جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

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Senior Design Project Report

Underwater pipes Leak Detection

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

Team 4

Team Members

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Abstract

Oil industry is one of the biggest sectors in Saudi Arabia. Many maintenance companies consider Saudi Arabia as their main client. In this project, we focus on leaking that happened underwater. Due to these issue, we tackle the problem of leaking on pipes underwater. This is important for oil and gas pipes underwater. Many companies cannot determine easily the leaks underwater, so we try to get over this problem by using a remote-control drone, a camera and image that proceeding by running software on website or application. Our prototype goes underwater near to the pipes and takes a clear video then send it to the software which will shows if there are any leaks in the pipes under any condition. Our idea will make companies like Saudi Aramco detecting the leaks easily and in professional way.

Acknowledgments

Most importunately, we might want to express our thanks to each one of the individuals who provide the chance to make this project. A kindly appreciation to our senior project advisor Dr. Nassim Khaled for his excellent support for our project and his sincere encouragement and suggestions.

Moreover, we might want likewise to recognize with much gratefulness to the faculty of Mechanical Engineering Department at Prince Mohammed Bin Fahd University also, we would like to thank our Dean Dr. Jamal F. Nayfeh for his wise leadership and continuous support.

Finally, Special thanks goes to our team *Abdullah Dulaijan, Metab AlSaleem, Hussain AlMuhanna and Omar AlQarab. Whom participating with a high potential and ultimate energy to find the method of finding the idea of gas leaking detection underwater pipe.

List of Acronyms (Symbols) used in the report

Symbol	Definition
P	Pressure
F	Force
E	Modulus of Elasticity
r_o	Outer radius
r_i	Inner radius
θ	Deflection of angle
I	Moment of Inertia
D	Diameter
A	Area
L	Length
y_{max}	Curvature

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Chapter 1: Introduction

1.1 Project Definition:

Nowadays, the offshore oil and gas industry are a major investment in Saudi Arabia and all industrial countries. In Saudi Arabia particularly, Saudi Aramco is taking the lead in offshore oil and gas industry in Saudi Arabia. In fact, Saudi Arabia's largest offshore oil fields are Safaniya, Zuluf, Manifa, Marjan, and Abu Safah, which together hold a total 76.1 Bbl. in reserves with a combined production capacity of 3.42 MMb/d. These offshore fields represent roughly 30% of total Saudi reserves and 3.8% of daily global demand. This variant of crude oil has a higher density and viscosity than light crude, making it harder and thus more expensive to extract. However, for offshore heavy crude wells, an advantage offsets the difficulty in extraction. Heavy crude is typically located at shallow depth, and is less vulnerable to oil spills and other damages. According to a conference that Saudi Aramco convened last year, the company stated that there are some difficulties in detecting leaks in the underwater pipelines, which costs the company many gases and oil loses in the sea, which eventually increases the danger of sea pollution. This project can be defined as the detection process of underwater pipes by using the underwater drone technology for decreasing the losses of material especially gases which can be undetectable by eyes and to make it easier and faster to check all the locations in a live video of the pipes. In addition, it can increase the safety in the sea environment by keep checking pipelines without any diving operations.

1.2 Project Objectives:

1) Detecting the leakage pipe underwater automatically .
2) Decreasing the losses of material especially gases.
3) Preventing the pollution in sea environment.

Chapter 2: Literature Review

2.1 Project Background:

Pipeline networks are the safest and safest means of transportation for oil, gas, and other liquid products. As a means of long distance transportation, pipelines must meet the requirements of safety, reliability and high efficiency. If properly maintained, pipelines can last indefinitely without leakage. Most important leaks occur due to damage from nearby excavations. If the pipeline is not properly maintaining, it can corrode, especially in construction joints, low points where moisture accumulates, or sites with defects in the pipe. However, the scanning tools and correction can identify these defects before they progress to the leak. Other causes of leakage include accidents, ground movement, or vandalism. However, the primary purpose of leak detection systems is to help pipeline controllers detect and locate leaks. Provides alarms and displays other relevant data on pipeline controllers to assist in decision-making. Pipe leaking detection systems can enhance system productivity and reliability by reducing downtime and inspection time.

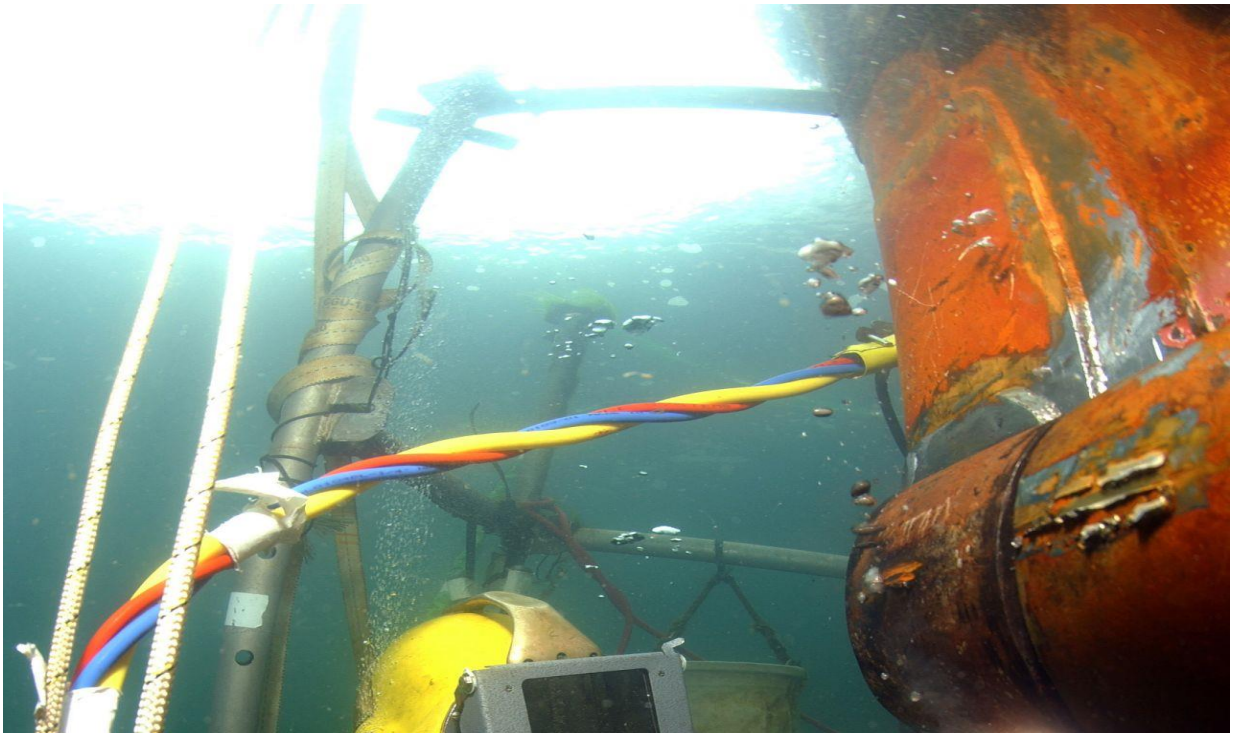


Figure 2.1.1: Leak detection in underwater pipe

Many techniques used to detect any leaks in subsea pipelines. These days, all techniques used in subsea pipelines discussed and compared with reference to the advantages and disadvantages of each. Therefore, if the submarine pipeline leak detection system designed according to the real state, in terms of pipeline fluid specifications, pipeline length, pipeline specifications, pipeline location, cost-effectiveness, accuracy.

This paper focuses on reviewing the history of underwater robots, advances in navigation techniques and underwater robots, and focusing on their applications. After an introduction, the paper reviews the evolution of underwater robots from the mid-19th century to the modern era. Progress in navigation and sensing techniques for underwater robots, and their applications in seabed mapping and monitoring of underwater oil leaks reviewed. Modern navigation and sensing techniques in underwater robots have enabled their applications in visualization of the seabed, detection of pipelines, and seismic monitoring of underwater oil fields and the like. This paper provides a recent review of underwater robots in terms of history, navigation and sensing techniques, and their applications in seabed mapping and seismic monitoring of underwater oil fields.

Figure 2.1.2: Underwater drone

2.2 Previous Work

The first project was about leaks in the pipeline networks that exist under the seas and stations. It based on the concept of searching for a robot suitable for depiction of depths and shred leaks in the pipes. Their project carried out using one type of metal for the manufacture of pipes. Saudi Aramco uses this type in the oil fields under the sea. The sizes specified in Armco are 12 inches maximum. In addition, a Saudi Aramco employee received the information. Moreover, by emailing him all the details. However, the position we are working on and the extent of the idea that we have. We have received great admiration and sufficient reinforcement. He said that the idea is brilliant, and we will contribute to serve the problem facing Armco in the underwater leaks. On the other hand, we have been looking for the types of materials that we will use. It also took us enough time to find the factory that suits us in manufacturing in terms of price and quality. The price was agreeing to be SR 350 per piece. We want two pieces of high-efficiency metal pipes. Meanwhile, gas cylinders and rent ability per day investigated; it is not important what kind of gas. Rather, it is important to have any visible dehydration of the bubbles under the water.

Figure 2.2.1: Pipes manufacturing workshops.

2.3 Comparative Study

In fact, our project did not start from scratch. We want to take advantage of others and them experience. Therefore, we have gone through some similar projects that may enhance our idea and improve our knowledge. Therefore, they used an electromagnetic sensor to detect leaks / cracks in water pipes. When old metal pipes erode, they begin to fragile, leading to the possibility of cracks appearing in the pipes. In addition, corrosion can corrode leading to restrict water flow in the pipe. Using an electromagnetic sensor to monitor the reflected signal from the tubes in real time provides the necessary information to determine where the leak occurred in the tube. The analysis of the reflected signal can provide the operator with information about the leak condition inside the pipe. This work describes how the system was designed, as well as built on a scale suitable for insertion into a water pipe with a diameter of 100 mm.

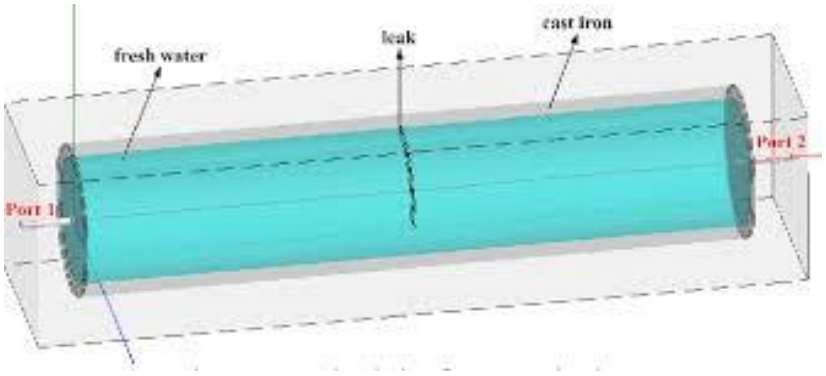


Figure 2.3.1: Water pipe leak detection using electromagnetic wave sensor for the water industry workshops

In the second project, there was a new method of leak detection and location relies on vibration sensors and generalized correlation techniques. Given the errors in estimating power spectral density and frequency spectrum density, the proposed method uses a high probability-adjusted

primary filter with a regulating factor. We derive the theoretical variance of the time difference and estimation error by combining in the discrete frequency field and find the optimal regulation factor that reduces the theoretical variance in practical water pipe channels. The proposed method has been compared with conventional correlation techniques through numerical simulations using the water pipe channel model, and it is evident from field measurement that the proposed modified ML filter outperforms conventional primary filters for generalized correlation. In addition, we provide a formula for calculating the leakage location using time difference estimation when connecting different types of pipes.

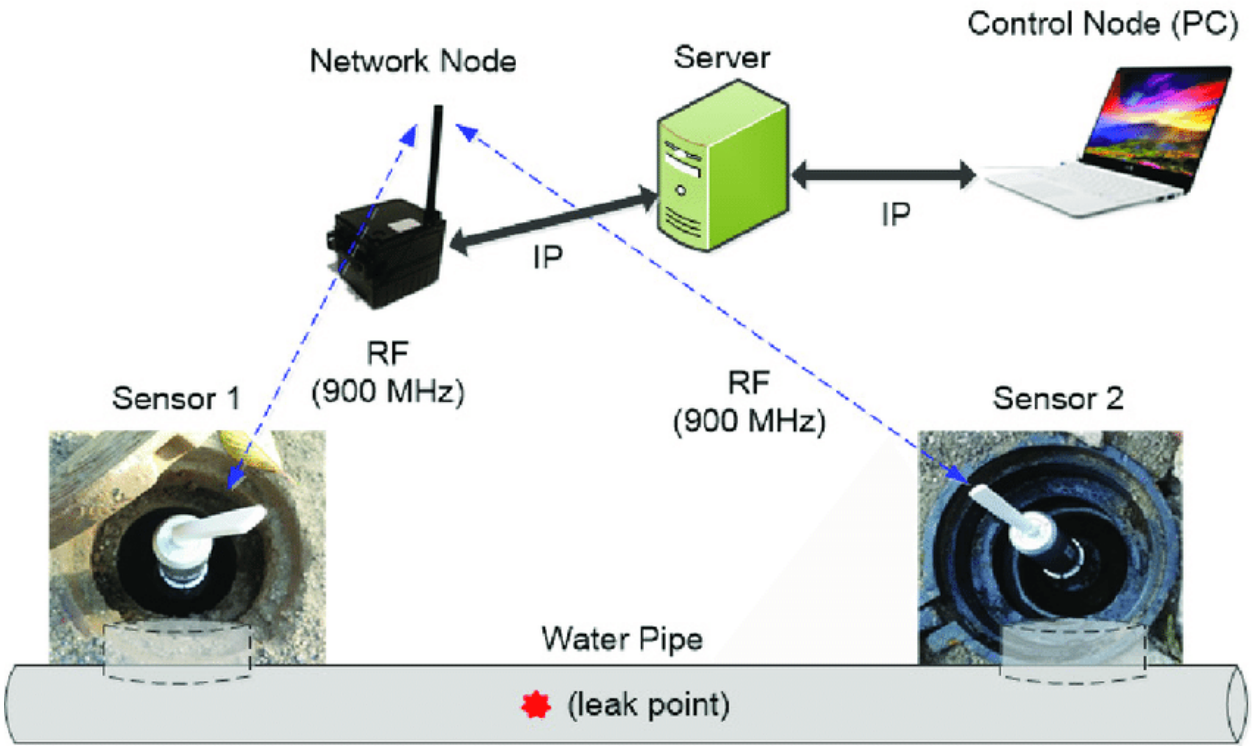


Figure 2.3.2: Leak detection and location of water pipes using vibration sensors and modified ML Pre-filter.

In the first project, they succeeded in using an electromagnetic sensor to detect leaks / cracks in the water pipes. They stated that it could provide the necessary information to determine where the leak occurred in the pipe. Analysis of the operator's reflex signal can provide information about the leak condition inside the pipe. In the second project, they used the proposed method as a modified primary filter to adjust the probability with a regulating factor. We derive the theoretical variance of the time difference and error estimation by combining in a discrete frequency field and finding the optimal regulation factor that reduces the theoretical variance in practical water pipe channels. The proposed method compared with conventional correlation methods through numerical simulations using the water pipe channel model. We benefited from their project in terms of equations, results, and components. However, we managed to improve our project based on these data.

Chapter 3: System Design

3.1 Design Constraints and Design Methodology:

3.1.1 Geometrical Constraints

Looking into the intricacy of our project, it can be surely judged by the topic "leak detection in underwater pipelines" that the device which we intend to complete as a prototype has a similar geometrical aspect as that of the drone. However, while pipeline leak detection consists of many different equipment such as image processing units and tethers. It was agreed to keep the overall weight and volume of the prototype as minimum as possible due to the fact that such kind of devices need to be transported on different sites and should have the ease of mobility and portability.

3.1.2 Sustainability

Sustainability is a huge concern regarding to our project. If given wider perspective related to the issue of leak detection in underwater pipes, it can save a lot of famous oil and gas companies from the material loss. Because, such kind of additional tech is a necessity nowadays to reduce losses and to also to keep control on the environment aspect of it nature, leaking fluids or gases from the pipes are extremely harmful to the environment. Therefore, the sustainability of our project can be claimed to have a very positive outcome.

3.1.3 Environmental Concern

Leaking Pipe can cause a lot of problems for the companies, maintenance department and also for the budget that goes into resolving those problems. Subsequently, it appears that environmental concern related to these leakages as they are prone and harmful in oil and gas

industries since the leaking fluid or gas can affect the ecosystem badly and can result in all new sort of problems. However, in terms of the prototype which will be used to tackle such a problem, there are no environmental concerns since it produces without hydrocarbons and has no harmful waterproofing sealant across it which would interact with the seawater (if underwater). Similarly, the propulsion systems will be purely based on the source of Direct Current via a chargeable and disposable battery instead of using a Lithium-Ion battery which has a negative effect on the environment.

3.1.4 Social Impact

The era we are living in consists of many well-planned and careful steps in running business and to provide it to the community, especially, in case of oil and gas industries since the oil and gas resources are scarce, there is an ultimatum to not waste any of the resources we acquire. Keeping this concern as a priority, there can be a very promising social impact related to our prototype because it serves to provide all the possibilities to cope with the leaking problems in pipes and to rectify them as soon as possible to avoid further damage. As an advantage, there can also be added an NDT (Non-Destructive Testing) type of ultrasonic image processors in the future to detect a pipe that will fail in the close future and can be dealt with it accordingly.

3.1.5 Economic

Pipelines as we know are made of steel. So most pipelines in oil and gas industries has extreme lengths and can faces many kinds of severe and wide range of atmosphere. These pipelines are coated with cathode protection in order to avoid any corrosion damage but considering other external factors like a sharp bend and a change of flowrate could negatively affect the pipelines from inside. This matter is a huge concern. In order to go with all maintenance procedures, it

would cost the organization or the company a lot of resources. Time and money to be spend in to deal with it. Because, if there is one small leak occurred due to pitting or erosion corrosion. It could all end up in a very hefty bill. Therefore, projects and prototypes such as ours can be a very economical addition into the field to deal with these concerns beforehand and avoid losses in all sectors.

3.1.6 Safety

Safety is our number one priority while carrying out any kind of project and prototype building. Additionally, in industrial sectors like oil and gas sectors. There is a high-risk concerns and every individual need to complete risk assessment before executing a task. Similarly, if in case of pipe leakage detection, the prototype needs to be safe from the fluid that leaks from the pipe as it could negatively affect the performance of the pipe. Also, there is another thing to be considered is the ability to remotely proceed to the leak site without any human personnel as gasses like H_2S can be very fatal for human health. So, there are some parameters can be considered to have a positive safety input into our prototype and the matter of pipe leak detection.

3.1.7: Ethics

It would be extremely unethical to claim the idea of pipe detection underwater remote-control drone as a new-born one because there already exists ROVs (Remoted Operated Underwater Vehicles) which perform a similar task but as big and bulky and those vehicles are responsible to perform many different tasks. However, our prototype idea is only centered to one main objective and that objective is of pipe leak detection. These is a major problem and to solve such

a matter we conducted a mini-research to review some articles after which we confidently choose this idea which would benefit the oil and gases industries in the offshore sector.

3.2 Engineering Design Standards

Engineering standards was followed in each component of our system. In this section, we described each component that we select for the project. The selected components are the following: Power vision Drone, stainless steel pipes, Oxygen tank and it hose. Power dolphin drone standards were chosen regarding it features which will help us while performing the tests. The stainless steel pipes standards were according to Saudi Aramco underwater pipelines dimensions and ASME standards. Oxygen gas were chosen because it is the safer gas to perform the leaking detection tests without polluting the pool's water.

- Satiric Pressure threads (AISI).
- Standard-Weight Steel Pipe (U.S. Customary Units).
- ANSI B36.19 (Stainless steel Pipe).

STAINLESS STEEL PIPE DIMENSION AS PER ASTM & WEIGHT-KG. PER MTR. (ANSI B36.19)

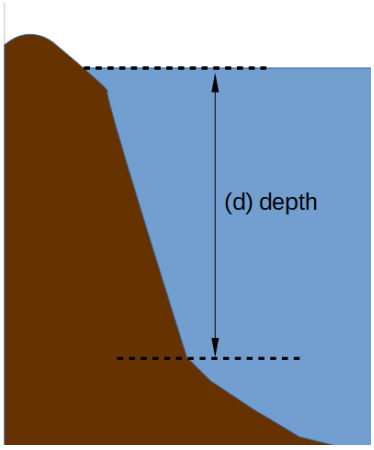
Nominal Bore		Outside Diameter	Sch-5S		Sch-10S		Sch-40S		Sch-80S		Sch-160S		Sch-XXS	
mm	INCH	mm	Wt mm	Weight (Kg/mt)	Wt mm	Weight (Kg/mt)	Wt mm	Weight (Kg/mt)	Wt mm	Weight (Kg/mt)	Wt mm	Weight (Kg/mt)	Wt mm	Weight (Kg/mt)
3	1/8	10.3	1.24	0.276	1.24	0.28	1.73	0.37	2.41	0.47	-	-	-	-
6	1/4	13.7	1.24	0.390	1.65	0.49	2.24	0.631	3.02	0.80	-	-	-	-
10	3/8	17.1	1.24	0.490	1.65	0.63	2.31	0.845	3.20	1.10	-	-	-	-
15	1/2	21.3	1.65	0.800	2.11	1.00	2.77	1.27	3.75	1.62	4.75	1.94	7.47	2.55
20	3/4	26.7	1.65	1.03	2.11	1.28	2.87	1.68	3.91	2.20	5.54	2.89	7.82	3.63
25	1	33.4	1.65	1.30	2.77	2.09	3.38	2.50	4.55	3.24	6.35	4.24	9.09	5.45
32	1 1/4	42.2	1.65	1.65	2.77	2.70	3.56	3.38	4.85	4.47	6.35	5.61	9.70	7.77
40	1 1/2	48.3	1.65	1.91	2.77	3.11	3.68	4.05	5.08	5.41	7.14	7.25	10.16	9.54
50	2	60.3	1.65	2.40	2.77	3.93	3.91	5.44	5.54	7.48	8.74	11.1	11.07	13.44
65	2 1/2	73.0	2.11	3.69	3.05	5.26	5.16	8.63	7.01	11.4	9.53	14.9	14.2	20.39
80	3	88.9	2.11	4.51	3.05	6.45	5.49	11.30	7.62	15.2	11.1	21.3	15.24	27.65
100	4	114.3	2.11	5.84	3.05	8.36	6.02	16.07	8.56	22.3	13.49	33.54	17.12	41.03
125	5	141.3	2.77	9.47	3.40	11.57	6.55	21.8	9.53	31.97	15.88	49.11	19.05	57.43
150	6	168.3	2.77	11.32	3.40	13.84	7.11	28.3	10.97	42.7	18.2	67.56	21.95	79.22
200	8	219.1	2.77	14.79	3.76	19.96	8.18	42.6	12.7	64.6	23.0	111.2	22.23	107.8
250	10	273.1	3.40	22.63	4.19	27.78	9.27	60.5	12.7	96.0	28.6	172.4	25.40	155.15
300	12	323.9	3.96	31.25	4.57	36.00	9.52	73.88	12.7	132.0	33.32	238.76	25.40	186.97
350	14	355.6	3.96	34.36	4.78	41.3	11.13	94.59	19.05	158.08	35.71	281.70	-	-
400	16	406.4	4.19	41.56	4.78	47.29	12.7	123.30	21.41	203.33	40.46	365.11	-	-
450	18	457.2	4.19	46.80	4.78	53.42	14.27	155.80	23.8	254.36	45.71	466.40	-	-
500	20	508.0	4.78	59.25	5.54	68.71	15.09	183.42	26.19	311.2	49.99	564.68	-	-
600	24	609.6	5.54	82.47	6.35	94.45	17.48	255.41	30.96	442.08	59.54	808.22	-	-

Table 3.2.1: Stain steel Engineering Standards

3.3 Theory and Theoretical Calculations

3.3.1 Underwater Pressure

The underwater pressure calculator will calculate the pressure which exerted under the water by the water column directly as a function of water density (ρ), underwater depth (d), and acceleration due to gravity (g).



- (**ρ**) is the density of the water (see below).
- (**d**) is the depth under water.

The formula for the pressure underwater is:

$p = \rho \cdot g \cdot d$

$\rho = 1000\ kg/dm^3$

g = 9.81 meter per second

$p = 1000 \times 9.81 \times 200$

d = 200 meter

p = 1962000000 Pascale

3.3.2 Distance and battery for The Drone

The following can determine the speed of playback segments (or any other activity) for those who have access to time at intermittent points. The drone can sail at the highest speed of 4.5 m / s. Consider being FPV races or mapping for fishing above the water. Also, the drone powered by 5800 mAh IPX8 battery supports 2 hours of battery life. In a complex aquatic environment, long battery life can prolong maximum water control requirements.

For one hour: $4.5 \times 3600 = 16200$ m. In one hour, it took 16.2 km. In two hours, it took 32.4 km.

3.4 Product Subsystems and Selection of Components

We can see various parts of the project including drone, stainless steel pipes and the oxygen tank. The drone is the main part of our prototype which is the method to detect the leaking in the pipe. It will be in the water and it has a camera that will capture a video or pictures of the pipe and depends on the situation of the pipe. The drone will send by a sensor that it discovers gas bubbles from the pipe which will send a message to the application that we have leaking in the pipe with all info about it such as it location by coordinates and video or image of the pipe.

3.5 Manufacturing and assembly (Implementation)

In terms of selection of the materials, we have chosen two different materials. The first one was stainless steel for the pipes as stainless steel is light than many materials. Also, on economical side it is cheaper. For the Oxygen hose we chose Rubber for mainly one reason, which was the most prevalent among other connecting materials. This type of hose is considered the most popular.

The set-up of the project was the hardest part in our manufacturing phase. It required both time and efforts to fit all the parts together. The work is divides into two parts, the first part which is underwater drone attached with camera need software and hardware. We want to make a software and hardware to connect the drone to a mobile for info transformation. The other part was manufacturing the pipe with insolated side by arc welding and the other side has an external opening hole. That external hole will be connected with the oxygen hose. Also, a small hole in the middle of the pipe was made to imagine the leaking. Then, our test was in a pool.

1	Underwater Drone	1 Piece
2	Stainless Steel Pipe	2 Piece
3	Air Hose	1 Piece
4	Electric air motor	1 Piece
5	Swimming Pool	1 piece

Table 3.5.1: Exploded assembly of the system

Component Name	Picture
Underwater Drone	
Stainless Steel Pipes	
Electric air motor	
Swimming Pool	

Table3.5.2: The project components

Figure3.5.3: External hole

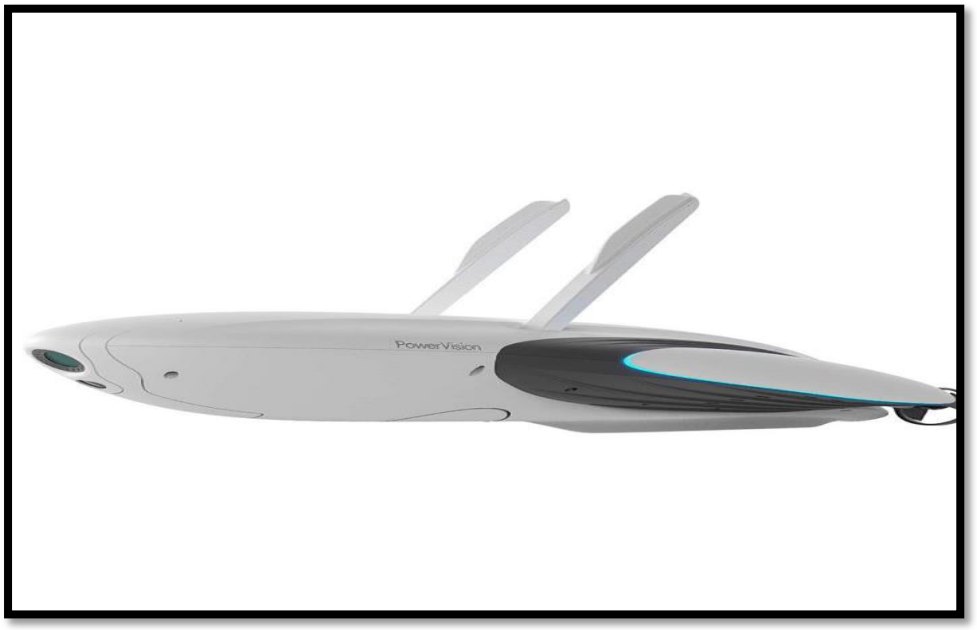
Figure3.5.4: Insolated side by arc welding

Chapter 4: System Testing and Analysis

4.1 Tools

4.1.1 Under Water Drone

We choose the drone can sail at the highest speed of 4.5 m / s. Also, the drone powered by 5800 mAh IPX8 battery supports 2 hours of battery life. In a complex aquatic environment, long battery life can prolong maximum water control requirements. We used drone to move under water and to move towards the targeted hole that needs to be detected with the help of remote control.



4.1.2 Stainless Steel Pipe

We selected stainless steel for the pipes because of two main reasons. The first one is that the stainless steel is lighter than many other materials. The second main edge is that, it is quite cheaper in economical perspective. So, we selected stainless steel as the material for the pipe that is being used in the testing. The next task is to manufacture the pipe with insolated side by arc welding and the other side has an external opening hole. That external hole will be connected

with the oxygen hose. Also, a small hole in the middle of the pipe was made to imagine the leaking.

4.1.3 Electric air motor and the Hose

Oxygen tank is for sure used to provide the oxygen and for the Oxygen hose we chose Rubber for mainly one reason, which was the most prevalent among other connecting materials. This type of hose is considered the most popular. That external hole that was made in the stainless steel pipe will be connected with the oxygen hose.

4.1.4 Camera and Software

The other important part of the testing is getting the video from the camera with the help of the moving drone at our required spot where the hole was intentionally made for the testing purposes. So, for this purpose camera is the integral part of the project. We used simple 5 MP lens camera that was fixed on the drone.

The video made from the camera was then analyzed using a software or application designed for this particular purpose.

4.2 Procedure

Following procedure was adapted for the testing purposes:

- We selected a pool for the underwater testing of the leakage.
- The next step was to set up the link of the software through the camera fixed on the drone in order to analyze the video.
- Then the stainless steel pipe was set.
- The next step was to move drone with the help of the remote control towards the place of the intentionally made hole on the pipe.
- The video was made through the camera and the hole was detected using software/application.

4.3 Calculations and Results

- (**ρ**) is the density of the water (see below).
- (**d**) is the depth under water.

The formula for the pressure underwater is:

$p = \rho \cdot g \cdot d$

$\rho = 1000\ kg/m^3$

$g = 9.81\ m/s$

$d = 200\ m$

$p = 1000 \times 9.81 \times 200$

$p = 1962000000$ Pascale

Chapter 5: Project Management

5.1 Project Plan

Task 1	Start Date	Days to complete
Identifying the project	3/9/2019	30
Determine the objectives		
Subdividing small tasks to collect information		
Writing chapter 1 of the report		
Write chapter 2		
Search and review the previous work		
Task 2		
Brain storming and gathering ideas for the conceptual design	4/10/19	13
Draw the first conceptual design		
Selected the appropriate Materials		
Searching for the parts		
Order the parts what we want on global sites		
Buying the available part from local shop		
Task 3		
Solid works Design	**17/10/2019**	14
Calculation		
Testing the system		
Writing Chapter 3		
Task 4		
Initial prototype	1/11/2019	13
Preparing the Mid-term presentation	**14/11/2019**	
Writing Chapter 4		

Task 5		
Start assembly the project	15/11/2019	15
Testing the system		
Finding the errors and upgrade the system		
Task 6		
Finishing the final report	1/12/2019	20
Finalized the project		
Final presentation		

Table 5.1: Tasks and their duration

Task 1	**Responsible**
Identifying the project	All team
Determine the objectives	
Subdividing small tasks to collect information	
Search and review the previous work	
Write Chapter 1	
Preparing and submit the forms	
Write Chapter 2	
Task 2	
Brain storming and gathering ideas for the conceptual design	All Team
Draw the first conceptual design	Abdullah
Selected the appropriate Materials	All team
Searching for the parts	Metab + Omar
Order the parts what we want on global sites	Hussain
Buying the available part from local shop	Metab + Omar + Abdullah
Task 3	
Solid works Design	Abdullah
Calculation	Hussain
Testing the system	All team

Writing Chapter 3	All team
Task 4	
Initial prototype	Hussain
Preparing the Mid-term presentation	Abdullah
Writing Chapter 4	All team
Task 5	
Start assembly the project	All team
Testing the system	
Finding the errors and upgrade the system	
Task 6	All team
Finishing the final report	Metab
Finalized the project	All team
Final presentation	All team

Table 5.2: Tasks and assigned members

5.2 Contribution of Team Members

The tasks in this project were assigned to one member or more members. It depends to the ability of doing the task and the time required to complete the task. Table given below shows the tasks and the members with how many percentages of contributing for each member.

Task 1	Responsible	Percent Complete
Identifying the project	All Team	100%
Determine the objectives		
Subdividing small tasks to collect information		
Search and review the previous work		
Write Chapter 1		
Preparing and submit the forms		
Write Chapter 2		

Task 2		
Brain storming and gathering ideas for the conceptual design	All Team	100%
Draw the first conceptual design	Abdullah	100%
Selected the appropriate Materials	All Team	100%
Searching for the parts	Metab + Omar	100%
Order the parts what we want on global sites	Hussain	100%
Buying the available part from local shop	Metab + Omar + Abdullah	100%
Task 3		
Solid works Design	Abdullah	100%
Calculation	Hussain	100%
Testing the system	All Team	100%
Writing Chapter 3	All Team	100%
Task 4		
Initial prototype	Hussain	100%
Preparing the Mid-term presentation	Abdullah	100%
Writing Chapter 4	All team	100%
Task 5		100%
Start assembly the project	All Team	100%
Testing the system		
Finding the errors and upgrade the system		
Software and hardware	Omar	100%
Task 6	All Team	100%
Finishing the final report	Metab	100%
Finalized the project	All Team	100%
Final presentation	All Team	100%

Table 5.3: Tasks the contribution of the members

5.3 Project Execution Monitoring

During our project, we had many activities which relate to improve our project. These activities including the important meeting and events that related to our senior project. The given below table shows the list of meeting and other events for our project during spring semester 2019.

Time/Date	Activities/Events
Three time a week	Assessment Class
Weekly	Meeting with group members
Biweekly	Meeting with advisor
10/11/2019	Finish first prototype
14/11/2019	Midterm presentation
25/12/2019	Finishing final prototype
15/11/2019	Test the system
12 /12/2019	Final submission of report
19/12/2019	Final presentation

Table 5.4: Dates of the activates and events

5.4 Challenges and Decision making

During the project phases, we faced some challenges that affect the progress of the project. Following challenges are the main challenges we have faced:

- Selecting the appropriate Materials
- Integration of the camera with the software
- Restricted use of particular remote controlled Drone

5.4.1 Selecting the appropriate Materials

There were two types of material involved in our project. One for the pipe that was used for the detection of hole and the second was the material of the hose. It was required to select the material in such an optimized way that it could satisfy both the important requirements; Suitable ad economical. Hence, we went through a thorough research in order to select the stainless steel as it was meeting both the requirements. Same was the case with hose and rubber was selected as it was most used for such applications.

5.4.2 Integration of Camera with Software

The next challenge we faced was the integration of camera with some sort of application in order to analyze the video made by the camera for detection of the leakage. Hence, this was time taking process. We developed an app for this purpose and integrated it with the camera for detection purposes.

5.4.3 Restricted use of drone

As we were using underwater drone, hence the important thing was to look fo5r the restrictions in use of the camera. For example, how much depth it can get and how much speed it can move etc. The choice of the testing spot was also depending upon the specifications of the underwater drone. Hence, keeping in view the need of prototype, we selected one of the available drones.

5.5 Project Bill of Materials

The table given below shows the materials that we purchased and their costs in Saudi Riyals (SR). This table includes also the manufacturing and failed part costs.

Material	Cost
Underwater Drone	5026 RS
Customize square weights	100RS
Electric air motor	100RS
Stainless steel pipe	700RS
Total	5926 RS

Table 5.5: Bill of Materials

Chapter 6: Project Analysis

6.1 Life-long Learning

During work on this project, we have honed our skills and gained practical knowledge about the important skills which were required to complete our project. We learnt to solve the real-time problems in the industry. By working as a team, we succeed to improve our skills in time management, communicate in effective way with members of the group. In this part, we will discuss the skills and experiences which we have learned since we worked in our project.

6.1.1 Software Skills

In our project, there was a critical use of software/app because that was actually used to detect and analyze the leakage in the stainless steel pipe. So, we learnt about the integration of software with the hardware as well. Also, we leant and used Microsoft word in this project for making this report.

6.1.2 Hardware skills

In our project, we dealt with the lot of hardware. The pipe made up of stainless steel for detection of hole or leakage, the remote controlled drone for moving into underwater and reaching at the spot etc. We also integrated the software with the camera fixed on the drone. We also used mathematical calculations for finding the pressure head.

6.1.3 Time Management Skills

The next most important learning of this project was the time management. While we want to reach to our purpose, we have to manage the time to fit with the tasks. We divided the tasks into specific deadline to be finished on or before the deadline. We divide our tasks and subtasks into start and end dates.

6.1.4 Project Management Skills

In our project, we divided the works between members of the group. Each one of the members has his own work which should be done individually. Then, we had a meeting two times a week to discuss and collect the work that has done by that member. Mostly, our group has divided to two teams. The first team was focusing on the research and report while the other team was focusing on the prototype and manufacturing.

6.2 Impact of Engineering Solutions

Our project is basically a solution to an engineering problem that arises in most of the oil fields and power sector. Leakages cause a loss of huge energy and therefore, engineers are always trying to forward more competitive and reliable solution. Our project has impact in the following areas:

6.2.1 Economy

Leakage in an oil pipeline is sometimes lethal for any privately owned or government oil industry. Maintenance groups and companies charge a huge amount for repair and maintenance of the effected pipelines. Country like Saudi Arabia, which has a huge dependence of its economy on its oilfields and oil exports, can suffer a lot from this. Hence, our project, underwater leakage detection can help leaking of funds and hence can support economy.

6.2.2 Industry

It’s not only the oil industry that can have underwater applications, but also different power plants having boilers etc can also have the such problems. Hence, our project serves its purpose from application to application in an efficient way targeting multiple industries.

6.2.3 Environmental

Underwater environment affects badly by the leakage of oil into the water. It is one of the major problems of onshore oilfields. Hence the aquatic life can be damaged heavily from it. So, underwater leakage can be lethal for aqua-culture. Hence, our project can prevent aquatic environment from disturbing and it has sound environment impact.

6.3 Contemporary Issues Addressed

The major issue was the range of the drone. We used remote controlled underwater drone with some specific speed and specific distance range. So how to manage the distance, depth and sped according to need of time is the major issue. This generally requires some good mathematical work that can tell us about relation between two quantities by keeping one constant. There was no physical issue addressed or noticed in our project.

Chapter 7: Conclusion and Future Recommendation

7.1 Conclusion

The core purpose of this project was to solve or seek to solve a real-time industrial issue with some simple, applicable and economical solution. We worked on this project keeping these things as standard and made this project, a reality. The project is successfully able to detect the hole/leakage in the stainless steel pipe with the help of video made by the camera fixed on the underwater done that is remotely controlled. The detected hole was then also made to analyze on the LED using integration of camera with the application that was designed particularly or this project. In this project, we learned how to solve various industrial problems that are integral part of the oil industry. Moreover, we improved our skills regarding to engineering software and hardware along with mathematical solutions to problems. This project as any other project has some challenges like the selection of appropriate specifications of drone that could perform experiment in specific depth at specific distance.

7.2 Future Recommendations

We have selected a particular drone with limited specifications. But there are various expensive drones available that can have good depth and speeds so further experimentation can be done using them. Also, we have targeted only single issue underwater. We can also extend the applications to underwater study as well which is a fast-growing field. Also, one can use the technique of Image processing for further results of leakage detection.

References:

- Rehman, K., & Nawaz, F. (2017, March). Remote pipeline monitoring using wireless sensor networks. In *2017 International Conference on Communication, Computing and Digital Systems (C-CODE)* (pp. 32-37). IEEE.
- Boaz, L., Kaijage, S., & Sinde, R. (2014, July). An overview of pipeline leak detection and location systems. In *Proceedings of the 2nd Pan African International Conference on Science, Computing and Telecommunications (PACT 2014)* (pp. 133-137). IEEE.
- Xiao, Q., Li, J., Sun, J., Feng, H., & Jin, S. (2018). Natural-gas pipeline leak location using variational mode decomposition analysis and cross-time–frequency spectrum. *Measurement*, *124*, 163-172.
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- https://www.mdpi.com/1424-8220/17/9/2104.
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Appendix A: Progress report

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**Fall semester**	**ACADEMIC YEAR:**	**2019/2020**
PROJECT TITLE	Underwater Pipes Leak Detection		
SUPERVISORS	**Dr.** Nassim Khaled		

Month 2: October

ID Number	**Member Name**
*Abdullah AlDulaijan	201402316
Hussain AlMuhanna	201402030
Omar AlQarab	201502532
Metab AlSaleem	201401614

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**
	Work dividing – Researching – testing	*Abdullah AlDulaijan	100%	
	Calculation - Order the parts what we want on global sites – Researching – testing	Hussain AlMuhanna	100%	
	Responsible for design in the workshop – Researching – testing	Omar AlQarab	100%	
	Responsible for design in the workshop – Researching – testing	Metab AlSaleem	100%	

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

#	Task description	Team member/s assigned
	Solid works Design	Abdullah AlDulaijan
	Chick and Testing our equipment	All team
	Working in chapter 4	All team
	Preparing for mid-term presentation	All team
	Calculation of hole diameter of the leakage	Metab Alsaleem

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome f:
An understanding of professional and ethical responsibility.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d:
An ability to function on multidisciplinary teams.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
d1. Ability to develop team work plans and allocate resources and	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate	Demonstrates satisfactory ability to develop team work plans and allocate	Understands and applies proper and accurate team work plans and allocate resources and tasks

tasks		resources and tasks	resources and tasks	
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects
d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	*Abdullah AlDulaijan	3	4	4	3
2	Hussain AlMuhanna	4	3	3	4
3	Omar AlQarab	3	3	4	4
4	Metab AlSaleem	3	4	3	4

Comments on individual members

Name	Comments
*Abdullah AlDulaijan	No comments
Hussain AlMuhanna	No comments
Omar AlQarab	No comments
Metab AlSaleem	No comments

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**Fall semester**	**ACADEMIC YEAR:**	**2019/2020**
PROJECT TITLE	Underwater Pipes Leak Detection		
SUPERVISORS	**Dr.** Nassim Khaled		

Month 3: November

ID Number	Member Name
*Abdullah AlDulaijan	201402316
Hussain AlMuhanna	201402030
Omar AlQarab	201502532
Metab AlSaleem	201401614

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
	-Solid works Design - Chick and Testing our equipment - Working in chapter 4 -Preparing for mid-term presentation	*Abdullah AlDulaijan	100%	
	-Chick and Testing our equipment -Working in chapter 4 -Calculation of hole diameter of the leakage -Preparing for mid-term presentation	Hussain AlMuhanna	100%	
	- Chick and Testing our equipment -Working in chapter 4 - Preparing for mid-term presentation	Omar AlQarab	100%	

	-Chick and Testing our equipment - Working in chapter 4 -Preparing for mid-term presentation	Metab AlSaleem	100%	

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

#	Task description	Team member/s assigned
	Finding the errors and upgrade the system	All team
	Hardware and software	Omar AlQarab
	Finishing the final report	All team
	Testing the system	All team
	Final presentation	All team

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome f:
An understanding of professional and ethical responsibility.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d:

An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d1. Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Understands and applies proper and accurate team work plans and allocate resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects
d3. Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	3. Understands and communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	*Abdullah AlDulaijan	3	3	4	4
2	Hussain AlMuhanna	4	3	4	3
3	Omar AlQarab	4	3	3	4
4	Metab AlSaleem	4	4	3	3

Comments on individual members

Name	Comments
*Abdullah AlDulaijan	No comments
Hussain AlMuhanna	No comments
Omar AlQarab	No comments
Metab AlSaleem	No comments

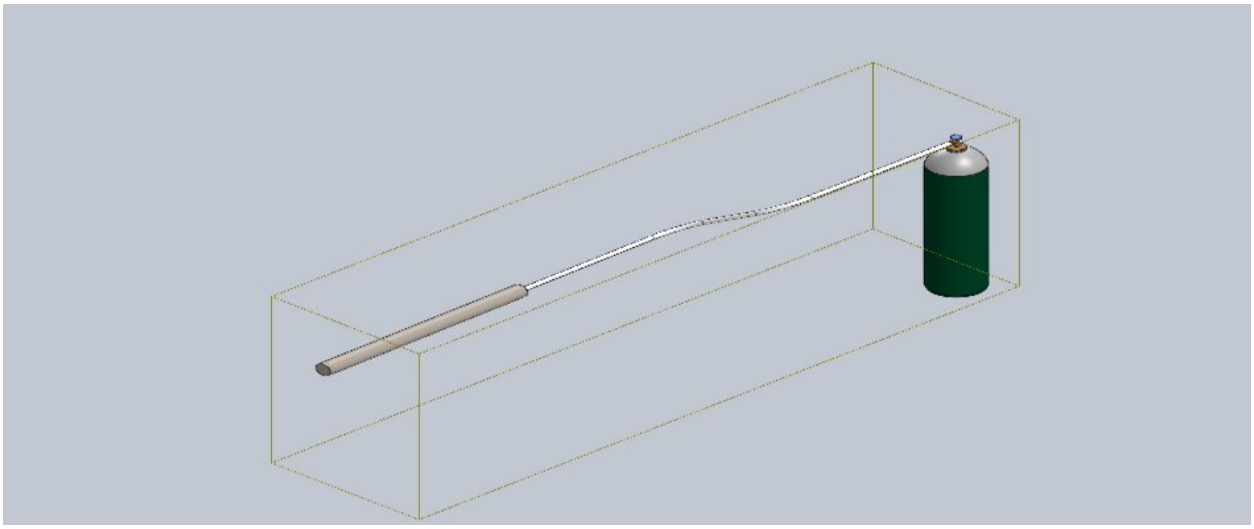
Appendix B: Engineering standards (Local and International)

- Satiric Pressure threads (AISI).
- Standard-Weight Steel Pipe (U.S. Customary Units).
- ANSI B36.19 (Stainless steel Pipe).

STAINLESS STEEL PIPE DIMENSION AS PER ASTM & WEIGHT-KG. PER MTR. (ANSI B36.19)

Nominal Bore		Outside Diameter	Sch-5S		Sch-10S		Sch-40S		Sch-80S		Sch-160S		Sch-XXS	
mm	INCH	mm	Wt mm	Weight (Kg/mt)	Wt mm	Weight (Kg/mt)	Wt mm	Weight (Kg/mt)	Wt mm	Weight (Kg/mt)	Wt mm	Weight (Kg/mt)	Wt mm	Weight (Kg/mt)
3	1/8	10.3	1.24	0.276	1.24	0.28	1.73	0.37	2.41	0.47	-	-	-	-
6	1/4	13.7	1.24	0.390	1.65	0.49	2.24	0.631	3.02	0.80	-	-	-	-
10	3/8	17.1	1.24	0.490	1.65	0.63	2.31	0.845	3.20	1.10	-	-	-	-
15	1/2	21.3	1.65	0.800	2.11	1.00	2.77	1.27	3.75	1.62	4.75	1.94	7.47	2.55
20	3/4	26.7	1.65	1.03	2.11	1.28	2.87	1.68	3.91	2.20	5.54	2.89	7.82	3.63
25	1	33.4	1.65	1.30	2.77	2.09	3.38	2.50	4.55	3.24	6.35	4.24	9.09	5.45
32	1 1/4	42.2	1.65	1.65	2.77	2.70	3.56	3.38	4.85	4.47	6.35	5.61	9.70	7.77
40	1 1/2	48.3	1.65	1.91	2.77	3.11	3.68	4.05	5.08	5.41	7.14	7.25	10.16	9.54
50	2	60.3	1.65	2.40	2.77	3.93	3.91	5.44	5.54	7.48	8.74	11.1	11.07	13.44
65	2 1/2	73.0	2.11	3.69	3.05	5.26	5.16	8.63	7.01	11.4	9.53	14.9	14.2	20.39
80	3	88.9	2.11	4.51	3.05	6.45	5.49	11.30	7.62	15.2	11.1	21.3	15.24	27.65
100	4	114.3	2.11	5.84	3.05	8.36	6.02	16.07	8.56	22.3	13.49	33.54	17.12	41.03
125	5	141.3	2.77	9.47	3.40	11.57	6.55	21.8	9.53	31.97	15.88	49.11	19.05	57.43
150	6	168.3	2.77	11.32	3.40	13.84	7.11	28.3	10.97	42.7	18.2	67.56	21.95	79.22
200	8	219.1	2.77	14.79	3.76	19.96	8.18	42.6	12.7	64.6	23.0	111.2	22.23	107.8
250	10	273.1	3.40	22.63	4.19	27.78	9.27	60.5	12.7	96.0	28.6	172.4	25.40	155.15
300	12	323.9	3.96	31.25	4.57	36.00	9.52	73.88	12.7	132.0	33.32	238.76	25.40	186.97
350	14	355.6	3.96	34.36	4.78	41.3	11.13	94.59	19.05	158.08	35.71	281.70	-	-
400	16	406.4	4.19	41.56	4.78	47.29	12.7	123.30	21.41	203.33	40.46	365.11	-	-
450	18	457.2	4.19	46.80	4.78	53.42	14.27	155.80	23.8	254.36	45.71	466.40	-	-
500	20	508.0	4.78	59.25	5.54	68.71	15.09	183.42	26.19	311.2	49.99	564.68	-	-
600	24	609.6	5.54	82.47	6.35	94.45	17.48	255.41	30.96	442.08	59.54	808.22	-	-

Appendix C:CAD drawing and Bill of Materials



Material	Cost
Underwater Drone	5026 RS
Customize square weights	100RS
Electric air motor	100RS
Stainless steel pipe	700RS
Total	5926 RS

Table 5.5: Bill of Materials

Appendix D: Gantt Chart

Task 1	Start Date	Days to complete
Identifying the project	3/9/2019	30
Determine the objectives		
Subdividing small tasks to collect information		
Writing chapter 1 of the report		
Write chapter 2		
Search and review the previous work		
Task 2		
Brain storming and gathering ideas for the conceptual design	4/10/19	13
Draw the first conceptual design		
Selected the appropriate Materials		
Searching for the parts		
Order the parts what we want on global sites		
Buying the available part from local shop		
Task 3		
Solid works Design	17/10/2019	14
Calculation		
Testing the system		
Writing Chapter 3		
Task 4		
Initial prototype	1/11/2019	13
Preparing the Mid-term presentation	14/11/2019	
Writing Chapter 4		
Task 5		

Start assembly the project	15/11/2019	15
Testing the system		
Finding the errors and upgrade the system		
Task 6		
Finishing the final report	1/12/2019	20