Investigation of the Thermal Effects on the Flow Resisting Properties of Hydrocarbon Flow in a Pipeline Using CFD Simulation

by

Nurliyana Zadora Binti Choe

Dissertation submitted in partial fulfillment of

the requirements for the

Bachelor of Engineering (Hons)

(Petroleum Engineering)

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UniversitiTeknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak DarulRidzua

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Petroleum Engineering Programmes
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in partial fulfillment of the requirements for the
BACHELOR OF ENGINEERING (Hons)
(PETROLEUM ENGINEERING)

Approved by,

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(Ir. Dr. Mohd Shiraz bin Aris)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
September 2012

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.

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NURLIYANA ZADORA BINTI CHOE

ABSTRACT

Deepwater transportation of hydrocarbon reservoirs is commonly transported through subsea flowlines to surface processing facilities. During the transportation, the flowlines and the contents may be cooled to a deepwater temperature of 3ºC. Depending on the hydrocarbon fluids behavior and characteristics, this colder seabed may cause increased in viscosity and/or solidification of wax in the flowline. Severe wax deposition may lead to several problems in reduced production and impaired flow assurance which may eventually block the flowline. This problem will cause very high maintenance cost for cleaning work and could be very time consuming. Therefore, the subsea flowline temperature should be maintained above the Wax Appearance Temperature (WAT, 314K) by heat from an active heating system. The wax appearance temperature (WAT) is the temperature at which the crude oil first precipitates solid wax. This is possibly the single most important characteristic in examining wax deposition potential in crude oil. In this thermal management of active heating system, hot fluid such as water will circulate along the pipeline in a flow-loop to maintain the temperature and avoid solid depositions during both flowing and shut-down conditions.

The purpose of this project is to investigate the effect of thermal on the flow resisting properties of hydrocarbon flow in a pipeline using simulation. The simulation is performed using Computational Fluid Dynamic (CFD) simulation software (GAMBIT and FLUENT) to provide a pipeline bundle arrangement design that has the most effective heat transfer mechanism and has been validated with data generated from experimental activities.

ACKNOWLEDGEMENT

First and foremost, I would like to take this opportunity to express my appreciation to my project supervisor, Ir. Dr. Mohd Shiraz bin Aris, who had continuously monitored and guiding my project throughout the duration of nine months. Without his continuous advice, I would not have completed my project. Thank you so much.

Instead of that, I would like to thank to all my friends for continuous support given to me morally or technically especially to my classmates who understand the effort that I put in order to make my project complete and success.

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CHAPTER 1

INTRODUCTION

Heat transfer analysis especially in deepwater production pipelines is one of major importance for the prediction and prevention of flow assurance which can interrupt the hydrocarbon flow. The production flow through a deepwater pipeline can cause serious problems. The heat loss due to the critical temperature gradient between the crude in the pipeline and the environment can results in a successive wax deposition on the walls of the pipeline. This problem will eventually cause:

1. Reduction of the internal diameter of the tubular, restricting and ultimately blocking flow.
2. Increased surface roughness on the pipe wall, causing increased pumping pressure and reduced throughput
3. Accumulations that fill process vessels and storage tanks, causing system upsets and costly, labor-intensive cleanup and disposal problems.
4. Interference with valve operation and instrumentation.

Besides, during the subsea operation, the wells are often required to be shut-in, thus leaving non-flowing fluids in the pipeline. Under this shut-in wells condition, thermal insulation may not be able to maintain the temperature of the hydrocarbon fluids above that at which wax deposition may occur, especially when the shut-in duration is extended.

Efficient flowline thermal management system is capable of preventing the hydrocarbon temperature from dropping below the wax appearance temperature (WAT). Active heating method is one of the widely used thermal management system especially in deepwater field. Bundle system with hot fluid active heating is an effective alternative solution which will be chosen method for further analysis and evaluation for this project.

1.1 BACKGROUND STUDY

Development of production activities in the deepwater faced major challenges. The colder seabed temperatures and larger pressure drops caused by long-distance pipelines connecting subsea system to a surface production facility are of meticulous concern. Production from these reservoirs flows from the wellheads through jumpers, manifolds, flowlines, and risers to reach the delivery point is not problem-free.

It is well-known that the viscosity of crude oils decreases with an increase in temperature. Ekeh Modesty K., in his studies state that the temperature dependence of viscosity which means as viscosity increases in cold areas the flow resistance increases and if the temperature becomes low enough, the wax in crude may precipitate and deposit.

Figure 1.1 below shows the relationship of viscosity and temperature in Angsi crude well located in Malaysia which is studied by Ekeh Modesty K.

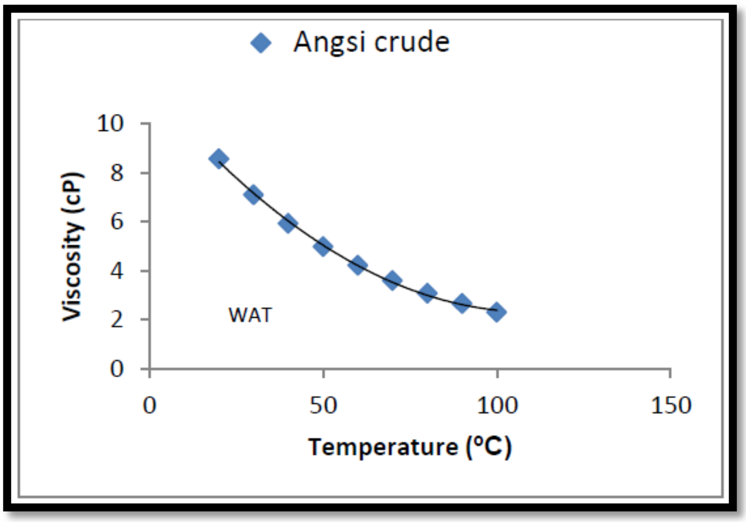


FIGURE 1.1 Effect of Wax Precipitation on Viscosity of Angsi Crude.[2]

Apart from that, flow assurance challenges, mainly wax deposition often take place once the temperature of the fluid drops below wax appearance temperature (WAT). According to A.A. Sulaiman et al., The WAT ranged between 21°C and 46°C from the deepest (8,000 ft) to the shallowest (5,000 ft) reservoir. From experimental study of WAT by United States Department of Energy in 2008, it was found that wax can start to precipitate at temperatures as high as 40.6°C.

To avoid these problems, the subsea production thermal management system can be designed and introduce into the flowline. Thermal management system is a way of controlling the temperature of the crude that flows inside a flowline . According to SPE 140997, over the last ten years, pipeline design and operation of thermal management system have become increasingly important for preventing blockages in the flowline system due to the wax deposition.

Generally, thermal management system consists of thermal insulation (passive mechanism) and thermal heating (active mechanism). The division is shown in figure 1.2 below.

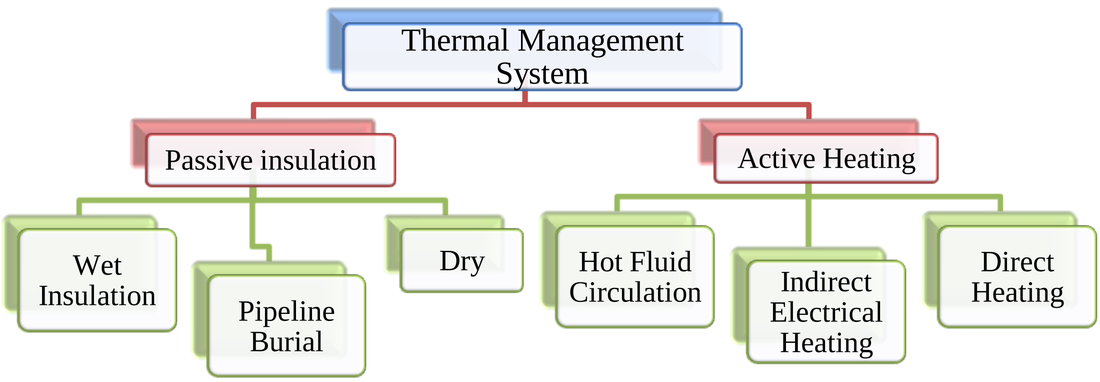


FIGURE 1.2 Methods Used As Thermal Management System for Flowlines in Oil and Gas Fields.

Passive pipeline insulation has been popular flow assurance solutions for the industry. However, as the water depth increases, some fields cannot depend only on pipeline insulation to fulfill operational thermal requirements because the environment is becoming more aggressive.

Active heating method is the most practical, effective and economical solution to fulfill the thermal requirement of flowline especially in deepwater fields where flowline and riser lengths are such to extend over a large temperature and pressure differences. By using active heating, it is capable of maintaining the temperature of hydrocarbons above the wax appearance temperature over long distance as well as to avoid viscosity of crude increase and also able to heat the hydrocarbon fluids above WAT in wells shut-in conditions. In this project, active heating system of hot fluid circulation concepts are considered and evaluated.

Basically in this system, hot fluid will circulate along the pipeline in a flow-loop to maintain the temperature and avoid solid depositions during both flowing and shut-down conditions. Heat transfer analysis of the equipment and pipeline systems is of great importance for the prediction and prevention of increase and crude viscosity and wax deposits.

According to SPE 90054, hot fluid heated bundle configurations have been succeeded in several projects such as Statoil's Gullfakes, ConocoPhilips' Britannia, and BP's King Gulf of Mexico.

1.2 PROBLEM STATEMENT

Flow assurance is critical for deepwater pipeline and system operation. If the fluid temperature inside the pipeline becomes too low, it may cause the viscosity of the fluids become thicker which eventually leads restriction to the hydrocarbon flow and wax deposition will occur. In worst case scenario, it can totally block the flowline. Temperature seems to be the major and most critical factor in crude flow and wax deposits. Thus, effective management of the thermal system properties is crucial to the success of a field development.

Although wax deposition is a normally encountered problem in production operations, there is no universally effective treatment for the problem. Treatment methods are usually highly case-dependent, requiring the proper identification of the mechanisms for wax deposition and the development of a predicting technique that is specific for the target field. A properly designed and implemented treatment method for preventing wax deposition is essential to cost-effective production in deepwater field.

The significant of this project is to investigate thermal effects on flow resisting properties of hydrocarbon flow in a pipeline using Computational Fluid Dynamic (CFD) Simulation, with the main goal of investigating the temperature distribution in bundle pipeline which leading to increase in viscosity and wax deposit and possible ways of mitigating this. By using CFD simulation software, it can reduces the time and operation cost compared by experimental in order to measure the optimum parameter and the behavior of the hydrocarbon flow.

1.3 OBJECTIVE OF THE STUDY

The objective of the study is to achieve the following:

- To analyze the temperature distribution inside the pipeline bundle that may lead to possible wax problems.
- To validate the simulation work with experimental data.
- To design possible bundle arrangement of pipeline with the most effective heat transfer mechanism to prevent wax deposition in pipeline

This investigation can be achieved by undertaking CFD simulation as the tool together with validation data generated from experimental activities.

1.4 SCOPE OF THE STUDY

The scopes of the project are as below:

- Develop a 2-D and 3-D computer model to simulate the Hydrocarbon flow in a selected flowline bundle configuration. The model can be solved by the "Gambit" and "Fluent" package of the CFD simulator.
- To study the thermal performance of the flowline bundle, and the thermal interaction among the product line, test line, and heat flow and return line.
- To investigate the thermal effects on wax deposition of hydrocarbon flow in a pipeline.
- To validate the CFD calculations against the data generated from the experimental work.
- To propose the recommendation to improve this study for further research.
- To submit the final report that includes the whole study.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Problems related to wax deposition of heavy organic fractions during production, transportation, and storage of crude oils can lead to considerable financial losses.

Solid layers formed on the walls of pipelines increases pressure drop, increasing power requirements and often plugging pipelines. Conventionally chemical injection of glycol and methanol and pour point depressant are used to mitigate the solid formation of wax. But, as the flowline getting long-distance, the chemical injection is no longer preferable due to economic concern. The use of passive insulation is also a proven thermal management method but still the installation cost of an insulated and buried pipeline are no longer an economically an attractive solution.

Simulation of the flowline bundle with heat flow and return in a close loop is an effective alternative solution which will be the favorable method for further analysis and evaluation for this project. The designed pipeline system had to be able to maintain the steady state temperatures above the product WAT under the operation pressure throughout the subsea system.

2.2WAX DEPOSITION

Basically, wax is a common term used to describe all kinds of undesirable solid matter being deposited or dissolved during cooling or heating in flowline. Wax appearance temperature (WAT) is the temperature at which the first wax crystal appears in a crude oil; it is also termed *cloud point*.

Wax deposition occurs when the temperature is insufficient to keep the wax fully dissolved in the crude. Therefore, due to decreased in solubility, wax molecules contained in the crude oil will start to deposit on the pipe wall. Some of the factors that affect the deposition of wax will be considered in this study.

2.2.1 Temperature Effect

Temperature control is the single most important parameter for obtaining accurate and precise kinematic viscosity measurements. This is especially true for petroleum products as their rate of viscosity change per unit temperature is significantly greater than other products. Thus a slight variation in temperature can have a very large effect on the viscosity of a fluid.

Feridun Esmaeilzadeh on his earlier study at Pa2-CK pipeline came out with graph in figure 2.1 below:

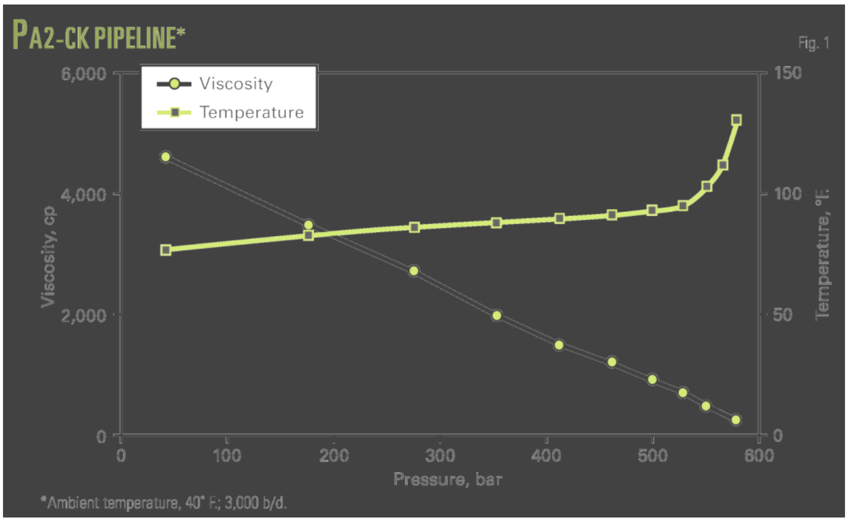


FIGURE 2.1 Relationship of Viscosity, Temperature and Pressure at PA2-CK Pipeline[16]

From figure 2.1, shows the viscosity variation while transferring oil from PA2 field to CK production unit vs. pipeline flow temperature. Decreasing oil flow temperature from 130º F to 77º F increases oil viscosity and pipeline pressure drop by a factor of 19 and 115, respectively.

Besides, temperature also seems to be the most critical factor in wax deposition due to its direct relationship with the solubility of paraffin. Sadeghazad et al. (1998) reported that temperature and the amount of light constituent are the two most important factors affecting wax deposition. Paraffin solubility increases with increasing temperature and decreases with decreasing temperature. Wax precipitates from crude oil when the operating temperature is at or below the WAT. It has been reported that wax deposition will not occur until the operating temperature falls to or below the WAT (Erickson et al., 1993).

The ambient temperature around the pipe is generally less than the oil temperature in the pipe. Thus, there is loss of heat through the pipe wall to the surroundings because a temperature gradient exists between the bulk oil and the colder pipe wall. This temperature gradient leads to wax deposition when the pipe wall temperature falls below the cloud point. Haq (1981) showed that keeping the pipe wall temperature constant at a value below the cloud point of the oil and varying the bulk oil temperature reduce the amount of wax deposited as the temperature difference between the bulk oil and pipe wall increases (Figure 2.2).

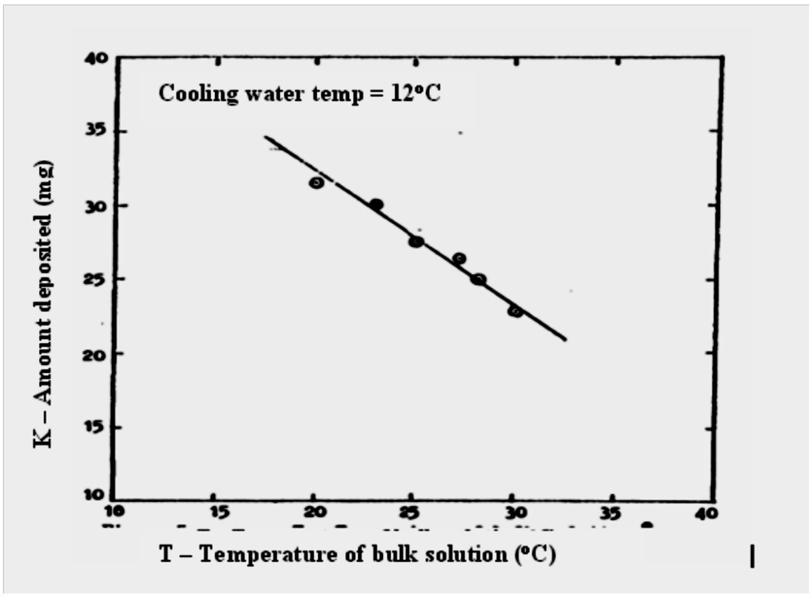


FIGURE 2.2 Effect of Temperature Gradient on Wax Deposition (Haq, 1981)[17]

The viscometry technique employs the linear relationship between fluid viscosity and temperature. According to this technique, the WAT is determined from a plot of natural log of viscosity (LN Viscosity) versus inverse of absolute temperature (1/T) to be the point at which deviation from linearity occurs as temperature is lowered (Figure 2.3).

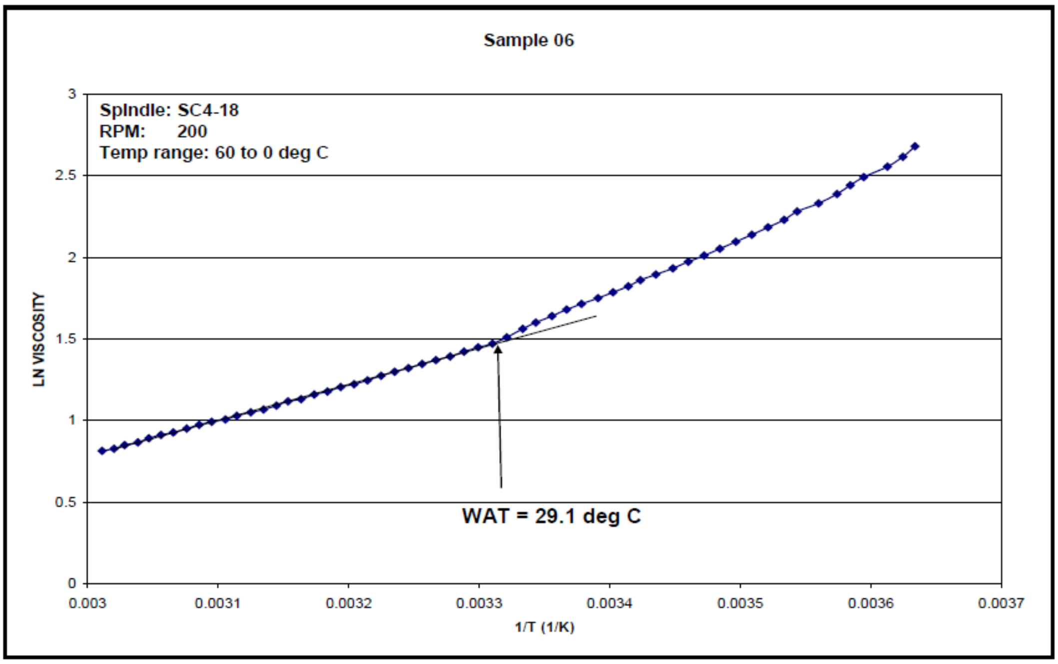


FIGURE 2.3 Typical Viscosity-Temperature Relationships for the WAT.[3]

2.2.2 Pressure Effect

Pressure also plays a significant role in wax deposition. It is an important parameter in the exploitation of reservoir fluids According to P. J. Jansens et al. (Biwic 2006), increasing in pressure causes the decrease in the solubility of precipitating components in liquid phase. Thus, the solid phases will precipitate at higher temperature. Therefore, it can be concluded that increase in pressure, decrease the solubility of the wax component in crude oil and eventually increase the amount of precipitated wax. Figure 2.4 below shows the phenomenon.

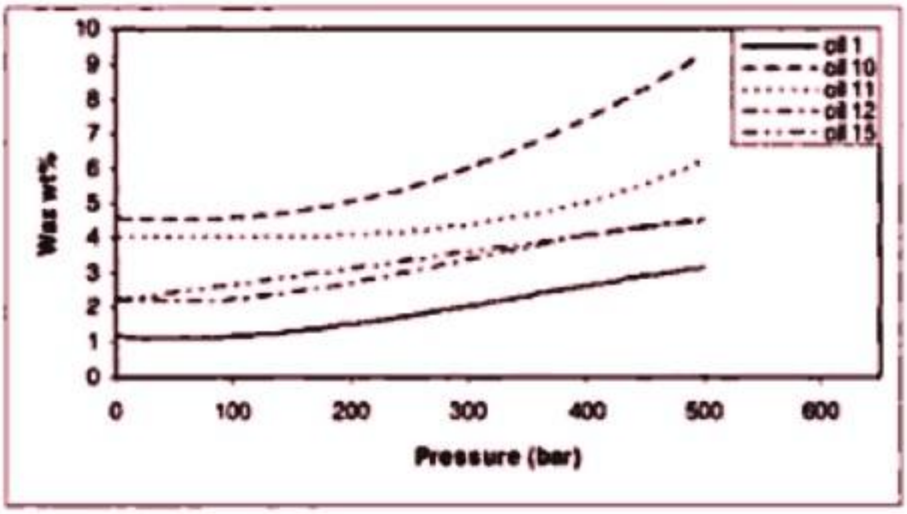


FIGURE 2.4 The Effect of Pressure on the Weight Percent of the Precipitated Solid from Oil System at Different Temperatures[7]

Brown et al. (1994) studied the effect of pressure on the cloud point of dead oil as well as live oil by measuring cloud point at atmospheric pressure and higher pressures. Both the experimental and modeling results presented in figure 2.5 show that the cloud point is a linear function of pressure for the dead oil with the predictions having a greater slope.

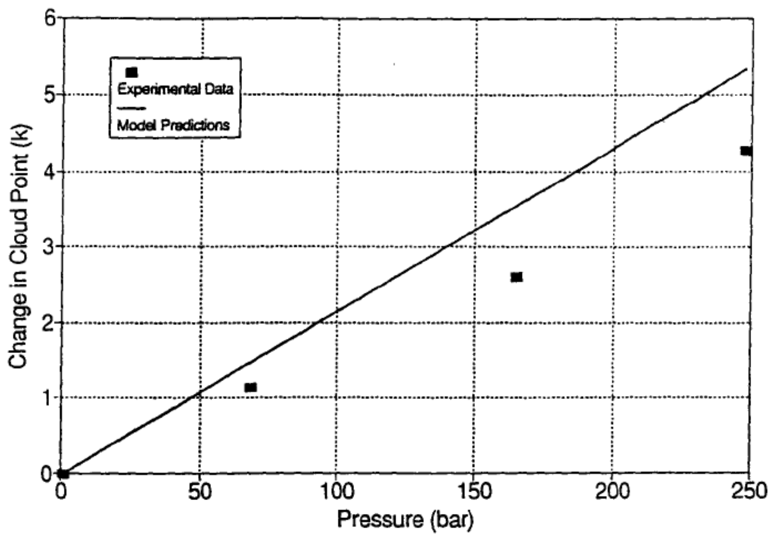


FIGURE 2.5 The Effect of Pressure on Cloud Point[12]

From the graph generated from Brown et al. studies shows that the wax appearance temperature increases with increase in pressure above the bubble point, at constant composition. This means that increase in pressure in one-phase liquid region will encourage wax deposition. The WAT increases with increase in pressure for STO, commonly referred to as dead oil (Brown et al., 1994; Karan et al., 2000). Huanquan et al. (1997) reported that the WAT increases with increase in pressure for a fixed component liquid mixture.

2.3 HEAT TRANSFER FUNDAMENTAL

Heat is defined as energy transferred from one body to another by thermal interaction, temperature difference or gradient. Heat transfer analysis is important in thermal design of pipeline bundle which predicts the temperature profile along the pipeline. This information if required for wax deposition analysis.

The production fluid temperature in steady-state operation decreases as it flows along the pipeline due to the heat transfer through the pipe wall to the surroundings. In order to prevent for the wax deposition to take place, the temperature profile in the whole pipeline system should be higher than the requirements during normal operation. In this case, there are 2 distinct modes in which heat transfer takes place:

2.3.1 Heat Transfer by Conduction

Conduction heat transfer occurs when a temperature gradient exists in a stationery medium, which may be gas, liquid or solid. Heat energy will flow from the region of high temperature to the region of low temperature. This type of heat transfer can be described by Fourier`s Law which states that "Rate of heat transfer is linearly proportional to the temperature gradient". For problems where the temperature variation is only 1-dimensional, Fourier's Law of heat conduction simplies to the scalar equations,

$$q = -k \frac{dT}{dx}$$

Where the heat flux, *q* depends on a given temperature profile, *T* and thermal conductivity, *k*. The minus sign ensures that heat flows down the temperature gradient.

2.3.2 Heat Transfer by Convection

Convection heat transfer occurs when heat energy transmits between solid surface and a fluid system in motion when there is a temperature difference between both bodies. This type of heat transfer cannot be ignored when there is a significant fluid motion around the solid. When a temperature of solid due to an external field such as fluid buoyancy can result in fluid movement, the process is called Natural Convection. Other than that, when the fluid movement is carried by an external devices such as pump, the process is called Forced Convection.

2.4 ACTIVE HEATING

Khalefa et al, 2003 said that active heating is a practical, effective and economical solution for flowline thermal management system. Active heating is also capable of maintaining the temperature of hydrocarbons above the wax appearance temperature (WAT) over long distance pipeline.

According to Fouad et al, 2004, one of active heating methods is circulation of hot fluid. Hot fluid circulation method is a proven technique for heating flowlines which has been used widely in deepwater projects. In general, a simple hot water circulation system is a long fixed tube heat exchanger with a heating medium on the outer side and the production fluid on the inner side of the tube (M.M.Myo Thant et al ,2011).

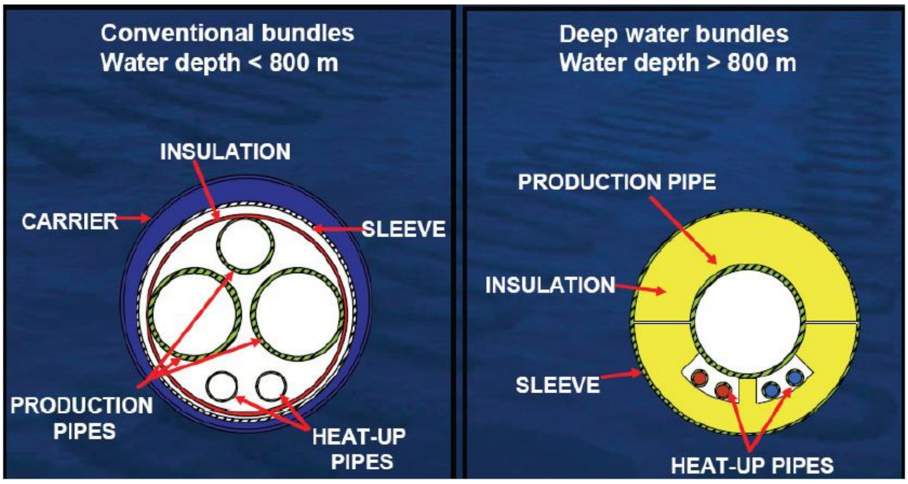


FIGURE 2.6 General Arrangement of Conventional and Deepwater Application Hot Water Circulation Heating Method. [18]

2.4 COMPUTATIONAL FLUID DYNAMIC (CFD)

CFD stands for Computational Fluid Dynamics. It means predicting physical fluid flows and heat transfer using computational methods.

Fluid flows are encountered in virtually all areas of industry. For example, the oil and gas industry includes whole world of different fluid behavior, reservoir condition, heat transfer mechanisms, such as cooling, active heating, insulation and etcetera. Understanding how all these fluid and heat transfer mechanisms work is important for engineers to improve the operation of the mechanism and reduce its impact on the natural resources. Using CFD software, virtual prototype of a product design are able to build so that it can be analyze and generate data and images allowing engineers to predict the performance of particular product design.

2.4.1 GAMBIT

GAMBIT is a state-of-the-art preprocessor for engineering analysis. With advanced geometry and meshing tools in a powerful, flexible, tightly-integrated, and easy-to-use interface, GAMBIT can dramatically reduce preprocessing times for many applications.

Complex models can be built directly within GAMBIT's solid geometry modeler. Using a virtual geometry overlay and advanced cleanup tools, imported geometries are quickly converted into suitable flow domains. A comprehensive set of highly-automated and size function driven meshing tools ensures that the best mesh can be generated, whether structured, multi-block, unstructured, or hybrid. With geometry in place it generates a mesh for the surface and volume of the geometry allowing it to be used for computational fluid dynamics.

GAMBIT is an application that is distributed along with FLUENT. GAMBIT is used as a tool to generate or import geometry so that it can be used as a basis for simulations run in FLUENT.

2.4.2 FLUENT

FLUENT software contains the broad physical modeling capabilities needed to model flow, turbulence, heat transfer, and reactions for industrial applications ranging from air flow over an aircraft wing to combustion in a furnace, from bubble columns to oil platforms, from blood flow to semiconductor manufacturing, and from clean room design to wastewater treatment plants. Special models that give the software the ability to model in-cylinder combustion, aero acoustics, turbo machinery, and multiphase systems have served to broaden its reach.

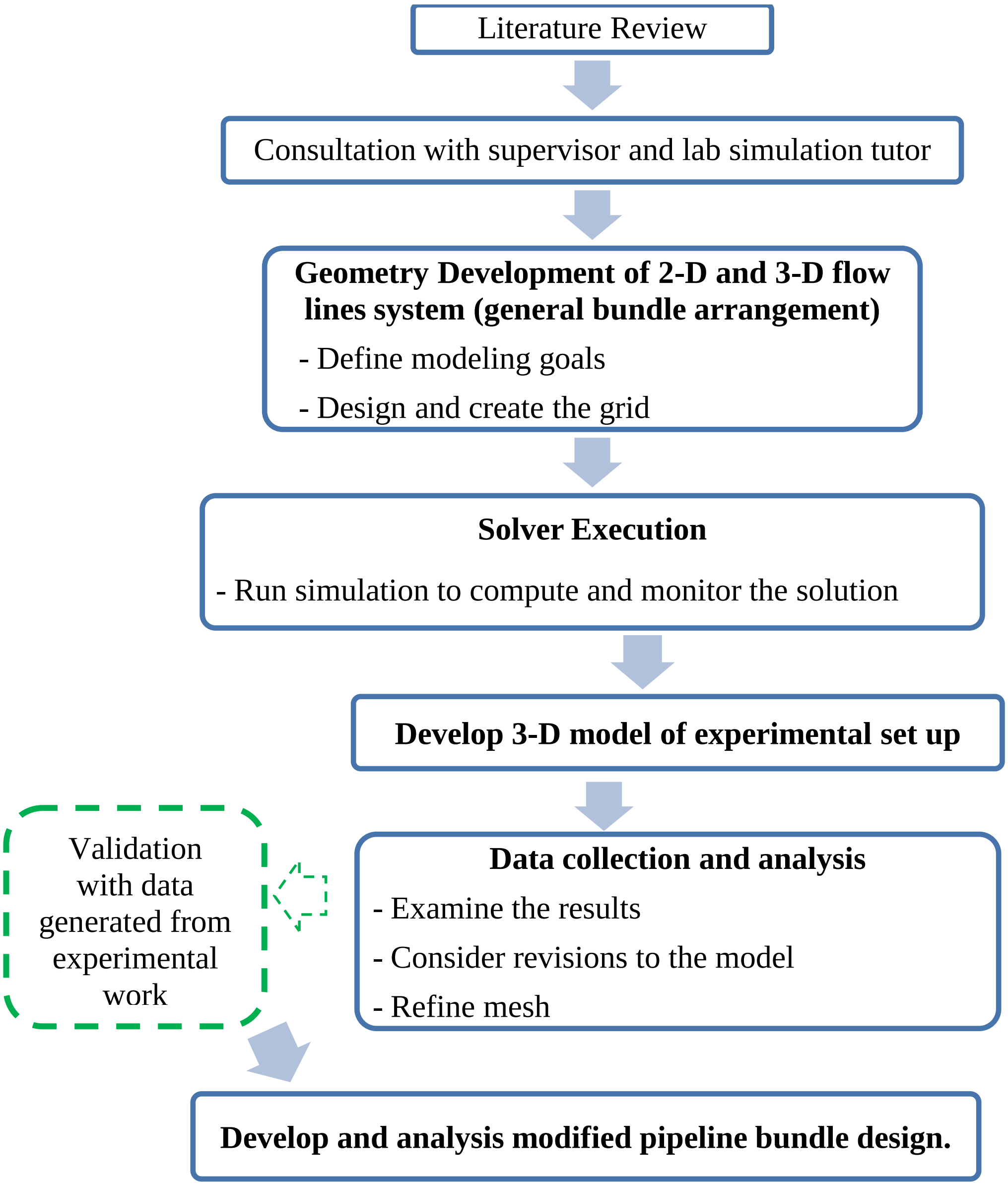
FLUENT is a “Flow Modeling Software”. It is used to model fluid flow within a defined geometry using the principles of computational fluid dynamics. Unlike GAMBIT, which it is shipped with, it utilizes a multi window pane system for displaying various configuration menus and grids instead of a single window with several embedded sub-windows restricted within the space of the parent window. FLUENT is able to read geometries generated in GAMBIT and model fluid flow within them. It can model various scenarios using computational fluid dynamics, including compressible and incompressible flow, multiphase flow, combustion, and heat transfer.

CHAPTER 3

METHODOLOGY

3.1 RESEARCH METHODOLOGY

This section will describe on how the research method will take place to get the result. The research methodology will include as below:



3.2 PROJECT ACTIVITIES

This project will conduct a simulation work to investigate the thermal effects on the flow resisting properties of hydrocarbon flow in pipeline. The aim is to analyze the existing pipeline bundle design, model experimental setup of pipeline flow-loop, validate CFD model with experiment set up and make modification to the general bundle arrangement to find the most effective heat transfer mechanism that will prevent wax deposition in subsea pipeline. The simulation work will be explained below:

3.2.1 Geometry of General Bundle Arrangement

In this study, CFD has been used for analysing the existing design geometry as used in Liu, L. el al study as the general bundle. The design information have been undertaken to develop a 2-D and 3-D model to study the prediction of heat transfer inside the bundle design as an early result. Glycol water solution is used as the heating medium that fills the space between the pipes inside the bundle. The pipeline bundle information as in Table 3.1 and Table 3.2 is used, while the general configuration of bundle as shown in figure 3.1.

TABLE 3.1 Previous Experiment of Prediction of Heat Transfer Inside Pipeline Bundle Geometry by Liu, L. el al.

Pipe	**Inner diameter (mm)**	**Material**	**Temperature (K)**
Sleeve	750	Steel	288
Product	340	Copper	313
Test	190	Copper	313
Heat sources	95	Copper	350

TABLE 3.2 Material Properties

Material	**Density (kg/m3)**	**Heat capacity (J/kg/K)**	**Thermal conductivity (W/m/K)**	**Viscosity (kg/m-s)**
Water	996	4182.5	0.604	0.001003
Glycol water solution	1090	3893.7	0.5019	0.00063
Steel	7700	502.1	52.34	-
Copper	8954	398	400	-

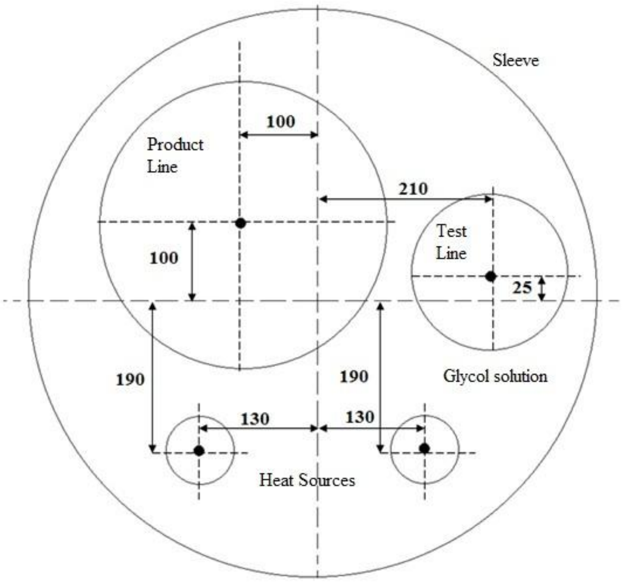


FIGURE 3.1 General Arrangement of the Selected Bundle for the Project

The bundle was modeled with sleeve as a steel cylinder and copper pipelines inside the bundle. The model was created 2-D and 3-D in GAMBIT software which is also used as a pre-processor for meshing and boundary zone definitions.

For 3-D general bundle arrangement, just sweep the real 2-D faces along the edge of 3 meter long.

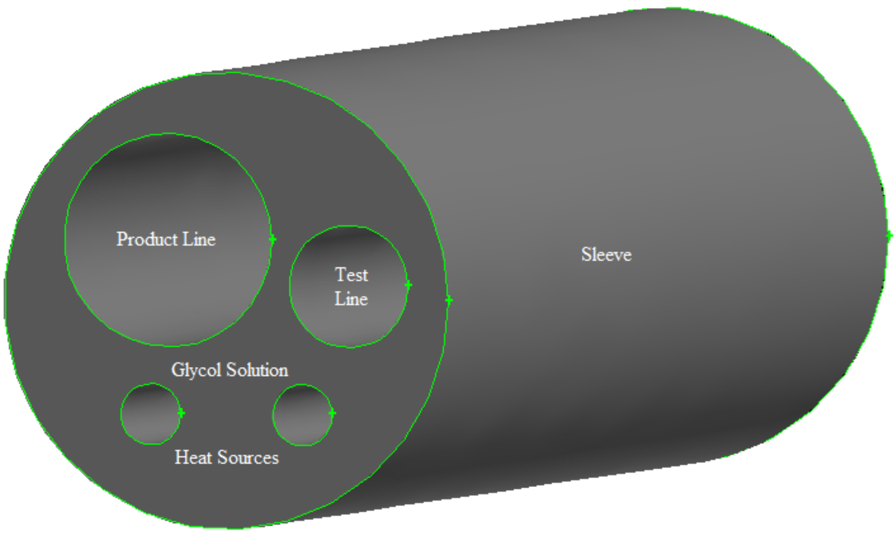


FIGURE 3.2 3-D General Bundle Arrangement Setup in GAMBIT

3.2.2 Meshing Properties of General Bundle Arrangement

In order to perform a flow simulation by using FLUENT software, first create a phase where the flow characteristics are analyzed. The modeling and meshing of the phase is done by using the GAMBIT software.

All the geometries of the pipeline bundle are modeled based on design drawing before any meshing is done to the model. The next step of completing the model is to perform meshing onto the model. The type of mesh depends on the suitability of the geometry of the model. Choosing the inappropriate mesh will cause error during the meshing process and also affect accuracy of results during the analyzing process in FLUENT.

In the meshing of the 2D model, the element chosen is Tri and the type is Pave. The Tri element is chosen because GAMBIT will automatically mesh the entire face and cover more comprehensively the sharp corner of the geometry. The description for each option can be seen in Table 3.3.

TABLE 3.3 Descriptions of 2-D Mesh Types

Option	Description
Tri	Specifies that the mesh includes only triangular mesh elements
Pave	Creates an unstructured grid of mesh elements

After the meshing step is completed, the boundary types of each zone of the model are specified. In this model, the boundary types involved is wall for all edges.

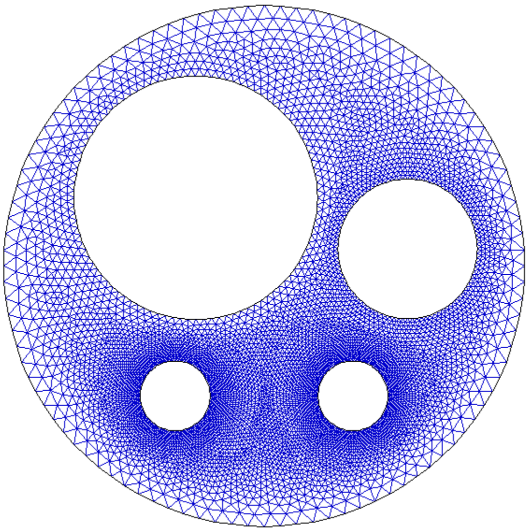


FIGURE 3.3 Meshing (interval count 200) 2-D Bundle Arrangements

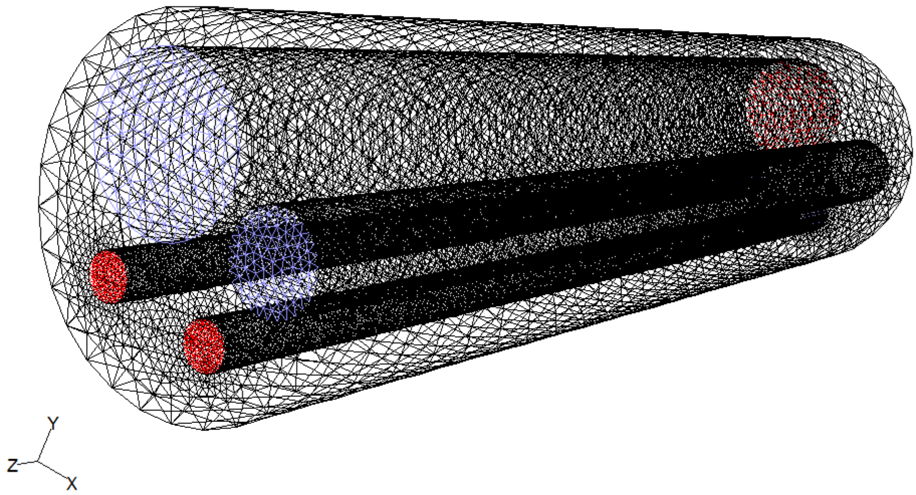


FIGURE 3.4 Meshing (sweep with mesh from 2D face) 3-D Bundle Arrangement Setup

3.2.3 Boundary Condition for General Bundle Arrangement

For 2-D general arrangement, 1 domain with 5 boundary conditions has been specified for the bundle model. The domain filled with glycol solution is used with no slip wall type of boundary condition (zero velocity at wall) for all four internal pipes which are product line, test line, heat sources lines and sleeve.

The main aim of the work is to visualize the temperature distribution for different pipe temperature configuration. Fixed wall temperatures are used for each of the pipes. Below are the temperature (ºC) ranges of the pipes which will be used for the simulations:

For 3-D general bundle arrangement, the boundary condition has glycol inlet temperature set at 300K, product line inlet set at 323K and the heat sources inlet set a 373K. All the outlets are set to be an outflow.

For 2-D and 3-D boundary condition model summarize as table 3.4 below:

TABLE 3.4 Model Boundary Condition Summarize

Model	**Setting**	
Space	2D	3D
Material	Steel Glycol water Solution	Steel, Copper Water (heat medium)
Boundary condition	All pipes are set as “wall”	Wall Inlet Outlet
Time	Steady	
Viscous	k-epsilon turbulence model	
Heat Transfer	Enabled	
Radiation	None	

3.2.4 Experimental setup

In order to assess the applicability of Computational Fluid Dynamics (CFD) model, it is necessary to have some experimental data which can be used to validate the CFD predictions. Experimental studies on the temperature distribution in a pipeline in a simple flow loop model were conducted at Corrosion Research Centre, Block I, Universiti Teknologi PETRONAS. The experimental setup as per figure below:

FIGURE 3.5 The View of The Flow Loop of Experimental Setup

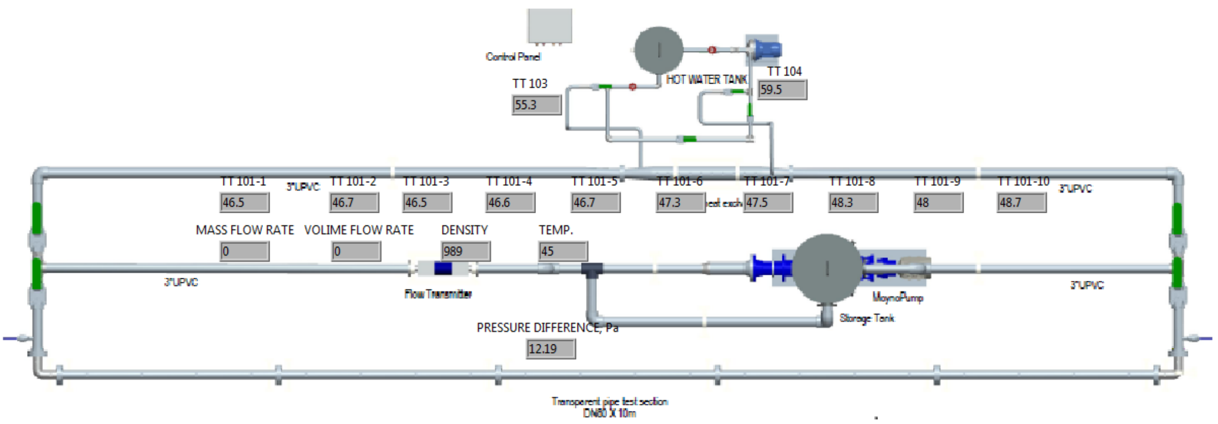


FIGURE 3.6 The View of The Experimental Setup

3.2.5 CFD 3-D Experimental setup model

The simple configuration of experimental set up includes PIP arrangement with water as the heating to the inner pipe. The design information as in Table 5 is considered in this CFD simulation and the model shown in Figure 15.

TABLE 3.5 CFD Model of Experimental Set up Information

Pipe	Inner diameter (mm)	Material	Temperature (K)
Sleeve	102	Steel	288
Product	50	Copper	313

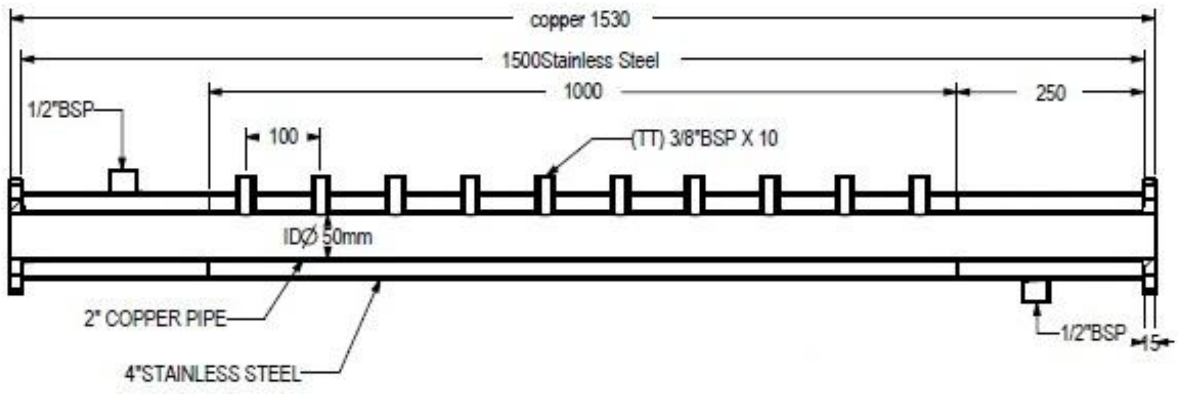


FIGURE 3.7 Pipeline Flow Loop Arrangements

The 2” inside and 4” PIP flowline systems rely on active heating. A novel PIP arrangement as shown in Figure 7 is used to circulate a heat medium (water) in the annular space between the 8" and 12" pipes to actively heat the flowlines over their entire length of 5ft with inlets and outlets of two fluids that flow counter-current to each other (Figure 8). The product wall select as shell conductive to allow heat transfer occurred between both fluids.

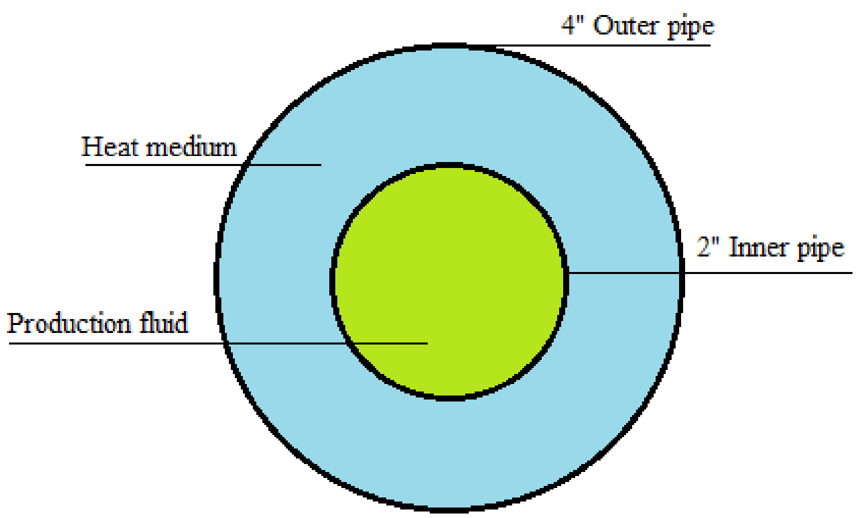


FIGURE 3.8 PIP Arrangements

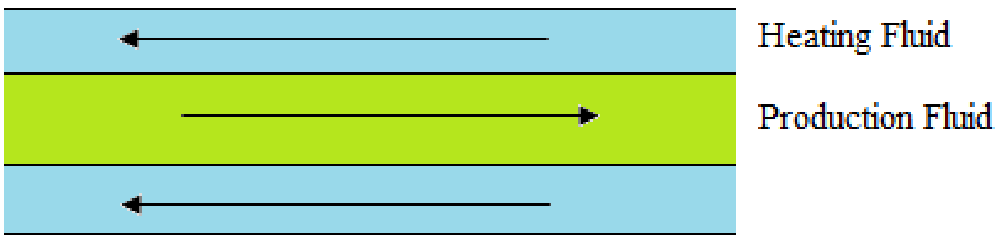


FIGURE 3.9 Counter Current Flow Directions

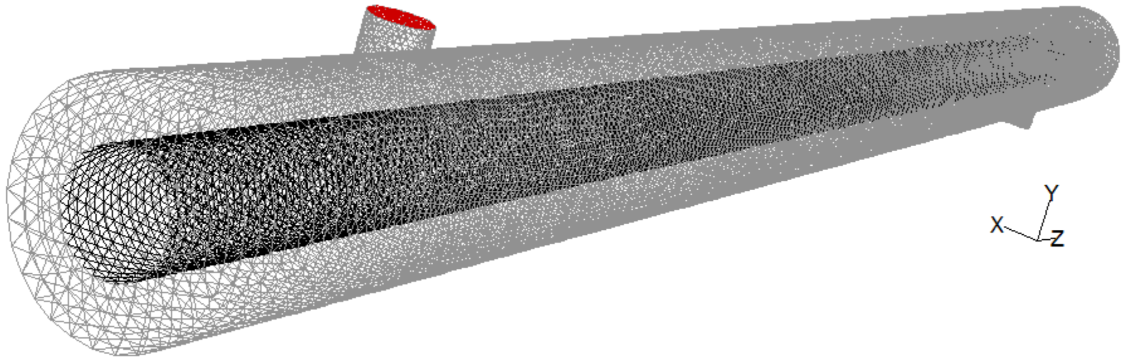


FIGURE 3.10 The View of 3-D PIP Flow Loop Arrangement Meshed in GAMBIT

The appropriate boundary conditions used to solve for heat flow through the cylinder. Boundary conditions applied at the domain ends helped in maintaining continuity.

For obtaining the temperature distribution inside the pipeline, the temperature was maintained constant at 310K on the fluid flow in the inner pipe while the outer fluid is set at temperature of 343K at the inlet and outlet boundary condition is set as outflow. In this case, water is used as heat medium as well as the fluid flow inside the inner pipe.

Second Order Spatial Discretizations schemes were used for their higher accuracy and the simple pressure-velocity coupling scheme was selected. . Lastly residuals for equations (continuity, x-velocity, y- velocity, k and epsilon) were set to 1E-03, while equation energy sets to 1E-06. Then, run for 3780 iterations.

3.2.6 CFD 2-D modified general bundle arrangement design model

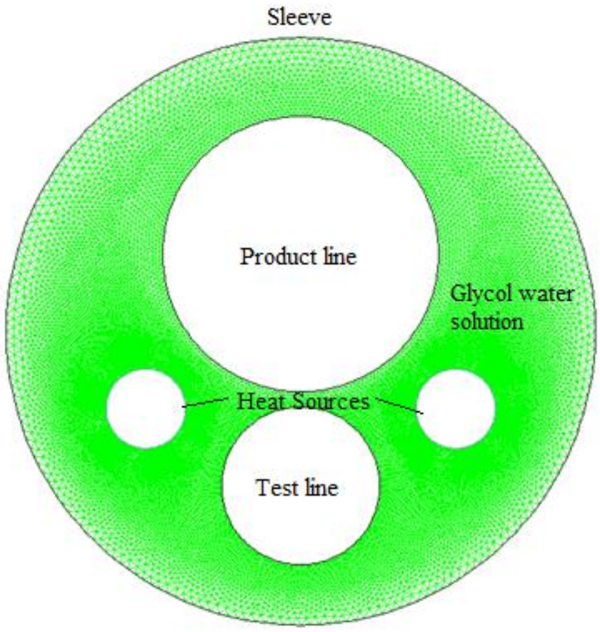


FIGURE 3.11 Meshing (interval count 200) 2-D Modified General Bundle Arrangements

For 2-D modified general bundle arrangement, all the pipeline properties and boundaries conditions are the same as the existing design, but the configuration of pipeline inside the bundle has been modified as shown in figure 3.11. The modifications are made to study the thermal interaction between pipelines with the new configuration to see either the heat transfer mechanism is at its best with this arrangement.

3.3 KEY MILESTONE

This is the section to describe works that have to be done in certain period.

TABLE 3.6 Key Milestones

Milestones	Suggested Completion date
Topic selection	May 2012
Research work • Data gathering from journal and technical paper • Study the previous work related to thermal management in hydrocarbon pipeline.	June 2012
Consultation with Simulation tutor • Install CFD software • Familiarization with CFD software (GAMBIT and FLUENT)	August 2012
Start construct 2 D basic geometry using GAMBIT 2.4 • Geometry construct, meshing and set up boundary conditions.	September 2012
Solve mesh using FLUENT 6.3.26 • Set up all condition to default • Set up temperature range of each boundary • Solve and analysis data generated • Mesh refines and simulation steps repeated and analysis continues.	September 2012
Validate result with data generate from experimental work	October 2012
Reporting	November 2012

3.4 GANTT CHART

No.	**Project Activities**	**Weeks**													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	FYP 1 (May 2012)														
1	Selection of Project Topic														
2	Preliminary Research Work														
3	Data gathering from journals and technical papers														
4	Consultation with supervisor and simulation tutor														
5	Start construct general bundle arrangement using GAMBIT 2.4														
6	Solve using FLUENT 6.3.26														
7	Proposal Defense presentation														
8	Submission of Interim Report														
	FYP 2 (September 2012)														
9	Project Work Continues														
10	Pre-SEDEX (Poster presentation)														
11	Submission of Draft Report														
12	Submission of Dissertation (softbound)														
13	Oral Presentation (Viva)														
14	Submission of Project Dissertation (hardbound)														

3.5 TOOLS AND EQUIPMENT REQUIRED

Tools and equipment that will be using for this study is as following:

- Computational Fluid Dynamic (CFD) Simulation Software
  1. FLUENT 6.3.26
  2. GAMBIT 2.4

CHAPTER 4

RESULTS AND DISCUSSION

4.1 General Bundle Arrangement Temperature distribution

For 2-D general bundle arrangement the temperature distribution was obtained as shown below. Figure 4.1 displays filled contours of temperature variation.

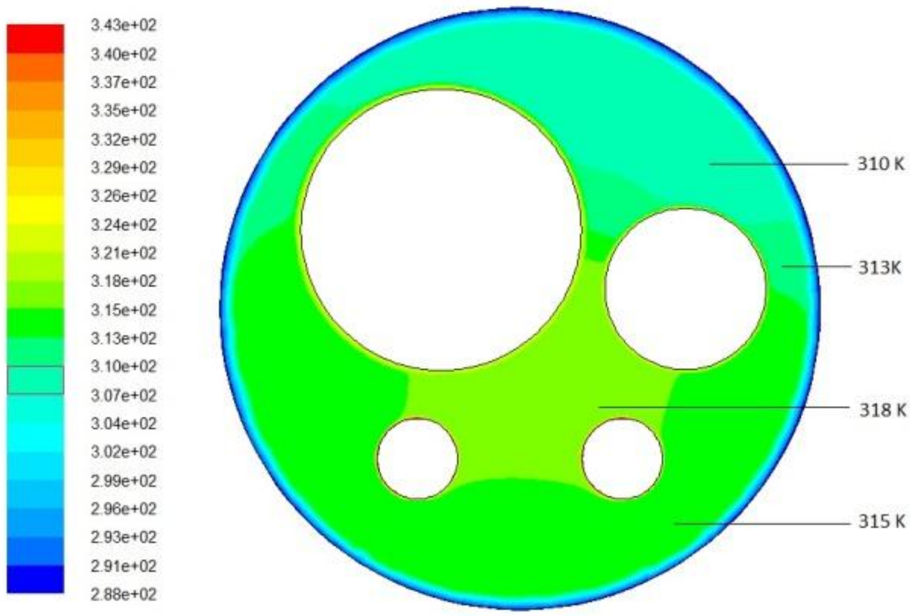


FIGURE 4.1 Contour Plots of Temperature (K) For 2-D General Bundle Arrangement

The figure shows temperature distribution of the 2D surface. The flow modeled so that the flow from heat sources distributed to the product and test pipelines. Figure above shows that the temperature dissipates unevenly leaving some region with temperature below WAT. These regions are said to have the potential wax build up. In 3-D view of temperature distribution in general bundle arrangement (Figure 4.2) also shows the same result. The temperature is not fully transferred to heating up the product and test line.

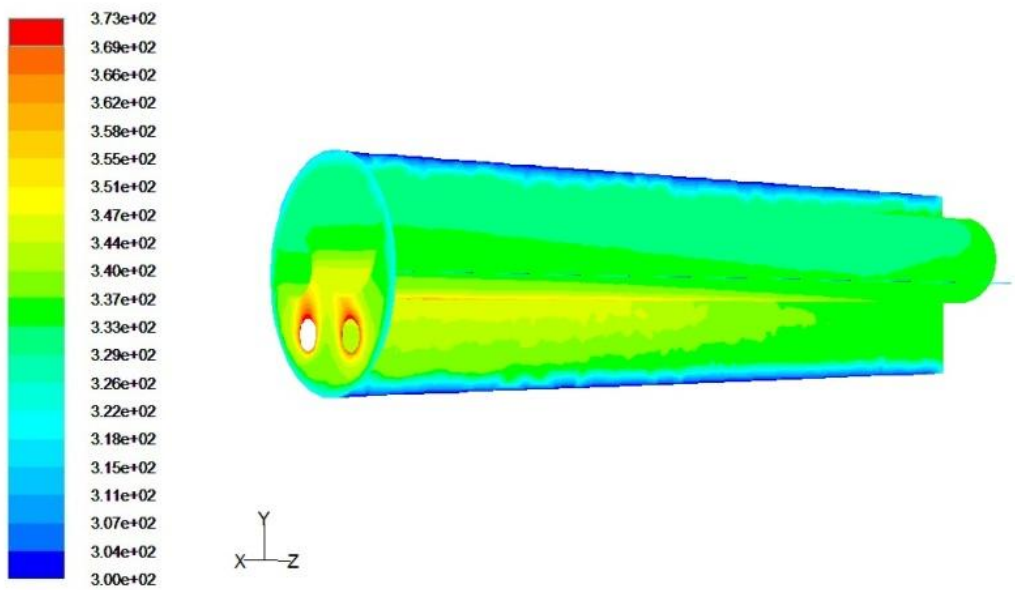


FIGURE 4.2 3-D General Bundle Arrangement Temperature Distributions

4.2 CFD Experimental set up Temperature Distribution

For 3-D experimental set up model, figure 12 shows the temperature distribution along the pipeline.

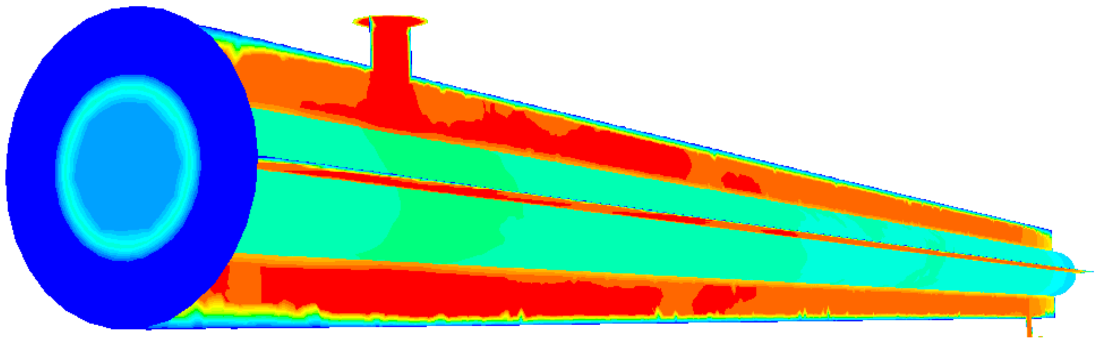


FIGURE 4.3 3-D CFD Experimental Model Temperature Distributions

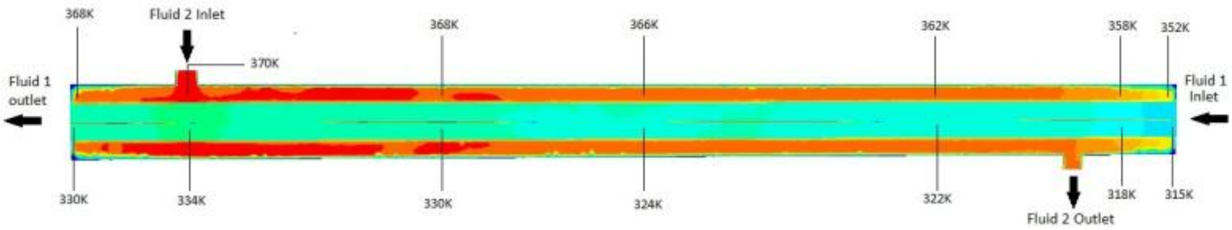
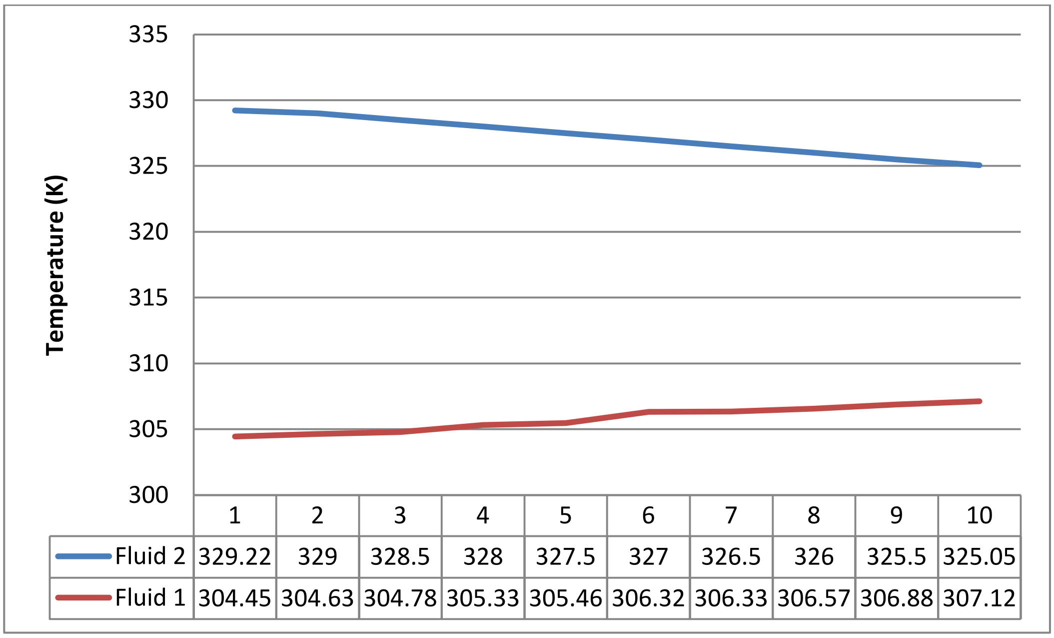


FIGURE 4.4 Contour plots of temperature (K) for 3-D PIP Flow Loop Arrangement

The Figure 4.4 shows temperature distribution occurred in the flow loop line. The temperature distribution can be summarizing in graph in Figure 4.5.



	1	2	3	4	5	6	7	8	9	10
Fluid 2	329.22	329	328.5	328	327.5	327	326.5	326	325.5	325.05
Fluid 1	304.45	304.63	304.78	305.33	305.46	306.32	306.33	306.57	306.88	307.12

FIGURE 4.5 Graph of Temperature Distribution Inside The PIP Flow Loop Arrangement Between Two Fluid Medium.

The graph shows that the Fluid 2 (heating medium) cools down near the inner pipeline inlet since it have been travel along the distance of 5ft. Fluid 1 flow at rate of 0.5 m/s while Fluid 2 flowrate is 1 m/s. The Fluid 1(inner fluid) is heated at most near the heat source inlet. Since Fluid 1 has lower flowrate that Fluid 2, therefore it takes time to fully heating the Fluid 1. But this PIP Flow Loop arrangement has successful to maintain the temperature of Fluid 1 above the WAT.

4.3 Validation of Thermal Analysis

To validate the thermal analysis of simulation above, the graph of temperature profile during experimental work is obtained and compared with the graph of temperature profiles at selected time points from 3-D CFD Model. Figure 4.6 below shows the experimental result graph.

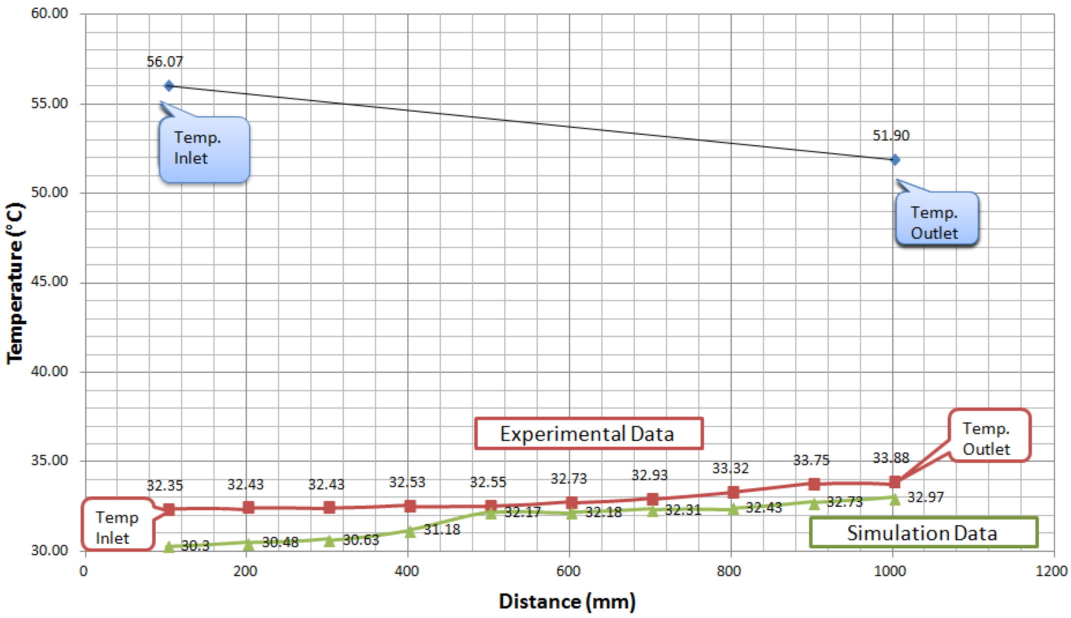


FIGURE 4.6 Graph of Temperature Distribution of Experimental Work With CFD Simulation.

The closeness of the graphs supports the correctness of the simulation. The small deviation between the graphs can be accounted to experimental errors and approximations used in simulation.

4.4 2-D Modified General Bundle Arrangement Design Temperature distribution

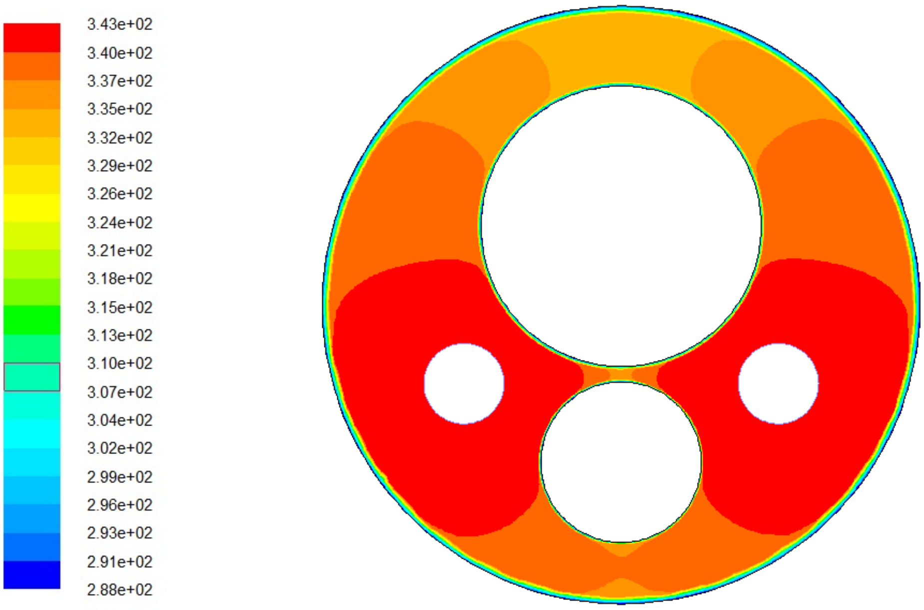


FIGURE 4.7 Contour of Temperature Distribution of Modified General Bundle Arrangement Design.

The figure shows temperature distribution of the 2D modified general bundle arrangement design surface. The design has been modified and modeled so that the flow from heat sources distributed to the product and test pipelines more evenly. Figure 4.7 shows that the temperature dissipates evenly leaving no region that possible wax deposition could occur. The temperature is now fully transferred to heating up the product and test line.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

A brief summary of the work completed and significant conclusions derived from this work are highlighted below.

1. Direct heating has more efficient heat exchange between the heating water and heated fluids.
2. For General Bundle Arrangement, the product and test line should placed in the middle while the heat sources should shifted away so that the temperature dissipates around the product and test line.
3. Modification to the general bundle arrangement is needed in order to design a better pipeline that has the best heat transfer mechanism to maintain the production line above WAT.
4. For Experimental Flow Loop set up, since the result obtained from this bundle configuration has successful maintain the temperature of inner pipe to be above WAT, therefore, this option is applicable in future designing a better pipeline with best heat transfer mechanism.

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