Estimating Pressure Drop in Natural Gas Pipeline: (A Case Study of Rumuji – Bonny NLNG Pipeline)

Boms Allen Aka, Nmegbu Godwin Chukwuma Jacob and Ehirim Emmanuel O.

Abstract

Pressure drop estimation in natural gas pipelines is of great importance in the natural gas transmission process. Transported natural gas must reach desired destination, at specified pressure and temperature conditions. This work estimates and analyses the drop in pressure during the transportation process. Interest is placed on what leads to pressure change and the effect of the pipe and gas properties on drop in pressure. The NLNG Rumuji to Bonny 36" pipeline is used as a case study during this research. Direct field pressure data were obtained and analyzed using the Weymouth, Panhandle A and Panhandle B equations for steady state compressible gas flow. The LMNO Engineering software was used in varying gas and pipe conditions to investigate their effect on the pressure drop in the line. Gas flow temperature, specific gravity, internal diameter and pipe length were varied in 6 to 7 steps to obtain a trend in the pressure output and pressure drop. The three model equations were used to compare generated pressure drop values vis a vis field measured pressure output values to ascertain flow equation best suitable for the line. The analysis revealed that for a flowing temperature, T = 549.27ºR, pipe length, L = 52.2 miles, pipe internal diameter, d = 34.68", gas compressibility, Z = 0.82, pipe efficiency factor = 0.92, pipeline initial pressure, P_1 = 1025.4 Psia and gas flow rate, Q = 890MMSCFD, the pressure drop was decreasing with decrease in T & L. At decreasing d, pressure drop was observed to be increasing using the 3 model equations.

Keywords: Pressure Drop; Gas Flow Equations, Gas Transmission, Gas Properties, Pipeline Properties, LMNO Engineering Software.

1.0 INTRODUCTION

Natural gas transportation is a fundamental activity conducted by the gas industry that basically consists of moving gas from one location to another by any appropriate means, including pipeline systems (Borraz-Sanchez, 2010). While various means might be applied to transport natural gas, it is well known that pipelines represent the most economical means to transport large quantities.

The total pressure required to transport natural from one point to another is a function of the frictional component, elevation component and pipe delivery component. Stewart (2015) added the acceleration component.

Pressure drop is a common occurrence in long distance gas transmission systems principally as a result of internal friction between the gas molecules or friction between the gas molecules and the wall of the pipe conduit. Menon, (2005) outlined that the gas flow rate and resulting pressure drop will depend on the gas properties, the length of the pipe, pipe diameter and internal design (roughness), initial gas pressure and temperature at the gas transmission point.

Pressure drop has also been seen to occur at pipe elbows, valves, nodes etc. A total sum of this individual drops in pressure amounts to a huge percentage pressure decline from the initial value at the gas transmission points (GTP) to any other point along the pipe network. Other significant contributors to pressure drop may include mechanical deformation along the line, pipe failure due to vandalism and corrosion leading to zero output at the desired output station.

It is very important to track this decline in pressure, the rate of the decline along the pipe stretch to ensure that the transmitted gas reach desired destination and at required conditions of pressure and temperature. Also having this data facilitates an excellent decision making process whether a compressor station is required on not, and in relation to the length of the pipeline.

A significant drop in pressure below required value indicates inadequate quantity of gas approaching the gas plants to be processed for export. It may take months to identify causes and proffer solutions. This amount to huge loss of revenue (millions of dollars) and down time. It is therefore of immense importance to be able to predict pressures at any point along the pipe line, considering the internal (Pipe and Natural gas properties) and external factors (vandalism, corrosion, etc.) responsible for pressure drop.

Predicting pressure drop accurately along pipelines is a huge accomplishment in the gas transportation monitoring. With the aid of a more established pressure drop model equations and software, pressure along any point on the pipeline can be estimated from locations away from the pipeline.

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It is therefore necessary to establish the most suitable pressure drop expression adaptable from existing flow equations that closely or accurately estimates pressure drop along the Rumuji to Bonny Natural gas pipeline

- To extend previously suggested pressure drop and gas flow models in literature in order to bring them closer to physical reality as it relates Rumuji to Bonny Gas pipeline
- To utilize a computer program that will calculate the pressure drop at any giving distance or point along the pipeline putting into considering the various possible cause of pressure drop in the specified pipeline under review
- Select the best governing flow equation for gas transport suitable to this pipeline system
- To compare calculated values to actual field data, and provide detail explanations for variations and similarities.
- To recommend ways to minimize pressure drop

1.1 Gas Properties vs Pipeline Properties & Pressure Drop

1.2 Gas Properties and Pressure Drop

Gas are usually characterized by low density and viscosity which expands to occupy the medium of transportation, Menon, (2005) indicates that a slight change in pressure affects the density of gas more than that of a liquid.

$$G = \frac{\rho_g}{\rho_{air}} = \frac{M_g}{M_{air}} \quad (1)$$

Mokhatab et al., (2006) argues that the volume of a real gas is less than that of an ideal gas, and that the ratio of the real volume to the ideal volume is a measure of the amount the gas deviates from perfect behavior (compressibility factor). Compressibility, Z, is the ratio of the volume occupied by a gas at a temperature and pressure to the volume it will occupy if it behaved ideally

It has been observed that liquids show a reduction in viscosity with increasing temperature. With high temperatures, viscosity increases in gases, the drag force will do the same. Lower-viscosity fluids flow easily in pipes and cause less drop in pressure during transportation. Gas viscosities are usually determined from correlations (PetroWiki, 2015)

$$v = \frac{\mu}{\rho} \quad (2)$$

$$\mu = \frac{\sum\left(\mu_i y_i \sqrt{M_i}\right)}{\sum\left(y_i \sqrt{M_i}\right)} \quad (3)$$

1.3 Pipeline Properties and Pressure Drop

Pipe sections are produced in steel rolling mills and inspected to assure they meet required standards for intended locations (Pipeline Safety Trust, 2015). Industrial standards, such as ASME/ANSI B36.10/B36.19 are applied in the design of Gas pipelines (PetroWiki, 2018). They are usually made of Carbon Steel Material certified by API and American Society of Testing and Materials (ASTM). Pipelines are traditionally buried underground, 2ft to 4ft depending on topography or 5ft to 6ft above the ground with specific consideration to the environment to all wildlife or and potential risk to the line.

Table 1 Pipeline Specification Source: Shunam (2018)

Size Inches	Identification	Thickness, Inches	ID Inches	Weight lb/ft
36	STD EX 40	0.750	34.5	12906.1

PetroWiki (2018) presents that selection of pipe thickness depends on the following:

- The maximum and working pressures
- Maximum and working temperatures
- Chemical properties of the fluid
- The fluid velocity
- The pipe material and grade
- The safety factor or code design application

Society of Petroleum Engineers (2018) suggests the following minimum basic parameters required to design a pipe system are as follows:

- The characteristics and physical properties of the fluid.
- The desired mass-flow rate (or volume) of the fluid to be transported.
- The pressure, temperature, and elevation at Point A.
- The pressure, temperature, and elevation at Point B.
- The distance between Point A and Point B (or length the fluid must travel) and equivalent length (pressure losses) introduced by valves and fittings.

$$t = \frac{PD}{2(H_s + P)} \quad (4)$$

$$R = \frac{E_m r}{f_s S_y - {P_d D}/{4t}} \quad (5)$$

1.3.1 Pipeline Properties

The **Reynolds Number**, R_e, describes the degree of turbulence in flow in pipelines. It is a dimensionless parameter (Petrowiki, 2018) that is used in characterizing flow in a pipe especially when there is substantial velocity gradient (i.e. Shear)

- $R_e < 2000$, flow is said to be laminar (viscous)
- $R_e > 4000$, flow is turbulent

- R_e Between 2000 and 4000, flow is unpredictable / critical or transient

The Rumuji to Bonny pipeline has a Reynolds in excess of 2.4 X10^{10}

$$R_e = \frac{\rho V d}{\mu} \quad (6)$$

Reynolds number for a natural gas pipeline is given as shown below

$$R_e = \frac{20\, QG}{\mu d} \quad (7)$$

Another dimensionless parameter that is critical to understanding the calculation of pressure drop in a gas pipeline at a specific flow rate is the **Friction factor**. It is hugely dependent on the Reynolds number. Fanning and Darcy friction factors are as represented in the relationship below (Mauri, 2015):

$$f_D = 4f_f = \frac{64}{R_e} \quad (8)$$

For fully rough pipes, friction factor depends more on the pipe internal roughness and less on the Reynolds number. In the transition zone between smooth pipe flow and flow in fully rough pipes, f depends on the pipe roughness, pipe inside diameter, and the Reynolds number (Menon, 2005).

$$K = \frac{e}{d} \quad (9)$$

For turbulent flow with $R_e > 4000$, typical of gas flow, friction factor f can be calculated the below equation

$$\frac{1}{\sqrt{f}} = -2\mathrm{Log}_{10}\left(\frac{e}{3.7D} + \frac{2.51}{R_e\sqrt{f}}\right) \quad (10)$$

Table 2: Pipe Materials and common pipe roughness value (source: Pipeflow, 2018)

Material Surface	Roughness, mm	Roughness, in
Concrete	0.3 – 3.0	0.012 – 0.12
Cast Iron	0.2600	0.01000
Galvanized Iron	0.1500	0.00600
Asphalted Cast Iron	0.1200	0.00480
Commercial/welded steel	0.0450	0.00180
Epoxy, vinyl ester & Isophthalic pipe	0.0050	0.00019
PVC and Plastic pipes	0.0015	0.00006

McKetta (1992) explains another important pipeline property, the **Transmission factor**, F. It is a measure of the amount of gas that can be transmitted in a pipeline. It varies inversely as the square root of the friction factor. The gas flow rate is directly proportional to the Transmission factor

$$F = \frac{2}{\sqrt{f}} \quad (11)$$

Gas flow equations for pipelines were developed with assumptions of perfectly clean lines filled with gas, but in reality, the lines could have, water, condensates etc., accumulating in lower spots in the line. So, for flow rates calculated for the 100% efficient cases are usually modified by multiplying with a **Pipeline Efficiency** factor, E. Guo (2011) explains that the efficiency factor expresses the actual flow capacity as a function of the theoretical flow rate. A 0.85 to 0.95 efficiency factor indicates a clean pipeline

Table 3: Pipeline Efficiency Factor Values (Source: Guo (2011))

Type of Pipeline	Fluid Content (gal/MMcf)	Efficiency E
Dry Gas	0.1	0.92
Gas and condensate	800	0.6
Casing-head gas	7.2	0.77

1.3.1.1 *Pressure Drop in Pipe Bends*

Pipe bends provides flexibility to gas transport systems by allowing routing and distribution. Smaller pipe bend radius results in higher pressure drop and could lead to severe erosion of the pipe wall (Kunii, 1991)

$$\Delta p_b = 2 f_b \bar{\rho} \mu_g^2 \quad (12)$$

$$f_b = C\left(\frac{1}{R_e^2}\frac{R_d}{R_B}\right)^{1/10} \quad (13)$$

Fan (2005) explains that when a gas molecule flow passes through a bend, the particle velocity is lowered by friction, the effects of gravitation and collision with the wall. Typical arrangements of bend are as follows:

- Pipe bend in a horizontal plane
- Pipe bend in the vertical plane with a horizontal approach flow
- Pipe bend in the vertical plane with a vertical approach flow

1.3.1.2 *Pressure Drop at Valves and Fittings*

Pressure drop as a result of valves and fittings on the pipeline system is caused by specific disruption of the flow (Pipe flow, 2018 & Petrowiki, 2015). Losses at fittings hve been observed to be minor in relation to the total pressure drop in the pipeline system.

According to Beggs (2000), pressure drop at valves and fittings can be approximated by an equivalent concept. This requires replacing each valve by an equivalent of pipe that would produce the same drop in pressure as the valve. Fluid Head loss is given by the equation below:

$$\Delta p_f = K_r \frac{v^2}{2g_c} \quad (14)$$

Table 3.0: Resistance Coefficients for Valves, Pipes and Fittings (Petrowiki, 2018)

Fitting Type	**K_r**
Globe valve, wide open	10.0
Angle Valve, wide open	5.0
Gate valve, wide open	0.2
Gate valve Half open	5.6
Return Bend	2.2
90° Weld Elbow	0.9
45° Weld Elbow	0.4
Tee	1.8

1.3.1.3 Temperature Variation and Pressure Drop

Temperature variation along a pipeline results from heat transfers between the fluid and the pipeline and its immediate environment. Temperature change has been seen to affect the specific gravity of the gas, the viscosity and hence the friction loss. This result in change in change in pressure required to transport. For long distance transmission, flow has been widely assumed to be isothermal where the gas temperature becomes the same as the temperature of the surrounding soil (ambient)

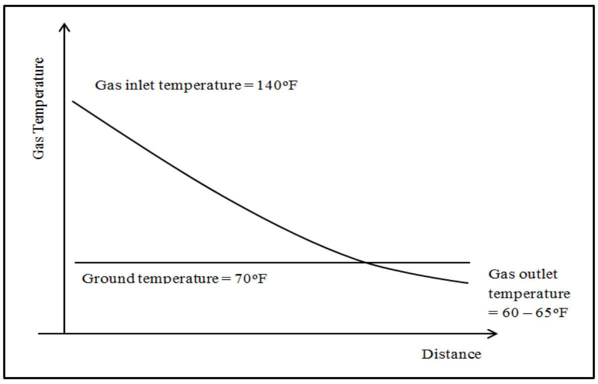

Figure 1.0: Joule-Thompson cooling effect Illustration (Menon, 2014)

Gas temperatures can drop below the ambient soil temperature as in figure 1.0 above. This amounts to transported gas reaching destination at significantly lower temperatures (resulting in lower pressure drop).

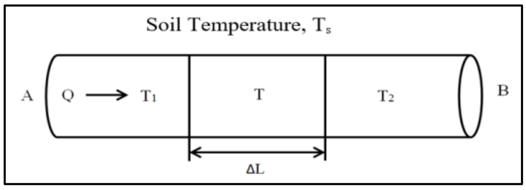

Figure 2: Temperature Analysis

$$T_L = T_s + \mu_J A\left(\frac{dp}{dL}\right) + \left[T_1 - T_s - \mu_J A\left(\frac{dp}{dL}\right)\right] e^{\frac{-L}{A}} \quad (15)$$

$$T_2 = T_s + (T_1 - T_s)e^{-\theta} \quad (16)$$

2.0 MATERIALS AND METHODS

2.1 Conceptual framework

Long-distance transport of natural gas through the transmission pipelines is usually connected with considerable pressure losses. The quantitative representation of pressure drops depends on several factors, e.g. length, diameter and full-length profile of the pipeline, physical properties of transported gas, intensity and character of flow of natural gas. The technical condition of the pipeline, especially its roughness inside, which is proportional to the exploitation life of the pipeline, importantly influences the pressure losses.

The Weymouth, Panhandle A, and Panhandle B equations were developed to simulate compressible gas flow in long pipelines. The Weymouth was first developed followed by Panhandle A and B equations. The equations were developed from the fundamental energy equation for compressible flow, but each has a special representation of the friction factor to allow the equations to be solved analytically. They will be used to characterize the gas flow in the Rumuji-Bonny Gas Pipeline

2.2 Materials

The below materials will be used to extensively analyze the topic in view:

- Rumuji – Bonny gas pipeline information
- Pressure data for 11 weeks from a routine pipeline pressure monitoring weekly report
- Transmitted natural gas properties
- Gas flow rate data for the 11 weeks of gas transmission
- 3 Gas flow models, Weymouth, Panhandle A and Panhandle B gas flow equations
- MS Excel and LMNO Engineering software were also used support the analysis

2.3 Gas Flow Equations

Consider a steady-state flow of dry gas in a horizontal, uniform diameter pipeline, with the following assumptions:

- Flow is steady state
- Flow is assumed to be isothermal,
- No mechanical/external work is done by or on the system (Gou, 2011), $W = 0$

- Gas compressibility is assumed to be constant
- The natural gas behaves as an ideal system, i.e., $P_1V_1 = P_2V_2$
- Kinetic energy losses are negligible
- Changes in elevation along the pipeline is negligible, $\Delta H = 0$
- Friction coefficient is assumed to be constant along the entire length of the pipeline

2.3.1 The Weymouth Equation

The friction factor is dependent on the internal diameter of the pipe

$$Q = 433.5E\left(\frac{T_b}{P_b}\right)\left(\frac{P_1^2 - e^sP_2^2}{GT_fL_eZ}\right)^{0.5} d^{2.667} \quad (17)$$

$$L_e = \frac{L(e^s - 1)}{s} \quad (18)$$

$$s = 0.0375G\left(\frac{\Delta H}{T_fZ}\right) \quad (19)$$

2.3.2 Panhandle A Equation

The friction factor is dependent on the Reynolds number

$$Q = 435.9E\left(\frac{T_b}{P_b}\right)^{1.079}\left[\frac{(P_1^2 - e^sP_2^2)}{TL_eG^{0.86}}\right]^{0.54} d^{2.6182} \quad (20)$$

$$f = \frac{0.085}{R_e^{0.147}} \quad (21)$$

2.3.3 Panhandle B Equation

The friction factor is dependent on the Reynolds number

$$Q = 737E\left(\frac{T_b}{P_b}\right)^{1.02}\left[\frac{(P_1^2 - P_2^2)}{G^{0.961}TLZ}\right]^{0.51} d^{2.53} \quad (22)$$

$$f = \frac{0.015}{R_e^{0.0392}} \quad (23)$$

2.3 The Rumuji – Bonny NLNG Pipeline

Table 4.0 describes the fundamental properties of this pipeline

Table 4: Pipeline Information (Eresia-Eke, 2017)

Pipe Information	Value	Unit
Pipe OD	36	Inches
Pipe ID	34.86	Inches
Material	Steel	
Roughness	45µm	3
Inner coating	Polyethylene thermal bonding	
Length	86	Km
Temperature	5-10 deg below ambient	

Table 5 shows a distribution of the obtained field pressure data for a period of 11 weeks. Both input and out pressure date were obtained

Table 5: PHC/GTS Weekly Report Pressure Measurement

Week Number	Average Pressure input, Psi	Average Pressure output, Psi	Field Measured Flowrate data, MMSCFD
Week 20	1025.4	871.59	890
Week 21	1013.1	861.14	888
Week 22	1034.8	879.58	860
Week 23	1034.8	880.00	858
Week 24	1034.0	875.55	872
Week 25	1035.7	878.94	853
Week 26	1061.0	881.22	900
Week 27	1074.7	882.38	920
Week 28	1051.5	880.91	899
Week 29	1056.6	879.99	914
Week 30	1025.4	870.11	880

According to the NLNG Pipeline Integrity Manual (2005), the following Gas properties characterize the flowing has in the pipeline.

Table 6: Fluid Properties (source: Pipeline Integrity Manual, 2005)

Property	Value
Fluid transported	Dry Gas methane
Average measured inlet pressure	71 bars
Average measured out let pressure	63 bars
Gas flow rate, Average	892MMSCFD
Specific Gravity	0.6
Gas Viscosity	0.0141cp
Gas base temperature	25ºC/536.6ºR
Gas flowing temperature	32ºC/549.27ºR
Compressibility factor	0.82

2.4 Methods

The various pressure and flow rate data from Table 5 were inserted into the LMNO Engineering Compressible gas flow software and a series of pressure output data were generated. The software provides the possibility of using the 3 model equations in which all analysis in this research is based on, Weymouth equation, Panhandle A and Panhandle B equations. One model equation is used per time to generate a set of pressure output values when the field measured values from Table 5 were inserted. The proper unit that govern the equation was selected

Three Pressure Output values, P_2, were generated using the three model equations individually. These P_2 data generated were compared to the measured field Pressure output data with the help of MS Excel.

Input parameters: Gas specific gravity, Gas compressibility, Pipeline efficiency factor, Gas flowing temperature, Pipe internal diameter, Gas flow rate, Input pressure

2.4.1 Varying Pipe Properties

Further analysis was carried out to determine the effect of any change in the pipeline properties on the pressure drop and pressure output value. At a constant input pressure and flow rate, the pipe length and pipe internal diameter was varied in 7 steps and a corresponding pressure drop patterns were generated. These calculations were carried out using the 3 specified model equations that were used in designing the software

2.4.2 Varying Gas Properties

Another analysis was carried out by varying the temperature of the flowing gas to see its effect on the outlet pressure and pressure drop values, keeping the initial input pressure and gas flowrate constant. Results were generated using the Weymouth, Panhandle A and Panhandle E equations.

Subsection

3.0 RESULT AND DISCUSSION

3.1 Comparing Pressure & Flowrate Values

Figure 3 below shows an analysis of the different pressure outputs calculated using the selected flow models.

While all the pressure profiles show the same change pattern, the pressure profile from the Weymouth equation shows closeness to the field measured pressure output in week 27 and a higher deviation in week 21 and 30. Panhandle A pressure profile shows greater deviation from the field value, especially at week 27. The below pressure profiles show that the Panhandle B equation is best suitable for describing the Rumuji to Bonny Pipeline. It showed closeness to the field value in week 21 and week 30.

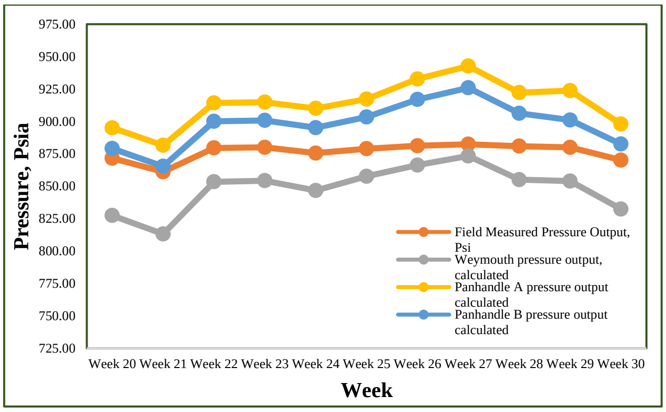

Figure 3: Measured vs Calculated Pressure Output/Week

In figure 4, it is observed that the Flowrate signature calculated from Panhandle B equation shows closeness to the field measured flowrate, intersecting at week 7 and week 9 respectively. The flow rate calculated from the Weymouth equation showed the largest variation from the field measured flow rate, hence the Weymouth equation cannot be best used to describe the Rumuji to Bonny 36" Pipeline. The Panhandle B equation offers best description to the pipeline under review.

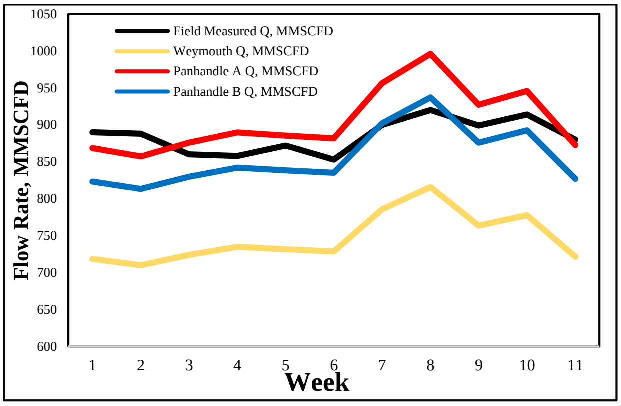

Figure 5: Measured Pressure Output Vs Calculated Pressure Output Per Week

3.2 Varying Temperature using Weymouth and Panhandle A and Panhandle B analysis

Figure 6,7 & 8 is a relationship between the Pressure output, Pressure drop and Gas flow temperature. Varying the flow line temperature by 5^oR in 7 steps and keeping the following constant (Q = 890MMSCFD, P_1 = 1025.4psi, Z = 0.82, E = 0.9, L = 52.2mile, d = 34.9", G = 0.6). It was observed that Pressure drop increased with increasing temperature. Conceptually, Increasing the temperature of gas results in increase in gas viscosity leading to high resistance to flow and hence higher pressure drop

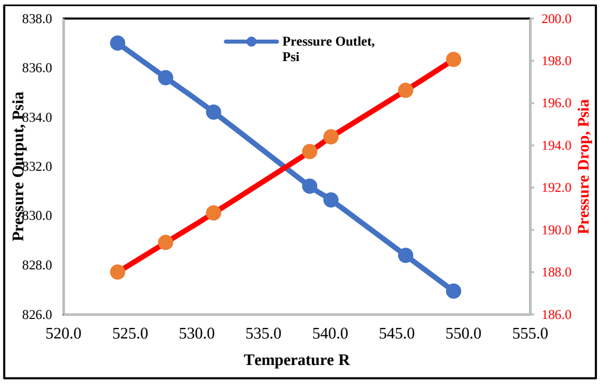

Figure 6: Varying Temperature (Weymouth Analysis)

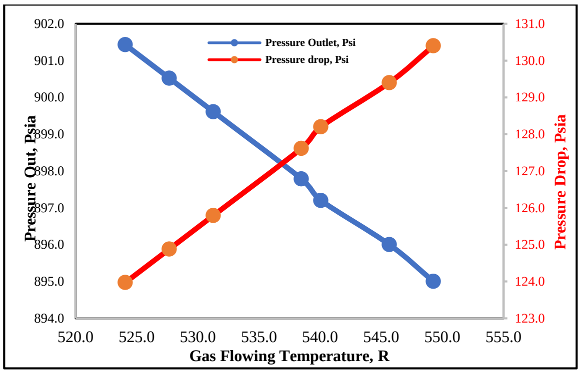

Figure 7: Varying Temperature (Panhandle A Analysis)

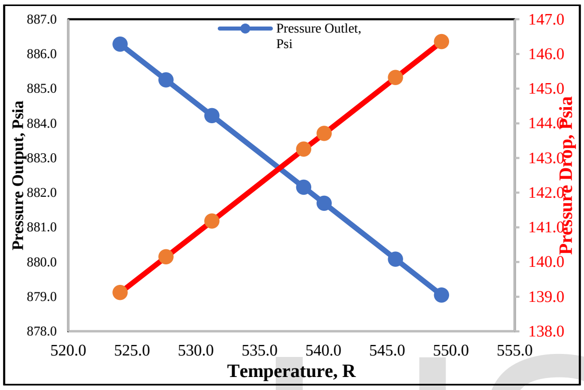

Figure 8: Varying Temperature (Weymouth Analysis)

3.3 Varying Internal Diameter using Weymouth and Panhandle A and Panhandle B analysis

Figure 9,10 & 11 are graph that show variation of the pipe internal diameter and pressure drop in the pipeline. It is observed that as pipe ID increased, keeping the following constant (Q = 890MMSCFD, P_1 = 1025.4psi, Z = 0.82, E = 0.9, L = 52.2mile, T = 549.25°R, G = 0.6), the pressure-drop decreased. This is because of less collision between the gas molecules themselves and with the walls of the pipe, less friction and eventually decreasing $P_1 - P_2$

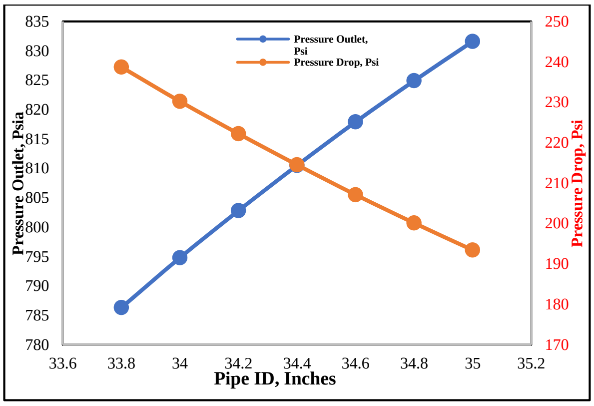

Figure 9: Varying Pipe ID (Weymouth Analysis)

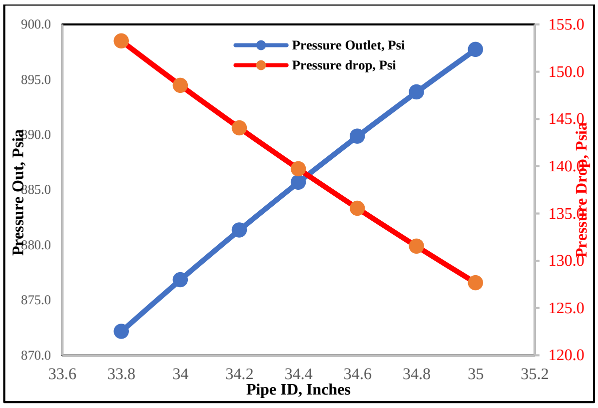

Figure 10: Varying Pipe ID (Panhandle A Analysis)

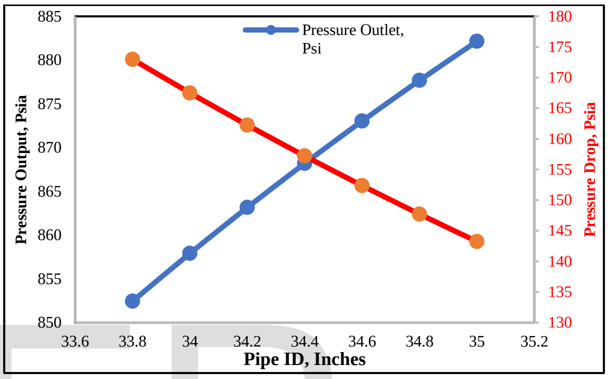

Figure 11: Varying Pipe ID (Panhandle B Analysis)

3.4 Varying Length using Weymouth and Panhandle A and Panhandle B analysis

Figure 12, 13 & 14 are plots of pressure drop and pressure outlet vs varying pipe length. Attempt was made to increase the Pipeline length (keeping the following constant, Q = 890MMSCFD, P_1 = 1025.4psi, Z = 0.82, E = 0.9, d = 34.86", T = 549.25°R, G = 0.6), to see its impact on pressure drop. Increasing the pipeline length results in larger gas volume, lesser collision between gas molecules with the pipe wall and with the gas molecules themselves, hence outlet pressure becomes far less than initial pressure. This eventually leads to higher pressure drop.

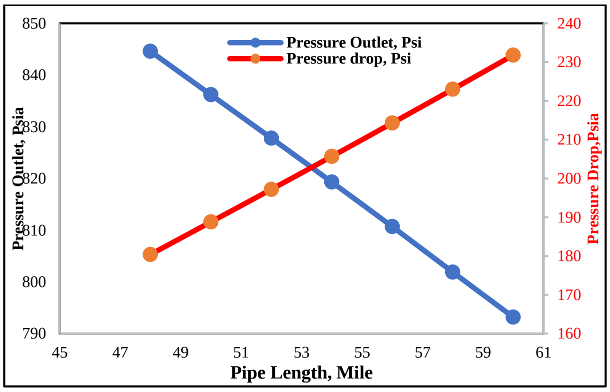

Figure 12: Varying Pipe Length (Weymouth Analysis)

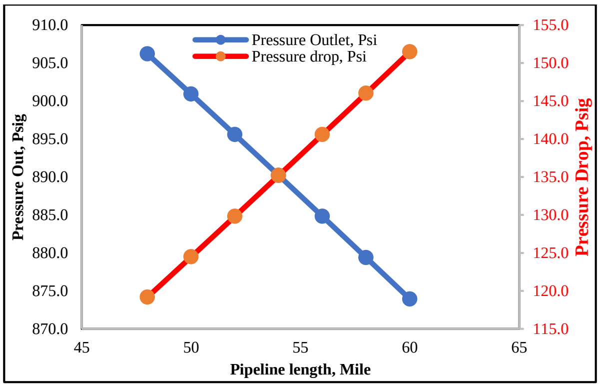

Figure 13: Varying Pipe Length (Panhandle A Analysis)

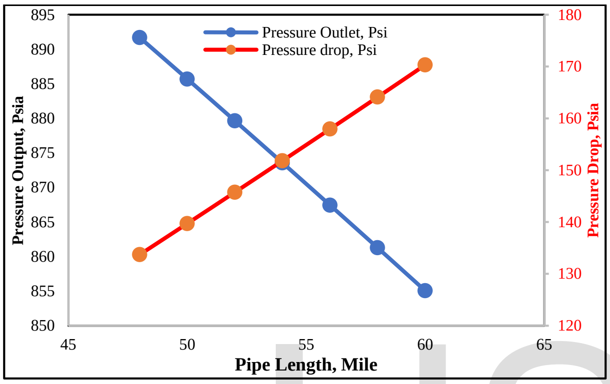

Figure 14: Varying Pipe Length (Panhandle B Analysis)

4.0 CONCLUSION

Following the extensive analysis carried out in this research, the following conclusion has been drawn:

- The Weymouth, Panhandle A and Panhandle B equations were used to establish a pressure model used to monitor pressure drop behavior in the Rumuji to Bonny pipeline
- The LMNO Engineering Software for compressible gas flow is an excellent tool for predicting pressure drop in long distance gas pipeline. The various cause of pressure drop in gas pipeline are a list of the following: length, Roughness of the pipe, size of Pipe, initial transport pressure, flow line temperature, Specific gravity of the gas, etc.
- The Panhandle B equation is best suitable for characterizing flow and pressure drop in the Rumuji to Bonny Gas pipeline
- There are major similarities between the measured field pressure output data and the calculated pressure output data using the model equations discussed in this research
- The following ways to minimize pressure drop as discovered in this research is as follows
  - Ensure to transport natural gas at reduced flow line temperature
  - Consider installing a compressor if gas is required to be transported through very long distance. The longer the pipeline, the greater the pressure drop
  - For very large diameter pipes, initial transport pressure must be very large, pressure drop increases with decreasing pipe diameter
  - Heavier gases will tend to produce higher pressure drop,
  - Pressure drop is high at bends and valves.

5.0 Recommendation

To effectively estimate, reduce pressure drop and optimize pipeline delivery, it is essential to follow these recommendations:

- Ensure that heavier particles that can precipitate and cause friction are removed during the gas processing stage before transmitting through long distance pipeline
- A compressor may be required if pressure drop expected is greater than 20% of the initial pressure required to transport
- Burying gas pipeline is of great importance as it helps to keep the flow line temperature low hence reducing gas viscosity and pressure drop
- Ensure that the internal of the pipe is coated to provide a smooth travel surface hence reducing relative roughness of the pipe
- Higher elevations will cause higher pressure drop, it is recommended to avoid elevations if possible

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