Natural Gas Pipeline Network Modeling Using PIPSYS Program

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Abstract

Natural gas is considered one of the most important sources of energy currently available in the world, and Some difficulties face the process of transporting gas through pipelines, including terrain and stages that occur during the transportation process, and this study was based on simulating the transfer of the produced gas from three wells that were linked Together with a steel pipe network of different lengths and diameters from 3 to 6 inches and a total length of about 3274 meters

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connected to the main transportation pipeline with a diameter of 6 inches and by observing the change in heat loss caused by the piping network. It was shown a decrease in the amount of heat lost from the pipes as a result of wrapping these pipes with a layer of Asphalt with a thickness of one millimeter to avoid the occurrence of corrosion of the outer surface and to prevent the formation of hydrates, and with the continued flow of gas in the steady-state through the network. It was shown through the results obtained from the PIPSYS program. The flow pattern was an annular mist of all pipes. The final pressure of the last production line was also calculated after adjusting the operating pressure of well A with the pressure of the last production line until it reached the desired values of 6895 kpa, 34.61°C and a flow rate of 1300 kg mol per hour, as well as a decrease in the maximum head pressure drop this part, was -9.6 kpa And, by making some adjustments to the fluid package, i.e. by testing three models of state equations in the gas phase and all results were close, as well as calculating the phase diagram of pressure, temperature, and the ability to form hydrates in the outlet conditions of the last part of the network.

***Keywords**: pressure drop, phase diagram, pipeline, gas transportation*

1. Introduction

Pipeline transportation has long been accustomed to deliver gas to markets. However, the activity of natural gas to markets through pipelines is often related to technical, economic, and even political constraints. Pipelines are terribly convenient, however not versatile suggests that of transportation because the gas leaves the supply and reaches its destination. Once the system has to be decommissioned, the assembly and receiving facilities and also the piping system typically need to be removed because the gas process can't be simply saved, except probably by increasing the piping pressured by many percentages (Granmore 2000). Natural gas is often found in places wherever there's no native market, parenthetically in several offshore fields around the world. For natural gas to be commercially available, it has to be collected, processed, and transported. Very often, the collected natural gas (raw gas) must be transported over a substantial distance in pipelines of various sizes, since process on-site, particularly for offshore fields, is to be reduced. The length of those pipes varies between facilities, from the many feet to the hundreds of miles, through a mountainous piece of land with completely different temperature conditions. Liquid condensation in pipelines generally happens because of the multi-component nature of the natural gas being transferred and its past behavior, which is related to the inevitable changes in temperature and pressure that occur on the pipeline. The raw pipe is subjected to a multi-phase transport, gas condensate-water flow through condensation (2021). A pipeline should transport fluids over a varied topography and under numerous conditions. Ideally, this may be done effectively with an appropriately sized tube that adequately explains pressure drop, heat loss, and includes line installations of adequate size and specification, similar to compressors, heaters, or accessories. Because of the quality of the pipe network calculations, this is more often than not a troublesome errand. It isn't exceptional for a huge pipe to be chosen amid the planning stage to compensate for mistakes in weight misfortune calculations. With a multiphase stream, this may lead to expanded weight and temperature misfortunes expanded fluid taking care of prerequisites and expanded pipeline erosion. Exact liquid modeling dodges these and other complications and comes about in a more conservative channeling framework. To realize this, you would like single-phase and single-phase stream innovation competent of accurately and productively mimicking pipe stream. PIPESYS has broad capabilities to precisely and effectively demonstrate pipeline power through pressure. It employments the foremost solid single-phase and multi-phase stream innovation accessible to recreate pipe stream. Working as a straightforward expansion of HYSYS, PIPESYS has got to HYSYS functionalities, such as the component database and liquid properties. PIPESYS contains numerous online gadgets and establishment choices that are important to the development and testing of pipelines. The expansion models channels that span different heights and situations (2021). For coastal and seaward gas, a pipeline is a suitable alternative for transporting normal gas to the advertising. In any case, like transport separations, pipelines got to be unrewarding, where expansive distance across and creased pipelines include exceptionally tall capital speculation. Long-distance requires both huge, high-value markets and demonstrated considerable saves to be financially reasonable. Pipeline innovation has progressed essentially inside the past twenty a long time; in any case, overcoming challenges of pipe estimate, separate, and most extreme water profundities that in lower gas- transportation costs (Granmore 2000). Within the industry supply chain, the operation of a pipeline is a fundamental portion of the transport between the “upstream ends” that goes before it and the dispersion or “downstream end” that takes after. Pipeline operations have moved from standardizing (i.e. characterized by obligatory prerequisites) to their current position, performance-based, and guided by chance administration standards. These patterns stem from competitive strengths that decrease working costs; they have moreover advanced much appreciated to the encounter procured over a few decades of pipeline operations as well as innovations and applications created on the street. These improvements have given pipeline administrators the devices they got to survive in these conditions. Pipeline offices have developed to the point where numerous of them have surpassed their unique life anticipation. Approximately 25 a long time at the time of ideation. Nowadays, most of these establishments proceed to function, mostly for financial reasons, since they are as well costly to supplant conjointly incompletely since these establishments stay commendable of ceaseless utilize (i.e. that they are still considered secure). Recognizing this, working companies proceed to extricate esteem from these offices, but beneath examination and expanded mindfulness of their presence and their vulnerabilities. Current pipeline operations have taken on a modern measurement of execution. Whereas fundamental exercises proceed, such as mechanical operations and upkeep of offices, counting pipelines, valves, valve actuators, etc., erosion anticipation and control, pipeline checking, and the accentuation on security, we presently consider esteem for cash. Continuously accomplish security, unwavering quality, and effectiveness. These challenges ended up more overwhelming as these channeling frameworks have created and combined, frequently securing frameworks construct by others agreeing to the uncommon plan, generation, and working rationalities. Moreover, the reorganization and fatigue of staff have seen much of the company's information and data documented or disposed of. A few companies have remained autonomous, whereas numerous have ended up a portion of a bigger corporate substance. On the way to overcome these advancements, pipeline administrators are presently successful to standardize their measures and compare their execution against industry benchmarks to assess their execution and recognize ranges for development. The advancement of other foundations at or close the pipeline right-of-way has driven an increment in third-party occurrences and calls to adjacent areas. Pipeline controllers too advanced amid this time and expanded their mindfulness of the industry, but permitted them to define their office administration programs. Industry-sponsored investigation programs have been made to superior get the impacts of pipeline occurrences on hazard evaluation (Mokhatab 2005). This work guides us through the construction of a gas condensate pipe made up of four pipe units. A fluid system with a hypothetical component is employed in an exceeding pressure drop calculation for a predetermined flow through the pipeline. All units for this job are SI units. In this study, we discuss the problem of thermal loss of network components due to the low temperature of the surrounding atmosphere. This is considered to be one of the most important problems facing the process of transporting natural gas through pipes, which has caused the formation of hydrates. Heat loss and corrosion reduction, pressure differences were also calculated during the network for different models of equations of state in the gas phase, which is considered to be one of the important factors in operations transport. Use the program to set all the pressure in the network and obtain the required operating values.

2. Materials and Methods

In this application, PIPESYS Version7.3 from Aspen Technology, Inc. and it's an extension of Aspen HYSYS 3.1 software the performance style of the little gas condensation assembly system was designed The steps and method of the solution that were performed in the program are shown previously (2021). The subsequent figure shows the physical composition of this technique on a topographical map. The system consists of 3 wells cover a section of roughly one square mile connected to a gas plant through a network of pipelines.

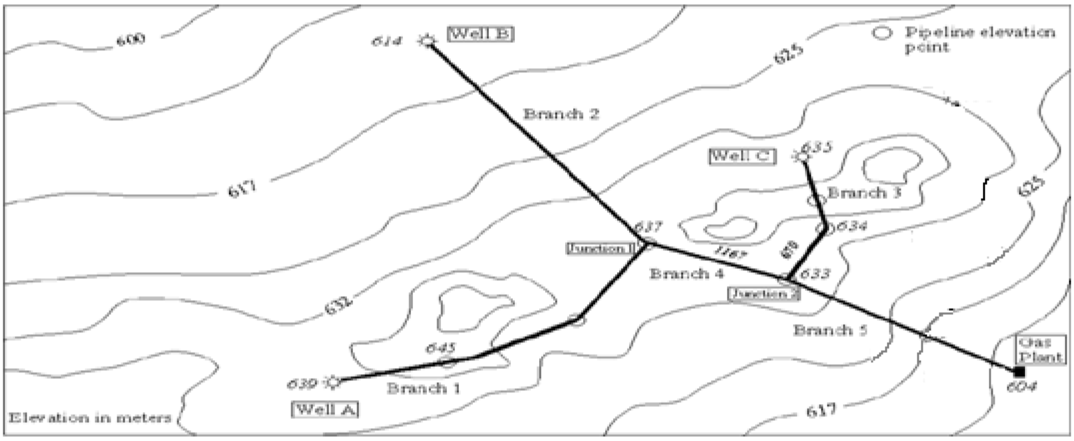

Figure 1. Field data show that wells provide the following rates

The three wells have the same composition. The residue of all heavier components of the condensate has a molecular weight of 122 and a density of 760 kg / m^3. The properties of this component are taken into account using the hypothetical installation of the component in HYSYS. The analysis of the composition of the gas condensate produced the following information in Table 1(Fanaei, 2010):

Table 1: Analysis of the composition of the gas			
Component	**Mole fraction**	**Component**	**Mole fraction**
Methane	0.62300	n-Pentane	0.00405
Ethane	0.28000	n-Hexane	0.00659
Propane	0.01630	C_{7+}	0.00992
i-Butane	0.00433	Nitrogen	0.00554
n-Butane	0.00821	Carbon Dioxide	0.02250
i-Pentane	0.00416	Hydrogen Sulfide	0.01540

Type 40 steel tubing is used everywhere and all branches are buried 0.914 meter deep. Not all pipes are insulated. The consequent table summarizes the peak knowledge for all branches. The peak provided for the tube units corresponds to the pipe termination (i.e. downstream end). The peak and diameters of the tube and also the length of every branch are shown in Table 2 (Fanaei, 2010):

Table 2: Diameters, Length and, Elevation of the pipes

Branch	**Unit**	**Rate (m^3/Day)**	**Diameter (m)**	**Length (m)**	**Elevation (m)**
Branch 1	Well A	27.92	N/A	N/A	639
	Pipe Unit 1		0.0762	288	643
	Pipe Unit 2			338	637
	Pipe Unit 3			322	637
Branch 2	Well B	24.03	N/A	N/A	614
	Pipe Unit 1		0.0762	860	637
Branch 3	Well C	32.79	N/A	N/A	636
	Pipe Unit 1		0.0762	161	617
	Pipe Unit 2			102	634
	Pipe Unit 3			204	633
Branch 4	Pipe Unit 1	51.95	0.1016	356	633
Branch 5	Pipe Unit 1	84.74	0.1524	643	604

The branches showing the uneven landscape are partitioned into a few areas with height focuses characterized for the focuses where the slant changes fundamentally.

These situations in the exhibit are set apart in the schematic bar outline with the stature esteem. For each branch, the rise and distance data acquired from the geological guide is shown. With this information, it is conceivable to mimic the presentation of a specific framework utilizing the PIPESYS augmentation, at that point figure significant boundaries, for example, pressure drops, temperature changes, and the measure of liquid maintenance. . Notwithstanding determining stream frameworks. In this work, the pace of each borehole is determined and is autonomous of the pace of some other borehole. In such cases, the framework can be displayed with a solitary assurance of the pressing factor drop per branch.

Simultaneously, temperature and pressing factor figurings can be made if the temperature of each well is known. As the pressing factors are constant all through the organization, pressing factor must be given in one spot. For instance, the pressing factor can be changed at each borehole or at the last conveyance point and PIPESYS will figure the pressing factor somewhere else. A pressing factor of 7308 kPa is indicated for opening A. PIPESYS at that point decides the pressing factors in different pieces of the framework that meet this detail. In the event that conceivable, heat move figurings ought to be made toward stream. The temperatures of the wellheads are likewise known. For this work, the temperatures of the liquids in Welles A, B, and C are referred to and should be entered as indicated conditions.

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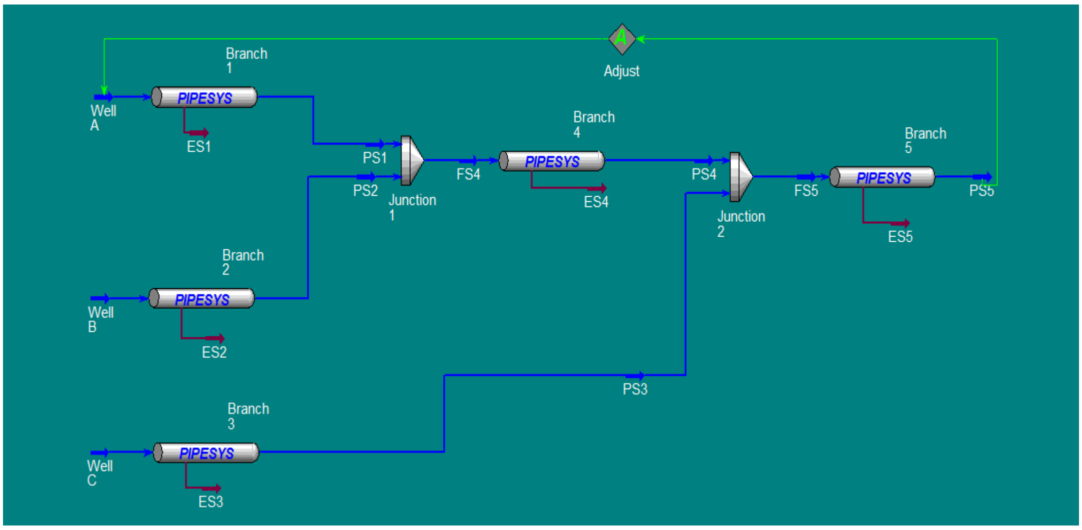

Figure 2. Schematic Process Flow Diagram for the pipeline system

Then, PIPESYS performs iterative calculations of the pipeline in all the branches so that the starting place has an identified temperature and pressure.

3. Theory and Calculation

Process simulation programs are useful for simulating such processes since various vapor / liquid balance models are available in the programs. At Aspen HYSYS, the SRK (Soave, 1972), PR (Peng and Robinson, 1976) and TST (Twu, Tassone, Sim and Watanasiri, 2005) equilibrium models are available for systems containing methane, carbon dioxide, and water. In SRK-Twu and PR-Twu models, the original α function is replaced by a function of (Twu, Bluck, Cunningham and Coon, 1991). The PR model contains only one adjustable parameter for each pair of binary components, while the TST contains 5 adjustable parameters for each binary pair. SRK with HV is available in Aspen Plus, but this model is not available in Aspen HYSYS.

The SRK equations of state are shown in equations 1 to 8.

$$P = \frac{RT}{(V-b)} - \frac{a}{V(V+b)} \quad (1)$$

$$b = \sum_{i=1}^{N} x_i\, b_i \quad (2)$$

$$b_i = \frac{0.08664 R T_c}{P_c} \quad (3)$$

$$a = \sum_{i=1}^{N} \sum_{j=1}^{N} x_i x_j \left(a_i a_j\right)^{0.5} \left(1 - k_{ij}\right) \quad (4)$$

$$a_i = a_{ci}\alpha_i \quad (5)$$

$$a_{ci} = \frac{0.42748 R^2 T_c^2}{P_c} \quad (6)$$

$$\alpha_i = [1 + m_i(1 - T_r^{0.5})]^2 \quad (7)$$

$$m_i = 0.48 + 1.574\omega_i - 0.176\omega_i^2 \qquad (8)$$

T, P, v, and R are the temperature, pressure, molar volume, and universal gas constant, respectively.

The properties of the vapor phase are calculated by the Peng-Robinson equation of state. The Peng-Robinson equation of state (PR) could be a modification of the Redlich-Kwong equation of state and was published in 1976 by Peng and Robinson. Only the critical data of pure substances are a prerequisite for application due to the plain pattern and the generalized parameters for the PR equation. Moreover, analytical solutions could be observed mathematically, which makes the PR equation widely applied in engineering. The expression is as follows (SMITH, 2005):

$$P = \frac{RT}{(V-b)} - \frac{\theta_{PR}}{V^2+2bV-b^2} \qquad (9)$$

$$\theta_{PR} = a''[1 + (0.37464 + 1.54226\omega - 0.26992\omega^2)(1 - T_r^{0.5})]^2 \qquad (10)$$

$$a'' = \frac{0.45724R^2T_c^2}{P_c} \qquad (11)$$

$$b = \frac{0.07780RT_c}{P_c} \qquad (12)$$

Pipeline networks have been designed in recent years, using a simple formula such as Weymouth and Panhandle (KUMAR, 1987), (MOHITPOUR, 2003), but in recent years technical programs such as

PIPEPHASE (SIMULATION SCIENCES INC., 1988), PIPESYS (Fanaei, 2010) and HYSYS (ABD. HAMID, 2013) have increased. In general, to predict flow rate, pressure, and temperature change of gas along pipelines, three equations of mass, momentum, and energy balances must be solved simultaneously (Osiadacz and Chaczykowski, 2001). These equations for the pipeline at an angle θ from the horizontal are as follows:

Mass Balance Equation

$$\frac{\partial \rho}{\partial t} + \frac{\partial (\rho u)}{\partial x} = 0 \qquad (13)$$

Momentum balance equation

$$\frac{\partial (\rho u)}{\partial t} + \frac{\partial (\rho u^2 + P)}{\partial x} = -\rho\, g\, sin\theta - 2\frac{f\rho u|u|}{D} \qquad (14)$$

Energy balance equation

$$q\rho A dx = \frac{\partial}{\partial t}\left[(\rho A dx)\left(C_v T + \frac{u^2}{2} gz\right)\right] + \frac{\partial}{\partial x}\left[(\rho A u dx)\left(C_v T + \frac{u^2}{2} gz + \frac{P}{\rho}\right)\right] \qquad (15)$$

Where:

$$\rho = \frac{P}{ZRT} \qquad (16)$$

4. Results and Discussion

Table 3 shows the results of the mass and energy balancing values for all network lines and streams shown in Figure 2 in SI units at Adjusted operating pressure and Normal operating pressure. This is evident in the pressure change of well A before and after the adjustment process of the network pressure operating system, and this is positive for the stability of the flow rate and the rate of production of the well.

Table 3:Summary of results of the mass and energy balancing values for all network lines

The mass and energy balancing values for all network lines at Adjusted operating pressure					
Name of Stream	FS5	FS4	PS5	PS4	PS3
Vapor Fraction	0.9615	0.9605	0.9599	0.9590	0.9652
Temperature °C	36.0074	35.5587	34.4855	33.8626	39.4509
Pressure (Kpa)	6952.8075	7092.6068	6894.7594	6952.8075	6952.8075
Molar Flow (kgmole/hr)	1299.9648	796.9133	1299.9648	796.9133	503.0515
Mass Flow (kg/h)	31072.6018	19048.3383	31072.6018	19048.3383	12024.2635
Liquid Volume Flow (m^3/h)	84.7473	51.9524	84.7473	51.9524	32.7949
Heat Flow (KJ/h)	-116845765.55	-71695062.47	-116963817.30	-71755084.17	-45090681.3820
Name of Stream	PS2	PS1	Well C	Well B	Well A
Vapor Fraction	0.9634	0.9579	0.9683	0.9705	0.9650
Temperature °C	38.1178	33.3829	43.3333	46.1111	40.5556
Pressure (Kpa)	7092.6068	7092.6068	7256.3459	7428.7954	7536.1465
Molar Flow (kgmole/hr)	368.5724	428.3409	503.0515	368.5724	428.3409
Mass Flow (kg/h)	8809.8565	10238.4818	12024.2635	8809.8565	10238.4818
Liquid Volume Flow (m^3/h)	24.0280	27.9244	32.7949	24.0280	27.9244
Heat Flow (KJ/h)	-33089910.57	-38605151.90	-45001354.69	-32918410.29	-38443840.4473
The mass and energy balancing values for all network lines at Normal operating pressure					
Name of Stream	FS5	FS4	PS5	PS4	PS3
Vapor Fraction	0.9622	0.9612	0.9607	0.9597	0.9658
Temperature °C	35.8533	35.4186	34.2966	33.6765	39.3472
Pressure (Kpa)	6702.7545	6848.4338	6639.9763	6702.7545	6702.7545
Molar Flow (kgmole/hr)	1299.9648	796.9133	1299.9648	796.9133	503.0515
Mass Flow (kg/h)	31072.6018	19048.3383	31072.6018	19048.3383	12024.2635
Liquid Volume Flow (m^3/h)	84.7473	51.9524	84.7473	51.9524	32.7949
Heat Flow (KJ/h)	-116745593.00	-71634433.42	-116862953.09	-71694128.69	-45051464.31
Name of Stream	PS2	PS1	Well C	Well B	Well A
Vapor Fraction	0.9640	0.9586	0.9688	0.9709	0.9655
Temperature °C	37.9918	33.2302	43.3333	46.1111	40.5556
Pressure (Kpa)	6848.4338	6848.4338	7018.9756	7195.1674	7308.4446
Molar Flow (kgmole/hr)	368.5724	428.3409	503.0515	368.5724	428.3409
Mass Flow (kg/h)	8809.8565	10238.4818	12024.2635	8809.8565	10238.4818
Liquid Volume Flow (m^3/h)	24.0280	27.9244	32.7949	24.0280	27.9244
Heat Flow (KJ/h)	-33062231.11	-38572202.31	-44962268.27	-32891020.79	-38411271.32

Figures 3 and 4 shows the change in temperature and pressure on the arrangement through the fifth branch of the pipeline network. This was calculated using three models of state equations, namely Soave-Redlich-Kwong equation of state; (SRK), Peng-Robinson; (PR), Peng-Robinson-Stryjek-Vera; (PRSV). By observing the curves of the obtained results, they were close, and the Peng Robinson equation was adopted in calculating the rest of the results in this work because it is more appropriate and from Figure 4 it was found that the largest value of the pressure drop was in the middle of the branch approximately due to the influencing flow factors.

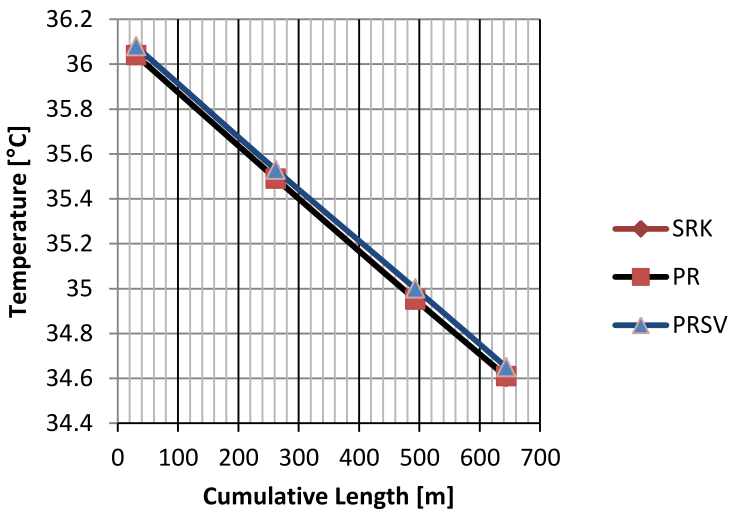

Figure 3.Temperature change during the Branch 5 of the pipe network

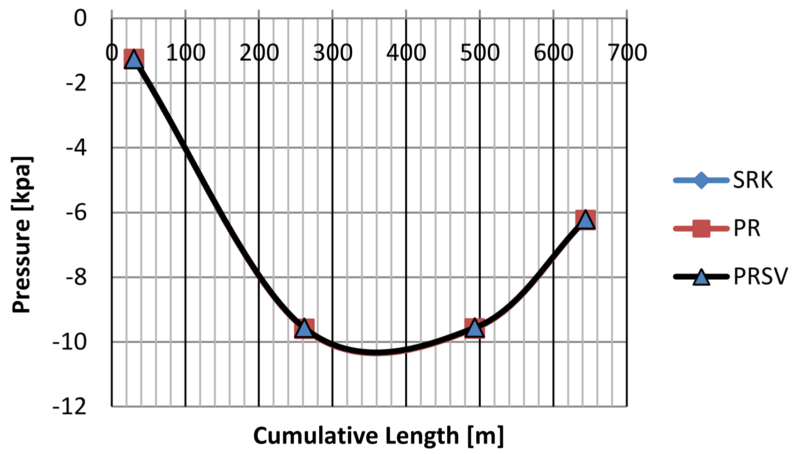

Figure 4. Pressure change during the Branch 5 of the pipe network

Figure 5 is the phase diagram of Branch 5 of the piping network, and through the calculations using the PIPSYS program, the critical point (P, T) was (9908.14, -14.1) and the conditions for hydrate formation were between the two points (429, -9.11), and (12835, 22.25) but this was avoided. The problem is at the final exit stream (PS5), and therefore hydrates are not formed at these operating conditions.

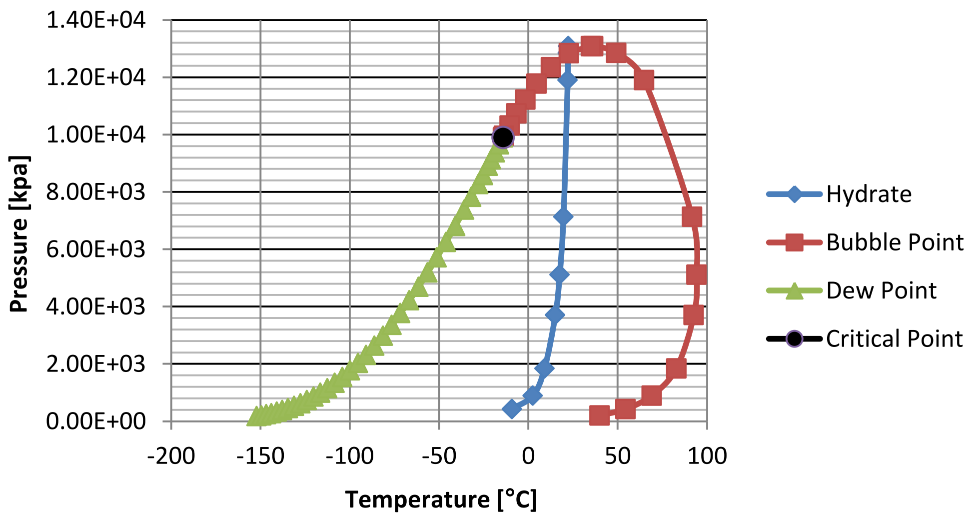

Figure 5. Hydrate formation condition and Phase diagram

Figure 6showing the thermal loss of each part of the pipelines in the case of thermal insulation with a layer of asphalt with a thickness of one mm and without insulation, as it was found that the largest event occurred in the second part and this is due to the large length of this part compared to the rest of the parts in the network**.**

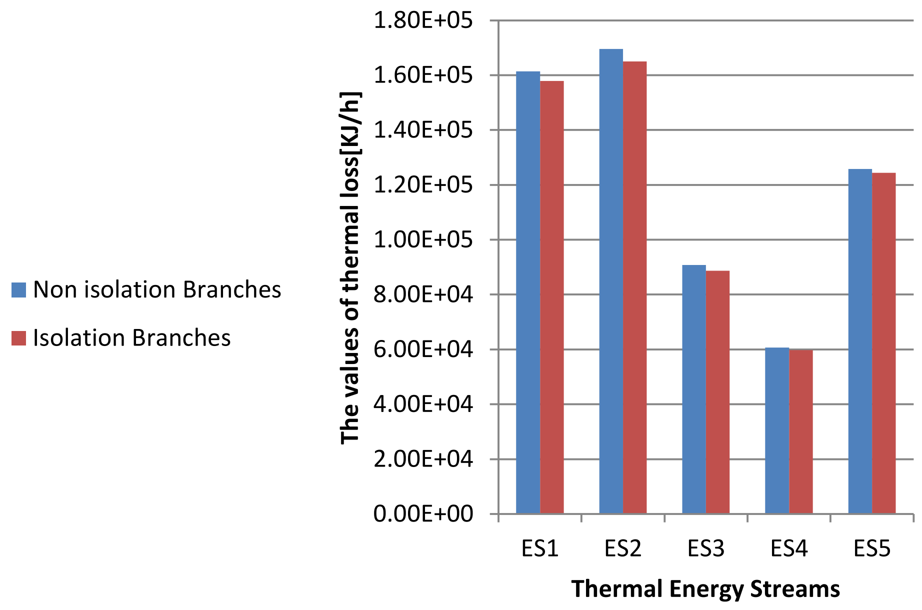

Figure 6.Thermal loss in network branches

Figure 7 shows the operating pressure of the three wells and Branch 5 in the case of normal operation and adjusted operation where there is a clear difference between the two cases and it is preferable to operate the network over the adjusted mode because of its more advantages.

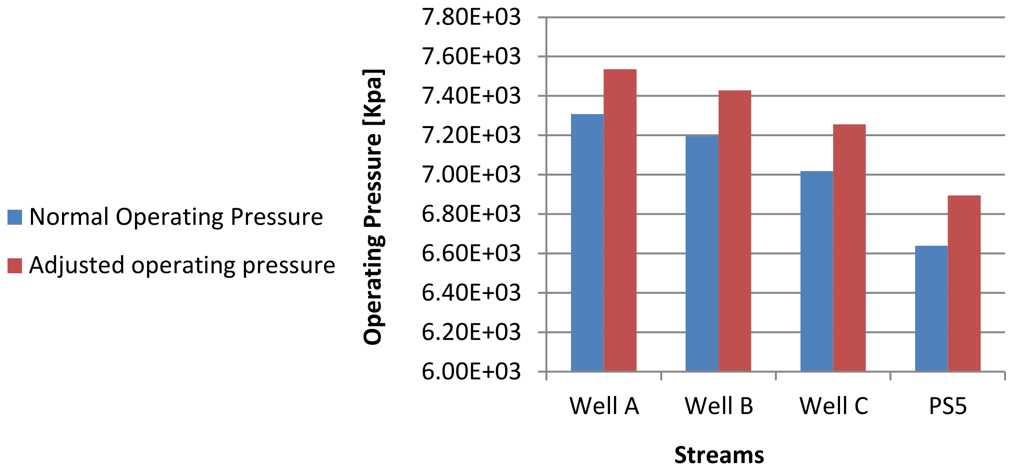

Figure 7. Normal and Adjusted pressure of three wells last stream

5. Conclusions

In this paper, the transportation of natural gas from three production wells through a network of steel pipelines over rough terrain was simulated using PIPSYS program with different diameters ranging from 3 to 6 inches and a total length of about 3274 meters for the purpose of power supply operations. The transmission process was tested under stable transport conditions, studying some important factors, like temperature, pressure, and pressure drop that affects gas flow from wells through the network over the length of flow using different models of state equations to calculate the maximum pressure difference in the fifth and last branch and the conditions of hydrate formation and the critical point. All results were close as the best-operating conditions for the network were determined from pressure and temperature. The thermal loss of all branches of the network was also studied, and the results were mixed for all branches. This work can be developed to study all variables of the gas flow in an unstable state with the same operating conditions of the network.

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