Project One Formal Report – Revised

ME 4465

Thermal Fluids Systems Design, Fall 2018

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Submitted on 12/4/18 to Professor Mary Hofle

Executive Summary

In order to design the most effective piping system schedule 40 piping with a nominal pipe diameter of 1.5" was used. The calculated velocity was 9.46 feet/s. Piping supports were spaced less than twenty feet apart to increase the overall safety of the piping system, and the system includes a check valve and globe valve in order to boost safety. The piping skirts the edge of every building so as not to compromise the stability and structural integrity of the buildings on site. The objective is to deliver 100 gpm of water at 140 degrees Fahrenheit from a pump discharge to a holding tank. Other given problem information is: the plot size is 60ft by 140 ft with a 10-foot distance between the tank and right boundary. The pump provides pressure to overcome 50 psi of pressure loss, and the holding tank is open to atmospheric pressure (P_{atm}=0 (gauge)). The piping must be horizontal and of constant diameter, schedule 40, and our system must include a globe and check valve. The maximum flow velocity is 15 ft/s, and the piping cannot be attached to any building or tank.

These findings meet the stated objectives and deliverables of keeping the fluid velocity beneath 15 ft/s, as the final velocity was 9.46 ft/s, having a pressure drop of less than 50 psi, as the calculated pressure drop was 10.74 psi, using schedule 40 steel and delivering 100 gpm of water. Included in this report is a Solidworks model of the system and MATLAB simulation of the equations which back the conclusions found in the report.

Contents

Problem Description

Our Team has been tasked with designing a piping system to deliver 100 gpm of water at 140 degrees Fahrenheit from a pump discharge to a holding tank. The plot size is 60ft by 140 ft with a 10-foot distance between the tank and right boundary. The pump provides pressure to overcome 50 psi of pressure loss, and the holding tank is open to atmospheric pressure (P_{atm}=0 (gauge pressure)). The piping must be horizontal and of constant diameter, schedule 40, and our system must include a globe and check valve. The maximum flow velocity is 15 ft/s, and the piping cannot be attached to any building or tank. It is thus our job to determine the minimum piping diameter and length between the pump and tanks and create diagrams and schematics displaying our work.

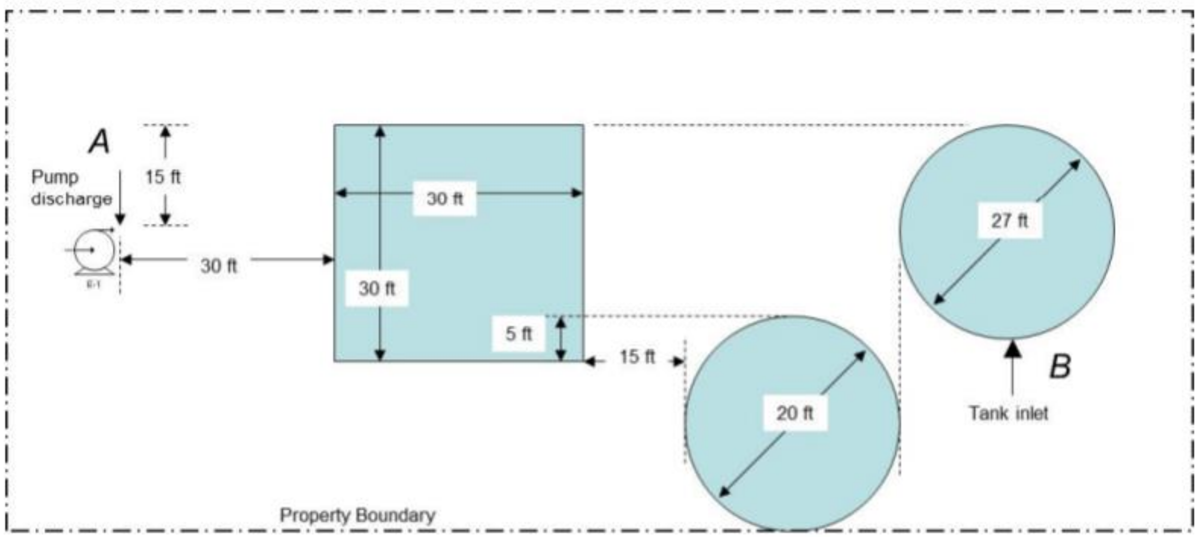


Figure S-1: Compound Overview

Design Description

The piping is made from Schedule 40 1.5" AISI 1010 hot rolled steel, which has a roughness ("e") factor of 0.00015 ft. Below is shown a table of critical values, taken from the hand calculations and coding results.

Table of Critical Values

Inner Pipe Diameter must be greater than	2.067in or .17225 feet
Nominal Pipe Size	2"
Friction Factor	0.024
Total Head Loss	25.2 ft
Total Minor Loss	14.61 ft
Total Friction Loss	10.59 ft
Max pipe velocity (2in)	9.47 ft/s
Pressure Drop	10.74 psi

Table D1- Design Deliverables

Table of Minor Losses

45 Deg Elbows	0.3
90 Deg Elbows	0.57
Check Valve (Swing)	1.9
Globe Valve	6.5
Screwed Fittings	0.72
Entry Loss (Sharp Edge)	0.5
Exit Loss (Sharp Edge)	0.1
Total Minor Loss	**10.59**

Table D2- Table of Minor Losses (K values)

Table of Iterations

Friction Factor	**Calculated Pipe Diameter (feet)**
0.02129950769	0.122601548
0.02123257129	0.1241549009
0.02123591057	0.1240767682

Table D3- Table of Iterations

Theory: (Full calculations can be found in appendix 1 &2)

Total Head Loss: The pipe layout was first drawn out to determine the shortest distance from the pump to the tank inlet. With this length known the diameter of the pipe could be determined. Using the modified Bernoulli equation

$$h_f = f\frac{L}{D}\frac{V^2}{2g} \tag{1}$$

Pg. 433, Munson 7th Ed.

the total maximum head loss hf of the system was found to be 117.4 ft. V is the velocity of the fluid, g is the gravitational constant, L is the length of the pipe, D is the diameter, and f is the friction factor.

Using the equation for the velocity using the mass flow rate and area with v being the velocity of the fluid, Q the mass flow rate of the fluid, and A the area of the pipe.

$$V = \frac{Q}{A} \tag{2}$$

Equation 3.19, Munson 7th Ed.

the area was put in terms of diameter using equation (3).

$$A = \frac{\pi}{4} D^2 \tag{3}$$

and substituted. Using the friction loss equation $h_f = f \frac{L}{D} \frac{V^2}{2g}$ (1) and plugging in the above equations it can be shown that:

$$D^5 = \frac{8fLQ^2}{\pi^2 g h_l} \tag{4}$$

Pg 443, Munson, 7th Ed.

Given values were plugged in, the max allowable velocity, gravity, and the total length of pipe. giving the diameter in terms of the friction factor.

Calculating Reynold's Number:

The Reynolds number can be calculated using the following equation:

$$Re = \frac{\rho V D}{\mu} \tag{5}$$

Pg. 362, Munson 7th Ed.

was also left in terms of the diameter, with Re being Reynold's Number, v being the fluid velocity, D the diameter of the pipe, μ being the dynamic viscosity of the fluid, and ρ being the density of the fluid. With the value of

$$f = (-1.8 \ln(\left(\frac{6.9}{Re}\right) + \left(\frac{\left(\frac{\epsilon}{D}\right)}{3.7}\right)^{1.11})^2 \tag{6}$$

Equation 8.35b, Munson 7th Ed.

Given Q+ΔP find Diameter:

In special cases where the diameter must be found but the change in pressure is known, ΔP and the volumetric flow rate Q is known the diameter can be found by guessing a value for the friction factor, f. This value is then plugged into equation (6) to solve for the diameter (remembering that Reynold's Number is a function of the fluid velocity and diameter, of which the velocity is known). Once a value is found for the diameter the e/D ratio can be found, and then Reynold's number can be used in conjunction with the Moody diagram shown below in figure T-1. The Moody diagram then gives a new value of the friction factor can be found, and the process can be started over with the new friction factor. This process should be continued until the same friction factor is repeatedly given from the Moody diagram, then the corresponding diameter is known.

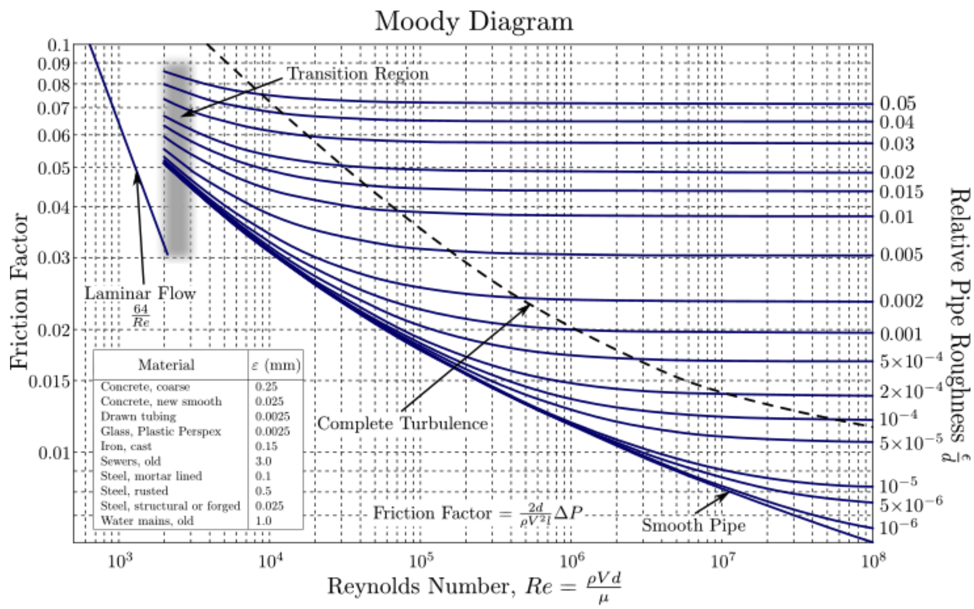


Figure T-1: Moody Diagram

Find Change in Pressure:

The Modified Bernoulli Equation is,

$$\frac{P_1}{\gamma} + \frac{(v_1)^2}{2g} + z_1 = \frac{P_2}{\gamma} + \frac{(v_2)^2}{2g} + z_2 + h_l(\text{i.e. } h_f + h_m)$$

ME 4465 Lecture, Date: 08/23/2018

If uniform fluid velocity is assumed, then '$\frac{(v_1)^2}{2g}$' = '$\frac{(v_2)^2}{2g}$'. Similarly, if no elevation change is considered, then 'z_1'=' z_2'. Hence, If the head loss and specific gravity of the fluid is known equation 8 can be used as a Modification of Modified Bernoulli's Equation to solve for the change in pressure as shown:

$$h_l = \Delta P/\gamma \tag{8}$$

Equations:

1. $h_f = f\frac{L}{D}\frac{V^2}{2g}$
2. $V = \frac{Q}{A}$
3. $A = \frac{\pi}{4}D^2$
4. $D\text{^}5 = \frac{8*f*L*Q\text{^}2}{\pi^2*g*hl}$
5. $Re = \frac{\rho VD}{\mu}$
6. $f = (-1.8\ln(\left(\frac{6.9}{Re}\right) + \left(\frac{\left(\frac{\epsilon}{D}\right)}{3.7}\right)^{1.11})^2$
7. $hl = \frac{\Delta P}{\gamma}$
8. $h_l = \Delta P/\gamma$

Notation:

ΔP = change in pressure

V = velocity

A = area

h_f = friction head loss

h_L = total head loss

Re = Reynolds number

f = friction factor

ϵ = roughness

D = diameter

ρ = density

μ = dynamic viscosity

γ = specific gravity

Appendix 1: Computer Code

Part one of the computer code calculates the friction factor iteratively using the Reynolds Number, pipe diameter, and roughness and outputs it to an excel table. The final output value was 0.0212. For more detail see the theory section on calculating using the iterative process to find the diameter.

Part 2 calculates the minor losses using the K values found in table D2 and the modified Bernoulli equation.

Part 3 calculates the friction loss based on the total head loss and the value for minor losses from part 2.

Part 4 calculates the actual velocity inside the pipe based on the friction losses, pipe diameter, and length. This is different than the section velocity given by using equation 2 as it includes the velocity loss due to friction.

Part 5 uses the Haaland equation to calculate the new friction factor using the pipe diameter, Reynold number, and the roughness. This friction factor is plugged back into part one for the iteration until it stabilizes.

All values are then outputted in the output table of the code (Figure C4).

```matlab
%Shishir Khanal
%ME 4465; Project - 1
%Group Partners:
%       Sayler Massey
%       Matthew Wright
% Purpose of the code:
%     Part-1: Friction Factor calculation iteration
%     Part - II: Minor Loss Calculation
%     Part-III: Calculate the friction loss
%     Part-IV: Calculate the Actual Velocity
%     Part V: Haaland and minorloss functions
%----------------------------------------------------------
clear;
clc;
%clears the worksheet and command screen

%----------------------------------------------------------

% Part-1: Friction factor calculation iteration

Guessf = 0.02;
% taking the guess friction factor to be 0.02
PipeDia = (0.001385*Guessf)^(1/5);
%derived through modified Bernoulli's
ReynoldNum = (2.94*(10^6))* PipeDia;
% equations derived through Reynold's number equation
epsilon = 0.00015;
%Chosing material to be Common Steel(e=0.00015)
Data = zeros(5,2);
%Vector to store the itersted values for the friction factor and pipe
%Diameter
FrictonFactor = Haaland(epsilon,PipeDia,ReynoldNum);
% FrictionFactor contains the ff from Haaland Equation
count = 1;
%counter index to iterate the vector in the loop
Data(count,1)=FrictonFactor;
Data(count,2)= PipeDia;
% storing the new values of first friction factor in the vector
count=count+1;
while fix(FrictonFactor*10^5)/10^5 ~= fix(Guessf*10^5)/10^5
    %comparing the friction factor obtained and guessed in the 4th decimal
    %place
    Guessf = FrictonFactor;
    % taking the previous calculated value of friction factor if the guessed
    % value doesnot equal calculated value.
    PipeDia = (0.001385*Guessf)^(1/5);
    ReynoldNum = (2.94*10^6)* PipeDia;
    %recalculate the pipediameter and Reynolds number with the new ff value
    FrictonFactor = Haaland(epsilon,PipeDia,ReynoldNum);
    %Recalculate the friction factor using the Haaland function
    Data(count,1)=FrictonFactor;
    Data(count,2)= PipeDia;
    % store the new values of friction factor in the vector
    count=count+1;
    %increment the counter index
end
```

Figure C1: Computer Code Part 1

```
T = table(Data(:,1),Data(:,2));
T.Properties.VariableNames = {'FrictionFactor','PipeDiameter'};
writetable(T,'ItrationTable.xls');
% creates the table and exports to excel file

%-------------------------------------------------------------

% Part - II: Minor Loss Calculation

%Coefficients for minor loss Vaiues for
% 45 deg elbows (flanged)(Regular) = .2(*4)
% 90 deg elbows (long Radius) = .34
% Check Valve(Swing) = 2.1
% Globe Valve = 7.1
% Screwed Fittings = .72(*5)
% Entry loss(Sharp Edged) = 0.5
% Exit loss(Sharp Edged) = 1
vel = 15;
% Assume the velocity to be 15 ft/s
kSum = 4*(.2)+0.34+2.1+7.1+(5*.72)+0.5+1;
% sum the minor loss coeficients
LossMinor = minorloss(kSum, vel);
% Calculate the minor loss from the minorloss function

%---------------------------------------------------------

%Part-III: Calculate the friction loss

HeadlossTotal = 117.4;
%headloss from the calculation(Assuming Delta P = 50 psi)
FrictionLoss = HeadlossTotal - LossMinor;
% total head Loss is the sum of friction loss and the minor loss

%---------------------------------------------------------

%Part-IV: Calculate the Actual Velocity

g=32.2;
% acel due to gravity = 32.2 ft/s^2
PipeLength = 129.87;
% length of pipe used = 129.87 ft
Dia = 0.13417;
% Diameter od pipe used was 1.5 in (nominal)
% Internal Diameter = 1.61 in = 0.13417 ft
ActualVelocity = ((FrictionLoss*2*Dia*g)/(FrictonFactor*PipeLength))^(1/2);

%---------------------------------------------------------

%Part V: Haaland and minorloss functions

function FrictionFactor = Haaland(epsilon,PipeDia,ReynoldNum)
%Haaland Equation to calculate the friction factor
 %   Haaland equation to calculate the friction factor
% Input Variables = Reynolds Number, Epsilon = Relative Roughness of the
```

Figure C2: Computer Code Part 2

```
% pipe surface and the Diameter of the pipe
% Output Value = frition factor
term1 =((epsilon/PipeDia)/3.7)^1.11;
term2 = (6.9/ReynoldNum);
FrictionFactor = 1/(-1.8*log10(term1+term2))^2;

end

function MLoss = minorloss(flowCoeff, velocity )
%UNTITLED Summary of this function goes here
%   Calculates the minor loss
% units in British Units
acelgr = 32.2 ;
MLoss = (flowCoeff*(velocity)^2)/(2*acelgr);
end

%----------------------------------------------------------------
```

Figure C3: Computer Code Part 3

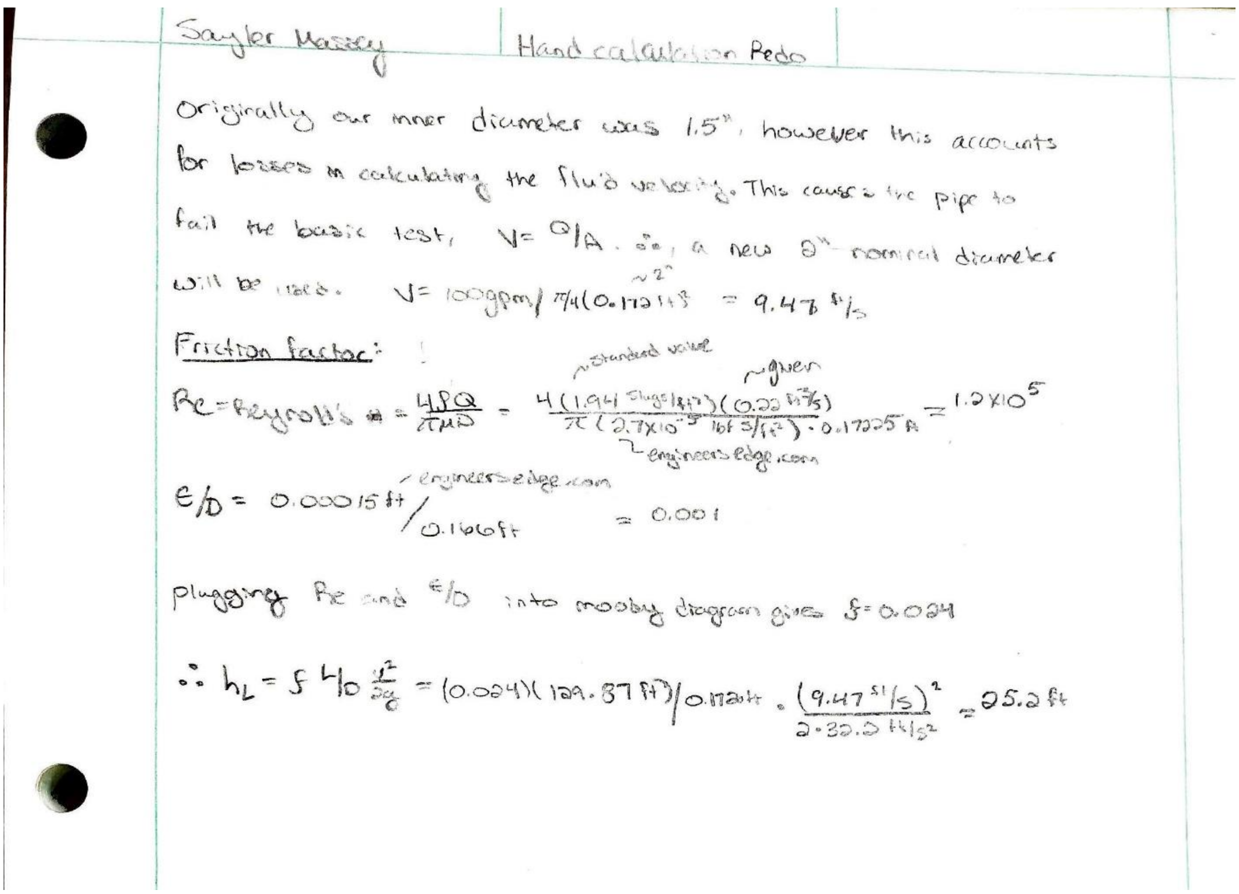
Workspace

Name	Value
ActualVelocity	14.0999
count	4
Data	[0.0213,0.1226;0.0212,...
Dia	0.1342
epsilon	1.5000e-04
FrictionLoss	63.4559
FrictonFactor	0.0212
g	32.2000
Guessf	0.0212
HeadlossTotal	117.4000
kSum	15.4400
LossMinor	53.9441
PipeDia	0.1241
PipeLength	129.8700
ReynoldNum	3.6479e+05
T	5x2 table
vel	15

Figure C4: MATLAB Output Values

Appendix 2: Hand Calculations

The hand calculations back up key findings found in the code. For more information on what the calculations do and how they are used visit the theory section of the report. Figure H1 and H2 were completed as an update to encompass the need for a larger pipe diameter. They include using the original diameter of 1.5” and doing the test V=Q/A to come up with a larger diameter of size 2”. This diameter is then plugged back into the equation to find the velocity (9.47 ft/s), and then the friction factor is found using Reynold’s Number (0.024). Finally, a check is run to make sure that the pump can overcome the change in pressure. The pump is capable of overcoming 50 psi of pressure drop and the new pipe diameter only has a 10.74 psi pressure drop. Figure H3 and H4 encompass the initial calculations done, taking the given pressure drop of 50 psi and 100 gpm flow rate and using the iterative method developed in the theory to develop a diameter necessary for the piping.



Sayler Massey | Hand calculation Redo

Originally our inner diameter was 1.5", however this accounts for losses in calculating the fluid velocity. This causes the pipe to fail the basic test, $V = Q/A$. ∴, a new 2" nominal diameter will be used. $V = 100\text{gpm} / \frac{\pi}{4}(0.172\text{ft})^2 = 9.47\ \text{ft/s}$

Friction factor:

$$Re = \text{Reynold's } \# = \frac{4\rho Q}{\pi \mu D} = \frac{4\,(\overbrace{1.94\ \text{slugs/ft}^3}^{\text{standard value}})(\overbrace{0.22\ \text{ft}^3/\text{s}}^{\text{given}})}{\pi\,(\underbrace{2.7\times10^{-5}\ \text{lbf s/ft}^2}_{\text{engineersedge.com}})\cdot 0.17225\ \text{ft}} \approx 1.2\times10^{5}$$

$$\epsilon/D = \overbrace{0.00015\ \text{ft}}^{\text{engineersedge.com}} / 0.166\ \text{ft} = 0.001$$

plugging Re and ϵ/D into moody diagram gives $f = 0.024$

$$\therefore h_L = f\frac{L}{D}\frac{V^2}{2g} = (0.024)(129.87\ \text{ft})/0.172\text{ft} \cdot \frac{(9.47\ \text{ft/s})^2}{2\cdot 32.2\ \text{ft/s}^2} \approx 25.2\ \text{ft}$$

Figure H1: Hand Calculations Redo

using the new head loss and eqn (8), $h_L = \frac{\Delta P}{\gamma}$

$$25.2\,ft = \frac{\Delta P}{61.39 \frac{lbm}{ft^3}} \Rightarrow \Delta P = 1547 \frac{lbm}{ft^2} \cdot \frac{1\,ft^2}{144\,in^2} = \underline{\underline{10.74\,psi}}$$

Figure H2: Hand Calculations Pressure drop test

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Matthew Wright

ME 4465; Project-1

Group Members:
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Matthew Wright

1/2

* Calculation of total Head loss Pipe Diameter & Reynold's Number

From Modified Bernoulli's Equation,

$$h_L = \frac{\Delta P}{\gamma} = \frac{\Delta P}{\rho g}$$

$\Delta P = 50$ psi (Using the optimum provided)

$g = 32.2\ ft\,s^{-2}$

$$h_L = \frac{50\ lbf\ in^{-2}}{(1.39\ lbm\ ft^{-3} \times 32.2\ ft\,s^{-2})\ lbf} \times \frac{32.2\ lbm\ ft\,s^{-2}}{}$$

$$= \frac{50\ in^{-2}}{61.39\ ft^{-3}} \times \frac{144\ in^2}{1\ ft^2}$$

$$\boxed{\therefore h_L = 117.4\ ft}$$

Specific volume $v_f(T=140°F) = 0.01629\ ft^3\,lbm^{-1}$

[Source C&G: Thermodynamics: Table A-4E]

$$\rho_f(T=140°F) = \frac{1}{v_f(T=140°F)} = 61.39\ lbm\ ft^{-3}$$

Note:
This is not the actual head loss but it is the optimum possible head loss.

Similarly,

$$h_L = f\frac{L}{D}\frac{v^2}{2g} = f\frac{L}{D}\frac{Q^2}{2A^2 g}$$

$$= f\,\frac{8LQ^2}{\pi D^5 g}$$

$\vec{v} = \frac{\vec{Q}}{A} \quad A = \frac{\pi}{4}D^2$

$$\boxed{\therefore D^5 = \frac{8fLQ^2}{\pi^2 g h_L}}$$

L = length of pipe = 129.87 ft
Q = flow rate = 100 gpm = .223 $ft^3\,sec^{-1}$
h_L = Total head loss = 117.4 ft

Substituting the values,

$$D^5 = \frac{8 \times 129.87\ ft \times (.223\ ft^3 s^{-1})^2}{\pi \times 32.2\ ft\,s^{-2} \times 3.69\ ft}\,f$$

$$\boxed{D^5 = 0.001385 f}$$

Also,

$$\text{Reynolds Number} = \frac{\rho v D}{\mu}$$

$$= \frac{61.39\ lbm\ ft^{-3} \times 15\ ft\,s^{-1} \times D}{9.743\times10^{-6}\ lbf\ s\ ft^{-2}}$$

$$\boxed{Re^{\#} = 2.94 \times 10^6\ ft^{-1}\ D}$$

ρ = Density of water @140°F = 61.39 $lbm\ ft^{-3}$
$\vec{v}$ = Optimum flow velocity = 15 $ft\,s^{-1}$
μ = Dynamic viscosity of H_2O @140°F = 9.743×10^{-6} $lbf\ s\ ft^{-2}$

Figure H3: Hand Calculations Page 1

Shishir Khanal | ME 4465: Project-1 | Group Members: Sayler Massey | 2/2

Matthew Wright

* Estimating the Change in Pressure along the length of Pipe

Now,

Modified Bernoulli Equation is:

$$\frac{P_1}{\rho g} + \cancel{\frac{v_1^2}{2g}} + \cancel{z_1} = \frac{P_2}{\rho g} + \cancel{\frac{v_2^2}{2g}} + \cancel{z_2} + h_f + h_m$$

We have,

No elevation changes ($z_1 = z_2$)

Constant velocity of fluid ($\vec{V}_1 = \vec{V}_2$)

$$\frac{P_1 - P_2}{\rho g} = h_f + h_m$$

$$\therefore \frac{\Delta P}{\gamma} = h_f + h_m \quad —(1)$$

$\gamma = 61.39 \text{ lbf ft}^{-3}$

h_m = Variable "Loss Minor" from code

$= 53.9441 \text{ ft}$

$$h_f = f \frac{L}{D} \frac{v^2}{2g}$$

$$= 0.0212 \times \frac{129.87 \text{ ft}}{0.13417 \text{ ft}} \times \frac{(14.0999 \text{ ft s}^{-1})^2}{2 \times 32.2 \text{ ft s}^{-2}}$$

$f \Rightarrow$ Variable "FrictionFactor" from Code

$f = 0.0212$

D = Internal Diameter of Sch 40 $1\frac{1}{2}$" Nominal diameter pipe

$D = 1.61" = 0.13417 \text{ ft}$

$$\therefore h_f = 63.35 \text{ ft}$$

$\vec{V} \Rightarrow$ Variable "ActualVelocity" from code

$\vec{V} = 14.0999 \text{ ft s}^{-1}$

Eqn (1),

$$\Delta P = [63.35 \text{ ft} + 53.944 \text{ ft}] \times 61.39 \text{ lbf ft}^{-3}$$

$$\Delta P = 7200.58 \text{ lbf ft}^{-2} \times \frac{(1 \text{ ft})^2}{(12 \text{ in})^2}$$

$$\boxed{\Delta P = 50.0 \text{ psi}}$$

Figure H4: Hand Calculations Page 2

SOLIDWORKS FloXpress Report

SOLIDWORKS FloXpress is a first pass qualitative flow analysis tool which gives insight into water or air flow inside your SOLIDWORKS model. To get more quantitative results like pressure drop, flow rate etc you will have to use SOLIDWORKS Flow Simulation. Please visit www.solidworks.com to learn more about the capabilities of SOLIDWORKS Flow Simulation.

Model

Model Name: Piping project 1 flow.SLDPRT

Smallest Flow Passage

Smallest flow passage: 2.07 in

Fluid

Water

Inlet

Type	Volume Flow Rate
Faces	End cap1[1]//Face
Value	386 in^3/s 140.00 °F

Outlet

Type	Environment Pressure
Faces	End cap1[2]//Face
Value	14.69595 lbf/in^2 68.09 °F

Results

Name	Unit	Value
Maximum Velocity	in/s	159.59

Appendix 3: Diagrams and Schematic

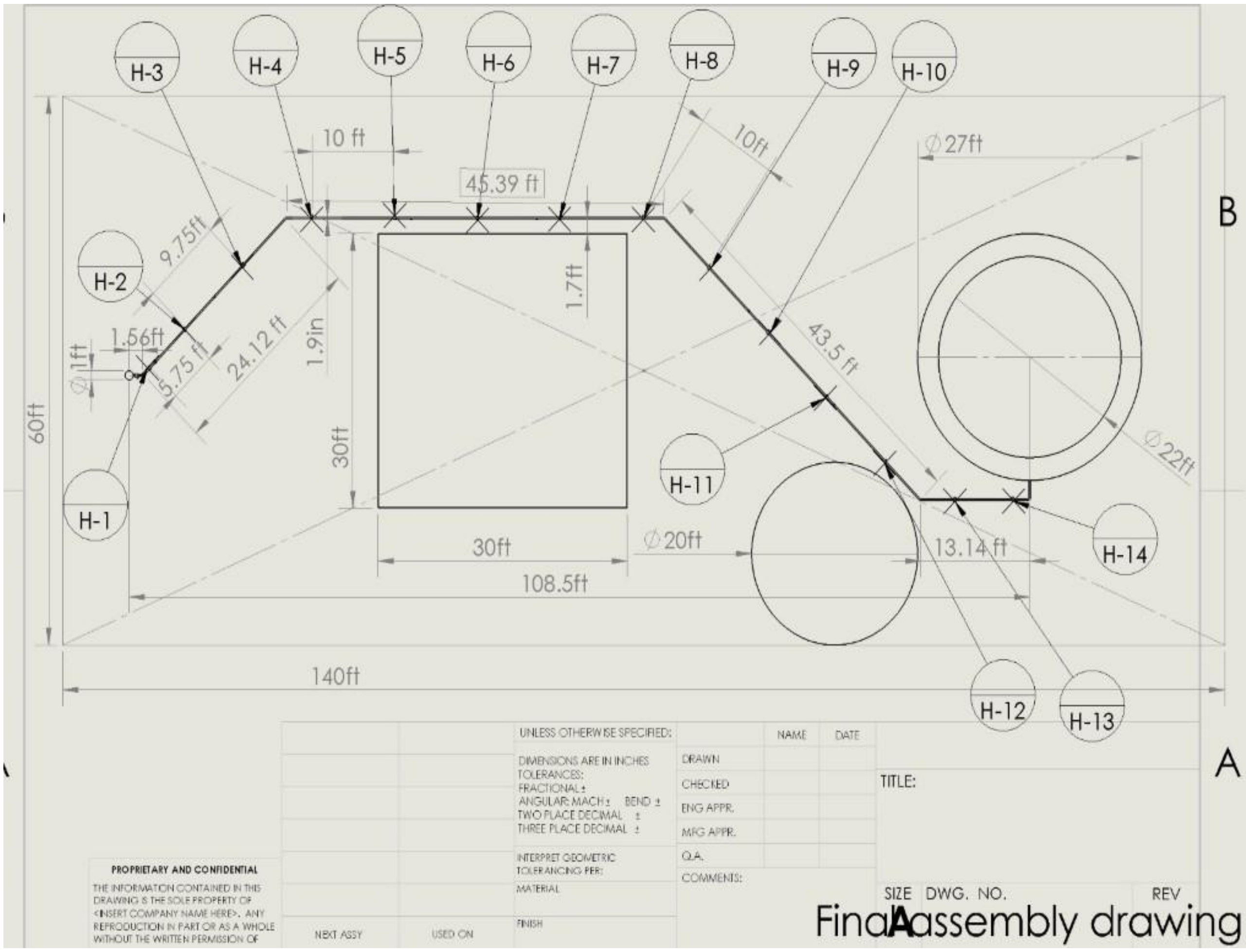

Figure D1: Top Down View

Figure D1 gives a top down view of the compound and Solidworks piping. Included are the dimensions of the piping. X marks the location of the supports and the boundary can be seen as 60ft x 140ft.

Solidworks

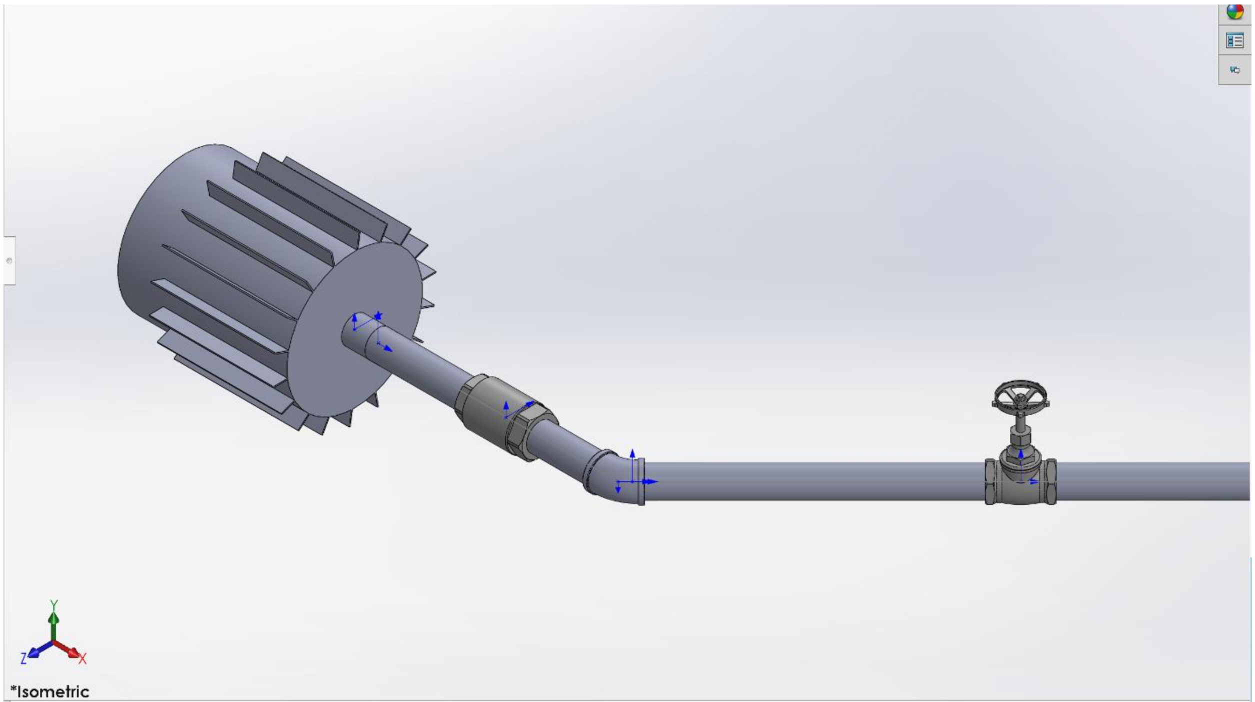

Figure D2: Pump and Initial Piping

Figure D2 displays the default pump, the check valve, the shutoff valve, and the initial sections of piping.

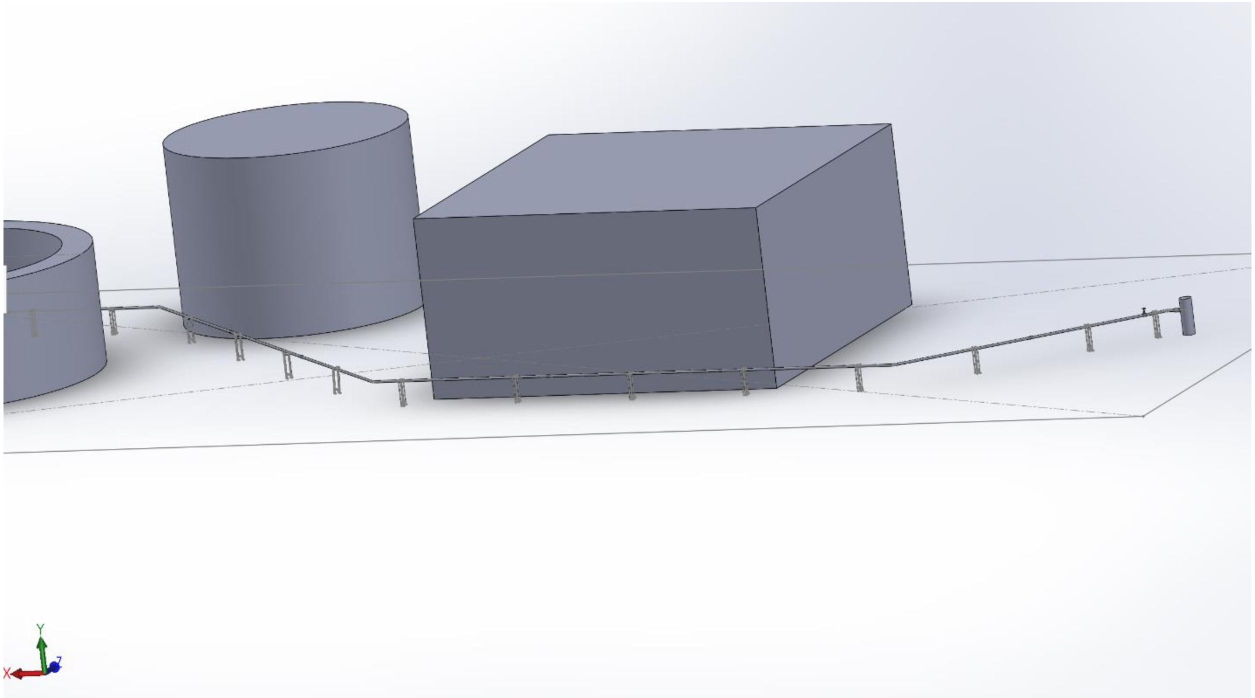

Figure D3: Isometric Plant View

Figure D3 shows an isometric view of the plant and supports.

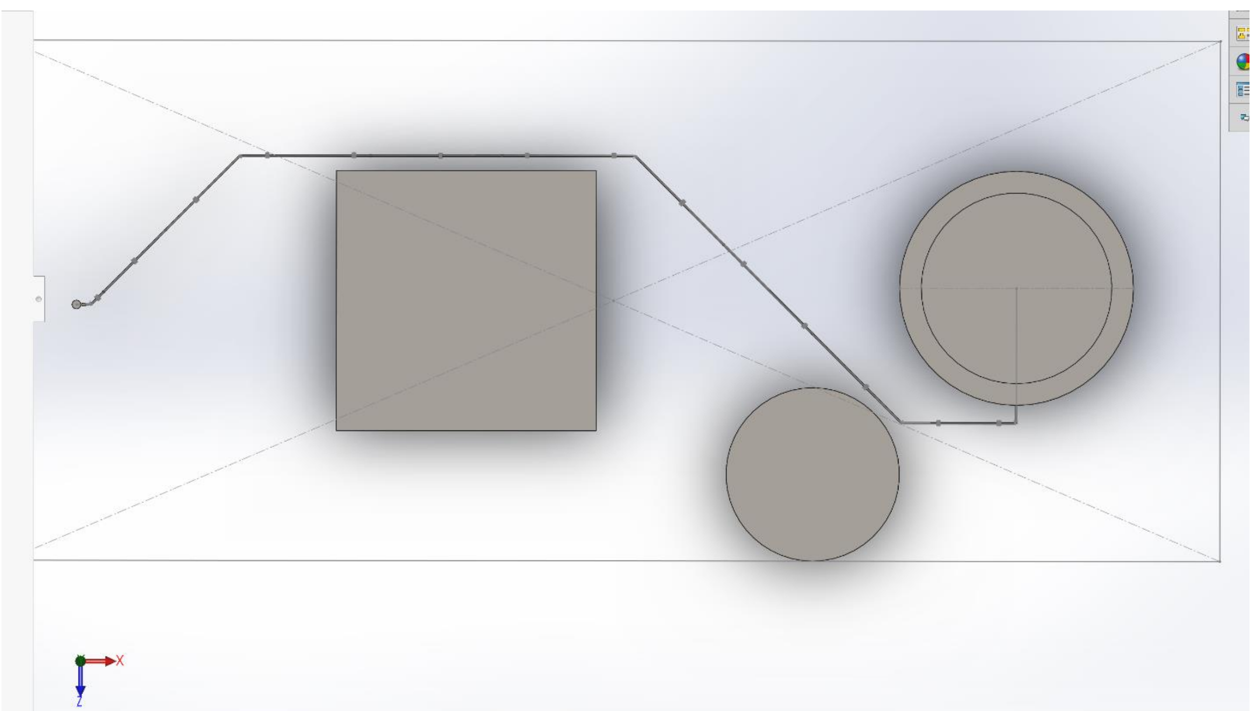

Figure D4: Top View

Figure D4 displays a top overview of the compound.

Piping and Instrumentation Diagram

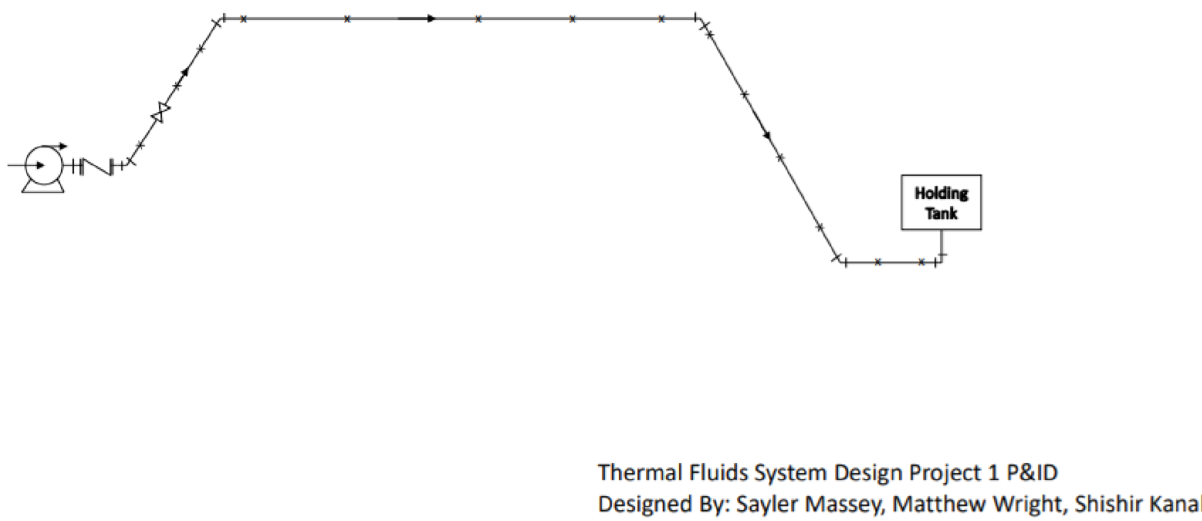

Figure D5: P&ID

Figure D5 displays the P&ID of the compound. Included are supports and valve checks along with the pump and holding tank.

Appendix 4: Fluid Properties

Table B.1

Physical Properties of Water (BG Units)[a]

Temperature (°F)	Density, ρ (slugs/ft^3)	Specific Weight[b], γ (lb/ft^3)	Dynamic Viscosity, μ (lb·s/ft^2)	Kinematic Viscosity, ν (ft^2/s)	Surface Tension[c], σ (lb/ft)	Vapor Pressure, p_v [lb/in.^{2}(abs)]	Speed of Sound[d], c (ft/s)
32	1.940	62.42	3.732 E − 5	1.924 E − 5	5.18 E − 3	8.854 E − 2	4603
40	1.940	62.43	3.228 E − 5	1.664 E − 5	5.13 E − 3	1.217 E − 1	4672
50	1.940	62.41	2.730 E − 5	1.407 E − 5	5.09 E − 3	1.781 E − 1	4748
60	1.938	62.37	2.344 E − 5	1.210 E − 5	5.03 E − 3	2.563 E − 1	4814
70	1.936	62.30	2.037 E − 5	1.052 E − 5	4.97 E − 3	3.631 E − 1	4871
80	1.934	62.22	1.791 E − 5	9.262 E − 6	4.91 E − 3	5.069 E − 1	4819
90	1.931	62.11	1.500 E − 5	8.233 E − 6	4.86 E − 3	6.979 E − 1	4960
100	1.927	62.00	1.423 E − 5	7.383 E − 6	4.79 E − 3	9.493 E − 1	4995
120	1.918	61.71	1.164 E − 5	6.067 E − 6	4.67 E − 3	1.692 E + 0	5049
140	1.908	61.38	9.743 E − 6	5.106 E − 6	4.53 E − 3	2.888 E + 0	5091
160	1.896	61.00	8.315 E − 6	4.385 E − 6	4.40 E − 3	4.736 E + 0	5101
180	1.883	60.58	7.207 E − 6	3.827 E − 6	4.26 E − 3	7.507 E + 0	5195
200	1.869	60.12	6.342 E − 6	3.393 E − 6	4.12 E − 3	1.152 E + 1	5089
212	1.860	59.83	5.886 E − 6	3.165 E − 6	4.04 E − 3	1.469 E + 1	5062

[a]Based on data from *Handbook of Chemistry and Physics*, 69th Ed., CRC Press, 1988. Where necessary, values obtained by interpolation.

[b]Density and specific weight are related through the equation $\gamma = \rho g$. For this table, $g = 32.174$ ft/s^2.

[c]In contact with air.

[d]Based on data from R. D. Blevins, *Applied Fluid Dynamics Handbook*, Van Nostrand Reinhold Co., Inc., New York, 1984.

Figure A4-1: Fluid Properties of water, used in numerous calculations to find the specific gravity of water

Munson 8th

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Classroom Lecture:

Intellectual Property of Mary Hofle, Bernoulli equation from lecture given on August 23, 2018, was used.