
# ANALYSIS ON VARIOUS FACTORS AFFECTING PRESSURE DROP ALONG THE GAS TRANSPORTATION PIPELINE DESIGN

By

WIN AHKAR MEIN

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Petroleum Engineering)

SEPTEMBER 2012

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**CERTIFICATION OF APPROVAL**

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Approved by,

_____

AP AUNG KYAW

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

SEPTEMBER 2012

## CERTIFICATION OF ORIGINALITY

This is to certify that I, WIN AHKAR MEIN (A006116), 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.

_____

WIN AHKAR MEIN

# ABSTRACT

The final year project in its present form is to analyze the various factors effecting on pressure drop along the gas transportation pipeline design by using PIPESIM software. Initially to analyze the effect of factor that can cause the pressure drop along the gas transportation design. Typically author will focus on four main factors , Elevation: conversion of fluid potential energy into hydrostatic pressure, Friction (roughness) : shear stress between pipe wall and gas, Start node Temperature, Pipe sizing, which will cause the pressure drop along the gas pipeline. Consideration of pipeline transportation is very important before designing the gas transportation pipeline. There are majors problem may occur if failure to analyze on the pressure drop during designing the gas transportation pipeline. The result will be failure to fulfill the customer desire pressure and flow rate and it may lost the large amount of profit.

Author will develop the graphical relationship between these five main factors effecting on the pressure drop in this research. Designing a small model of gas transportation pipeline, simulating by PIPESIM software, analysis on outcome results are main criteria of this project. Brief introduction on project, theory and literature review of the project, methodology and project activities will be included in the report.

# ACKNOLEDGEMENT

I would like to take this opportunity to express my utmost gratitude to the individual that have taken the time and effort to assist me in completing the project. First and foremost, my utmost gratitude goes to my supervisor, A.P Aung Kyaw. Without his guidance and patience, I would not be succeeded to complete the project. A warmness thankful to the Final Year Project Coordinator, for provide me with all the initial information required to begin the project. Last but not least, thanks to all individuals that has helped me in any way, but whose name is not mentioned here.

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# CHAPTER 1

# INTRODUCTION

## 1.1 BACKGROUND OF STUDY

Pipelines transportation have become an important means of moving natural gas and with the expansion of market and large demand, millions of pipeline have been laid. Pipelines are long and continuously welded, they have a minimum number of curves, they have no sharp bends, and they are most often buried underground. Pipeline transportation is mostly considerable for gas because it takes large amount of volume to transport by mean of shipping and tanker. Pipeline is the most preferred option to transport oil, gas or products in bulk. It could be thousands of km long, branched and networked.

Configuration of both oil & gas pipeline are very similar. A cross country oil or gas pipeline system, normally starts with pumping of oil or compression of gas to develop the requisite pressure to travel a long distance. The pressure required for pumping of oil or compression of gas depends on pipeline length, pipe diameter, & destination pressure requirements. For long pipelines (hundreds of km), booster compressor for gas pipeline and booster pumps for oil pipeline are required along the length as in the graph below.

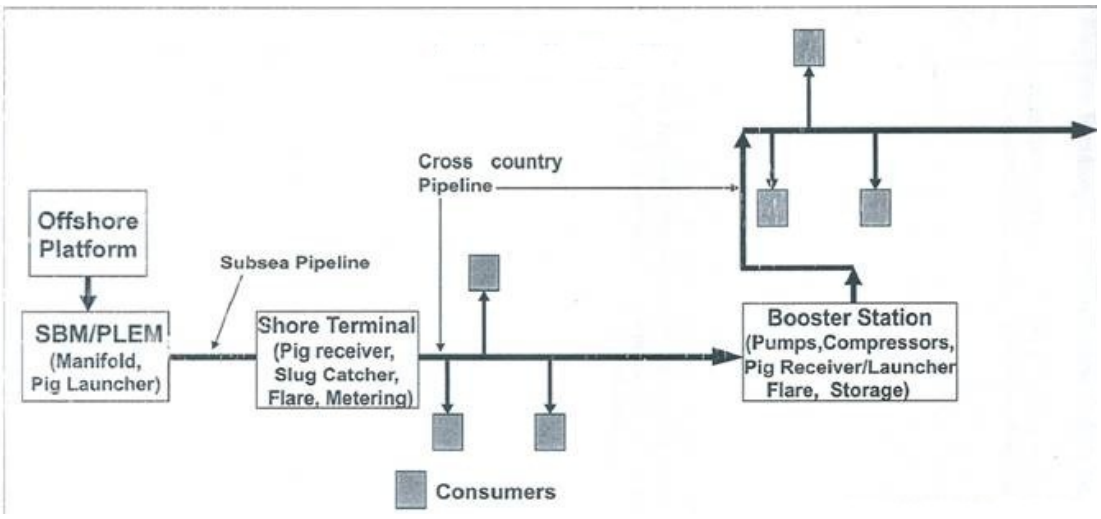



**Figure 1: Simple Pipeline Design Process flow**

In the past few decades, researchers have devoted much of their attention on consideration of pressure drop on gas transportation pipeline design. There are much pipelines simulation software that have been developed by developers including PIPESIM software to design the oil and gas transportation pipeline. In this final year project, author will be develop on graphical relationship within all the factors effecting on pressure drop along gas transportation pipeline. This software is used in some oil and gas companies to design and operate production-gathering and distribution systems with confidence. PIPESIM software produces details flow regime maps at the existing pipeline operating conditions, incorporating all angles of inclination. PIPESIM software uses the in-situ superficial gas and liquid velocities to identify the flow pattern at every node in the system, it make easy to determine the pressure distribution in pipeline system. Author will be analyze on how these distribution of pressure will affect on specific gravity of oil and gas. A wide varieties of methods can be simulate model in PIPESIM. In this project, Author will design the single phase (gas) flow.

## 1.2 PROBLEM STATEMENT

During natural gas transportation in pipeline, pressure drop along the pipeline will occur due to fraction factor, elevation and fittings.

It may result in

- reduce the maximum deliverability for gas
- to install additional pressure boost up equipment

## 1.3 OBJECTIVES

The objective of this work is:

- to analyze the factors that effecting on pressure drop on gas flow performance modelling the simple pipeline design by using PIPESIM simulation software.
- to develop graphical relationship within all the factors.

## 1.4 SCOPE OF STUDY

The scope of study involved would be starting from information gathering on toward simulating the simple gas transportation pipeline design. Necessary data and Information would be gathered from Myanmar Gas field case study to create

pipeline model for analyzing factors affecting on pressure drop along gas transportation pipeline. Study will be divided into two stages as FYP 1 and FYP 1. In FYP-1, and research will be made theoretical application of pressure drop on fluid flow calculation, necessary data will be collected to develop the simple pipeline design.

## 1.5 SIGNIFICANT OF PROJECT

Pressure drop is major problem to consider when designing the transportation pipeline. If it was not studied and pipeline designer could not do necessary research on pressure drop, it may failure to deliver the amount of customers desire pressure and flow rate and result in losing the large amount of profit from the project. That is a reason for author to motivate to study and analyze on factors which will cause the pressure drop along pipeline. Through this project, there are propose variables that need to be investigate such as pipeline design (pipe wall thickness, material of pipe, sizing of pipe) , phase envelope, pressure drops ( inlet temperature, pipe sizing, elevation) and gas flow rate. In ASME 31.8 specifications, steel pipe design formula and design factor can be considered.

## 1.6 FEASIBILITY OF THE PROJECT

There are total two semesters, 8 months of period to finish the final year projects. Since there will two semesters to analyze and develop model in PIPESIM, final year project was divided into two sections, FYP-1 and FYP-2. Especially for FYP-1, author will get one semester to do research on the projects and to gather necessary information and data. In FYP-2, the project will be finished by building model and analyze the results. Forty percentage of process will be occupied by finding research and gathering data before building model. Twenty percentage of process is building the model with different types of fluid properties and the rest will be more to the analysis on the specific gravity effect on fluid flow performance in transportation of oil and gas. Author will get 14 week to complete some research on theoretical application of specific gravity effect and case study of PIPESIM software. For FYP-2, there will have 14 week to construct the pipeline design and to develop the graphical relationship within all the factors that cause pressure drop. To achieve the goal of this project, author need to follow on the procedures and schedule of the work.

# CHAPTER 2

# THEORY AND LITERATURE REVIEW

## 2.1 THEORY

Several equations are used to calculate pressure drop along the gas transportation pipeline and these equation will be discussed.

### 2.1.1 Pressure Drop Calculation

Several equations are available that relate the gas flow rate with gas properties, pipe diameter and length, and upstream and downstream pressures.

#### 2.1.1.1 General Flow equation

The General Flow equation, also called the Fundamental Flow equation, for the steady-state isothermal flow in a gas pipeline is the basic equation for relating the pressure drop with flow rate. The most common form of this equation in the U.S. Customary System (USCS) of units is given in terms of the pipe diameter, gas properties, pressures, temperatures, and flow rate as (eq.2.0) follows.

$$Q = 1.1494 \times 10^{-3} \left( \frac{T_b}{P_b} \right) \left[ \frac{\left( P_1^2 - P_2^2 \right)}{G T_f L Z f} \right]^{0.5} D^{2.5} \quad \text{(SI units)} \qquad \text{Eq.2.0}$$

*Note: General Equation for flow rate calculation vs pressure drop without elevation effect*

The general flow equation for considerating with elevation effect, and frictional effect in SI unit is,

$$Q = (11.4946 \times 10^{-4}) \frac{1}{\sqrt{f}} \frac{T_b}{P_b} \left( \frac{P_1{}^2 - e^s P_2{}^2}{G T_f L_e Z} \right)^{0.5} D^{2.5} \qquad \text{Eq.2.1}$$

*Where,*

*Q = gas flow rate at standard conditions, m3/day*

*Tb = base temperature, K (273 + ◦C)*

*Pb = base pressure, kPa*

*Tf = average gas flow temperature, K (273 + ◦C)*

*P1 = upstream pressure, kPa*

*P2 = downstream pressure, kPa*

*H1 = upstream elevation, m*

*H2 = downstream elevation, m*

*Le = equivalent length of pipe, km*

*L = pipe length, k*

The parameters depend on the elevation difference H2 − H1, and the value of constant S can be calculate from the following Equation (Eq.2.2)

$$s = \frac{0.0375G(H_2 - H_1)}{T_f Z} \quad \text{Eq.2.2}$$

To find the slot between the elevation is,

$$j = \frac{e^s - 1}{s} \quad \text{Eq.2.3}$$

To find the Equivalent length,

$$L_e = j_1 L_1 + j_2 L_2 e^{s1} + j_3 L_3 e^{s2} + \cdots \quad \text{Eq.2.4}$$

*Note: The term j must be calculated for each slope of each pipe segment of length L1, L2, etc., that make up the length L. where j1, j2, etc., are calculated for each rise or fall in the elevation for pipe segments between the upstream and downstream ends.*

*where,*

*Le = equivalent length of pipe, mi*

*L = length of pipe between upstream and downstream ends (miles)*

*s = elevation correction factor, dimensionless*

### 2.1.1.2 Weymouth Equation

The Weymouth, Panhandle A, and Panhandle B equations were developed to simulate compressible gas flow in long pipelines. The Weymouth is the oldest and most common out of three. It was initially developed in 1912.

$$q_h = \frac{18.062 T_b}{p_b} \sqrt{\frac{\left(p_1^2 - p_2^2\right) D^{16/3}}{\gamma_g \bar{T} \bar{z} L}}$$

Eq.2.5

*L* = *length of pipe (mile)*

*D* = *Diameter of pipe(in.)*

*P1* = *upstream pressure*

*P2* = *downstream pressure*

*z* = *compressibility factor*

*Tb* = *base temperature*

*Pb* = *base pressure*

*qh = Flow rate (scf/hr)*

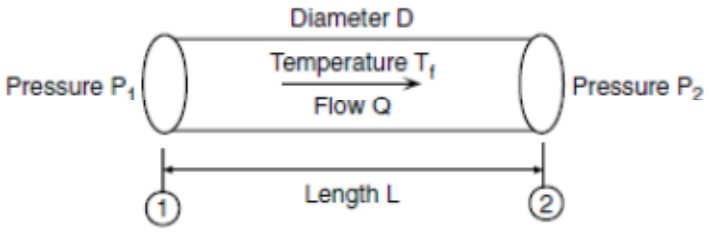



**Figure 2 Steady flow in gas pipeline**

### 2.1.1.3. Calculation for Friction Factor

Colebrook-White equation. The Colebrook-White equation for obtaining the friction factor is applicable for a wide range of flow in gas pipelines. Friction factor f is given for turbulent flow as:

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{e}{3.7D} + \frac{2.51}{\mathrm{Re}\sqrt{f}}\right) \quad \text{Eq.2.6}$$

*for Re > 4000.*

*where f = Darcy friction factor*

*D = pipe inside diameter, in*

*e = absolute pipe roughness, in*

*Re = Reynolds number of flow*

In SI units the Reynolds number is given by,

$$\mathrm{Re} = 0.5134\,\frac{P_b}{T_b}\,\frac{GQ}{\mu D} \quad \text{Eq.2.7}$$

*where Pb = base pressure, kPa*

*Tb = base temperature, K*

*G = gas gravity (air = 1.0)*

*Q = gas flow rate, m3/day*

*D = pipe internal diameter, mm*

$\mu$ *= gas viscosity, P*

## 2.2 LITERATURE REVIEW

In this project, there are several factors effecting on pressure drop that need to be understand before developing the graphical relationship between them. The efficient and effective movement of natural gas from producing regions to consumption regions requires an extensive and elaborate transportation system. In many instances, natural gas produced from a particular well will have to travel a great distance to reach its point of use. The transportation system for natural gas consists of a complex network of pipelines, designed to quickly and efficiently transport natural gas from its origin, to areas of high natural gas demand. Transportation of natural gas is closely linked to its storage: should the natural gas being transported not be immediately required, it can be put into storage facilities for when it is needed.

There are five main factors which cause pressure drop along gas pipeline.

- Elevation: conversion of fluid potential energy into hydrostatic pressure.
- Friction: shear stress between pipe wall and gas
- Fittings such as valves & pipeline elbow
- Start node Temperature
- Pipe sizing

**Mohammed A. Milan**,*Petroleum Engineering Handbook for the practicing engineer, Volume 1,* Pressure drop plays a role in calculation of deliverability of a gas production system starting from the pipeline and to compressors calculations, gathering system calculations and production string. In the end, the pipeline capacity will affect in maximum system deliverability for gas. According to the PIPESIM, training course, The contribution from the major terms; elevation and frictional can be summarized as; In well, the effect of elevation term will be (85-100%) with

compare to effect of frictional (0-15%). In pipeline transportation, the effect of elevation term will be (0-30%) and effect of frictional pressure drop will be (70-100%).

Based on 'Distribution Piping: Understanding Pressure Drop' by Compressed Air Challenge, excessive pressure drop will result in poor system performance and excessive energy consumption. Flows restrictions of any type in a system require higher operating pressures than are needed, resulting in higher energy consumption. The particular pressure rise resulting from resistance to flow can involve increasing the drive energy on the compressor by 1% of the connected power for each 2 psi of differential.

H. Dale Beggs stated in his 'Production Optimization Using Nodal Analysis' that the final design of a production system cannot be separated into reservoir performance and piping system performance and handled independently. The amount of oil and gas flowing into the well from the reservoir depends on the pressure drop in the piping system and the pressure drop in the piping system depends on the amount of fluid flowing through it. Therefore, the entire production system must be analyzed as a unit.

Donald F.B Jackson stated that in single phase flowing conditions, the effect of elevation on pressure loss calculations is generally limited to the net elevation change between the start and end of the pipeline. For gas pipelines, the elevation profile affects the in situ pressure, and hence the gas velocity and frictional pressure losses. The low density of natural gas mitigates the effect of hydrostatic head on the in situ pressure, and for most systems, the elevation profile has only minimal impact on the total pressure loss. The effect of the elevation profile on pressure losses in a multiphase pipeline is much more significant. He tried to compare this to single phase gas since the existence of single phase black oil is nearly zero nowadays. In multiphase flow, the different velocities of the gas and liquid phases create a gas liquid slip condition in which the denser liquid phase tends to accumulate in the uphill sections of the pipeline. This accumulation of liquid reduces the area for flow for the gas phase, which increases its velocity until an equilibrium condition is reached. At this steady state condition, the volume of liquid lifted up the hill is equal to the volume of liquid arriving at the base of the hill.

In Petroleum Engineering Handbook for the practicing engineer, Volume 1, by Mohammed A. Milan, pressure drop plays a role in calculation of deliverability of a gas production system starting from the pipeline and it works backward to compressors calculations, gathering system calculations, production string and reservoir. In the end, the pipeline capacity will affect the total system and result in maximum system deliverability for gas.

There are several companies developed the different types of pipeline design simulation software. According to the CanQualPro Training Systems, there are some pipeline design factors need to be consider before designing the pipeline.

### 2.2.1 Pressure Drop Due to Friction

Pressure drop is the pressure decrease from the inlet to the outlet as the flow increases. Pressure drop is important to know when understanding hydraulics and liquid behavior within a pipeline as the operator will be in a position to prevent pipeline incidents such of Maximum Allowable Working Pressure exceedances or low suction pressure to pipeline pumping facilities.The amount of pressure drop due to friction depends on the velocity of the liquid (laminar or turbulent flow), the liquid viscosity (determined by the products density and specific gravity) and the piping friction factor. These three factors are used to create the Reynolds numbers that reflects velocity variations due to laminar flow (low flow rates) and turbulent flow (high flow rates). This number is then used to determine the product's drag characteristics which are then used to determine the friction factor of the product at a given flow.

Example: Comparing crude oil and liquid propane, liquid propane will have a higher Reynolds number meaning that it will reach turbulent flow much sooner than crude oil in the same size pipe at the same flow rate.

The friction factor for the product within the pipe is now calculated using a Moody Diagram. This is used to calculate the pressure drop within the pipeline per kilometer. The Moody Diagram is a graph that relates the friction factor, the Reynolds number and relative roughness for flow within a pipe. This calculation can determine if the liquid will reach its destination with the proper amount of pressure for pump suction or to storage facilities. Moody Diagrams are found on the internet. Just enter Moody Diagrams in your search engine

### 2.2.2 Pressure Drop due to elevation

In a flat pipeline, the pressure needed to deliver the product is based on the delivery point requirements and the pressure drop within the pipeline. Final delivery point pressure takes into consideration such things as storage tank farm pressure requirements.

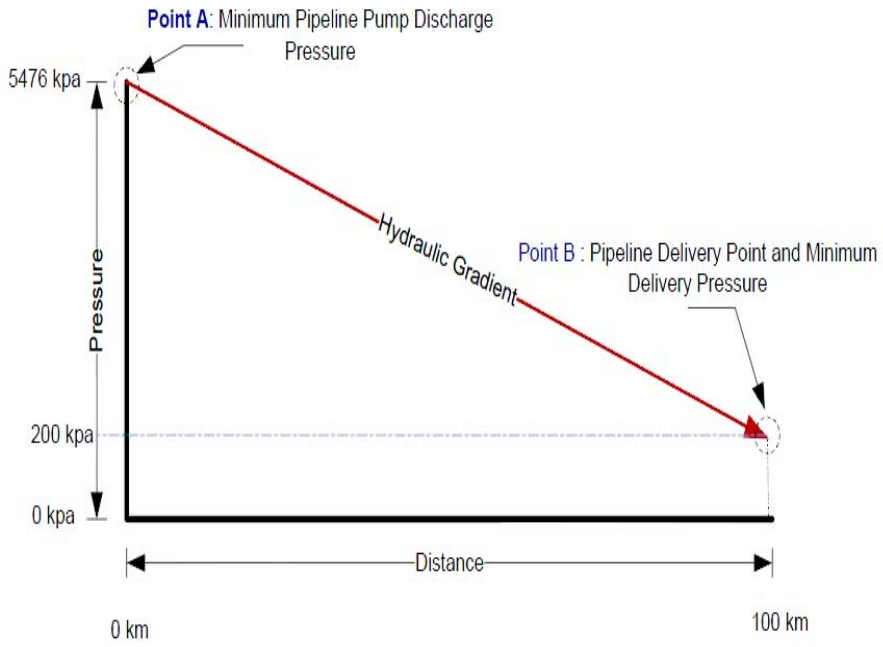



**Figure 3 Flat Elevation – Red Line Represents Pressure Drop**

As with a flat elevation, pressure requirements within an increased elevation pipeline are determined based on the final delivery point requirements. Within elevation changes there may be peaks that must be taken into consideration

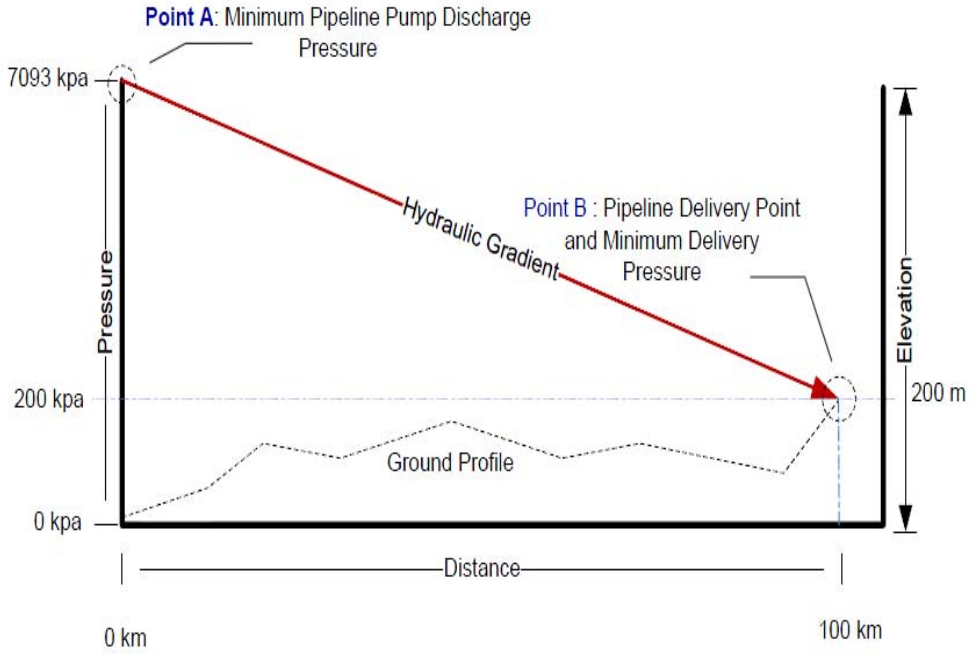



**Figure 4 Increasing Elevation – Red Line Represents Pressure Drop**

### 2.2.3 Pressure Drop due to Inlet node Temperature

Based on the research, according to the PIPSIM training course, the effect of inlet node temperature also may cause the minimum amount of pressure drop. Basically the starting node point of transportation pipeline start from Compressor station. Most of the natural gas are being treatment under the some process such as, Dehydration, Separation, H2S removal. From the Separation unit , most of the temperature set point are different base on the well head condition. According to the PIPESIM training course, the following graph can be seen as relationship between Inlet node temperature and Pressure drop.

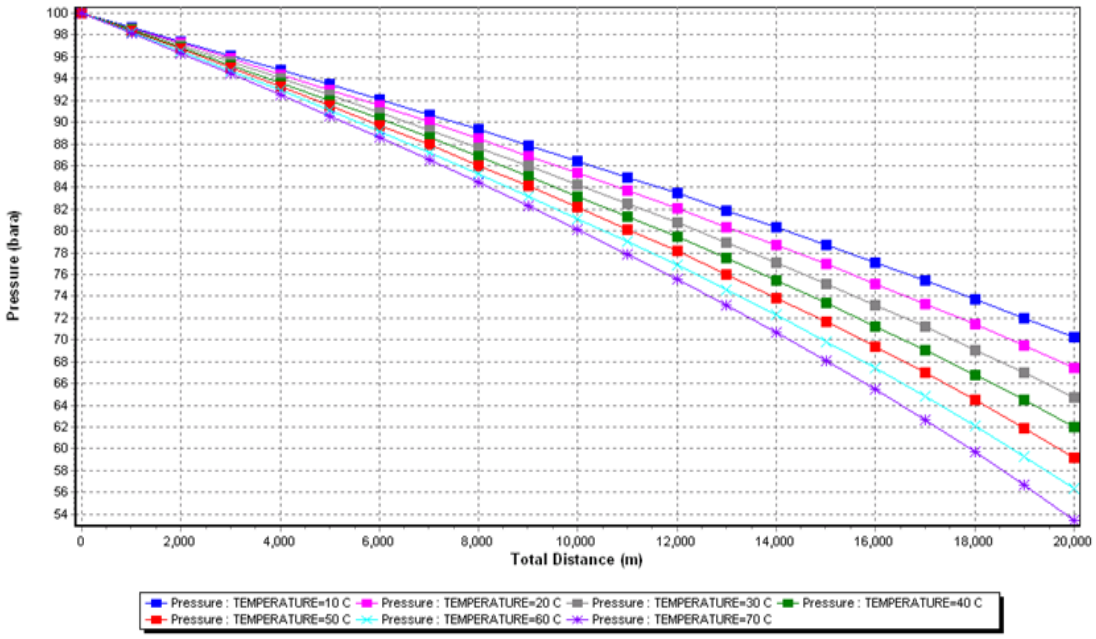



**Figure 5 Relationship between Pressure Vs Inlet Temperature**

### 2.2.4 Pressure drop due to Pipeline Sizing

There are different pipeline sizing can be consider during designing the pipeline. According to the PIPESIM Training Course, the different sizes of pipeline diameters may also effect the pressure drop along the gas transportation pipeline. The area of the inner pipeline is larger, or the diameter of the pipeline is large, there may be reduce in some pressure drop as describe in the Figure below. Vice Versa, minimum diameter of the pipeline will give the highest pressure drop along gas transportation pipeline.

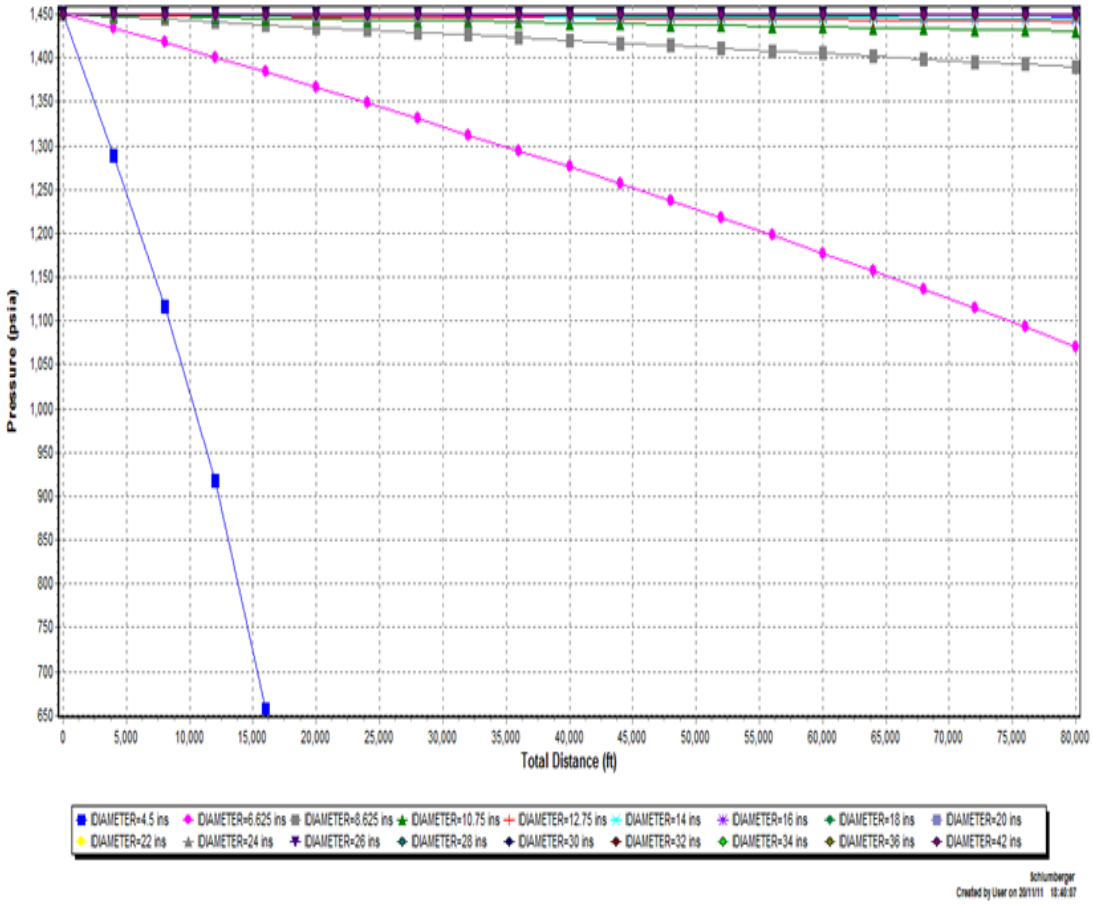



Figure 6 Relationship between Pressure Vs Pipe Diameter

# CHAPTER 3

# METHODOLOGY

## 3.1 RESEARCH METHODOLOGY

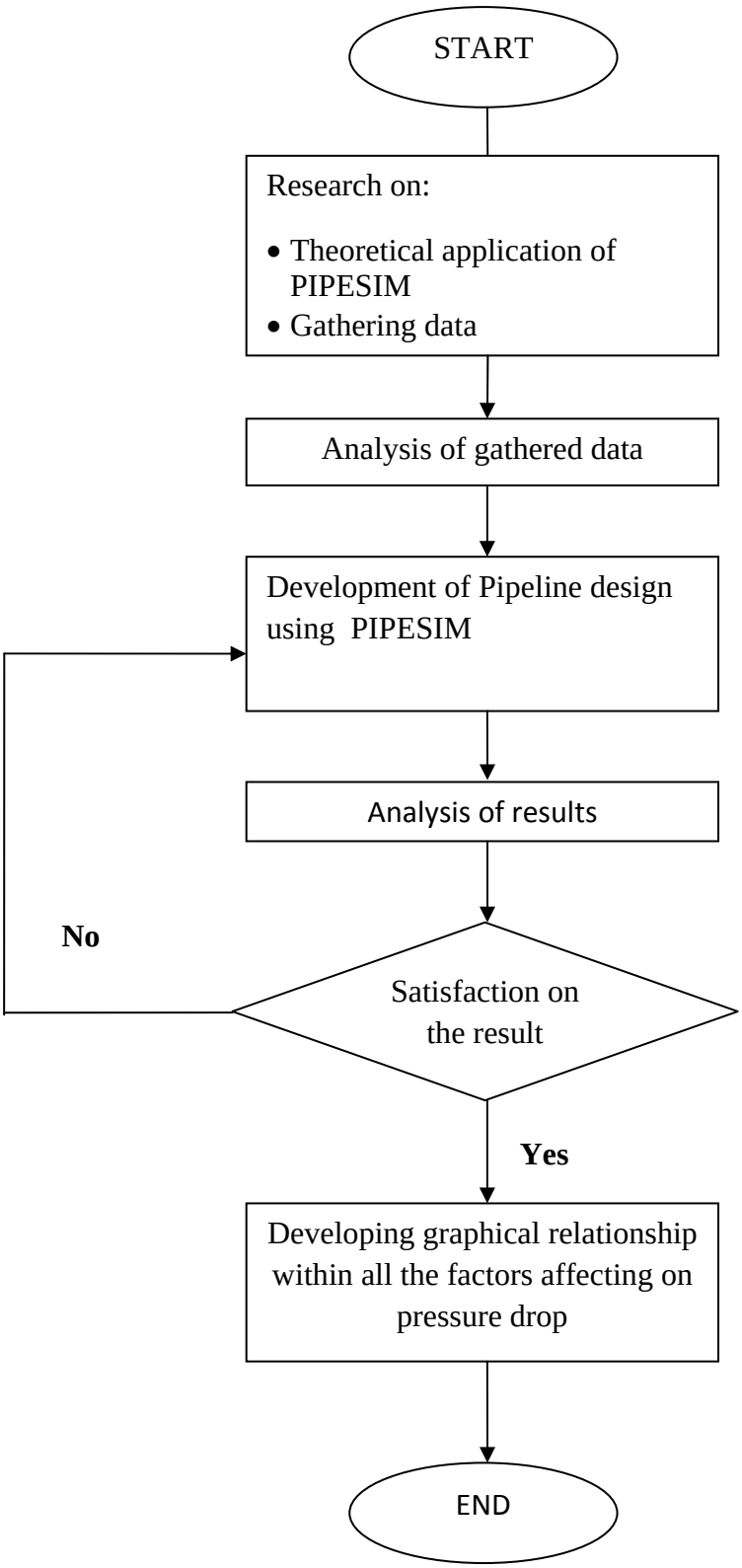
The research methodology to be carried out is as follows:

- to make research work on factors that affect on pressure drop in pipeline transportation, Understanding fundamental theories and concepts, performing a literature review, tools identification
- to obtain available software for this research work.
- to obtain data that required for simulating pipeline transportation design.
- to familiarize with the PIPESIM software

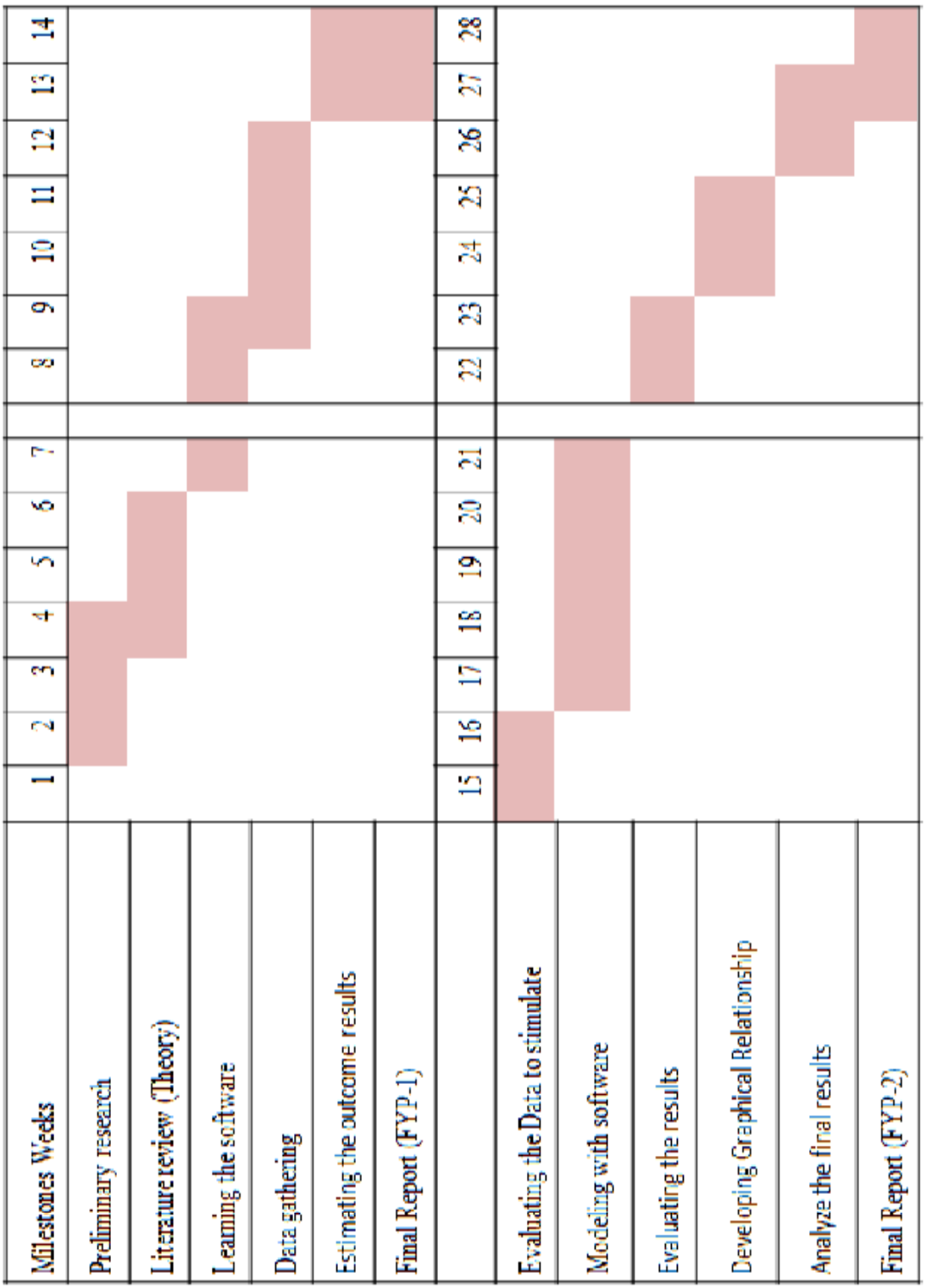
## 3.2 PROJECT ACTIVITIES

There are several steps included to analyze factors effect on pressure drop along the gas transportation pipeline. firstly author will gather the information about PIPESIM software to familiar with software. The data gathering and theoretical calculation needed to be done during FYP-1 period. During data gathering, author needed to get real performance compositional data for different types of fluid. After gathering data and information, author need to study on PIPESIM soft on how to build a new pipeline designs model using single phase flow system. As a final stage, basic simple pipeline design will construct and by inputting different types parameters and test on how these parameters will effect on the pressure drop along gas transportation pipeline. Author will illustrate by using graphs of flow rate Vs pressure drop, temperature Vs pressure drop to analyze on the effect. Author will describe basic work flow chart in below for the activities of work flow system.

### 3.3 THE WORK FLOW CHART



### 3.4 GANT CHART



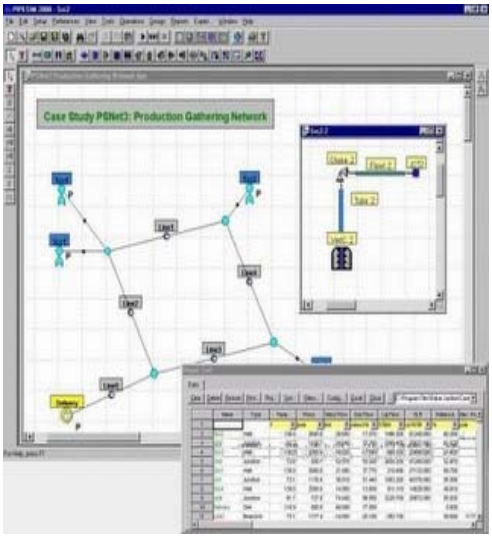
## 3.5 TOOLS AND SOFTWARE

### PIPESIM-Optimizing pipeline facilities design

In Universiti Teknologi PETRONAS, simulation software available regarding pipeline and facilities is PIPESIM by Schlumberger. PIPESIM is an applicable tool for modeling single phase gas flow from the reservoir through the production facilities to delivery point. In facilities modeling, PIPESIM can also be used to design systems by varying key system parameters, thus enabling optimal pipeline and equipment sizes to be determined.

Typical applications of module include:

- Multiphase flow in flowlines and pipelines
- Point by point generation of pressure and temperature profiles
- Transportation pipeline design and calculation flow rate
- Flowline & equipment performance modeling (system analysis)

# CHAPTER 4

# RESULTS AND DISCUSSION

In Final Year Project, Author used Pipe Simulation Software to run a Pipeline design with gas compositional model to analyze the various factors which effecting the pressure drop along the gas transportation pipeline. In this project, author used the following data to run the simulation without including facilities and pipeline will be started from compressor discharge point.

**For simulation of gas transportation pipeline design**

Pipeline Distance - 200 Miles (for Sensitivity Analysis)

- 177.10 Miles (for real case)

Pipeline Diameter - 24 inches

Wall Thickness - 0.77 inches

Compressor Discharge Pressure - 2325 Psi

Ambient Temp - 28

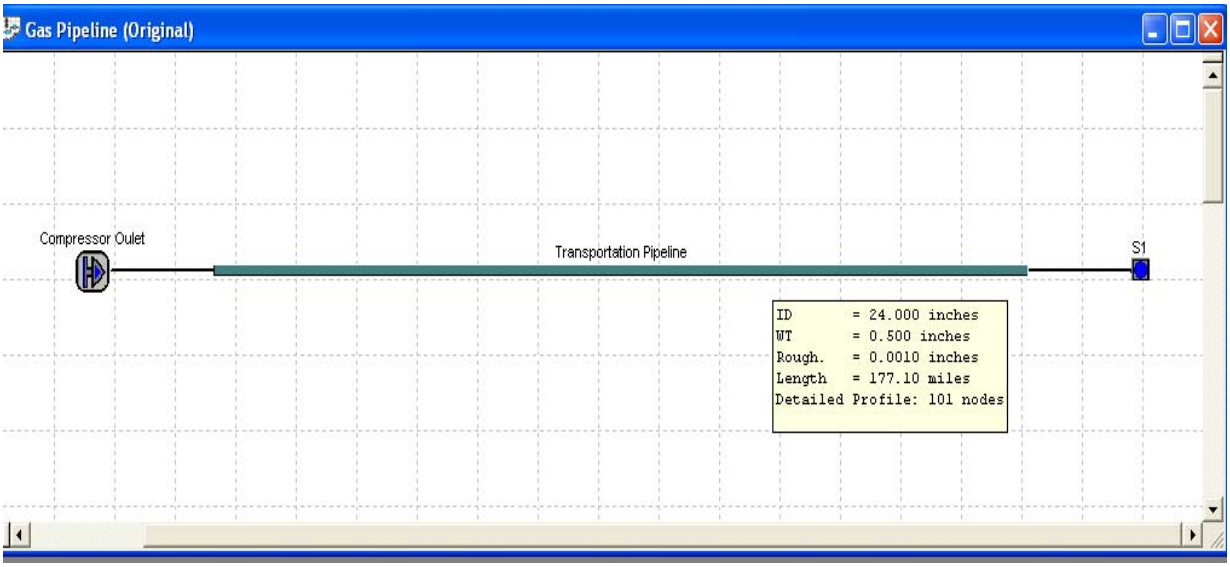



**Figure 7 Gas Transportation Pipeline diagram**

Real Gas field data is used for gas compositional phase envelope to simulate model.

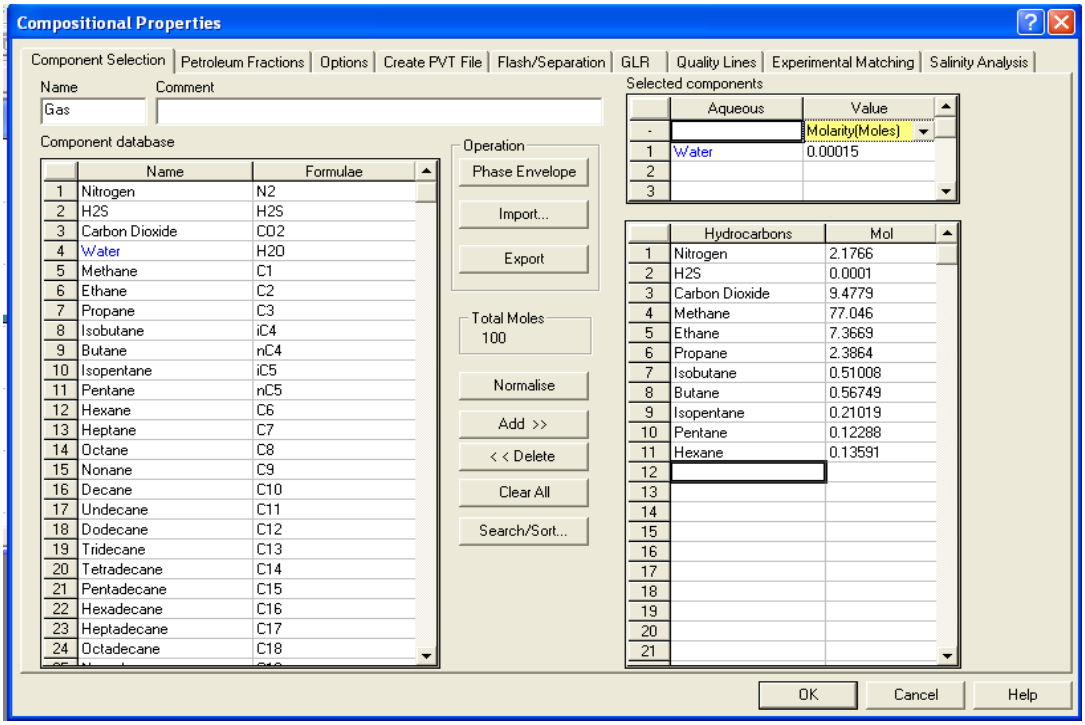



**Figure 8 Gas compositional properties table**

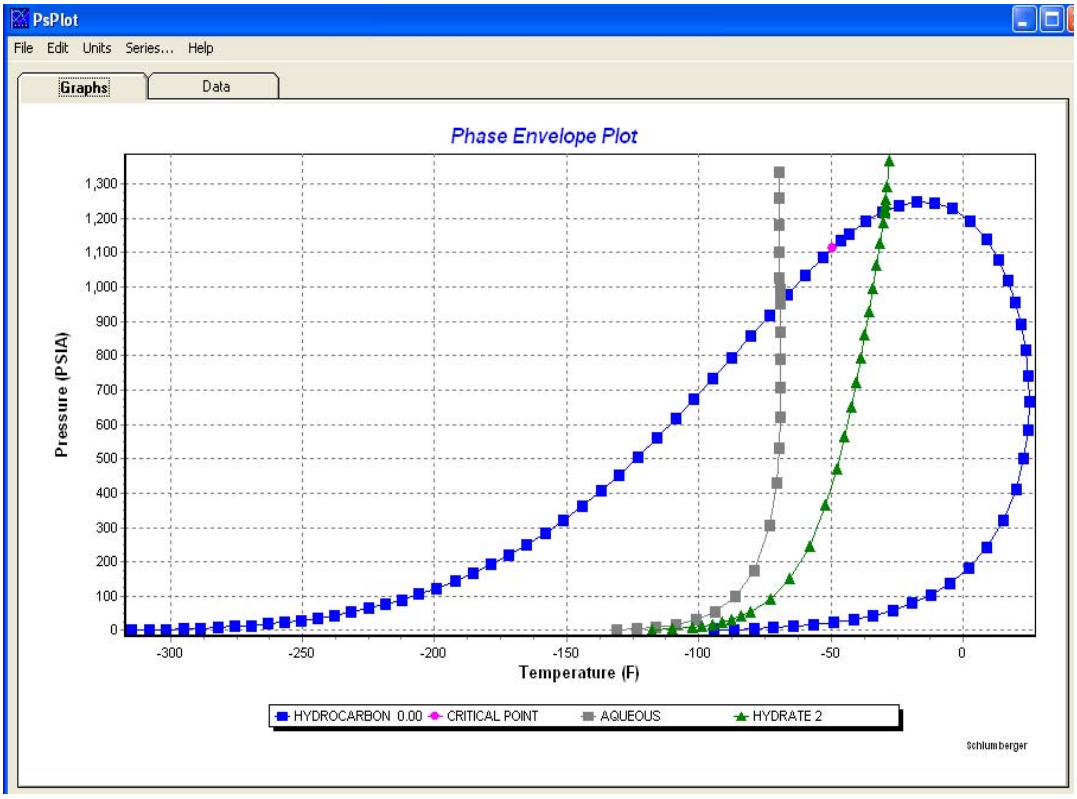



**Figure 9 Phase envelope for gas compositional**

### 4.1 Effect of elevation on pressure drop

To analyze the effect of elevation on pressure drop, author used two different scenarios. Firstly author used the real gas field data with zero pipeline elevation started from compressor outlet until it reached to the delivery point. For the another cases author used real gas field data with actual elevation to simulate the gas transportation pipeline model. The relationships graphs between pressure drops vs distances for each of the scenarios were obtained from the simulation.

#### 4.1.1 For zero elevation with actual gas field data,

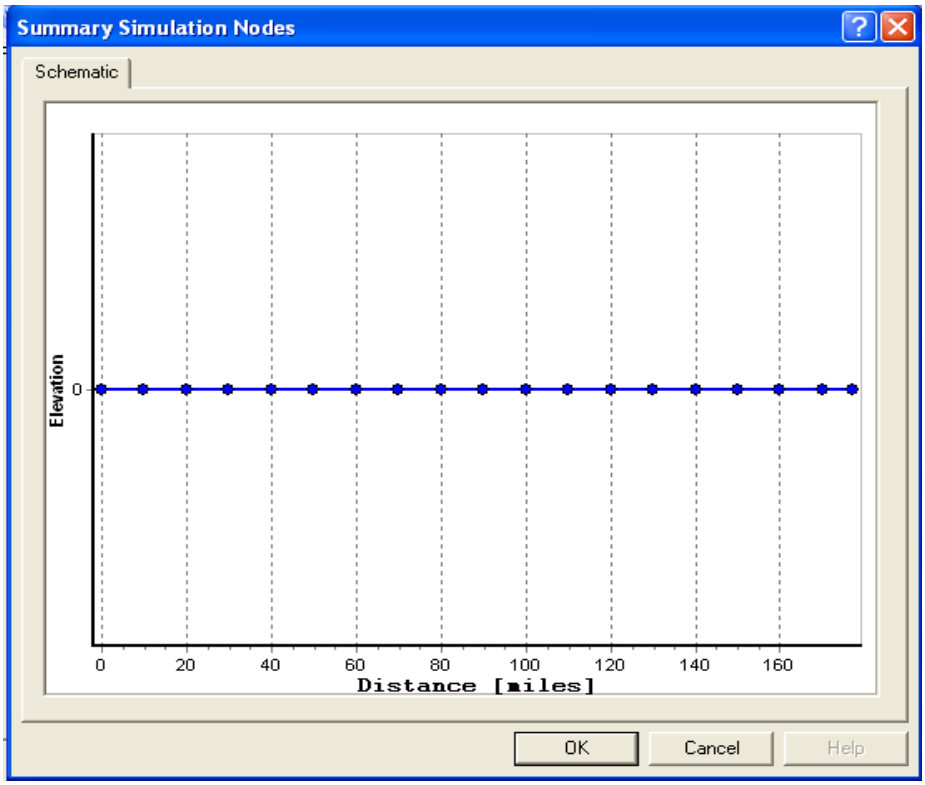



**Figure 10 Schematic pipeline diagram for zero elevation**

The Figure 10 above shown the schematic pipeline diagram with zero elevation for real gas field. The purpose of simulation for zero elevation with real gas data is to analyze the percentage of pressure drop caused by elevations and to compare pressure drop percentages between two of the results.. 460MMscf amount of gas were used to transport from the compressor outlet which is started node to the delivery point which is located 177.1miles away from start node.

**Table 1Experiment Results for Distance Vs Pressure**

| Total Distance (miles) | Pressure (psia) |
|---|---|
| 0.0000 | 2325.0145 |
| 0.0000 | 2325.0145 |
| 10.0000 | 2289.1343 |
| 20.0000 | 2253.8641 |
| 30.0000 | 2219.0638 |
| 40.0000 | 2184.7236 |
| 50.0000 | 2150.7434 |
| 60.0000 | 2117.0132 |
| 70.0000 | 2083.5530 |
| 80.0000 | 2050.2928 |
| 90.0000 | 2017.1426 |
| 100.0000 | 1984.0424 |
| 110.0000 | 1950.9122 |
| 120.0000 | 1917.7420 |
| 130.0000 | 1884.5018 |
| 140.0000 | 1851.1215 |
| 150.0000 | 1817.5513 |
| 160.0000 | 1783.7411 |
| 170.0000 | 1749.6109 |
| 177.1000 | 1725.1508 |
| 177.1000 | 1725.1508 |

Length of Pipeline = 177.104 miles

Gas Flow rate = 460 MMscf

Pipeline Diameter = 24 inches

Compressor Outlet Temp = 212 F

Outlet Pressure = 2325 psi

Total pressure drop = 599.86 psi

Pressure drop percentage =25.80%

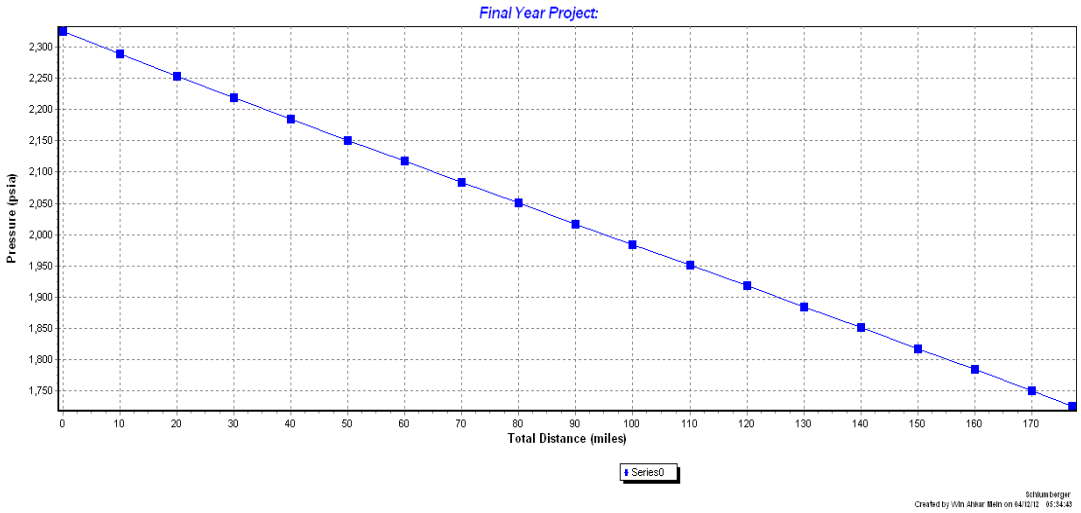



**Figure 11 Pressure (Psi) Vs Pipeline Distance (miles) graph**

The figure 11 above shown the relationships between Pressure vs total distance (length of pipeline). The constant slope was seen in the graph because the elevation of the pipeline was zero. It was observed that, 599.86 Psi of pressure will drop along the gas transportation pipeline which is caused by other factors such as compressor outlet temperature, pipeline diameters and pipeline roughness which will be discussed afterward. The 25.80% of pressure drop was observed from the simulation without elevation effect.

### 4.1.2 For elevation with actual gas field data,

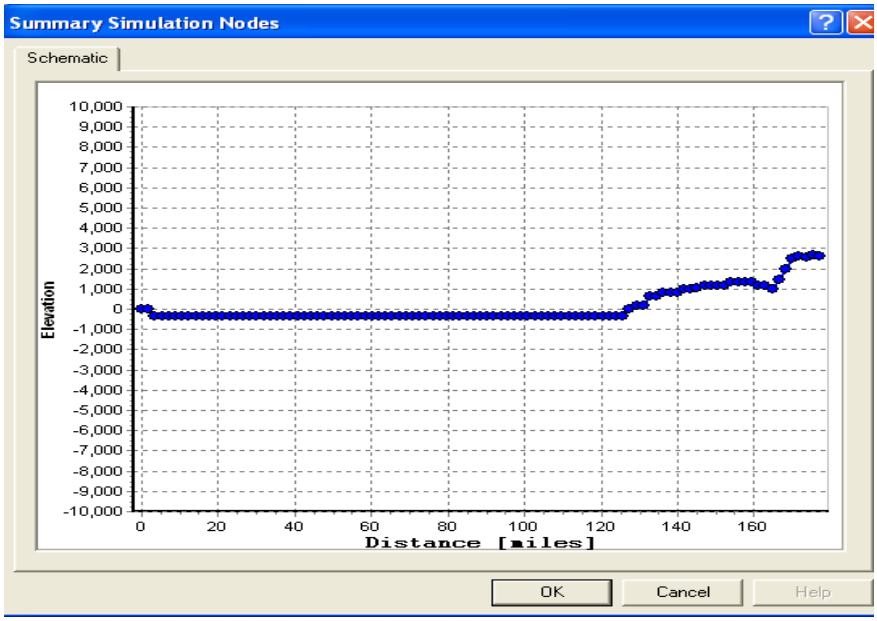



**Figure 12 schematic pipeline diagram with elevation**

The Figure 12 above shown the schematic pipeline diagram with elevation for real gas field. The purpose of simulation for zero real gas data with elevation is to analyze the percentage of pressure drop caused by elevations and to compare pressure drop percentages between two of the results.. 460MMscf amount of gas were used to transport from the compressor outlet which is started node to the delivery point which is located 177.1miles away from start node. In this scenario, the elevation of transportation pipeline was used as same in real gas field. Since the platform was located in offshore, the transportation pipeline start from 0 miles to 125 miles will be lied under subsea. The elevation of this portion will be zero since the seabed of oceanic was almost plain. Afterward, the elevation of pipeline on portion of 125 miles to 177.10 miles will be placed on the surface of uphill and downhill. The elevation of this portion will be positive and negative as seen in figure 12.

The simulation results can be seen in APPENDIX I. Author will be divided into three segments with zero elevation, uphill elevation and downhill elevation sections according to results. Below, Table 2-5shown different segments of pipeline elevation from the results.

**Table 2 Results for subsea pipelines zero elevation**

| Total Distance | Total Pressure |
|---|---|
| Miles | Psi |
| 0 | 2325.0145 |
| 10.6261 | 2304.3744 |
| 21.2511 | 2267.1041 |
| 30.1061 | 2236.4439 |
| 40.7311 | 2200.1137 |
| 51.3561 | 2164.1835 |
| 60.2112 | 2134.4633 |
| 70.8371 | 2099.0331 |
| 81.4631 | 2063.8529 |
| 90.317 | 2034.6327 |
| 100.9411 | 1999.6325 |
| 109.7911 | 1970.4623 |
| 120.4212 | 1935.3721 |
| 125.7311 | 1917.822 |

**Table 3 Results for uphill elevation**

| Total Distance | Total Pressure |
|---|---|
| Miles | Psi |
| 125.7311 | 1917.822 |
| 127.5023 | 1893.1818 |
| 132.8248 | 1838.2515 |
| 141.6754 | 1789.8912 |
| 152.3055 | 1744.2409 |
| 162.9259 | 1705.2806 |

**Table 4 Results for downhill elevation**

| Total Distance | Total Pressure |
|---|---|
| Miles | Psi |
| 162.9259 | 1705.2806 |
| 164.6962 | 1709.7107 |

**Table 5 Results for uphill elevation**

| Total Distance | Total Pressure | 170.0142 | 1609.23 |
|---|---|---|---|
| Miles | Psi | 171.7845 | 1596.55 |
| 164.6962 | 1709.7107 | 173.5644 | 1593.52 |
| 164.6962 | 1709.711 | 175.3347 | 1580.84 |
| 166.4687 | 1677.001 | 177.1045 | 1577.78 |
| 168.2411 | 1644.53 | 177.1045 | 1577.78 |

From the Table 2-5,

**s zero elevation, (From 0 miles to 125.73 miles), Pipeline Segment 125.73 miles**

Total pressure drop for = 407.178 psi

Total Pressure drop percentage = 17.51 %

**Uphill elevation, (125.73 miles to 162.93 miles), Pipeline Segment 37.2 miles**

Total pressure drop for = 212.5414 psi

Total Pressure drop percentage = 11.08 %

**Downhill elevation, (162.93 miles to 164.70 miles), Pipeline Segment 1.7 miles**

Total pressure drop for = -4.4301 psi

Total Pressure drop percentage = - 0.3 %

**Uphill elevation, (164.70 miles to 177.10 miles), Pipeline Segment 12.4 miles**

Total pressure drop for = 131.93 psi

Total Pressure drop percentage = 7.71%

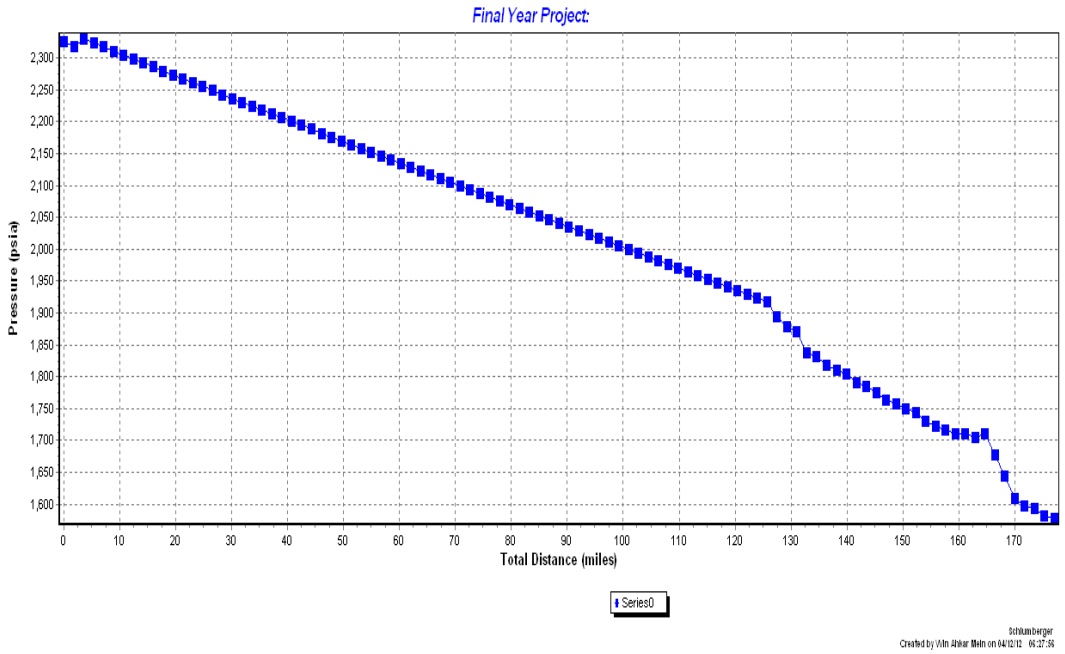



**Figure 13 Pressure (Psi) Vs Pipeline Distance (Miles) graph**

Based on the Figure 13, there are 4 portions of slopes can be seen according to different elevation of pipeline. Pipeline Segment 37.3 miles,11.80 percentage of pressure drop is a large number compare to 17.51 percentage of zero elevation with pipeline segment 125.73 because the pipeline segment of zero elevation is very much higher than uphill elevation. And again, downhill elevation with pipeline segments 1.7 miles have - 0.3 percentage because pressure is increase instead of decreasing in downhill elevation pipeline. It was observed that, the uphill elevation will greatly affect the pressure drop compare to zero elevation and downhill. The percentage of the pressure drop is increased compare to zero elevation case, because the upward elevation of pipeline will be result in losing some pressure due to specific gravity of the gas.

### 4.2 Sensitivity analysis on pipeline sizing factor

To analyze the effect of pressure drop due to pipeline sizing, author simulated the model using Gas transportation pipeline with elevation zero ft. By ranging the values of diameters, authors obtained the different types of pressure drop due to different types of pipeline sizing. "Figure 8", is the details simulation results of pressure drop according to different types of sizing ranging from 6 inch diameter to 56 inch diameter.

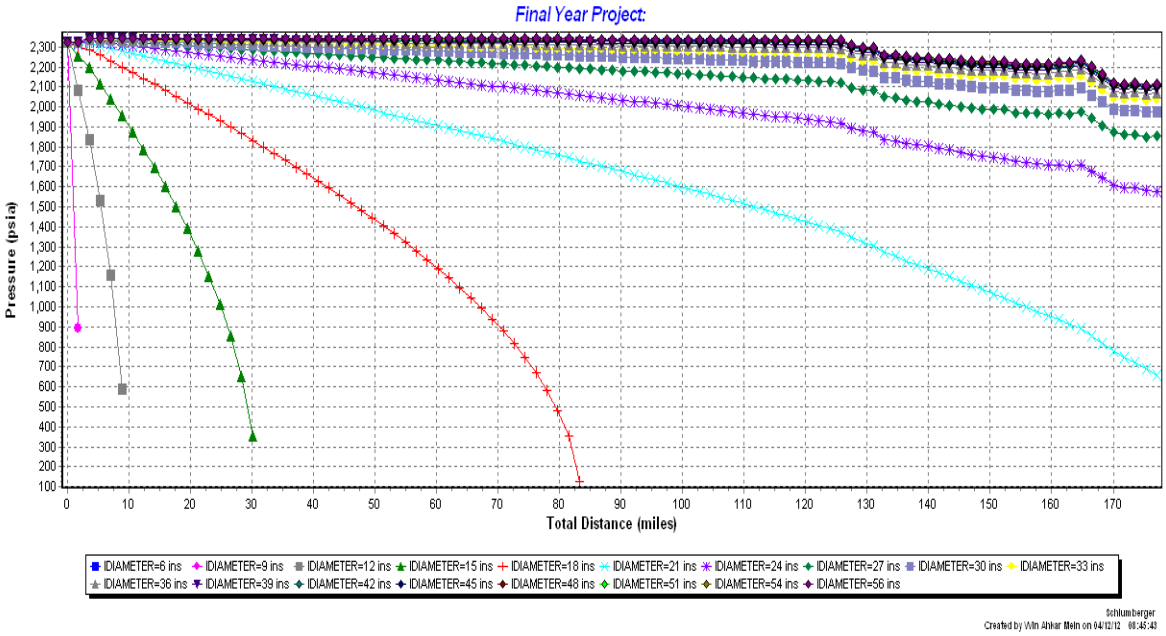



**Figure 14 Sensitivity analysis on pressure using various types of pipeline diameters**

The results from the sensitivity analysis of simulation can be seen in APPENDIX II. Below, Table 6 will be the summarized results of Pipeline diameter with percentage of pressure drop to analyze.

**Table 6 Summarized simulation results of pipeline sizing vs pressure drop percentage**

| Pipeline Diameter (inch) | Pressure drops (psi) | Percentage of pressure drop (%) |
|---|---|---|
| 6 | N/A | N/A |
| 9 | N/A | N/A |
| 12 | 1733.8548 | **N/A** |
| 15 | 1972.0823 | **N/A** |
| 18 | 2197.9947 | 94.6 |
| 21 | 1666.9404 | 71.7 |
| 24 | 747.2347 | 32.1 |
| 27 | 472.4629 | 20.3 |
| 30 | 350.0822 | 15.1 |
| 33 | 288.4918 | 12.4 |
| 36 | 255.2216 | 11 |
| 39 | 236.3315 | 10.1 |
| 42 | 225.2214 | 9.7 |
| 45 | 218.4914 | 9.2 |
| 48 | 214.3513 | 9.2 |
| 51 | 211.7713 | 9.2 |
| 54 | 210.1613 | 9.002 |
| 56 | 209.4613 | 9.009 |

According to the results obtained from simulation, the minimum diameter which can handle for Gas transportation system with gas flow rate 400MMscf/D is, 12 inches diameter. But according to the Table 6, using diameter 6, 9, 12. 15 and 18 inches diameters were failure to deliver to a point which is located at 177.10 miles. Which is because, less than 20 inches diameter invalid to use for a long transportation gas pipeline. Therefore, the minimum diameter which can handle the flow rate of 400MMscf/D is 21 inches diameters pipeline which gave 71.1% pressure drop at the delivery point. Since, sustaining the maximum delivery pressure as possible at the delivery point is very important fact in oil and gas system, the most suitable diameter is 56 inches diameter pipeline with 9% pressure drop which can give minimum pressure drop But, economic consideration was also one of the factors in oil and gas system to make profit, most suitable pipeline diameters are 25 to 35 inches diameter. And it was observed that, the large amount of pressure drop will decrease as pipeline sizing increase. Choosing suitable diameter is one of the important factor to design gas transportation pipeline.

### 4.3 For analysis on roughness value

To analyze the frictional factors, the roughness of the pipeline is important parameter. The roughness of the pipeline is directly proportional to the friction. In this project, author simulated the gas transportation system with gas production rate of 440 MMscf/d. " APPENDIX VIII to IX," is the details for simulation results with various ranges of roughness and pressure drop.

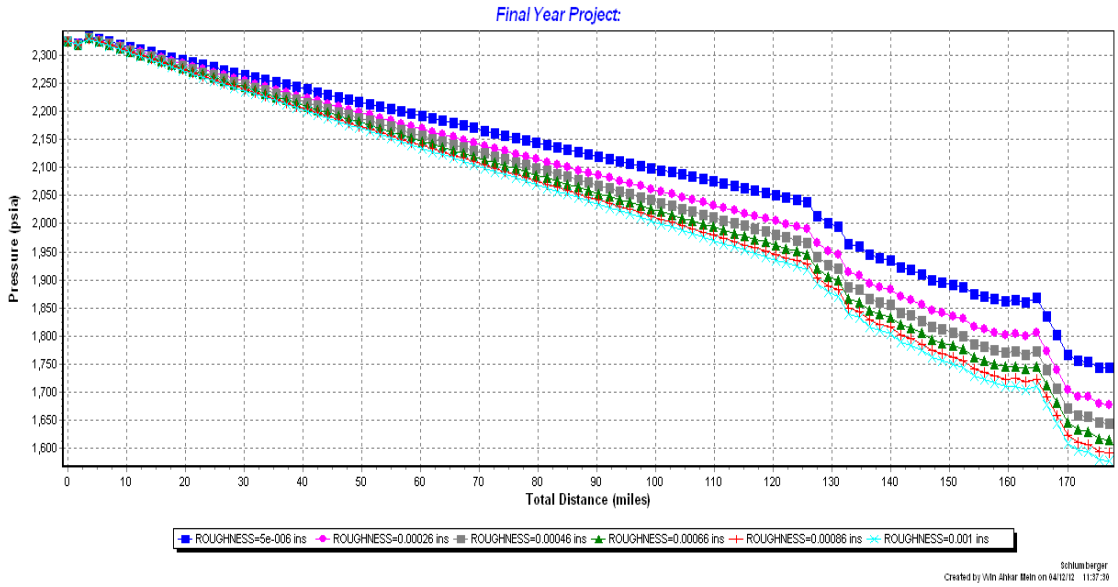



Figure 15 Sensitivity analysis on pressure drop using various roughness values

Table 7 Simulation results of different roughness values vs percentage of pressure drop

| Roughness | Pressure drop | Pressure drop (%) |
|---|---|---|
| 0.000005 | 581.00 | 25.00 |
| 0.00026 | 647.36 | 27.84 |
| 0.00046 | 681.71 | 29.32 |
| 0.00066 | 709.27 | 30.50 |
| 0.00086 | 732.63 | 31.51 |
| 0.001 | 727.23 | 31.278 |

Based on the results obtained, was observed that the pipeline with smallest value of roughness gave the smalles amount of pressure drop (25%) compare to other values which is 0.000005. The pressure drop due to the roughness occur due to the frictional force between wall of the pipe and gas flow are against the tendency of the flow toward. It may result in pressure drop along the gas pipeline. Most commonly used roughness is 0.0006 values which is used to calculated the frictional factor in oil and gas transportation pipeline. It was observed that, the roughness of pipeline also can give the additional pressure drop along the gas pipeline rather than elevation, pipeline sizing which are described above. It is very important to consider the roughness of the pipeline to calculate pressure drop along pipeline.

### 4.5 Sensitivity analysis on compressor discharge temperature

To run simulation on the sensitivity analysis of compressor discharge temperature, types of compressor with it maximum and minimum outlet temperature were studied and researched. It was obtained, the maximum and minimum outlet temperature of gas turbine compressor used in facilities were 180 F to 300F. APPENDIX X shown the results of different temperature outlet vs compressor discharge temperature.

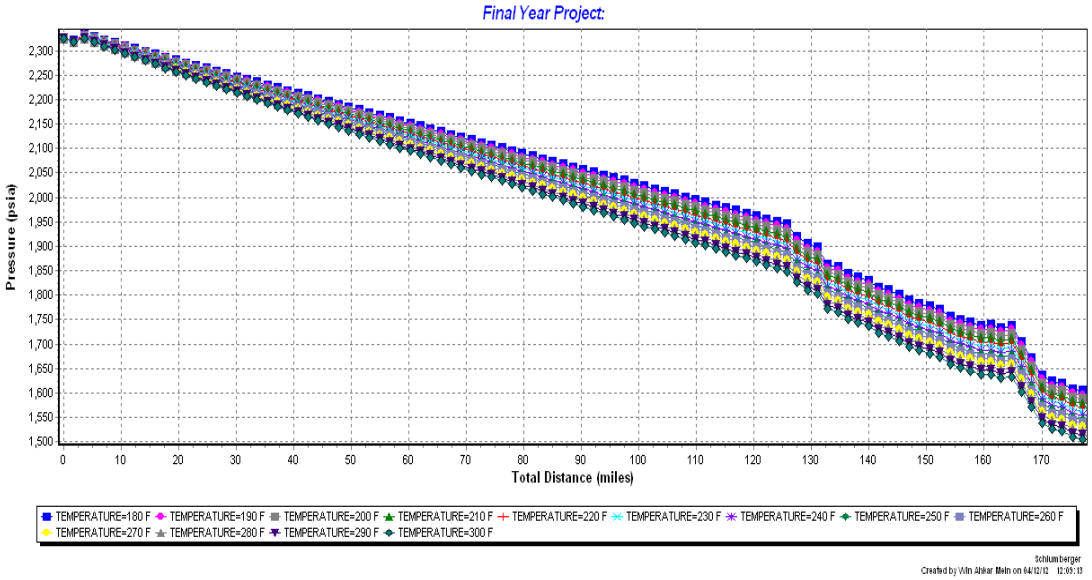



Figure 16 Sensitivity analysis on pressure drop using various compressor outlet temperature

Table 8 Simulation Results various inlet temp vs percentage of pressure drop

| Temperature (F) | Pressure drop (%) |
|---|---|
| 180 | 31.0 |
| 190 | 31.3 |
| 200 | 31.7 |
| 210 | 32.0 |
| 220 | 32.2 |
| 230 | 32.8 |
| 240 | 33.1 |
| 250 | 33.4 |
| 260 | 33.8 |
| 270 | 34.2 |
| 280 | 34.5 |
| 290 | 34.9 |
| 300 | 35.2 |

According to the simulation results by using different values of compressor outlet temperature, it was observed that the percentage of pressure drop for all the values of temperature is same from the result. By varying the outlet temperature of compressor is not a serious factor to consider in pipeline design. The compressor outlet temperature depending on the types of compressors which is installed for facilities. Based on the research, In oil and gas industry the maximum and minimum values of compressor outlet temperature for gas turbine would be 180F to 300F.

# CHAPTER 5

# CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

Real data from one of the Myanmar gas field will be used to simulate the pipeline design in PIPESIM Software. By simulating various different data on PIPESIM software and analyzing on the pressure drop results, it was found that there are four main major pressure drop factors which are affecting long distance transportation pipe line. Among these are

- increasing uphill elevation
- increasing roughness values
- increasing start node temperature, and
- decreasing pipe diameter.

In this report, author developed the graphical relationship within these factors after simulating the simple gas pipeline transportation designs. Furthermore, author could done some research for types of compressor with respect to outlet pressure and temperature to get better analysis result for compressor outlet temperature. As a conclusion, Pressure drop along the gas transportation pipeline is a common problem that always occur in transportation of oil and gas. These all the factors need to consider when we are designing the pipeline system to meet with customer desire pressure and flow rate.

## 5.2 Recommendation

In this report, the scope of work can be done within one semester to achieve objective. There are few recommendations for this project for further research. This project is focused only on four parameters which affecting pressure drop along gas transportation pipeline. For the future work, author would like to recommended that,

- To analyze on pressure drop caused by valves and pipeline fittings
- To make sensitivity analysis on various flow rate vs pressure drop
- To analyze on pressure drop caused by multi phases flow

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APPENDIX I

APPENDIX I Simulation Results for Real gas field data with elevation

| Column1 | Column2 |
|---|---|
| Total Distance (miles) | Pressure (psia) |
| | |
| Unit | Unit |
| 0 | 2325.0145 |
| 0 | 2325.0145 |
| 1.7709 | 2318.6145 |
| 3.5428 | 2329.5745 |
| 5.3137 | 2323.2445 |
| 7.0847 | 2316.9344 |
| 8.8556 | 2310.6444 |
| 10.6261 | 2304.3744 |
| 12.3971 | 2298.1143 |
| 14.1681 | 2291.8843 |
| 15.9391 | 2285.6643 |
| 17.7101 | 2279.4642 |
| 19.4811 | 2273.2742 |
| 21.2511 | 2267.1041 |
| 23.0222 | 2260.9441 |
| 24.7932 | 2254.7941 |
| 26.5642 | 2248.664 |
| 28.3352 | 2242.544 |
| 30.1061 | 2236.4439 |
| 31.8771 | 2230.3539 |
| 33.6481 | 2224.2739 |
| 35.4182 | 2218.2138 |
| 37.1892 | 2212.1738 |
| 38.9602 | 2206.1338 |
| 40.7311 | 2200.1137 |
| 42.5021 | 2194.0937 |
| 44.2731 | 2188.0936 |
| 46.0441 | 2182.1036 |
| 47.8152 | 2176.1236 |
| 49.5852 | 2170.1535 |
| 51.3561 | 2164.1835 |
| 53.1271 | 2158.2235 |
| 54.8981 | 2152.2734 |
| 56.6691 | 2146.3334 |
| 58.4402 | 2140.3933 |
| 60.2112 | 2134.4633 |
| 61.9822 | 2128.5333 |
| 63.7542 | 2122.6132 |
| 65.5252 | 2116.7032 |
| 67.2962 | 2110.8032 |
| 69.0661 | 2104.9231 |
| 70.8371 | 2099.0331 |
| 72.6081 | 2093.1531 |
| 74.3792 | 2087.283 |
| 76.1502 | 2081.423 |
| 77.9212 | 2075.5529 |
| 79.692 | 2069.7029 |
| 81.4631 | 2063.8529 |
| 83.2341 | 2058.0028 |
| 85.0051 | 2052.1528 |
| 86.7752 | 2046.3128 |
| 88.5462 | 2040.4727 |
| 90.317 | 2034.6327 |
| 92.0881 | 2028.8027 |
| 93.8591 | 2022.9626 |
| 95.6301 | 2017.1326 |
| 97.4011 | 2011.2925 |
| 99.1722 | 2005.4625 |
| 100.9411 | 1999.6325 |
| 102.7112 | 1993.8024 |
| 104.4811 | 1987.9724 |
| 106.2511 | 1982.1324 |
| 108.0212 | 1976.3023 |
| 109.7911 | 1970.4623 |
| 111.5612 | 1964.6223 |
| 113.3411 | 1958.7422 |
| 115.1112 | 1952.9022 |
| 116.8811 | 1947.0621 |
| 118.6511 | 1941.2221 |
| 120.4212 | 1935.3721 |
| 122.1911 | 1929.522 |
| 123.9612 | 1923.672 |
| 125.7311 | 1917.822 |
| 127.5023 | 1893.1818 |
| 129.2725 | 1877.9417 |
| 131.0424 | 1871.0917 |
| 132.8248 | 1838.2515 |
| 134.5947 | 1832.2714 |
| 136.3652 | 1817.0913 |
| 138.135 | 1810.1613 |
| 139.9051 | 1804.1313 |
| 141.6754 | 1789.8912 |
| 143.4453 | 1783.8311 |
| 145.2153 | 1774.1311 |
| 146.9854 | 1762.621 |
| 148.7555 | 1756.511 |
| 150.5256 | 1750.4009 |
| 152.3055 | 1744.2409 |
| 154.0758 | 1729.1308 |
| 155.8456 | 1722.9707 |
| 157.6157 | 1716.7807 |
| 159.3856 | 1710.5907 |
| 161.1559 | 1711.4907 |
| 162.9259 | 1705.2806 |
| 164.6962 | 1709.7107 |
| 166.4687 | 1677.0005 |
| 168.2411 | 1644.5303 |
| 170.0142 | 1609.23 |
| 171.7845 | 1596.55 |
| 173.5644 | 1593.5199 |
| 175.3347 | 1580.8399 |
| 177.1045 | 1577.7798 |
| 177.1045 | 1577.7798 |

APPENDIX II

APPENDIX II Simulation results of various pipeline sizing vs pressure drop

| Distance | Pressure | Distance2 | Pressure3 | Distance4 | Pressure5 | Distance6 | Pressure7 |
|---|---|---|---|---|---|---|---|
| (miles) | (psi) | (miles) | (psi) | (miles) | (psi) | (miles) | (psi) |
| D (inch) | 6 | D (inch) | 9 | D (inch) | 12 | D (inch) | 15 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 2338.09 | | 9350.35 | 895.8876 | 9350.35 | 2085.623 | 9350.35 | 2251.974 |
| | | 11689.8 | | 18706 | 1835.7114 | 18706 | 2193.8837 |
| | | | | 28056.3 | 1532.8096 | 28056.3 | 2117.4132 |
| | | | | 37407.2 | 1159.4172 | 37407.2 | 2038.7327 |
| | | | | 46757.6 | 591.1597 | 46757.6 | 1957.6022 |
| | | | | 51431.7 | | 56105.8 | 1873.7017 |
| | | | | | | 65456.7 | 1786.6011 |
| | | | | | | 74807.6 | 1695.7606 |
| | | | | | | 84158.4 | 1600.51 |
| | | | | | | 93509.3 | 1500.0294 |
| | | | | | | 102860 | 1393.2487 |
| | | | | | | 112206 | 1278.528 |
| | | | | | | 121557 | 1153.1672 |
| | | | | | | 130908 | 1013.4763 |
| | | | | | | 140259 | 852.1023 |
| | | | | | | 149610 | 652.7031 |
| | | | | | | 158960 | 352.9322 |
| | | | | | | 163635 | |

APPENDIX III Simulation results of various pipeline sizing vs pressure drop

| Distance8 | Pressure9 | Distance10 | Pressure11 | Distance12 | Pressure13 |
|---|---|---|---|---|---|
| (miles) | (psi) | (miles) | (psi) | (miles) | (psi) |
| D (inch) | 18 | D (inch) | 21 | D (inch) | 24 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 9350.35 | 2296.7543 | 9350.35 | 2312.2744 | 9350.35 | 2318.6145 |
| 18706 | 2285.4643 | 18706 | 2316.8244 | 18706 | 2329.5745 |
| 28056.3 | 2256.9841 | 28056.3 | 2304.1544 | 28056.3 | 2323.2445 |
| 37407.2 | 2228.3139 | 37407.2 | 2291.4943 | 37407.2 | 2316.9344 |
| 46757.6 | 2199.4437 | 46757.6 | 2278.8242 | 46757.6 | 2310.6444 |
| 56105.8 | 2170.3735 | 56105.8 | 2266.1741 | 56105.8 | 2304.3744 |
| 65456.7 | 2141.0834 | 65456.7 | 2253.5041 | 65456.7 | 2298.1143 |
| 74807.6 | 2111.5432 | 74807.6 | 2240.834 | 74807.6 | 2291.8843 |
| 84158.4 | 2081.763 | 84158.4 | 2228.1639 | 84158.4 | 2285.6643 |
| 93509.3 | 2051.7228 | 93509.3 | 2215.4838 | 93509.3 | 2279.4642 |
| 102860 | 2021.4026 | 102860 | 2202.8037 | 102860 | 2273.2742 |
| 112206 | 1990.8024 | 112206 | 2190.1037 | 112206 | 2267.1041 |
| 121557 | 1959.8822 | 121557 | 2177.4036 | 121557 | 2260.9441 |
| 130908 | 1928.622 | 130908 | 2164.6735 | 130908 | 2254.7941 |
| 140259 | 1897.0318 | 140259 | 2151.9334 | 140259 | 2248.664 |
| 149610 | 1865.0916 | 149610 | 2139.1833 | 149610 | 2242.544 |
| 158960 | 1832.8014 | 158960 | 2126.4133 | 158960 | 2236.4439 |
| 168311 | 1800.1312 | 168311 | 2113.6432 | 168311 | 2230.3539 |
| 177662 | 1767.041 | 177662 | 2100.8531 | 177662 | 2224.2739 |
| 187008 | 1733.5308 | 187008 | 2088.063 | 187008 | 2218.2138 |
| 196359 | 1699.5206 | 196359 | 2075.2429 | 196359 | 2212.1738 |
| 205710 | 1665.0104 | 205710 | 2062.4129 | 205710 | 2206.1338 |
| 215060 | 1629.9402 | 215060 | 2049.5628 | 215060 | 2200.1137 |
| 224411 | 1594.2799 | 224411 | 2036.6927 | 224411 | 2194.0937 |
| 233762 | 1557.9797 | 233762 | 2023.7926 | 233762 | 2188.0936 |
| 243113 | 1520.9795 | 243113 | 2010.8725 | 243113 | 2182.1036 |
| 252464 | 1483.2293 | 252464 | 1997.9325 | 252464 | 2176.1236 |
| 261810 | 1444.699 | 261810 | 1984.9624 | 261810 | 2170.1535 |
| 271160 | 1405.2988 | 271160 | 1971.9623 | 271160 | 2164.1835 |
| 280511 | 1364.9585 | 280511 | 1958.9322 | 280511 | 2158.2235 |
| 289862 | 1323.5883 | 289862 | 1945.8621 | 289862 | 2152.2734 |
| 299213 | 1281.078 | 299213 | 1932.7621 | 299213 | 2146.3334 |
| 308564 | 1237.2577 | 308564 | 1919.622 | 308564 | 2140.3933 |
| 317915 | 1191.9974 | 317915 | 1906.4419 | 317915 | 2134.4633 |
| 327266 | 1145.1571 | 327266 | 1893.2318 | 327266 | 2128.5333 |
| 336622 | 1096.5168 | 336622 | 1879.9817 | 336622 | 2122.6132 |
| 345973 | 1045.8465 | 345973 | 1866.7016 | 345973 | 2116.7032 |
| 355324 | 992.7732 | 355324 | 1853.3816 | 355324 | 2110.8032 |
| 364669 | 936.9238 | 364669 | 1840.0415 | 364669 | 2104.9231 |
| 374020 | 877.6585 | 374020 | 1826.6514 | 374020 | 2099.0331 |
| 383371 | 814.1511 | 383371 | 1813.2113 | 383371 | 2093.1531 |
| 392722 | 745.3326 | 392722 | 1799.7312 | 392722 | 2087.283 |
| 402073 | 669.7272 | 402073 | 1786.2111 | 402073 | 2081.423 |
| 411424 | 584.4346 | 411424 | 1772.6311 | 411424 | 2075.5529 |
| 420774 | 483.889 | 420774 | 1759.001 | 420774 | 2069.7029 |
| 430125 | 355.6702 | 430125 | 1745.3209 | 430125 | 2063.8529 |
| 439476 | 127.0198 | 439476 | 1731.5708 | 439476 | 2058.0028 |
| 441814 | | 448827 | 1717.7707 | 448827 | 2052.1528 |
| | | 458173 | 1703.9106 | 458173 | 2046.3128 |
| | | 467524 | 1689.9805 | 467524 | 2040.4727 |
| | | 476874 | 1675.9805 | 476874 | 2034.6327 |
| | | 486225 | 1661.9004 | 486225 | 2028.8027 |
| | | 495576 | 1647.7503 | 495576 | 2022.9626 |
| | | 504927 | 1633.5102 | 504927 | 2017.1326 |
| | | 514278 | 1619.2001 | 514278 | 2011.2925 |
| | | 523629 | 1604.8 | 523629 | 2005.4625 |
| | | 532969 | 1590.3199 | 532969 | 1999.6325 |
| | | 542315 | 1575.7498 | 542315 | 1993.8024 |
| | | 551660 | 1561.0997 | 551660 | 1987.9724 |
| | | 561006 | 1546.3496 | 561006 | 1982.1324 |
| | | 570352 | 1531.5096 | 570352 | 1976.3023 |
| | | 579697 | 1516.5695 | 579697 | 1970.4623 |
| | | 589043 | 1501.5194 | 589043 | 1964.6223 |
| | | 598441 | 1486.2693 | 598441 | 1958.7422 |
| | | 607787 | 1470.9992 | 607787 | 1952.9022 |
| | | 617132 | 1455.6091 | 617132 | 1947.0621 |
| | | 626478 | 1440.089 | 626478 | 1941.2221 |
| | | 635824 | 1424.4389 | 635824 | 1935.3721 |
| | | 645169 | 1408.6588 | 645169 | 1929.522 |
| | | 654515 | 1392.7287 | 654515 | 1923.672 |
| | | 663860 | 1376.6486 | 663860 | 1917.822 |
| | | 673212 | 1346.9384 | 673212 | 1893.1818 |
| | | 682559 | 1323.7783 | 682559 | 1877.9417 |
| | | 691904 | 1306.3581 | 691904 | 1871.0917 |
| | | 701315 | 1270.6179 | 701315 | 1838.2515 |
| | | 710660 | 1253.2378 | 710660 | 1832.2714 |
| | | 720008 | 1229.4077 | 720008 | 1817.0913 |
| | | 729353 | 1210.8776 | 729353 | 1810.1613 |
| | | 738699 | 1192.7074 | 738699 | 1804.1313 |
| | | 748046 | 1168.9273 | 748046 | 1789.8912 |
| | | 757391 | 1150.1972 | 757391 | 1783.8311 |
| | | 766737 | 1128.897 | 766737 | 1774.1311 |
| | | 776083 | 1106.1969 | 776083 | 1762.621 |
| | | 785429 | 1086.5668 | 785429 | 1756.511 |
| | | 794775 | 1066.6167 | 794775 | 1750.4009 |
| | | 804173 | 1046.2065 | 804173 | 1744.2409 |
| | | 813520 | 1020.2364 | 813520 | 1729.1308 |
| | | 822865 | 999.0952 | 822865 | 1722.9707 |
| | | 832211 | 977.5191 | 832211 | 1716.7807 |
| | | 841556 | 955.472 | 841556 | 1710.5907 |
| | | 850903 | 936.8168 | 850903 | 1711.4907 |
| | | 860249 | 913.7687 | 860249 | 1705.2806 |
| | | 869596 | 895.7186 | 869596 | 1709.7107 |
| | | 878955 | 857.8854 | 878955 | 1677.0005 |
| | | 888313 | 819.5441 | 888313 | 1644.5303 |
| | | 897675 | 779.0799 | 897675 | 1609.23 |
| | | 907022 | 748.4147 | 907022 | 1596.55 |
| | | 916420 | 720.9115 | 916420 | 1593.5199 |
| | | 925767 | 688.1563 | 925767 | 1580.8399 |
| | | 935112 | 658.0741 | 935112 | 1577.7798 |
| | | 935112 | 658.0741 | 935112 | 1577.7798 |

APPENDIX IV Simulation results of various pipeline sizing vs pressure drop

| Distance14 | Pressure15 | Distance16 | Pressure17 | Distance18 | Pressure19 |
|---|---|---|---|---|---|
| (miles) | (psi) | (miles) | (psi) | (miles) | (psi) |
| D (inch) | 27 | D (inch) | 30 | D (inch) | 33 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 9350.35 | 2321.5145 | 9350.35 | 2322.9745 | 9350.35 | 2323.7645 |
| 18706 | 2335.4246 | 18706 | 2338.3646 | 18706 | 2339.9546 |
| 28056.3 | 2331.9745 | 28056.3 | 2336.3546 | 28056.3 | 2338.7246 |
| 37407.2 | 2328.5445 | 37407.2 | 2334.3646 | 37407.2 | 2337.5046 |
| 46757.6 | 2325.1345 | 46757.6 | 2332.3845 | 46757.6 | 2336.2946 |
| 56105.8 | 2321.7345 | 56105.8 | 2330.4145 | 56105.8 | 2335.0846 |
| 65456.7 | 2318.3545 | 65456.7 | 2328.4545 | 65456.7 | 2333.8846 |
| 74807.6 | 2314.9844 | 74807.6 | 2326.5145 | 74807.6 | 2332.6945 |
| 84158.4 | 2311.6344 | 84158.4 | 2324.5745 | 84158.4 | 2331.5145 |
| 93509.3 | 2308.2944 | 93509.3 | 2322.6445 | 93509.3 | 2330.3445 |
| 102860 | 2304.9744 | 102860 | 2320.7245 | 102860 | 2329.1745 |
| 112206 | 2301.6644 | 112206 | 2318.8145 | 112206 | 2328.0045 |
| 121557 | 2298.3643 | 121557 | 2316.9144 | 121557 | 2326.8545 |
| 130908 | 2295.0743 | 130908 | 2315.0244 | 130908 | 2325.7045 |
| 140259 | 2291.8043 | 140259 | 2313.1444 | 140259 | 2324.5545 |
| 149610 | 2288.5343 | 149610 | 2311.2744 | 149610 | 2323.4245 |
| 158960 | 2285.2943 | 158960 | 2309.4144 | 158960 | 2322.2945 |
| 168311 | 2282.0542 | 168311 | 2307.5644 | 168311 | 2321.1745 |
| 177662 | 2278.8342 | 177662 | 2305.7144 | 177662 | 2320.0545 |
| 187008 | 2275.6242 | 187008 | 2303.8844 | 187008 | 2318.9445 |
| 196359 | 2272.4242 | 196359 | 2302.0544 | 196359 | 2317.8345 |
| 205710 | 2269.2442 | 205710 | 2300.2343 | 205710 | 2316.7344 |
| 215060 | 2266.0641 | 215060 | 2298.4243 | 215060 | 2315.6344 |
| 224411 | 2262.8941 | 224411 | 2296.6143 | 224411 | 2314.5444 |
| 233762 | 2259.7441 | 233762 | 2294.8243 | 233762 | 2313.4644 |
| 243113 | 2256.5941 | 243113 | 2293.0243 | 243113 | 2312.3744 |
| 252464 | 2253.4541 | 252464 | 2291.2443 | 252464 | 2311.3044 |
| 261810 | 2250.334 | 261810 | 2289.4643 | 261810 | 2310.2244 |
| 271160 | 2247.214 | 271160 | 2287.6943 | 271160 | 2309.1644 |
| 280511 | 2244.104 | 280511 | 2285.9243 | 280511 | 2308.0944 |
| 289862 | 2240.994 | 289862 | 2284.1742 | 289862 | 2307.0344 |
| 299213 | 2237.904 | 299213 | 2282.4142 | 299213 | 2305.9844 |
| 308564 | 2234.8139 | 308564 | 2280.6742 | 308564 | 2304.9344 |
| 317915 | 2231.7339 | 317915 | 2278.9342 | 317915 | 2303.8844 |
| 327266 | 2228.6639 | 327266 | 2277.2042 | 327266 | 2302.8444 |
| 336622 | 2225.6039 | 336622 | 2275.4742 | 336622 | 2301.8144 |
| 345973 | 2222.5539 | 345973 | 2273.7542 | 345973 | 2300.7743 |
| 355324 | 2219.5138 | 355324 | 2272.0342 | 355324 | 2299.7443 |
| 364669 | 2216.4838 | 364669 | 2270.3242 | 364669 | 2298.7243 |
| 374020 | 2213.4538 | 374020 | 2268.6241 | 374020 | 2297.6943 |
| 383371 | 2210.4338 | 383371 | 2266.9241 | 383371 | 2296.6743 |
| 392722 | 2207.4238 | 392722 | 2265.2341 | 392722 | 2295.6643 |
| 402073 | 2204.4237 | 402073 | 2263.5441 | 402073 | 2294.6543 |
| 411424 | 2201.4237 | 411424 | 2261.8541 | 411424 | 2293.6443 |
| 420774 | 2198.4337 | 420774 | 2260.1741 | 420774 | 2292.6343 |
| 430125 | 2195.4437 | 430125 | 2258.5041 | 430125 | 2291.6243 |
| 439476 | 2192.4637 | 439476 | 2256.8341 | 439476 | 2290.6243 |
| 448827 | 2189.4937 | 448827 | 2255.1641 | 448827 | 2289.6243 |
| 458173 | 2186.5236 | 458173 | 2253.5041 | 458173 | 2288.6343 |
| 467524 | 2183.5636 | 467524 | 2251.844 | 467524 | 2287.6443 |
| 476874 | 2180.6036 | 476874 | 2250.184 | 476874 | 2286.6543 |
| 486225 | 2177.6536 | 486225 | 2248.534 | 486225 | 2285.6643 |
| 495576 | 2174.7036 | 495576 | 2246.884 | 495576 | 2284.6742 |
| 504927 | 2171.7535 | 504927 | 2245.234 | 504927 | 2283.6942 |
| 514278 | 2168.8135 | 514278 | 2243.594 | 514278 | 2282.7142 |
| 523629 | 2165.8835 | 523629 | 2241.954 | 523629 | 2281.7342 |
| 532969 | 2162.9535 | 532969 | 2240.324 | 532969 | 2280.7542 |
| 542315 | 2160.0235 | 542315 | 2238.694 | 542315 | 2279.7842 |
| 551660 | 2157.1035 | 551660 | 2237.064 | 551660 | 2278.8142 |
| 561006 | 2154.1834 | 561006 | 2235.4339 | 561006 | 2277.8442 |
| 570352 | 2151.2634 | 570352 | 2233.8139 | 570352 | 2276.8742 |
| 579697 | 2148.3534 | 579697 | 2232.1939 | 579697 | 2275.9042 |
| 589043 | 2145.4534 | 589043 | 2230.5839 | 589043 | 2274.9442 |
| 598441 | 2142.5334 | 598441 | 2228.9639 | 598441 | 2273.9742 |
| 607787 | 2139.6333 | 607787 | 2227.3539 | 607787 | 2273.0142 |
| 617132 | 2136.7333 | 617132 | 2225.7439 | 617132 | 2272.0642 |
| 626478 | 2133.8433 | 626478 | 2224.1439 | 626478 | 2271.1042 |
| 635824 | 2130.9533 | 635824 | 2222.5339 | 635824 | 2270.1542 |
| 645169 | 2128.0633 | 645169 | 2220.9339 | 645169 | 2269.1942 |
| 654515 | 2125.1733 | 654515 | 2219.3438 | 654515 | 2268.2441 |
| 663860 | 2122.2932 | 663860 | 2217.7438 | 663860 | 2267.2941 |
| 673212 | 2098.5031 | 673212 | 2194.0737 | 673212 | 2243.534 |
| 682559 | 2085.193 | 682559 | 2181.4736 | 682559 | 2231.2039 |
| 691904 | 2081.253 | 691904 | 2178.7736 | 691904 | 2229.1139 |
| 701315 | 2048.2628 | 701315 | 2145.3634 | 701315 | 2195.2737 |
| 710660 | 2045.3428 | 710660 | 2143.7434 | 710660 | 2194.3137 |
| 720008 | 2032.1027 | 720008 | 2131.2133 | 720008 | 2182.0636 |
| 729353 | 2028.1426 | 729353 | 2128.5033 | 729353 | 2179.9736 |
| 738699 | 2025.2226 | 738699 | 2126.8933 | 738699 | 2179.0136 |
| 748046 | 2013.0226 | 748046 | 2115.4532 | 748046 | 2167.8835 |
| 757391 | 2010.0925 | 757391 | 2113.8432 | 757391 | 2166.9235 |
| 766737 | 2003.0425 | 766737 | 2107.8631 | 766737 | 2161.4435 |
| 776083 | 1993.9524 | 776083 | 2099.7031 | 776083 | 2153.7134 |
| 785429 | 1991.0124 | 785429 | 2098.0931 | 785429 | 2152.7534 |
| 794775 | 1988.0724 | 794775 | 2096.4731 | 794775 | 2151.7934 |
| 804173 | 1985.1124 | 804173 | 2094.8531 | 804173 | 2150.8334 |
| 813520 | 1971.9323 | 813520 | 2082.343 | 813520 | 2138.5833 |
| 822865 | 1968.9823 | 822865 | 2080.723 | 822865 | 2137.6233 |
| 832211 | 1966.0323 | 832211 | 2079.103 | 832211 | 2136.6633 |
| 841556 | 1963.0822 | 841556 | 2077.493 | 841556 | 2135.7033 |
| 850903 | 1968.3123 | 850903 | 2084.603 | 850903 | 2143.7934 |
| 860249 | 1965.3723 | 860249 | 2082.993 | 860249 | 2142.8434 |
| 869596 | 1974.7423 | 869596 | 2094.5231 | 869596 | 2155.5134 |
| 878955 | 1941.1121 | 878955 | 2060.1328 | 878955 | 2120.5532 |
| 888313 | 1907.7519 | 888313 | 2026.0326 | 888313 | 2085.893 |
| 897675 | 1871.0817 | 897675 | 1988.3724 | 897675 | 2047.5228 |
| 907022 | 1860.7916 | 907022 | 1978.9523 | 907022 | 2038.4727 |
| 916420 | 1861.8116 | 916420 | 1981.6524 | 916420 | 2042.0227 |
| 925767 | 1851.5415 | 925767 | 1972.2323 | 925767 | 2032.9727 |
| 935112 | 1852.5516 | 935112 | 1974.9323 | 935112 | 2036.5227 |
| 935112 | 1852.5516 | 935112 | 1974.9323 | 935112 | 2036.5227 |

APPENDIX V Simulation results of various pipeline sizing vs pressure drop

| Distance20 | Pressure21 | Distance22 | Pressure23 | Distance24 | Pressure25 |
|---|---|---|---|---|---|
| (miles) | (psi) | (miles) | (psi) | (miles) | (psi) |
| D (inch) | 36 | D (inch) | 39 | D (inch) | 42 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 9350.35 | 2324.2145 | 9350.35 | 2324.4745 | 9350.35 | 2324.6445 |
| 18706 | 2340.8746 | 18706 | 2341.4346 | 18706 | 2341.7846 |
| 28056.3 | 2340.0846 | 28056.3 | 2340.9046 | 28056.3 | 2341.4246 |
| 37407.2 | 2339.3046 | 37407.2 | 2340.3846 | 37407.2 | 2341.0746 |
| 46757.6 | 2338.5246 | 46757.6 | 2339.8746 | 46757.6 | 2340.7146 |
| 56105.8 | 2337.7546 | 56105.8 | 2339.3646 | 56105.8 | 2340.3646 |
| 65456.7 | 2336.9946 | 65456.7 | 2338.8546 | 65456.7 | 2340.0246 |
| 74807.6 | 2336.2346 | 74807.6 | 2338.3546 | 74807.6 | 2339.6746 |
| 84158.4 | 2335.4746 | 84158.4 | 2337.8546 | 84158.4 | 2339.3346 |
| 93509.3 | 2334.7246 | 93509.3 | 2337.3546 | 93509.3 | 2338.9946 |
| 102860 | 2333.9846 | 102860 | 2336.8646 | 102860 | 2338.6546 |
| 112206 | 2333.2446 | 112206 | 2336.3746 | 112206 | 2338.3246 |
| 121557 | 2332.5045 | 121557 | 2335.8846 | 121557 | 2337.9946 |
| 130908 | 2331.7745 | 130908 | 2335.4046 | 130908 | 2337.6646 |
| 140259 | 2331.0545 | 140259 | 2334.9246 | 140259 | 2337.3346 |
| 149610 | 2330.3245 | 149610 | 2334.4446 | 149610 | 2337.0146 |
| 158960 | 2329.6145 | 158960 | 2333.9746 | 158960 | 2336.6946 |
| 168311 | 2328.8945 | 168311 | 2333.5046 | 168311 | 2336.3746 |
| 177662 | 2328.1845 | 177662 | 2333.0346 | 177662 | 2336.0546 |
| 187008 | 2327.4845 | 187008 | 2332.5745 | 187008 | 2335.7346 |
| 196359 | 2326.7845 | 196359 | 2332.1045 | 196359 | 2335.4246 |
| 205710 | 2326.0845 | 205710 | 2331.6445 | 205710 | 2335.1046 |
| 215060 | 2325.3845 | 215060 | 2331.1945 | 215060 | 2334.7946 |
| 224411 | 2324.6945 | 224411 | 2330.7345 | 224411 | 2334.4846 |
| 233762 | 2324.0045 | 233762 | 2330.2845 | 233762 | 2334.1846 |
| 243113 | 2323.3245 | 243113 | 2329.8345 | 243113 | 2333.8746 |
| 252464 | 2322.6445 | 252464 | 2329.3845 | 252464 | 2333.5746 |
| 261810 | 2321.9645 | 261810 | 2328.9445 | 261810 | 2333.2646 |
| 271160 | 2321.2945 | 271160 | 2328.4945 | 271160 | 2332.9645 |
| 280511 | 2320.6145 | 280511 | 2328.0545 | 280511 | 2332.6645 |
| 289862 | 2319.9545 | 289862 | 2327.6145 | 289862 | 2332.3745 |
| 299213 | 2319.2845 | 299213 | 2327.1845 | 299213 | 2332.0745 |
| 308564 | 2318.6245 | 308564 | 2326.7445 | 308564 | 2331.7845 |
| 317915 | 2317.9645 | 317915 | 2326.3145 | 317915 | 2331.4845 |
| 327266 | 2317.3045 | 327266 | 2325.8845 | 327266 | 2331.1945 |
| 336622 | 2316.6544 | 336622 | 2325.4545 | 336622 | 2330.9045 |
| 345973 | 2316.0044 | 345973 | 2325.0245 | 345973 | 2330.6145 |
| 355324 | 2315.3544 | 355324 | 2324.5945 | 355324 | 2330.3245 |
| 364669 | 2314.7044 | 364669 | 2324.1745 | 364669 | 2330.0345 |
| 374020 | 2314.0544 | 374020 | 2323.7445 | 374020 | 2329.7445 |
| 383371 | 2313.4144 | 383371 | 2323.3245 | 383371 | 2329.4645 |
| 392722 | 2312.7744 | 392722 | 2322.9045 | 392722 | 2329.1745 |
| 402073 | 2312.1344 | 402073 | 2322.4845 | 402073 | 2328.8945 |
| 411424 | 2311.5044 | 411424 | 2322.0745 | 411424 | 2328.6045 |
| 420774 | 2310.8644 | 420774 | 2321.6545 | 420774 | 2328.3245 |
| 430125 | 2310.2344 | 430125 | 2321.2345 | 430125 | 2328.0445 |
| 439476 | 2309.6044 | 439476 | 2320.8245 | 439476 | 2327.7645 |
| 448827 | 2308.9744 | 448827 | 2320.4145 | 448827 | 2327.4845 |
| 458173 | 2308.3444 | 458173 | 2320.0045 | 458173 | 2327.2045 |
| 467524 | 2307.7244 | 467524 | 2319.5945 | 467524 | 2326.9245 |
| 476874 | 2307.0944 | 476874 | 2319.1845 | 476874 | 2326.6545 |
| 486225 | 2306.4744 | 486225 | 2318.7745 | 486225 | 2326.3745 |
| 495576 | 2305.8544 | 495576 | 2318.3645 | 495576 | 2326.1045 |
| 504927 | 2305.2344 | 504927 | 2317.9645 | 504927 | 2325.8245 |
| 514278 | 2304.6144 | 514278 | 2317.5545 | 514278 | 2325.5545 |
| 523629 | 2304.0044 | 523629 | 2317.1545 | 523629 | 2325.2745 |
| 532969 | 2303.3944 | 532969 | 2316.7544 | 532969 | 2325.0045 |
| 542315 | 2302.7744 | 542315 | 2316.3544 | 542315 | 2324.7345 |
| 551660 | 2302.1644 | 551660 | 2315.9544 | 551660 | 2324.4645 |
| 561006 | 2301.5544 | 561006 | 2315.5544 | 561006 | 2324.1945 |
| 570352 | 2300.9444 | 570352 | 2315.1544 | 570352 | 2323.9245 |
| 579697 | 2300.3443 | 579697 | 2314.7544 | 579697 | 2323.6545 |
| 589043 | 2299.7343 | 589043 | 2314.3544 | 589043 | 2323.3845 |
| 598441 | 2299.1243 | 598441 | 2313.9644 | 598441 | 2323.1145 |
| 607787 | 2298.5243 | 607787 | 2313.5644 | 607787 | 2322.8445 |
| 617132 | 2297.9243 | 617132 | 2313.1744 | 617132 | 2322.5745 |
| 626478 | 2297.3243 | 626478 | 2312.7744 | 626478 | 2322.3045 |
| 635824 | 2296.7243 | 635824 | 2312.3844 | 635824 | 2322.0445 |
| 645169 | 2296.1243 | 645169 | 2311.9944 | 645169 | 2321.7745 |
| 654515 | 2295.5243 | 654515 | 2311.5944 | 654515 | 2321.5045 |
| 663860 | 2294.9343 | 663860 | 2311.2044 | 663860 | 2321.2445 |
| 673212 | 2271.0042 | 673212 | 2287.1043 | 673212 | 2296.9543 |
| 682559 | 2258.7741 | 682559 | 2274.8842 | 682559 | 2284.7242 |
| 691904 | 2257.0141 | 691904 | 2273.3142 | 691904 | 2283.2542 |
| 701315 | 2222.7839 | 701315 | 2238.744 | 701315 | 2248.384 |
| 710660 | 2222.1839 | 710660 | 2238.344 | 710660 | 2248.114 |
| 720008 | 2210.0238 | 720008 | 2226.2039 | 720008 | 2235.9639 |
| 729353 | 2208.2638 | 729353 | 2224.6439 | 729353 | 2234.5139 |
| 738699 | 2207.6638 | 738699 | 2224.2439 | 738699 | 2234.2439 |
| 748046 | 2196.6637 | 748046 | 2213.2838 | 748046 | 2223.2839 |
| 757391 | 2196.0637 | 757391 | 2212.8838 | 757391 | 2223.0139 |
| 766737 | 2190.8337 | 766737 | 2207.7938 | 766737 | 2217.9938 |
| 776083 | 2183.3036 | 776083 | 2200.3637 | 776083 | 2210.6038 |
| 785429 | 2182.7036 | 785429 | 2199.9737 | 785429 | 2210.3338 |
| 794775 | 2182.1036 | 794775 | 2199.5737 | 794775 | 2210.0738 |
| 804173 | 2181.4936 | 804173 | 2199.1837 | 804173 | 2209.8038 |
| 813520 | 2169.3435 | 813520 | 2187.0536 | 813520 | 2197.6637 |
| 822865 | 2168.7435 | 822865 | 2186.6636 | 822865 | 2197.3937 |
| 832211 | 2168.1435 | 832211 | 2186.2636 | 832211 | 2197.1237 |
| 841556 | 2167.5435 | 841556 | 2185.8736 | 841556 | 2196.8537 |
| 850903 | 2176.1936 | 850903 | 2194.8737 | 850903 | 2206.1038 |
| 860249 | 2175.5936 | 860249 | 2194.4837 | 860249 | 2205.8438 |
| 869596 | 2188.9337 | 869596 | 2208.2438 | 869596 | 2219.9038 |
| 878955 | 2153.5534 | 878955 | 2172.5135 | 878955 | 2183.8636 |
| 888313 | 2118.4532 | 888313 | 2137.0433 | 888313 | 2148.0834 |
| 897675 | 2079.523 | 897675 | 2097.6831 | 897675 | 2108.3631 |
| 907022 | 2070.6229 | 907022 | 2088.863 | 907022 | 2099.5731 |
| 916420 | 2074.6529 | 916420 | 2093.1831 | 916420 | 2104.0731 |
| 925767 | 2065.7729 | 925767 | 2084.373 | 925767 | 2095.2931 |
| 935112 | 2069.7929 | 935112 | 2088.683 | 935112 | 2099.7931 |
| 935112 | 2069.7929 | 935112 | 2088.683 | 935112 | 2099.7931 |

APPENDIX VI Simulation results of various pipeline sizing vs pressure drop

| Distance26 | Pressure27 | Distance28 | Pressure29 | Distance30 | Pressure31 |
|---|---|---|---|---|---|
| (miles) | (psi) | (miles) | (psi) | (miles) | (psi) |
| D (inch) | 45 | D (inch) | 48 | D (inch) | 51 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 9350.35 | 2324.7545 | 9350.35 | 2324.8245 | 9350.35 | 2324.8745 |
| 18706 | 2342.0146 | 18706 | 2342.1846 | 18706 | 2342.2946 |
| 28056.3 | 2341.7646 | 28056.3 | 2342.0046 | 28056.3 | 2342.1646 |
| 37407.2 | 2341.5146 | 37407.2 | 2341.8146 | 37407.2 | 2342.0346 |
| 46757.6 | 2341.2646 | 46757.6 | 2341.6446 | 46757.6 | 2341.9046 |
| 56105.8 | 2341.0246 | 56105.8 | 2341.4646 | 56105.8 | 2341.7746 |
| 65456.7 | 2340.7746 | 65456.7 | 2341.2846 | 65456.7 | 2341.6446 |
| 74807.6 | 2340.5346 | 74807.6 | 2341.1146 | 74807.6 | 2341.5146 |
| 84158.4 | 2340.2946 | 84158.4 | 2340.9446 | 84158.4 | 2341.3846 |
| 93509.3 | 2340.0546 | 93509.3 | 2340.7746 | 93509.3 | 2341.2646 |
| 102860 | 2339.8246 | 102860 | 2340.6046 | 102860 | 2341.1346 |
| 112206 | 2339.5846 | 112206 | 2340.4346 | 112206 | 2341.0146 |
| 121557 | 2339.3546 | 121557 | 2340.2646 | 121557 | 2340.8946 |
| 130908 | 2339.1246 | 130908 | 2340.1046 | 130908 | 2340.7746 |
| 140259 | 2338.8946 | 140259 | 2339.9346 | 140259 | 2340.6546 |
| 149610 | 2338.6746 | 149610 | 2339.7746 | 149610 | 2340.5346 |
| 158960 | 2338.4446 | 158960 | 2339.6146 | 158960 | 2340.4146 |
| 168311 | 2338.2246 | 168311 | 2339.4546 | 168311 | 2340.2946 |
| 177662 | 2337.9946 | 177662 | 2339.2946 | 177662 | 2340.1846 |
| 187008 | 2337.7746 | 187008 | 2339.1346 | 187008 | 2340.0646 |
| 196359 | 2337.5546 | 196359 | 2338.9746 | 196359 | 2339.9546 |
| 205710 | 2337.3346 | 205710 | 2338.8246 | 205710 | 2339.8346 |
| 215060 | 2337.1246 | 215060 | 2338.6646 | 215060 | 2339.7246 |
| 224411 | 2336.9046 | 224411 | 2338.5146 | 224411 | 2339.6046 |
| 233762 | 2336.6946 | 233762 | 2338.3546 | 233762 | 2339.4946 |
| 243113 | 2336.4746 | 243113 | 2338.2046 | 243113 | 2339.3846 |
| 252464 | 2336.2646 | 252464 | 2338.0546 | 252464 | 2339.2746 |
| 261810 | 2336.0546 | 261810 | 2337.9046 | 261810 | 2339.1646 |
| 271160 | 2335.8446 | 271160 | 2337.7546 | 271160 | 2339.0546 |
| 280511 | 2335.6346 | 280511 | 2337.6046 | 280511 | 2338.9446 |
| 289862 | 2335.4246 | 289862 | 2337.4546 | 289862 | 2338.8346 |
| 299213 | 2335.2246 | 299213 | 2337.3046 | 299213 | 2338.7346 |
| 308564 | 2335.0146 | 308564 | 2337.1646 | 308564 | 2338.6246 |
| 317915 | 2334.8046 | 317915 | 2337.0146 | 317915 | 2338.5146 |
| 327266 | 2334.6046 | 327266 | 2336.8646 | 327266 | 2338.4046 |
| 336622 | 2334.4046 | 336622 | 2336.7246 | 336622 | 2338.3046 |
| 345973 | 2334.1946 | 345973 | 2336.5746 | 345973 | 2338.1946 |
| 355324 | 2333.9946 | 355324 | 2336.4346 | 355324 | 2338.0946 |
| 364669 | 2333.7946 | 364669 | 2336.2846 | 364669 | 2337.9846 |
| 374020 | 2333.5946 | 374020 | 2336.1446 | 374020 | 2337.8846 |
| 383371 | 2333.3946 | 383371 | 2336.0046 | 383371 | 2337.7746 |
| 392722 | 2333.1946 | 392722 | 2335.8646 | 392722 | 2337.6746 |
| 402073 | 2332.9945 | 402073 | 2335.7246 | 402073 | 2337.5746 |
| 411424 | 2332.8045 | 411424 | 2335.5746 | 411424 | 2337.4646 |
| 420774 | 2332.6045 | 420774 | 2335.4346 | 420774 | 2337.3646 |
| 430125 | 2332.4045 | 430125 | 2335.2946 | 430125 | 2337.2646 |
| 439476 | 2332.2145 | 439476 | 2335.1546 | 439476 | 2337.1646 |
| 448827 | 2332.0145 | 448827 | 2335.0146 | 448827 | 2337.0546 |
| 458173 | 2331.8245 | 458173 | 2334.8746 | 458173 | 2336.9546 |
| 467524 | 2331.6245 | 467524 | 2334.7446 | 467524 | 2336.8546 |
| 476874 | 2331.4345 | 476874 | 2334.6046 | 476874 | 2336.7546 |
| 486225 | 2331.2445 | 486225 | 2334.4646 | 486225 | 2336.6546 |
| 495576 | 2331.0545 | 495576 | 2334.3246 | 495576 | 2336.5546 |
| 504927 | 2330.8545 | 504927 | 2334.1946 | 504927 | 2336.4546 |
| 514278 | 2330.6645 | 514278 | 2334.0546 | 514278 | 2336.3546 |
| 523629 | 2330.4745 | 523629 | 2333.9146 | 523629 | 2336.2546 |
| 532969 | 2330.2845 | 532969 | 2333.7846 | 532969 | 2336.1546 |
| 542315 | 2330.0945 | 542315 | 2333.6446 | 542315 | 2336.0546 |
| 551660 | 2329.9045 | 551660 | 2333.5046 | 551660 | 2335.9546 |
| 561006 | 2329.7145 | 561006 | 2333.3746 | 561006 | 2335.8546 |
| 570352 | 2329.5245 | 570352 | 2333.2346 | 570352 | 2335.7546 |
| 579697 | 2329.3445 | 579697 | 2333.1046 | 579697 | 2335.6546 |
| 589043 | 2329.1545 | 589043 | 2332.9645 | 589043 | 2335.5546 |
| 598441 | 2328.9645 | 598441 | 2332.8345 | 598441 | 2335.4646 |
| 607787 | 2328.7745 | 607787 | 2332.7045 | 607787 | 2335.3646 |
| 617132 | 2328.5845 | 617132 | 2332.5645 | 617132 | 2335.2646 |
| 626478 | 2328.4045 | 626478 | 2332.4345 | 626478 | 2335.1646 |
| 635824 | 2328.2145 | 635824 | 2332.2945 | 635824 | 2335.0646 |
| 645169 | 2328.0345 | 645169 | 2332.1645 | 645169 | 2334.9746 |
| 654515 | 2327.8445 | 654515 | 2332.0345 | 654515 | 2334.8746 |
| 663860 | 2327.6545 | 663860 | 2331.9045 | 663860 | 2334.7746 |
| 673212 | 2303.2144 | 673212 | 2307.3044 | 673212 | 2310.0444 |
| 682559 | 2290.9343 | 682559 | 2294.9743 | 682559 | 2297.6643 |
| 691904 | 2289.5343 | 691904 | 2293.6243 | 691904 | 2296.3443 |
| 701315 | 2254.4041 | 701315 | 2258.2641 | 701315 | 2260.7841 |
| 710660 | 2254.2241 | 710660 | 2258.1341 | 710660 | 2260.6841 |
| 720008 | 2242.034 | 720008 | 2245.904 | 720008 | 2248.404 |
| 729353 | 2240.644 | 729353 | 2244.564 | 729353 | 2247.084 |
| 738699 | 2240.454 | 738699 | 2244.424 | 738699 | 2246.994 |
| 748046 | 2229.4839 | 748046 | 2233.4039 | 748046 | 2235.9339 |
| 757391 | 2229.2939 | 757391 | 2233.2739 | 757391 | 2235.8339 |
| 766737 | 2224.3039 | 766737 | 2228.3039 | 766737 | 2230.8639 |
| 776083 | 2216.9338 | 776083 | 2220.9139 | 776083 | 2223.4639 |
| 785429 | 2216.7438 | 785429 | 2220.7839 | 785429 | 2223.3639 |
| 794775 | 2216.5538 | 794775 | 2220.6438 | 794775 | 2223.2639 |
| 804173 | 2216.3638 | 804173 | 2220.5138 | 804173 | 2223.1639 |
| 813520 | 2204.1937 | 813520 | 2208.2938 | 813520 | 2210.9138 |
| 822865 | 2204.0037 | 822865 | 2208.1638 | 822865 | 2210.8138 |
| 832211 | 2203.8137 | 832211 | 2208.0238 | 832211 | 2210.7138 |
| 841556 | 2203.6337 | 841556 | 2207.8938 | 841556 | 2210.6138 |
| 850903 | 2213.0538 | 850903 | 2217.4338 | 850903 | 2220.2538 |
| 860249 | 2212.8638 | 860249 | 2217.3038 | 860249 | 2220.1538 |
| 869596 | 2227.1439 | 869596 | 2231.7439 | 869596 | 2234.7139 |
| 878955 | 2190.8437 | 878955 | 2195.2437 | 878955 | 2198.0437 |
| 888313 | 2154.8234 | 888313 | 2159.0135 | 888313 | 2161.6635 |
| 897675 | 2114.8332 | 897675 | 2118.8032 | 897675 | 2121.2732 |
| 907022 | 2106.0531 | 907022 | 2110.0232 | 907022 | 2112.4832 |
| 916420 | 2110.6732 | 916420 | 2114.7332 | 916420 | 2117.2532 |
| 925767 | 2101.9031 | 925767 | 2105.9631 | 925767 | 2108.4731 |
| 935112 | 2106.5231 | 935112 | 2110.6632 | 935112 | 2113.2432 |
| 935112 | 2106.5231 | 935112 | 2110.6632 | 935112 | 2113.2432 |

APPENDIX VII Simulation results of various pipeline sizing vs pressure drop

| Distance32 | Pressure33 | Distance34 | Pressure35 |
|---|---|---|---|
| (miles) | (psi) | (miles) | (psi) |
| D (inch) | 54 | D (inch) | 56 |
| 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 |
| 9350.35 | 2324.9145 | 9350.35 | 2324.9245 |
| 18706 | 2342.3846 | 18706 | 2342.4346 |
| 28056.3 | 2342.2846 | 28056.3 | 2342.3446 |
| 37407.2 | 2342.1846 | 37407.2 | 2342.2646 |
| 46757.6 | 2342.0846 | 46757.6 | 2342.1846 |
| 56105.8 | 2341.9846 | 56105.8 | 2342.1046 |
| 65456.7 | 2341.8946 | 65456.7 | 2342.0246 |
| 74807.6 | 2341.7946 | 74807.6 | 2341.9446 |
| 84158.4 | 2341.7046 | 84158.4 | 2341.8646 |
| 93509.3 | 2341.6146 | 93509.3 | 2341.7846 |
| 102860 | 2341.5146 | 102860 | 2341.7146 |
| 112206 | 2341.4246 | 112206 | 2341.6346 |
| 121557 | 2341.3346 | 121557 | 2341.5546 |
| 130908 | 2341.2446 | 130908 | 2341.4846 |
| 140259 | 2341.1546 | 140259 | 2341.4046 |
| 149610 | 2341.0646 | 149610 | 2341.3346 |
| 158960 | 2340.9746 | 158960 | 2341.2646 |
| 168311 | 2340.8946 | 168311 | 2341.1946 |
| 177662 | 2340.8046 | 177662 | 2341.1146 |
| 187008 | 2340.7146 | 187008 | 2341.0446 |
| 196359 | 2340.6346 | 196359 | 2340.9746 |
| 205710 | 2340.5446 | 205710 | 2340.9046 |
| 215060 | 2340.4646 | 215060 | 2340.8346 |
| 224411 | 2340.3746 | 224411 | 2340.7646 |
| 233762 | 2340.2946 | 233762 | 2340.6946 |
| 243113 | 2340.2146 | 243113 | 2340.6246 |
| 252464 | 2340.1346 | 252464 | 2340.5646 |
| 261810 | 2340.0446 | 261810 | 2340.4946 |
| 271160 | 2339.9646 | 271160 | 2340.4246 |
| 280511 | 2339.8846 | 280511 | 2340.3546 |
| 289862 | 2339.8046 | 289862 | 2340.2946 |
| 299213 | 2339.7246 | 299213 | 2340.2246 |
| 308564 | 2339.6446 | 308564 | 2340.1546 |
| 317915 | 2339.5646 | 317915 | 2340.0946 |
| 327266 | 2339.4846 | 327266 | 2340.0246 |
| 336622 | 2339.4046 | 336622 | 2339.9646 |
| 345973 | 2339.3246 | 345973 | 2339.8946 |
| 355324 | 2339.2446 | 355324 | 2339.8246 |
| 364669 | 2339.1746 | 364669 | 2339.7646 |
| 374020 | 2339.0946 | 374020 | 2339.7046 |
| 383371 | 2339.0146 | 383371 | 2339.6346 |
| 392722 | 2338.9346 | 392722 | 2339.5746 |
| 402073 | 2338.8646 | 402073 | 2339.5046 |
| 411424 | 2338.7846 | 411424 | 2339.4446 |
| 420774 | 2338.7046 | 420774 | 2339.3846 |
| 430125 | 2338.6346 | 430125 | 2339.3146 |
| 439476 | 2338.5546 | 439476 | 2339.2546 |
| 448827 | 2338.4846 | 448827 | 2339.1946 |
| 458173 | 2338.4046 | 458173 | 2339.1246 |
| 467524 | 2338.3246 | 467524 | 2339.0646 |
| 476874 | 2338.2546 | 476874 | 2339.0046 |
| 486225 | 2338.1746 | 486225 | 2338.9446 |
| 495576 | 2338.1046 | 495576 | 2338.8746 |
| 504927 | 2338.0246 | 504927 | 2338.8146 |
| 514278 | 2337.9546 | 514278 | 2338.7546 |
| 523629 | 2337.8846 | 523629 | 2338.6946 |
| 532969 | 2337.8046 | 532969 | 2338.6346 |
| 542315 | 2337.7346 | 542315 | 2338.5746 |
| 551660 | 2337.6546 | 551660 | 2338.5146 |
| 561006 | 2337.5846 | 561006 | 2338.4446 |
| 570352 | 2337.5146 | 570352 | 2338.3846 |
| 579697 | 2337.4346 | 579697 | 2338.3246 |
| 589043 | 2337.3646 | 589043 | 2338.2646 |
| 598441 | 2337.2946 | 598441 | 2338.2046 |
| 607787 | 2337.2146 | 607787 | 2338.1446 |
| 617132 | 2337.1446 | 617132 | 2338.0846 |
| 626478 | 2337.0746 | 626478 | 2338.0246 |
| 635824 | 2336.9946 | 635824 | 2337.9646 |
| 645169 | 2336.9246 | 645169 | 2337.9046 |
| 654515 | 2336.8546 | 654515 | 2337.8446 |
| 663860 | 2336.7746 | 663860 | 2337.7846 |
| 673212 | 2311.9244 | 673212 | 2312.8544 |
| 682559 | 2299.5043 | 682559 | 2300.4043 |
| 691904 | 2298.1943 | 691904 | 2299.1043 |
| 701315 | 2262.4441 | 701315 | 2263.2141 |
| 710660 | 2262.3641 | 710660 | 2263.1541 |
| 720008 | 2250.034 | 720008 | 2250.794 |
| 729353 | 2248.734 | 729353 | 2249.504 |
| 738699 | 2248.664 | 738699 | 2249.434 |
| 748046 | 2237.564 | 748046 | 2238.314 |
| 757391 | 2237.484 | 757391 | 2238.254 |
| 766737 | 2232.5139 | 766737 | 2233.2739 |
| 776083 | 2225.1039 | 776083 | 2225.8539 |
| 785429 | 2225.0339 | 785429 | 2225.7939 |
| 794775 | 2224.9539 | 794775 | 2225.7239 |
| 804173 | 2224.8839 | 804173 | 2225.6639 |
| 813520 | 2212.5838 | 813520 | 2213.3538 |
| 822865 | 2212.5138 | 822865 | 2213.2838 |
| 832211 | 2212.4438 | 832211 | 2213.2238 |
| 841556 | 2212.3638 | 841556 | 2213.1638 |
| 850903 | 2222.0739 | 850903 | 2222.9139 |
| 860249 | 2222.0039 | 860249 | 2222.8539 |
| 869596 | 2236.6539 | 869596 | 2237.544 |
| 878955 | 2199.8437 | 878955 | 2200.6637 |
| 888313 | 2163.3335 | 888313 | 2164.0835 |
| 897675 | 2122.8132 | 897675 | 2123.4732 |
| 907022 | 2114.0032 | 907022 | 2114.6632 |
| 916420 | 2118.8232 | 916420 | 2119.5132 |
| 925767 | 2110.0332 | 925767 | 2110.7132 |
| 935112 | 2114.8532 | 935112 | 2115.5532 |
| 935112 | 2114.8532 | 935112 | 2115.5532 |

APPENDIX VIII Simulation results of various pipeline roughness value vs pressure drop

| Distance | Pressure | Distance2 | Pressure3 | Distance4 | Pressure5 |
|---|---|---|---|---|---|
| (miles) | (psi) | (miles) | (psi) | (miles) | (psi) |
| Roughness (inch) | 0.000005 | Roughness (inch) | 0.00026 | Roughness (inch) | 0.00046 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 1.7709 | 2320.3045 | 1.7709 | 2319.6145 | 1.7709 | 2319.2645 |
| 3.5428 | 2332.9845 | 3.5428 | 2331.5945 | 3.5428 | 2330.8845 |
| 5.3137 | 2328.3345 | 5.3137 | 2326.2645 | 5.3137 | 2325.2045 |
| 7.0847 | 2323.7045 | 7.0847 | 2320.9545 | 7.0847 | 2319.5445 |
| 8.8556 | 2319.0945 | 8.8556 | 2315.6544 | 8.8556 | 2313.9044 |
| 10.6261 | 2314.4944 | 10.6261 | 2310.3844 | 10.6261 | 2308.2844 |
| 12.3971 | 2309.9144 | 12.3971 | 2305.1244 | 12.3971 | 2302.6744 |
| 14.1681 | 2305.3544 | 14.1681 | 2299.8843 | 14.1681 | 2297.0943 |
| 15.9391 | 2300.8143 | 15.9391 | 2294.6643 | 15.9391 | 2291.5143 |
| 17.7101 | 2296.2743 | 17.7101 | 2289.4543 | 17.7101 | 2285.9643 |
| 19.4811 | 2291.7643 | 19.4811 | 2284.2642 | 19.4811 | 2280.4242 |
| 21.2511 | 2287.2643 | 21.2511 | 2279.0842 | 21.2511 | 2274.9042 |
| 23.0222 | 2282.7742 | 23.0222 | 2273.9242 | 23.0222 | 2269.3842 |
| 24.7932 | 2278.2942 | 24.7932 | 2268.7641 | 24.7932 | 2263.8841 |
| 26.5642 | 2273.8342 | 26.5642 | 2263.6241 | 26.5642 | 2258.4041 |
| 28.3352 | 2269.3742 | 28.3352 | 2258.5041 | 28.3352 | 2252.9241 |
| 30.1061 | 2264.9441 | 30.1061 | 2253.3841 | 30.1061 | 2247.474 |
| 31.8771 | 2260.5141 | 31.8771 | 2248.294 | 31.8771 | 2242.024 |
| 33.6481 | 2256.1041 | 33.6481 | 2243.204 | 33.6481 | 2236.6039 |
| 35.4182 | 2251.714 | 35.4182 | 2238.144 | 35.4182 | 2231.1939 |
| 37.1892 | 2247.324 | 37.1892 | 2233.0839 | 37.1892 | 2225.7839 |
| 38.9602 | 2242.954 | 38.9602 | 2228.0439 | 38.9602 | 2220.4038 |
| 40.7311 | 2238.594 | 40.7311 | 2223.0139 | 40.7311 | 2215.0238 |
| 42.5021 | 2234.2439 | 42.5021 | 2217.9938 | 42.5021 | 2209.6638 |
| 44.2731 | 2229.9039 | 44.2731 | 2212.9838 | 44.2731 | 2204.3037 |
| 46.0441 | 2225.5739 | 46.0441 | 2207.9838 | 46.0441 | 2198.9637 |
| 47.8152 | 2221.2639 | 47.8152 | 2203.0037 | 47.8152 | 2193.6237 |
| 49.5852 | 2216.9538 | 49.5852 | 2198.0237 | 49.5852 | 2188.3036 |
| 51.3561 | 2212.6538 | 51.3561 | 2193.0537 | 51.3561 | 2182.9936 |
| 53.1271 | 2208.3638 | 53.1271 | 2188.0936 | 53.1271 | 2177.6836 |
| 54.8981 | 2204.0837 | 54.8981 | 2183.1436 | 54.8981 | 2172.3835 |
| 56.6691 | 2199.8137 | 56.6691 | 2178.1936 | 56.6691 | 2167.0935 |
| 58.4402 | 2195.5437 | 58.4402 | 2173.2636 | 58.4402 | 2161.8135 |
| 60.2112 | 2191.2937 | 60.2112 | 2168.3335 | 60.2112 | 2156.5334 |
| 61.9822 | 2187.0336 | 61.9822 | 2163.4135 | 61.9822 | 2151.2634 |
| 63.7542 | 2182.7936 | 63.7542 | 2158.4935 | 63.7542 | 2146.0034 |
| 65.5252 | 2178.5636 | 65.5252 | 2153.5934 | 65.5252 | 2140.7534 |
| 67.2962 | 2174.3436 | 67.2962 | 2148.6934 | 67.2962 | 2135.5033 |
| 69.0661 | 2170.1235 | 69.0661 | 2143.8134 | 69.0661 | 2130.2733 |
| 70.8371 | 2165.9235 | 70.8371 | 2138.9333 | 70.8371 | 2125.0533 |
| 72.6081 | 2161.7235 | 72.6081 | 2134.0633 | 72.6081 | 2119.8332 |
| 74.3792 | 2157.5335 | 74.3792 | 2129.2033 | 74.3792 | 2114.6232 |
| 76.1502 | 2153.3534 | 76.1502 | 2124.3432 | 76.1502 | 2109.4132 |
| 77.9212 | 2149.1734 | 77.9212 | 2119.4932 | 77.9212 | 2104.2131 |
| 79.692 | 2145.0034 | 79.692 | 2114.6532 | 79.692 | 2099.0231 |
| 81.4631 | 2140.8434 | 81.4631 | 2109.8232 | 81.4631 | 2093.8431 |
| 83.2341 | 2136.6833 | 83.2341 | 2104.9931 | 83.2341 | 2088.653 |
| 85.0051 | 2132.5333 | 85.0051 | 2100.1631 | 85.0051 | 2083.483 |
| 86.7752 | 2128.3933 | 86.7752 | 2095.3431 | 86.7752 | 2078.313 |
| 88.5462 | 2124.2532 | 88.5462 | 2090.533 | 88.5462 | 2073.1429 |
| 90.317 | 2120.1232 | 90.317 | 2085.713 | 90.317 | 2067.9729 |
| 92.0881 | 2115.9932 | 92.0881 | 2080.913 | 92.0881 | 2062.8129 |
| 93.8591 | 2111.8632 | 93.8591 | 2076.1029 | 93.8591 | 2057.6528 |
| 95.6301 | 2107.7431 | 95.6301 | 2071.3029 | 95.6301 | 2052.4928 |
| 97.4011 | 2103.6231 | 97.4011 | 2066.5029 | 97.4011 | 2047.3428 |
| 99.1722 | 2099.5131 | 99.1722 | 2061.7129 | 99.1722 | 2042.1827 |
| 100.9411 | 2095.4131 | 100.9411 | 2056.9228 | 100.9411 | 2037.0427 |
| 102.7112 | 2091.303 | 102.7112 | 2052.1328 | 102.7112 | 2031.8927 |
| 104.4811 | 2087.213 | 104.4811 | 2047.3528 | 104.4811 | 2026.7526 |
| 106.2511 | 2083.113 | 106.2511 | 2042.5627 | 106.2511 | 2021.6026 |
| 108.0212 | 2079.013 | 108.0212 | 2037.7827 | 108.0212 | 2016.4626 |
| 109.7911 | 2074.9229 | 109.7911 | 2033.0027 | 109.7911 | 2011.3125 |
| 111.5612 | 2070.8329 | 111.5612 | 2028.2226 | 111.5612 | 2006.1725 |
| 113.3411 | 2066.7229 | 113.3411 | 2023.4126 | 113.3411 | 2000.9925 |
| 115.1112 | 2062.6429 | 115.1112 | 2018.6326 | 115.1112 | 1995.8524 |
| 116.8811 | 2058.5628 | 116.8811 | 2013.8526 | 116.8811 | 1990.7124 |
| 118.6511 | 2054.4828 | 118.6511 | 2009.0825 | 118.6511 | 1985.5724 |
| 120.4212 | 2050.4028 | 120.4212 | 2004.3125 | 120.4212 | 1980.4224 |
| 122.1911 | 2046.3328 | 122.1911 | 1999.5325 | 122.1911 | 1975.2823 |
| 123.9612 | 2042.2627 | 123.9612 | 1994.7624 | 123.9612 | 1970.1423 |
| 125.7311 | 2038.1927 | 125.7311 | 1989.9924 | 125.7311 | 1965.0023 |
| 127.5023 | 2014.2926 | 127.5023 | 1965.8123 | 127.5023 | 1940.6721 |
| 129.2725 | 2000.3325 | 129.2725 | 1951.3522 | 129.2725 | 1925.942 |
| 131.0424 | 1995.2524 | 131.0424 | 1945.5721 | 131.0424 | 1919.802 |
| 132.8248 | 1962.6622 | 132.8248 | 1912.8919 | 132.8248 | 1887.0718 |
| 134.5947 | 1958.5322 | 134.5947 | 1908.0419 | 134.5947 | 1881.8317 |
| 136.3652 | 1944.6421 | 136.3652 | 1893.6518 | 136.3652 | 1867.1716 |
| 138.135 | 1939.5321 | 138.135 | 1887.8218 | 138.135 | 1860.9616 |
| 139.9051 | 1935.3921 | 139.9051 | 1882.9417 | 139.9051 | 1855.6916 |
| 141.6754 | 1922.502 | 141.6754 | 1869.5217 | 141.6754 | 1841.9915 |
| 143.4453 | 1918.352 | 143.4453 | 1864.6316 | 143.4453 | 1836.7015 |
| 145.2153 | 1910.3119 | 145.2153 | 1855.9416 | 145.2153 | 1827.6714 |
| 146.9854 | 1900.3519 | 146.9854 | 1845.3815 | 146.9854 | 1816.7813 |
| 148.7555 | 1896.1818 | 148.7555 | 1840.4515 | 148.7555 | 1811.4613 |
| 150.5256 | 1892.0118 | 150.5256 | 1835.5214 | 150.5256 | 1806.1313 |
| 152.3055 | 1887.8218 | 152.3055 | 1830.5714 | 152.3055 | 1800.7612 |
| 154.0758 | 1874.0217 | 154.0758 | 1816.2613 | 154.0758 | 1786.1911 |
| 155.8456 | 1869.8317 | 155.8456 | 1811.3013 | 155.8456 | 1780.8211 |
| 157.6157 | 1865.6516 | 157.6157 | 1806.3413 | 157.6157 | 1775.4411 |
| 159.3856 | 1861.4616 | 159.3856 | 1801.3712 | 159.3856 | 1770.061 |
| 161.1559 | 1864.9516 | 161.1559 | 1803.8612 | 161.1559 | 1772.0111 |
| 162.9259 | 1860.7616 | 162.9259 | 1798.8912 | 162.9259 | 1766.621 |
| 164.6962 | 1868.1217 | 164.6962 | 1805.1013 | 164.6962 | 1772.2311 |
| 166.4687 | 1835.1814 | 166.4687 | 1772.2611 | 166.4687 | 1739.4408 |
| 168.2411 | 1802.5012 | 168.2411 | 1739.6708 | 168.2411 | 1706.8906 |
| 170.0142 | 1766.711 | 170.0142 | 1704.0606 | 170.0142 | 1671.4004 |
| 171.7845 | 1755.6209 | 171.7845 | 1692.3606 | 171.7845 | 1659.3703 |
| 173.5644 | 1755.0909 | 173.5644 | 1690.8605 | 173.5644 | 1657.3503 |
| 175.3347 | 1744.0009 | 175.3347 | 1679.1705 | 175.3347 | 1645.3303 |
| 177.1045 | 1743.4609 | 177.1045 | 1677.6505 | 177.1045 | 1643.3002 |
| 177.1045 | 1743.4609 | 177.1045 | 1677.6505 | 177.1045 | 1643.3002 |

APPENDIX IX

APPENDIX IX Simulation results of various pipeline roughness value vs pressure drop

| Distance6 | Pressure7 | Distance8 | Pressure9 | Distance10 | Pressure11 |
|---|---|---|---|---|---|
| (miles) | (psi) | (miles) | (psi) | (miles) | (psi) |
| Roughness (inch) | 0.00066 | Roughness (inch) | 0.00086 | Roughness (inch) | 0.001 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 1.7709 | 2318.9845 | 1.7709 | 2318.7545 | 1.7709 | 2318.6145 |
| 3.5428 | 2330.3345 | 3.5428 | 2329.8645 | 3.5428 | 2329.5745 |
| 5.3137 | 2324.3745 | 5.3137 | 2323.6745 | 5.3137 | 2323.2445 |
| 7.0847 | 2318.4345 | 7.0847 | 2317.5045 | 7.0847 | 2316.9344 |
| 8.8556 | 2312.5144 | 8.8556 | 2311.3544 | 8.8556 | 2310.6444 |
| 10.6261 | 2306.6244 | 10.6261 | 2305.2344 | 10.6261 | 2304.3744 |
| 12.3971 | 2300.7443 | 12.3971 | 2299.1243 | 12.3971 | 2298.1143 |
| 14.1681 | 2294.8743 | 14.1681 | 2293.0243 | 14.1681 | 2291.8843 |
| 15.9391 | 2289.0343 | 15.9391 | 2286.9543 | 15.9391 | 2285.6643 |
| 17.7101 | 2283.2042 | 17.7101 | 2280.8942 | 17.7101 | 2279.4642 |
| 19.4811 | 2277.3842 | 19.4811 | 2274.8442 | 19.4811 | 2273.2742 |
| 21.2511 | 2271.5842 | 21.2511 | 2268.8241 | 21.2511 | 2267.1041 |
| 23.0222 | 2265.8041 | 23.0222 | 2262.8041 | 23.0222 | 2260.9441 |
| 24.7932 | 2260.0241 | 24.7932 | 2256.7941 | 24.7932 | 2254.7941 |
| 26.5642 | 2254.2641 | 26.5642 | 2250.804 | 26.5642 | 2248.664 |
| 28.3352 | 2248.514 | 28.3352 | 2244.824 | 28.3352 | 2242.544 |
| 30.1061 | 2242.784 | 30.1061 | 2238.864 | 30.1061 | 2236.4439 |
| 31.8771 | 2237.064 | 31.8771 | 2232.9239 | 31.8771 | 2230.3539 |
| 33.6481 | 2231.3639 | 33.6481 | 2226.9839 | 33.6481 | 2224.2739 |
| 35.4182 | 2225.6839 | 35.4182 | 2221.0739 | 35.4182 | 2218.2138 |
| 37.1892 | 2220.0038 | 37.1892 | 2215.1638 | 37.1892 | 2212.1738 |
| 38.9602 | 2214.3438 | 38.9602 | 2209.2738 | 38.9602 | 2206.1338 |
| 40.7311 | 2208.6938 | 40.7311 | 2203.3937 | 40.7311 | 2200.1137 |
| 42.5021 | 2203.0537 | 42.5021 | 2197.5237 | 42.5021 | 2194.0937 |
| 44.2731 | 2197.4237 | 44.2731 | 2191.6637 | 44.2731 | 2188.0936 |
| 46.0441 | 2191.8037 | 46.0441 | 2185.8136 | 46.0441 | 2182.1036 |
| 47.8152 | 2186.2036 | 47.8152 | 2179.9736 | 47.8152 | 2176.1236 |
| 49.5852 | 2180.6036 | 49.5852 | 2174.1536 | 49.5852 | 2170.1535 |
| 51.3561 | 2175.0136 | 51.3561 | 2168.3235 | 51.3561 | 2164.1835 |
| 53.1271 | 2169.4335 | 53.1271 | 2162.5135 | 53.1271 | 2158.2235 |
| 54.8981 | 2163.8635 | 54.8981 | 2156.7035 | 54.8981 | 2152.2734 |
| 56.6691 | 2158.2935 | 56.6691 | 2150.9034 | 56.6691 | 2146.3334 |
| 58.4402 | 2152.7334 | 58.4402 | 2145.1134 | 58.4402 | 2140.3933 |
| 60.2112 | 2147.1734 | 60.2112 | 2139.3233 | 60.2112 | 2134.4633 |
| 61.9822 | 2141.6334 | 61.9822 | 2133.5433 | 61.9822 | 2128.5333 |
| 63.7542 | 2136.0933 | 63.7542 | 2127.7733 | 63.7542 | 2122.6132 |
| 65.5252 | 2130.5633 | 65.5252 | 2122.0032 | 65.5252 | 2116.7032 |
| 67.2962 | 2125.0433 | 67.2962 | 2116.2532 | 67.2962 | 2110.8032 |
| 69.0661 | 2119.5332 | 69.0661 | 2110.5132 | 69.0661 | 2104.9231 |
| 70.8371 | 2114.0332 | 70.8371 | 2104.7731 | 70.8371 | 2099.0331 |
| 72.6081 | 2108.5332 | 72.6081 | 2099.0431 | 72.6081 | 2093.1531 |
| 74.3792 | 2103.0431 | 74.3792 | 2093.3131 | 74.3792 | 2087.283 |
| 76.1502 | 2097.5631 | 76.1502 | 2087.593 | 76.1502 | 2081.423 |
| 77.9212 | 2092.083 | 77.9212 | 2081.883 | 77.9212 | 2075.5529 |
| 79.692 | 2086.613 | 79.692 | 2076.1729 | 79.692 | 2069.7029 |
| 81.4631 | 2081.143 | 81.4631 | 2070.4729 | 81.4631 | 2063.8529 |
| 83.2341 | 2075.6829 | 83.2341 | 2064.7629 | 83.2341 | 2058.0028 |
| 85.0051 | 2070.2229 | 85.0051 | 2059.0728 | 85.0051 | 2052.1528 |
| 86.7752 | 2064.7729 | 86.7752 | 2053.3828 | 86.7752 | 2046.3128 |
| 88.5462 | 2059.3128 | 88.5462 | 2047.6928 | 88.5462 | 2040.4727 |
| 90.317 | 2053.8728 | 90.317 | 2042.0027 | 90.317 | 2034.6327 |
| 92.0881 | 2048.4228 | 92.0881 | 2036.3127 | 92.0881 | 2028.8027 |
| 93.8591 | 2042.9727 | 93.8591 | 2030.6327 | 93.8591 | 2022.9626 |
| 95.6301 | 2037.5327 | 95.6301 | 2024.9426 | 95.6301 | 2017.1326 |
| 97.4011 | 2032.0927 | 97.4011 | 2019.2626 | 97.4011 | 2011.2925 |
| 99.1722 | 2026.6526 | 99.1722 | 2013.5826 | 99.1722 | 2005.4625 |
| 100.9411 | 2021.2226 | 100.9411 | 2007.9025 | 100.9411 | 1999.6325 |
| 102.7112 | 2015.7826 | 102.7112 | 2002.2225 | 102.7112 | 1993.8024 |
| 104.4811 | 2010.3525 | 104.4811 | 1996.5425 | 104.4811 | 1987.9724 |
| 106.2511 | 2004.9225 | 106.2511 | 1990.8624 | 106.2511 | 1982.1324 |
| 108.0212 | 1999.4825 | 108.0212 | 1985.1824 | 108.0212 | 1976.3023 |
| 109.7911 | 1994.0424 | 109.7911 | 1979.5023 | 109.7911 | 1970.4623 |
| 111.5612 | 1988.6124 | 111.5612 | 1973.8123 | 111.5612 | 1964.6223 |
| 113.3411 | 1983.1424 | 113.3411 | 1968.0923 | 113.3411 | 1958.7422 |
| 115.1112 | 1977.7023 | 115.1112 | 1962.4122 | 115.1112 | 1952.9022 |
| 116.8811 | 1972.2723 | 116.8811 | 1956.7222 | 116.8811 | 1947.0621 |
| 118.6511 | 1966.8323 | 118.6511 | 1951.0422 | 118.6511 | 1941.2221 |
| 120.4212 | 1961.3922 | 120.4212 | 1945.3521 | 120.4212 | 1935.3721 |
| 122.1911 | 1955.9622 | 122.1911 | 1939.6621 | 122.1911 | 1929.522 |
| 123.9612 | 1950.5222 | 123.9612 | 1933.9721 | 123.9612 | 1923.672 |
| 125.7311 | 1945.0821 | 125.7311 | 1928.272 | 125.7311 | 1917.822 |
| 127.5023 | 1920.622 | 127.5023 | 1903.7019 | 127.5023 | 1893.1818 |
| 129.2725 | 1905.6819 | 129.2725 | 1888.5818 | 129.2725 | 1877.9417 |
| 131.0424 | 1899.2418 | 131.0424 | 1881.8917 | 131.0424 | 1871.0917 |
| 132.8248 | 1866.4616 | 132.8248 | 1849.0715 | 132.8248 | 1838.2515 |
| 134.5947 | 1860.9116 | 134.5947 | 1843.2615 | 134.5947 | 1832.2714 |
| 136.3652 | 1846.0315 | 136.3652 | 1828.1914 | 136.3652 | 1817.0913 |
| 138.135 | 1839.5315 | 138.135 | 1821.4214 | 138.135 | 1810.1613 |
| 139.9051 | 1833.9414 | 139.9051 | 1815.5713 | 139.9051 | 1804.1313 |
| 141.6754 | 1820.0114 | 141.6754 | 1801.4512 | 141.6754 | 1789.8912 |
| 143.4453 | 1814.4013 | 143.4453 | 1795.5612 | 143.4453 | 1783.8311 |
| 145.2153 | 1805.0913 | 145.2153 | 1786.0111 | 145.2153 | 1774.1311 |
| 146.9854 | 1793.9412 | 146.9854 | 1774.6411 | 146.9854 | 1762.621 |
| 148.7555 | 1788.2912 | 148.7555 | 1768.711 | 148.7555 | 1756.511 |
| 150.5256 | 1782.6311 | 150.5256 | 1762.771 | 150.5256 | 1750.4009 |
| 152.3055 | 1776.9411 | 152.3055 | 1756.791 | 152.3055 | 1744.2409 |
| 154.0758 | 1762.141 | 154.0758 | 1741.8109 | 154.0758 | 1729.1308 |
| 155.8456 | 1756.441 | 155.8456 | 1735.8208 | 155.8456 | 1722.9707 |
| 157.6157 | 1750.7309 | 157.6157 | 1729.8208 | 157.6157 | 1716.7807 |
| 159.3856 | 1745.0109 | 159.3856 | 1723.8108 | 159.3856 | 1710.5907 |
| 161.1559 | 1746.5209 | 161.1559 | 1724.9408 | 161.1559 | 1711.4907 |
| 162.9259 | 1740.7909 | 162.9259 | 1718.9207 | 162.9259 | 1705.2806 |
| 164.6962 | 1745.9009 | 164.6962 | 1723.6107 | 164.6962 | 1709.7107 |
| 166.4687 | 1713.1507 | 166.4687 | 1690.8805 | 166.4687 | 1677.0005 |
| 168.2411 | 1680.6405 | 168.2411 | 1658.4103 | 168.2411 | 1644.5303 |
| 170.0142 | 1645.2303 | 170.0142 | 1623.0601 | 170.0142 | 1609.23 |
| 171.7845 | 1632.9402 | 171.7845 | 1610.53 | 171.7845 | 1596.55 |
| 173.5644 | 1630.5002 | 173.5644 | 1607.73 | 173.5644 | 1593.5199 |
| 175.3347 | 1618.2001 | 175.3347 | 1595.1999 | 175.3347 | 1580.8399 |
| 177.1045 | 1615.7401 | 177.1045 | 1592.3799 | 177.1045 | 1577.7798 |
| 177.1045 | 1615.7401 | 177.1045 | 1592.3799 | 177.1045 | 1577.7798 |

# APPENDIX X

## APPENDIX X Simulation results of compressor outlet temp vs pressure drop

| Distance (miles) | Pressure (psi) | Distance (miles) | Pressure (psi) | Distance (miles) | Pressure (psi) | Distance (miles) | Pressure (psi) |
|---|---|---|---|---|---|---|---|
| Temperature (F) | 180 | Temperature (F) | 190 | Temperature (F) | 200 | Temperature (F) | 210 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 1.7709 | 2319.1045 | 1.7709 | 2318.9545 | 1.7709 | 2318.8045 | 1.7709 | 2318.6445 |
| 3.5428 | 2331.9845 | 3.5428 | 2331.2245 | 3.5428 | 2330.4845 | 3.5428 | 2329.7245 |
| 5.3137 | 2326.1345 | 5.3137 | 2325.2245 | 5.3137 | 2324.3345 | 5.3137 | 2323.4245 |
| 7.0847 | 2320.2945 | 7.0847 | 2319.2345 | 7.0847 | 2318.2045 | 7.0847 | 2317.1445 |
| 8.8556 | 2314.4744 | 8.8556 | 2313.2644 | 8.8556 | 2312.0944 | 8.8556 | 2310.8844 |
| 10.6261 | 2308.6644 | 10.6261 | 2307.3044 | 10.6261 | 2305.9944 | 10.6261 | 2304.6444 |
| 12.3971 | 2302.8644 | 12.3971 | 2301.3544 | 12.3971 | 2299.9043 | 12.3971 | 2298.4143 |
| 14.1681 | 2297.0843 | 14.1681 | 2295.4243 | 14.1681 | 2293.8343 | 14.1681 | 2292.2143 |
| 15.9391 | 2291.3143 | 15.9391 | 2289.5043 | 15.9391 | 2287.7843 | 15.9391 | 2286.0243 |
| 17.7101 | 2285.5543 | 17.7101 | 2283.6042 | 17.7101 | 2281.7342 | 17.7101 | 2279.8442 |
| 19.4811 | 2279.8042 | 19.4811 | 2277.7142 | 19.4811 | 2275.7042 | 19.4811 | 2273.6842 |
| 21.2511 | 2274.0742 | 21.2511 | 2271.8442 | 21.2511 | 2269.6942 | 21.2511 | 2267.5341 |
| 23.0222 | 2268.3441 | 23.0222 | 2265.9841 | 23.0222 | 2263.6941 | 23.0222 | 2261.4041 |
| 24.7932 | 2262.6241 | 24.7932 | 2260.1341 | 24.7932 | 2257.7041 | 24.7932 | 2255.2841 |
| 26.5642 | 2256.9141 | 26.5642 | 2254.2941 | 26.5642 | 2251.734 | 26.5642 | 2249.174 |
| 28.3352 | 2251.204 | 28.3352 | 2248.464 | 28.3352 | 2245.774 | 28.3352 | 2243.074 |
| 30.1061 | 2245.514 | 30.1061 | 2242.644 | 30.1061 | 2239.824 | 30.1061 | 2237.004 |
| 31.8771 | 2239.824 | 31.8771 | 2236.844 | 31.8771 | 2233.8939 | 31.8771 | 2230.9339 |
| 33.6481 | 2234.1439 | 33.6481 | 2231.0439 | 33.6481 | 2227.9739 | 33.6481 | 2224.8839 |
| 35.4182 | 2228.4739 | 35.4182 | 2225.2539 | 35.4182 | 2222.0639 | 35.4182 | 2218.8538 |
| 37.1892 | 2222.8139 | 37.1892 | 2219.4638 | 37.1892 | 2216.1638 | 37.1892 | 2212.8338 |
| 38.9602 | 2217.1538 | 38.9602 | 2213.6938 | 38.9602 | 2210.2738 | 38.9602 | 2206.8238 |
| 40.7311 | 2211.5038 | 40.7311 | 2207.9238 | 40.7311 | 2204.3937 | 40.7311 | 2200.8237 |
| 42.5021 | 2205.8738 | 42.5021 | 2202.1637 | 42.5021 | 2198.5137 | 42.5021 | 2194.8337 |
| 44.2731 | 2200.2437 | 44.2731 | 2196.4037 | 44.2731 | 2192.6537 | 44.2731 | 2188.8537 |
| 46.0441 | 2194.6237 | 46.0441 | 2190.6537 | 46.0441 | 2186.7936 | 46.0441 | 2182.8836 |
| 47.8152 | 2189.0037 | 47.8152 | 2184.9236 | 47.8152 | 2180.9436 | 47.8152 | 2176.9236 |
| 49.5852 | 2183.4036 | 49.5852 | 2179.1936 | 49.5852 | 2175.1036 | 49.5852 | 2170.9735 |
| 51.3561 | 2177.8036 | 51.3561 | 2173.4736 | 51.3561 | 2169.2635 | 51.3561 | 2165.0335 |
| 53.1271 | 2172.2035 | 53.1271 | 2167.7635 | 53.1271 | 2163.4335 | 53.1271 | 2159.0935 |
| 54.8981 | 2166.6135 | 54.8981 | 2162.0635 | 54.8981 | 2157.6035 | 54.8981 | 2153.1634 |
| 56.6691 | 2161.0335 | 56.6691 | 2156.3634 | 56.6691 | 2151.7934 | 56.6691 | 2147.2334 |
| 58.4402 | 2155.4534 | 58.4402 | 2150.6734 | 58.4402 | 2145.9934 | 58.4402 | 2141.3234 |
| 60.2112 | 2149.8734 | 60.2112 | 2144.9834 | 60.2112 | 2140.1933 | 60.2112 | 2135.4033 |
| 61.9822 | 2144.3034 | 61.9822 | 2139.3033 | 61.9822 | 2134.4033 | 61.9822 | 2129.5033 |
| 63.7542 | 2138.7333 | 63.7542 | 2133.6333 | 63.7542 | 2128.6233 | 63.7542 | 2123.6132 |
| 65.5252 | 2133.1633 | 65.5252 | 2127.9633 | 65.5252 | 2122.8432 | 65.5252 | 2117.7232 |
| 67.2962 | 2127.6033 | 67.2962 | 2122.2932 | 67.2962 | 2117.0732 | 67.2962 | 2111.8432 |
| 69.0661 | 2122.0432 | 69.0661 | 2116.6332 | 69.0661 | 2111.3132 | 69.0661 | 2105.9831 |
| 70.8371 | 2116.4832 | 70.8371 | 2110.9832 | 70.8371 | 2105.5531 | 70.8371 | 2100.1131 |
| 72.6081 | 2110.9332 | 72.6081 | 2105.3231 | 72.6081 | 2099.7931 | 72.6081 | 2094.2631 |
| 74.3792 | 2105.3731 | 74.3792 | 2099.6731 | 74.3792 | 2094.0431 | 74.3792 | 2088.403 |
| 76.1502 | 2099.8131 | 76.1502 | 2094.0231 | 76.1502 | 2088.303 | 76.1502 | 2082.563 |
| 77.9212 | 2094.2631 | 77.9212 | 2088.373 | 77.9212 | 2082.553 | 77.9212 | 2076.723 |
| 79.692 | 2088.713 | 79.692 | 2082.733 | 79.692 | 2076.813 | 79.692 | 2070.8829 |
| 81.4631 | 2083.153 | 81.4631 | 2077.083 | 81.4631 | 2071.0729 | 81.4631 | 2065.0529 |
| 83.2341 | 2077.603 | 83.2341 | 2071.4429 | 83.2341 | 2065.3429 | 83.2341 | 2059.2228 |
| 85.0051 | 2072.0429 | 85.0051 | 2065.7929 | 85.0051 | 2059.6028 | 85.0051 | 2053.3928 |
| 86.7752 | 2066.4929 | 86.7752 | 2060.1528 | 86.7752 | 2053.8728 | 86.7752 | 2047.5728 |
| 88.5462 | 2060.9329 | 88.5462 | 2054.5128 | 88.5462 | 2048.1428 | 88.5462 | 2041.7527 |
| 90.317 | 2055.3828 | 90.317 | 2048.8628 | 90.317 | 2042.4127 | 90.317 | 2035.9327 |
| 92.0881 | 2049.8228 | 92.0881 | 2043.2227 | 92.0881 | 2036.6827 | 92.0881 | 2030.1127 |
| 93.8591 | 2044.2727 | 93.8591 | 2037.5727 | 93.8591 | 2030.9527 | 93.8591 | 2024.2926 |
| 95.6301 | 2038.7127 | 95.6301 | 2031.9227 | 95.6301 | 2025.2226 | 95.6301 | 2018.4726 |
| 97.4011 | 2033.1627 | 97.4011 | 2026.2726 | 97.4011 | 2019.4826 | 97.4011 | 2012.6626 |
| 99.1722 | 2027.6026 | 99.1722 | 2020.6326 | 99.1722 | 2013.7526 | 99.1722 | 2006.8425 |
| 100.9411 | 2022.0526 | 100.9411 | 2014.9926 | 100.9411 | 2008.0225 | 100.9411 | 2001.0325 |
| 102.7112 | 2016.4926 | 102.7112 | 2009.3425 | 102.7112 | 2002.2925 | 102.7112 | 1995.2124 |
| 104.4811 | 2010.9425 | 104.4811 | 2003.7025 | 104.4811 | 1996.5525 | 104.4811 | 1989.4024 |
| 106.2511 | 2005.3825 | 106.2511 | 1998.0525 | 106.2511 | 1990.8224 | 106.2511 | 1983.5824 |
| 108.0212 | 1999.8125 | 108.0212 | 1992.4024 | 108.0212 | 1985.0824 | 108.0212 | 1977.7623 |
| 109.7911 | 1994.2524 | 109.7911 | 1986.7524 | 109.7911 | 1979.3523 | 109.7911 | 1971.9323 |
| 111.5612 | 1988.6824 | 111.5612 | 1981.1024 | 111.5612 | 1973.6123 | 111.5612 | 1966.1123 |
| 113.3411 | 1983.0824 | 113.3411 | 1975.4223 | 113.3411 | 1967.8423 | 113.3411 | 1960.2522 |
| 115.1112 | 1977.5123 | 115.1112 | 1969.7623 | 115.1112 | 1962.1022 | 115.1112 | 1954.4322 |
| 116.8811 | 1971.9323 | 116.8811 | 1964.1022 | 116.8811 | 1956.3622 | 116.8811 | 1948.6122 |
| 118.6511 | 1966.3523 | 118.6511 | 1958.4422 | 118.6511 | 1950.6222 | 118.6511 | 1942.7821 |
| 120.4212 | 1960.7622 | 120.4212 | 1952.7722 | 120.4212 | 1944.8721 | 120.4212 | 1936.9521 |
| 122.1911 | 1955.1722 | 122.1911 | 1947.1021 | 122.1911 | 1939.1221 | 122.1911 | 1931.122 |
| 123.9612 | 1949.5822 | 123.9612 | 1941.4321 | 123.9612 | 1933.3721 | 123.9612 | 1925.282 |
| 125.7311 | 1943.9821 | 125.7311 | 1935.7521 | 125.7311 | 1927.612 | 125.7311 | 1919.452 |
| 127.5023 | 1918.742 | 127.5023 | 1910.7119 | 127.5023 | 1902.7519 | 127.5023 | 1894.7718 |
| 129.2725 | 1903.3419 | 129.2725 | 1895.3618 | 129.2725 | 1887.4618 | 129.2725 | 1879.5217 |
| 131.0424 | 1896.7018 | 131.0424 | 1888.6518 | 131.0424 | 1880.6917 | 131.0424 | 1872.6917 |
| 132.8248 | 1862.9316 | 132.8248 | 1855.1816 | 132.8248 | 1847.5115 | 132.8248 | 1839.7915 |
| 134.5947 | 1857.2016 | 134.5947 | 1849.3715 | 134.5947 | 1841.6215 | 134.5947 | 1833.8214 |
| 136.3652 | 1841.8615 | 136.3652 | 1834.0914 | 136.3652 | 1826.3814 | 136.3652 | 1818.6313 |
| 138.135 | 1835.1414 | 138.135 | 1827.3014 | 138.135 | 1819.5313 | 138.135 | 1811.7213 |
| 139.9051 | 1829.3614 | 139.9051 | 1821.4514 | 139.9051 | 1813.6013 | 139.9051 | 1805.7113 |
| 141.6754 | 1815.0113 | 141.6754 | 1807.1313 | 141.6754 | 1799.3112 | 141.6754 | 1791.4512 |
| 143.4453 | 1809.1913 | 143.4453 | 1801.2412 | 143.4453 | 1793.3512 | 143.4453 | 1785.4111 |
| 145.2153 | 1799.5812 | 145.2153 | 1791.6012 | 145.2153 | 1783.6811 | 145.2153 | 1775.7211 |
| 146.9854 | 1788.0812 | 146.9854 | 1780.1011 | 146.9854 | 1772.1811 | 146.9854 | 1764.211 |
| 148.7555 | 1782.2111 | 148.7555 | 1774.1611 | 148.7555 | 1766.161 | 148.7555 | 1758.121 |
| 150.5256 | 1776.3311 | 150.5256 | 1768.211 | 150.5256 | 1760.141 | 150.5256 | 1752.0209 |
| 152.3055 | 1770.411 | 152.3055 | 1762.211 | 152.3055 | 1754.0609 | 152.3055 | 1745.8709 |
| 154.0758 | 1755.1809 | 154.0758 | 1747.0209 | 154.0758 | 1738.9208 | 154.0758 | 1730.7608 |
| 155.8456 | 1749.2509 | 155.8456 | 1741.0109 | 155.8456 | 1732.8408 | 155.8456 | 1724.6108 |
| 157.6157 | 1743.3009 | 157.6157 | 1734.9908 | 157.6157 | 1726.7408 | 157.6157 | 1718.4407 |
| 159.3856 | 1737.3308 | 159.3856 | 1728.9608 | 159.3856 | 1720.6407 | 159.3856 | 1712.2607 |
| 161.1559 | 1738.7408 | 161.1559 | 1730.2008 | 161.1559 | 1721.7207 | 161.1559 | 1713.1907 |
| 162.9259 | 1732.7608 | 162.9259 | 1724.1508 | 162.9259 | 1715.6007 | 162.9259 | 1707.0006 |
| 164.6962 | 1737.8208 | 164.6962 | 1729.0208 | 164.6962 | 1720.2707 | 164.6962 | 1711.4707 |
| 166.4687 | 1704.3306 | 166.4687 | 1695.7706 | 166.4687 | 1687.2705 | 166.4687 | 1678.7105 |
| 168.2411 | 1671.0504 | 168.2411 | 1662.7804 | 168.2411 | 1654.5303 | 168.2411 | 1646.2003 |
| 170.0142 | 1634.7802 | 170.0142 | 1626.8201 | 170.0142 | 1618.8701 | 170.0142 | 1610.84 |
| 171.7845 | 1622.1001 | 171.7845 | 1614.1401 | 171.7845 | 1606.2 | 171.7845 | 1598.16 |
| 173.5644 | 1619.4801 | 173.5644 | 1611.39 | 173.5644 | 1603.32 | 173.5644 | 1595.1599 |
| 175.3347 | 1606.8 | 175.3347 | 1598.72 | 175.3347 | 1590.6499 | 175.3347 | 1582.4799 |
| 177.1045 | 1604.14 | 177.1045 | 1595.93 | 177.1045 | 1587.7399 | 177.1045 | 1579.4399 |
| 177.1045 | 1604.14 | 177.1045 | 1595.93 | 177.1045 | 1587.7399 | 177.1045 | 1579.4399 |

APPENDIX XI Simulation results of compressor outlet temp vs pressure drop

| Distance (miles) | Pressure (psi) | Distance (miles) | Pressure (psi) | Distance (miles) | Pressure (psi) | Distance (miles) | Pressure (psi) |
|---|---|---|---|---|---|---|---|
| Temperature (F) | 220 | Temperature (F) | 230 | Temperature (F) | 240 | Temperature (F) | 250 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 1.7709 | 2318.4945 | 1.7709 | 2318.3545 | 1.7709 | 2318.1945 | 1.7709 | 2318.0545 |
| 3.5428 | 2329.0445 | 3.5428 | 2328.3845 | 3.5428 | 2327.7045 | 3.5428 | 2327.0845 |
| 5.3137 | 2322.5945 | 5.3137 | 2321.7945 | 5.3137 | 2320.9745 | 5.3137 | 2320.2045 |
| 7.0847 | 2316.1644 | 7.0847 | 2315.2244 | 7.0847 | 2314.2544 | 7.0847 | 2313.3544 |
| 8.8556 | 2309.7544 | 8.8556 | 2308.6744 | 8.8556 | 2307.5744 | 8.8556 | 2306.5144 |
| 10.6261 | 2303.3644 | 10.6261 | 2302.1444 | 10.6261 | 2300.9043 | 10.6261 | 2299.7143 |
| 12.3971 | 2296.9943 | 12.3971 | 2295.6343 | 12.3971 | 2294.2643 | 12.3971 | 2292.9343 |
| 14.1681 | 2290.6443 | 14.1681 | 2289.1443 | 14.1681 | 2287.6343 | 14.1681 | 2286.1743 |
| 15.9391 | 2284.3142 | 15.9391 | 2282.6642 | 15.9391 | 2281.0342 | 15.9391 | 2279.4342 |
| 17.7101 | 2277.9942 | 17.7101 | 2276.2142 | 17.7101 | 2274.4442 | 17.7101 | 2272.7242 |
| 19.4811 | 2271.7042 | 19.4811 | 2269.7842 | 19.4811 | 2267.8741 | 19.4811 | 2266.0341 |
| 21.2511 | 2265.4241 | 21.2511 | 2263.3741 | 21.2511 | 2261.3241 | 21.2511 | 2259.3541 |
| 23.0222 | 2259.1641 | 23.0222 | 2256.9741 | 23.0222 | 2254.7941 | 23.0222 | 2252.704 |
| 24.7932 | 2252.9241 | 24.7932 | 2250.604 | 24.7932 | 2248.284 | 24.7932 | 2246.064 |
| 26.5642 | 2246.684 | 26.5642 | 2244.244 | 26.5642 | 2241.794 | 26.5642 | 2239.444 |
| 28.3352 | 2240.464 | 28.3352 | 2237.904 | 28.3352 | 2235.3239 | 28.3352 | 2232.8439 |
| 30.1061 | 2234.2639 | 30.1061 | 2231.5739 | 30.1061 | 2228.8739 | 30.1061 | 2226.2639 |
| 31.8771 | 2228.0739 | 31.8771 | 2225.2639 | 31.8771 | 2222.4339 | 31.8771 | 2219.7038 |
| 33.6481 | 2221.8939 | 33.6481 | 2218.9638 | 33.6481 | 2216.0238 | 33.6481 | 2213.1638 |
| 35.4182 | 2215.7238 | 35.4182 | 2212.6838 | 35.4182 | 2209.6238 | 35.4182 | 2206.6438 |
| 37.1892 | 2209.5738 | 37.1892 | 2206.4138 | 37.1892 | 2203.2337 | 37.1892 | 2200.1337 |
| 38.9602 | 2203.4437 | 38.9602 | 2200.1537 | 38.9602 | 2196.8537 | 38.9602 | 2193.6437 |
| 40.7311 | 2197.3237 | 40.7311 | 2193.9037 | 40.7311 | 2190.5037 | 40.7311 | 2187.1736 |
| 42.5021 | 2191.2137 | 42.5021 | 2187.6736 | 42.5021 | 2184.1536 | 42.5021 | 2180.7136 |
| 44.2731 | 2185.1136 | 44.2731 | 2181.4536 | 44.2731 | 2177.8136 | 44.2731 | 2174.2736 |
| 46.0441 | 2179.0336 | 46.0441 | 2175.2536 | 46.0441 | 2171.4935 | 46.0441 | 2167.8435 |
| 47.8152 | 2172.9636 | 47.8152 | 2169.0635 | 47.8152 | 2165.1835 | 47.8152 | 2161.4235 |
| 49.5852 | 2166.9035 | 49.5852 | 2162.8935 | 49.5852 | 2158.8935 | 49.5852 | 2155.0234 |
| 51.3561 | 2160.8435 | 51.3561 | 2156.7335 | 51.3561 | 2152.6134 | 51.3561 | 2148.6234 |
| 53.1271 | 2154.8034 | 53.1271 | 2150.5734 | 53.1271 | 2146.3534 | 53.1271 | 2142.2434 |
| 54.8981 | 2148.7734 | 54.8981 | 2144.4334 | 54.8981 | 2140.0933 | 54.8981 | 2135.8833 |
| 56.6691 | 2142.7434 | 56.6691 | 2138.3033 | 56.6691 | 2133.8533 | 56.6691 | 2129.5233 |
| 58.4402 | 2136.7233 | 58.4402 | 2132.1833 | 58.4402 | 2127.6233 | 58.4402 | 2123.1932 |
| 60.2112 | 2130.7133 | 60.2112 | 2126.0633 | 60.2112 | 2121.4032 | 60.2112 | 2116.8632 |
| 61.9822 | 2124.7033 | 61.9822 | 2119.9632 | 61.9822 | 2115.1932 | 61.9822 | 2110.5532 |
| 63.7542 | 2118.7032 | 63.7542 | 2113.8532 | 63.7542 | 2108.9932 | 63.7542 | 2104.2431 |
| 65.5252 | 2112.7032 | 65.5252 | 2107.7631 | 65.5252 | 2102.8031 | 65.5252 | 2097.9531 |
| 67.2962 | 2106.7131 | 67.2962 | 2101.6831 | 67.2962 | 2096.6231 | 67.2962 | 2091.673 |
| 69.0661 | 2100.7431 | 69.0661 | 2095.6031 | 69.0661 | 2090.443 | 69.0661 | 2085.403 |
| 70.8371 | 2094.7731 | 70.8371 | 2089.533 | 70.8371 | 2084.283 | 70.8371 | 2079.143 |
| 72.6081 | 2088.813 | 72.6081 | 2083.463 | 72.6081 | 2078.113 | 72.6081 | 2072.8829 |
| 74.3792 | 2082.853 | 74.3792 | 2077.403 | 74.3792 | 2071.9629 | 74.3792 | 2066.6329 |
| 76.1502 | 2076.903 | 76.1502 | 2071.3529 | 76.1502 | 2065.8029 | 76.1502 | 2060.3928 |
| 77.9212 | 2070.9629 | 77.9212 | 2065.3029 | 77.9212 | 2059.6628 | 77.9212 | 2054.1528 |
| 79.692 | 2065.0329 | 79.692 | 2059.2728 | 79.692 | 2053.5228 | 79.692 | 2047.9228 |
| 81.4631 | 2059.1028 | 81.4631 | 2053.2428 | 81.4631 | 2047.3928 | 81.4631 | 2041.7027 |
| 83.2341 | 2053.1728 | 83.2341 | 2047.2128 | 83.2341 | 2041.2727 | 83.2341 | 2035.4727 |
| 85.0051 | 2047.2528 | 85.0051 | 2041.2027 | 85.0051 | 2035.1527 | 85.0051 | 2029.2627 |
| 86.7752 | 2041.3427 | 86.7752 | 2035.1927 | 86.7752 | 2029.0427 | 86.7752 | 2023.0626 |
| 88.5462 | 2035.4227 | 88.5462 | 2029.1827 | 88.5462 | 2022.9426 | 88.5462 | 2016.8626 |
| 90.317 | 2029.5127 | 90.317 | 2023.1826 | 90.317 | 2016.8426 | 90.317 | 2010.6725 |
| 92.0881 | 2023.6026 | 92.0881 | 2017.1826 | 92.0881 | 2010.7525 | 92.0881 | 2004.4825 |
| 93.8591 | 2017.7026 | 93.8591 | 2011.1925 | 93.8591 | 2004.6725 | 93.8591 | 1998.3025 |
| 95.6301 | 2011.7925 | 95.6301 | 2005.1925 | 95.6301 | 1998.5825 | 95.6301 | 1992.1324 |
| 97.4011 | 2005.8925 | 97.4011 | 1999.2025 | 97.4011 | 1992.5024 | 97.4011 | 1985.9624 |
| 99.1722 | 1999.9925 | 99.1722 | 1993.2124 | 99.1722 | 1986.4324 | 99.1722 | 1979.7923 |
| 100.9411 | 1994.0924 | 100.9411 | 1987.2324 | 100.9411 | 1980.3624 | 100.9411 | 1973.6423 |
| 102.7112 | 1988.2024 | 102.7112 | 1981.2524 | 102.7112 | 1974.2923 | 102.7112 | 1967.4923 |
| 104.4811 | 1982.3024 | 104.4811 | 1975.2723 | 104.4811 | 1968.2323 | 104.4811 | 1961.3422 |
| 106.2511 | 1976.4023 | 106.2511 | 1969.2923 | 106.2511 | 1962.1622 | 106.2511 | 1955.1922 |
| 108.0212 | 1970.5023 | 108.0212 | 1963.3122 | 108.0212 | 1956.1022 | 108.0212 | 1949.0422 |
| 109.7911 | 1964.6023 | 109.7911 | 1957.3322 | 109.7911 | 1950.0322 | 109.7911 | 1942.8921 |
| 111.5612 | 1958.6922 | 111.5612 | 1951.3422 | 111.5612 | 1943.9721 | 111.5612 | 1936.7521 |
| 113.3411 | 1952.7522 | 113.3411 | 1945.3221 | 113.3411 | 1937.8721 | 113.3411 | 1930.572 |
| 115.1112 | 1946.8421 | 115.1112 | 1939.3421 | 115.1112 | 1931.802 | 115.1112 | 1924.422 |
| 116.8811 | 1940.9321 | 116.8811 | 1933.3521 | 116.8811 | 1925.742 | 116.8811 | 1918.282 |
| 118.6511 | 1935.0221 | 118.6511 | 1927.362 | 118.6511 | 1919.672 | 118.6511 | 1912.1319 |
| 120.4212 | 1929.112 | 120.4212 | 1921.362 | 120.4212 | 1913.6019 | 120.4212 | 1905.9819 |
| 122.1911 | 1923.202 | 122.1911 | 1915.3719 | 122.1911 | 1907.5219 | 122.1911 | 1899.8318 |
| 123.9612 | 1917.282 | 123.9612 | 1909.3719 | 123.9612 | 1901.4519 | 123.9612 | 1893.6818 |
| 125.7311 | 1911.3619 | 125.7311 | 1903.3719 | 125.7311 | 1895.3718 | 125.7311 | 1887.5318 |
| 127.5023 | 1886.8618 | 127.5023 | 1879.0417 | 127.5023 | 1871.2117 | 127.5023 | 1863.5116 |
| 129.2725 | 1871.6617 | 129.2725 | 1863.8816 | 129.2725 | 1856.0916 | 129.2725 | 1848.4315 |
| 131.0424 | 1864.7616 | 131.0424 | 1856.9116 | 131.0424 | 1849.0515 | 131.0424 | 1841.3215 |
| 132.8248 | 1832.1414 | 132.8248 | 1824.5614 | 132.8248 | 1816.9613 | 132.8248 | 1809.4913 |
| 134.5947 | 1826.0914 | 134.5947 | 1818.4413 | 134.5947 | 1810.7613 | 134.5947 | 1803.2012 |
| 136.3652 | 1810.9413 | 136.3652 | 1803.3312 | 136.3652 | 1795.6812 | 136.3652 | 1788.1612 |
| 138.135 | 1803.9613 | 138.135 | 1796.2812 | 138.135 | 1788.5612 | 138.135 | 1780.9811 |
| 139.9051 | 1797.8712 | 139.9051 | 1790.1112 | 139.9051 | 1782.3211 | 139.9051 | 1774.6611 |
| 141.6754 | 1783.6511 | 141.6754 | 1775.9111 | 141.6754 | 1768.141 | 141.6754 | 1760.501 |
| 143.4453 | 1777.5311 | 143.4453 | 1769.721 | 143.4453 | 1761.871 | 143.4453 | 1754.1509 |
| 145.2153 | 1767.811 | 145.2153 | 1759.961 | 145.2153 | 1752.0809 | 145.2153 | 1744.3309 |
| 146.9854 | 1756.291 | 146.9854 | 1748.4309 | 146.9854 | 1740.5409 | 146.9854 | 1732.7708 |
| 148.7555 | 1750.1209 | 148.7555 | 1742.1909 | 148.7555 | 1734.2208 | 148.7555 | 1726.3808 |
| 150.5256 | 1743.9509 | 150.5256 | 1735.9408 | 150.5256 | 1727.9008 | 150.5256 | 1719.9807 |
| 152.3055 | 1737.7208 | 152.3055 | 1729.6408 | 152.3055 | 1721.5207 | 152.3055 | 1713.5307 |
| 154.0758 | 1722.6507 | 154.0758 | 1714.6007 | 154.0758 | 1706.5106 | 154.0758 | 1698.5406 |
| 155.8456 | 1716.4207 | 155.8456 | 1708.2907 | 155.8456 | 1700.1306 | 155.8456 | 1692.0906 |
| 157.6157 | 1710.1807 | 157.6157 | 1701.9806 | 157.6157 | 1693.7406 | 157.6157 | 1685.6305 |
| 159.3856 | 1703.9306 | 159.3856 | 1695.6506 | 159.3856 | 1687.3405 | 159.3856 | 1679.1505 |
| 161.1559 | 1704.7006 | 161.1559 | 1696.2606 | 161.1559 | 1687.8005 | 161.1559 | 1679.4605 |
| 162.9259 | 1698.4306 | 162.9259 | 1689.9205 | 162.9259 | 1681.3805 | 162.9259 | 1672.9704 |
| 164.6962 | 1702.7006 | 164.6962 | 1693.9906 | 164.6962 | 1685.2605 | 164.6962 | 1676.6605 |
| 166.4687 | 1670.1804 | 166.4687 | 1661.7004 | 166.4687 | 1653.1903 | 166.4687 | 1644.8103 |
| 168.2411 | 1637.9002 | 168.2411 | 1629.6502 | 168.2411 | 1621.3501 | 168.2411 | 1613.1801 |
| 170.0142 | 1602.81 | 170.0142 | 1594.8099 | 170.0142 | 1586.7599 | 170.0142 | 1578.8198 |
| 171.7845 | 1590.1299 | 171.7845 | 1582.1199 | 171.7845 | 1574.0698 | 171.7845 | 1566.1198 |
| 173.5644 | 1586.9899 | 173.5644 | 1578.8598 | 173.5644 | 1570.6998 | 173.5644 | 1562.6397 |
| 175.3347 | 1574.3098 | 175.3347 | 1566.1798 | 175.3347 | 1557.9997 | 175.3347 | 1549.9297 |
| 177.1045 | 1571.1498 | 177.1045 | 1562.8797 | 177.1045 | 1554.5897 | 177.1045 | 1546.4096 |
| 177.1045 | 1571.1498 | 177.1045 | 1562.8797 | 177.1045 | 1554.5897 | 177.1045 | 1546.4096 |

# APPENDIX XII Simulation results of compressor outlet temp vs pressure drop

| Distance (miles) | Pressure (psi) | Distance (miles) | Pressure (psi) | Distance (miles) | Pressure (psi) | Distance (miles) | Pressure (psi) | Distance (miles) | Pressure (psi) |
|---|---|---|---|---|---|---|---|---|---|
| ıperature (F) | 260 | Temperature (F) | 270 | Temperature (F) | 280 | Temperature (F) | 290 | Temperature (F) | 300 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 | 0 | 2325.0145 |
| 1.7709 | 2317.9145 | 1.7709 | 2317.7645 | 1.7709 | 2317.6245 | 1.7709 | 2317.4845 | 1.7709 | 2317.3445 |
| 3.5428 | 2326.4945 | 3.5428 | 2325.8845 | 3.5428 | 2325.3145 | 3.5428 | 2324.7645 | 3.5428 | 2324.2045 |
| 5.3137 | 2319.4745 | 5.3137 | 2318.7245 | 5.3137 | 2318.0045 | 5.3137 | 2317.3245 | 5.3137 | 2316.6344 |
| 7.0847 | 2312.4844 | 7.0847 | 2311.5944 | 7.0847 | 2310.7344 | 7.0847 | 2309.9244 | 7.0847 | 2309.0944 |
| 8.8556 | 2305.5144 | 8.8556 | 2304.4944 | 8.8556 | 2303.4944 | 8.8556 | 2302.5444 | 8.8556 | 2301.5844 |
| 10.6261 | 2298.5743 | 10.6261 | 2297.4243 | 10.6261 | 2296.2843 | 10.6261 | 2295.1943 | 10.6261 | 2294.1043 |
| 12.3971 | 2291.6543 | 12.3971 | 2290.3643 | 12.3971 | 2289.0943 | 12.3971 | 2287.8743 | 12.3971 | 2286.6543 |
| 14.1681 | 2284.7542 | 14.1681 | 2283.3442 | 14.1681 | 2281.9442 | 14.1681 | 2280.5842 | 14.1681 | 2279.2242 |
| 15.9391 | 2277.8842 | 15.9391 | 2276.3342 | 15.9391 | 2274.8142 | 15.9391 | 2273.3142 | 15.9391 | 2271.8342 |
| 17.7101 | 2271.0442 | 17.7101 | 2269.3542 | 17.7101 | 2267.7041 | 17.7101 | 2266.0841 | 17.7101 | 2264.4641 |
| 19.4811 | 2264.2141 | 19.4811 | 2262.4041 | 19.4811 | 2260.6241 | 19.4811 | 2258.8741 | 19.4811 | 2257.1241 |
| 21.2511 | 2257.4241 | 21.2511 | 2255.4741 | 21.2511 | 2253.5641 | 21.2511 | 2251.694 | 21.2511 | 2249.824 |
| 23.0222 | 2250.644 | 23.0222 | 2248.564 | 23.0222 | 2246.524 | 23.0222 | 2244.534 | 23.0222 | 2242.544 |
| 24.7932 | 2243.884 | 24.7932 | 2241.684 | 24.7932 | 2239.514 | 24.7932 | 2237.404 | 24.7932 | 2235.2839 |
| 26.5642 | 2237.144 | 26.5642 | 2234.8239 | 26.5642 | 2232.5239 | 26.5642 | 2230.2839 | 26.5642 | 2228.0539 |
| 28.3352 | 2230.4239 | 28.3352 | 2227.9839 | 28.3352 | 2225.5639 | 28.3352 | 2223.1939 | 28.3352 | 2220.8439 |
| 30.1061 | 2223.7139 | 30.1061 | 2221.1639 | 30.1061 | 2218.6238 | 30.1061 | 2216.1338 | 30.1061 | 2213.6538 |
| 31.8771 | 2217.0338 | 31.8771 | 2214.3638 | 31.8771 | 2211.7038 | 31.8771 | 2209.0938 | 31.8771 | 2206.4938 |
| 33.6481 | 2210.3638 | 33.6481 | 2207.5838 | 33.6481 | 2204.8038 | 33.6481 | 2202.0837 | 33.6481 | 2199.3537 |
| 35.4182 | 2203.7237 | 35.4182 | 2200.8137 | 35.4182 | 2197.9337 | 35.4182 | 2195.0937 | 35.4182 | 2192.2437 |
| 37.1892 | 2197.0937 | 37.1892 | 2194.0637 | 37.1892 | 2191.0737 | 37.1892 | 2188.1136 | 37.1892 | 2185.1536 |
| 38.9602 | 2190.4937 | 38.9602 | 2187.3436 | 38.9602 | 2184.2236 | 38.9602 | 2181.1636 | 38.9602 | 2178.0936 |
| 40.7311 | 2183.9036 | 40.7311 | 2180.6336 | 40.7311 | 2177.4036 | 40.7311 | 2174.2236 | 40.7311 | 2171.0435 |
| 42.5021 | 2177.3336 | 42.5021 | 2173.9436 | 42.5021 | 2170.5935 | 42.5021 | 2167.3135 | 42.5021 | 2164.0135 |
| 44.2731 | 2170.7735 | 44.2731 | 2167.2735 | 44.2731 | 2163.8035 | 44.2731 | 2160.4135 | 44.2731 | 2157.0135 |
| 46.0441 | 2164.2335 | 46.0441 | 2160.6235 | 46.0441 | 2157.0435 | 46.0441 | 2153.5234 | 46.0441 | 2150.0234 |
| 47.8152 | 2157.7135 | 47.8152 | 2153.9934 | 47.8152 | 2150.2934 | 47.8152 | 2146.6634 | 47.8152 | 2143.0534 |
| 49.5852 | 2151.2034 | 49.5852 | 2147.3734 | 49.5852 | 2143.5634 | 49.5852 | 2139.8233 | 49.5852 | 2136.0933 |
| 51.3561 | 2144.7034 | 51.3561 | 2140.7734 | 51.3561 | 2136.8533 | 51.3561 | 2133.0033 | 51.3561 | 2129.1633 |
| 53.1271 | 2138.2233 | 53.1271 | 2134.1833 | 53.1271 | 2130.1533 | 53.1271 | 2126.1933 | 53.1271 | 2122.2432 |
| 54.8981 | 2131.7433 | 54.8981 | 2127.6033 | 54.8981 | 2123.4732 | 54.8981 | 2119.4032 | 54.8981 | 2115.3432 |
| 56.6691 | 2125.2833 | 56.6691 | 2121.0432 | 56.6691 | 2116.8132 | 56.6691 | 2112.6332 | 56.6691 | 2108.4631 |
| 58.4402 | 2118.8332 | 58.4402 | 2114.4932 | 58.4402 | 2110.1532 | 58.4402 | 2105.8831 | 58.4402 | 2101.6031 |
| 60.2112 | 2112.4032 | 60.2112 | 2107.9531 | 60.2112 | 2103.5131 | 60.2112 | 2099.1431 | 60.2112 | 2094.7631 |
| 61.9822 | 2105.9831 | 61.9822 | 2101.4231 | 61.9822 | 2096.8931 | 61.9822 | 2092.413 | 61.9822 | 2087.933 |
| 63.7542 | 2099.5731 | 63.7542 | 2094.9031 | 63.7542 | 2090.273 | 63.7542 | 2085.693 | 63.7542 | 2081.113 |
| 65.5252 | 2093.1731 | 65.5252 | 2088.403 | 65.5252 | 2083.663 | 65.5252 | 2078.993 | 65.5252 | 2074.3129 |
| 67.2962 | 2086.793 | 67.2962 | 2081.913 | 67.2962 | 2077.073 | 67.2962 | 2072.3029 | 67.2962 | 2067.5329 |
| 69.0661 | 2080.423 | 69.0661 | 2075.4529 | 69.0661 | 2070.4929 | 69.0661 | 2065.6329 | 69.0661 | 2060.7629 |
| 70.8371 | 2074.0629 | 70.8371 | 2068.9829 | 70.8371 | 2063.9329 | 70.8371 | 2058.9628 | 70.8371 | 2053.9928 |
| 72.6081 | 2067.7129 | 72.6081 | 2062.5329 | 72.6081 | 2057.3828 | 72.6081 | 2052.3028 | 72.6081 | 2047.2428 |
| 74.3792 | 2061.3629 | 74.3792 | 2056.0928 | 74.3792 | 2050.8428 | 74.3792 | 2045.6628 | 74.3792 | 2040.5027 |
| 76.1502 | 2055.0328 | 76.1502 | 2049.6628 | 76.1502 | 2044.3127 | 76.1502 | 2039.0427 | 76.1502 | 2033.7727 |
| 77.9212 | 2048.7028 | 77.9212 | 2043.2427 | 77.9212 | 2037.8027 | 77.9212 | 2032.4227 | 77.9212 | 2027.0626 |
| 79.692 | 2042.3827 | 79.692 | 2036.8327 | 79.692 | 2031.2927 | 79.692 | 2025.8226 | 79.692 | 2020.3626 |
| 81.4631 | 2036.0727 | 81.4631 | 2030.4327 | 81.4631 | 2024.7926 | 81.4631 | 2019.2326 | 81.4631 | 2013.6726 |
| 83.2341 | 2029.7627 | 83.2341 | 2024.0326 | 83.2341 | 2018.3026 | 83.2341 | 2012.6526 | 83.2341 | 2006.9925 |
| 85.0051 | 2023.4526 | 85.0051 | 2017.6426 | 85.0051 | 2011.8225 | 85.0051 | 2006.0725 | 85.0051 | 2000.3325 |
| 86.7752 | 2017.1626 | 86.7752 | 2011.2525 | 86.7752 | 2005.3525 | 86.7752 | 1999.5125 | 86.7752 | 1993.6724 |
| 88.5462 | 2010.8625 | 88.5462 | 2004.8725 | 88.5462 | 1998.8825 | 88.5462 | 1992.9624 | 88.5462 | 1987.0324 |
| 90.317 | 2004.5825 | 90.317 | 1998.5025 | 90.317 | 1992.4224 | 90.317 | 1986.4124 | 90.317 | 1980.3924 |
| 92.0881 | 1998.3025 | 92.0881 | 1992.1324 | 92.0881 | 1985.9624 | 92.0881 | 1979.8623 | 92.0881 | 1973.7623 |
| 93.8591 | 1992.0224 | 93.8591 | 1985.7624 | 93.8591 | 1979.5123 | 93.8591 | 1973.3323 | 93.8591 | 1967.1323 |
| 95.6301 | 1985.7624 | 95.6301 | 1979.4023 | 95.6301 | 1973.0623 | 95.6301 | 1966.7923 | 95.6301 | 1960.5122 |
| 97.4011 | 1979.5023 | 97.4011 | 1973.0523 | 97.4011 | 1966.6223 | 97.4011 | 1960.2722 | 97.4011 | 1953.9022 |
| 99.1722 | 1973.2423 | 99.1722 | 1966.7023 | 99.1722 | 1960.1822 | 99.1722 | 1953.7422 | 99.1722 | 1947.3021 |
| 100.9411 | 1967.0023 | 100.9411 | 1960.3722 | 100.9411 | 1953.7522 | 100.9411 | 1947.2321 | 100.9411 | 1940.7021 |
| 102.7112 | 1960.7622 | 102.7112 | 1954.0422 | 102.7112 | 1947.3321 | 102.7112 | 1940.7221 | 102.7112 | 1934.1021 |
| 104.4811 | 1954.5222 | 104.4811 | 1947.7121 | 104.4811 | 1940.9221 | 104.4811 | 1934.2121 | 104.4811 | 1927.512 |
| 106.2511 | 1948.2922 | 106.2511 | 1941.3921 | 106.2511 | 1934.5121 | 106.2511 | 1927.712 | 106.2511 | 1920.922 |
| 108.0212 | 1942.0621 | 108.0212 | 1935.0721 | 108.0212 | 1928.102 | 108.0212 | 1921.222 | 108.0212 | 1914.3419 |
| 109.7911 | 1935.8321 | 109.7911 | 1928.762 | 109.7911 | 1921.702 | 109.7911 | 1914.7319 | 109.7911 | 1907.7619 |
| 111.5612 | 1929.602 | 111.5612 | 1922.452 | 111.5612 | 1915.3019 | 111.5612 | 1908.2419 | 111.5612 | 1901.1919 |
| 113.3411 | 1923.342 | 113.3411 | 1916.1019 | 113.3411 | 1908.8819 | 113.3411 | 1901.7319 | 113.3411 | 1894.5918 |
| 115.1112 | 1917.112 | 115.1112 | 1909.7919 | 115.1112 | 1902.4819 | 115.1112 | 1895.2518 | 115.1112 | 1888.0218 |
| 116.8811 | 1910.8919 | 116.8811 | 1903.4919 | 116.8811 | 1896.1018 | 116.8811 | 1888.7818 | 116.8811 | 1881.4717 |
| 118.6511 | 1904.6619 | 118.6511 | 1897.1818 | 118.6511 | 1889.7118 | 118.6511 | 1882.3117 | 118.6511 | 1874.9117 |
| 120.4212 | 1898.4418 | 120.4212 | 1890.8818 | 120.4212 | 1883.3217 | 120.4212 | 1875.8417 | 120.4212 | 1868.3617 |
| 122.1911 | 1892.2118 | 122.1911 | 1884.5718 | 122.1911 | 1876.9417 | 122.1911 | 1869.3817 | 122.1911 | 1861.8116 |
| 123.9612 | 1885.9818 | 123.9612 | 1878.2717 | 123.9612 | 1870.5517 | 123.9612 | 1862.9116 | 123.9612 | 1855.2716 |
| 125.7311 | 1879.7517 | 125.7311 | 1871.9617 | 125.7311 | 1864.1716 | 125.7311 | 1856.4516 | 125.7311 | 1848.7215 |
| 127.5023 | 1855.8816 | 127.5023 | 1848.2215 | 127.5023 | 1840.5615 | 127.5023 | 1832.9714 | 127.5023 | 1825.3714 |
| 129.2725 | 1840.8315 | 129.2725 | 1833.2014 | 129.2725 | 1825.5714 | 129.2725 | 1818.0013 | 129.2725 | 1810.4313 |
| 131.0424 | 1833.6514 | 131.0424 | 1825.9614 | 131.0424 | 1818.2613 | 131.0424 | 1810.6313 | 131.0424 | 1802.9912 |
| 132.8248 | 1802.0612 | 132.8248 | 1794.5912 | 132.8248 | 1787.1111 | 132.8248 | 1779.6911 | 132.8248 | 1772.2511 |
| 134.5947 | 1795.7012 | 134.5947 | 1788.1512 | 134.5947 | 1780.5911 | 134.5947 | 1773.1011 | 134.5947 | 1765.581 |
| 136.3652 | 1780.6811 | 136.3652 | 1773.1611 | 136.3652 | 1765.631 | 136.3652 | 1758.151 | 136.3652 | 1750.6609 |
| 138.135 | 1773.4311 | 138.135 | 1765.841 | 138.135 | 1758.241 | 138.135 | 1750.7009 | 138.135 | 1743.1409 |
| 139.9051 | 1767.031 | 139.9051 | 1759.371 | 139.9051 | 1751.6909 | 139.9051 | 1744.0709 | 139.9051 | 1736.4308 |
| 141.6754 | 1752.8909 | 141.6754 | 1745.2409 | 141.6754 | 1737.5708 | 141.6754 | 1729.9708 | 141.6754 | 1722.3407 |
| 143.4453 | 1746.4709 | 143.4453 | 1738.7408 | 143.4453 | 1730.9908 | 143.4453 | 1723.3107 | 143.4453 | 1715.6007 |
| 145.2153 | 1736.6108 | 145.2153 | 1728.8408 | 145.2153 | 1721.0607 | 145.2153 | 1713.3307 | 145.2153 | 1705.5806 |
| 146.9854 | 1725.0408 | 146.9854 | 1717.2607 | 146.9854 | 1709.4507 | 146.9854 | 1701.7106 | 146.9854 | 1693.9406 |
| 148.7555 | 1718.5707 | 148.7555 | 1710.7107 | 148.7555 | 1702.8306 | 148.7555 | 1695.0106 | 148.7555 | 1687.1605 |
| 150.5256 | 1712.0907 | 150.5256 | 1704.1606 | 150.5256 | 1696.2006 | 150.5256 | 1688.3005 | 150.5256 | 1680.3705 |
| 152.3055 | 1705.5706 | 152.3055 | 1697.5606 | 152.3055 | 1689.5205 | 152.3055 | 1681.5405 | 152.3055 | 1673.5304 |
| 154.0758 | 1690.6005 | 154.0758 | 1682.6205 | 154.0758 | 1674.6004 | 154.0758 | 1666.6404 | 154.0758 | 1658.6403 |
| 155.8456 | 1684.0805 | 155.8456 | 1676.0105 | 155.8456 | 1667.9204 | 155.8456 | 1659.8804 | 155.8456 | 1651.8103 |
| 157.6157 | 1677.5405 | 157.6157 | 1669.4004 | 157.6157 | 1661.2304 | 157.6157 | 1653.1103 | 157.6157 | 1644.9603 |
| 159.3856 | 1670.9904 | 159.3856 | 1662.7704 | 159.3856 | 1654.5303 | 159.3856 | 1646.3303 | 159.3856 | 1638.1002 |
| 161.1559 | 1671.1404 | 161.1559 | 1662.7804 | 161.1559 | 1654.3803 | 161.1559 | 1646.0303 | 161.1559 | 1637.6502 |
| 162.9259 | 1664.5804 | 162.9259 | 1656.1403 | 162.9259 | 1647.6703 | 162.9259 | 1639.2402 | 162.9259 | 1630.7802 |
| 164.6962 | 1668.0804 | 164.6962 | 1659.4503 | 164.6962 | 1650.7903 | 164.6962 | 1642.1802 | 164.6962 | 1633.5302 |
| 166.4687 | 1636.4402 | 166.4687 | 1628.0202 | 166.4687 | 1619.5601 | 166.4687 | 1611.15 | 166.4687 | 1602.69 |
| 168.2411 | 1605.02 | 168.2411 | 1596.8 | 168.2411 | 1588.5399 | 168.2411 | 1580.3199 | 168.2411 | 1572.0498 |
| 170.0142 | 1570.8898 | 170.0142 | 1562.8997 | 170.0142 | 1554.8597 | 170.0142 | 1546.8596 | 170.0142 | 1538.8196 |
| 171.7845 | 1558.1797 | 171.7845 | 1550.1797 | 171.7845 | 1542.1296 | 171.7845 | 1534.1196 | 171.7845 | 1526.0595 |
| 173.5644 | 1554.5897 | 173.5644 | 1546.4696 | 173.5644 | 1538.3096 | 173.5644 | 1530.1795 | 173.5644 | 1522.0095 |
| 175.3347 | 1541.8696 | 175.3347 | 1533.7396 | 175.3347 | 1525.5695 | 175.3347 | 1517.4295 | 175.3347 | 1509.2294 |
| 177.1045 | 1538.2396 | 177.1045 | 1529.9995 | 177.1045 | 1521.7095 | 177.1045 | 1513.4494 | 177.1045 | 1505.1494 |
| 177.1045 | 1538.2396 | 177.1045 | 1529.9995 | 177.1045 | 1521.7095 | 177.1045 | 1513.4494 | 177.1045 | 1505.1494 |