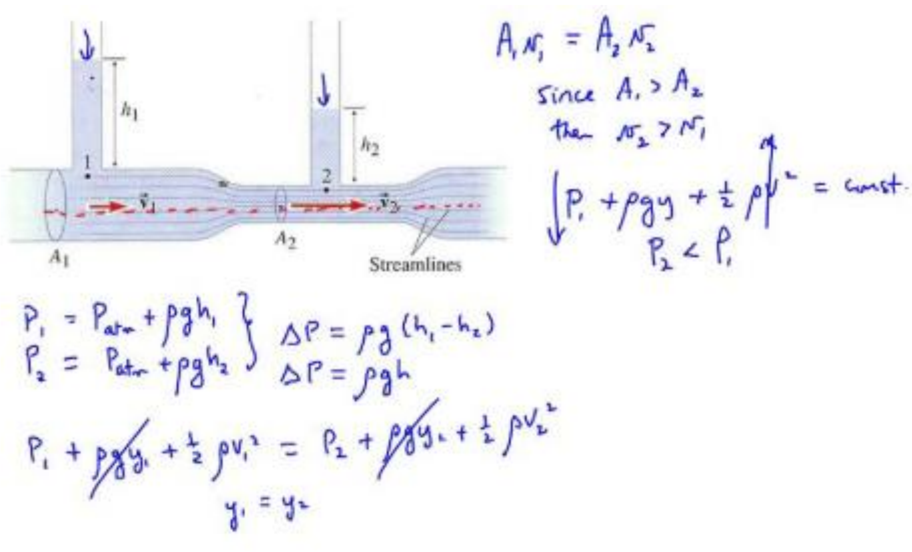


Figure 14.2 Venturi Calculations

Calculations:

Taking

Cd = 0.94 from text book fig 15.3,we get

Using

$$Q = CA_1\sqrt{\frac{2g(p_1 - p_2)/\gamma}{(A_1/A_2)^2 - 1}}$$

We will find A1 and P2 from above equation

$$0.228=0.94*0.0409\sqrt{\frac{2*32.2(5.27-\square 2)/58.61}{\left(\frac{0.\square 409}{\square 2}\right)^2-1}}$$

A2= 0.0204ft^2

P2= 2.876 psf

Height of the mercury

$$v_1 = C\sqrt{\frac{2gh[(\gamma_m/\gamma_f) - 1]}{(A_1/A_2)^2 - 1}}$$

$$0.2280=0.94\sqrt{\frac{2*32.2*h(844.9/58.56)-1}{(0.0409/0.0204)^2-1}}$$

H=6.67in

and V2= Q/A2

=0.0028/0.0204

=0.137 ft/sec

Summary:

P2	2.876 psf
V2	0.137 ft/sec
A2	0.0204ft^2
h	6.67in

Table 14.1

Analysis:

In the wake of finding the release coefficient for the venturi being utilized, the comprehend work in exceed expectations was utilized to get the correct weight and territory of the venturi throat. These were observed to be the volumetric stream rate condition, the venturi speed was observed. After these were discovered, the comprehend work was utilized to locate the correct manometer stature the mercury will be the point at which the framework is at operational stream rate.

Final drawings

1. Plot plan (task 19)
2. Elevations view (task 19)
3. Isometrics (task 19)

Task 19

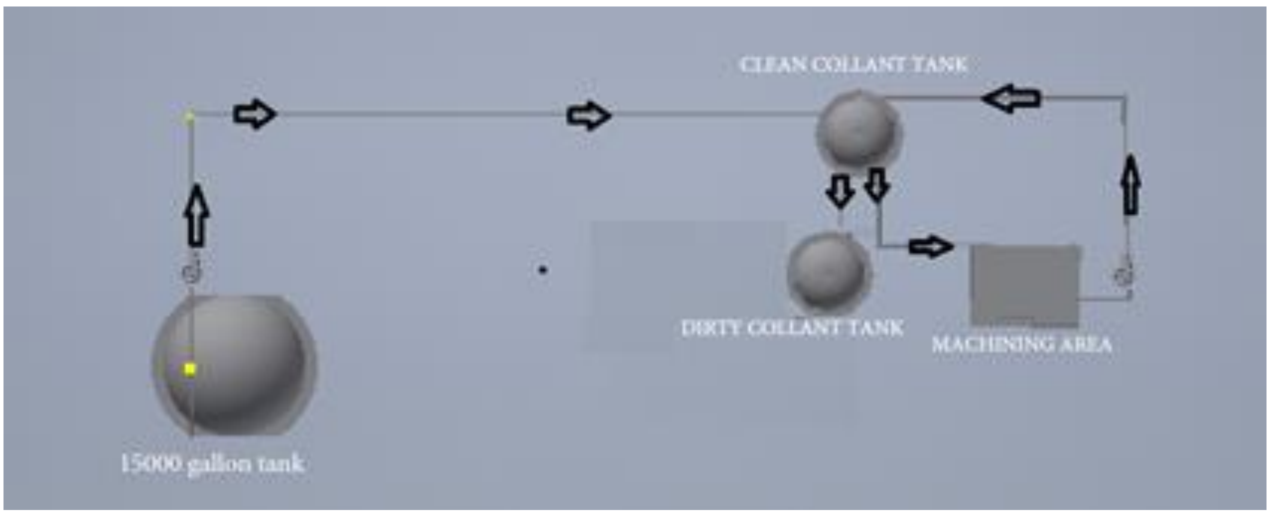


Figure 19.1

Isometric

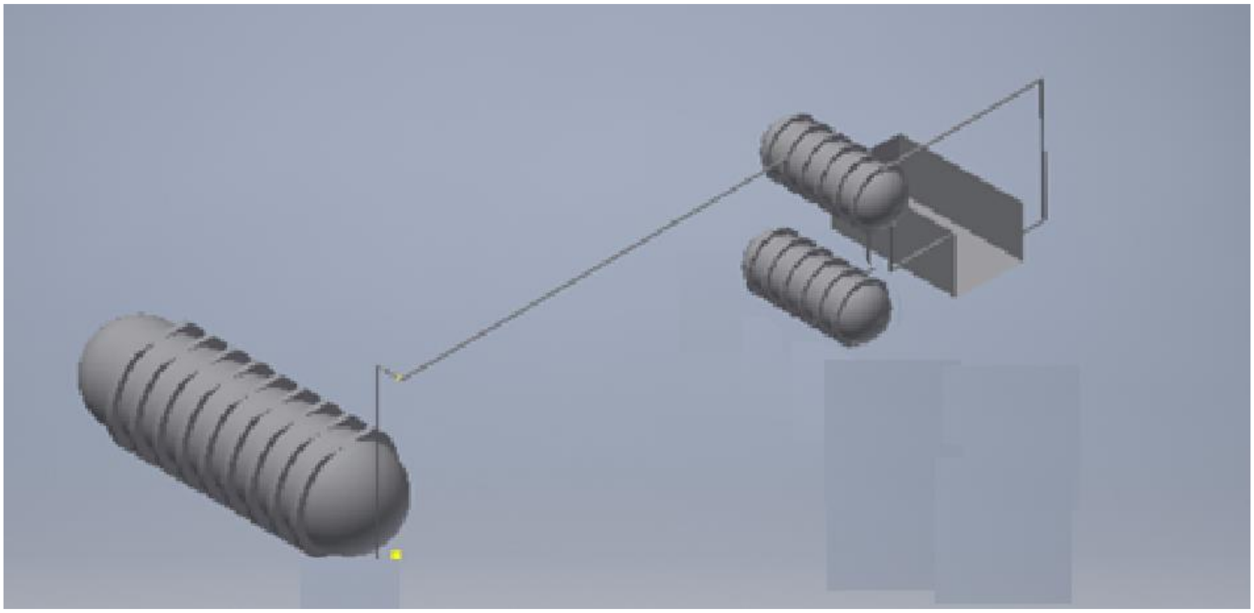


Figure 19.2

Elevation

Bill of materials and equipment list (task 20)

Task 20

<u>Purpose:</u>

Prepare bill of material (cost is not required on this project). Include everything you designed/selected. The bill of material should contain the materials of the system as well as all the equipment

Bill of material				
	Amount	Size	Description	Material
15000 Gallon tank Components				
Tank	1	18000	Main storage tank	Fiber glass
Flange	1	0.0795 in	-	Forged steel

PVC pipe	1	1.5 in	-	PVC
PUMP	1		Sulzer pump	Standard
Elbow	3	1.5 in	Standard 90	PVC
Gate valve	2	1.5 in	-	Steel
1000 Gallon tank Components				
Tank	1	1100	Main storage tank	Fiber glass
PVC pipe	1	3.5 in	-	PVC
Elbow	2	3.5 in	Standard 90	PVC
Gate valve	1	3.5 in	-	Steel
Machining Area				
PVC pipe	1	1.5 in	-	PVC
PUMP	1		Sulzer pump	Standard
Elbow	3	1.5 in	Standard 90	PVC
Gate valve	2	1.5 in	-	Steel
4000 Gallon tank Components				
Tank	1	4000	Main storage tank	Fiber glass
PVC pipe	1	3.5 in	-	PVC
Elbow	1	3.5 in	Standard 90	PVC
Gate valve	1	3.5 in	-	Steel

Table 20.1

Final remarks & Appendix (task 21)

Joshua-

This project was a good precursor to working in the field. It created a possible real world scenario and fostered teamwork to complete the work within the deadline. I am not sure of where I may end up working, but even if I do not use the fluids applications in my place of work, I still will have more experience working in a group setting. While much of this project was rushed and much of it is badly formatted, the majority of the design and calculations were sound. Given more time and less work from other classes or part-time work, our group could have formatted it nicely and given a well furnished report. Even so, the technical strength of our report will stand.

Ahmed-

It is such a great opportunity to be involved in this project where I have learned many aspects in designing a piping system. I became more familiar with most of the processes and calculations using helpful equations such as, Bernoulli's. Also, I have developed a skill of communication with my team members and how shall we cooperate to get the required tasks completed, and how to help one another to get to the desired result. Many projects I have been involved in the past, were pretty far from what is actually happening in the industry, However, I can say that this project is giving me an idea of what is actually happening in real life regarding piping systems.

Foster-

This project is the second major group project I've worked on at Old Dominion. Opportunities like these don't come very often. Both of these projects have offered a very real experience of what it would be like working in the field. I wish more classes offered opportunities like these group projects. I believe that projects like these are the best way to learn content since the learnings can be easily applied to real world applications. There are certainly aspects of our project that could have been better, but overall, I think we're all satisfied with the outcome. Thank you for providing this opportunity.