



جامعة الأمير محمد بن فهد PRINCE MOHAMMAD BIN FAHD UNIVERSITY

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Senior Design Project Report

Design and construction of a piping network system for domestic use

In partial fulfillment of the requirements for the
Degree of Bachelor of Science in Mechanical Engineering

Team Members

	Student Name	Student ID
1	Mohammed Al-Boushi	201303694
2	Omar Hassan	201300315
3	Mohammed Al-Nasheri	200901642
4	Fahad Al-Jubreen	201300079
5	Madhi Al-Hajri	201202517

Project Advisors:

Instructor : Dr. Nader Sawalhi
Advisor Name: Esam Jassem

Abstract

Pipes network analysis involves the analysis of the fluid flow through hydraulics network, containing several interconnected branches. To provide water to many users, municipal water supplies often route it through a water supply network. However, the main requirement for designers is how to size the piping system and how to determine the flow rates and pressure drops in the individual sections of the network. This is a common need in hydraulic design. This project is about designing a network which will consist of interconnected pipes, while of problems in hydraulic design, with solution methods typically referred to as pipe network analysis. Water utilities generally make use of specialized software to automatically solve these problems. The yield of a system can be measured by either its value or its net benefit. For a water supply system, the true value or the net benefit is a reliable water supply service having adequate quantity and good quality of the product. For example, if the existing water supply of a city needs to be extended to supply a new municipality, the impact of the new branch of the system must be designed to supply the new needs, while maintaining supply to the old system.

The objectives of the study are:

1. Designing a pipe network system for the buildings.
2. Producing a prototype of the designing.
3. Testing the designing system.
4. Calculate the major and minor losses associated with pipe flow in the piping networks and determine the pumping power requirements.

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Last but not least, many thanks go to the Mechanical Engineering faculty who invested their time & effort to guide us through the path of knowledge.

Acronyms / Symbols

- 1) H- Head
- 2) H_f - friction head
- 3) G - Gravitational acceleration
- 4) K- Internal pipe roughness
- 5) N - Rotational speed
- 6) n_s - Specific speed
- 7) Q - Flow rate
- 8) Re - Reynolds number
- 9) η - Efficiency
- 10) ν - Kinematic viscosity

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Chapter 1

Introduction

1.1 Project Definition

The aim with this project is to create a fully working pipeline system that carries out water flow and distributes it to different locations with the help of a pump, it will be a prototype of what all of us can actually see in each city of how the water flow from the main water tank and gets distributed to the locations of the houses, calculation and checking for the major and minor losses will be done to see how much power will be needed to feed the system so it works smoothly and perfectly. For the simplicity of the project and similarities the design base and calculations will be as if water is going to be distributed from one water tank to a small neighborhood that consist of 4 houses and each house will need two water pipes going to it.

1.2 Project Objectives

The main objective of doing this research is to allow us as Mechanical Engineers at Prince Mohamad Bin Fahd University (PMU) to be able to identify how the fluid flows inside the pipes

- 1) design and build our individual piping system's prototype
- 2) Checking for any faulty connection is a must
- 3) Calculate the major and minor losses associated with pipe flow in the piping networks

4) Determine the pumping power requirements,

After doing all of these steps, a check will be done to determine the main differences that could be found between the real life situations and the data that can be acquired by the theoretical design.

1.3 Project Specification

Fig 1.1 shows us what the basic idea of the piping system will be, it is the first prototype that was built, another prototype must be done because usually from the calculations you can see that the further we go from the tank and closer to where we want our water to be distributed, the less water pressure will be in the system and the smaller pipe dimensions will be needed due to the fact that the water will be distributed from the main pipe to the other pipes.



Fig 1.1 (First Prototype)

1.4 Applications

Pipeline water system is used to distribute water from the main tank to the houses, another pipeline water system can be used to other way, to gather the water from houses and takes it to either a wastewater treatment plant, another design that could be done is to create a pipeline system that collects rain water and takes it to a specific rain water tank.

Chapter 2

Literature Review

Literature Review is done on this research to see what previous researchers have found about piping systems, and see what can be done to build a fully-working prototype that carries out our design and is sufficient enough to handle the losses that will happen in the system.

2.1 Project Background

Water pipeline systems are very crucial in everyone's day-to-day activity, everyone now is used to have water flowing inside his/her house, we as a species even stopped noticing how much we are developed and that we cannot live a day without this system. The major and minor losses are going to be a hassle in the making of this project, because the system cannot have more or less power than it actually needs, more power in the system means that the system will have more power pressure than it needs, which will either yield the pipes to collapse or the joints to break, less power means that the pipeline system will not have sufficient power pressure to accurately deliver the water to the designated destinations.

2.2 Previous Work

2.2.1 Summary of Computational techniques for fluid dynamics

Chapter 11 of the book "Computational techniques for fluid dynamics" describes the governing equations of the basics of fluid mechanics, Flecher also clearly described the

equations of motion and it stated “consider a small control volume through which the fluid moves, and to required that mass and energy are conserved, and that the rate of change of the three components of linear momentum are equal to the corresponding components of the applied force”, this is the basic idea that will be used to design and construct this project.

2.2.2 Dynamics of Piping

Lee made a very interesting article in 1995 that studied the dynamics of piping systems in an unsteady flow, it is more complicated than the design of this project, Lee’s entire study was made with the basic idea of studying the unsteady flow, the article shows that with the use of Ordinary Differential Equations and newton’s laws of motion, a set of different equations can be done to find the axial and transverse equations of motion of the pipeline and the equations of momentum and continuity of the internal flow. The equations are applied to a simply supported inclined straight pipeline which is very close to the pipeline system design of this project.

2.2.3 Summary of piping-systems solutions using Mathcad

This research have stated earlier that nowadays software are there to help us as engineers calculating the piping systems, with the help of Hodge in his article “piping-systems solutions using Mathcad” we will have a basic understanding on how does Mathcad combine the formulas and equations that has been developed along the years to the design of this project. Examples can be found in the article to help understanding the worksheets include but not limited to series piping systems, parallel piping systems and piping networks. The Mathcad solutions are not going to be the same as the solutions that people usually get from the conventional techniques because it does not negate any loss and tries to calculate as much equations as it can.

2.2.4 The Swedish Nuclear Power Inspectorate Database

Nyman and Hegedus wrote such an amazing article with their database that they collected from The Swedish Nuclear Power Inspectorate. They wanted to show how reliable is the piping system components; they wanted to see where does most the failures happen in the piping system. The quantitative results that they collected are shown as condition probabilities of pipe failures. Finally the article was able to state that the Pipe failures are rare events.

2.2.5 ASAE S376.1

How can we design and build anything as practical in real life engineers without standards, "American Society of Agricultural Engineers" has released a really informing standard that this research can follow for the sake of designing this project. (Standard ASAE S376.1), The standards is more concerned with the use of polyvinyl chloride Pipes which are usually called (PVC), the standard divides these Thermoplastic pipes into low and high pressure categories, these categories are based on both the pipe diameter and the design operating pressure.

Low Pressure

- Nominal diameter-114 to 630 mm (4 to 24 inch)
- Internal pressure-545 kPa (79 psi) or less

High Pressure

- Nominal diameter-21 to 710 mm (0.5 to 27 inch)
- Internal pressure-550 to 2170 kPa (80 to 315 psi) including surge pressure

Surge pressure only happened when the pipe gets an unsteady flow where the fluid inside it gets a rapid change in pressure, this will not be taken into consideration for this research due to the fact that water flowing to houses is not requires to have any rapid change in pressure, if this case were to happen then the pipes leading to the houses may face a high pressure that may lead to a failure in the system. The formulas that this standard use are as follows

The standard asks to find the dimension ratio which is the diameter divided by the thickness of the pipe, and then it uses this ratio to find the pressure rating, which is then used for the engineers to pick the PVC pipe that can handle that pressure. The following figure 2.1 is taken directly from the standard.

$$DR = \frac{D}{t}$$

where

D = outside or inside pipe diameter depending on how the pipe size is controlled, mm

t = wall thickness, mm

The dimension ratio is dimensionless. The minimum wall thickness for thermoplastic pipe is specified as 1.52 mm (0.060 inch). Certain dimension ratios have been selected as standard and are designated in tabulated data as Standard Dimension Ratios.

For outside diameter based pipe, the pressure rating is given as

$$PR = \frac{2S}{DR - 1}$$

or

$$PR = \frac{2S}{\frac{D_0}{t} - 1}$$

where

PR = pressure rating, kPa (psi)

S = hydrostatic design stress, kPa (psi)

D₀ = average outside diameter, mm (in.)

t = minimum wall thickness, mm (in.)

Fig 2.1 (Calculations of Pressure Rating)

2.3 Comparative Study

2.3.1 Project in Al-Khobar

Figures 2.2 and 2.3 are pictures of a water tank in a private compound here in Al-Khobar, this project takes fresh water from a tank after it treats the water and distributes it to 34 different villas.



Fig 2.2 (Water Tank)



Fig 2.3 (Pipe from water tank)

This specific pipeline system uses three DPL 10 water pressure motors, the specification for these motors are as follows

Working range

- Head (H): 5 - 254 mwc
- Flow (Q): 1,90 - 125 m³/h
- Ambient temperature: -20 - +40 °C
- Temperature medium: -20 - +140 °C. DPV125 max +120 °C

We can see these motors in figures Fig 2.4, Fig 2.5, Fig 2.6.



Fig 2.4 (Pumps side view) Fig 2.5 (Pumps Back View) (Fig 2.6 (Pumps Powering the System))

The sizes of the used to supply the 34 villas are as follows:

- 4 inches in diameter for the pipes coming out from the water tank
- 1.5 inches in diameter for the pipes carrying the water inside the house

2.3.2 Optimal Design of a Pump and Piping System

“Optimal Design of a Pump and Piping System” is a research done at Bradley University by a senior mechanical engineer student named Curtis Brackett. The objective of his project was to show that undergraduate mechanical engineers can integrate engineering modeling techniques to predict and acquire the optimum pump size, pipe diameters and the wall thickness of pipe diameters for specific flows. The system they designed contained three different size pumps and two branches of pipes with each branch having a specific flange for the team to add different size orifices. The students should find the optimum pipe diameters from an analytical approach and to use the project to check for the calculations they made. Fig 2.7 shows the basic layout of the project, while Figure 2.8 shows the project itself after the researchers constructed it.

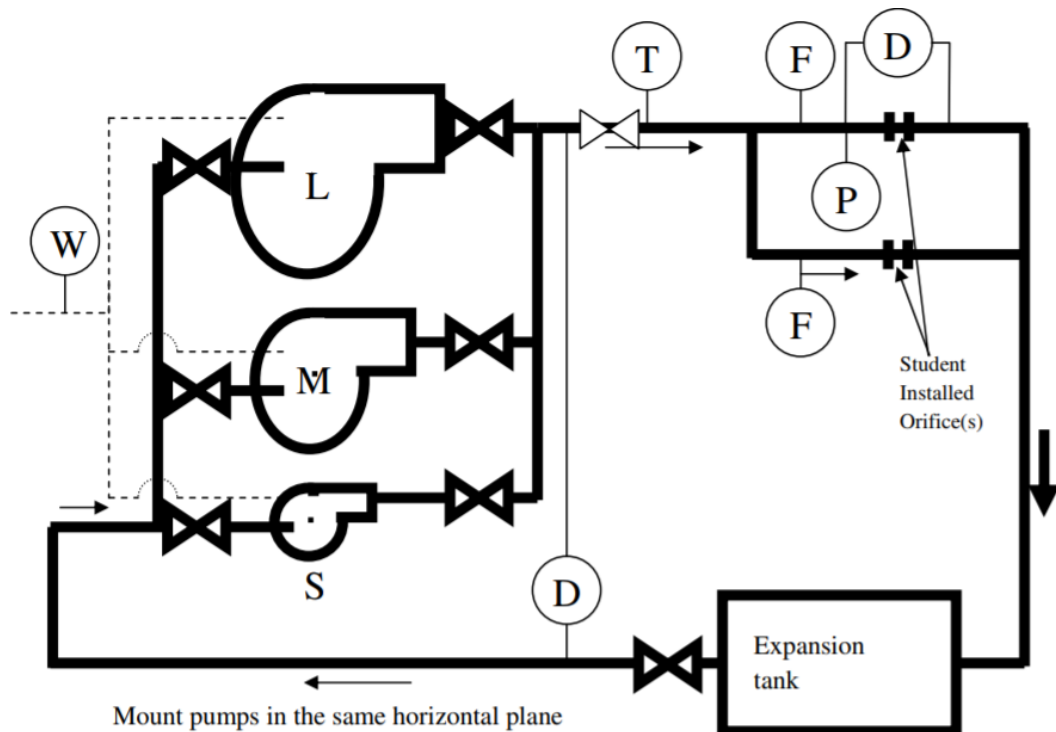


Fig 2.7 (Design Drawing)

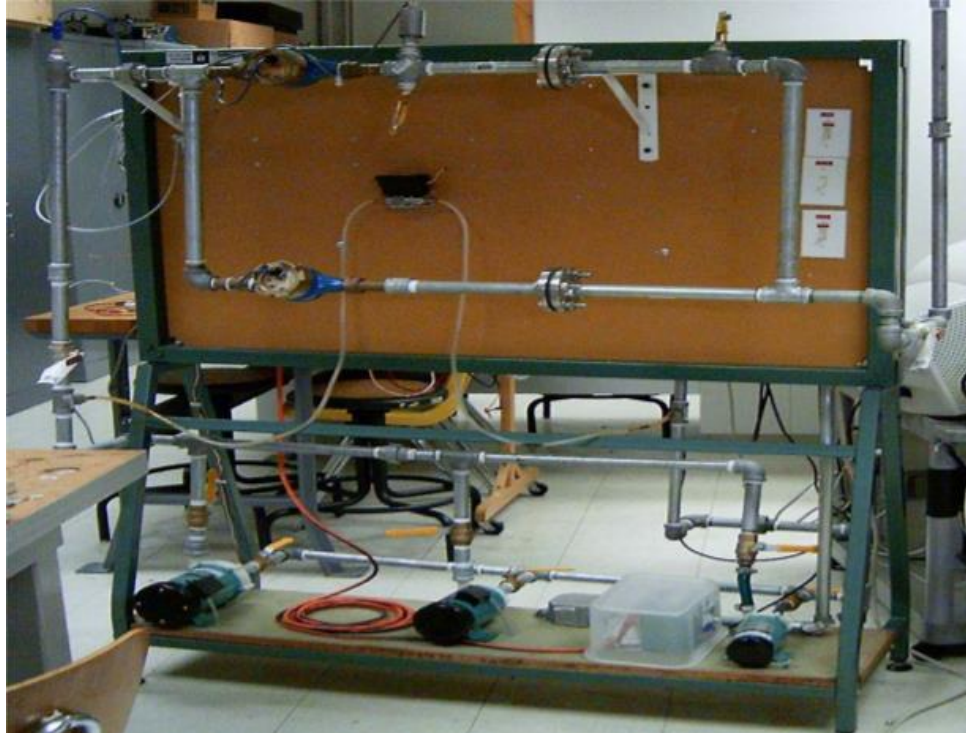


Fig 2.8 (Previous Project Prototype)

The optimum pipe diameters for the researcher's project was 1.6 cm pipe diameter for the upper branches and 1.2 cm pipe diameter for lower branches, the minimum total cost of the project was \$1,263. Table 2.1 shows the data that the researches got from their project.

Table 2.1 (Findings of a Previous Project)

	Flow Rate Upper (L)	Flow Rate Lower (L)	Power Consumption (W)
Predicition	10.00	5.00	45.0
Actual	8.97	6.13	40.9
Error	11%	18%	10%

2.3.3 Summary of a Pumping System Design

“Pumping System Design for Petroleum Industry In Line With Vision 2030” is a research that was done by Morris Meta Miriti and Mang’aa Caleb Osiemo as their final year project as mechanical engineers, the similarities between this project and this research are that both of which must design and pick the right pipes to use with the exact power needed for the pipeline system. The main objective of the study that was constructed by these engineers is to design an efficient petroleum pumping system (from Mombasa to Nairobi) that meets the demand Nairobi in 2030. The main challenges that the researchers faced were leakages, spillage, pipe burst and degradation of the pipeline due to corrosion.

The installed parameters at the time of research were:

- Flow Rate, $Q_o = 880 \text{ m}^3/\text{hour}$
- Pipe diameter = 0.3556 m^2
- Pipe length, $L = 450 \text{ km}$

Pressure

- Design, maximum — 8.136MPa
- Operating, maximum — 8.136MPa

The methodology that the researchers used to finish their project was that they would first start off by doing a basic pipeline design, and then they would pick the right pipe sizes for different sections of the system, a determination of a pressure is a must to make sure that the pipes strengths would be able to handle the pressure that would be exerted on the pipes by the

fluid flowing inside them, they would then select the right valves for the system and finally design the valve spacing and rapid shutdown for any emergency-type situation.

The estimated demand by 2030, Q is calculated as follows;

$$Q = Q_0 (1+R)^n$$

$Q = 1256.86 \text{ m}^3/\text{hr}$, which can be written as $Q = 3.49 \times 10^{-1} \text{ m}^3/\text{s}$. They then found out that the needed diameter is $d = 0.4714 \text{ m}$. After this the researchers used “ISO Standard ISO 3183:2007(E)” to pick (Steel Grade L245 or A) as their required steel pipe

Further calculation showed that Reynold number is $Re = 1.42 \times 10^4$. They calculated the head and found out $H = 3979 \text{ m}$. They did three different cases to study, the first one for gasoline, then for Turbine Fuel and one for Diesel. They then picked the pump based on the highest head that was found from the calculations.

And last but not least the engineers had to run a check to make sure that the pressure in the pipes is actually less than the pressure strength that the (Steel Grade L245 or A) can handle.

Table 2.2 shows the different pipe grades, steel grades that engineers can pick from

Table 2.2 (Different Pipe Grades)

PSL	Delivery condition	Pipe grade/steel grade ^{a,b}
PSL 1	As-rolled, normalizing rolled, normalized or normalizing formed	L175 or A25
		L175P or A25P
		L210 or A
	As-rolled, normalizing rolled, thermomechanical rolled, thermomechanical formed, normalizing formed, normalized, normalized and tempered; or, if agreed, quenched and tempered for SMLS pipe only	L245 or B
	As-rolled, normalizing rolled, thermomechanical rolled, thermomechanical formed, normalizing formed, normalized, normalized and tempered or quenched and tempered	L290 or X42
		L320 or X46
		L360 or X52
		L390 or X56
		L415 or X60
		L450 or X65
L485 or X70		

Chapter 3

Design Methodology

3.1 Design Constrains

For the sake of finishing this project on a complete fashion, the design drawing of the project will be done on 3D CAD design program on PC which is called “Solidworks”, the way this research will take the pipe and the power sizing’s at first is by taking information’s from the first comparative study that was done on this research, after acquiring the data from the project that distributed the water to 34 different villas, similar proportions calculations will be done to find what we need in the system and then check if the system will be sufficient enough to work properly.

Figures 3.1 show the different types of pipes and joins needed in the system, while Fig 3.2 shows how the different piping and joints are to be connected in the project, Fig 3.3, Fig 3.4, and Fig 3.5 are made to see how the project is going to look after it gets built.

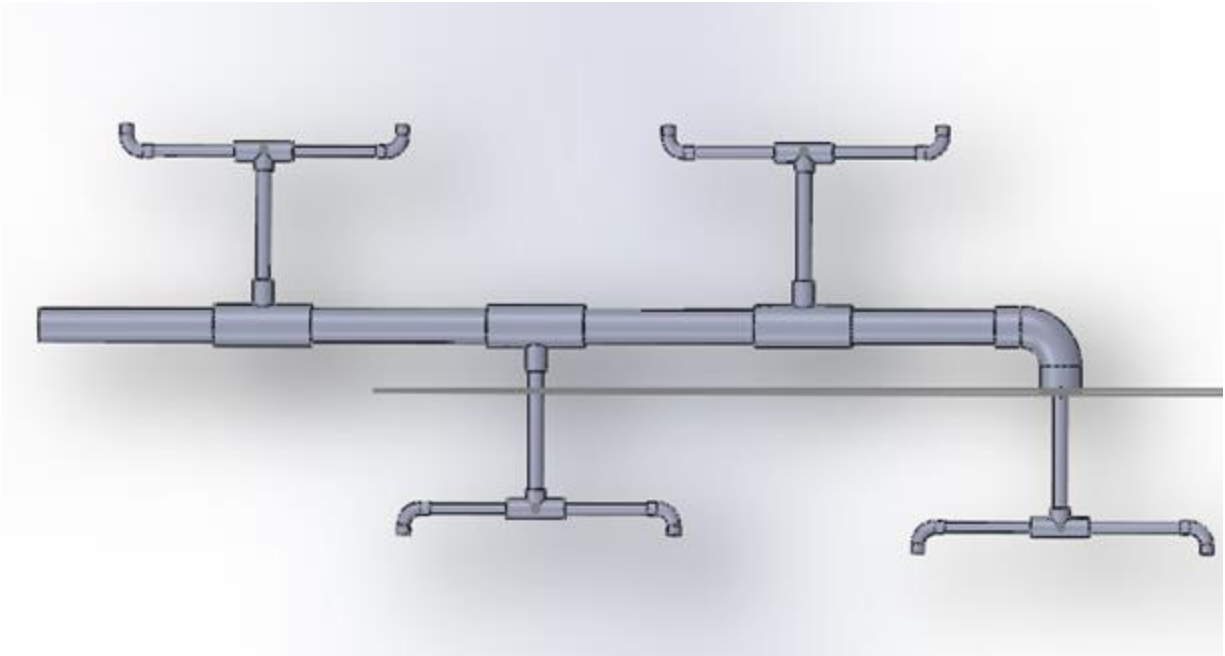


Fig 3.3 (Collapse View)

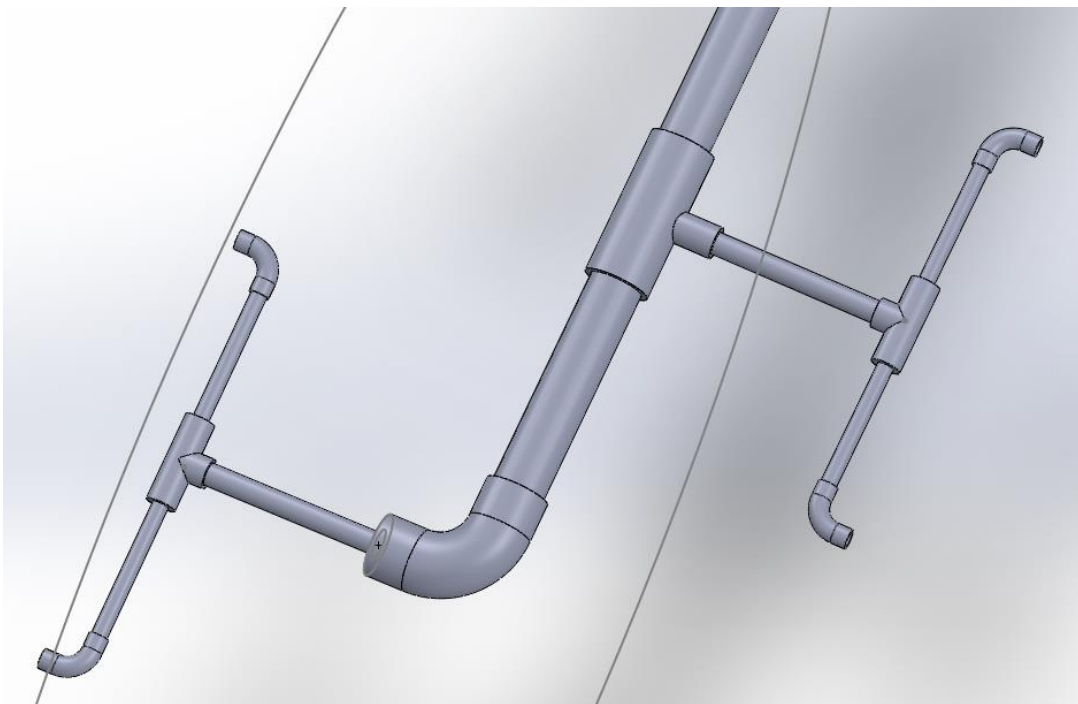


Fig 3.4 (Side View 1)

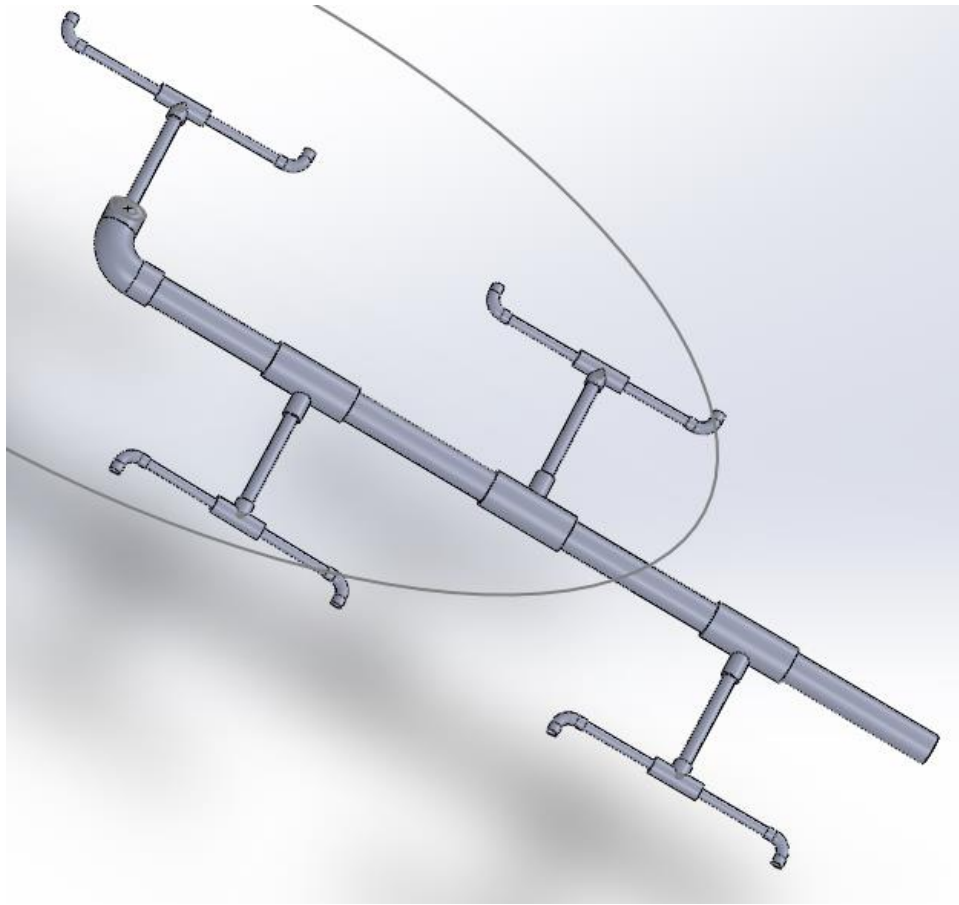


Fig 3.5 (Side View 2)

3.2 Engineering Standards

3.2.2 ASME B31.1-2007

The design of this project will be based on the engineering standard “ASME B31.1-2007”, this standard was written and prepared for Power Piping, Power Piping means that the pipes will have a pressure built inside them due to some sort of power, Powerless Piping systems is when the only force that pushes the liquid inside the pipes is earth’s gravitational force. But in this project the water pump is needed to take the water from the tank and distributes it to the 4 main houses.

The main chapter that we will be concerned with in this standard is Chapter II (Design Chapter), we might also use other chapters to check for the dimensions used in the system and check for the general material requirements. Allowable stress values to be used for the design of power piping systems are given in the Tables in Appendix A in the standard. This project is to be built using PVC piping, so the table for the PVC pipes is the one to be used in designing this project. The table concerned with PVC in the standard is called (Table 111-4.2.1) and will be shown in Appendix 1

The main calculations that this research will be based around are finding the pressure, the internal and external design pressure and dynamic effects such as impact, of course not to mention the fact that self-weight should not be a problem because it is a PVC piping system but a check must be done on the system in that area.

3.2.2 ASAE S376.1

Another engineering standard that will be considered in the making of this research is ASAE S376.1; this standard was picked to help this research because it is mainly concerned with the pipeline system design, the standard is established to relate the dimensions of the pipeline and the type of the material used in the pipeline system to its ability to resist loads and its own strength. ASAE S376.1 is only focused on thermoplastic pipes such as polyvinyl chloride (PVC) and polyethylene (PE).

The pressure category that the standard specify was discussed earlier in 2.2.5, the standard stated that thermoplastic pipes internal pressure is divided into two different category, High pressure and Low pressure.

The standard gives a table to show how much is the hydrostatic design stress for the variety of pipes materials out in the market, Table 3.1 show the hydrostatic design stress for different pipes.

Table 3.1 (Maximum Hydrostatic Design Stress)

Maximum hydrostatic design stress for thermoplastic pipe. (Adapted from ASAE Standard S376.1.)

Compound	Standard Code Designation	Hydrostatic Design Stress	
		(MPa)	(psi)
PVC	PVC 1120	13.8	2000
PVC	PVC 1220	13.8	2000
PVC	PVC 2120	13.8	2000
PVC	PVC 2116	11.0	1600
PVC	PVC 2116	8.6	1250
PVC	PVC 2110	6.9	1000
PE	PE 3408	5.5	800
PE	PE 3406	4.3	630
PE	PE 3306	4.3	630
PE	PE 2306	4.3	630
PE	PE 2305	3.4	500
ABS	ABS 1316	11.0	1600
ABS	ABS 2112	8.6	1250
ABS	ABS 1210	6.9	1000

Another aspect that the standard focuses upon is Concept of Water Hammer, Water hammer happens when a sudden change in velocity inside a pipe occurs, this creates a huge difference in pressure inside the pipes which sometimes could be the main reason for failures especially in connections, this concept is pretty complicated and will not be considered in this research because the prototype that will be built will only be able to supply water for four houses and is pretty small, the pump that will be used will have a consistent pressure output and will not cause an unsteady flow in the pipeline system. The equations used in the calculations for the water hammer is as follows:

$$\delta H = \left(\frac{a}{g}\right) \delta v \quad \text{Eqn 3.1}$$

δH = Surge Pressure, a = Pressure wave Velocity

g = Gravity, δv = Change in Fluid Velocity

3.3 Theory and Theoretical Calculations

The main idea behind the calculations for this project was simply the fact that we needed to find the major and minor losses of the system, the main calculation steps were:

- 1) Find the flow rate for each specific pipe in the pipeline
- 2) Find Reynolds number for each pipe section
- 3) Find the friction factor for each pipe section
- 4) Find the major head loss due to the length of each pipe
- 5) Find the velocity in each pipe section
- 6) Find the minor head loss due to the bushings, tee section and elbow
- 7) Find the total head loss
- 8) Design the pumping power required from the highest head loss to be found in the system
- 9) Test the system to make sure that the prototype will run as it is designed
- 10) Testing for the flow rate using digit flow rate sensor

Tables 3.2, 3.3 and 3.4, show the calculated values for each pipe in the pipeline system.

Table 3.2 (Design Calculations for Head Loss)

	A1	A2	A3		L1	L2	L3		d1	d2	d3		u	
	0.0020258	0.0002849	0.0001266		0.3	0.2	0.15		0.0508	0.01905	0.0127		0.001	
							ma	Vb	Vc					
							0.8	0.2	0.1	0.6	0.4			
									0.04064	0.00381				
	A	B	C	D	E	F	G	H	I	J	K	I		
Q	0.000222222	5.55556E-05	2.77778E-05	0.000167	5.55556E-05	2.77778E-05	0.000111	6E-05	2.77778E-05	5.55556E-05	2.77778E-05	2.77778E-05		3600
Ry	5572.551839	3715.034559	2786.275919	4179.414	3715.034559	2786.275919	2786.276	3715	2786.27592	1393.13796	3715.034559	2786.275919		1000
f	0.062231203	0.017227296	0.0222969728	0.063897	0.017227296	0.0222969728	0.02297	0.0172	0.022296973	0.045939456	0.017227296	0.0222969728		0.001
L	0.3	0.5	0.65	0.6	0.8	0.95	0.9	1.1	1.25	1.2	1.4	1.55		
V	0.109695902	0.195014937	0.219391805	0.082272	0.195014937	0.219391805	0.054848	0.195	0.2193918	0.027423976	0.195014937	0.219391805		
A	0.002025802	0.000284878	0.000126613	0.002026	0.000284878	0.000126613	0.002026	0.0003	0.00012661	0.002025802	0.000284878	0.000126613		
D	0.0508	0.01905	0.0127	0.0508	0.01905	0.0127	0.0508	0.0191	0.0127	0.0508	0.01905	0.0127		
3/D	0.029527559	0.078740157	0.118110236	0.029528	0.078740157	0.118110236	0.029528	0.0787	0.11811024	0.029527559	0.078740157	0.118110236		
g	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81		
	2	2	2	2	2	2	2	2	2	2	2	2		
v/2	0.012033191	0.038030826	0.048132764	0.006769	0.038030826	0.048132764	0.003008	0.038	0.04813276	0.000752074	0.038030826	0.048132764		
	0.000224652	0.000327584	0.000718638	0.000259	0.000524135	0.001050317	6.22E-05	0.0007	0.001382	4.14599E-05	0.000917236	0.001713675		
	0.996696	0.373761	0.249174	0.996696	0.373761	0.249174	0.996696	0.3738	0.249174	0.996696	0.373761	0.249174		
h	0.000225397	0.000876454	0.00288408	0.00026	0.001402326	0.004215194	6.24E-05	0.0019	0.00554631	4.15973E-05	0.00245407	0.006877421		

Calculations

Table 3.3 (A) (Calculations 1)

	A	B	C	D	E	F
Q(m ³ /s)	0.000222222	5.55556E-05	2.77778E-05	0.000166667	5.55556E-05	2.77778E-05
Ry	5572.551839	3715.034559	2786.275919	4179.413879	3715.034559	2786.275919
<i>f</i>	0.062231203	0.017227296	0.022969728	0.063897335	0.017227296	0.022969728
V (m/s)	0.109695902	0.195014937	0.219391805	0.082271927	0.195014937	0.219391805
h total (m)	0.000348059	0.002458951	0.005202553	0.001218661	0.003329812	0.006878655
pump power (kw)	0.000815881	0.001440998	0.001524404	0.002142485	0.001951341	0.00201552

Table 3.3 (B) (Calculations 1)

	G	H	I	J	K	L
Q(m ³ /s)	0.000111111	5.55556E-05	2.77778E-05	5.55556E-05	5.55556E-05	2.77778E-05
Ry	2786.275919	3715.034559	2786.275919	1393.13796	3715.034559	2786.275919
<i>f</i>	0.022969728	0.017227296	0.022969728	0.045939456	0.017227296	0.022969728
V (m/s)	0.054847951	0.195014937	0.219391805	0.027423976	0.195014937	0.219391805
h total (m)	0.000898034	0.003733021	0.008087106	0.000766073	0.00414773	0.009307057
pump power (kw)	0.001052535	0.002187631	0.002369609	0.000448935	0.002430659	0.272706772

Table 3.4 (A) (Calculations and given data)

	A	B	C	D	E	F
L (m)	0.3	0.5	0.65	0.6	0.8	0.95
D (m)	0.0508	0.01905	0.0127	0.0508	0.01905	0.0127
A (m ²)	0.002025802	0.000284878	0.000126613	0.002025802	0.000284878	0.000126613
h major (m)	0.000225397	0.000876454	0.00288408	0.00026036	0.001402326	0.004215194
h minor (m)	0.000613312	0.000969185	0.000735975	6.89977E-05	0.000969185	0.000735975
k	0.2	0.5	0.3	0.2	0.5	0.3

Table 3.4 (B) (Calculations and given data)

	G	H	I	J	K	l
L (m)	0.9	1.1	1.25	1.2	1.4	1.55
D (m)	0.0508	0.01905	0.0127	0.0508	0.01905	0.0127
A (m ²)	0.002025802	0.000284878	0.000126613	0.002025802	0.000284878	0.000126613
h major (m)	6.2396E-05	0.001928198	0.005546307	4.15973E-05	0.00245407	0.006877421
h minor (m)	3.06656E-05	0.000969185	0.000735975	1.14996E-05	0.000969185	0.000735975
k	0.2	0.5	0.3	0.3	0.5	0.3

Equations used to find the results above

$$Q = 0.8/3600 \text{ (0.8 from domestic house experiment)} \quad \text{Eqn 3.2}$$

$$Re = (D \cdot V \cdot \rho) / \mu \quad \text{Eqn 3.3}$$

$$f = \{-1.8 \cdot [\text{LOG}((6.9/Re) + ((\nu/D)/3.7)^{1.11})]\}^{-2} \quad \text{Eqn 3.4}$$

$$h_{\text{total}} = h_{\text{minor}} + h_{\text{major}} \quad \text{Eqn 3.5}$$

$$V = Q/A \quad \text{Eqn 3.6}$$

L = Length of Pipes

$$A = \pi (D^2)/4$$

$$H_{\text{major}} = [f \cdot L \cdot (V^2)] / (D \cdot 2 \cdot g) \quad \text{Eqn 3.7}$$

K can be found in the tables.

$$H_{\text{minor}} = (k \cdot V^2) / (2 \cdot 9.81) \quad \text{Eqn 3.8}$$

$$\text{Pump power} = (Q \cdot h \cdot g \cdot \rho) / \text{pump Efficiency} \quad \text{Eqn 3.9}$$

We can see from the calculated value that the max h calculated is 0.272706772, which means that the required pumping power will be calculated from this value, after the use of a safety factor of 1.35, we were able to see that the needed pumping power is 0.3565 KW, the pump that will be used in this project will have a pumping power of 3.7 KW which is close enough to our calculations. Fig 3.6 show the exact pump that was used in this project



Fig 3.6 (Pump used in the System)

3.4 Product Subsystems and selection of Components

The selection for the different sizes of the pipes were fairly simple, because this research was a mini project of an already constructed pipeline system, the idea behind the selection of the pipes were to mimic the previous work but to cut the dimensions by half to see how the prototype would work. PVC pipes were used because they are the main used type of pipes in small water pipeline systems. Fig 3.7 show exactly what the dimension is for each pipe in the pipeline system

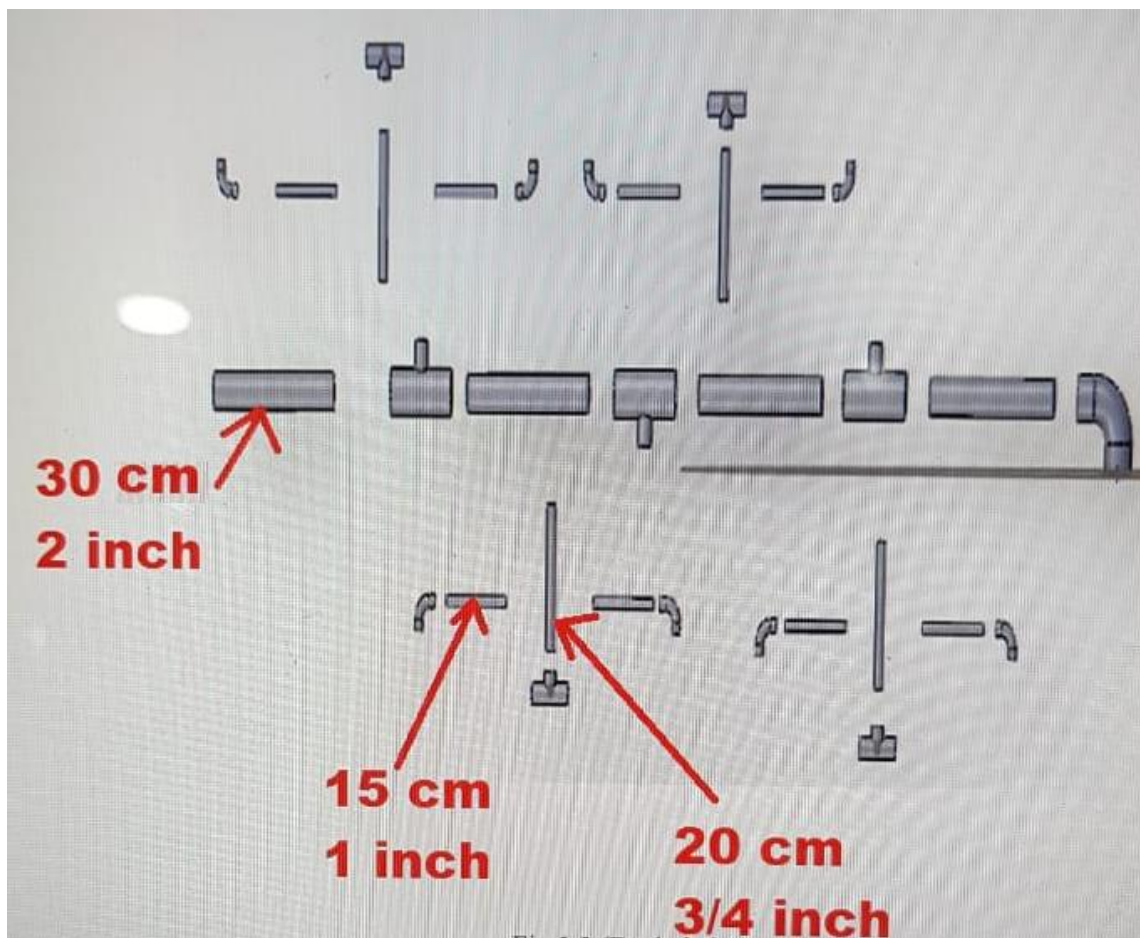


Fig 3.7 (Different sizes of Pipes)

The following figures will show the main three parts of the pipes parts, which are the main pipe that is feeding the water to the system (Fig3.8), the tee section which divides the pipeline system to either the water going out of the system or to the continuity of the main pipe (Fig3.9), the tee section which is on the end which is divided into two exact pipes which lead the water to outside the system (Fig3.10) or the elbow at the end of the system that takes the last line of the water to the end tee section (Fig 3.11).



Fig 3.8 (Main Pipe)



Fig 3.9 (Main Tee Section)



Fig 3.10 (Tee Section at the End)



Fig 3.11 (Elbow)

3.5 Manufacturing and assembly

The only problem that could have probably faced the assembly of the prototype could have been if improper parts were used, but because we picked the parts that matched together in the system, the assembly of the prototype went smoothly.

The steps were as follows:

- 1) Calculate the proper pipes, tee sections and elbows (fittings) for the project
- 2) Obtain the parts
- 3) Check if the parts fit properly by assembling them without the use of any products
- 4) Apply P-70 Primer on the pipes and fittings to soften the pipe, remove the sheen off the pipe and to clean it (Fig 3.12)
- 5) Apply heavy duty PVC cement to glue the pipes and fittings (Fig 3.13)
- 6) Assemble the pipes, tee sections and elbow to each other and wait for the cement to dry



Fig 3.12 (P-70 Primer)



Fig 3.13 (PVC Cement)

Chapter 4

System Testing and Analysis

4.1 Experimental Setup, Sensors and data acquisition system

The way this system is going to be tested is by running two different types of tests, the first test will be where we set a series of Pressure Gauge Sensors (PGS) to be able to find the pressure gauge at each specific point that is desired by the individual running the test, while the second test will be done throughout a specific sensor called a Digit Flow Sensor (DFS).

The pressure gauge sensor is a device that can be set on any PVC pipe, its one and only task is to show how much pressure is going through inside the PVC pipe, the way that it will be set in the prototype is that there will be a pressure gauge sensor at each pipe leading outside of the system, this will show us the difference in pressure and we will be able to see how much loss is actually being lost in the system and we will be able to compare with the calculations that was done earlier in chapter 3, Fig 4.1 show how the pressure gauge sensor looks like. While Fig 4.2 show the four different pressure gauge sensors after they are set in the prototype of the project.



Fig 4.1 (Pressure Gauge Sensor)



Fig 4.2 (PGS in the System)

The other set of data that will be acquired to be able to get the findings of the tests are using the Digi Flow Sensors, the specific sensor that will be used in the making of this research is “Savant DigiFlow 6710M”, this sensor accurately finds the flow rate inside the pipe that it is being installed on. Fig 4.3 shows how the device looks, Fig 4.4 shows how the Digi Flow Sensor was used in the prototype, and Fig 4.5 is a picture of the completed system after the installation of all the sensors.



Fig 4.3 (Digi Flow 6710m)

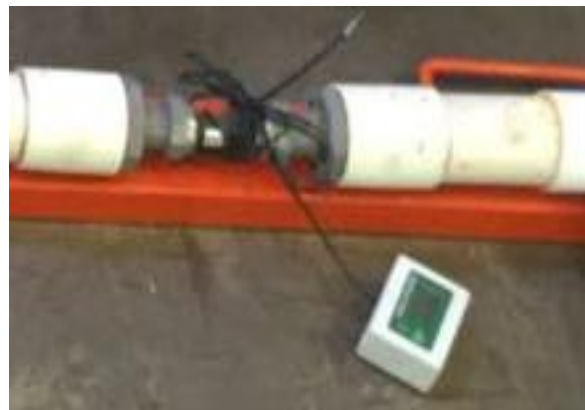


Fig 4.4 (Sigi Flow in the system)



Fig 4.5 (The Finalized Prototype)

These are the specifications for the Digi Flow Sensor that was used in the testing of the project.

Features:

- Flow totalizing up to 99999 liters
- Flow rate display from 0.8 to 8.0 liter/min.
- Battery operated, 2 AA batteries
- Low battery power alert
- Automatic data memorized when battery power is off

Application:

- Water cooler
- Water dispenser
- Cooling system for machinery

Operating Voltage: 3 DC Volts

4.2 Results, Analysis and Discussion

4.2.1 Results of Digi Flow Sensor Tests

The test results from the first test that we used to find the flow rate at different pipes are all shown in the table 4.1; the number of the opened and closed pipes is 1,2,3,4 from the first pipe flowing outside of the system till the last respectively. Flow 1 and Flow 2 are the data taken from the Digi Flow Sensors that were shown in Fig 4.4.

Table 4.1 (Flow of the system during tests)

	1	2	3	4	Flow 1 (L/m)	Flow 2 (L/m)
Test 1	Open	Open	Open		13.2	0
Test 2	Open	Open		Open	12.9	5.47
Test 3	Open		Open	Open	12.37	6.34
Test 4		Open	Open	Open	23.87	6.03
Test 5			Open	Open	24.48	12.24
Test 6	Open			Open	6.25	6.43
Test 7	Open	Open			8.16	0
Test 8		Open	Open		24	0
Test 9				Open	23.07	23.04
Test 10			Open		0	24.48
Test 11		Open			24	0
Test 12	Open				0	0
Test 13	Open	Open	Open	Open	7.22	2.87

The word open means that the pipe was opened at the time the test took place, and the blank space means that the pipe was closed and no flow was going through it.

4.2.2 Results of Pressure Gauge Sensors Tests

As stated in section 4.1, the way this test was conducted, we set up all the different pressure gauges then some pipes were closed and the others remained opened and findings of the different pressure is shown in the table 4.2 below.

Table 4.2 (Pressure in the system during the tests)

	1	2	3	4	pressure 1 (bar)	pressure 2 (bar)	pressure 3 (bar)	pressure 4 (bar)
Test 1	Open	Open	Open		0.13	0.13	0.12	0.14
Test 2	Open	Open		Open	0.15	0.15	0.15	0.12
Test 3	Open		Open	Open	0.13	0.14	0.13	0.13
Test 4		Open	Open	Open	0.14	0.13	0.13	0.13
Test 5			Open	Open	0.17	0.17	0.15	0.16
Test 6	Open			Open	0.15	0.17	0.16	0.15
Test 7	Open	Open			0.15	0.15	0.15	0.16
Test 8		Open	Open		0.17	0.15	0.15	0.17
Test 9				Open	0.27	0.27	0.27	0.25
Test 10			Open		0.29	0.29	0.25	0.29
Test 11		Open			0.29	0.26	0.28	0.28
Test 12	Open				0.26	0.29	0.28	0.28
Test 13	Open	Open	Open	Open	0	0	0	0
Test 14					4	4	4	4



Fig 4.6 (PGS in the System)

4.3 Findings and Discussion

If we look at the first flow rate when all the pipes are opened we can see that it is 7.22 liters per minute, and the calculated value of that specific pipe was $0.0001666 \text{ m}^3/\text{sec}$, to convert it to liter/min, we need to multiply by 60000 and the answer will be 10 liter/min, taking a safety factor of 1.35, we can conclude that the actual values of the flow in the system is exactly the same as the calculated values. The same can be said for the second flow, the calculated value was 3.3 liter/min and the test showed a value of 2.87 liters/min which is close enough when we consider the safety factor as well.

In order for us to compare the pressure values that we gained from these tests we needed to put a pressure gauge at the pipe flowing inside the system and compare the water pressure going inside the system with the pressure leaving the system, but because of different time limitation we were not able to obtain such data, thus we could not compare the values of the tests.

The fact that we only did the calculations as if all the pipes are wide open means that we could only compare the one set of tests with the results that we have, but we could not compare all the 14 different sets because we only have one to compare with in our calculations.

Chapter 5

Project Management

5.1 Project Plan

A project is called a project because it is unique and has a start and a finish date, to be able to end this project with the given time of one semester, a table was written to help specifying tasks with start and finish date for each task.

Lists of Tasks:

Table 5.1 (Tasks)

Name of Task	Duration in Days	Start	Finish
Milestone 1			
1. Initiating and planning of the Project	1	25/Jan/2018	25/Jan/2018
1.1 Kick off Meeting	1	28/Jan/2018	28/Jan/2018
1.2 Preparation of Gantt Chart	3	1/Feb/2018	3/Feb/2018
1.3 Purchasing materials for first Prototype	1	5/Feb/2018	5/Feb /2018
1.4 searching the engineering standards	5	5/Feb/2018	10/Feb/2018
1.5 Assembly of first Prototype	1	7/Feb/2018	7/Feb/2018
1.6 Weekly Meeting with the Supervisors	Weekly		
1.7 Discussing the First Prototype	1	10/Feb/2018	10/Feb/2018
1.8 Acknowledgment	1	11/Feb/2018	11/Feb/2018

Milestone 2			
Abstract	2	12/Feb/2018	13/Feb/2018
Table of Content	1	14/Feb/2018	14/Feb/2018
Chapter I: Introduction	1	15/Feb/2018	15/Feb/2018
1. Introduction	1	18/Feb/2018	18/Feb/2018
1.1 Project Definition	1	19/Feb/2018	19/Feb/2018
1.2 Project Objectives	2	18/Feb/2018	19/Feb/2018
1.3 Project Specifications	1	18/Feb/2018	18/Feb/2018
1.4 Applications	1	19/Feb/2018	19/Feb/2018
Chapter II: Literature Review	1	19/Feb/2018	20/Feb/2018
2.1 Project background	2	20/Feb/2018	22/Feb/2018
2.2 Previous Work	5	22/Feb/2018	27/Feb/2018
2.3 Comparative Study	5	25/Feb/2018	2/Mar/2018
Preparing of Project Summary	2	5/Mar/2018	7/Mar/2018
Milestone 3			
Chapter III: Design Methodology	1	6/Mar/2018	7/Mar/2018
3.1 Design Constrains	1	7/Mar/2018	8/Mar/2018
3.1.1 Preparing CAD Drawings	4	4/Mar/2018	8/Mar/2018
3.2 Engineering Standards	1	4/Mar/2018	4/Mar/2018
3.2.2 Summarizing ASME B31.1-2007	2	8/Mar/2018	10/Mar/2018
3.2.2 Summarizing ASAE S376.1	2	10/Mar/2018	12/Mar/2018
3.3 Theory and Theoretical Calculations	15	8/Mar/2018	23/Mar/2018
3.4.1 Product Subsystems	1	14/Mar/2018	15/Mar/2018

3.4.2 Selecting of Components	1	15/Mar/2018	16/Mar/2018
Preparing the Mid-Term Presentation	7	20/Mar/2018	27/Mar/2018
Making Mid-Term Presentation	1	29/Mar/2018	29/Mar/2018
Milestone 4			
Making of Prototype II		/2018	/2018
Obtaining the Sensors for the Project	5	20/Mar/2018	25/Mar/2018
Acquiring data from the Sensors	3	4/Apr/2018	7/Apr/2018
Writing of Chapter 4	5	9/Apr/2018	14/Apr/2018
Writing of Chapter 5	4	12/Apr/2018	16/Apr/2018
Writing of Chapter 6	2	20/Apr/2018	22/Apr/2018
Writing of Chapter 7	1	22/Apr/2018	23/Apr/2018

5.2 Contribution of Team Members

One hand does not clap as they say, what helped in the finishing of this project is the team spirit that was there to help produce a well-made project. The table below shows the contribution of different team members with the tasks of this project.

Table 5.2 (Team Members Contribution)

#	Task Description	Team Members Assigned	Progress Made
1	Purchasing all the materials for first Prototype	Mohammed Al-Boushi	100%
2	Obtaining different sensors for the project	Omar Hassan	100%
3	Making first prototype	Mohammed Al-Boushi	100%
4	Writing chapter 1	Omar Hassan	100%
5	Writing chapter II	Mohammed Al-Nasheri	100%
6	Writing Chapter III	Fahad Al-Jubreen	100%
7	Writing Chapter VI	Mohammed Al-Nasheri	100%
8	Writing Chapter V	Mohammed Al-Nasheri	100%
9	Writing Chapter VI	Fahad Al-Jubreen	100%
10	Writing Chapter VII	Fahad Al-Jubreen	100%
11	Preparing the Calculations	Mohammed Al-Boushi	100%
12	Creating Gantt Chart	Omar Hassan	100%
13	Preparing the Mid-Term Presentation	Omar Hassan	100%
14	Purchasing all the materials for 2nd Prototype	Mohammed Al-Boushi	100%
15	Assembly of Second Prototype	Mohammed Al-Boushi	100%
16	Obtaining Sensors	Madhi Al-Hajri	100%
17	Obtaining Pump	Madhi Al-Hajri	100%

5.3 Project Execution Monitoring

The meetings that were involved in the making of this project was not one or two meetings, there were various meetings with Dr. Nader Sawalhi to help us writing this research and finishing it in a modern fashion, Dr. Essam Jasem helped us a lot as well because he was responsible to help us obtain the different set of equations to be able to achieve this engineering project to the quality that we as students of Prince Mohamad Bin Fahd University would wish to.

We had at least one meeting between the team members weekly, but sometimes we needed to meet for more than three times a week just to be able to finish the required work for this project. Meetings involved discussion of different ideas for the project, making sure that every team members is on track and insured that the work is being done as smoothly as possible.

Different tests that was conducted in this project are the sensors that were bought lately and assembled on the second prototype to show the how much the pressure may vary from each pipe, the pressure sensors could still be attached if this project were to be re-developed and made to provide real-time monitoring of the system

5.4 Challenges and Decision Making

The most important challenge that we faced as a team was scheduling for the team members timings, each one of the team member has their own life outside of university and all are working full time in different private companies. Whenever we needed to sit and meet as a team it was a real hassle to be able to find a time that fits each individual from the team members.

Beside the fact that it was really hard for us to meet whenever we needed as a team, another thing that was a factor to delay the making of this project was the fact that we did not know which engineering standard to follow, this yielded in us having problems while writing the report and while making the hand calculations of this research.

Another really important challenge that we faced was the fact that we could not find the sensors needed for the second prototype of this project, we needed different sensors for different pipe sizes and it was hard for us to find them sold separately, most companies that sell them for small sizes sell the sensors in large quantities and it was never our intention to get a lot more than what we need to maintain a proper monitoring on the project.

The main thing that limited the continuation of this project was the fact that we could not find as much resources as we needed, we needed more digit flow sensors to obtain the full flow rates and to compare with what we had calculated but there was no way we would be able to order them from USA and to get them in Saudi Arabia by the specified time of the project.

5.5 Project Bill of Materials and Budget

Table 5.3 (Bill of Material)

Product	Specification	Quantity	Price (SR)
Pump	0.37 KW	1	400
PVC Pipe	2 in	1.5 m	50
PVC Pipe	1 in	1 m	35
PVC Pipe	1/2 in	1.5 m	40
Tee Section	2 in	3	30
Tee Section	1/2 in	4	40
Elbow Section	2 in	8	32
Bushing	2 in	4	32
Bushing	1 in	4	32
Bushing	1/2 in	4	32
Pressure Gauge	1/2 in	4	160
Valves	1/2 in	4	40
Flow Rate Sensor	-	2	400
Manufacturing	-	-	300
Total Cost		1623 SR	

Chapter 6

Project Analysis

6.1 Life-long Learning

Excel is a really powerful program for engineers, we needed to use it to help us in the calculations for this project, I would likely say that I did certainly learned a lot at excel just from this project alone, I learnt how to organize an entire spread sheet and to end up with a well-written spread sheet just to do all different types of calculations for this project

Having challenges is a really good aspect when it comes to any project; challenges mean that it forces us to get out of our comfort zone and to implement what we learned throughout our entire life cycle. The challenge that we faced when it came down to us not being able to arrange a meeting whenever we needed was a real life-long lesson learnt, it just helped us developing our individuals project management skills. Just for us to see that we cannot meet whenever we want but we actually need to plan anything a head.

Time is the only aspect in life that cannot return once it is passed, we were really on a tight schedule on this project, and this tight schedule helped us as a team to be able to produce more outcomes and to put more effort in less time.

6.2 Impact of Engineering Solutions

What advantages am I supposed to say when it comes to pure water distribution to the houses, any house is not even considered a place to live in if it does not have proper water distribution system for it, this project just makes sure that the water distribution system (Pipe-Line System) are up for the task that they are assigned to do. The economic impact is great because we cannot imagine how hard it would be if water were to cut down from any house of ours for even a day, it would generate great problems because we are not even equipped with what is needed to deal with the lack of water in our houses, this project makes sure that the pipeline system is requiring least maintenance and will work properly for its maximum designed life cycle.

6.3 Contemporary Issues Addressed

We all know that Saudi Arabia is a huge desert that we live on, it did develop a lot since oil was found in it. Water consumption currently in Saudi Arabia is a lot more than what the country had ever accounted for, people got so used to the idea that water is cheap and everywhere that they forgot what the actual worth of water is like, because Saudi Arabia is a country on dessert then it means that it takes a lot of money for the factories to produce water that can be used as tap water. This project is just concerned with the fact that water needs to be distributed to all the houses in a specific neighborhood. We are so glad that we can actually see nowadays that the country started to advice people more and more about the consumption of water, hopefully people will start understanding the true value of water and to be able to see how much it actually cost the country to produce these huge amounts of water and to distribute it to different places in the desserty country.

Chapter 7

Conclusions and Future

Recommendation

7.1 Conclusion

The results from the tests matched the results that were found in the calculations with the only difference being the safety factor, which means that the calculations and the tests were done correctly, a pump with the power of 0.37 KW was found to sufficiently supply the system with the needed power but it will generate low pressure in case all pipes were opened simultaneously

Checking the previous work of a previous similar project saved a lot of time and effort and reduced the challenged that was going to face the team. Why should we re-invent the wheel, we were able to find a similar project that helped us start our assumption for the pipes and then continue on forward to finalize the project

The main project experience that we can all agree is that this project helped us understand how real engineering work is supposed to take place and how much important is all the different types of engineering standard and how much easy it is to look it up and to search for any information that we are lacking.

7.2 Future Recommendation

For the recommendations of any future similar project as this one we would recommend that the researchers would re-calculate the same calculations that were done in this project but to take into consideration the fact that some pipes could be closed, our calculations were all based as if all the pipes are open, but when we did the tests, it was obvious that we needed more calculated values to allow us to compare with the tested values.

Another thing that needs to be taken into consideration if someone wants to add to this project is that we needed more Digit Flow Sensors to acquire more flow rate data, but we were unable to obtain the sensors because we needed to order the sensors from United States of America and we could not find them here in Saudi Arabia, and by the time that we were ready to start the testing we did not have the as much sensors as we would have liked to have. More sensors would have meant that we could have compared the flow entering the system with the flow going outside of the water piping system

The project could easily be done on bigger scale, it just needs more funds and more calculations regarding the head loss calculations, usually similar projects have ups and downs, they have more than just simple 90 degree angles inside the pipeline system and the system is not as simple as this project, future research can be done to see how much different angles contribute to the pumping power required for the system.

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Appendix A

Table III-4.2.1 Hydrostatic Design Stresses (HDS) and Recommended Temperature Limits for Thermoplastic Piping Components

ASTM Spec. No.	Material	Recommended Temperature Limits [Notes (1), (2), (3)]		Hydrostatic Design Stress at [Note (6)]										
		Minimum, °F [Note (4)]	Maximum, °F [Note (5)]	73°F, ksi [Note (7)]	100°F, ksi	140°F, ksi	180°F, ksi							
D 2846 F 441 F 442	CPVC4120	0	180	2.0	1.6	1.05	0.5							
D 2513 F 2145								PA32312	-20	180	1.25	1.1	0.8	0.63
D 2104 D 2239 D 2447 D 2513 D 2737 D 3035															PE2406 PE3408	-30 -30	140 140	0.63 0.80	0.54 0.64	0.4 0.4	... ...
...	POP2125 [Note (8)]	30	210	...	...	...	...			
...	PP [Note (8)]	30	210	...	...	...	...			
D 1785 D 2241 D 2513 D 2672	PVC1120 PVC1220 PVC2110 PVC2112 PVC2116 PVC2120	0	100	2.0	1.2	...	...					
		0	100	2.0	1.2	...	...					
		0	100	1.0	0.6	...	...					
		0	100	1.25	0.8	...	...					
		0	100	1.6	1.0	...	...					
F 599	PVDC [Note (8)]	0	175	...	...	...	...			
F 491	PVDF [Note (8)]	0	275	...	...	...	...			

NOTES:

- (1) These recommended limits are for low pressure applications with water and other fluids that do not significantly affect the properties of the thermoplastic material. In conservative practice, the upper temperature limits may be reduced at higher pressures depending on the required service and expected life. Lower temperature limits are affected more by the environment, safeguarding, and installation conditions than by strength.
- (2) Because of low thermal conductivity, temperature gradients through the piping component wall may be substantial. Tabulated limits apply where more than half the wall thickness is at or below the stated temperature.
- (3) These recommended limits apply only to listed materials. Manufacturers should be consulted for temperature limits on specific types and kinds of materials not listed.
- (4) Minimum for installation.
- (5) Maximum for design.
- (6) The HDS listed is for water service only, reflecting a design factor of 0.5. For other services, refer to PPI TR-9 or the manufacturer for recommended design factors.
- (7) Use these hydrostatic design stress values at all lower temperatures.
- (8) Nonpressure-boundary materials typically used as liners. No established HDS.

Appendix B1

Table III-4.3.2 Modulus of Elasticity, Nonmetals

Material Description	<i>E</i> , ksi (73.4°F) [Note (1)]
Thermoplastics	
Acetal	410
ABS, Type 1210	300
ABS, Type 1316	340*
PVC, Type 1120	410
PVC, Type 1220	410
PVC, Type 2110	340*
PVC, Type 2116	360
Chlorinated PVC	420*
Chlorinated polyether	160*
PE, Type 2306	120
PE, Type 3306	130
PE, Type 3406	130
PE, Type 3408	130
Polypropylene	120*
Polypropylene (vinylidene/chloride)	100*
Poly(vinylidene fluoride)	194*
Poly(tetrafluoroethylene)	57*
Poly(fluorinated ethylenepropylene)	67*
Poly(perfluoroalkoxy)	100*
Thermosetting Resins, Axially Reinforced	
Epoxy-glass, centrifugally cast	1,200–1,900
Epoxy-glass, filament-wound	1,100–2,000
Polyester-glass, centrifugally cast	1,200–1,900
Polyester-glass, filament-wound	1,100–2,000
Polyester-glass, hand lay-up	800–1,000

Appendix B2

TABLE 10-1 Maximum hydrostatic design stress for thermoplastic pipe. (Adapted from ASAE Standard S376.1.)

Compound	Standard Code Designation	Hydrostatic Design Stress	
		(MPa)	(psi)
PVC	PVC 1120	13.8	2000
PVC	PVC 1220	13.8	2000
PVC	PVC 2120	13.8	2000
PVC	PVC 2116	11.0	1600
PVC	PVC 2116	8.6	1250
PVC	PVC 2110	6.9	1000
PE	PE 3408	5.5	800
PE	PE 3406	4.3	630
PE	PE 3306	4.3	630
PE	PE 2306	4.3	630
PE	PE 2305	3.4	500
ABS	ABS 1316	11.0	1600
ABS	ABS 2112	8.6	1250
ABS	ABS 1210	6.9	1000

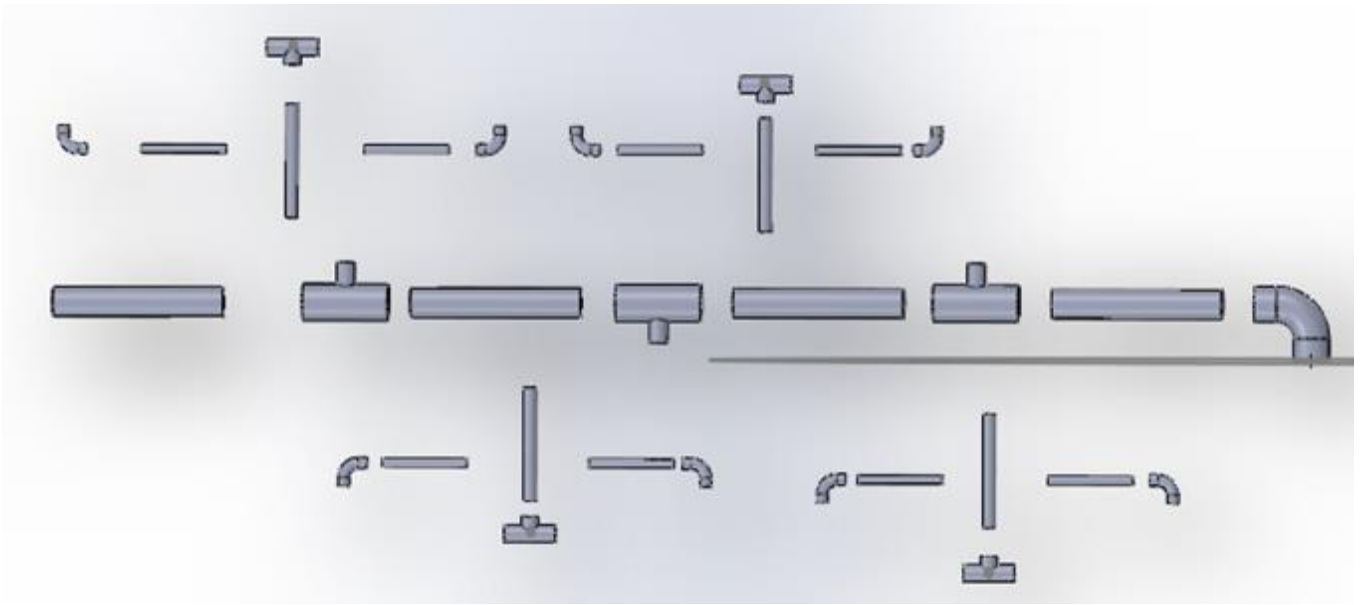


Fig C2 (Exploded view)

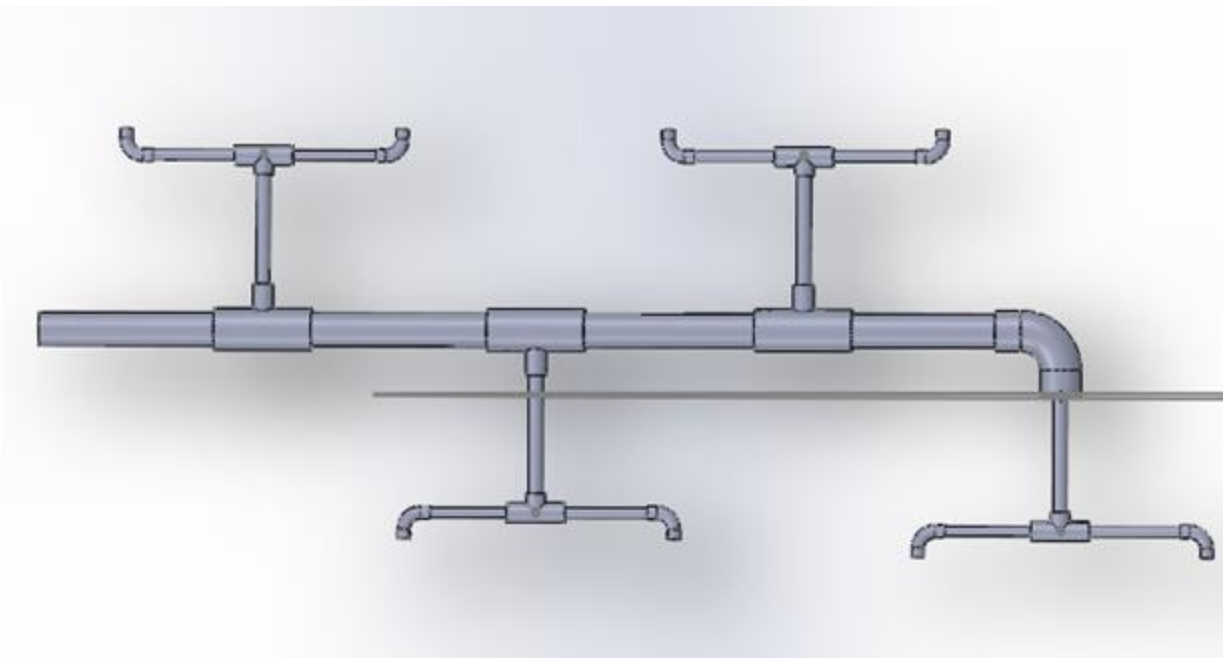


Fig C3 (Collapse View)

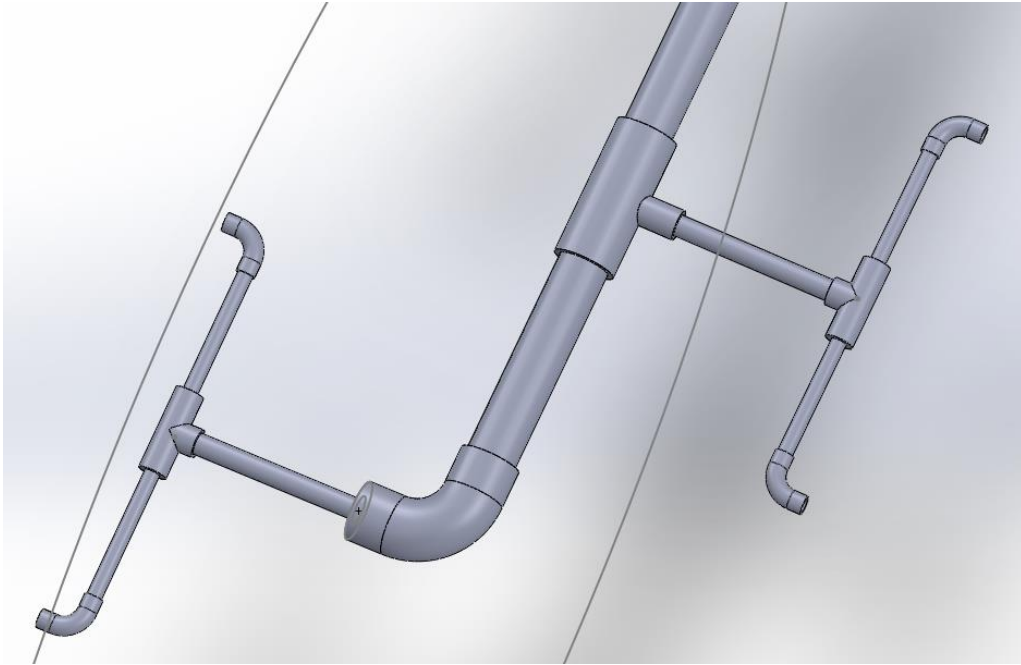


Fig C4 (Side View 1)

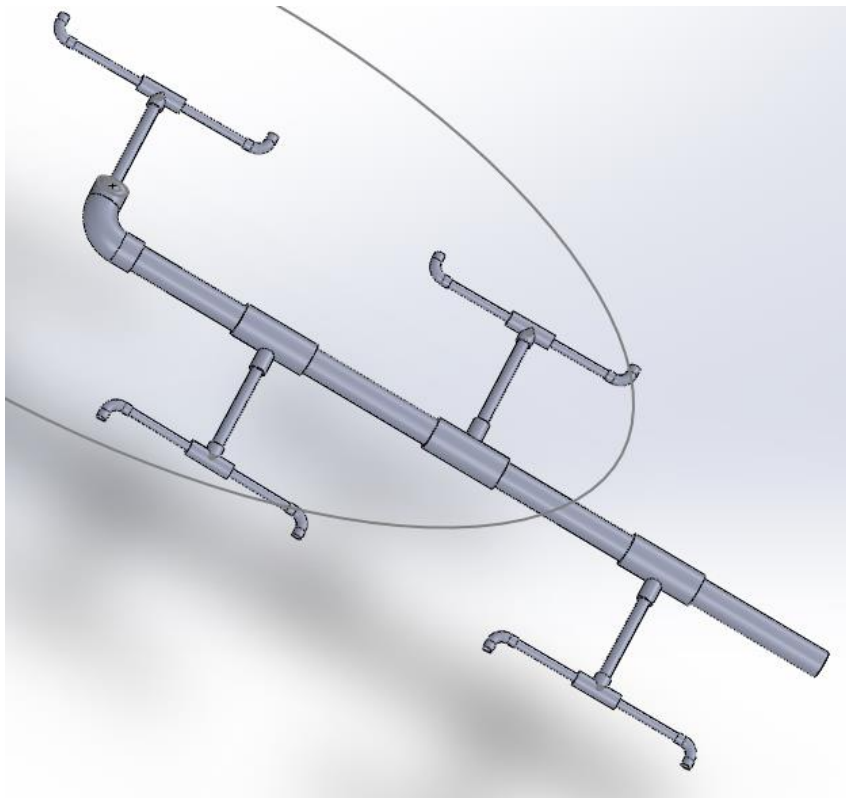


Fig C5 (Side View 2)

Appendix D1

All Excel Sheet Calculations

Table A1

	A	B	C	D	E	F
Q	0.000222222	5.55556E-05	2.77778E-05	0.000167	5.55556E-05	2.77778E-05
Ry	5572.551839	3715.034559	2786.275919	4179.414	3715.034559	2786.275919
f	0.062231203	0.017227296	0.022969728	0.063897	0.017227296	0.022969728
L	0.3	0.5	0.65	0.6	0.8	0.95
V	0.109695902	0.195014937	0.219391805	0.082272	0.195014937	0.219391805
A	0.002025802	0.000284878	0.000126613	0.002026	0.000284878	0.000126613
D	0.0508	0.01905	0.0127	0.0508	0.01905	0.0127
3/D	0.029527559	0.078740157	0.118110236	0.029528	0.078740157	0.118110236
g	9.81	9.81	9.81	9.81	9.81	9.81
	2	2	2	2	2	2
V^2	0.012033191	0.038030826	0.048132764	0.006769	0.038030826	0.048132764
	0.000224652	0.000327584	0.000718638	0.000259	0.000524135	0.001050317
	0.996696	0.373761	0.249174	0.996696	0.373761	0.249174
h	0.000225397	0.000876454	0.00288408	0.00026	0.001402326	0.004215194

Table A2

	G	H	I	J	K	L
Q	0.000111	6E-05	2.778E-05	5.55556E-05	5.55556E-05	2.77778E-05
Ry	2786.276	3715	2786.2759	1393.13796	3715.034559	2786.275919
f	0.02297	0.0172	0.0229697	0.045939456	0.017227296	0.022969728
L	0.9	1.1	1.25	1.2	1.4	1.55
V	0.054848	0.195	0.2193918	0.027423976	0.195014937	0.219391805
A	0.002026	0.0003	0.0001266	0.002025802	0.000284878	0.000126613
D	0.0508	0.0191	0.0127	0.0508	0.01905	0.0127
3/D	0.029528	0.0787	0.1181102	0.029527559	0.078740157	0.118110236
g	9.81	9.81	9.81	9.81	9.81	9.81

Appendix D2

All Excel Sheet Calculations

Table D21 (A)

	A	B	C	D	E	F
Q(m ³ /s)	0.000222222	5.55556E-05	2.77778E-05	0.000166667	5.55556E-05	2.77778E-05
Ry	5572.551839	3715.034559	2786.275919	4179.413879	3715.034559	2786.275919
<i>f</i>	0.062231203	0.017227296	0.022969728	0.063897335	0.017227296	0.022969728
V (m/s)	0.109695902	0.195014937	0.219391805	0.082271927	0.195014937	0.219391805
h total (m)	0.000348059	0.002458951	0.005202553	0.001218661	0.003329812	0.006878655
pump power (kw)	0.000815881	0.001440998	0.001524404	0.002142485	0.001951341	0.00201552

Table D21 (B)

	G	H	I	J	K	L
Q(m ³ /s)	0.000111111	5.55556E-05	2.77778E-05	5.55556E-05	5.55556E-05	2.77778E-05
Ry	2786.275919	3715.034559	2786.275919	1393.13796	3715.034559	2786.275919
<i>f</i>	0.022969728	0.017227296	0.022969728	0.045939456	0.017227296	0.022969728
V (m/s)	0.054847951	0.195014937	0.219391805	0.027423976	0.195014937	0.219391805
h total (m)	0.000898034	0.003733021	0.008087106	0.000766073	0.00414773	0.009307057
pump power (kw)	0.001052535	0.002187631	0.002369609	0.000448935	0.002430659	0.272706772

Appendix D2

All Excel Sheet Given Data

Table D22 (A)

	A	B	C	D	E	F
L (m)	0.3	0.5	0.65	0.6	0.8	0.95
D (m)	0.0508	0.01905	0.0127	0.0508	0.01905	0.0127
A (m ²)	0.002025802	0.000284878	0.000126613	0.002025802	0.000284878	0.000126613
h major (m)	0.000225397	0.000876454	0.00288408	0.00026036	0.001402326	0.004215194
h minor (m)	0.000613312	0.000969185	0.000735975	6.89977E-05	0.000969185	0.000735975
k	0.2	0.5	0.3	0.2	0.5	0.3

Table D22 (B)

	G	H	I	J	K	L
L (m)	0.9	1.1	1.25	1.2	1.4	1.55
D (m)	0.0508	0.01905	0.0127	0.0508	0.01905	0.0127
A (m ²)	0.002025802	0.000284878	0.000126613	0.002025802	0.000284878	0.000126613
h major (m)	6.2396E-05	0.001928198	0.005546307	4.15973E-05	0.00245407	0.006877421
h minor (m)	3.06656E-05	0.000969185	0.000735975	1.14996E-05	0.000969185	0.000735975
k	0.2	0.5	0.3	0.3	0.5	0.3

Appendix E1

Pressure Gauge Sensor Test Data

Table E1

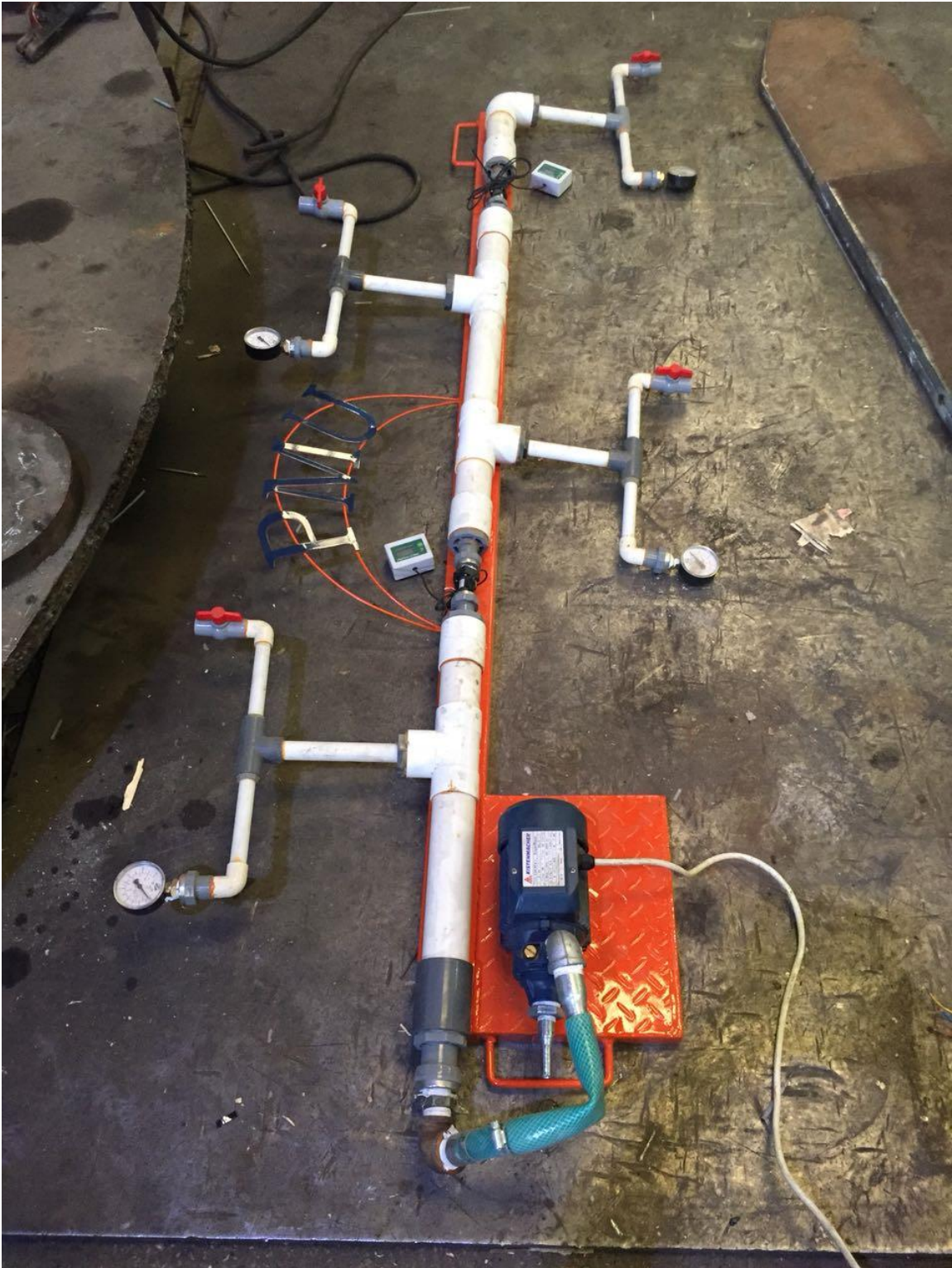
	1	2	3	4	pressure 1 (bar)	pressure 2 (bar)	pressure 3 (bar)	pressure 4 (bar)
Test 1	Open	Open	Open		0.13	0.13	0.12	0.14
Test 2	Open	Open		Open	0.15	0.15	0.15	0.12
Test 3	Open		Open	Open	0.13	0.14	0.13	0.13
Test 4		Open	Open	Open	0.14	0.13	0.13	0.13
Test 5			Open	Open	0.17	0.17	0.15	0.16
Test 6	Open			Open	0.15	0.17	0.16	0.15
Test 7	Open	Open			0.15	0.15	0.15	0.16
Test 8		Open	Open		0.17	0.15	0.15	0.17
Test 9				Open	0.27	0.27	0.27	0.25
Test 10			Open		0.29	0.29	0.25	0.29
Test 11		Open			0.29	0.26	0.28	0.28
Test 12	Open				0.26	0.29	0.28	0.28
Test 13	Open	Open	Open	Open	0	0	0	0
Test 14					4	4	4	4

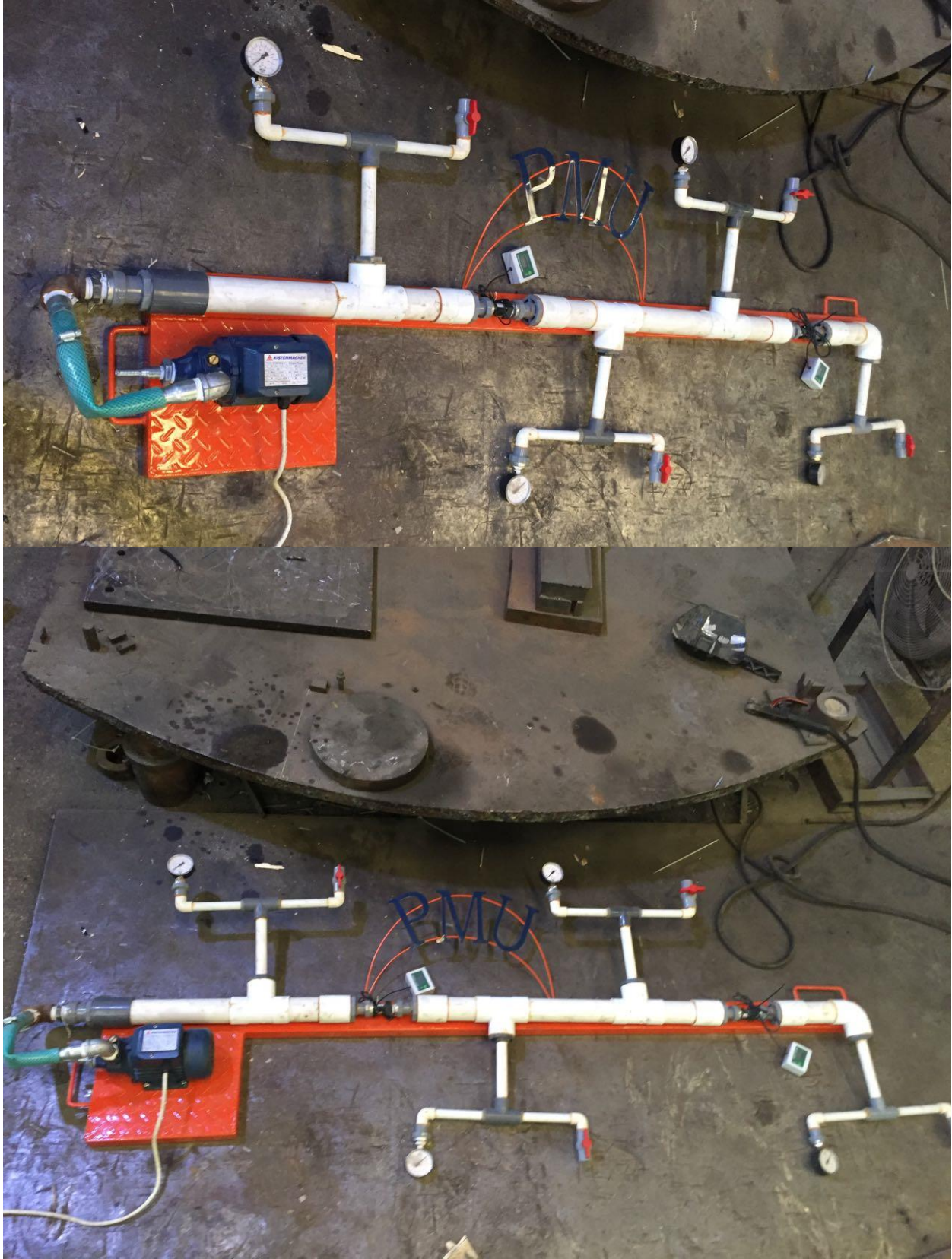
Appendix E2

Digit Flow Sensor Test Data

	1	2	3	4	Flow 1 (L/m)	Flow 2 (L/m)
Test 1	Open	Open	Open		13.2	0
Test 2	Open	Open		Open	12.9	5.47
Test 3	Open		Open	Open	12.37	6.34
Test 4		Open	Open	Open	23.87	6.03
Test 5			Open	Open	24.48	12.24
Test 6	Open			Open	6.25	6.43
Test 7	Open	Open			8.16	0
Test 8		Open	Open		24	0
Test 9				Open	23.07	23.04
Test 10			Open		0	24.48
Test 11		Open			24	0
Test 12	Open				0	0
Test 13	Open	Open	Open	Open	7.22	2.87

Appendix F, Figures of the Prototype













Appendix G Bill of Material

Product	Specification	Quantity	Price (SR)
Pump	0.37 KW	1	400
PVC Pipe	2 in	1.5 m	50
PVC Pipe	1 in	1 m	35
PVC Pipe	1/2 in	1.5 m	40
Tee Section	2 in	3	30
Tee Section	1/2 in	4	40
Elbow Section	2 in	8	32
Bushing	2 in	4	32
Bushing	1 in	4	32
Bushing	1/2 in	4	32
Pressure Gauge	1/2 in	4	160
Valves	1/2 in	4	40
Flow Rate Sensor	-	2	400
Manufacturing	-	-	300
Total Cost		1623 SR	

Appendix H (Progress Reports)

Progress Report #1

Month: February

ID Number	Member Name
201303694	Mohammed Al-Boushi
200901642	Mohammad Al-Nasheri
201300079	Fahad Al-Jubreen
201300315	Omar Hassan
201202517	Madhi Al-Hajri

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Gantt Chart	Mohammad Al-Nasheri	100	
2	Prototype #1	Mohammed Al-Boushi	100	
3	Writing the Abstract of the Project	Fahad Al-Jubreen	100	
4	Writing Chapter #1	Madhi Al-Hajri	100	
5	Writing Chapter #2, Previous Work	Omar Hassan and Mohammad Al-Nasheri	100	
6	Writing Chapter #2, Comparative Study	Mohammed Al-Boushi	100	

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
7	Doing the prototype calculations	Mohammed Al-Boushi
8	Making a check for the system	Fahad Al-Jubreen
9	Building prototype #2	Omar Hassan
10	Writing Chapter #3	Mohammad Al-Nasheri
11	Writing Chapter #4	Madhi Al-Hajri

Progress Report #2

Month: March

SEMESTER:	Spring Semester	ACADEMIC YEAR:	2018
PROJECT TITLE	DEIGN AND CONSTRUCTION OF A PIPING NETWORK SYSTEM FOR DEMOTIC USE		
SUPERVISORS	Dr. Essam Jasim		
ID Number	Member Name		
201303694	Mohammed Al-Boushi		
200901642	Mohammad Al-Nasheri		
201300079	Fahad Al-Jubreen		
201300315	Omar Hassan		
201202517	Madhi Al-Hajri		

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Continuing of Chapter II	Mohammad Al-Nasheri	100	
2	Writing of Chapter III	Mohammed Al-Boushi	100	
3	Velocity and flow rate calculation	Fahad Al-Jubreen	100	
4	Major losses calculations	Madhi Al-Hajri	100	
5	Adding pressure gauge sensor	Omar Hassan and	100	
6	Built Prototype II	Mohammed Al-Boushi	100	

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
7	Writing of Chapter IV	Mohammed Al-Boushi
8	Pump design	Fahad Al-Jubreen
9	Minor losses calculations	Omar Hassan
10	Preparing of final presentation	Mohammad Al-Nasheri
11	Adding flow rate sensor	Madhi Al-Hajri