CHAPTER 1
INTRODUCTION

1.1 Background of Study

LNG pipeline, like any other pipeline are exposed to corrosion problem. The most common types of corrosion are general corrosion, stray current corrosion, microbiological corrosion, and stress corrosion cracking. This corrosion affects the pipeline from inside out of the pipeline. However, internal corrosion is harder to detect as compare to the external corrosion. This is due to inefficiency of techniques to perform surveillance inside the pipeline while the corrosion is still at early stages.

Capacitive sensors can directly sense variety of things. This includes motion, chemical composition and electric field. This detection ability is very important to build a sensor device. In detection of chemical composition, the main variable to be considered is the dielectric constant which is a product of electric field and permittivity of the material located in between the parallel plate of the capacitor.

Every material has a different value of dielectric constant depends on how the material acts upon applied electric field. The change of dielectric constant will cause changes in voltages across the capacitor. Hence, the chemical composition of the material reside in the capacitor can be detected by comparing the voltage measured and the pre-determined voltage. By applying this knowledge, a capacitor sensor can be implemented in detecting the corrosion of inner wall of a LNG pipeline.

1.2 Problem Statement

1.2.1 Problem Identification

According to Neil G. Thompson [1], during transmission of natural gas through pipeline, the presence of corrosion agent such as H_2O, CO_2, O_2 or any reduction reactants will cause corrosion to occur from inside. If the problem were unintended fast enough, this might lead to leakage and worse the pipeline will be ruptured and this will bring great losses to the owner company and its vendor. According to Pete Kremen [2], the leakage of the pipeline will release natural gases into the environment and this might affect the public safety and the environment.

Conventionally, according to Neil G. Thompson [1], there were many ways to perform inspection on a pipeline. This includes electrical surveys, direct inspection (digs), in-line inspection (smart PIG), and hydrostatic testing. However these inspections are mostly very expensive and often missed the earlier stage of corrosion (10% of wall thickness to change) [1]. Therefore, it is very important to come up with a device which is cost effective and intelligent enough to detect the presence of corrosion in a pipeline during the early stage to give the opportunity for the engineers to perform further action.

Even so, with cheap and robust sensor design, sensitivity of sensor is always an issue when designing a sensor. According to Baxter [6], the sensitivity of capacitor sensor varies according to the cross sectional area of the capacitor and the gap between the two parallel plate. The needs of sensitivity also might vary according to specific application. For corrosion detection application, there is a need for a sensitive sensor to detect any changes in permittivity.

1.2.2 Significant of the Project

The project will be focus on the designing a parallel plate capacitor sensor with a reliable sensitivity and applicable for corrosion detection application. There is a small number of studies on the sensitivity of parallel plate capacitor. This project will deepen the understanding on capacitor sensor as well as the sensitivity issue of a capacitor sensor especially in the application for corrosion detection in LNG pipeline.

1.3 Objective & Scope of Study

1.3.1 Objective

The objective of the project is to design and construct a sensor device that can detect corrosion in LNG pipeline using a capacitor. This can be achieved by focusing on the sensitivity of the sensor due to many variables factors.

1.3.2 Scope of Study

The scope of studies of the project is to design the sensor device to detect the corrosion inside a LNG pipeline. In this case, the corrosion indicated by iron oxide in form of dust. The studies will be performed under a normal atmospheric pressure and at room temperature and at liquid state of kerosene as substitute of LNG.

The focus will be on the sensitivity issues of the capacitive sensor. This includes many variable factors such as area of capacitor plate, gap between capacitor, and frequency of operation. Studies through experiment and simulation are performed to understand the effect of specific variables on the sensitivity.

This project is to be completed within two (2) semesters and the capacitive sensor circuit is the important part of the project which must be completed prior to the experimental works which involve determining the effect of area, gap, and frequency upon the sensitivity of the capacitor.

The scope of this project is relevant to the electrical and electronics course as it utilizes the characteristics of a passive element – capacitor. The oil and gas industry is certainly in need of an innovative sensor to detect the level of corrosion for easy monitoring and maintenance handling.

CHAPTER 2
LITERATURE REVIEW

2.1 Properties of LNG

Understanding the nature of LNG is very important to precede the project. According to [3], natural gas is a fuel and a combustible substance. In its liquid state, LNG is not explosive and cannot burn. For LNG to burn, it must first vaporize, then mix with air in the proper proportions (the flammable range is 5% to 15%), and then be ignited. In the case of a leak, LNG vaporizes rapidly, turning into gas and mixing with air. While this mixture is within the flammable range, there is risk of ignition which would create fire and thermal radiation hazards. When the natural gas is liquefied into LNG, the maximum transport pressure set is around 25kPa (3.6 psi) and the temperature is approximately -163 °C. In conclusion, the possible hazards are flammability, freezing, and asphyxia. Extra caution must be taken into consideration.

In this project the value of dielectric constant for the LNG is very important. However, LNG is a mixture of few materials depending on the purity and the grading of the LNG. LNG typically contains more than 90% methane. It also contains small amounts of ethane, propane, butane and some heavier alkanes. Through certain purification process, 100% of methane can be obtained. In this project we will assume that any sample of LNG is 100% of methane. Hence,

Dielectric constant of LNG is, $\varepsilon_r = 1.7$ (according to [4])

2.2 Corrosion in LNG Pipeline and Formation of Iron Oxide

Today, according to [5], steel alloy is the material of choice for high pressure pipeline. Hence the corrosion of the pipeline will lead to separation of the alloy (iron carbon) into iron oxide and carbon.

Corrosion inner pipeline wall will leave small particle or sediment in the lower surface of the pipeline. These sediments will move along the pipeline together with the flow of liquid. The components of sediments are iron oxide, carbon, iron, air bubble, and many other materials (minor).

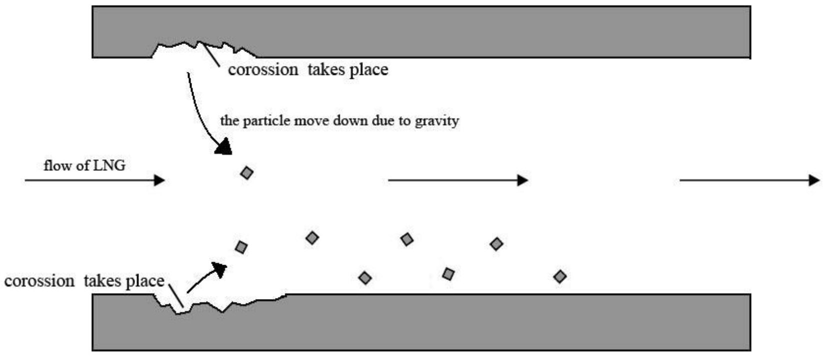

Figure 1 Other particles in LNG pipeline

The lighter particle (e.g. air bubbles) will float to the top of pipeline, while the heavier particle will be on the lower surface of the pipeline due to gravity. This characteristic can be used to design the sensor only to detect the particle at the lower surface so that only particle which indicates the presence of corrosion will be taken into consideration by the sensor.

For this project, the corrosion of the pipeline can be detected by the presence of the iron oxide (oxide of pipeline) alone. Changes of voltage in capacitor will indicate the presence of iron oxide in the LNG pipeline. Hence knowing the dielectric constant of the iron oxide is very important.

Dielectric constant of Iron Oxide, $\varepsilon_r = 14.2$ (according to [4])

2.3 Parallel Plate Capacitor

The following figure shows the basic design of a parallel plate capacitor (see figure 2).

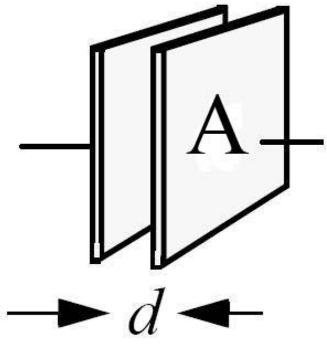

Figure 2 Capacitor

According to [6],

$$C = \frac{\varepsilon_o \varepsilon_r A}{d}$$ Equation (1)

C is the capacitance in farads, F

A is the area of each plate, measured in square meters

ε_r is the relative static permittivity

ε_0 is the permittivity of free space where $\varepsilon_0 = 8.854 \times 10^{-12}$ F/m

d is the separation between the plates

In this project, the capacitance value will be affected by the material which goes through the parallel plate capacitor. Understanding that there will be more than one material in between the parallel plate (mixture of LNG and iron oxide with varying ratio), the value of ε_r in equation (1) is not $\varepsilon_r = 1.7$ or $\varepsilon_r = 14.2$. Instead, the value will depend on the ratio of LNG and iron oxide. Therefore, the following equation can is applied:

$$C = \frac{\varepsilon_o \varepsilon_k A}{d}$$ Equation (2)

ε_k is depending on ratio of LNG and iron oxide.

The exact capacitance value of any ratio can be obtained through experiment. However, for design purpose, we must know the maximum and minimum possible value of the capacitance:

Minimum C, with only LNG present:

$$C = \frac{\varepsilon_o \varepsilon_{LNG} A}{d}$$ Equation (3)

Maximum C, with only iron oxide present:

$$C = \frac{\varepsilon_o \varepsilon_{IO} A}{d}$$ Equation (4)

For analytical purpose, we also must know the voltage to capacitance relation. This is because the only the voltage can be detected using meter instead of capacitance.

According to [7],

$$V = \frac{1}{C} \int I dt$$ Equation (5)

With relationship of between voltage and capacitance known, we can calculate the value of capacitance as reflected by any indicated voltage across the capacitor or the current through the capacitor.

2.4 Wireless Communication

Wireless networks utilize radio waves and/or microwaves to maintain communication channels between devices [8]. Wireless networking is a more modern alternative to wired networking that relies on copper and/or fiber optic cabling between network devices [8]. A wireless network offers advantages and disadvantages compared to a wired network [8]. Advantages of wireless include mobility and elimination of unsightly cables. Disadvantages of wireless include the potential for radio interference due to weather, other wireless devices, or obstructions like walls [8].

The high efficiency of RFs data transmission and its relatively small size have favored RFs to be used widely for mobile communication [9]. Transmitting data from field to the main control room for any plant can cut the cost for cabling and maintenance.

Despite the disadvantage which related to the wireless technology, it is still a practical and favorable solution to implement it in this project since pipelines can be hundreds of meter long. It will not be a wise decision to lay cable up to this distance due to its cost and the heavy maintenance work which need to be done.

CHAPTER 3
METHODOLOGY

3.1 Procedure Identification

The final expectation of the project is to achieve the objectives of the project which are:

- Design and fabricate a parallel plate capacitor sensor.
- Study the sensitivity of the parallel plate capacitor sensor.
- Enable wireless communication for data transfer for the system.

To achieve this objective, a well structured work flow was design. To begin with, the project will start with research work. Then, the design process took place after all the concept and theory are understood. This is then continued with survey and buying of equipment. When performing survey and buying of equipment, all the design work must be considered. This is to avoid any compatibility problem. The device is then constructed and experiment will be performed. The result from the experiment will then be analyzed and compared. This will come to conclusion of the project and recommendation by the author regarding the project.

3.2 Flow Chart

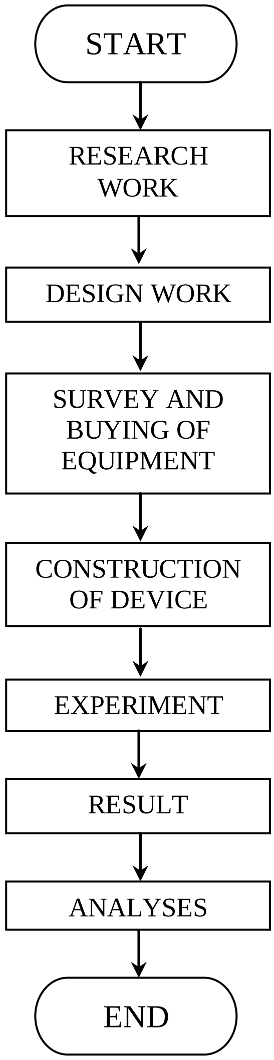

Figure 3 Flow Chart

According to figure 3, the projects start as soon as the title of the project was accepted. The title for the project is “DETECTION OF CORROSION INSIDE A LIQUEFIED NATURAL GAS PIPELINE”.

During the research work, important information and reference were studied to improve the understanding on the specific field. Deep understanding on the following topics is important to continue the project.

- corrosion in pipeline
- properties of LNG
- application of capacitor as a sensor

Design work is proceeded after deep understanding on the regarding matter has been establish. This design work includes the overall sensor system design. The design work includes how the systems and subsystems should operate and function.

Equipments and materials are surveyed and bought after the design work is completed. This is to avoid any compatibility and functionality issues.

The device is constructed according to design. If any part of the system is dysfunctional, troubleshooting is performed to understand the error and rectify it as soon as possible.

On the experiment part of the project, the constructed device is tested. The capacitor sensor will be tested on its sensitivity and ability to work at a simulated condition.

From the experiment the results will be analyzed. The experimental results will be compared with the theoretical value. Analysis on results and any possible error is made. Through the analysis, conclusion and recommendations are made.

3.3 Gantt Chart

3.3.1 Milestone for first semester of 2-semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic	■	■						MID SEMESTER BREAK							
2	Preliminary Research Work		■	■	■											
3	Submission of Preliminary Report				●											
4	Seminar 1						●									
5	Project Work					■	■	■								
6	Submission of Progress Report									●						
7	Seminar 2 (compulsory)													●		
8	Project work continues									■	■	■	■	■		
9	Submission of Interim Report Final Draft														●	
10	Oral Presentation															●

■ Progress work

Figure 4 Gantt chart FYP1

3.3.2 Milestone for second semester of 2-semester Final Year Project

No.	Detail/ Week	1	2	3	4	5	6	7	8	9		10	11	12	13	14
1	Project work continues	■	■	■	■						MID SEMESTER BREAK					
2	Submission of Progress Report					●										
3	Project work continue						■	■	■	■		■				
4	Poster Presentation												●			
5	Project Work Continue												■	■		
6	Submission of Draft Report														●	
7	Submission of Final Report Soft Cover															●
8	Submission of Technical Report															●
9	Submission of Interim Report Final Draft															●
10	Oral Presentation															●

■ Progress work

Figure 5 Gantt chart FYP2

3.4 Tools and Equipment

3.4.1 Hardware

- Digital Multi Meter
- Oscilloscope
- Automatic stirrer
- AC power generator
- Function generator

3.4.2 Software

- Cadence PSD 14.2 Capture CIS
- Microsim Eval 8, Pspice Schematics and Capture
- Multisim electronic workbench 8
- Microsoft Excel
- MPLAB IDE V7.6