Gas Hydrate Mobile Application

by

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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 specifies in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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FATIN NUR AMIRAH BINTI MOHD FARIDZA

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"Praise to Allah, the most Gracious and the most Merciful"

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Thank you very much.

ABSTRACT

Determining the formation of gas hydrate is critical due to the fact that it could reduce the production level in pipelines due to the blockage form by hydrates. In the long run it could then damage those pipelines. However, most current software could not support real time analysis of hydrate formation. Therefore, this research project develops a mobile application to determine the occurrence of gas hydrate formation in offshore pipelines.

The mobile application is available for android users including engineers and researchers. The mobile application determines the gas hydrate formation based on four types of natural gas which are methane, propane, carbon dioxide and nitrogen. These are the four most frequent gases that lead to formation of hydrate and have established fixed equilibrium graph. Based on the integration of those various phase equilibrium graphs gathered (Roberts et al (1940); Makagon and Sloan (1994); Deaton and Frost (1946); Nakamura et al (2000)) hydrate and non-hydrate situation are determined in the form of graphs.

Rapid prototyping methodology was followed in designing and creating the mobile apps. The five phases started with planning, quick analysis and design, prototype cycle, implementation and testing were conducted with assistance from expert users. In assuring the accuracy of the gas hydrates formation, interview with expert users has been conducted. The introduction of this mobile application will be a breakthrough in oil and gas industry, where the occurrence of gas hydrate could be determined in real time and at any time and from anywhere. This would reduce the time taken for decision making and thus mitigation plans for gas hydrate removal could be taken as soonest.

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Chapter 1: Introduction

1.1 Background of Study

This project is related to oil and gas application to estimate condition of operating temperature and pressure that might cause hydrate blockage in pipeline. From the literature and surveys (Holland & Safety, 2013), it seems that technology is less explored in this case. For example, there are no mobile application systems that can accurately estimate the region of gas hydrate formation with the information of operating temperature and pressure in the pipeline. Therefore, it motivates this study to create a mobile application that can determine the formation of gas hydrate in region in the pipeline is normally operate in deepwater.

The mobile application will be developed by calculating the operating pressure and temperature. These are the two important parameters that can determine the formation of gas hydrates in pipeline. According to U.S. Geological Survey (2013), gas hydrate is defined as the mixture of natural gas and water in the form of crystalline solid. Hydrate exist in crystalline, ice-like solids formed molecule formed when the 'guest' molecule such as carbon dioxide (CO_2), methane (CH_4), ethane (C_2H_6) and nitrogen (N_2) is altered by the addition or existence of water molecule in the system hence to create another molecule with different properties. Hydrocarbon which composes of this 'guest' molecule will transform into hydrates and cause blockage in hydrocarbon flow line.

Initiatives have been developed to enhance the flow assurance of hydrocarbon such as the most regular traditional method is Thermodynamic Hydrate Inhibitor (THI) where glycol or methanol is used in large amount (about 30% of the volume). This situation resulted in higher operation cost by 150 Million USD/$year^3$. THI were aims to disrupt the thermodynamic stability favourable zones for hydrates to form. The principles are keeping the operating temperature above or below hydrate formation pressure or introduce chemical injection to heat the gas above hydrates equilibrium pressure (Paez, Blok, Vaziri and Islam, 2001)

The benefit of this mobile application is to assist engineers for fast decision making for gas hydrate mitigation plan if the pipeline falls under gas hydrate zone. This is important to ensure smooth operation and to achieve the targeted of oil production.

1.2 Problem Statement

The determination of gas hydrates formation is important in order to avoid the blockage in the gas transmission lines (Sloan & Koh, 2008). The blockage will cause the decrease of oil production in the pipeline and also lead to the damage of the pipeline. This is an important factor for decision making about mitigation plan for gas hydrate removal from pipeline

The current gas hydrate programs conducted by the U.S. and Japanese government mentioned that the techniques on how to determine the occurrence of gas hydrate are still scarce (Johnson, 2009). Besides, the current commercialization effort for gas hydrate is limited by the updated technology such as mobile application. There are various reasons why there are not many technologies being applied to this field that include lack of (Johnson, 2009):

- Systematic and various exploration medium for identifying sites where hydrate is concentrated and has resource potential.
- Proven technology for commercial-scale production.
- Environmental impact assessment protocol.

1.3 Objectives

The objectives for developing the Gas Hydrate mobile application are as per following:

i. To identify appropriate techniques that can determine the occurrence of gas hydrate in the pipeline.
ii. To create a mobile application that facilitates the process of determining the occurrence of hydrate gas.
iii. To validate the accuracy of the formulation of gas hydrate.

1.4 Scope of Study

This mobile application is limited to the following scopes:

i. Engineers & Researchers as the users – This mobile application will be designed for engineers and researchers. Engineers and researchers are chosen because these are the personnel that usually deal with gas hydrates in their daily work. However, other users such as petroleum engineering students and lecturers might be interested to use this application in laboratory for testing purposes.

ii. Condition in the pipeline – The application will focus only on the gas hydrate formation that occurs in the pipeline. This is because most of the researches about gas hydrate are being conducted that area. Thus, the gas hydrate mobile application can help to facilitate those researches. (See Chapter 2 for details)

iii. Natural gases of type Methane, Carbon Dioxide, Propane and Nitrogen - The reason why these four types of gases are chosen is because most gas hydrate happens due to the existence of them. Petroleum engineering experts also mentioned that these four types of gases have a fixed equilibrium line. Therefore, the fixed equilibrium lines will be helpful in the development of the mobile application. (See Chapter 2 for details)

iv. Android Mobile Application – Study by Simon Khalaf (2013) mentioned that Android application is the cheapest and the most downloadable mobile application. Therefore, this platform is chosen due to its popularity and high demand.

1.5 Significance of the Project

The formation of the gas hydrate could form a blockage in the pipeline and lead to the low production of oil. It can also damage the pipeline if the amount is too high.

Therefore, the gas hydrate mobile application will help the engineers and also researchers in order to determine the occurrence of a gas hydrate in a timely manner. It is important for them because it could reduce the time taken in decision making.

This mobile application would be applied in during assessment of pipeline condition. The mobile application can be used to predict the formation of the gas hydrate based on the operating pressure and also temperature of the pipeline. Thus, the engineers may plan the mitigation for hydrate removal the pipeline accordingly through the result of analysis from the mobile application.

Chapter 2: Literature Review

2.1 Understanding Gas Hydrates

Gas hydrate is the mixture of the gas and water in the form of crystalline solid (USGS, 2013). There are four factors that could lead to formation of gas hydrate which are the presence of water, natural gas, high pressure and low temperature.

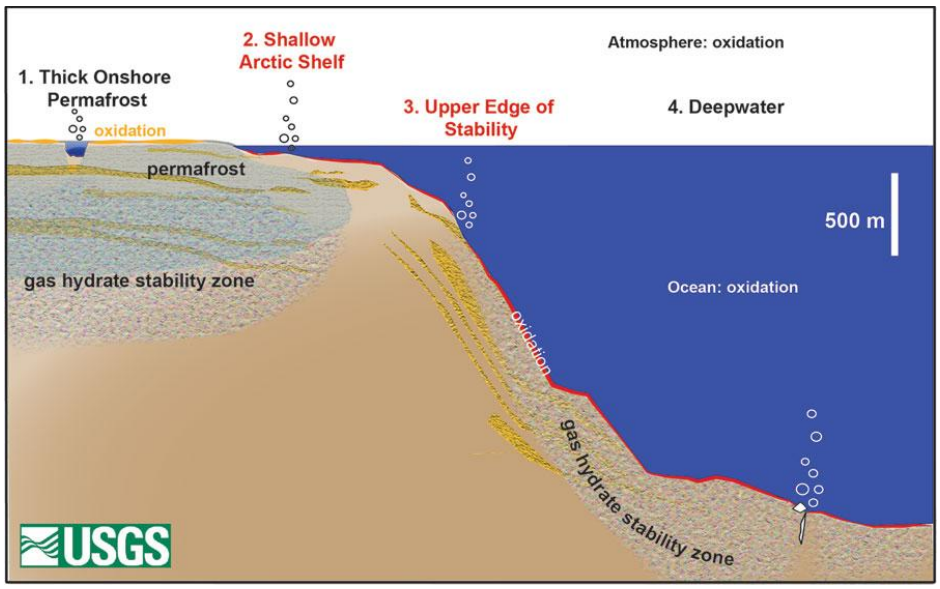


Figure 2.1: The occurrence place of gas hydrate

Based on Figure 2.1 which obtained from the U.S Geological Survey (2013), gas hydrate can be found either in the onshore where it lies underneath the permafrost or in the offshore normally below 500m depth on the seabed (Grauls, 2001). Most of the gas hydrates are made up from the methane as it is more stable in the seafloor.

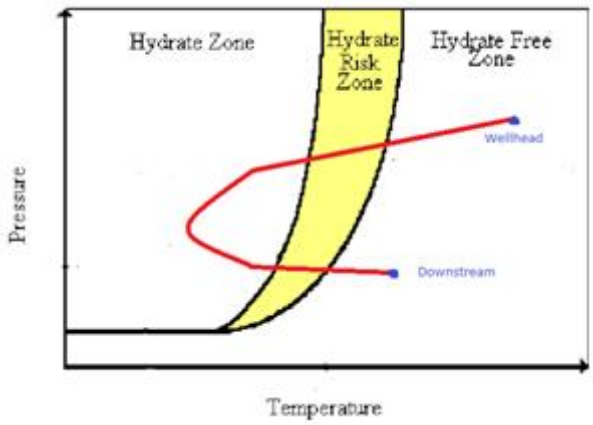


Figure 2.2: Example of gas hydrate fixed equilibrium line

The formation of the gas hydrate can be determined from the fixed equilibrium line of each of the natural gas through the amount of pressure and also the temperature. According to the Figure 2.2, if the point falls under the equilibrium line, meaning that there is no formation of gas hydrates in the current state and vice versa if the points are above the equilibrium line.

2.2 The Effects of Gas Hydrates Formation

The effect of the gas hydrate could be bad if it is formed in the gas transmission lines or also known as the pipelines (see Figure 2.3). It will create a blockage in the pipelines. Due to that, it can lower down the oil production level and may cause damage to the pipeline too.

Figure 2.3: Gas hydrates formed in the pipeline.

Besides, the methane of gas hydrate can be bad on the global climate change if it is being released too much (Zhen-guo Zhang et al., 2012). The burning effect of the methane gas can be three times worst than the releasing of carbon dioxide and the green house effect of the gas will cause the increase in global warming.

2.3 The Importance of having Technologies in this Area of Study

The usage of smart phones and tablets are now increasing worldwide. According to recent study from Simon Khalaf (2013), there has been 115 percent of growth in the usage of smart phones and tablets from the year 2012 to 2013. People nowadays are connecting more using those gadgets. However, the usage of mobile technology is still in its infancy in the oil and gas sector (Holland & Safety, 2013) as shown in Figure 2.4. In Figure 2.4, it is shown that the use of technology in oil and gas sector is hardly known.

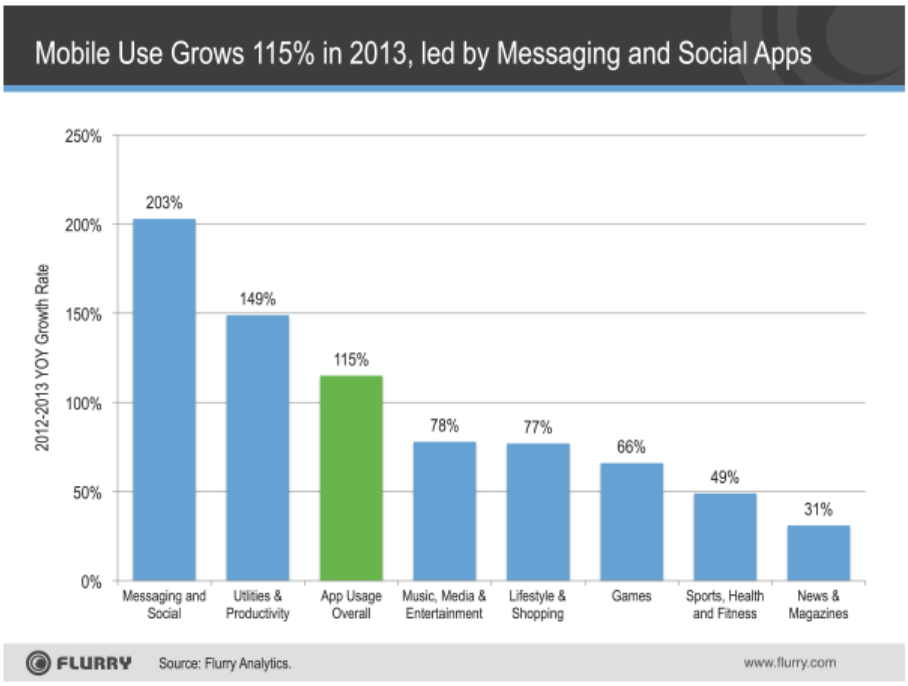


Figure 2.4: The statistic of mobile use growth adopted from Simon Khalaf (2013)

Although there is little technology designed in oil and gas sector, Holland and Safety (2013) have emphasized that there are a lot of benefits that can be gained from the use of mobile technology in this industry. Among them are to increase the efficiency in decision making, improve communication and the ease of data collection purposes.

Thus, the creation of gas hydrate mobile application could be beneficial to the oil and gas industry. With the help of this kind of mobile application, engineers and researchers can know the formation of gas hydrate in a very timely and handy manner for fast and accurate decision making.

2.4 Related Technologies

Other similar technologies which are related to gas hydrate which are available in the market are as shown in Table 2.1:

Table 2.1: Other similar technologies to determine gas hydrate

	dbrHydrate Fluid Analysis Software	**Hydrate Plus**	**Capillary Pressure**
Type	Software	Mobile Application	Mobile Application
Platform	Schlumberger's Internal Hub	iOS for Apple user	Android OS
Brief Description	Predicts initial gas-to-liquid hydrate formation conditions in multi-component hydrocarbon systems in the absence or presence of hydrate inhibitors	Calculates hydrate formation condition and inhibitor injection required	Demonstrates capillary pressure characteristics of a porous media in form of curves that significant for determination of fluid contacts location (OWC and GOC) and thickness of transition zones
Origin	United State	Canada	N/A
Developer	Schlumberger	Gas Liquid Engineering Ltd.	3ACEAPPS
Advantage	The recognized software that used for most of the oil and gas company	Can detect the amount of gas hydrate with	Provide graph for analysis purposes
Disadvantage	Can only be accessed with the licensed from Schlumberger	Only display the amount of gas hydrate that present	Calculating capillary pressure only
Price	N/A	US$19.99	Free

The three applications shown in Table 2.1 are all related to the oil and gas industry. *DbrHydrate Fluid Analysis Software* and *Hydrate Plus* are technologies that are being used to determine gas hydrate occurrence. As for the *DbrHydrate Fluid Analysis Software,* it is software that has been widely used in the oil and gas industry. However, it is stand-alone software that needs to be installed on a personal computer or a laptop. Therefore, if the engineers are offshore or on-site, *DbrHydrate Fluid Analysis Software* could not be used without having the computer and laptop.

As for the *Hydrate Plus*, it is a mobile application that can determine the percentage of the types of natural gas hydrate that form in the area that being tested. However, it does not have any graphical interface that could give better understanding about the condition of the gas hydrate formation. When there is no graphical user interface, it would be difficult to balance out and manipulate the pressure and temperature of the pipelines to be on its ideal state.

Thus, the gas hydrate mobile application will help to encounter those weaknesses revealed from the other available technologies. It will provide a handy application where everyone can access to it by using their smart phone or tablet anywhere and anytime. Besides, it will also provide a graphical interface in order to help users to understand the condition of the gas hydrate.

2.5. Review of Mobile Application Development Model

There are some model that is being implemented in developing a mobile application such as waterfall model, agile model and also the rapid prototyping model.

The waterfall development model is a sequential design model. Each phase need to be recorded and completed before moving on to the next phases (Base36, 2012). It is a systematic model but inflexible because it does not allow the developer to return to the previous step in developing the model.

The agile development model is a type of incremental model. The application will be developed in cycles from the planning, analysis, development and testing (Kumar, 2012). The developer can return to the previous phases of development if changes need to be done. It has a high flexibility in terms of developing the application. However, the drawback of this model is that the customer the cycle of development might be repeated lots of time as to have a clear view of the requirement from the users and could.

The rapid prototyping model is where prototype is being created as a method to understand about the customer's requirements. The prototype will be refined up until the customer reach the satisfaction (Raji, 2012). Even though it will take a longer time in developing the application, the rapid prototyping model can increase the mutual understanding between the developer and also customer. It will also help the

developer to avoid from developing a mobile application that fail to align with the customer expectations.

Chapter 3: Research Methodology

3.1 Mobile Application Development Model

Based on the comparison on the three types of the development models, the rapid prototyping is the best to implement in creating this mobile application. This is because it could increase the understanding of the developer about what kind of end product does the customer expect to receive.

3.2 Project Methodology: Rapid Prototyping

Rapid Prototyping model is chosen as the project methodology in conducting this project. This model aims in building prototype in an organize way and constantly improves it (Raji, 2012).

The rapid prototyping model is worked by the developer creating a prototype of the understanding of the user requirement. The user will then test the prototype and comments on the part that needs to be improved. The repetition of these steps will occur till the user is satisfied with the prototype that has been developed. With the advantage of developing the mobile application near to the user, it is easy to test out the prototype. Besides that, this methodology helps to improve the mutual understanding between the developer and user regarding the requirements and specifications of the mobile application.

3.3 Project Activities

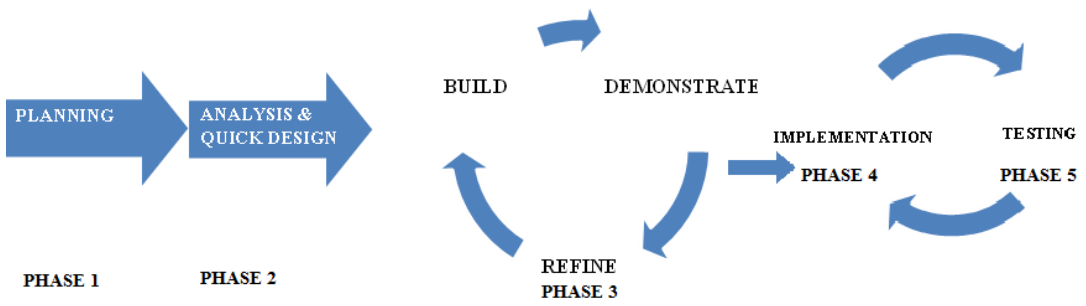


Figure 3.1: Rapid Prototype Model (adapted from Raji, 2012)

Phase 1: Planning

Title of the project is being selected during this phase. After decided on developing the gas hydrate mobile application, some research has been done in order to get the insight about gas hydrate before finalizing the title.

Phase 2: Analysis and quick design

During this phase, the requirement is gathered from the Petroleum Engineering experts and also past research is conducted in the area of gas hydrates. Based on the literature and other resources, the author explored the area of gas hydrates, petroleum engineering and mobile application. By seeking recommendations from the experts, objectives and the scope of the project were set to meet their requirements. Lastly, a draft of the user interface will be designed before developing the prototype.

Phase 3: Prototype Cycles

The cycles involve three steps which are building, demonstrating and refining. Firstly, the prototype will be built in order to portray the understanding of the developer on how it will work based on the requirements given. Secondly, the user will test the prototype using the demonstration and comments will be given for further improvement. Thirdly, the developer will refine the prototype based on the comments from the user and back to the first step. The cycles continue until the user satisfies with the prototype.

Phase 4: Implementation

When there is no longer change in the prototype from phase 2, the mobile application will be distributed to some of the potential users such as engineers, researchers in order to be tested.

Phase 5: Testing

The last phase of testing will be done with the real environment and variety of users. The purpose of this phase is to gain more feedback about how this mobile application will help them in determining the occurrence of gas hydrate. The type of test that will be conducted is usability test.

Usability Test – This test is done in order to identify any significant issues before it will be officially released to the intended users (Gaffney, 1999). Users will download this application from the Google Play. They will then need to answer a set of survey question in order to gain the feedback regarding the mobile application and to be used for further improvement of the gas hydrate mobile application.

3.4 System Flow Design

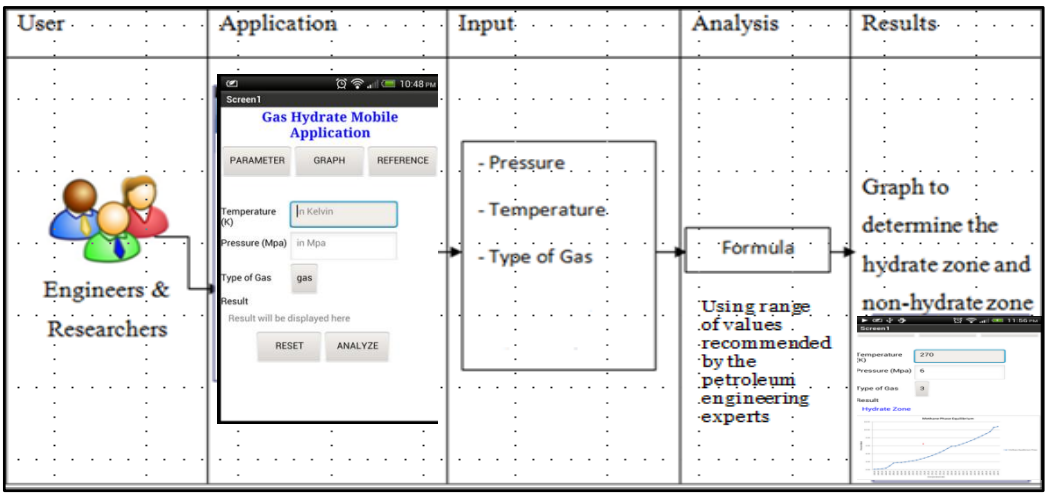


Figure 3.2: System Flow Diagram of Gas Hydrate Mobile Application

Figure 3.2 shows the system flow of the Gas Hydrate Mobile Application developed for this study. The users which consist of engineers and researchers will first open up the application through their smart phone or tablet. They will need to key in the input of parameters needed such as pressure, temperature and the type of gas that will be tested. Once completed, they will need to click on the analyze button in order to generate the graph. The application will then determine the point based on the fixed equilibrium graph of the type of gas and also the other parameters. The user will then be able to see whether the point is in the hydrate zone or non-hydrate zone.

3.5 Data Collection

3.4.1 Stages of Data Collection

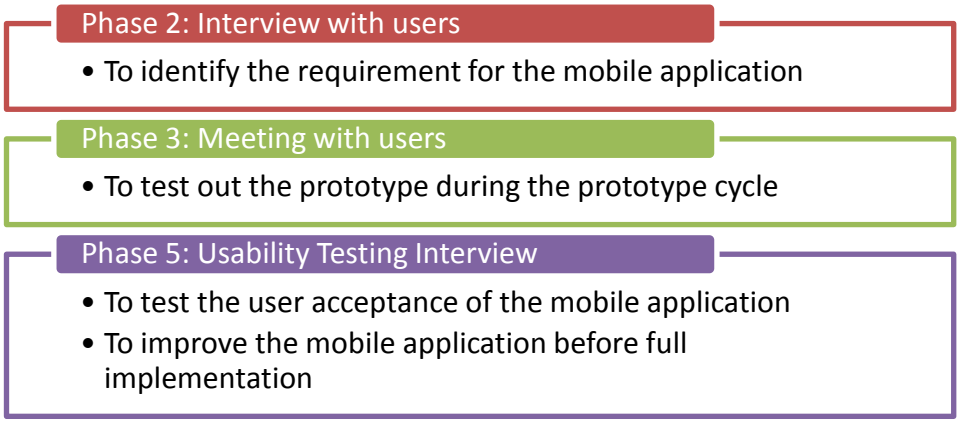


Figure 3.3: The data collection method based on the phases in rapid prototyping

3.4.2 Category of Respondent

Table 3.1: The Category of Respondent

	Phase 1: Interviews with users	**Phase 2: Meeting with the user**	**Phase 3: Usability Testing Interview**
Category 1: Petroleum Engineers	- Understanding on gas hydrate - How the mobile application will work? - Expected benefits gain from the mobile application	N/A	- User interface - Functionality - Accuracy - Acceptance -Overall Rating - Comments for future improvement
Category 2: Petroleum Engineer Lecturers and Researchers	- Understanding on gas hydrate - How can the mobile application beneficial for the teaching and research purposes?	- Testing and refining of the prototype	
Category 3: Petroleum Engineering Students	Understanding on gas hydrate - How can the mobile application beneficial for the learning purposes?	- Testing and refining of the prototype	

3.6 Key Milestones

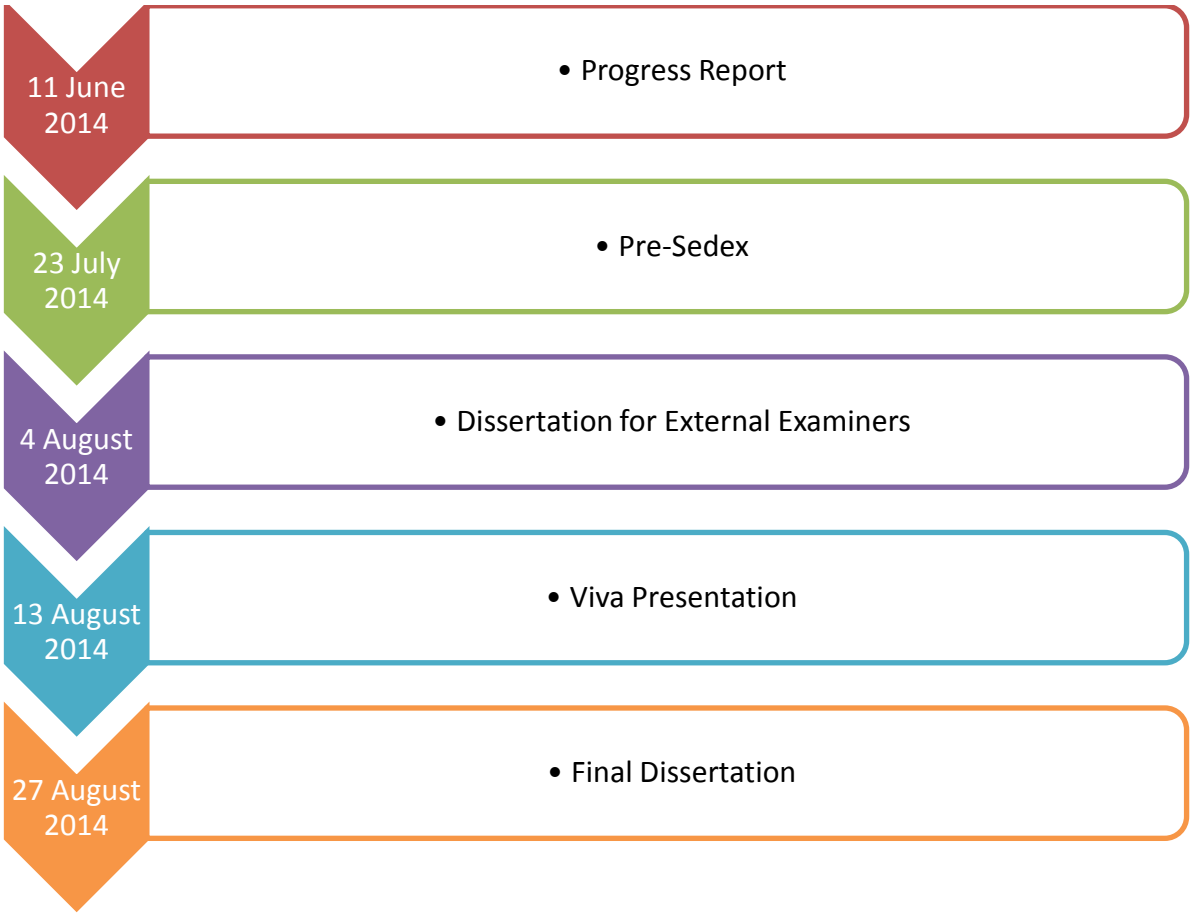
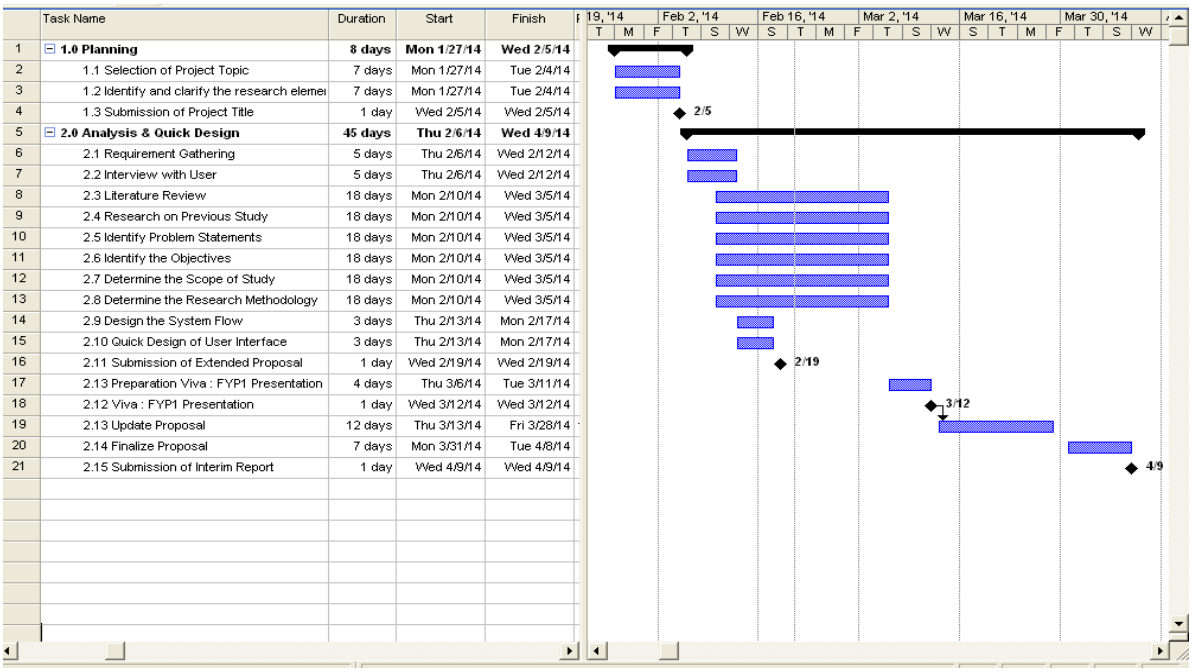


Figure 3.4: Key Milestone

3.7 Gantt Chart



	Task Name	Duration	Start	Finish
1	**1.0 Planning**	**8 days**	**Mon 1/27/14**	**Wed 2/5/14**
2	1.1 Selection of Project Topic	7 days	Mon 1/27/14	Tue 2/4/14
3	1.2 Identify and clarify the research elemer	7 days	Mon 1/27/14	Tue 2/4/14
4	1.3 Submission of Project Title	1 day	Wed 2/5/14	Wed 2/5/14
5	**2.0 Analysis & Quick Design**	**45 days**	**Thu 2/6/14**	**Wed 4/9/14**
6	2.1 Requirement Gathering	5 days	Thu 2/6/14	Wed 2/12/14
7	2.2 Interview with User	5 days	Thu 2/6/14	Wed 2/12/14
8	2.3 Literature Review	18 days	Mon 2/10/14	Wed 3/5/14
9	2.4 Research on Previous Study	18 days	Mon 2/10/14	Wed 3/5/14
10	2.5 Identify Problem Statements	18 days	Mon 2/10/14	Wed 3/5/14
11	2.6 Identify the Objectives	18 days	Mon 2/10/14	Wed 3/5/14
12	2.7 Determine the Scope of Study	18 days	Mon 2/10/14	Wed 3/5/14
13	2.8 Determine the Research Methodology	18 days	Mon 2/10/14	Wed 3/5/14
14	2.9 Design the System Flow	3 days	Thu 2/13/14	Mon 2/17/14
15	2.10 Quick Design of User Interface	3 days	Thu 2/13/14	Mon 2/17/14
16	2.11 Submission of Extended Proposal	1 day	Wed 2/19/14	Wed 2/19/14
17	2.13 Preparation Viva : FYP1 Presentation	4 days	Thu 3/6/14	Tue 3/11/14
18	2.12 Viva : FYP1 Presentation	1 day	Wed 3/12/14	Wed 3/12/14
19	2.13 Update Proposal	12 days	Thu 3/13/14	Fri 3/28/14
20	2.14 Finalize Proposal	7 days	Mon 3/31/14	Tue 4/8/14
21	2.15 Submission of Interim Report	1 day	Wed 4/9/14	Wed 4/9/14

Figure 3.5: Gantt Chart

3.8 Used Tools

Table 3.1: The Tools Used to Build Gas Hydrate Mobile Application

Hardware	**Software**
• Personal computer • Smart phone	• App Inventor 2 • Google Fusion Table

Chapter 4: Result and Discussion

4.1 User Interface

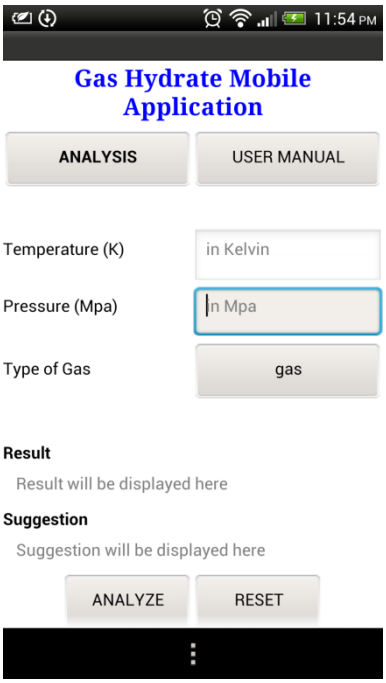


Figure 4.1: The Interface for Parameters Input

This is the page where the user will need to key in the temperature value of the pipeline in Kelvin, the pressure in Mega Pascal and also the type of gas to be tested. Then, the user will click on the analyze button in order to get the result whether the pipeline is in the gas hydrate risk zone or not.

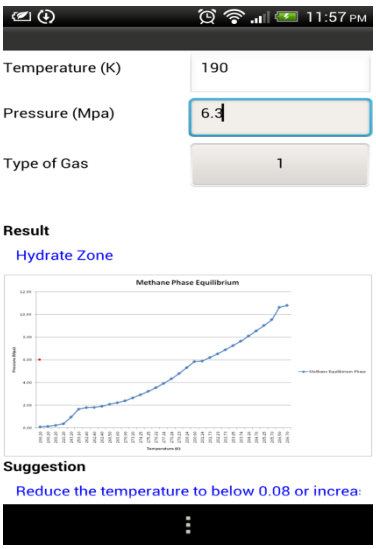


Figure 4.2: The Interface for Result

After the analyze button has been clicked, the mobile application will process the values and do the comparison based on the database in the Google fusion table. It will display the result either ‘Hydrate Zone’ or ‘Non-Hydrate Zone’. Then, it will also display the graph where the point is plotted based on the user input and lastly it will include the suggestion either to maintain or improve the condition of the pipeline in order to avoid the gas hydrate formation

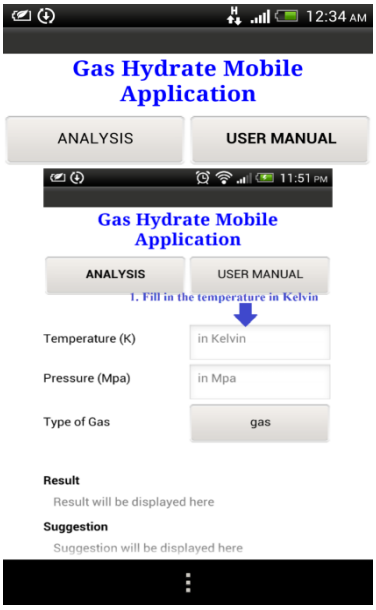


Figure 4.3: The Interface for User’s Manual

The user’s manual is the step-by-step tutorial on how to use the mobile application from the key in of input and up till the display of results.

Gas hydrate mobile application involved two types of user that will use this application which are engineers and researchers. However, both of them will be using the application in the same way.

4.2 System Flow

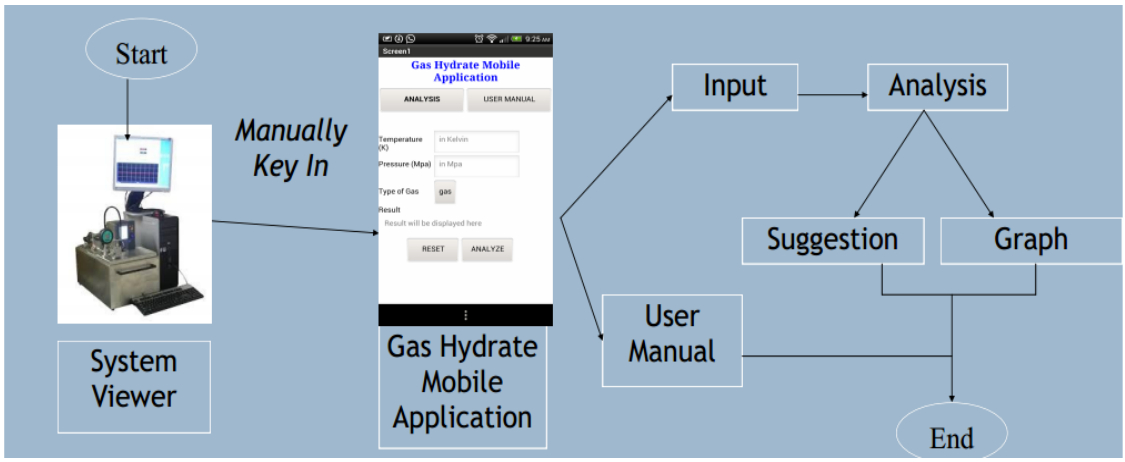


Figure 4.4: System Flow for Gas Hydrate Mobile Application

Figure 4.4 shows the system flow for gas hydrate mobile application. The process will start when users can refer the current condition of the pipeline based on the system viewer. Next, they will open the mobile application through their smart phones. Users will be brought to the page where they need to key in the parameters and they will click the analysis button. Then, it will display the result which consist of the graph based on the input that has been keyed in and also suggestion to maintain or improve the current condition of the pipeline. If user would like to set all input back to default, they can just click on the reset button. Lastly, any user having difficulty in understanding the mobile application can refer to the user manual's page.

4.3 Discussion of Results and Findings

4.3.1 Interview Results & Findings

Informal interviews have been conducted with several types of users such as engineer, lecturer and students. The purpose of the interview is to gain understanding about gas hydrate, to find the significance of having the mobile application and to identify the features need to be included in the mobile application.

According to the respondents of the interview, gas hydrate is a solid that based on the gas and water. Most of the respondents are focusing more on research of gas hydrate. For them, it will be very useful to have the gas hydrate mobile application because it will reduce the time taken for estimating the occurrence of the gas hydrate in their area of research. They have mentioned to have a result in graph in order to have better understanding about the condition of the gas hydrate formation.

As for the method in determining the occurrence of gas hydrate, the lecturer of Petroleum Engineering in UTP, Madam Mazuin Jasamai has suggested to use range of values based on the fixed equilibrium line of the natural gas graph. This is the best way as it could provide the highest accuracy of the result.

Based on the interview results, the gas hydrate mobile application will provide solutions to improve the process of estimating the occurrence of the gas hydrate.

4.4 Development Stage

4.4.1 Development of Equilibrium Phase Line of Natural Gas

The equilibrium phase line of natural gas is used in order to determine whether the pressure and temperature of the current pipeline is in the gas hydrate zone or non-gas hydrate zone. The development of the equilibrium phase line is by using the range of values of temperature (Kelvin) and pressure (Mega Pascal) of the gas based on the line. Those values are gained from the different scholars (Roberts et al (1940); Makagon and Sloan (1994); Deaton and Frost (1946); Nakamura et al (2000)).

Table 4.1: The values of Methane phase equilibrium line from different scholars.

Scholar/s (Year)	Temperature (K)	Pressure (MPa)
Roberts et al (1940)	259.10	1.65
	273.20	2.64
	280.90	5.85
	286.50	10.63
	286.70	10.80
Deaton and Frost (1946)	262.40	1.79
	262.20	1.90
	266.50	2.08
	268.60	2.22
Makagon and Sloan (1994)	190.20	0.08
	198.20	0.13
	208.20	0.22
	218.20	0.36
	243.20	0.96
	262.40	1.80
Nakamura et al (2000)	274.25	2.92
	275.25	3.22
	276.22	3.55
	277.24	3.92
	278.24	4.33
	279.23	4.79

	280.24	5.31
	281.24	5.89
	281.73	6.2
	282.23	6.53
	282.73	6.88
	283.25	7.25
	283.74	7.65
	284.26	8.1
	284.76	8.55
	285.25	9.03
	285.78	9.54

The values mentioned by different scholars will then be integrated. Those values will be filtered from the smallest pressure and temperature of the gas to the largest. Next, the value will be associated into the Google Fusion Table in order to generate the equilibrium phase line.

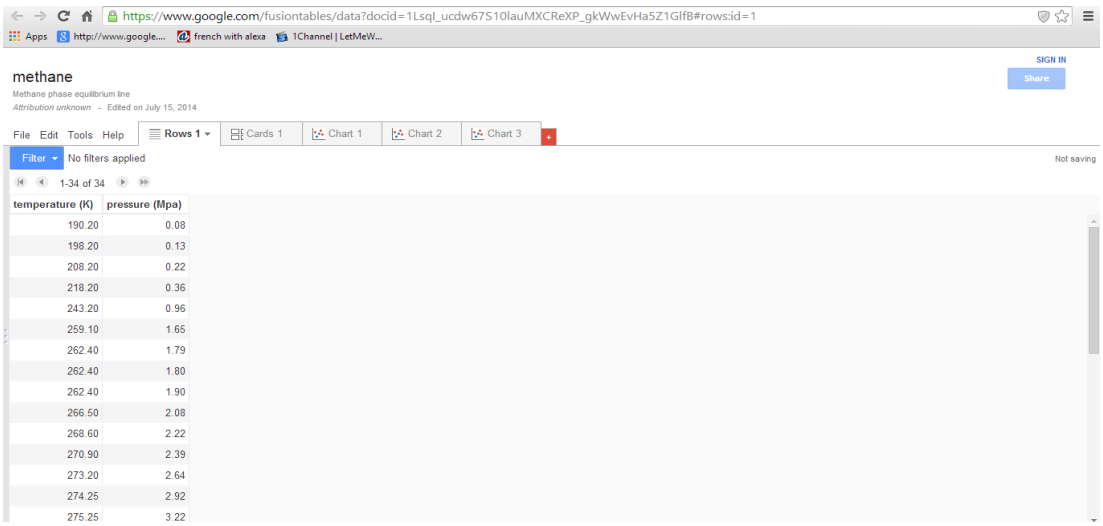


Figure 4.5: The values of gas equilibrium line in the Google Fusion Table

Once the values have been integrated into the Google Fusion Table, the process of generating the graph will be continued by creating a chart in the platform.

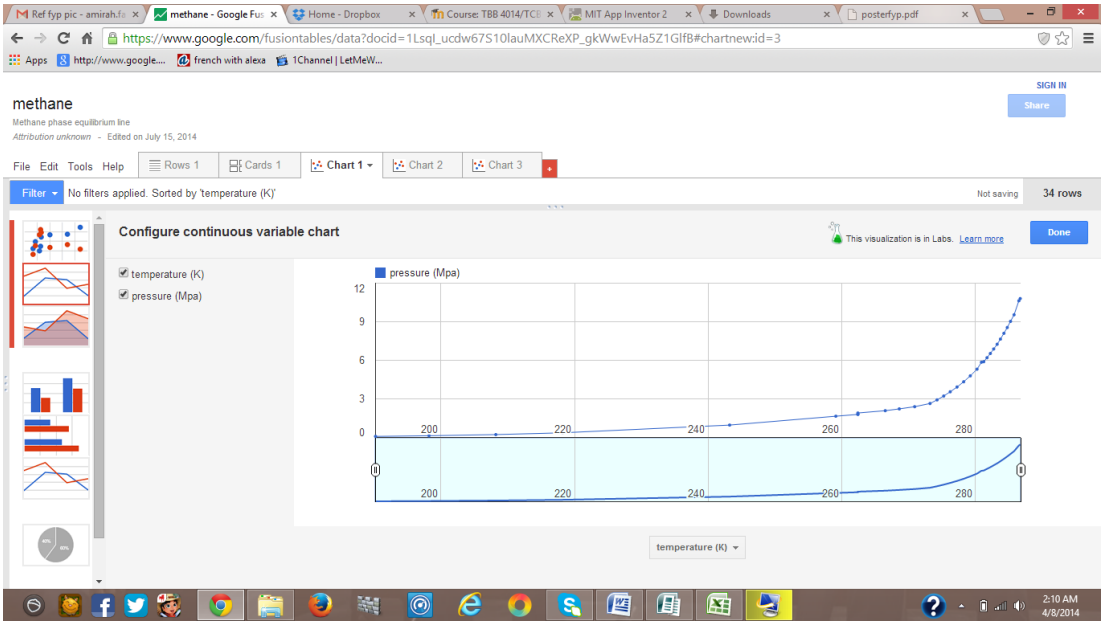


Figure 4.6: The graph of the equilibrium phase line of methane

4.4.2 Development of Gas Hydrate Mobile Application

Based on the values and chart in the Google Fusion Table, a set of rules has been created in order to link the fusion table with the MIT App Inventor 2. Below is the example of rules for the gas of type Methane:

- If the temperature is below 190.20 K, it is a non-gas hydrate zone.
- Else if the temperature is within 190.20 K to 286.70, the pressure will be compare with the values to determine the gas hydrate occurrence.
- Else, it is a non-gas hydrate zone.

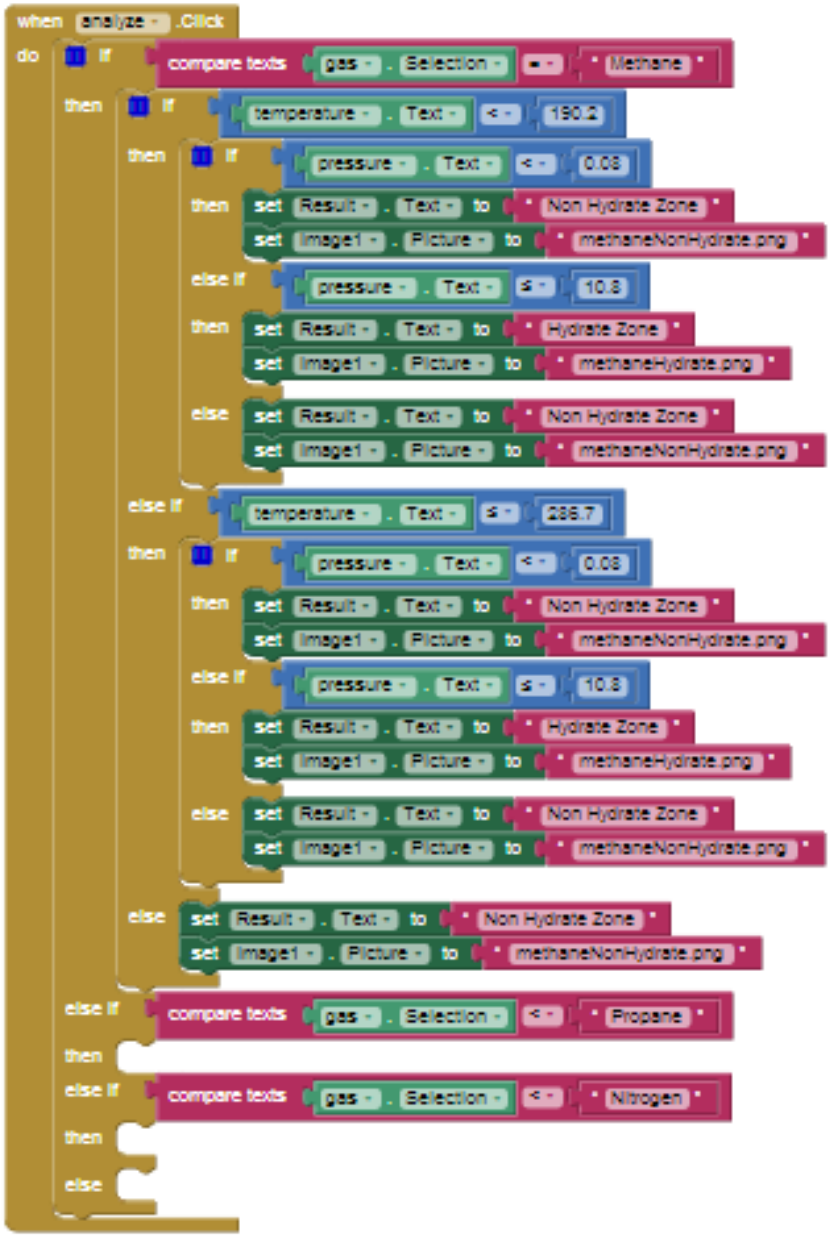


Figure 4.7: The coding for the methane gas.

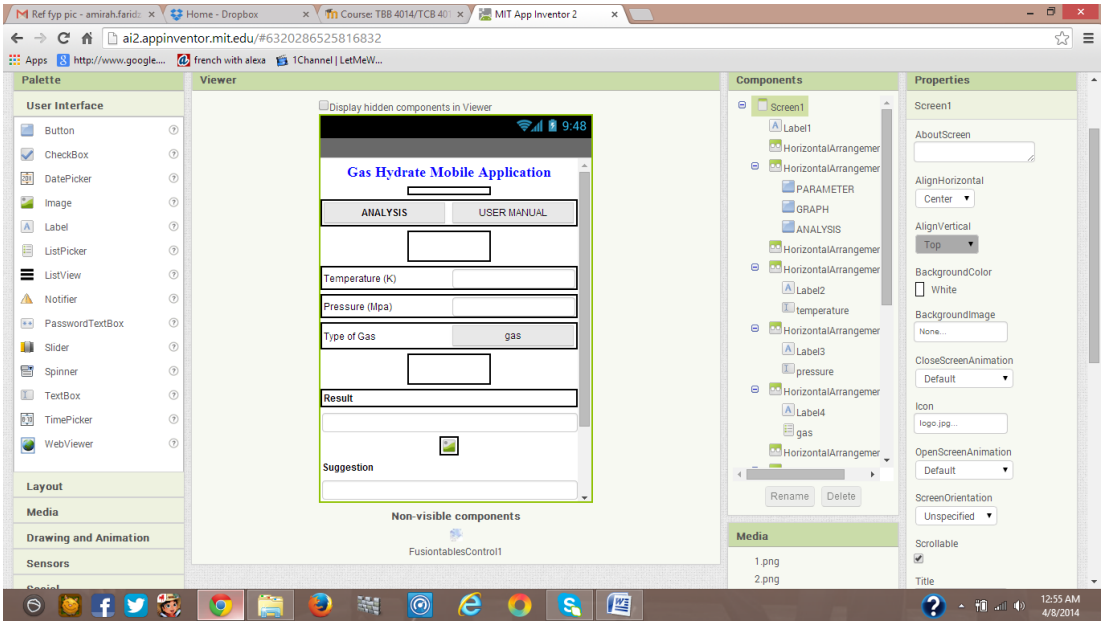


Figure 4.5: The snapshot of the MIT App Inventor

4.5 Implementation and Testing Stage

4.4.1 Implementation Stage

Implementation has been done by distributing the app to the five potential users. The users are selected among the engineers, petroleum engineering experts and students. The users are given a week to test the app.

4.4.2 System Testing

The system testing was done by the petroleum engineering experts. They received the a few values of the pressure and temperature to test whether the app will produce the exact output or not based on the output from the pipeline. The objective of this testing is to check on the accuracy of the application.

Table 4.2: Result of System Testing

Pressure (Mpa)	Temperature (K)	Expected Result	Testing Result
190.1	0.06	Non-Gas Hydrate	Non-Gas Hydrate
185.3	6.00	Gas Hydrate	Gas Hydrate
172.0	12.00	Non-Gas Hydrate	Non-Gas Hydrate
260.2	1.00	Non-Gas Hydrate	Non-Gas Hydrate
270.0	6.20	Gas Hydrate	Gas Hydrate
290.0	11.50	Non-Gas Hydrate	Non-Gas Hydrate

4.4.3 Usability Testing

The usability testing was done by interviewing or collecting feedback from the users. The purpose of this testing is to know feedback from the users about the gas hydrate mobile application. Based on the testing's result, it shows that most users said that the app helps to save the time in determining the occurrence of gas hydrate. This is because it helps to cut off the amount to access the gas hydrate software in the laptop or computer. They can just simply use their smart phones which are more convenient.

Chapter 5: Conclusion and Recommendation

5.1 Relevancy to the Objective

5.1.2 Identification of the Technique to Determine the Occurrence of Gas Hydrate

The appropriate technique to be embedded into the mobile application has been identified which is by using the list of values on the phase equilibrium line (Roberts et. al. (19940); Deaton and Frost (1946); Makagon and Sloan (1994); Nakamura et. al. (2000)). The values gathered from the scholars has been integrated to be in one list. The list is then being verified by the Petroleum Engineering expert. The list of values then is stores in the Google Fusion Table and the equilibrium fixed graph is developed. The chart is used to make a comparison whether the input values from the user lead to the gas hydrate formation or not.

5.1.2 The mobile application could facilitate the process of determining the gas hydrate formation

Before the gas hydrate mobile application is being developed, the engineers or researchers cannot have a quick analysis to determine the gas hydrate formation. They need to bring the raw data from the system viewer to the office and manually key in the data. By the time they have determine the gas hydrate formation, the amount of gas hydrate formed will increase. Thus, the mobile application helps the engineers and researchers to have an instant analysis on the gas hydrate formation.

5.1.3 Accuracy of the mobile application has been validated through system testing with experts

The accuracy of the mobile application is very important as the gas hydrate formed in the pipeline could lead to a blockage and reduce the productivity of the pipeline. The system testing is done in order to test the accuracy of the mobile application. The testing is done by the petroleum engineering experts by using the values generated from a prototype of pipeline in a lab. The result has proven that the gas hydrate mobile application is very accurate.

5.2 Suggested Future Work

5.2.1 Include another Three Types of Natural Gas

Due to the time constraint, the three type of natural gas which are Propane, Nitrogen and Carbon Dioxide cannot be included as per planned. Thus, these gases can be added for the future work and also will increase the variety and reliability of the mobile application.

5.2.2 Auto Key-In of the Parameter

Currently, the engineers and researchers need to manually key in the parameter to the gas hydrate mobile application. The auto key-in features can be done by connected to the system viewer of the pipeline. This will help the users to save more time for the analysis purposes and reduce the human error when key in the input.

5.2.3 Adding "Type of Inhibitor" as a Parameter

Inhibitor is used during the mitigation plan on removing the gas hydrate. By adding another parameter which is "Type of Inhibitor" will help the engineers and researchers to know whether their mitigation plan is successful or not.

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