

Offshore Gas Gathering Network and Pipeline Analysis Using PIPESIM

By

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This dissertation is submitted in fulfillment of

the requirements for the

Bachelor of Engineering (Hons.)

(Petroleum Engineering)

April 2011

Universiti Teknologi PETRONAS

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CERTIFICATION OF APPROVAL

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A dissertation submitted to the

Petroleum Engineering Department

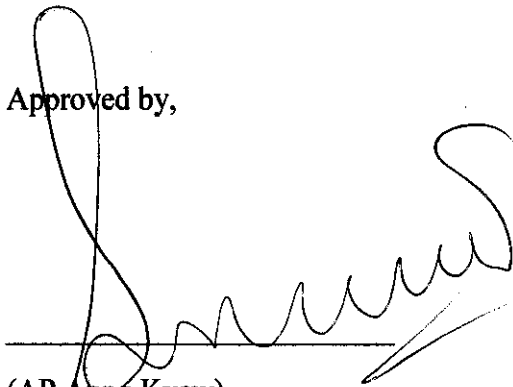
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CERTIFICATION OF ORIGINALITY

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



Mohd Farriz Ijaz Bin Noordin

Abstract

This project is about modeling and analyzing gas gathering network and pipeline to obtain an optimize gas production from wells to the gas processing plant and to the pipeline. The oil and gas company are looking for betterment in the gas gathering network in order to achieve the best gas gathering design and to increase the production optimization. This project will evaluate two different case studies which have different design criteria and reservoir properties. Both case studies have specific objective to obtain at the end of the project. For the first case study the main objective is to evaluate a looped gas gathering network from three different wells data. In this case study, the last result will be the deliverability of gas gathering network. In the second case study, the main objective is to model a pipeline to transport condensate form a satellite platform to a processing platform. The end result to be obtained in the second case study is to evaluate and select the pipeline size and to evaluate the pipeline insulation requirement. Basically this project is utilizing the PIPESIM software as a medium to analyze both cases. Most of the modeling and graphs are made from this software. Comparisons between the results are made between software and theory. From this project I had increase my ability of analyzing and understanding the basic principal of surface facilities and pipeline system. At the end of the project, there will be discussion made to both cases in order to increase the deliverability of the gathering network and pipeline systems.

ACKNOWLEDGEMENT

By completing this project, I manage to learn so many things regarding surface facilities in offshore processing platform and pipeline facilities. I know that at the beginning of this project I didn't have a clear idea of how all the processors and wells are connected to each other. By doing this project I enhance my understanding from basic to a better level of knowledge.

Thank you for all the supports that been given to me through completing this project. I would like to take this advantage to thank my supervisor, AP Aung Kyaw for sharing knowledge and guide me through this project. I would like to thank to all the lecturers who are directly or indirectly involves in this project. Thank you for all the knowledge and guidance. Last but not lease, I would like to thank to all my friends for the continuous supports from the beginning of this project.

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CHAPTER 1: INTRODUCTION

1.1 Background

The main key aims of a conceptual gas gathering network design is to confirm the project is feasible and to direct the later design stages towards an optimal design. In order to achieve this, numerous options must be analyze in different manners to select the potential of the software technology and to screen out unworkable solution. It is important to take a multidisciplinary approach to a conceptual design of gathering network such as disciplines in drilling, well completion, flow assurance, process equipments and pipeline design in order to accelerate the system design generally. In this project, I have decided to use PIPESIM software to design and evaluate two different case study in order to achieve an optimize gas gathering network design.

The case studies in this project consist of two different situations. For the first case study I plan to do a network analysis on a looped gas gathering network and find the deliverability of the system. On the other hand, the second case study is to model a condensate pipeline structure and determine the pipeline size, pipeline insulation requirement and to screen pipeline for severe riser slugging.

PIPESIM is a Steady State Multiphase Flow Simulation software develops by Schlumberger for design and diagnostic analysis of oil and gas production. PIPESIM simulation consists of six modules which are Pipeline & Facilities, Well Performance Analysis, Network Analysis, Production Optimization (GOAL), Field Planning (FPT) and Multilateral (HoSim).

Each module can construct and analyze different area of production operation. It starts from the reservoir up to the well head and continue with the surface facilities and lastly to the main pipeline to transport the gas to consumer. PIPESIM allow users to enter real data and simulate the behavior of the flow system and the deliverability of gas from reservoir to consumer. This gives advantages to the users/engineers to critically design the best gas gathering network system in order to achieve the best design.

1.2 Problem Statement

Currently, oil and gas company are trying to achieve for more effective conceptual design by looking at more tie-backs, various gas properties, the minimal power supply for processing equipments and looking at more technical details. This is the main challenges the stage of conceptual design where the rate of changes are very high. With these issues, conceptual design software, PIPESIM was developed to provide value to gas gathering network development.

In this project, a gathering network will be simulate using PIPESIM and the main evaluation is to improve the efficiency of the gas gathering network such as the deliverability of gas and the optimization of pipeline and surface facilities. This project is mainly to develop and analyze two different case studies and how to optimize the production of these two case studies. The elaboration of each the case studies are as below:

Case Study 1

In case study 1, the main objective is to determine the deliverability of a production network of a looped gas gathering network. The network connects three producing gas wells in a looped gathering system and delivers commingled product to a single delivery point. The three well have different gas composition, gas from well 1 and well 2 have same gas composition and well 3 have different composition. In this case study, I will develop a network of three gas wells to a processing plant. There are several main steps in this case study in order to achieve the end results. The main steps are as below:

- a) Build a model of the network.
- b) Specify the network boundary conditions.
- c) Solve the network and establish the deliverability

Case Study 2

In the second case study, a subsea pipeline is to be designed to transport condensate from a satellite platform to a processing platform. Compositional analysis of the condensate has been obtained (refer to appendices). In order to achieve the end results and to

determine the pipeline size and the pipeline insulation requirement, the following tasks need to perform:-

- a) Develop a compositional model of the hydrocarbon phases.
- b) Add the aqueous phase to the compositional model and identify the hydrate envelope. Hydrates are to be avoided by operating the pipeline above the hydrate formation temperature.
- c) Select a pipeline size.
- d) Determine the pipeline insulation requirement.
- e) Screen the pipeline for severe riser slugging. Severe riser slugging is to be avoided.
- f) Size a slug catcher.

1.3 Objective

The main objective of this project is to know the best method of using PIPESIM in order to design a gas gathering network. The objectives are as below:-

- a) To build a gas gathering network base on the case study.
- b) To specify the boundary conditions of reservoir and facilities.
- c) To solve the network and establish the deliverability.
- d) To select appropriate gas gathering and pipeline design.

1.4 Scope of Study

This project have various scope of study within the knowledge of Petroleum Engineering and Production Engineering, the main scope involved in this project are :

- a) PIPESIM simulation, how to use the software.
- b) The gas properties
- c) Pipeline design principles
- d) Gas gathering design principles

CHAPTER 2: LITERATURE REVIEW

2.1 The background of gas gathering system

Gas Gathering lines are small-diameter pipelines move natural gas from the wellhead to the natural gas processing plant or to an interconnection with a larger mainline pipeline. Transporting natural gas from the wellhead to the final customer involves several physical transfers of custody and multiple processing steps. A natural gas pipeline system begins at the natural gas producing well or field. Once the gas leaves the producing well, a gas gathering system directs the flow either to a natural gas processing plant or directly to the mainline transmission grid, depending upon the initial quality of the wellhead product.

The processing plant produces pipeline-quality natural gas. This gas is then transported by pipeline to consumers or is put into underground storage for future use. Storage helps to maintain pipeline system operational integrity and/or to meet customer requirements during peak-usage periods.

Transporting natural gas from wellhead to market involves a series of processes and an array of physical facilities. Among these are:

- **Gas Processing Plant** – This operation extracts natural gas liquids and impurities from the natural gas stream.
- **Mainline Transmission Systems** – These wide-diameter, long-distance pipelines transport natural gas from the producing area to market areas.
- **Market Hubs/Centers** – Locations where pipelines intersect and flows are transferred.
- **Underground Storage Facilities** – Natural gas is stored in depleted oil and gas reservoirs, aquifers, and salt caverns for future use.
- **Peak Shaving** – System design methodology permitting a natural gas pipeline to meet short-term surges in customer demands with minimal infrastructure. Peaks can be handled by using gas from storage or by short-term line-packing.

The Natural Gas Gathering System

A natural gas pipeline system begins at a natural gas producing well or field. In the producing area many of the pipeline systems are primarily involved in "gas gathering" operations. That is, a pipeline is connected to a producing well, converging with pipes from other wells where the natural gas stream may be subjected to an extraction process to remove water and other impurities if needed. Natural gas exiting the production field is usually referred to as "wet" natural gas if it still contains significant amounts of hydrocarbon liquids and contaminants.

Under certain conditions some or all of the natural gas produced at a well may be returned to the reservoir in cycling, repressuring, or conservation operations and/or vented and flared. At this stage it is a mixture of methane and other hydrocarbons, as well as some non-hydrocarbons, existing in the gaseous phase or in a solution with crude oil. The principal hydrocarbons normally contained in the natural gas mixture are methane, ethane, propane, butane, and pentane. Typical non-hydrocarbon gases that may be present in reservoir natural gas are water vapor, carbon dioxide, helium, hydrogen sulfide, and nitrogen.

In proximity to the well are facilities that produce what is referred to as "lease condensate", that is, a mixture consisting primarily of pentanes and heavier hydrocarbons which is recovered as a liquid from natural gas. Other natural gas liquids, such as butane and propane, are recovered at downstream natural gas processing plants or facilities

Once it leaves the producing area, a pipeline system directs flow either to a natural gas processing plant or directly to the mainline transmission grid. Non-associated natural gas, that is, natural gas that is not in contact with significant quantities of crude oil in the reservoir, is sometimes of pipeline quality after undergoing a decontamination process in the production area, and does not need to flow through a processing plant prior to entering the mainline transmission system.

The Natural Gas Processing Plant

The principal service provided by a natural gas processing plant to the natural gas mainline transmission network is that it produces pipeline quality natural gas. Natural gas mainline transmission systems are designed to operate within certain tolerances. Natural gas entering the system that is not within certain specific gravities, pressures, Btu content range, or water content level will cause operational problems, pipeline deterioration, or even cause pipeline rupture.

Natural gas processing plants are also facilities designed to recover natural gas liquids from a stream of natural gas that may or may not have passed through lease separators and/or field separation facilities. These facilities also control the quality of the natural gas to be marketed. Several types of natural gas processing plants, employing various techniques and technologies to extract contaminants and natural gas liquids, are used to produce pipeline quality "dry" gas. At many processing plants the primary objective is the production of dry gas (demethanizing). Any remaining natural gas liquids extraction stream is directed to a separate plant to undergo what is referred to as a "gas fractionation" process.

But a number of natural gas processing plants do include these gas fractionation plants where saturated hydrocarbons are removed from natural gas and separated into distinct parts, or "fractions," such as propane, butane, and ethane. Essentially, natural gas is methane, a colorless, odorless, flammable hydrocarbon gas (CH_4). Also present in natural gas production, especially that in association with oil production, are a number of petroleum gases. They include (in addition to ethane, propane and butane) ethylene, propylene, butylene, isobutane, and isobutylene. They are derived from crude oil refining or natural gas fractionation and are liquefied through pressurization.

The Transmission Grid and Compressor Stations

The natural gas mainline (transmission line) is a wide-diameter, often-times long-distance, portion of a natural gas pipeline system, excluding laterals, located between the gathering system (production area), natural gas processing plant, other receipt points, and the principal customer service area(s). The lateral, usually of smaller

diameter, branches off the mainline natural gas pipeline to connect with or serve a specific customer or group of customers.

A natural gas mainline system will tend to be designed as either a grid or a trunkline system. The latter is usually a long-distance, wide-diameter pipeline system that generally links a major supply source with a market area or with a large pipeline/LDC serving a market area. Trunklines tend to have fewer receipt points (usually at the beginning of its route), fewer delivery points, interconnections with other pipelines, and associated lateral lines.

A grid type transmission system is usually characterized by a large number of laterals or branches from the mainline, which tend to form a network of integrated receipt, delivery and pipeline interconnections that operate in, and serve major market areas. In form, they are similar to a local distribution company (LDC) network configuration, but on a much larger scale.

Between the producing area, or supply source, and the market area, a number of compressor stations are located along the transmission system. These stations contain one or more compressor units whose purpose is to receive the transmission flow (which has decreased in pressure since the previous compressor station) at an intake point, increase the pressure and rate of flow, and thus, maintain the movement of natural gas along the pipeline.

Gas compressors are used on a natural gas mainline transmission system are usually rated at 1,000 horsepower or more and are of the centrifugal (turbine) or reciprocating (piston) type. The larger gas compression stations may have as many as 10-16 units with an overall horsepower rating of from 50,000 to 80,000 HP and a throughput capacity exceeding three billion cubic feet of natural gas per day. Most compressor units operate on natural gas (extracted from the pipeline flow); but in recent years, and mainly for environmental reasons, the use of electricity driven compressor units has been growing.

Many of the larger mainline transmission routes are what is generally referred to as "looped." Looping is when one pipeline is laid parallel to another and is often used as a way to increase capacity along a right-of-way beyond what is possible on one line,

or an expansion of an existing pipeline(s). These lines are connected to move a larger flow along a single segment of the pipeline system. Some very large pipeline systems have 5 or 6 large diameter pipes laid along the same right-of-way. Looped pipes may extend the distance between compressor stations, where they can transfer part of their flow, or the looping may be limited to only a portion of the line between stations. In the latter case, the looping often serves as essentially a storage device, where natural gas can be line-packed as a way to increase deliveries to local customers during certain peak periods.

To address the potential for pipeline rupture, safety cutoff meters are installed along a mainline transmission system route. Devices located at strategic points are designed to detect a drop in pressure that would result from a downstream or upstream pipeline rupture and automatically stop the flow of natural gas beyond its location. Monitoring the pipeline as a whole are apparatus known as SCADA which means Supervisory Control and Data Acquisition. SCADA systems provide monitoring staff the ability to direct and control pipeline flows, maintaining pipeline integrity and pressures as natural gas is received and delivered along numerous points on the system, including flows into and out of storage facilities.

Natural Gas Market Centers/Hubs

Natural gas market centers and hubs evolved, beginning in the late 1980s, as an outgrowth of natural gas market restructuring and the execution of a number of Federal Energy Regulatory Commission's (FERC) Orders culminating in Order 636 issued in 1992. Order 636 mandated that interstate natural gas pipeline companies transform themselves from buyers and sellers of natural gas to strictly natural gas transporters. Market centers and hubs were developed to provide new natural gas shippers with many of the physical capabilities and administrative support services formally handled by the interstate pipeline company as "bundled" sales services.

Two key services offered by market centers/hubs are transportation between and interconnections with other pipelines and the physical coverage of short-term receipt/delivery balancing needs. Many of these centers also provide unique services that help expedite and improve the natural gas transportation process overall, such as Internet-based access to natural gas trading platforms and capacity release programs.

Most also provide title transfer services between parties that buy, sell, or move their natural gas through the center.

As of the end of 2008, there were a total of 33 operational market centers in the United States (24) and Canada (9).

Underground Storage Facilities

At the end of the mainline transmission system, and sometimes at its beginning and in between, underground natural gas storage and LNG (liquefied natural gas) facilities provide for inventory management, supply backup, and the access to natural gas to maintain the balance of the system. There are three principal types of underground storage sites used in the United States today: depleted reservoirs in oil and/or gas fields, aquifers, and salt cavern formations. In one or two cases mine caverns have been used. Two of the most important characteristics of an underground storage reservoir are the capability to hold natural gas for future use, and the rate at which natural gas inventory can be injected and withdrawn (its deliverability rate).

Most underground storage facilities, 327 out of 399 at the beginning of 2008, are depleted reservoirs, which are close to consumption centers and which were relatively easy to convert to storage service. In some areas, however, most notably the Midwestern United States, some natural aquifers have been converted to natural gas storage reservoirs. An aquifer is suitable for natural gas storage if the water-bearing sedimentary rock formation is overlaid with an impermeable cap rock. While the geology of aquifers is similar to that of depleted production fields, their use in natural gas storage usually requires more base (cushion) gas and greater monitoring of withdrawal and injection performance. Deliverability rates may be enhanced by the presence of an active water drive.

During the past 20 years, the number of salt cavern storage sites has grown significantly because of its rapid cycling (inventory turnover) capability coupled with its ability to respond to daily, even hourly, variations in customer needs. The large majority of salt cavern storage facilities have been developed in salt dome formations located in the Gulf Coast States. Salt caverns leached from bedded salt formations in Northeastern, Midwestern, and Western States have also been developed but the

number has been limited due to a lack of suitable geology. Cavern construction is more costly than depleted field conversions when measured on the basis of dollars per thousand cubic feet of working gas capacity, but the ability to perform several withdrawal and injection cycles each year reduces the per-unit cost of each thousand cubic feet of natural gas injected and withdrawn.

Peak Shaving

Underground natural gas storage inventories provide suppliers with the means to meet peak customer requirements up to a point. Beyond that point the distribution system still must be capable of meeting customer short-term peaking and volatile swing demands that occur on a daily and even hourly basis. During periods of extreme usage, peaking facilities, as well as other sources of temporary storage, are relied upon to supplement system and underground storage supplies.

Peaking needs are met in several ways. Some underground storage sites are designed to provide peaking service, but most often LNG (liquefied natural gas) in storage and liquefied petroleum gas such as propane are vaporized and injected into the natural gas distribution system supply to meet instant requirements. Short-term linepacking is also used to meet anticipated surge requirements.

The use of peaking facilities, as well as underground storage, is essentially a risk-management calculation, known as peak-shaving. The cost of installing these facilities is such that the incremental cost per unit is expensive. However, the cost of a service interruption, as well as the cost to an industrial customer in lost production, may be much higher. In the case of underground storage, a suitable site may not be locally available. The only other alternative might be to build or reserve the needed additional capacity on the pipeline network. Each alternative entails a cost.

A local natural gas distribution company (LDC) relies on supplemental supply sources (underground storage, LNG, and propane) and uses linepacking to "shave" as much of the difference between the total maximum user requirements (on a peak day or shorter period) and the baseload customer requirements (the normal or average) daily usage. Each unit "shaved" represents less demand charges (for reserving pipeline capacity on the trunklines between supply and market areas) that the LDC must pay.

The objective is to maintain sufficient local underground natural gas storage capacity and have in place additional supply sources such as LNG and propane air to meet large shifts in daily demand, thereby minimizing capacity reservation costs on the supplying pipeline.

Prior to FERC Order 636 in 1992, many interstate pipeline companies had a completely integrated supply system that was capable of delivering natural gas from the wellhead to the ultimate retail gas consumer. But, following Order 636, which separated gathering, marketing, and transmission operations, many pipeline companies reorganized and broke up this system into discrete parts and assigned them to affiliated companies.

The facilities, functions, and services required for gathering, processing, and transportation were placed in affiliated companies or were spun off or sold to other companies. Since most gas prices were no longer regulated, gas gathering service charges became subject to market forces and were a function of buyer/seller negotiation, isolated from the transmission charges imposed by the pipeline transporter.

2.2 Network Boundary Conditions

In order to determine the network boundary condition the following definitions are used:

Lone Node: A lone node is a node with only one branch connected, i.e. a production well, an injection well, a source or a sink.

Boundary conditions: The fluid pressure, temperature, and flowrate at each lone node in the network. The following rules apply:

Rule for Temperatures: The fluid temperature at all sources and the static reservoir temperature at all production wells must be specified by the user. The fluid temperature at all sinks and injection wells are always calculated.

Rules for Pressures and Flowrates: There are two rules for specification of pressure and flowrate boundary conditions:

Rule 1 - Degrees of Freedom. The total number of flowrates, pressures and PQ curves specified must equal the total number of lone nodes.

Rule 2 - At Least one Pressure. A least one pressure must be specified at one of the lone nodes.

2.3 Network Tolerance

A network has converged when the pressure balance and mass balance at each node is within the specified tolerance. The calculated pressure at each branch entering and leaving a node is averaged.

The tolerance of each pressure is calculated from the equation:

$$\mathbf{Ptol = I(P - Pave.) / Pave. \times 100\%I}$$

If all Ptol values are within the specified network tolerance then that node has passed the pressure convergence test. This is repeated for each node.

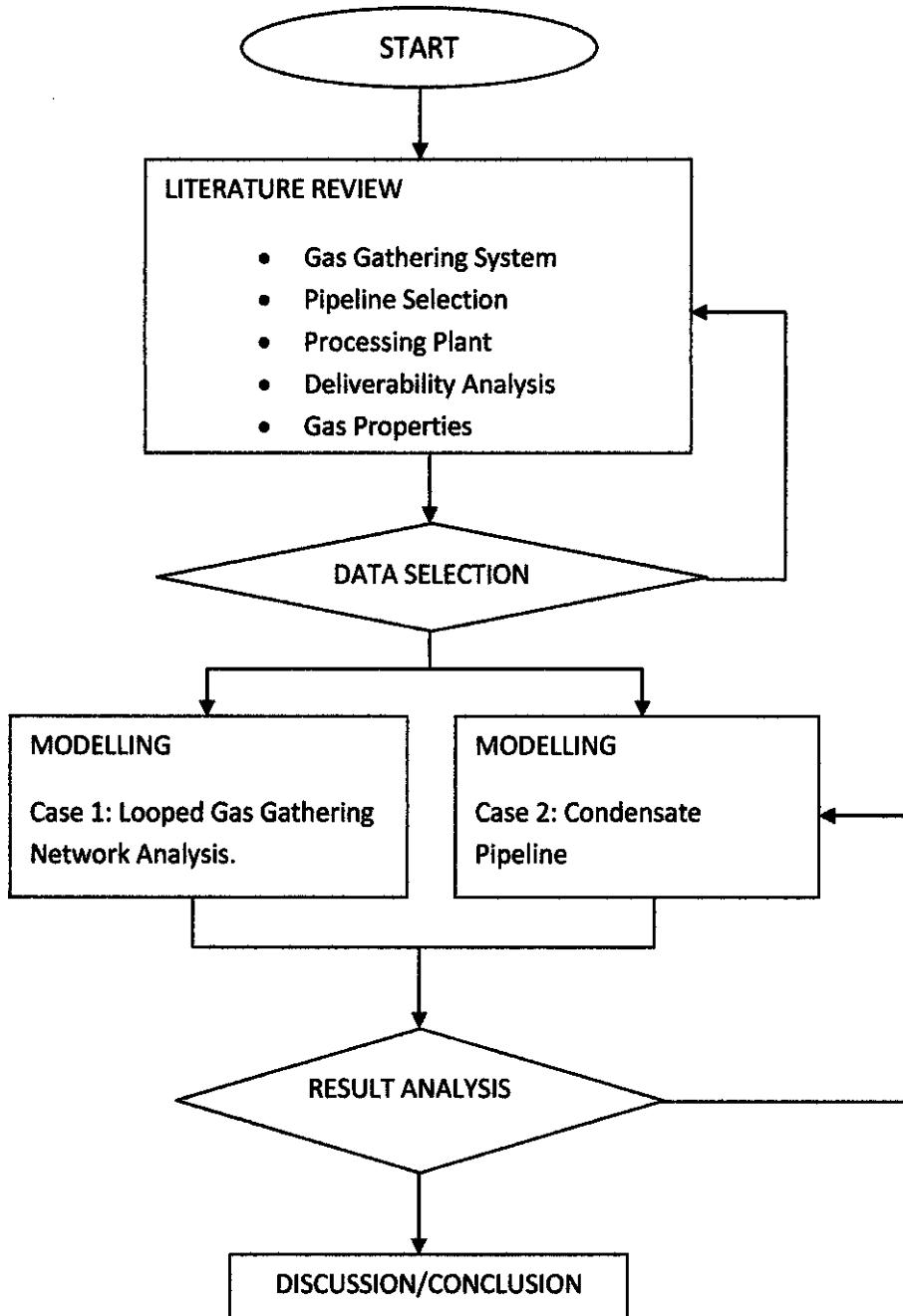
The total mass flowrate into and the total mass flowrate out of a node are averaged. The tolerance is calculated from the equation:

$$\mathbf{Ftol = I(Tot. mass flowrate in - Tot. mass flowrate ave.) / Tot. mass flowrate ave. \times 100\%I}$$

If the Ftol value is within the specified network tolerance then that node has passed the mass convergence test. This is repeated for each node. When all of the above conditions are satisfied, the network has coverage.

CHAPTER 3: PROJECT METHODOLOGY

3.1 Project Flow Chart



3.2 Project Gantt chart

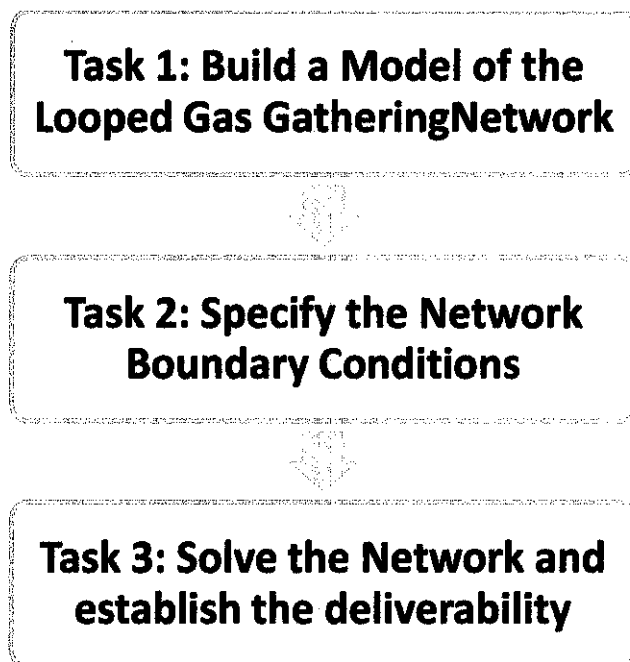
| No | Details | Weeks | | | | | | | | | | | | | | | | |
|----|--|-------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | |
| 1 | Literature Review | █ | █ | █ | █ | █ | █ | █ | █ | █ | █ | █ | | | | | | |
| 2 | Data Preparation and Selection for both cases | | | █ | █ | █ | █ | | | | | | | | | | | |
| 3 | Software Familiarization | | | | | █ | █ | █ | █ | █ | | | | | | | | |
| 4 | Modeling Case 1: Looped Gas Gathering Network Analysis | | | | | | █ | █ | █ | █ | █ | | | | | | | |
| 5 | Modeling Case 2: | | | | | | | | █ | █ | █ | █ | | | | | | |
| 6 | PRE-EDX combined with seminar/ Poster Exhibition/ Submission of Final Report (CD Softcopy & Softbound) | | | | | | | | | | | █ | █ | | | | | |
| 7 | EDX | | | | | | | | | | | | █ | █ | | | | |
| 8 | Final Oral Presentation | | | | | | | | | | | | | | █ | █ | | |
| 9 | Delivery of Final Report to External Examiner / Marking by External Examiner | | | | | | | | | | | | | | | █ | █ | |
| 10 | Submission of hardbound copies | | | | | | | | | | | | | | | | █ | █ |

3.3 Case Methodology

The methodology of this project is divided into two, base on the case studies. Each method is to perform in the PIPESIM simulation software, and the gas and condensate properties of each case study will be determine first. The project methodologies are as below:-

Case Study 1

The workflow of Case Study 1 is as below:



Task 1: Build a Model of the Network

The following steps are to be carried out:-

1. Enter the engineering data for Well 1.
2. Copy the data to Well 2 since the data is same with Well 1.
3. Enter and modify the data for well 3.
4. Specify the composition at each production well. The composition of each production stated in the appendices.
5. Connect the network together.
6. Define the engineering data for each branch.

Task 2: Specify the Network Boundary Conditions

It is necessary to summarize the rules for specification of network boundary conditions. The network solver solves the fluid pressures, temperatures, and flowrates around a network for a user-specified set of boundary conditions.

Task 3: Solve the Network and establish the deliverability

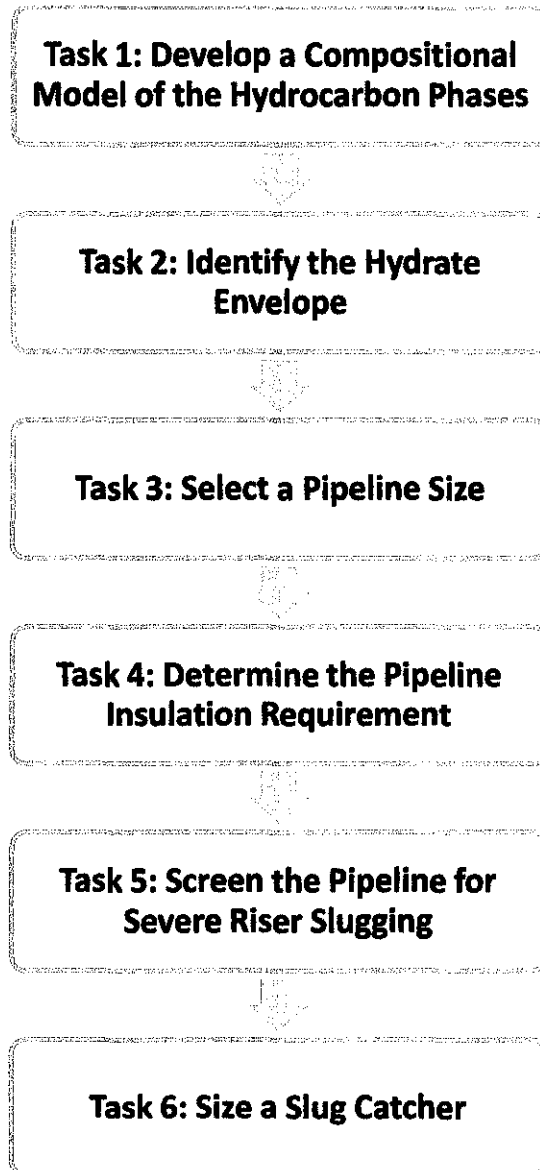
First it is necessary to explain the network tolerance. A network has converged when the pressure balance and mass balance at each node is within the specified tolerance.

In this case study, the following steps are required:

- Set the network tolerance.
- Run the model.
- View the tabular reports.
- View the graphical reports.

Case Study 2

Work Flow Diagram for Case Study 2



Task 1: Develop a Compositional Model of the Hydrocarbon Phases

The following steps are to be carried out:-

- Add the pure hydrocarbon components.
- Characterize and add a petroleum fraction.
- Generate the hydrocarbon phase envelope.

Task 2: Identify the Hydrate Envelope

Hydrate formation is to be avoided by operating above the hydrate formation temperature at all times. The following steps are to be carried out:

- Add the aqueous component.
- Generate the hydrate envelope.

Task 3: Select a Pipeline Size

Find the smallest pipeline I.D. that will allow the design flowrate of 10,000 STB/d of condensate to be transported from the satellite platform whilst maintaining an arrival pressure of not lower than 1,000 psia at the processing platform. The pipeline sizes available are 8", 10", or 12" I.D. as described in the data section in the appendices.

This can be determined as follows:

- Use the pressure temperature profiles operation to calculate the pressure drop for each of the three pipeline size options.

Task 4: Determine the Pipeline Insulation Requirement

Minimum arrival temperature is required to prevent the formation of hydrates. The insulation has a thermal conductivity of 0.15 Btu/hr/ft/°F and a thickness of 0.75" or 1" as describe in the appendices. This can be determined as follows:

- Use the pressure temperature profiles operation to calculate the temperature profile for the design and turndown flowrate cases with 0.75" thermal insulation thickness.
- Re-run the model with 1.0" thermal insulation thickness and compare the temperature profiles.

Task 5: Screen the Pipeline for Severe Riser Slugging

Severe riser slugging is likely in a pipeline system followed by a riser under certain conditions. The elements leading to severe riser slugging are:

1. The presence a long slightly downward inclined pipeline prior to the riser.
2. Fluid flowing in the "stratified" or "segregated" flow regime (as opposed to the usual "slug" or "intermittent" flow regime).
3. A slug number (PI-SS) of lower than 1.0.

The PI-SS number can also be used to estimate the severe riser slug length from the equation:

$$\text{slug length} = \text{riser height} / \text{PI-SS number.}$$

Severe riser slugging is to be avoided in this case. The necessary information can be extracted from the model as follows:-

- Configure the model output such that slug information, and flow regime maps are printed for the fluid at the riser base.

Task 6: Size a Slug Catcher

Having established that normal slug flow is expected, it is now necessary to size a slug catcher.

The size will be determined by the largest of three design criteria:

1. The requirement to handle the largest slugs envisaged (chosen to be statistically the 1/1000 population slug size).
2. The requirement to handle liquid swept in front of a pig.
3. Transient effects, i.e. the requirement to handle the liquid slug generated when the production flow is ramped up from 5,000 to 10,000 STB/d.

CHAPTER 4: RESULT

4.1 Case 1: Looped Gas Gathering Method

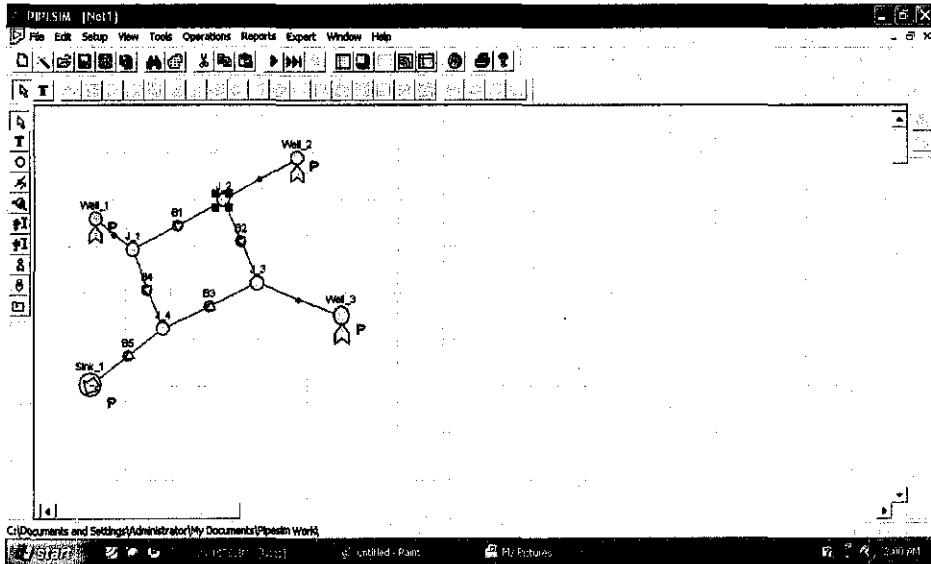


Figure 1: Layout of Network System

Above figure shows the layout in the model. The network show how the three wells are connected and gathered to Sink 1. Base on PIPESIM software, when above figure have been model its show that the network is completely connect and ready to evaluate. The data of each well are provided in the appendices.

Pressure profile

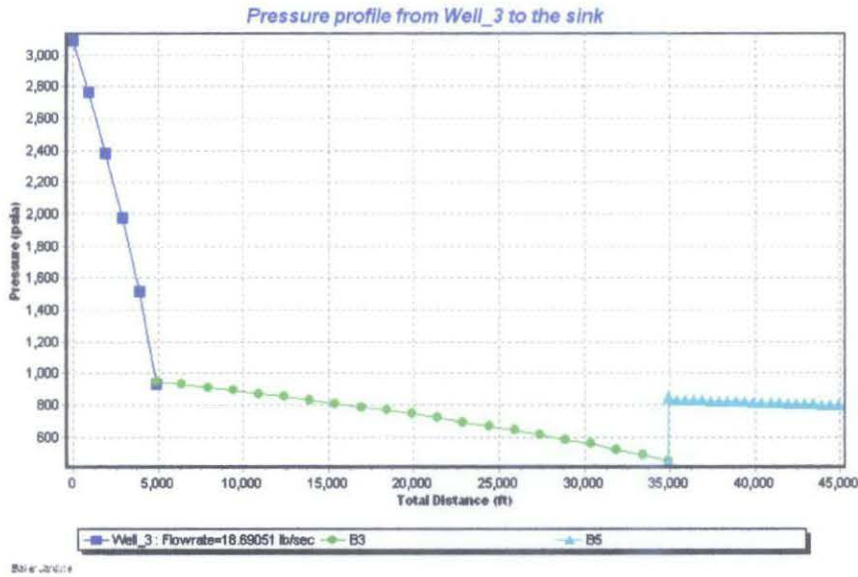


Figure 2: Pressure Profile

Shown above is the pressure profile to be obtain from all the three wells in case study 1. The pressure profile shows the pressure depletion from reservoir through the gathering networks. As shown above, the blue line pressure depletion is the well pressure depletion which is from the bottom hole pressure to the well head pressure. The green pressure line is though the gathering network and the last line is the pressure profile in the pipeline. I expect to get the same pressure profile for Well 1 and Well 2.

4.2 Case Study 2: Condensate Pipeline

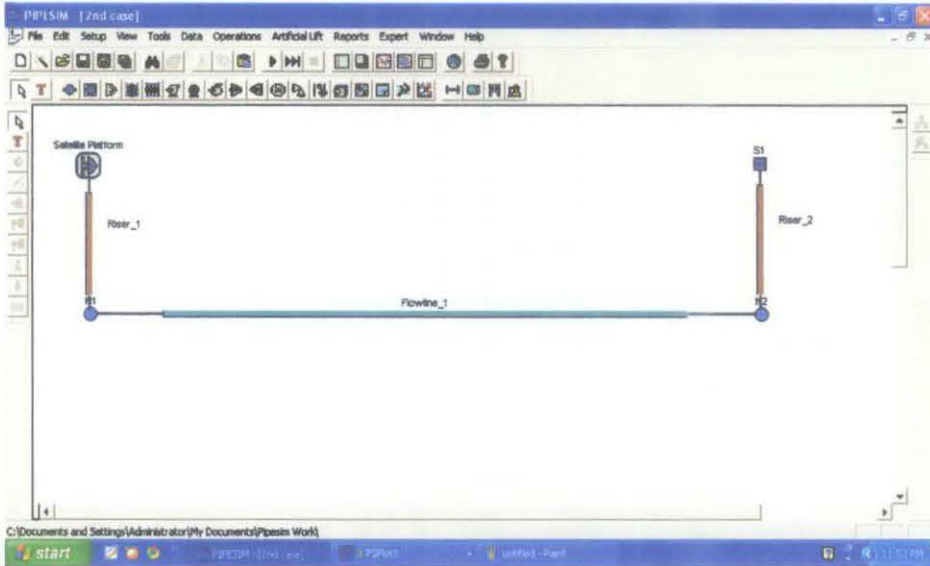


Figure 3: Pipeline Modeling Layout of Condensate

In case 2, condensate gas is determined to be transported from a satellite platform to a gas processing plant by using risers and pipeline. The riser is used to transport from wells to pipeline by 400ft. The length of the pipeline is 5 miles. Based on the figure above, it shows the layout of the whole transporting system of condensate gas.

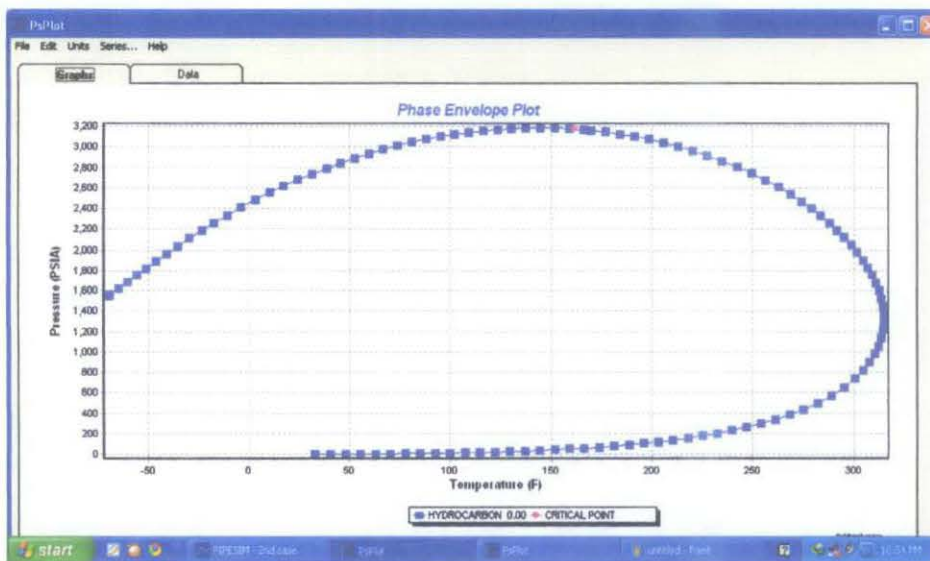


Figure 4: Hydrocarbon Phase Envelope

Base from the PVT data, a phase envelope is determined to get the phase envelope. This is important to know the phase of the transported fluid either in one phase or two phase behavior. The phase behavior of the fluid varies with pressure and temperature.

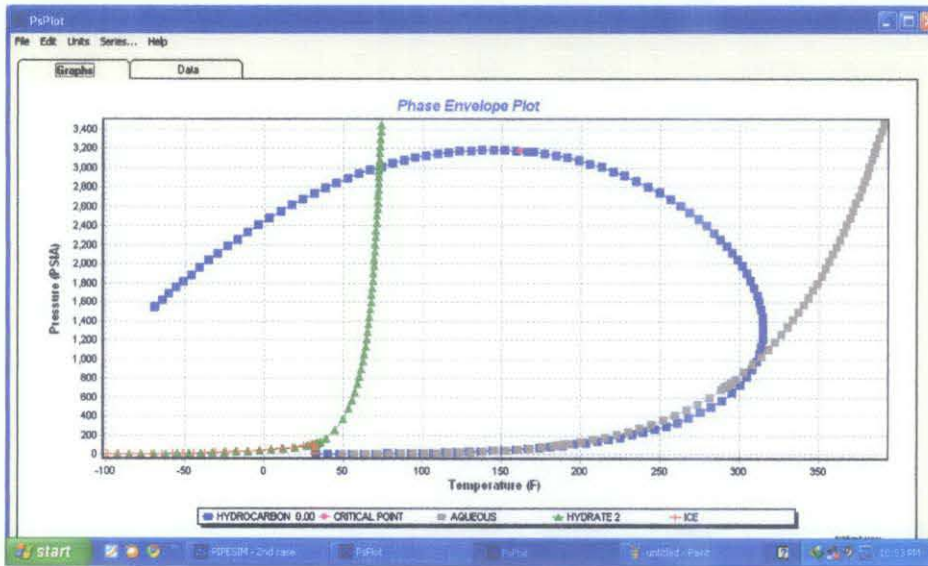


Figure 5: Phase Envelope of hydrates.

Some of gas reservoir have tendency to form hydrates compound by the present of water in the reservoir. These hydrates can cause line blockage. The tendency to form hydrates is dependent also on pressure and temperature at all times. By adding the aqueous component (water component) the above phase envelope generated. From the above phase envelope, note that hydrates component tend to form in the pipeline and risers. Base from the above phase envelope, its shows that hydrates formation can be avoided by operating the pipeline at temperature above 75 F at all times.

Pipeline Size Selection

Pipeline selection is one of the most important criteria in designing transportation system. In this case, a liquid flowrate of 10,000 bbl/day need to achieve by the inlet pressure of 1500 psia. I have selected three different pipelines ID which are the 8", 10" and 12" to evaluate which is the most suitable pipeline size.

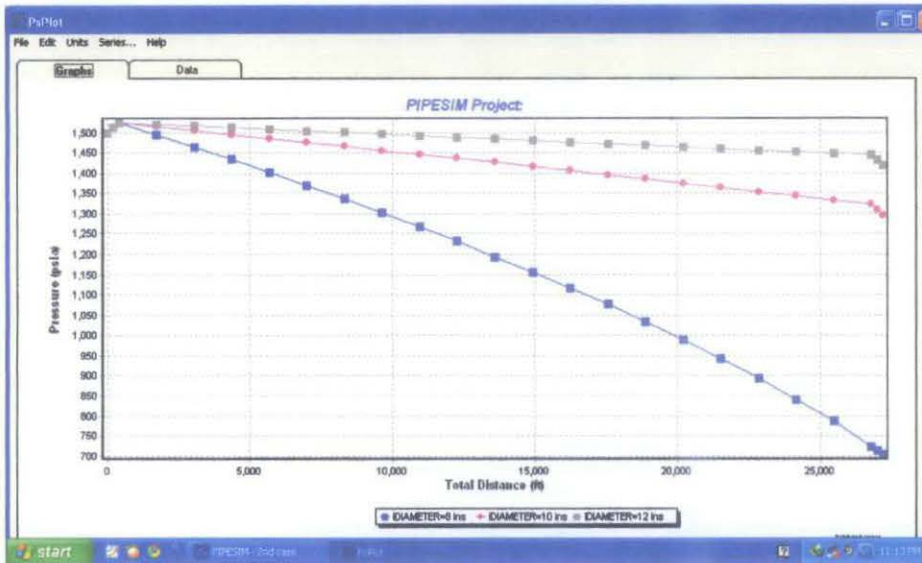


Figure 6: Pressure vs Total Distance

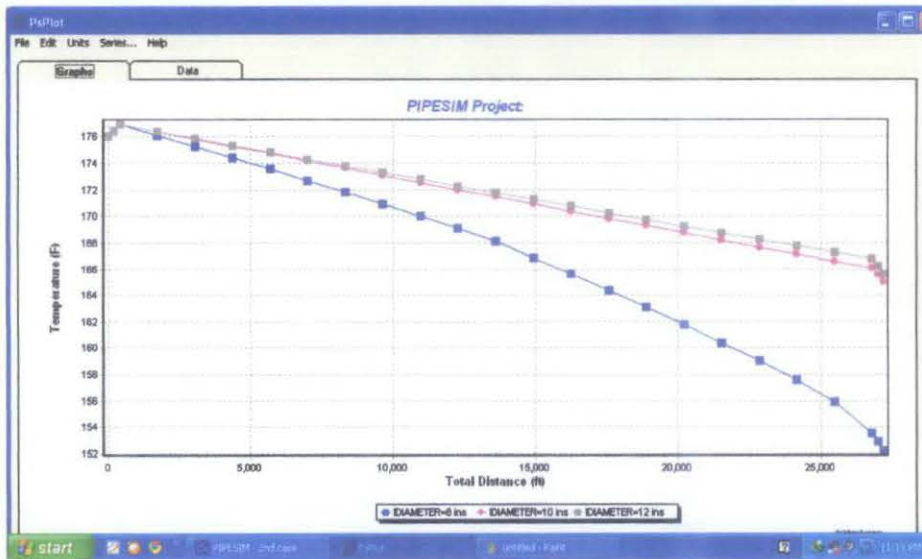


Figure 7: Temperature vs Total Distance

Base from the two above figures, we can see the pressure and temperature depletion across the total system as it moves from the satellite platform to the processing plant. The best pipeline ID is 10" which it will have temperature drop not less than 75 F which is the hydrates can be form. The 10" pipeline also satisfy the arrival condition of at least 1000 psia.

Pipeline Insulation Requirement

Thermal insulation is used to insulate the pipeline and maintain an arrival temperature of not less than 75 F. It required to find the smallest thickness of insulation to be used in the pipeline. By evaluating the thickness of 0.75" and 1", the below graph achieved.

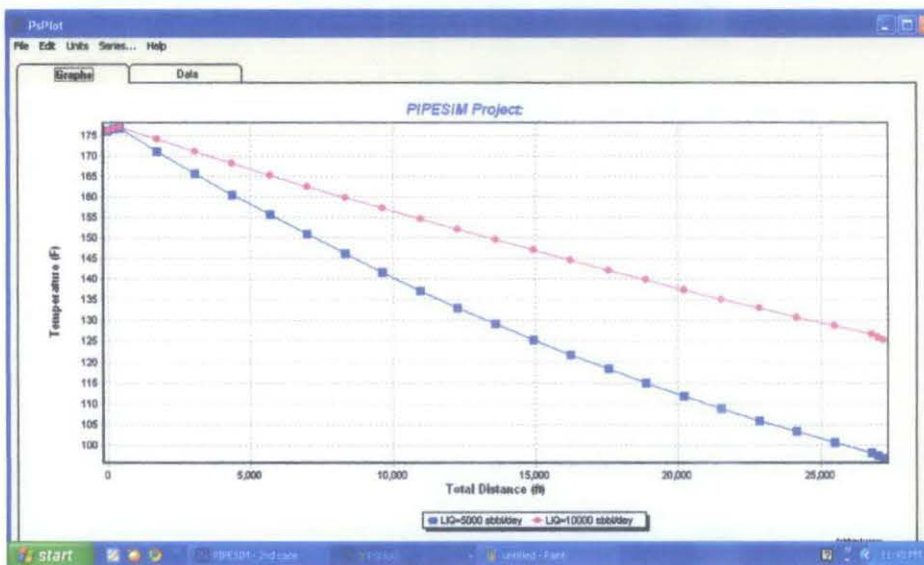


Figure 8: 1" Insulation

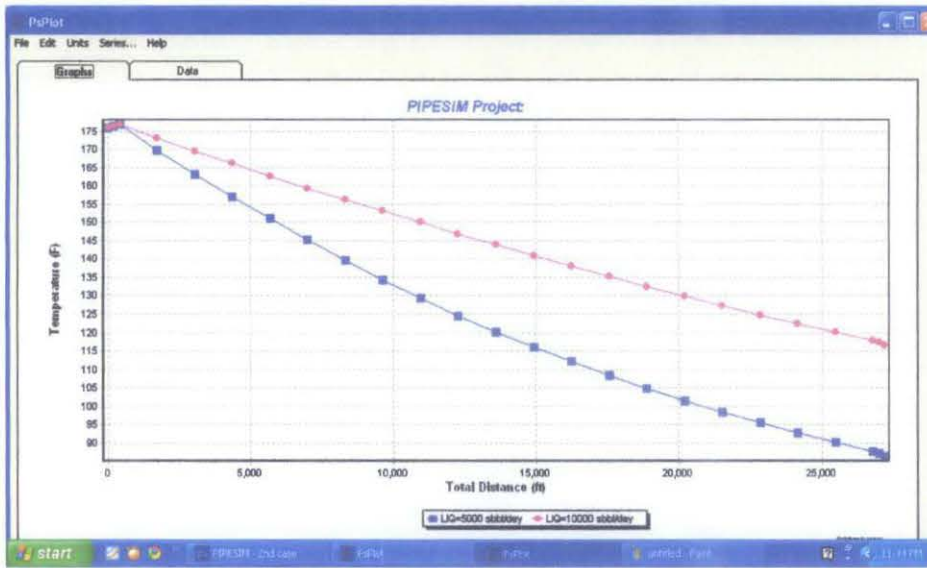


Figure 9: 0.75" Insulation

From both insulation thicknesses, it can be seen that 1" insulation is required to maintain an arrival temperature of 75 F.

CHAPTER 5: CONCLUSION & RECOMMENDATION

Conclusion

As the conclusion, a better understanding of gas gathering network can be obtain by reading more about the current technologies that applicable in the industry. By studying these two case studies, I manage to develop a better understanding of the gas gathering network design and how to analyze further in the future. This project will give me some of the taste of building a gathering network of different well data and reservoir fluids.

Recommendation

From my opinion, gas gathering network is one of the important surface design in order to achieve more optimize production and transportation of hydrocarbon from the wells to the specified destination. I would like to suggest to have a subject on this gathering network and include the surface facilities to explain how does the network can be optimize by using specific pipeline design and surface facilities such as pumps and compressor. This would gain the understanding of the students towards the important of gas gathering network in the oil and gas industry beside the well and reservoir performance.

References

1. **Aspects of Gas Gathering**, by *William Hurst, William C Goodson, Russell E Leeser.*
2. **An Efficient Model for Evaluating Field Gathering System Design**, by *J. R. Dempsey, SPE-AIME, International Computer Applications Ltd., J. K. Patterson, SPE-AIME, International Computer Applications Ltd., K. H. Coats, SPE-AIME, International Computer Applications Ltd., J. P. Brill, SPE-AIME, U. of Tulsa*
3. **Natural Gas Production**, by *Chi U. Iko*
4. **Pipesim User Guide**, by *Schlumberger*
5. **Gas Gathering, Midstream Oil and Gas and Natural Gas**, *www.gasgathering.com*
6. **Natural Gas Engineering Handbook**, by *Boyun.*
7. **Using Intergrated Production Modelling (IPM) as an Optimization Tool for Field Development Planning and Management**, by *E.A Ageh, SPE, A Adegoke. O.J Uzoh, SPE, Shell Nigeria E&P.*
8. **Effiecient Conceptual Design of an Offshore Gas Gathering Network**, by *M.J Watson, N.J Hawkers and P.F Pickering, FEESA Limited and L.D Brown, ConocoPhillips Incorporated.*
9. **An Effective Method for Modelling Stagnant Liquid Columns in Gas Gathering Systems**
By *R.G. MCNEIL, D.R. LILLICO, Fekete Associates Inc*

Appendices

Data for Case Study 1

Completion and Tubing Data

| | Well 1 & 2 | Well 3 |
|--------------------------------------|---------------------------------|---------------------------------|
| Gas PI | 0.0004 mmSCF/d/psi ² | 0.0005 mmSCF/d/psi ² |
| Wellhead TVD | 0 | 0 |
| Mid Perforations TVD | 4500 ft | 4900 ft |
| Mid Perforations MD | 4500 ft | 4900 ft |
| Tubing I.D. | 2.4" | 2.4" |
| Wellhead Ambient Temp. | 60 °F | 60 °F |
| Mid Perforations Ambient Temperature | 130 °F | 140 °F |
| Heat Transfer coefficient | 0.2 Btu/hr/ft ² /F | 0.2 Btu/hr/ft ² /F |

Pure hydrocarbon components (Well 1 and Well 2)

| Component | Moles |
|------------|-------|
| Methane | 75 |
| Ethane | 6 |
| Propane | 3 |
| Isobutane | 1 |
| Butane | 1 |
| Isopentane | 1 |
| Pentane | 0.5 |
| Hexane | 0.5 |

Petroleum Fraction (Well 1 and Well 2)

| Name | Boiling Point (F) | Molecular Weight | Specific Gravity | Moles |
|------|-------------------|------------------|------------------|-------|
| C7+ | 214 | 115 | 0.683 | 12 |

Aqueous Component (Well 1 and Well 2)

| Component | Volume Ratio (%bbl/bbl) |
|-----------|-------------------------|
| Water | 10 |

Pure Hydrocarbon Components (Well 3)

| Component | Moles |
|------------|-------|
| Methane | 73 |
| Ethane | 7 |
| Propane | 4 |
| Isobutane | 1.5 |
| Butane | 1.5 |
| Isopentane | 1.5 |
| Pentane | 0.5 |
| Hexane | 0.5 |

Petroleum Fraction (Well 3)

| Name | Boiling Point (F) | Molecular Weight | Specific Gravity | Moles |
|------|-------------------|------------------|------------------|-------|
| C7+ | 214 | 115 | 0.683 | 10.5 |

Aqueous Component (Well 3)

| Component | Volume Ratio (%bbl/bbl) |
|-----------|-------------------------|
| Water | 5 |

Data for looped Gathering Lines

| | |
|-----------------------------------|--------------------------------|
| Rate of undulations | 10/1000 |
| Horizontal distance | 30000 ft |
| Elevation Difference | 0 ft |
| Inner diameter | 6" |
| Wall Thickness | 0.5" |
| Roughness | 0.001" |
| Ambient Temperature | 60 °F |
| Overall heat transfer coefficient | 0.2 Btu/hr/ft ² /°F |

Data for Deliver Line

| | |
|----------------------------------|---------|
| Separator type | Liquid |
| Separator efficiency | 100% |
| Compressor Differential Pressure | 400psi |
| Compressor efficiency | 70% |
| Aftercooler delta P | 15psi |
| Aftercooler outlet temperature | 120 F |
| Flowline rate of undulation | 10/1000 |
| Flowline Horizontal distance | 10000ft |
| Flowline Elevation Difference | 0 ft |
| Flowline inner diameter | 8" |
| Flowline wall thickness | 0.5" |
| Flowline Roughness | 0.001" |
| Flowline Ambient Temperature | 60 °F |

| | |
|--|--------------------------------|
| Flowline Overall heat transfer coefficient | 0.2 Btu/hr/ft ² /°F |
|--|--------------------------------|

Boundary Conditions

| Node | Pressure (psia) | Temperature (F) |
|--------|-----------------|-----------------|
| Well 1 | 2900 | 130 |
| Well 2 | 2900 | 130 |
| Well 3 | 3100 | 140 |
| Sink 1 | 800 | (Calculated) |

Data for Case Study 2

Layout

Condensate flows down a 400 ft x 10" ID riser from the satellite platform to the seabed, along a 5 mile pipeline, and up a 400 ft x 10" ID riser to the processing platform.

Boundary Condition

| | |
|--|-------------|
| Fluid inlet pressure at satellite platform | 1500 psia |
| Fluid inlet temperature at satellite platform | 176 °F |
| Design liquid flowrate | 10000 STB/d |
| Minimum arrival pressure at processing platform | 1000 psia |
| Minimum arrival temperature at processing platform | 75 °F. |

Pure Hydrocarbon Components

| Component | Moles |
|-----------|-------|
| Methane | 75 |
| Ethane | 6 |
| Propane | 3 |
| Isobutane | 1 |
| Butane | 1 |

| | |
|------------|-----|
| Isopentane | 1 |
| Pentane | 0.5 |
| Hexane | 0.5 |

Petroleum Fraction

| Name | Boiling Point (F) | Molecular Weight | Specific Gravity | Moles |
|------|-------------------|------------------|------------------|-------|
| C7+ | 214 | 115 | 0.683 | 12 |

Aqueous Component

| Component | Volume Ratio (%bbl/bbl) |
|-----------|-------------------------|
| Water | 10 |

Pipeline Size Available

| ID (") | Wall Thickness (") | Roughness (") |
|--------|--------------------|---------------|
| 8 | 0.5 | 0.001 |
| 10 | 0.5 | 0.001 |
| 12 | 0.5 | 0.001 |

Pipeline Data

| | |
|-----------------------|---------|
| Height of undulations | 10/1000 |
| Horizontal distance | 5 miles |
| Elevation difference | 0 |

| | |
|-----------------------------------|--------------------------------|
| Wall thickness | 0.5" |
| Roughness | 0.001" |
| Ambient Temperature | 50 °F |
| Overall heat transfer coefficient | 0.2 Btu/hr/ft ² /°F |

Pipe insulation study data

| | |
|---------------------------------|-------------------|
| Pipe thermal conductivity | 50 Btu/hr/ft/°F |
| Insulation thermal conductivity | 0.15 Btu/hr/ft/°F |
| Insulation thickness available | 0.75" or 1.0" |
| Ambient fluid | water |
| Ambient fluid velocity | 1.64 ft/sec |
| Burial Depth | 0 (half buried) |
| Ground Conductivity | 1.5 Btu/hr/ft/°F |

Data for Riser 1 & 2

| | |
|-----------------------------------|--------------------------------|
| Horizontal Distance | 0 |
| Elevation Difference (Riser 1) | -400 ft |
| Elevation Difference (Riser 2) | +400 ft |
| Inner Diameter | 10" |
| Wall Thickness | 0.5" |
| Roughness | 0.001" |
| Ambient Temperature | 50 °F |
| Overall heat transfer coefficient | 0.2 Btu/hr/ft ² /°F |