Real Time Pigging Monitoring System

by

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CERTIFICATION OF APPROVAL

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Approved by,

(Mr. Low Tan Jung)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
December 2006

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.

DYG MISHA FAZLYIANA ABG MASAGUS

ABSTRACT

A Pipeline Inspection Gauge or PIG in the pipeline industry is a tool that is sent down a pipeline and propelled by the pressure of the product in the pipeline itself. It is the chief tool used in pigging. This project is called Real Time Pigging Monitoring System, a monitoring system for monitor the progress of a PIG through a pipeline which often to a high degree of accuracy in order to maintain the stability of the pipeline.

ACKNOWLEDGEMENT

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I like to convey my gratitude and appreciation to Mr Low Tan Jung, who has been patient in sharing his professional thought, guidance, endless support, advice and constructive comments in helping me to complete this research report.

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ABBREVIATIONS

PIG	Pipeline Inspection Gauge
TBMS	Time-Based Marker System
GPS	Global Positioning System
CDI	Control Devices, Incorporated

CHAPTER 1

INTRODUCTION

1.1 Background

Pipe pigging is the propelling of a flexible elastomer projectile called a pig through a piping system. The pig can be driven with plant air, nitrogen gas, or a liquid medium such as another product, water, or a clean-in-place solution, depending upon the process requirements. The term "pig" comes from the fact that when a product line carrying a product with poor lubricating qualities, this lack of lubrication causes the projectile to squeal like a pig [3].

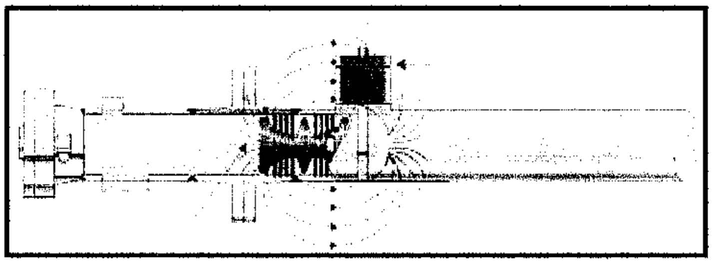


Figure 1 : Installation and Mounting of Sensors

As operations change with time, and the system remains fixed, problems can unfold. A survey of the pigging system and its operation can quite often result in improved performance merely by addressing pig design, thus avoiding expensive piping modifications. Often an existing system will have pipe or tubing of one ID, hose of another ID, and couplings of still another ID. In this case, open cell foam pigs are usually pressed into service as a one-size-fits-all-type answer to the problem. However, the open cell foam pig soaks up product, looses its structural integrity and its life is limited. In this case, a closed cell urethane pig, which has architecture with small diameter guide discs and sufficient diameter wiping discs, will greatly improve the overall pigging operation.

At times, a survey can uncover a situation where the plant air filter regulators used for launching the pigs have been undersized, forcing the operators to boost the pressure higher than required in an attempt to compensate for the lack of sufficient volume. Again, this is not a serious problem as filter regulators are relatively inexpensive. The correct pressure with sufficient volume of drive gas gives operations the best pig velocity control. This is most important on the return run for bi-directional systems, where the pig is in a gas to gas situation. Generally the operation should drive the pig at three to five feet per second during the fluid displacement run, and to extend pig life, no more than five to seven feet per second on the return run to home station.

1.2 Problem Statement

There are essentially two reasons to use a pipeline pig monitoring system .First is that a firm wishes to monitor the progress of a pig through a pipeline which often to a high degree of accuracy. The other is that a pig has become lodged with the operator having only a vague idea of where it is and must be located quickly.

1.3 Objective of Study

The objective of this study is to develop a simulation of a wireless system that can eliminate, or at least reduce the problems of monitoring pigging system as mentioned above. This project should be able to solve the problem of positioning and human labour consumption in mobile advertisement system.

1.4 Scope of study

1. **To know precisely where the pig are at all time.** When a pig become stuck or lodged due to an obstruction, the pipeline must be taken out of service and the point of obstruction located and cleared. This down time could result in hundreds of thousands of dollar/ringgit in lost revenue for every day the line is out of service.

2. **Intelligent pigs collect data as to the integrity or performance of the pipeline (such as diameter measurement/geometry, corrosion detection and leak detection).** With accurate pig location information, then can use the information from the ultrasonic sensor to observe the thickness of the pipe to know if there is any 'pitting' or corroded area in the pipe and cleanliness of the line.

3. By having this data, **the operator or the engineer can predict the range of time for the pipeline to maintain the stability of the pipeline.** This is due to the operation cost which is quite high and if the pig can detect any defect area throughout the pipeline, the operation cost can be reduced. And if the problems do not being detected earlier, it might create environmental problem such as oil spill. The company then has to pay more for the compound from the government for violates the environment.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 Related Works

This chapter will comprise of three (3) parts. The first part will describe about a case study by Jason A. Farqué which I felt most related to describe my project. The second part will describe New Marker System Combines - Advantages of TBMS and GPS by Norbert Thielager which I extracted as this article will explain how the technology advances help in enhancing the data transmission for pigging process in oil and gas industry. The last part will describe about Wireless Sensor Network (WSN).

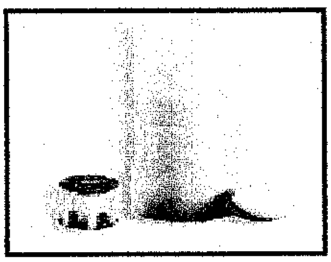
2.1.1 Case Study – CD42 Pig Location & Tracking System

According to Jason A. Farqué [4] – Vice President and Chief Programmer for C.D.I:

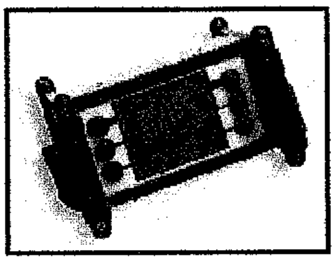
> *There are essentially two reasons to use a pipeline pig locator and tracker. One is that a firm or individual (the operator) wishes to monitor the progress of a pig through a pipeline, often to a high degree of accuracy. The other is that a pig has become lodged, with the operator having only a vague idea of where it is, and must be located quickly.*

Through a brief description of the instrument and a case study, this article discusses pig tracking and location with this modern equipment, and how it serves the needs of the pipeline field hand while producing information valuable to the pipeline owners and operators.

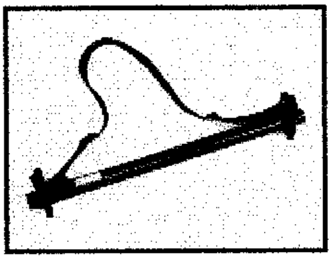
The CD42 is a computerized instrument consisting of a rugged, waterproof, computerized chassis, two receiving antennas (CD42-GP and CD42-LR) and a transmitter (CD42-T1).



Transmitter (CD42-T1)
Figure 2



Receiver + GUI
Figure 3



Antenna (CD42-GP
Figure 4

The transmitter will be inserted into foam pigs or mounted onto metal-bodied pigs. Receiving antenna orientation to the pipeline is very important to signal reception. Orienting an antenna either parallel or perpendicular to the transmitter produces two very different results.

As the pig travels through the pipeline toward an antenna placed parallel to the transmitter, the signal strength gradually increases peaks and then fades away when the transmitter passes as one would expect. However, with the antenna placed perpendicular to the pipeline, the signal gradually increases as the transmitter approaches, diminishes suddenly to zero when the transmitter and antenna are perfectly perpendicular to one another, increases again and then gradually fades as the transmitter moves away. Parallel orientation is useful to quickly find the rough location of a pig by walking along the line, or to observe a pig move by through the line. Perpendicular orientation gives the precise location of a pig through a procedure known as "nulling". Pointing directly at a transmitter in a pipeline with the antenna held perpendicular will give zero signals, but moving only one or two inches in either direction will cause pulses to appear on the display. By pointing at the pipeline and causing the signal to appear to be zero, the operator can know a pig's location to the nearest inch while it's in the pipeline.

For this case study (DIS GellyPIG), two CD42-T1 transmitters were used. The leading pig, once equipped with its transmitter, was loaded into the trap. The trap was closed and the pig was pushed forward into the line with solvent gels. DIS then used CDI's equipment and the process of nulling described above to determine whether the pig had traveled far enough out of the trap for the loading of the next pig. This process took less than one minute, and verified that the pig was indeed located several yards down line from the trap. DIS then continued to pump gels and solvents and to load pigs for the remainder of the day. The final transmitter equipped pig was launched at around 10:00pm that evening. For approximately two days DIS tracked both the leading and trailing pigs through the brush of Texas, monitoring their progress and keeping tabs on the volume of gel between the pigs. The process of tracking in this manner if often referred to as "leapfrogging" the pig, and is quite a common practice.

Sophisticated equipment that helps men in the field get their jobs done quickly does not have to be difficult to use. The CD42 uses a six button interface and simple icon driven menus to visually prompt the operator through the functions. The equipment is suited equally well to tracking and locating, can be left completely unmanned, and has the ability to record, count, print and display what it sees. By virtue of the LCD display's panning mode, the operator sees many transmitter pulses on the screen simultaneously, allowing him to see trends in the signal that tell him whether the pig is coming toward him, retreating away from him, or is stationary.

Features of CD42:

- The CD42-GP (General Purpose - antenna) allows CD42 to reject almost all of this unavoidable interference, and for the first time with any system allow the operator to walk the pipeline at a normal, continuous pace while tracking or locating a pig.
- The CD42-LR (Long Range - antenna) is used when geography, groundcover or a combination of the two, prohibit access to the pipeline closer than the 50 foot range of the CD42-GP. The CD42-LR is incredibly sensitive, detecting electric signals as slight as 0.00025 millivolts, which is quite easily generated by movement within the earth's magnetic field. This sensitivity is a tradeoff; however, because the CD42-LR antenna must be held perfectly still to be used. This balance of high sensitivity vs.
- Mobile versatility is the reason that two receiving antennas were created for the CD42 System.

2.1.2 New Marker System Combines - Advantages of TBMS and GPS

Pipetronix started the year 1996 with the introduction of the new Time-Based Marker System (TBMS).In co-operation with CDI of Tulsa, USA, the equipment used so far, consisting of generator, coils, batteries and connecting lines was replaced by a handy system, the so-called Pig Trip Box [5].

This box is positioned on the pipeline and records a pig's passage time with the precision of the GPS (Global Positioning System) atomic clocks. This satellite navigation system, available throughout the world, not only supplies the exact time, but also the position of the marker point. The electromagnetic trigger signal is recorded and subsequently interpreted on a laptop computer (see figure). Due to the characteristic shape of the signals received from the pig, they can easily be distinguished from spurious signals.

After the pig run, the time of passage is correlated to the time in the measured data of the pig. As the high-precision clock in the pig is synchronized with the GPS clock before the pig run, the marker point can be unambiguously related to the measured data.

The Pig Trip Box is watertight, robust and easy to operate. All functions are available by means of two buttons. An LCD display constantly informs the operator of the status of the unit. Pig passages are moreover indicated optically and acoustically.

Owing to the use of the GPS time, drift problems are of no importance. The batteries are designed so that the Pig Trip Box can be brought to the pipeline as early as 30 days before the pig run takes place. In this way, marker points that are difficult to reach do not have to be called at during the pig run, probably at night. Markering organization is made considerably easier, it is no longer necessary to assign a large number of marker crews. Even after 30 days in the field, a marker point can still be related to the measured data with an accuracy of ± 1.5 m.

The individual Pig Trip Boxes can be prepared at any moment and independent of the pig, as all boxes and the pig are synchronized with the GPS which is constantly available throughout the world.

Marker points and measured data too, can be related at any moment after the pig run. It is not necessary to read out all boxes at the same time as the measured data. Therefore the data can be checked after the pig run independently of reading-out of the marker data. The advantages and features of the Pipetronix TBMS at a glance:

- easy operation
- ready for use for 30 days
- suitable for all types of pigs
- high locating accuracy
- decentralized synchronization process
- marker data can be read out decentrally
- easy distinction between pig signals and spurious signals
- location coordinates of the marker points are available
- pig tracking unnecessary
- one single positioning for several pig runs
- up to 25 passages can be recorded

2.1.3 Wireless Sensor Architecture

As for this project it will definitely used sensors and it will create a group of pig processing simultaneously. Thus, I am using Wireless Sensor Architecture to describe what will happen within the data transmission form the receiver to the transmitter will create topology changes as nodes move through the network.

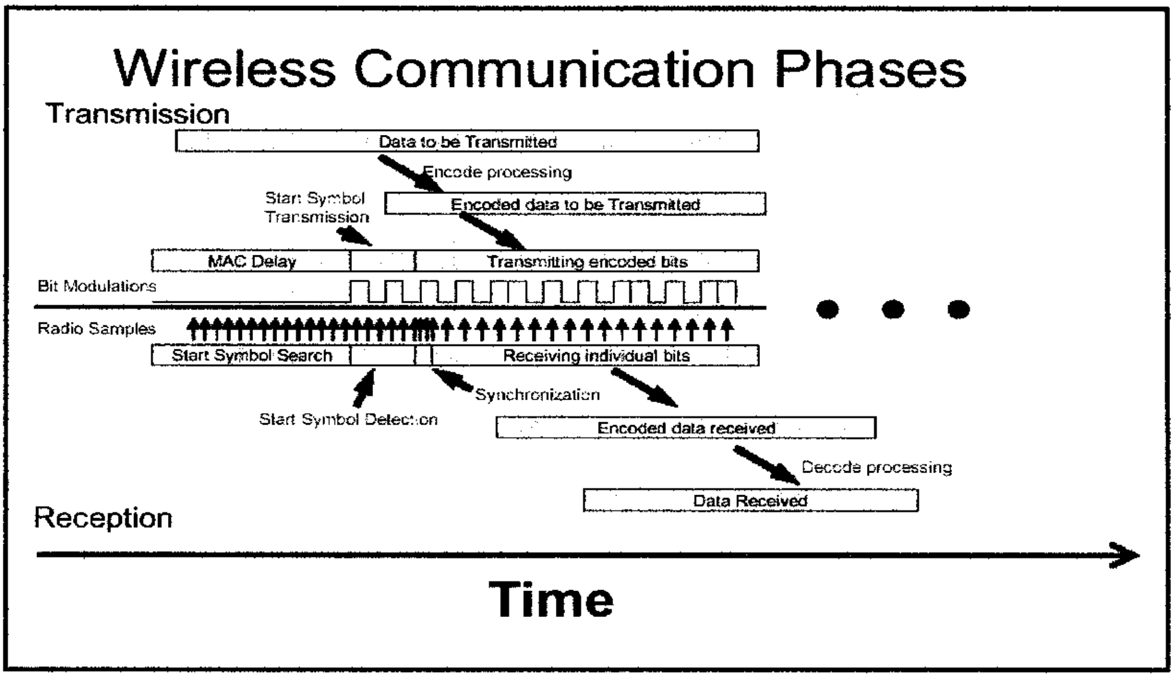


Figure 5: Phases of Wireless Communication for Transmission and Reception

According to Dr Jason Lester Hill [6], the concept of Wireless Sensor Network is based on simple equation:

$$Sensing + CPU + Radio = Thousand\ of\ Potential\ Application$$

With wireless sensor networks, objects can be tracked by simply tagging them with a small sensor node. The sensor node will be tracked as it moves through a field of sensor nodes that are deployed in the environment at known locations. Instead of sensing environmental data, these nodes will be deployed to sense the RF messages of the nodes attached to various objects. The nodes can be used as active tags that announce nodes attached to various objects. The nodes can be used as active tags that announce the presence of a device. A database can be used to record the location of tracked objects relative to the set of nodes at known locations. With this system, it becomes possible to ask where an object is currently, not simply where it was last scanned. The key evaluation metrics for wireless sensor networks are lifetime, coverage, cost and ease of deployment, response time, temporal accuracy, security, and effective sample rate.

2.2 System Description

This system is to detect location of the current processes and stuck pig. Figure below shows the pigging process whereby the pigging will be started from the satellite platform or from the mother platform. Under high pressure, the pig will travel along the pipeline until it reaches the destination – the crude oil terminal (See Figure 6)

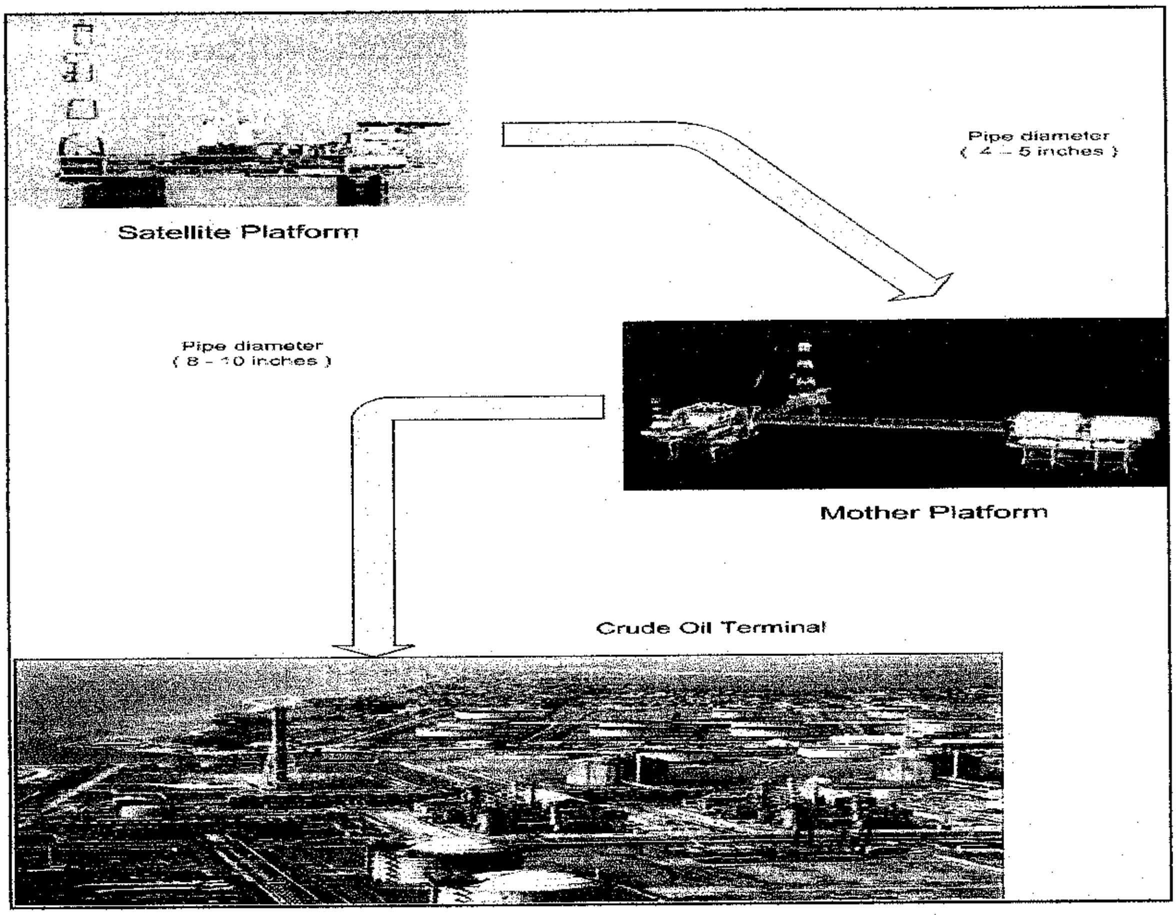


Figure 6: Pigging Process

But, as stated before, the pigs are prone to stuck in the middle of the cleaning process. The main components and operation sequence of the proposed system are illustrated in Figure 7:

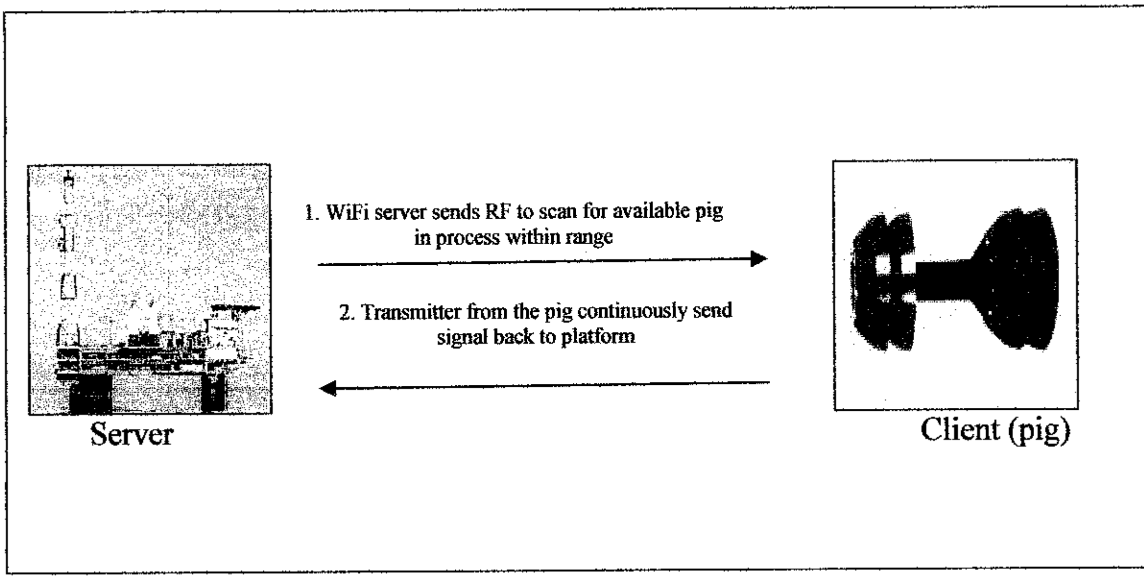


Figure 7: Real Time Pigging Monitoring system architecture

The main components and operations sequence of proposed Real Time Pigging Monitoring system are as follows.

1. The pig launched and transmitter/receiver are mounted into the pig
2. The WiFi server then will send RF to scan for available pig in process within range.
3. The transmitter inside the pig will continuously send signal back to the server to indicate its current location.
4. Receiver at the server display the information to the user through appropriate user interface

This system consists of two modules – client and server. One server should be able to connect to several clients simultaneously at any given time and it can start searching for available pigs that is currently in the processes.

On the client side, once the client is up or in this study – the pig being launched and running, the pig can continuously sending signal to the server to indicate its current location. The search process includes both device and service discovering. The device search is done for preknown and cached locations, meaning that the server has the basic location of the clients beforehand.

There are also some problems that might occur in this process which is the attenuation of the signal. Thus, beforehand, repeater or amplifier is being located along the pipes to strengthen the signals so that it wont lost within its signal transmission.

Result of the searching process is a list of available pigs in process. Server can view the location by calculating the range of the signals that being transmitted by the pigs.

This system can be both user-driven and not user- driver (automated), the user can be either automated the data gathering process or retrieved it when necessary. This system has three important features. It is wireless, accurate, and real time.

CHAPTER 3

METHODOLOGY

In this section, I will explain two main methodologies, research and design methodologies. Research methodology addresses the method used in gathering data for the study. Design methodology discusses the methods used in developing the prototype.

3.1 Research Methodology

3.1.1 Questionnaire

Questionnaires are an inexpensive way to gather data from a potentially large number of respondents. Often they are the only feasible way to reach a number of reviewers large enough to allow statistically analysis of the results. A well-designed questionnaire that is used effectively can gather information on both the overall performance of the test system as well as information on specific components of the system. If the questionnaire includes demographic questions on the participants, they can be used to correlate performance and satisfaction with the test system among different groups of users.

Although questionnaires may be cheap to administer compared to other data collection methods, they are every bit as expensive in terms of design time and interpretation.

Questionnaires are easy to administer confidentially. Often confidentiality is the necessary to ensure participants will respond honestly if at all. Examples of such cases would include studies that need to ask embarrassing questions about private or personal behavior.

3.1.2 Objective of the survey

The importance of well-defined objectives can not be over emphasized. A questionnaire that is written without a clear goal and purpose is inevitably going to overlook important issues and waste participants' time by asking useless questions. The questionnaire may lack a logical flow and thereby cause the participant to lose interest. Consequential, what useful data you may have collected could be further compromised. The problems of a poorly defined questionnaire do not end here, but continue on to the analysis stage. It is difficult to imagine identifying a problem and its cause, let alone its solution, from responses to broad and generalizing questions. In other words, how would it be possible to reach insightful conclusions if one didn't actually know what they had been looking for or planning to observe.

So, for this project, the objectives of the survey are to find out how users interact with the process, how it is the process flow, what exactly being used/happened in the field, what problem does occurred with the current system.

Therefore, by having this information it makes the project development clearer of its objective and the process flow.

3.2 Design Methodology

3.2.1 Incremental Development and Release

Developing systems through incremental release requires first providing essential operating functions, then providing system users with improved and more capable versions of a system at regular intervals. This model combines the classic software life cycle with iterative enhancement at the level of system development organization. It also supports a strategy to periodically distribute software maintenance updates and services to dispersed user communities. This in turn accommodates the provision of standard software maintenance contracts. It is therefore suitable for this project. This approach will also been extended through the use of software prototyping tools and techniques which more directly provide support for incremental development and iterative release for early and ongoing user feedback and evaluation. The system will be developed to enable user to feedback on the prototype during the development. A new prototype is then developed based on the feedbacks received.

3.2.2 Assembling Reusable Components

The basic approach of reusability is to configure and specialize pre-existing software components into viable application systems. Such source code components might already have associated specifications and designs associated with their implementations, as well as have been tested and certified.

There are many ways to utilize reusable software components in evolving software systems. However, the cited studies suggest their initial use during architectural or component design specification as a way to speed implementation. They might also be used for prototyping purposes if a suitable software prototyping technology is available.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Results

For this simulation, basically it will gain two results. First is the location of the current **location** of the pig in process and the **data from the pig itself** which are basically the pipe diameter and wall diameter.

4.1.1 Location Detection

As being mentioned in the previous chapter, the location will be detection by using WiFi technology. The process paths are needed to be predefined (Figure 8).

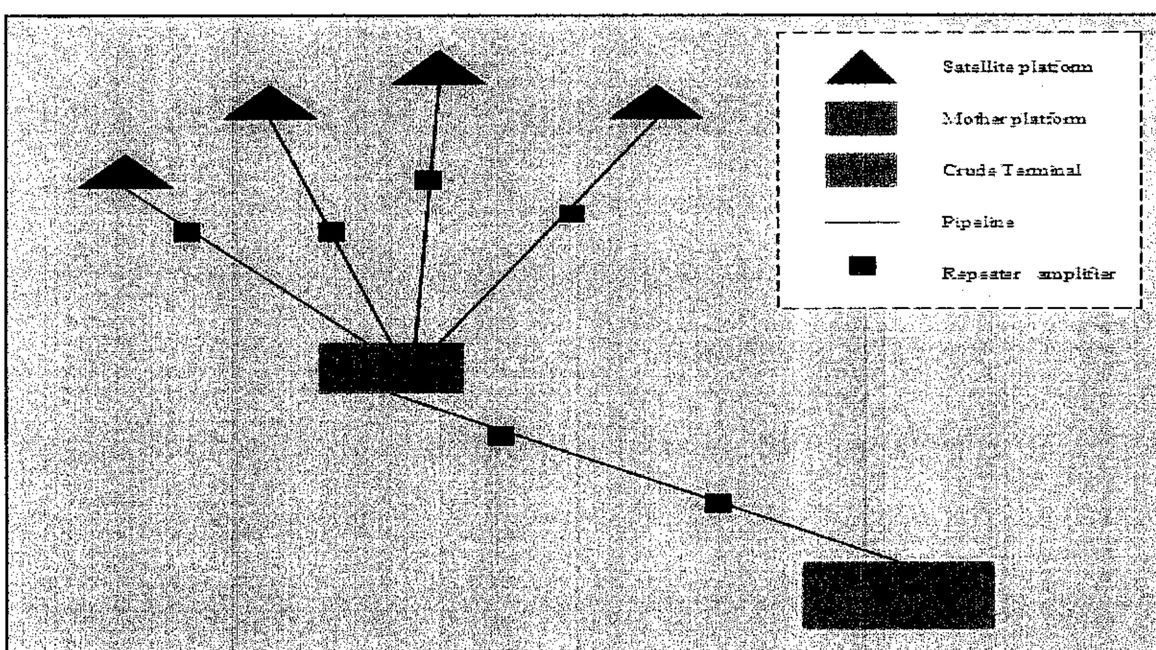


Figure 8: Predefined path in pigging process

At the pig launcher which is basically from the satellite platform, the transmitter/receiver will be mounted in the inspection pig. At the server side (situated at the mother platform), the server will sending signals in order to scan for available pigs in process (Figure 9)

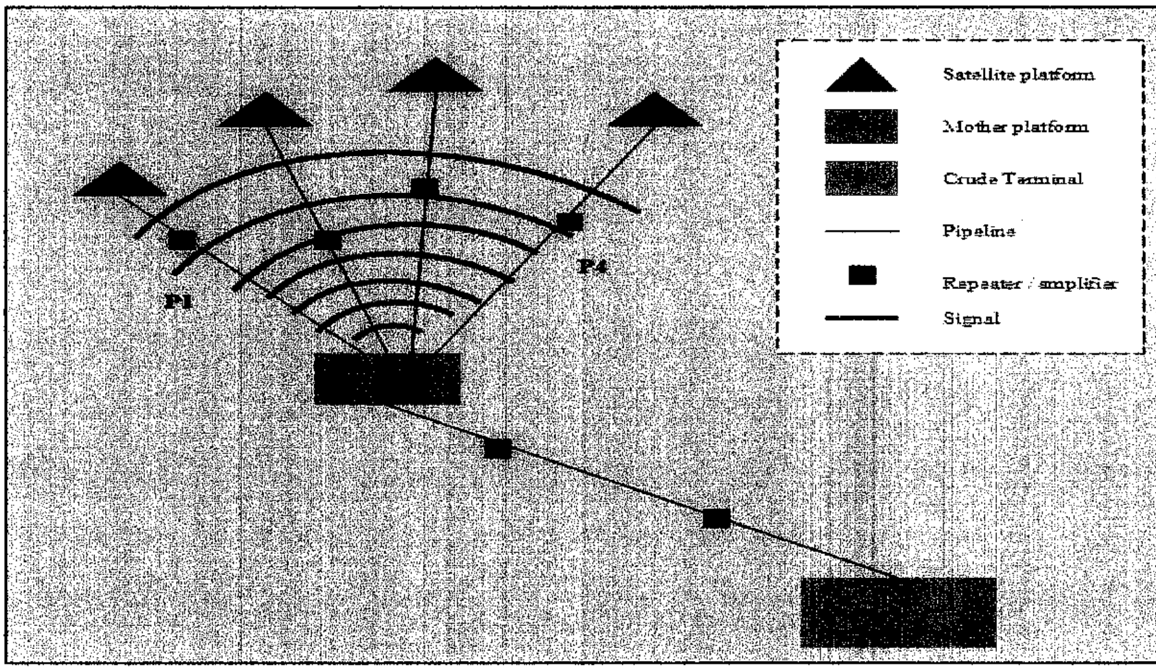


Figure 9: Server sends signal to scan for available pigs in process

As the pig passed the pig signal/sensor at the pig launcher (Figure 10) to indicate the starting point of the pigging process, the transmitter in the pig will start continuously sending signal.

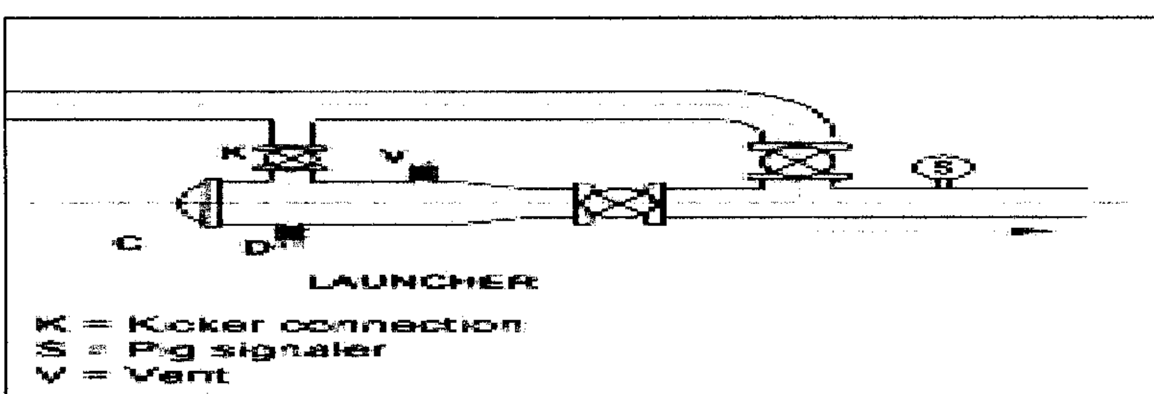


Figure 10: Pig launcher (s = pig signal/sensor/signaller)

For example, Pipeline 1 (P1) and Pipeline 4 (P4) are currently doing the pigging process, therefore, both transmitter in the pigs will continuously sending signal to the server side to show their current locations (Figure 11). We know that the signal's strength will be decreased as the distance increased, thus here is where the amplifiers/repeaters play their role, to strengthen the signals so that the signal can reach to its destination.

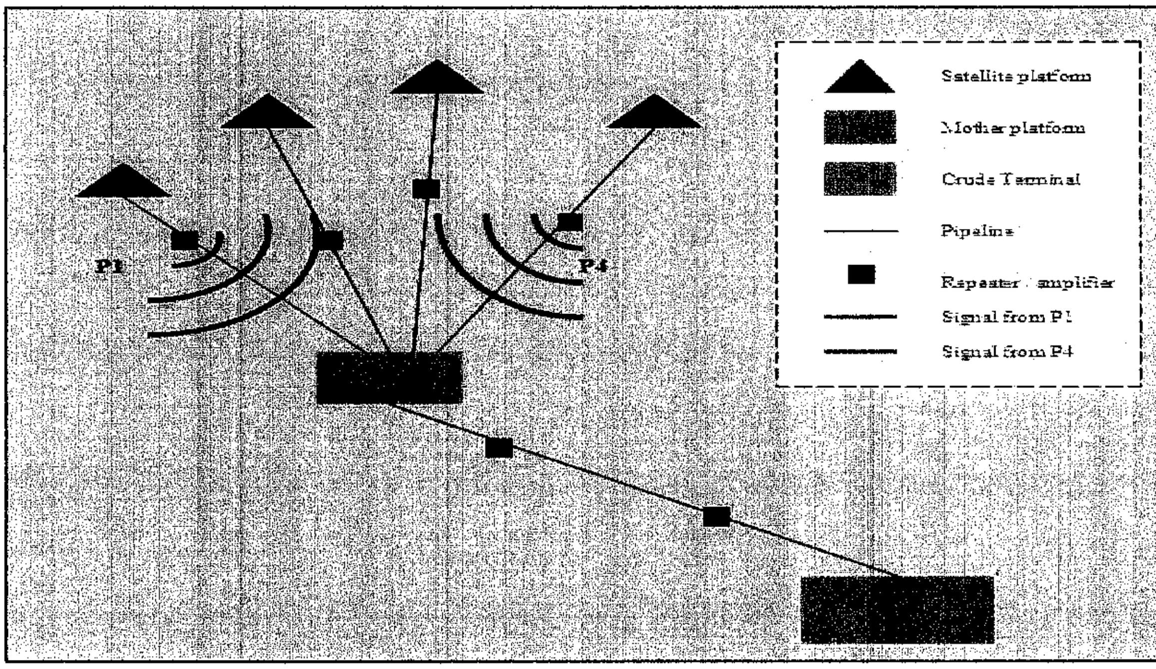


Figure11: The clients (pigs) sending signal back to server at the mother platform

Basically what we get from this process is as shown in Table 1 whereby the prediction of the current location of the pig is being calculated by knowing the strength of the signals.

Process	**Signal Strength (kHz)**	**Distance (km)**
P1		
P4		

Table 1: Signal Strength vs. Distance

4.1.2 Intelligent Data

The intelligent being mentioned here are the pipe diameter and wall thickness. Pipe thickness and damage to the pipe are measured by the ultrasonic sensors that have being mounted inside the pig itself. The data recorded can be stored in memory chips or computer disks carried on board or transmitted outside the pipe through a transmitter. The process of transmitting the data gathered is the same as the location detection transmission process which via WiFi technology.

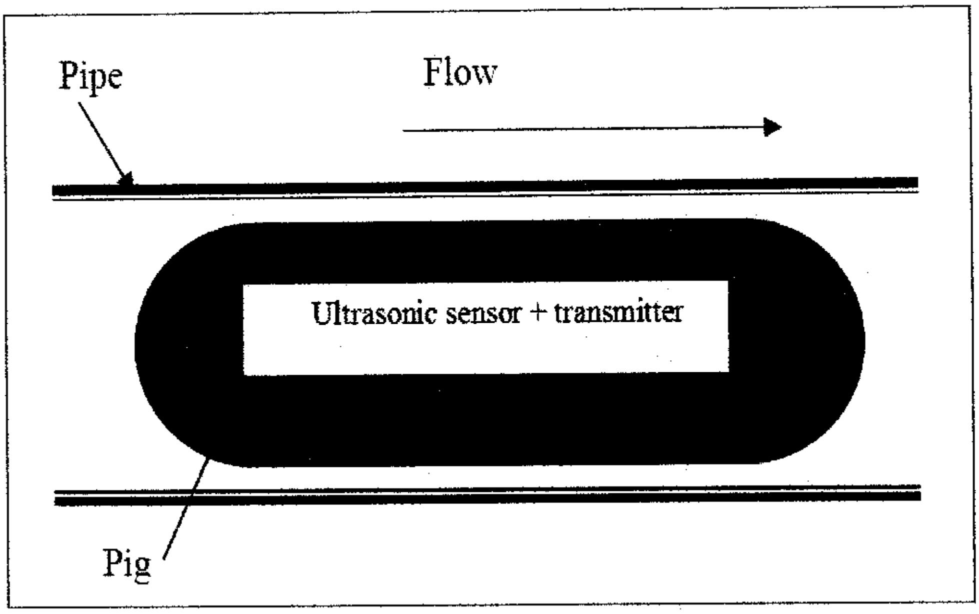


Figure12: Sensor(s) mounted in the clients (pigs)

Process	Pipe Thickness (cm)	Pipe Diameter (cm)
P1		
P4		

Table 2: Pipe thickness and diameter

These are particularly useful for inspecting old pipes and sometimes not-so-old pipes to determine how much the pipe has been affected by corrosion, erosion and other possible damage. This intelligent data, it plays an important role in modern pipeline integrity monitoring system.

4.2 Comparison of Annual Operating Cost

As for this study, I made some comparison for both conventional pipeline and pigging technology for its investment cost and annual operating cost.

Investment Cost , Conventional piping system	
Pipe material (20/m)	20 k
Erection (mainly pipe rack work, welded, 35/m)	35 k
Valves, flanges	10 k
TOTAL	65 k

Table 3: Investment Cost, Conventional piping system

Investment Cost , pigging system	
Pipe material (25/m)	25 k
Erection (mainly pipe rack work, welded, 40/m)	40 k
Valves, flanges	20 k
Higher expenditures for control equipment	20 k
TOTAL	105 k

Table 4: Investment Cost, pigging system

Operating Cost , Conventional piping system	
Cleaning agent	1.5 /m³
Loss of product	500/m³
Frequency of cleaning procedure	1 per week,50 per year
Wastewater disposal	0.5 /m³
TOC treatment and COD fees	1.00 /m³
Fractional product losses during rinsing	10 %
Pipe Content	5 m³
Filling with cleaning agent and cleaning once	15
Loss of product	250
Disposal of lost product and cleaning agent (10.5m³)	15
TOTAL	280 x 50 = 14 k

Table 5: Operating Cost, Conventional piping system

Operating Cost , pigging system	
Total pig travel	50 km/year
Pig service lifetime	20 km
3 pigs , (250 each)	750
Higher expenditures for maintenance for more complex system	2500
TOTAL	3250

Table 6: Operating Cost, pigging system

Total Cost Comparison		
	Investment Cost	Operating Cost per year
Conventional piping system	65 k	14 k
Pigging system	105 k	3.5 k

Table 7: Total Cost Comparison

** Remark: The values given are approximately to the current market value.

From this comparison , we can observed that although the pigging unit cause 40 k higher investment cost, a reduction of around 75 % in the operating cost results. Interestingly, a shorter pipeline (length 500m) also has a slightly higher P (pay out calculation) because the operating cost of pigging unit do not change greatly with the length of the pipeline and the investment cost of the conventional pipeline do not decrease proportionally. With increasing length, the P (pay out calculation) for single pipelines clearly shifts in favour of the pigging system.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

'Real-Time Pigging Monitoring System' is a technology promotes faster decision-making process for engineers and also the oil and gas community. 'Real-Time Pigging Monitoring System' increase efficiency by reducing time and effort to find information to make a decision. Hence by integrating this type of enhancement, it can improve the pig usage in oil and gas sectors in Malaysia. This system utilizes knowledge based to meet its objectives. As a whole, although there are some barriers and limitations involved, improvement and enhancement could be made to promote 'Real-Time Pigging Monitoring System' as alternative way of making decision process.

5.1 Future Work

Real-Time Pigging Monitoring System searching system needs to be made more reliable. To achieve this, the real implementation needs to be applied. Since this project can only view the simulation of the process, the real field test would be more reliable, compared to result achieved during the simulation test were some of the problem from the real environment cannot being detected.

However, a much more extensive and longer lasting user study would be needed to provide real assessment of the acceptance of changing in the oil and gas industries as it might be costly. Further, a larger scale deployment would require a thorough validation of the underlying candidate business models.

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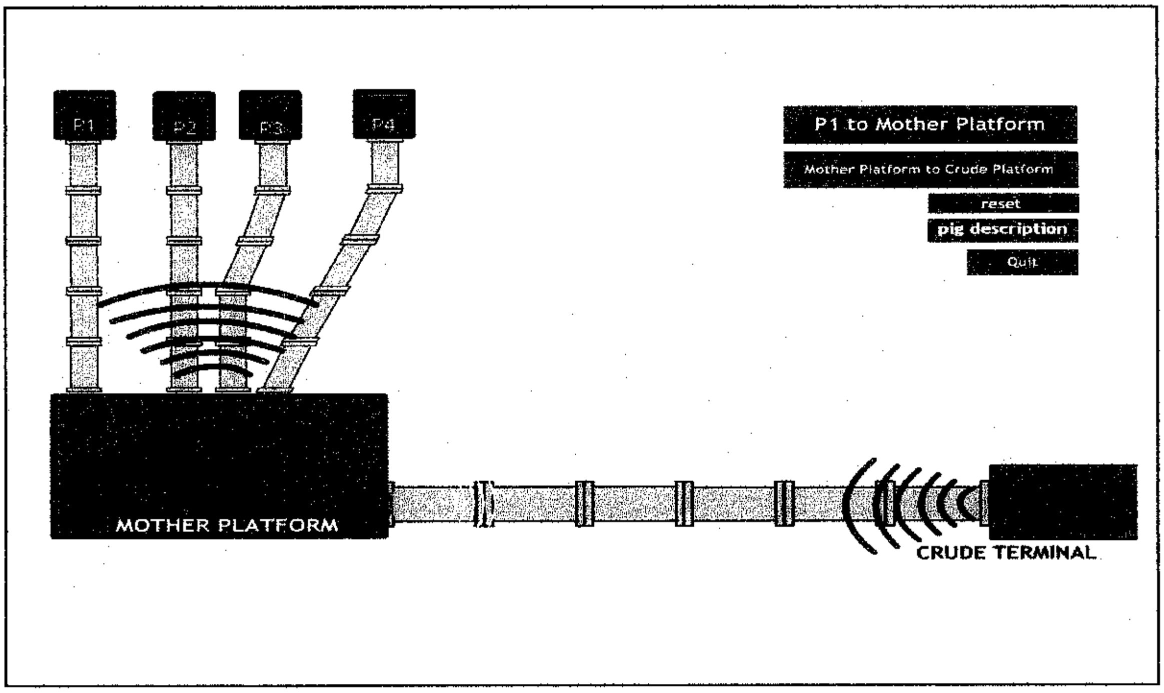
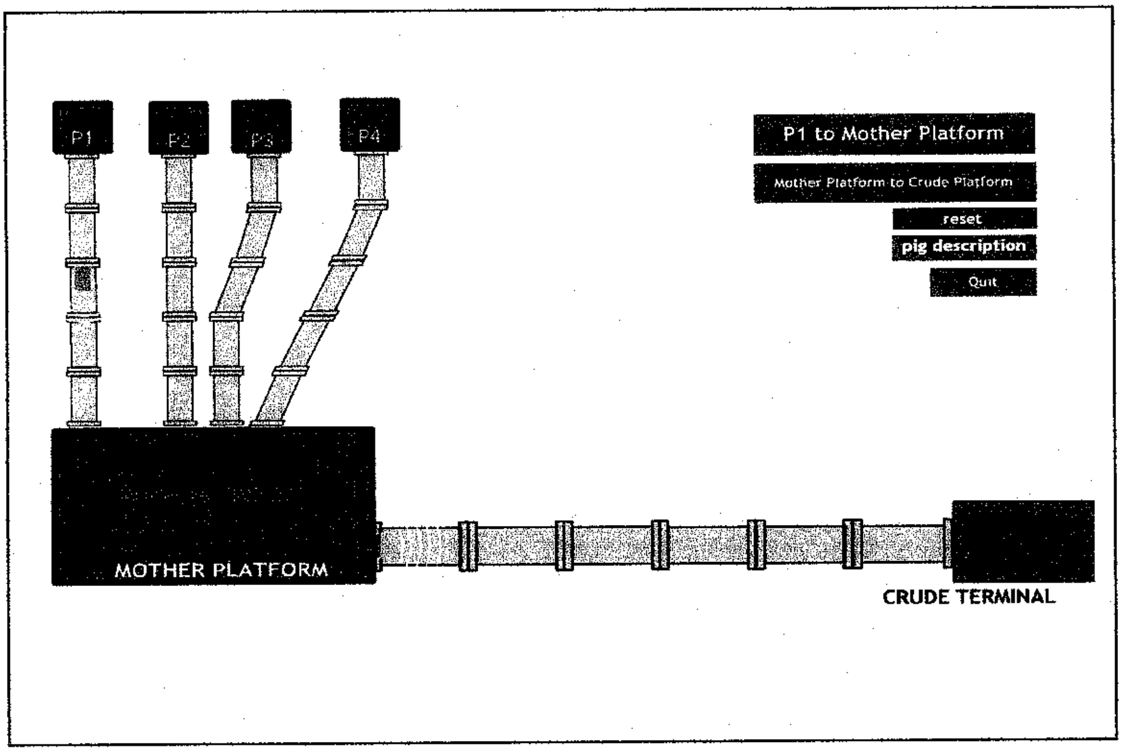
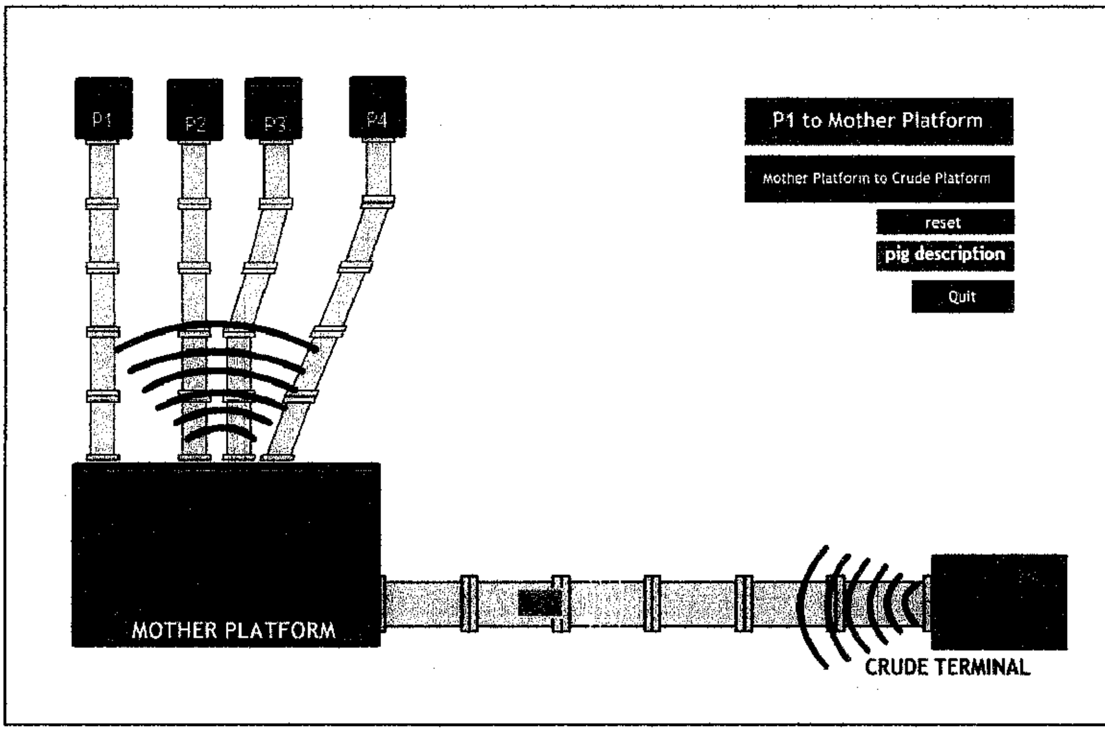
APPENDICES



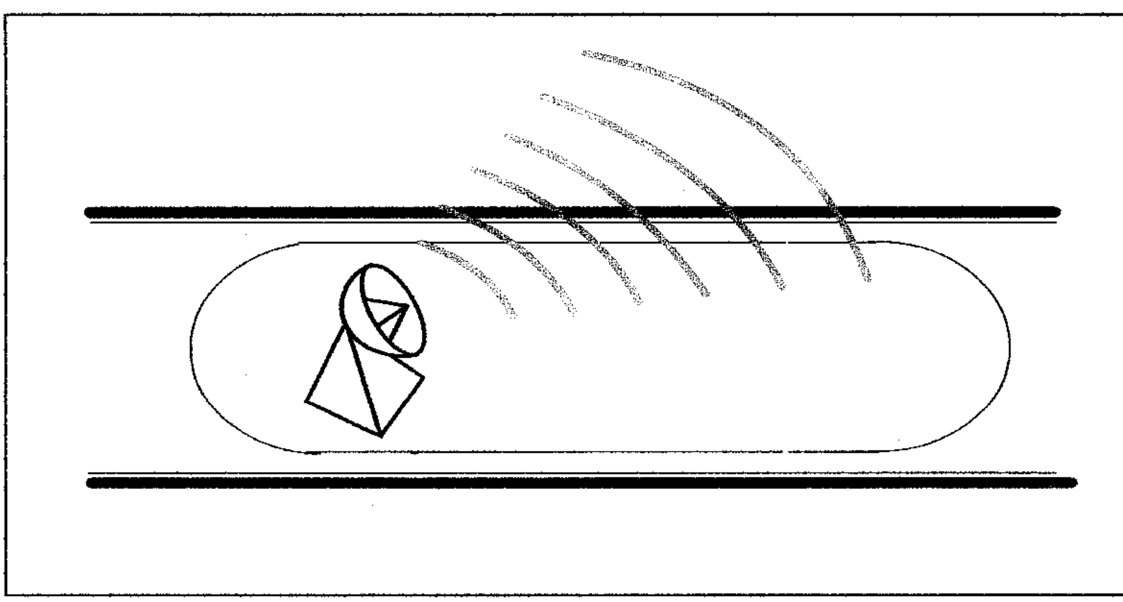
Appendix 1: Example Process of PI to Mother Platform



Appendix 2: Example Process of PI to Mother Platform



Appendix 3: Example Process of PI from mother to the crude terminal



Appendix 4: Pig Description