Online Monitoring System in Wax Formation in the Pipeline

by

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14794

Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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(CHEMICAL ENGINEERING)

Approved by,

____

(Dr Bawadi bin Abdullah)

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

IYLIA SYAHIRA BINTI MOHAMAD KHIR

ABSTRACT

The unwanted solidifying process of crude oil in pipeline is one of the major problems in the oil industry. Waxes, the heaviest saturated paraffin, tend to precipitate during the transportation flow line from the offshore to onshore. Electrical Capacitance Tomography (ECT), a form of Non-Destructive Test (NDT), is a new technique to gain information on the distribution of the contents in closed pipes. The variations on the dielectric properties of the material inside the pipeline are measurable to determine the condition of pipeline. ECT is the most advance monitoring system which inclusive of imaging data other than the numerical data. ECT is selected over other tomography modalities due to its advantages over others. The advantages of ECT can be briefly summarized, namely, it produce fast imaging speed, it release zero radiation, robust, low in cost, non-intrusive and non-invasive, and it can withstands to high pressure and temperature. These advantages suit with the aim to monitor the formation of wax in crude oil pipeline.

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In the name of Allah, the Most Gracious and the Most Merciful.

Praise to Him the Almighty that in His will and given strength, the final year project is successfully completed within the allocated eight months period. Upon completing the project undertake, I owe a great thanks to a many great people for their help and support, as well as their contribution in time, effort, advice, supervise, discuss and help during the period.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The functions of tomography have extended to petroleum industries applications to assist in visualizing conditions within the process pipeline. In the earlier stage of development of tomography, it started in the medical field before it is further explored for industrial applications inclusive of electrical insulation systems.

Electrical capacitance tomography (ECT) is one of the tomography modalities available in the current technology. ECT able to give descriptions of characteristics and phases of the flowing components within closed vessel. The result is obtained by measuring the dielectric properties variation of the material inside the vessel or pipe, followed by reconstructing the cross-sectional images based on the measured capacitance value.

1.2 Problem Statement

During the transportation of crude oil from the offshore to the platform or onshore, the inconsistency of the temperature and pressure of the crude oil lead to the formation of wax.

Inspection activities that are being done on crude oil pipelines commonly result in replacing the pipeline that has been clogged with hardened waxes. This has become an issue that it consumes lots of costs and time for pipeline replacement to take place, which indirectly delaying the transportation process of the material and daily profit gain.

Although ECT is an ideal option in producing images of an enclosed pipe, the image resolution depends on the sensitivity of the sensor. The sensor with external electrodes of the wall permittivity contributes to non-linear changes in capacitance which somehow increase or decrease relying on the thickness of the wall as well as the permittivity's of the sensor wall and contents.

1.3 Objectives and Scope of Study

The objectives of the final year project are:

i. To develop a real-time, in-stream, nondestructive method of determining formation of wax in pipeline.

ii. To fabricate a static test for the application of electrical capacitance tomography (ECT) in online monitoring system.

iii. To identify the level of wax formation at different temperatures.

The type of tomography model used for this project is specified which is the ECT. The study of ECT somehow is closely related to the Electrical and Electronic Engineering field, which required to be mastered in order to execute the project.

The ability of ECT in obtaining images from a static test will be investigated by conducting a laboratory scale experiment, with a small scale ECT sensor. The performance of the sensor will be investigated by setting the temperature as the manipulated variable. The goal is to quantify the percentage of wax formation at different level of temperature. The study does not involve changes in the sample flow rate. The electrodes configuration is being done externally that is on the outside of the wall.

Nevertheless, the project involves only the procedure to detect the problem that is the wax formation in pipeline, exclusive of ways to prevent it.

CHAPTER 2

LITERATURE REVIEW

2.1 Formation of Wax in Crude Oil Pipeline

Waxes, which are known as mostly heavy saturated paraffin, tend to precipitate when the temperature and pressure of oil fields drop during the production and transportation.

Wax Appearance Temperature (WAT) determines the deposition of the wax on the reservoir or pipelines when the temperature of the reservoir or production line falls below the WAT. WAT is regularly used to measure the tendency of a crude oil to produce wax in relation with pressure and temperature reduction. In simple words, WAT is the temperature at which the first wax crystal appears. Wax deposition will be complex and costly. It will cause a lot of difficulties in blocking of transport equipment and pipelines. If not treated, crude transportation can eventually decrease or in worst condition block the flow in production line (Aiyejina *et al*., 2011).

2.2 Online Monitoring System for Pipeline Inspection

Pipeline inspection involving formation of wax from crude oil requires a huge amount of expenditure especially when it involves installation and replacement of pipelines. It is therefore necessary to introduce the online monitoring system which can forecast the parameter of waxy crude oil and to understand its behaviour deeply.

2.3 Electrical Capacitance Tomography (ECT)

Tomography techniques were widely used in X-ray medical detection applications starting from 1980s. The word ‘tomography’ is derived from the Greek, where ‘tomos’ means ‘to slice’ and ‘graph’ means ‘image’ (Donthi, 2004).

The fundamental principles of electrical capacitance tomography (ECT) are the combination of multiple measurements at the periphery of a process pipeline or vessel, which provide information on the electrical properties of the process volume. The application of ECT visualizes multiphase unit processes in order to develop understanding, mainly to optimize performance and to provide a basis of control.

The basic ECT system consists of:

- Sensor Array – sets of electrodes grouped in measurement channels. Each electrode delivers a cross-sectional image.
- Measuring Unit – the accuracy of the image depends on the method used to construct the image from the inter-electrode capacitance measurements.
- Software (Control Computer) – configures measuring unit to fit the operating conditions, analyses raw voltage measurements using inverse algorithms to provide a conductivity map, inclusive of to analyze and export of tomographic data.

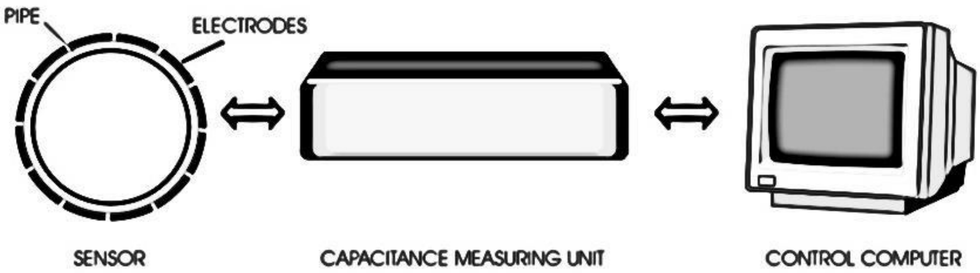


Figure 1: Basic Electrical Capacitance Tomography System (Ecttechov, 2010)

The relationship between the capacitance and dielectric properties can be given as:

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d_p} \quad (1)$$

C = capacitance (F)

ε_0= permittivity of free space

ε_r= permittivity of the dielectric

A = area of the plate

d_p= the distance between those plates

The capacitance increases with the electrodes area and decreases when the distance between electrodes increases. Permittivity is defined as a response measurement of response of a substance towards electrical field in a medium. It is expresses as the ratio of its electric displacement to the applied field strength. Any change of permittivity of the materials flow within the vessel produces different capacitance value inside the pipe.

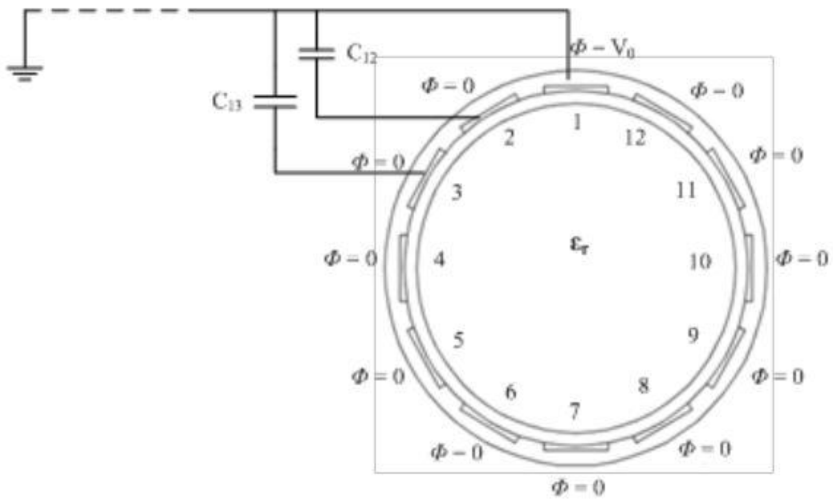


Figure 2: Measurement Principle of ECT System
(Shafquet A. *et. Al*, 2013)

2.4 ECT Measurement System Components and Configuration

2.4.1 Number of Electrodes

The number of electrodes is a part of designing an ECT sensor. The number of sensor electrodes to be used depends on the range of values of inter-electrode capacitances and the upper and lower measurement limits of the capacitance measurement circuit.

A small number of electrodes results in smaller number of required data acquisition channels, faster data acquisition rate since the number of capacitance measurement has been reduced, together with increment of inter-electrode capacitance. However, the drawback of small number of electrodes is that the number of independent capacitance measurements is low. As a result, a good image cannot be expected.

In getting the ECT image, the method used is to surround the pipe or vessel with a set of electrodes. Later, the capacitance measurements between each unique pair are taken. The number of independent capacitance measurement is calculated using the formula in Equation 1.

$$M = \frac{N \times (N-1)}{2} \qquad (Eqn. 1)$$

Where,

M	=	Number of independent capacitance
N	=	Number of electrodes

2.4.2 Capacitance Electrode Location

According to Process Tomography Ltd., if the vessel wall is non-conducting, capacitance electrodes can be located inside, within or outside the wall.

Figure shows the difference of 8-electrodes configuration. On the left hand side, the electrodes are mounted internally, that is on the inner part of the wall. The figure on the centre shows the electrodes are being located within the wall, also known as the embedded electrodes. This type of configuration is high in cost as it involves special manufacturing.

The third figure on the right hand side is the most suitable configuration in oil and gas industry, specifically involving the application of crude oil pipeline system. The electrodes are mounted externally that is on the outside of the vessel or pipeline wall. The electrodes will not get in contact with the substances inside the vessel or pipeline. This type of configuration is also preferable due to its easy access in the case of maintenance purpose.

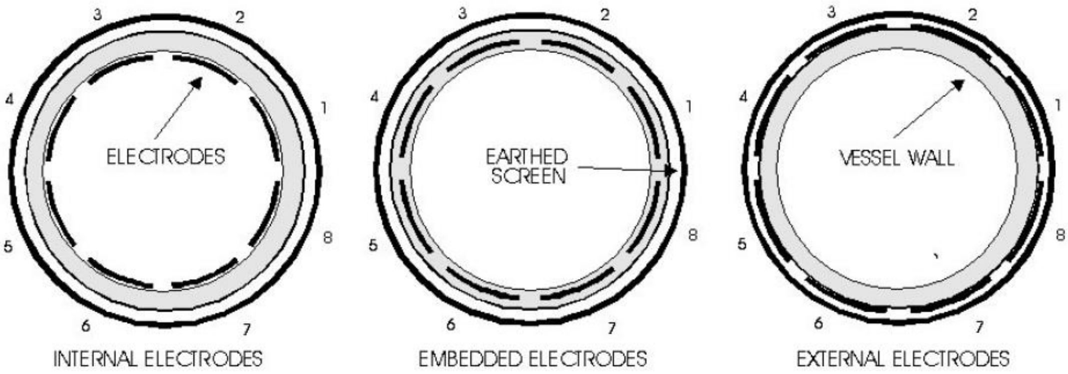


Figure 3: Circular Sensor Electrodes Configuration

For a small scale (laboratory scale) setup, it is much easier to fabricate the ECT sensor with the electrodes outside the wall. The electrodes available too is quite sensitive and easily get electric shocked when in contact with substances such as liquid, thus it is favourable to mount the electrodes outside the wall.

Table 1 shows comparison among few sets of number of electrodes with respective number of independent capacitance measurement.

Table 1: The Relationship between Number of Electrodes and Number of Independent Measurements

Number of Electrodes	**Number of Independent Measurements**	**Typical Speed (frame/second)**	**Example of Application**
6	15	400	Visualisation of cylinder engine combustion flame
8	28	200	Imaging of wet gas separator
12	66	100	Measurement of gas-oil-water three components flow
16	120	50	Imaging of nylon polymerization process

2.5 Calibration

A series of high accuracy and standard electric capacity is used as standard value to calibrate the electric capacity measuring circuit (Chen D., 2007). The sensor is connected in measuring unit to gain the small standard electric capacity, which considers the influence of electric capacity measuring circuit on sensor.

The method of calibration is to treat for example 15 mL water as the smallest unit, recording a component of water, then use the burette drip into the sensor in increasing sequence, at the same time recording the value of output voltage, to obtain the calibrated data.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology and Project Activities

The methodology for conducting this research project is innovation and exploration. The project is generally an empirical research; the results obtained from this research can be used to compare with other literature outcomes. All project activities in this research are mainly experimental work.

The capacitance sensor first has to be designed and fabricated by using the ECT concept. Few journals and researches on ECT were referred as listed in the Reference section. There are twelve electrodes in the sensor with copper foil as the conductive material. The fabrication stage required few hardware materials in order to build the sensor.

The material tested throughout the project was a condensate-like crude oil, named Exxol D80 oil. This sample of oil is characterized as an aliphatic hydrocarbon solvent. The experiment was conducted in static test which did not require the author to calibrate the flow rate. The presence of wax in the crude oil is being tested at different temperature, that are at 30ºC, 35 ºC , 40 ºC, and 45ºC.

3.2 Experimental Procedures

Figure 4 shows the general experimental procedures that will be implemented in this research project.

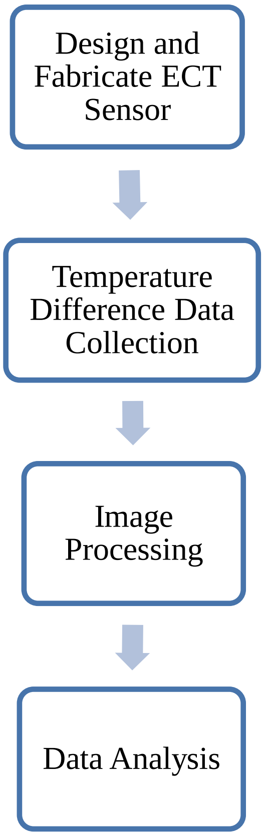


Figure 4: Experimental Procedure

Figure 5 shows the flowchart of the process flow of this project.

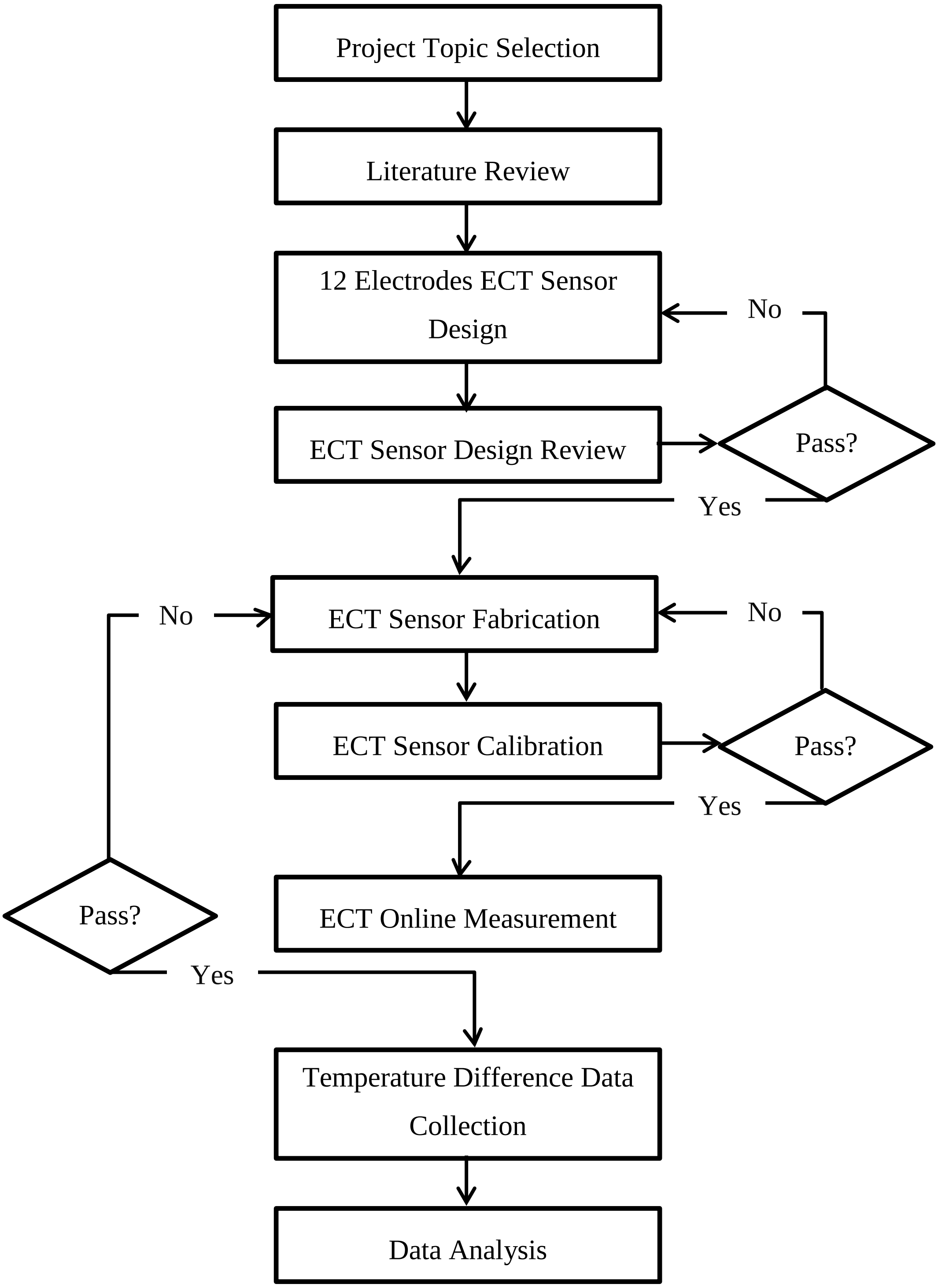


Figure 5: Flowchart of Project Process Flow

3.3 Design and Fabrication of ECT Sensor

The design of the ECT sensor consists of 12 electrodes. A Polyvinyl Chloride (PVC) pipeline is used as the body which are being filled with the Exxol D80 oil. The physical layout of the ECT sensor and the basic configuration of an ECT system static test for is shown in the Figure 6.

In this project, two electrodes will be excited at any point in time. The remaining electrodes are to be kept at ground potential and function as detectors until the measurement completes the full cycle or (N-1) electrodes for a single image.

A total of 66 raw capacitance measurements are required for a complete full cycle and for the reconstruction of a single tomogram image in this model.

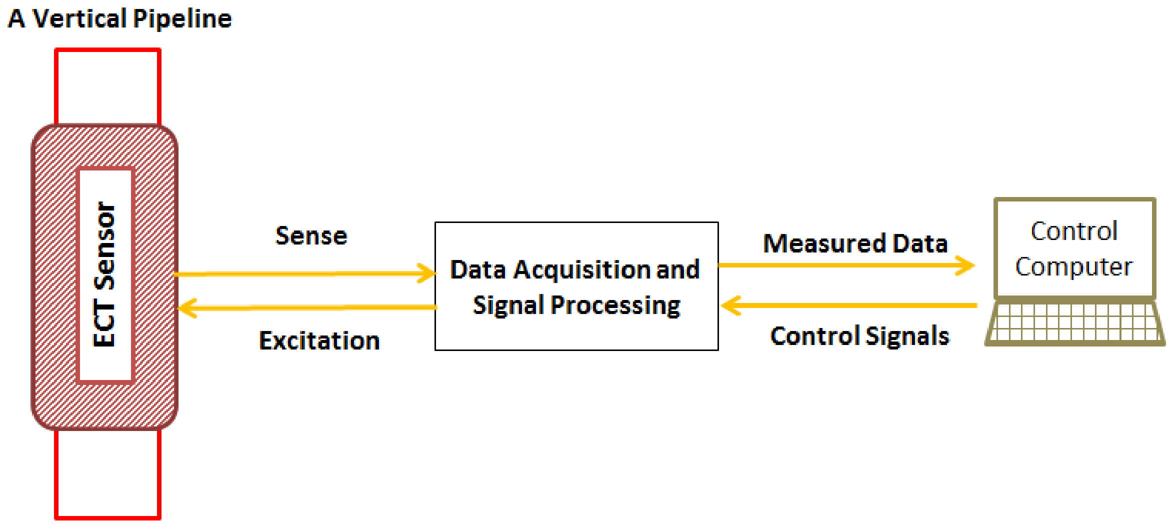


Figure 6: Illustration of ECT Sensor Static Test

3.3.1 Hardware and Software Needed

Table 2 shows list of hardware materials that are used for the fabrication and available software as the medium in obtaining desired result.

Table 2: Hardware and Software Needed

Hardware/Software	Description	Function
M3000	Consists of USB Device and ITS Software	To obtain the ECT Image
Polyvinyl Chloride (PVC) Pipe	• Inner diameter: 56 mm • Thickness: 2 mm	To act as the body and sensor holder
Electrode	• Length: 110 mm • Width: 10 mm	Act as sensor
GIMP Software	Graphic editor software	To conduct image processing
Soldering iron and lead	-	To soldier data cable to electrode

3.4 Key Milestones

Several key milestones for this research project must be achieved in order to meet the objective of this project.

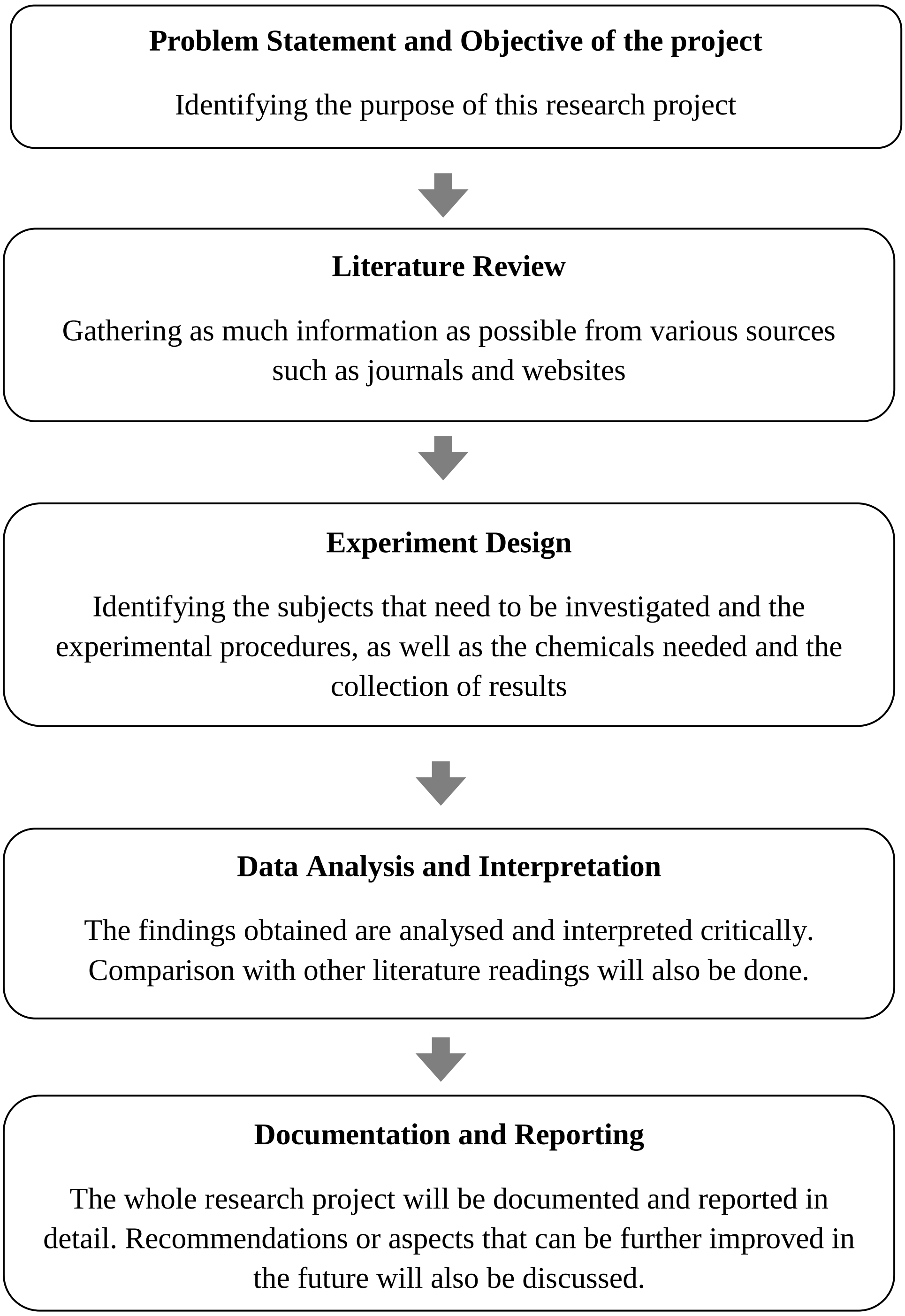


Figure 7: Key Milestones

3.5 Gantt Chart

Table 3 and 4 show the Gantt charts that need to be followed during this research for FYP I and FYP II respectively.

Table 3: Gantt Chart for FYP I

No	Detail / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of Project Title	■	■												
2	Preliminary Research Work and Literature Review		■	■	■	■	■								
3	Submission of First Draft of Extended Proposal Defence						●								
4	Submission of Extended Proposal Defence							●							
5	Preparation for Oral Proposal Defence							■							
6	Oral Proposal Defence Presentation								■ ●						
7	Preliminary Research Activity									■	■	■	■	■	■
8	Preparation of Interim Report				■	■	■	■	■	■	■	■	■		
9	Submission of Interim Draft Report													●	
10	Submission of Interim Final Report														●

● Planned Milestone

■ Process of Activity

Table 4: Gantt Chart for FYP II

No	Detail / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	ECT Sensor Design, Fabrication and Online Test	■	■	■	■	■	■									
2	Data Collection						■	■	■	■						
3	Image Processing and Data Analysis							●			■	■	■	■		
4	Submission of Progress Report							■ ●								
5	Pre-EDX											■ ●				
6	Submission of Draft Report													■ ●		
7	Submission of Dissertation														■ ●	
8	Submission of Technical Paper														●	
9	Oral presentation															●
10	Submission of Project Dissertation															●

● Planned Milestone

■ Process of Activity

3.6 Experiment Conducted

3.6.1 High Calibration

3.6.1.1 Material and Apparatus

1. Exxol D80 oil
2. ECT Sensor

3.6.1.2 Procedure

1. The Exxol D80 oil is heated up to 60 ºC.
2. The crude oil is then poured into the PVC pipeline. A thermometer is adjusted inside the pipeline to observe the temperature of the oil.
3. The ECT sensor is set on standby mode.
4. The crude oil is let to cool down to 50 ºC.
5. When the temperature has been achieved, the ECT image is obtained.

3.6.2 Low Calibration

3.6.2.1 Material and Apparatus

1. Exxol D80 oil
2. ECT Sensor

3.6.2.2 Procedure

1. The Exxol D80 oil is heated up to 60 ºC.
2. The crude oil is then poured into the PVC pipeline. A thermometer is adjusted inside the pipeline to observe the temperature of the oil.
3. The ECT sensor is set on standby mode.
4. The crude oil is let to cool down to 50 ºC.
5. When the temperature has been achieved, the ECT image is obtained.

3.6.3 Presence of Wax at Different Temperature

3.6.3.1 Material and Apparatus

1. Exxol D80 oil
2. ECT Sensor

3.6.3.2 Procedure

1. The Exxol D80 oil is heated up to 60 ºC.
2. The crude oil is then poured into the PVC pipeline. A thermometer is adjusted inside the pipeline to observe the temperature of the oil.
3. The ECT sensor is set on standby mode.
4. The crude oil is let to cool down to the desired temperature.
5. At temperature 45 ºC, the ECT image is obtained.
6. Step 4 and 5 are repeated, with the desired temperature of 40 ºC, 35 ºC and 30 ºC.
7. The ECT images are further processed using GIMP software.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 ECT Sensor Design and Fabrication

The first attempt of fabrication is not successful. Due to time constraint, the ECT sensor for this project is not able to be fabricated.

The author received assistance from other student, Irene Lock Sow Mei, to gain the ECT images using her ECT sensor.

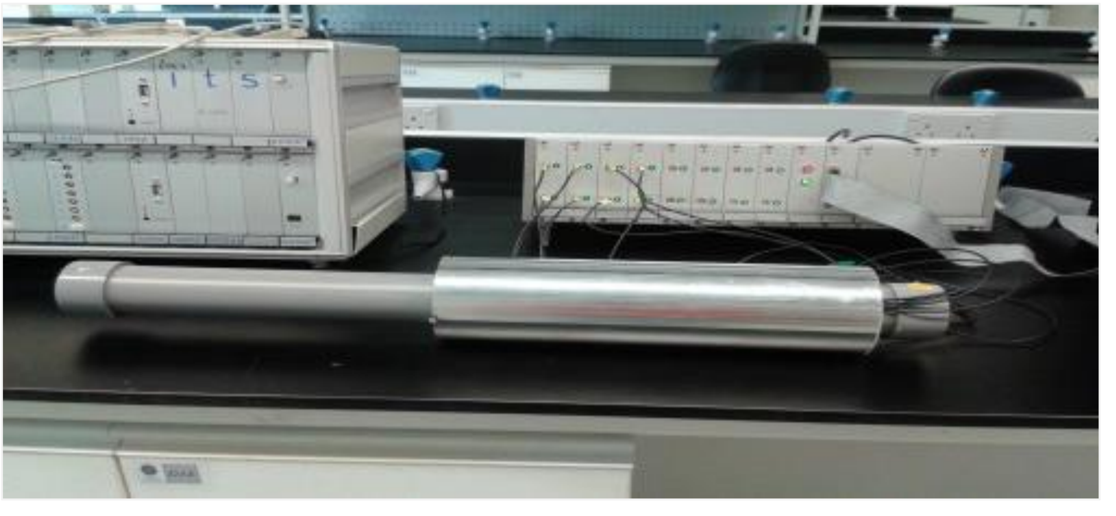


Figure 8: Physical Layout of Fabricated Single Plane 12 Electrodes ECT sensor (Irene, 2014)

4.2 Low and High Image Calibration

Before the experiment is being done, a small setup was done to calibrate high and low images. The experimental procedure is being done as presented in section 3.6.1 and 3.6.2.

For the low calibration, the smallest unit is a 100% wax. To achieve a complete wax formation, the sample is cooled to 19 ºC. The image formed is indicated in blue colour tomogram.

For the high calibration, the unit is a 100% liquid. The calibration is done with crude oil sample completely in liquid form. Red colour tomogram indicates the liquid state of the crude oil. Figure shows the outcome image of low and high calibration.

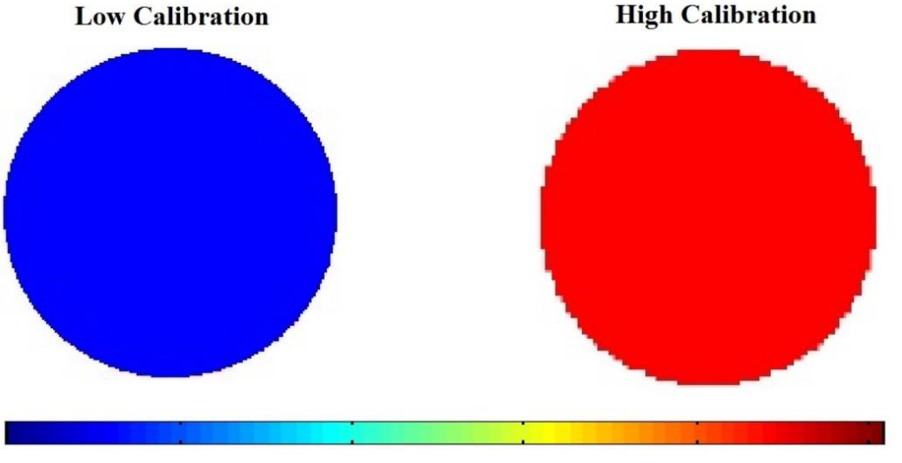


Figure 9: Low and High Calibration Images

4.3 Temperature Difference Data Collection

The experiment was done by getting the ECT images at 4 different temperatures. The ECT images are tabulated in Table 5A and Table 5B, together with rough estimation on the percentage distribution of crude oil and wax inside the pipeline.

Table 5A: ECT Images at Different Temperatures

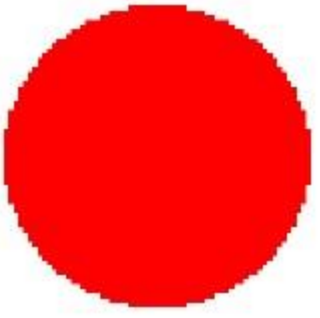
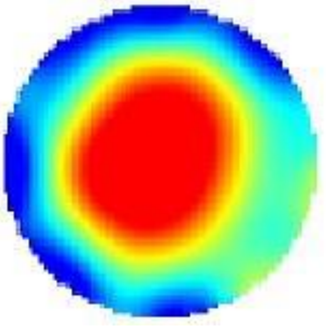
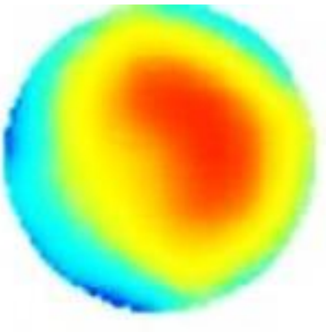
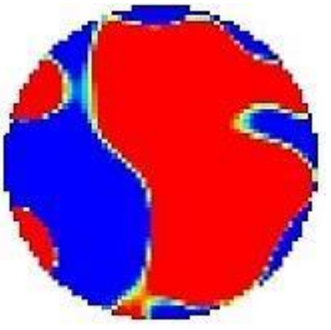
Temperature	ECT Image	Rough Estimation of Percentage Distribution (%)	
		Crude Oil	Wax
45 ºC		100	0
40 ºC		70	30
35 ºC		65	35

Table 5B: ECT Images at Different Temperatures (cont.)

Temperature	ECT Image	Rough Estimation of Percentage Distribution (%)	
		Crude Oil	Wax
30 ºC		55	45

4.4 Image Processing

As being tabulated in section 4.3, the ECT images obtained from ECT sensor only shows the tomogram colours when being recorded. Each colour indicates different states of the oil inside of the pipeline, without exact figure of colour distribution.

To quantify the data from the tomogram images, they are being processed using the graphics editor software, GIMP version 2.8, in order to quantify the percentage of oil (red tomogram) and wax (blue tomogram) at different temperatures. GIMP is the acronym for GNU Image Manipulation Program.

By doing this, a more accurate data on the percentage distribution can be obtained.

4.4.1 Quantifying Colour Distribution

To quantify the colour distribution in order to indicate how much portion of crude oil and wax, the images are first converted from RGB (Red Green Blue or coloured) images into grayscale images which consist of Black, Grey and White colours. By doing this, it is much easier to perform threshold on those images.

Threshold in image processing is a method of image segmentation. It converts grayscale image to binary image, a form of Black and White image. The steps were performed fully using the GIMP software.

The steps are completely automated, whereby the software automatically selects the threshold T. For this project, the method chose for threshold is the Histogram shape based method. The method is quite similar to Otsu's method, another method of threshold which is the clustering based method. Histogram shape based method assumed that the image is distributed into two key classes: the background and the foreground. This method will find the optimum threshold level that divides the histogram in two classes.

Figure 10 and 11 show the result from the Histogram Threshold method for tomogram image at temperature 35 ºC. In Figure 10, the green-dotted area shows the pixel point for black colour area, which indicates the distribution of the wax.

Previously, based on Figure 9, the blue colour is indicating the wax area while red area is specifies for the crude oil. In the orange-dotted area, the count and percentage of the Black pixel is displayed. Figure 11 is showing a similar result, except that the green-dotted area is now indicating the White pixel.

Overall results of percentage Black and White colour distribution are tabulated in Table 6, together with the Grayscale and Threshold images.

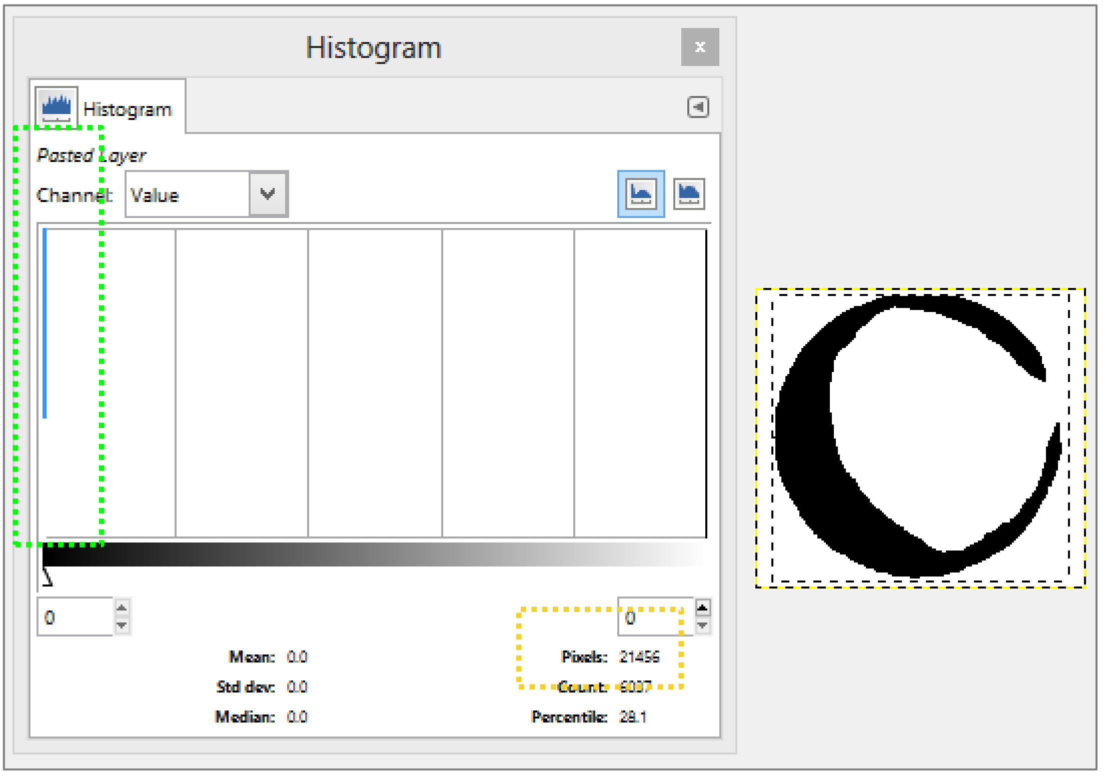


Figure 10: Low and High Calibration Images

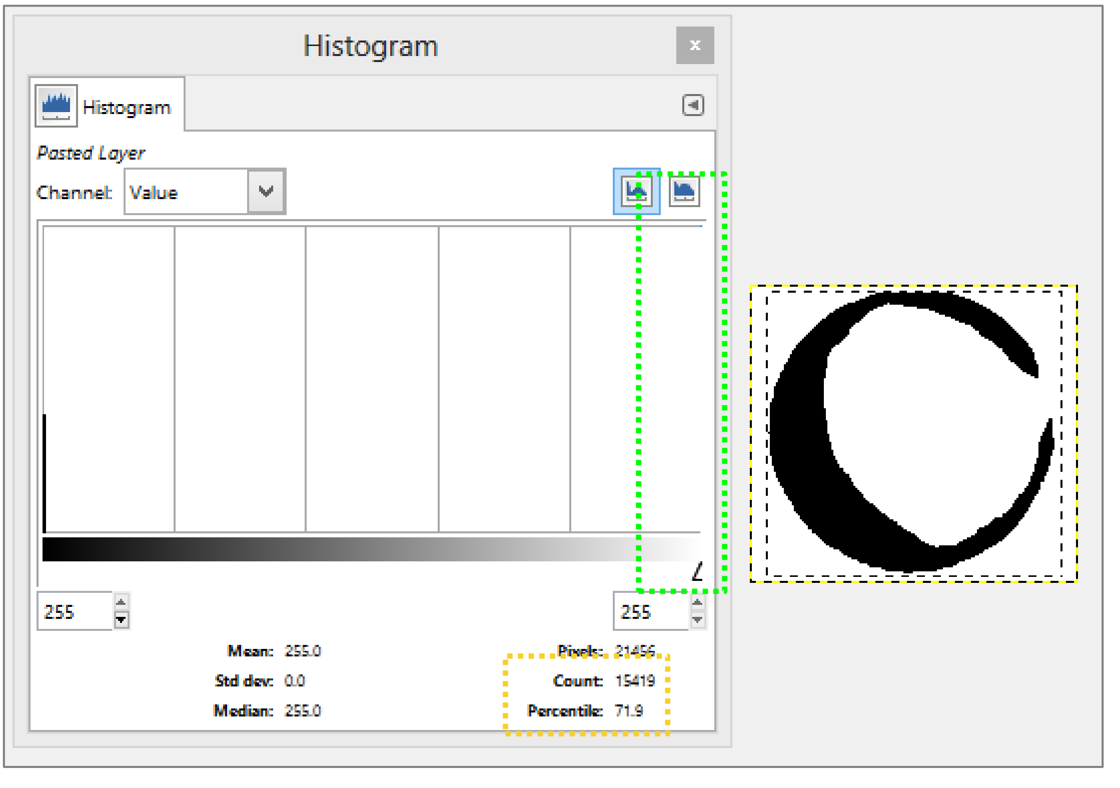
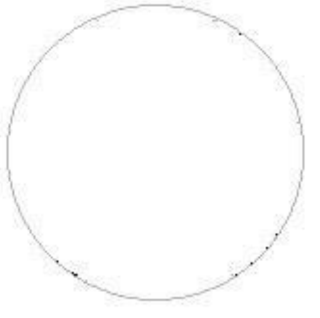
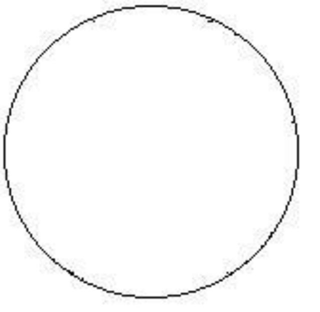
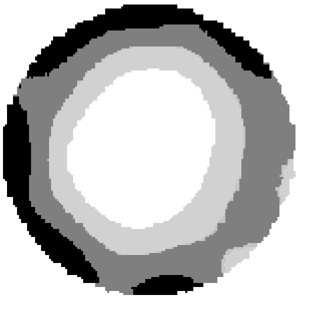
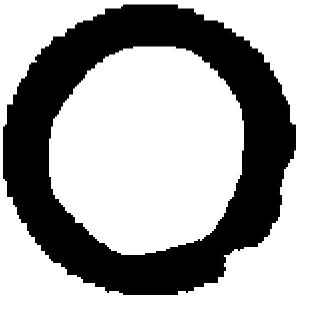


Figure 11: Low and High Calibration Images

Table 6: ECT Grayscale and Threshold Images

Temperature	ECT Grayscale Image	ECT Threshold Image	Percentage Distribution from Histogram Colour (%)	
			Crude Oil	Wax
45 ºC			99.8	0.2
40 ºC			61.3	38.7
35 ºC			71.9	28.1
30 ºC			74.6	24.7

4.5 Discussion

From the results, it can be seen that the percentage of wax can be detected even at 45ºC, with percentage of 0.2%. However, this percentage is neglected. This is because, the zoomed original image shows the small Black colour formed near the wall after threshold is actually a Cyan coloured pixel, which may come from the impurities in the crude oil.

The threshold images at 40 ºC and 35 ºC are converting dark grey area to black and the light greys to white, which lead to error in displaying the percentage distribution of crude oil and wax. Nevertheless, the physical observation from the experiment shows that the viscosity of the crude oil is increasing as temperature reaches 30 ºC, not supposed to be decreasing, which proof that the percentage obtained is having errors. The best result to show the formation of wax after threshold is at temperature of 30 ºC.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The aim of designing and fabricating the ECT sensor for this project is to monitor and indirectly forecasting the behavior of wax formation in pipeline under dynamic test.

The innovation of the application of CT scan from medical sector to ECT images of pipelines in oil and gas industry shows positive outcome which can be further implemented in industrial scale. The results clearly shows images of different composition in the pipeline whereby the area in blue colour indicates the presence of wax in the pipeline.

The process of tomography will help engineers to easily monitor the inner condition of pipelines and analyses the formation of layer of wax before it become worst.

5.2 Recommendation

Image processing is the next step to quantify a tomogram image. Few methods should be further attempted to get the most accurate and reliable results.

Dealing with different area of expertise is a tough challenge for an undergraduate student especially when having time constraint. This project mainly involves Electrical and Electronics application in order to design and fabricate the ECT sensor and calibrating the capacitance measurement. It is recommended to have a complete set of ECT system to run the project. By having that, the study can be done efficiently.

This project can be further explored to investigate other concern parameters in monitoring crude oil pipelines such as flow rate and concentration. Nonetheless, perhaps this method can be done to conduct a dynamic test in order to resemble the transportation of crude oil pipeline from the offshore to the upstream area.

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APPENDICES

APPENDIX I

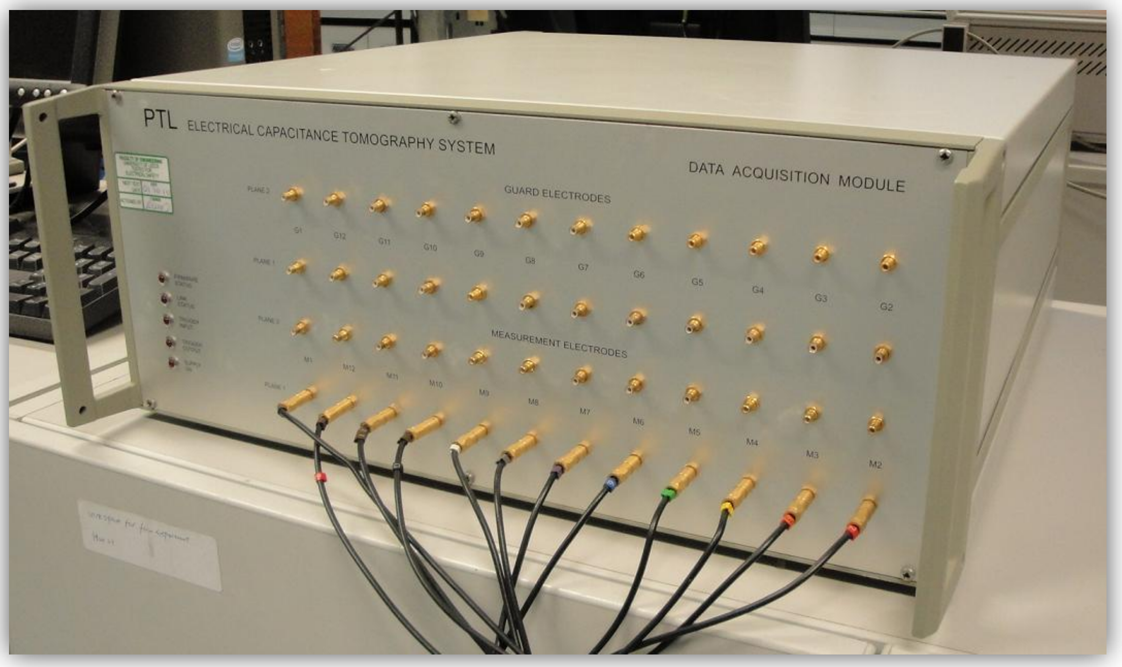

Figure 12: Data Acquisition Module

APPENDIX II

MATERIAL SAFETY DATA SHEET

SECTION 1	PRODUCT AND COMPANY IDENTIFICATION

PRODUCT

Product Name: **EXXSOL D80 FLUID**
Product Description: Dearomatized Hydrocarbons
Product Code:
Intended Use: Solvent

COMPANY IDENTIFICATION

Supplier: EXXONMOBIL CHEMICAL COMPANY
P.O. BOX 3272
HOUSTON, TX. 77253-3272 USA

24 Hour Health Emergency	(800) 726-2015
Transportation Emergency Phone	(800) 424-9300 CHEMTREC
Product Technical Information	(281) 870-6000/Health & Medical (281) 870-6884
Supplier General Contact	(281) 870-6000

SECTION 2	COMPOSITION / INFORMATION ON INGREDIENTS

Hazardous Constituent(s) Contained in Complex Substance(s)

Name	CAS#	Concentration*
DISTILLATES (PETROLEUM), HYDROTREATED LIGHT	64742-47-8	100%

* All concentrations are percent by weight unless material is a gas. Gas concentrations are in percent by volume.

SECTION 3	HAZARDS IDENTIFICATION

This material is considered to be hazardous according to regulatory guidelines (see (M)SDS Section 15).

POTENTIAL PHYSICAL / CHEMICAL EFFECTS

Combustible. Material can release vapors that readily form flammable mixtures. Vapor accumulation could flash and/or explode if ignited. Material can accumulate static charges which may cause an incendiary electrical discharge.

POTENTIAL HEALTH EFFECTS

Repeated exposure may cause skin dryness or cracking. If swallowed, may be aspirated and cause lung damage. May be irritating to the eyes, nose, throat, and lungs.

NFPA Hazard ID:	Health: 1	Flammability: 2	Reactivity: 0
HMIS Hazard ID:	Health: 1	Flammability: 2	Reactivity: 0

NOTE: This material should not be used for any other purpose than the intended use in Section 1 without expert advice. Health studies have shown that chemical exposure may cause potential human health risks which may vary from person to person.

SECTION 4	FIRST AID MEASURES

INHALATION

Remove from further exposure. For those providing assistance, avoid exposure to yourself or others. Use adequate respiratory protection. If respiratory irritation, dizziness, nausea, or unconsciousness occurs, seek immediate medical assistance. If breathing has stopped, assist ventilation with a mechanical device or use mouth-to-mouth resuscitation.

SKIN CONTACT

Wash contact areas with soap and water. Remove contaminated clothing. Launder contaminated clothing before reuse.

EYE CONTACT

Flush thoroughly with water. If irritation occurs, get medical assistance.

INGESTION

Seek immediate medical attention. Do not induce vomiting.

NOTE TO PHYSICIAN

If ingested, material may be aspirated into the lungs and cause chemical pneumonitis. Treat appropriately.

SECTION 5 FIRE FIGHTING MEASURES

EXTINGUISHING MEDIA

Appropriate Extinguishing Media: Use water fog, foam, dry chemical or carbon dioxide (CO_2) to extinguish flames.

Inappropriate Extinguishing Media: Straight Streams of Water

FIRE FIGHTING

Fire Fighting Instructions: Evacuate area. Prevent runoff from fire control or dilution from entering streams, sewers, or drinking water supply. Firefighters should use standard protective equipment and in enclosed spaces, self-contained breathing apparatus (SCBA). Use water spray to cool fire exposed surfaces and to protect personnel.

Unusual Fire Hazards: Combustible. Hazardous material. Firefighters should consider protective equipment indicated in Section 8.

Hazardous Combustion Products: Oxides of carbon, Incomplete combustion products, Smoke, Fume

FLAMMABILITY PROPERTIES

Flash Point [Method]: >77C (171F) [ASTM D-93]
Flammable Limits (Approximate volume % in air): LEL: 0.6 UEL: 5.0
Autoignition Temperature: 251°C (484°F) [Approximate]

SECTION 6 ACCIDENTAL RELEASE MEASURES

NOTIFICATION PROCEDURES

In the event of a spill or accidental release, notify relevant authorities in accordance with all applicable regulations. U.S. regulations require reporting releases of this material to the environment which exceed the reportable quantity or oil spills which could reach any waterway including intermittent dry creeks. The National

Response Center can be reached at (800)424-8802.

PROTECTIVE MEASURES

Avoid contact with spilled material. Warn or evacuate occupants in surrounding and downwind areas if required due to toxicity or flammability of the material. See Section 5 for fire fighting information. See Section 3 for Significant Hazards. See Section 4 for First Aid Advice. See Section 8 for Personal Protective Equipment.

SPILL MANAGEMENT

Land Spill: Eliminate all ignition sources (no smoking, flares, sparks or flames in immediate area). Stop leak if you can do it without risk. All equipment used when handling the product must be grounded. Do not touch or walk through spilled material. Prevent entry into waterways, sewer, basements or confined areas. A vapor suppressing foam may be used to reduce vapors. Use clean non-sparking tools to collect absorbed material. Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers. Large Spills: Water spray may reduce vapor; but may not prevent ignition in closed spaces. Recover by pumping or with suitable absorbent.

Water Spill: Stop leak if you can do it without risk. Warn other shipping. Remove from the surface by skimming or with suitable absorbents. Seek the advice of a specialist before using dispersants.

Water spill and land spill recommendations are based on the most likely spill scenario for this material; however, geographic conditions, wind, temperature, (and in the case of a water spill) wave and current direction and speed may greatly influence the appropriate action to be taken. For this reason, local experts should be consulted. Note: Local regulations may prescribe or limit action to be taken.

ENVIRONMENTAL PRECAUTIONS

Large Spills: Dike far ahead of liquid spill for later recovery and disposal. Prevent entry into waterways, sewers, basements or confined areas.

SECTION 7 HANDLING AND STORAGE

HANDLING

Avoid contact with skin. Use proper bonding and/or grounding procedures. Prevent small spills and leakage to avoid slip hazard. Material can accumulate static charges which may cause an electrical spark (ignition source).

Loading/Unloading Temperature: [Ambient]

Transport Temperature: [Ambient]

Static Accumulator: This material is a static accumulator.

STORAGE

Keep container closed. Handle containers with care. Open slowly in order to control possible pressure release. Store in a cool, well-ventilated area. Storage containers should be grounded and bonded. Drums must be grounded and bonded and equipped with self-closing valves, pressure vacuum bungs and flame arresters.
Storage Temperature: [Ambient]
Storage Pressure: [Ambient]

Suitable Containers/Packing: Barges; Drums; Tank Cars; Tank Trucks
Suitable Materials and Coatings: Carbon Steel; Stainless Steel; Polyethylene; Polypropylene; Teflon
Unsuitable Materials and Coatings: Natural Rubber; Butyl Rubber; Ethylene-proplyene-diene monomer

(EPDM); Polystyrene

SECTION 8 EXPOSURE CONTROLS / PERSONAL PROTECTION

EXPOSURE LIMIT VALUES

Exposure limits/standards (Note: Exposure limits are not additive)

Source	Form	Limit / Standard			Note	Source
DISTILLATES (PETROLEUM), HYDROTREATED LIGHT	Vapor.	RCP - TWA	1200 mg/m3	165 ppm	Total Hydrocarbons	ExxonMobil

NOTE: Limits/standards shown for guidance only. Follow applicable regulations.

ENGINEERING CONTROLS

The level of protection and types of controls necessary will vary depending upon potential exposure conditions. Control measures to consider:

Adequate ventilation should be provided so that exposure limits are not exceeded. Use explosion-proof ventilation equipment.

PERSONAL PROTECTION

Personal protective equipment selections vary based on potential exposure conditions such as applications, handling practices, concentration and ventilation. Information on the selection of protective equipment for use with this material, as provided below, is based upon intended, normal usage.

Respiratory Protection: If engineering controls do not maintain airborne contaminant concentrations at a level which is adequate to protect worker health, an approved respirator may be appropriate. Respirator selection, use, and maintenance must be in accordance with regulatory requirements, if applicable. Types of respirators to be considered for this material include:

Half-face filter respirator

For high airborne concentrations, use an approved supplied-air respirator, operated in positive pressure mode. Supplied air respirators with an escape bottle may be appropriate when oxygen levels are inadequate, gas/vapor warning properties are poor, or if air purifying filter capacity/rating may be exceeded.

Hand Protection: Any specific glove information provided is based on published literature and glove manufacturer data. Work conditions can greatly effect glove durability; inspect and replace worn or damaged gloves. The types of gloves to be considered for this material include:

If prolonged or repeated contact is likely, chemical resistant gloves are recommended. If contact with forearms is likely, wear gauntlet style gloves.

Eye Protection: If contact is likely, safety glasses with side shields are recommended.

Skin and Body Protection: Any specific clothing information provided is based on published literature or manufacturer data. The types of clothing to be considered for this material include:

If prolonged or repeated contact is likely, chemical, and oil resistant clothing is recommended.

Specific Hygiene Measures: Always observe good personal hygiene measures, such as washing after handling the material and before eating, drinking, and/or smoking. Routinely wash work clothing and protective equipment to remove contaminants. Discard contaminated clothing and footwear that cannot be cleaned. Practice good housekeeping.

ENVIRONMENTAL CONTROLS

See Sections 6, 7, 12, 13.

SECTION 9 PHYSICAL AND CHEMICAL PROPERTIES

Typical physical and chemical properties are given below. Consult the Supplier in Section 1 for additional data.

GENERAL INFORMATION

Physical State: Liquid
Form: Clear
Color: Colorless
Odor: Mild Petroleum/Solvent
Odor Threshold: N/D

IMPORTANT HEALTH, SAFETY, AND ENVIRONMENTAL INFORMATION

Relative Density (at 15.6 C): 0.798
Density: 798 kg/m³ (6.66 lbs/gal, 0.8 kg/dm³)
Flash Point [Method]: >77C (171F) [ASTM D-93]
Flammable Limits (Approximate volume % in air): LEL: 0.6 UEL: 5.0
Autoignition Temperature: 251°C (484°F) [Approximate]
Boiling Point / Range: 200C (392F) - 250C (482F)
Vapor Density (Air = 1): 6.2 at 101 kPa
Vapor Pressure: 0.023 kPa (0.17 mm Hg) at 20 C
Evaporation Rate (n-butyl acetate = 1): 0.1
pH: N/A
Log Pow (n-Octanol/Water Partition Coefficient): N/D
Solubility in Water: Negligible
Viscosity: 1.68 cSt (1.68 mm2/sec) at 40 C | 2.16 cSt (2.16 mm2/sec) at 25C
Oxidizing Properties: See Sections 3, 15, 16.

OTHER INFORMATION

Freezing Point: N/D
Melting Point: N/D
Pour Point: -39°C (-39°F)
Molecular Weight: 171 [Calculated]
Hygroscopic: No
Coefficient of Thermal Expansion: 0.00074 V/VDEGC

SECTION 10 STABILITY AND REACTIVITY

STABILITY: Material is stable under normal conditions.

CONDITIONS TO AVOID: Avoid heat, sparks, open flames and other ignition sources.

MATERIALS TO AVOID: Strong oxidizers

HAZARDOUS DECOMPOSITION PRODUCTS: Material does not decompose at ambient temperatures.

HAZARDOUS POLYMERIZATION: Will not occur.

SECTION 11 TOXICOLOGICAL INFORMATION

ACUTE TOXICITY

Route of Exposure	Conclusion / Remarks
Inhalation	
Toxicity: Data available.	Minimally Toxic. Based on test data for structurally similar materials.
Irritation: Data available.	Negligible hazard at ambient/normal handling temperatures. Based on test data for structurally similar materials.
Ingestion	
Toxicity: LD50 > 15000 mg/kg	Minimally Toxic. Based on test data for structurally similar materials.
Skin	
Toxicity: LD50 > 3160 mg/kg	Minimally Toxic. Based on test data for structurally similar materials.
Irritation: Data available.	Mildly irritating to skin with prolonged exposure. Based on test data for structurally similar materials.
Eye	
Irritation: Data available.	May cause mild, short-lasting discomfort to eyes. Based on test data for structurally similar materials.

CHRONIC/OTHER EFFECTS

For the product itself:

Vapor/aerosol concentrations above recommended exposure levels are irritating to the eyes and respiratory tract, may cause headaches, dizziness, anesthesia, drowsiness, unconsciousness and other central nervous system effects including death.
Prolonged and/or repeated skin contact with low viscosity materials may defat the skin resulting in possible irritation and dermatitis.
Small amounts of liquid aspirated into the lungs during ingestion or from vomiting may cause chemical pneumonitis or pulmonary edema.

Additional information is available by request.

The following ingredients are cited on the lists below: None.

--REGULATORY LISTS SEARCHED--

1 = NTP CARC	3 = IARC 1	5 = IARC 2B
2 = NTP SUS	4 = IARC 2A	6 = OSHA CARC

SECTION 12 ECOLOGICAL INFORMATION

The information given is based on data available for the material, the components of the material, and similar materials.

ECOTOXICITY

Material -- Not expected to be harmful to aquatic organisms.
Material -- Not expected to demonstrate chronic toxicity to aquatic organisms.

PERSISTENCE AND DEGRADABILITY

Biodegradation:

Material -- Expected to be readily biodegradable.

Hydrolysis:

Material -- Transformation due to hydrolysis not expected to be significant.

Photolysis:

Material -- Transformation due to photolysis not expected to be significant.

Atmospheric Oxidation:

Material -- Expected to degrade rapidly in air

OTHER ECOLOGICAL INFORMATION

VOC (EPA Method 24): 6.659 lbs/gal

SECTION 13 DISPOSAL CONSIDERATIONS

Disposal recommendations based on material as supplied. Disposal must be in accordance with current applicable laws and regulations, and material characteristics at time of disposal.

DISPOSAL RECOMMENDATIONS

Product is suitable for burning in an enclosed controlled burner for fuel value or disposal by supervised incineration at very high temperatures to prevent formation of undesirable combustion products.

REGULATORY DISPOSAL INFORMATION

RCRA Information: The unused product, in our opinion, is not specifically listed by the EPA as a hazardous waste (40 CFR, Part 261D), nor is it formulated to contain materials which are listed as hazardous wastes. It does not exhibit the hazardous characteristics of ignitability, corrositivity or reactivity and is not formulated with contaminants as determined by the Toxicity Characteristic Leaching Procedure (TCLP). However, used product may be regulated.

Empty Container Warning PRECAUTIONARY LABEL TEXT: Empty containers may retain residue and can be dangerous. DO NOT PRESSURIZE, CUT, WELD, BRAZE, SOLDER, DRILL, GRIND OR EXPOSE SUCH CONTAINERS TO HEAT, FLAME, SPARKS, STATIC ELECTRICITY, OR OTHER SOURCES OF IGNITION; THEY MAY EXPLODE AND CAUSE INJURY OR DEATH. Do not attempt to refill or clean container since residue is difficult to remove. Empty drums should be completely drained, properly bunged and promptly returned to a drum reconditioner. All containers should be disposed of in an environmentally safe manner and in accordance with governmental regulations.

SECTION 14 TRANSPORT INFORMATION

LAND (DOT)

Proper Shipping Name: PETROLEUM DISTILLATES, N.O.S.
Hazard Class & Division: COMBUSTIBLE LIQUID
ID Number: 1268
Packing Group: III

ERG Number: 128
Label(s): NONE
Transport Document Name: PETROLEUM DISTILLATES, N.O.S., COMBUSTIBLE LIQUID, UN1268, PG III

Footnote: This material is not regulated under 49 CFR in a container of 119 gallon capacity or less when transported solely by land, as long as the material is not a hazardous waste, a marine pollutant, or specifically listed as a hazardous substance.

LAND (TDG) : Not Regulated for Land Transport

SEA (IMDG) : Not Regulated for Sea Transport according to IMDG-Code

AIR (IATA) : Not Regulated for Air Transport

SECTION 15 REGULATORY INFORMATION

OSHA HAZARD COMMUNICATION STANDARD: When used for its intended purpose, this material is classified as hazardous in accordance with OSHA 29CFR 1910.1200.

NATIONAL CHEMICAL INVENTORY LISTING: AICS, DSL, EINECS, ENCS, KECI, PICCS, TSCA

EPCRA: This material contains no extremely hazardous substances.

SARA (311/312) REPORTABLE HAZARD CATEGORIES: Fire.

SARA (313) TOXIC RELEASE INVENTORY: This material contains no chemicals subject to the supplier notification requirements of the SARA 313 Toxic Release Program.

The Following Ingredients are Cited on the Lists Below:* None.

--REGULATORY LISTS SEARCHED--

1 = ACGIH ALL	6 = TSCA 5a2	11 = CA P65 REPRO	16 = MN RTK
2 = ACGIH A1	7 = TSCA 5e	12 = CA RTK	17 = NJ RTK
3 = ACGIH A2	8 = TSCA 6	13 = IL RTK	18 = PA RTK
4 = OSHA Z	9 = TSCA 12b	14 = LA RTK	19 = RI RTK
5 = TSCA 4	10 = CA P65 CARC	15 = MI 293	

Code key: CARC=Carcinogen; REPRO=Reproductive

* EPA recently added new chemical substances to its TSCA Section 4 test rules. Please contact the supplier to confirm whether the ingredients in this product currently appear on a TSCA 4 or TSCA 12b list.

SECTION 16 OTHER INFORMATION

N/D = Not determined, N/A = Not applicable

THIS SAFETY DATA SHEET CONTAINS THE FOLLOWING REVISIONS:

Revision Changes: Not Applicable

PRECAUTIONARY LABEL TEXT:

Contains: DISTILLATES (PETROLEUM), HYDROTREATED LIGHT

CAUTION!

HEALTH HAZARDS

Repeated exposure may cause skin dryness or cracking. If swallowed, may be aspirated and cause lung damage.

PHYSICAL HAZARDS

Combustible. Material can accumulate static charges which may cause an incendiary electrical discharge.

PRECAUTIONS

Avoid contact with skin. Use proper bonding and/or grounding procedures.

FIRST AID

Inhalation: Remove from further exposure. For those providing assistance, avoid exposure to yourself or others. Use adequate respiratory protection. If respiratory irritation, dizziness, nausea, or unconsciousness occurs, seek immediate medical assistance. If breathing has stopped, assist ventilation with a mechanical device or use mouth-to-mouth resuscitation.

Eye: Flush thoroughly with water. If irritation occurs, get medical assistance.

Oral: Seek immediate medical attention. Do not induce vomiting.

Skin: Wash contact areas with soap and water. Remove contaminated clothing. Launder contaminated clothing before reuse.

FIRE FIGHTING MEDIA

Use water fog, foam, dry chemical or carbon dioxide (CO_2) to extinguish flames.

SPILL/LEAK

Land Spill: Eliminate all ignition sources (no smoking, flares, sparks or flames in immediate area). Stop leak if you can do it without risk. Prevent entry into waterways, sewer, basements or confined areas. A vapor suppressing foam may be used to reduce vapors. Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers. Recover by pumping or with suitable absorbent.

Water Spill: Stop leak if you can do it without risk. Confine the spill immediately with booms. Warn other shipping. Remove from the surface by skimming or with suitable absorbents. Report spills as required to appropriate authorities. Seek the advice of a specialist before using dispersants.

Internal Use Only
MHC: 1A, 0, 0, 0, 2, 0

DGN: 4400220HUS (1007664)
