مجلة روافد المعرفة

تصدر عن كلية العلوم
جامعة الزيتونة

الرقم الدولي الموحد

ISSN: 2709-0345

ISSN : 2709-0345
Linking ISSN (ISSN-L): 2709-0345
Key-title: Rawāfid al-ma'rifat
Key-title in original characters: روافد المعرفة

العدد العاشر

12 - 2024

ترسل البحوث وجميع المراسلات المتعلقة بالمجلة إلى العنوان التالي:

كلية العلـــوم – جامعــة الزيتونــة – ترهـــونة

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الكلمة الافتتاحية،،

السلام عليكم ورحمة الله وبركاته،،

عليه نتوكل، وبه نستعين، نحمده سبحانه على كل عمل.

أعزائي القراء والمهتمين بالمعرفة والعلم،

بحمد الله وتوفيقه تم صدور العدد العاشر من مجلة "روافد المعرفة"، الصادرة عن كلية العلوم بجامعة الزيتونة. إن هذا الإصدار الذي نقدمه لكم يعكس التفاني والتميز الذي يتميز به فريق العمل والباحثين الذين ساهموا في إثراء هذا العدد بمقالاتهم وأبحاثهم الرائعة.

مجلة "روافد المعرفة" تعد نافذةً مهمة لنشر العلم والبحث العلمي، وهي تسعى جاهدة لتعزيز التواصل العلمي وتبادل المعرفة بين الباحثين والمهتمين بالمجالات العلمية المختلفة. إن تنوع المواضيع المطروحة في هذا العدد يعكس الاهتمام الكبير بمجالات العلوم الطبيعية والتطبيقية، ويعزز الوعي والفهم العلمي للقراء.

في هذا العدد العاشر، ستجدون مقالات متنوعة تتناول العديد من المواضيع المميزة والمفيدة في مجالات العلوم الطبيعية والتطبيقية. ولذلك، نحن واثقون من أن هذا العدد سيثري ثقافتكم ويوسّع آفاق المعرفة لديكم.

في ختام كلمتنا، أود أن نعرب عن امتناننا العميق للفريق الذي عمل بجد واجتهاد لجعل هذا العدد حقيقةً، وأشكر جميع الباحثين الذين شاركوا معنا معرفتهم وخبراتهم. وأتمنى أن يكون هذا العدد بمثابة نقطة انطلاق لمزيد من النجاح والتألق في المستقبل.

نتمنى لكم قراءة ممتعة ومفيدة، ونحن في انتظار ملاحظاتكم وآرائكم القيّمة.

شكراً لثقتكم ودعمكم المستمر.

دمتم بخير وعلم نافع.

هيئة التحرير

اشتراطات النشر في مجلة روافد المعرفة

1- أن يكون البحث أصيلاً ومبتكراً ولم يسبق نشره في أي جهة أخرى، وتتوفر فيه شروط البحث العلمي المعتمدة على الأصول العلمية والمنهجية المتعارف عليها في كتابة البحوث الاكاديمية.

-2- أن يكون البحث مكتوباً بلغة سليمة، ومراعياً لقواعد الضبط ودقة الرسوم والاشكال – إن وجدت و مطبوعاً بخط Microsoft Word (Simplified Arabic) ببنط (14) للغة العربية، وخط (Times New Roman) ببنط (12) للغة الإنجليزية، وألا تزيد صفحات البحث عن (35) صفحة متضمنة المراجع والملاحق (إن وجدت).

-3- يجب أن يشتمل البحث على العناصر التالية - عنوان البحث باللغتين العربية والإنجليزية - - ملخص تنفيذي باللغتين العربية والإنجليزية في نحو 100 - 125 كلمة والكلمات المفتاحية (keywords) بعد كل ملخص .

-4 يتم توثيق الهوامش وفق طريقة الجمعية الأمريكية السيكولوجية (APA) بإصدارتها المختلفة.

-5- يُفضل أن تكون الجداول والاشكال مدرجة في أماكنها الصحيحة، وأن تشمل العناوين والبيانات الإيضاحية الضرورية، ويراعى ألا تتجاوز أبعاد الاشكال والجداول حجم حيز الكتابة في صفحة.

-6- أن يكون البحث ملتزماً بدقة التوثيق، استخدام المصادر والمراجع، وأن تثبت مصادر ومراجع البحث في نهاية البحث.

7- تحتفظ المجلة بحقها في اخراج البحث وإبراز عناوينه بما يتناسب واسلوبها في النشر.

-8- - ترحب المجلة بنشر ما يصلها من ملخصات الرسائل الجامعية التي تمت مناقشتها وإجازتها على أن يكون الملخص من إعداد صاحب الرسالة نفسه.

9 - تُرسل نسخة من البحث مطبوعة على ورق بحجم (A4) إلى مقر المجلة، ونسخة إلكترونية إلى إيميل المجلة : wafedalmarefa@gmail.com او على رقم الواتساب 0921253199 على أن يدون على صفحة الغلاف اسم الباحث لقبه العلمي، مكان عمله، تخصصه، رقم هاتفه وبريده الإلكتروني.

10- يخطر الباحث بقرار صلاحية بحثه للنشر من عدمها خلال مدة شهرين من تاريخ استلام البحث.

11- في حالة ورود ملاحظات وتعديلات على البحث من المحكم ترسل تلك الملاحظات إلى الباحث لإجراء التعديلات اللازمة بموجبها على أن تعاد للمجلة خلال مدة أقصاها شهر واحد.

-12- الأبحاث التي لم تتم الموافقة على نشرها لا تعاد إلى الباحثين.

- 13- تؤول جميع حقوق النشر للمجلة.

ملاحظة.

البحوث المنشورة في هذه المجلة تعبر عن رأي أصحابها ولا تعبر بالضرورة عن رأي المجلة أو الكلية أو الجامعة.

المحتويات

Design of Natural Gas Transmitting Pipeline (A Case Study of a Typical Gas Transmitting Pipeline for Domestic Use in Libyan Benghazi City)

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الملخص

في هذه الايام تعتبر خطوط أنابيب الغاز الطبيعي هي من أكثر التقنيات تقدماً واستخداما في نقل الغاز الطبيعيً . تم تصميم انبوب لنقل الغاز الطبيعي لتزويد الغاز المنزلي في مدينة بنغازي. تم جمع البيانات الثانوية من خط غاز مباع وهي معدل تدفق الغاز والضغط ودرجة الحرارة وأجريت دراسة نظرية لتقدير طبيعة الغاز والخصائص الفيزيائية للغاز لاستخدامها في تصميم خط أنابيب الغاز. تم استخدام معادلات التصميم الهيدروليكي من أكواد ومواصفات الجمعية الامريكية للمهندسين الميكانيكيين ومعهد البترول الامريكي لتقدير بعض العوامل المستخدمة في التصميم. تم تقدير قطر الأنبوب، سماكة جدار الأنبوب، رقم الجدول الزمني، ضغط التشغيل الأقصى وضغط الانفجار وضغط الاختبار المائي للأنبوب وكانت قيمها على التوالي 12 بوصة، 0.157 بوصة، 10، 1133.85بي اس إي، 1968.5بي اس إي، 1417.3بي اس إي. لأغراض الدقة، يُقترح محاكاة خط الأنابيب المصمم ببرنامج حاسوبي مناسب لضمان تقارب جميع الثوابت المصممة التي تم الحصول عليها مع عملية المحاكاة.

الكلمات المفتاحية: خط انابيب، تصميم، غاز طبيعي، للاستخدام المنزلي.

Abstract

The research paper focuses on the design of a natural gas transmission pipeline for providing home gas in Benghazi city. The study utilizes advanced technologies in gas transmission, specifically natural gas pipelines. The research methodology involves the collection of secondary data on gas sales, which includes flow rate, pressure, and temperature. An empirical study is conducted to analyze the gas properties and calculate the physical characteristics necessary for pipeline design. To design the gas pipeline, hydraulic design formulas from recognized standards such as ASME B31.8 and API 5L are employed. These formulas are used to calculate various parameters critical to the design process, including pipe diameter, pipe wall thickness, schedule number, maximum operating pressure, burst pressure, and hydro test pressure. The calculated values for these parameters are determined as follows: pipe diameter of 12 inches, pipe wall thickness of 0.157 inches, schedule number of 10, maximum operating pressure of 1133.85 psi, burst pressure of 1968.5 psi, and hydro test pressure of 1417.3 psi. To ensure accuracy and precision, it is recommended to simulate the designed pipeline using appropriate software or programs. This simulation process will verify the convergence of all the designed parameters, confirming the feasibility and efficiency of the pipeline design. By employing simulation, any potential issues or discrepancies can be identified and addressed before the actual construction of the gas transmission pipeline.

Keywords: Pipeline, design, Natural Gas, Domestic.

1- Introduction

The efficient and effective transportation of natural gas, from its production site to the end consumers, necessitates a comprehensive and intricate transportation system. This system is closely linked to storage, as any excess natural gas that is not immediately required upon reaching the end of the pipeline or transportation system can be stored for later use. It can be released from storage facilities when there is a demand for it. It is important to note that the natural gas used by consumers differs significantly from the gas extracted from underground and brought to the wellhead [James, 2019].

Various options exist for the transportation of natural gas energy from oil and gas fields to the market [Guo Buoyan et al., 2005]. These options include Pipeline Natural Gas (PNG), Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), and Gas to Solid (GTS), such as hydrates. Among these options, pipeline transportation and LNG technology have emerged as the most significant and well-developed methods, while CNG and GTS technologies are still in the developmental stage [Correa, T., & Osorio, N, 2009].

Pipelines have emerged as a highly convenient method of transportation; however, they lack flexibility when it comes to delivering gas from a single source to a specific destination [Cranmore and Stanton, 2000]. Pipelines are essentially interconnected pipes that are fixed in place for the purpose of transmitting gases, liquids, slurries, and other substances from their points of origin to one or more distribution centers or large-volume customers. These pipes serve to establish connections between sources of supply and their intended destinations. Pipes, in this context, refer to tubes with a round cross-section that adhere to the dimensional requirements for nominal pipe size.

Over the past centuries, an average of more than 12,000 miles of newly constructed gas pipelines has been laid each year, with many of these pipelines crossing national borders. It is widely believed that if factors such as political stability and other variables can be ensured, pipelines can offer a sustainable long-term solution for natural gas transportation [Lyons W; 2011].

In the system approach to pipeline design, four interrelated aspects must be considered: hydraulic design, mechanical design, geotechnical design, and operations/maintenance design. These aspects collectively contribute to the overall design of the pipeline system.

The primary objective of pipeline design is to identify a suitable pipeline that can safely transport fluids from oil and gas fields to storage or utilization sites [Mike Y, 2010]. In order to ensure the safety of personnel and the general public, various codes and standards have been established to guide the design, construction, and operation of pipelines. These codes and standards aim to minimize the risks associated with high-pressure pipelines [Cult et al, 2008].

To design an appropriate gas pipeline, it is crucial to estimate the properties and compositions of the gas. Benghazi, the second largest city in Libya, is situated in the northeastern region of the country along the coast of the Gulf of Sidra, which borders the Mediterranean Sea. Currently, natural gas is not utilized for cooking and heating purposes in residential areas of Benghazi. Instead, liquefied petroleum gas (LPG), specifically propane or butane, is used as the primary gas supply within households. LPG is either purchased in cylinders or delivered in bulk through road tankers and stored in fixed cylinders located near the residences. The transport and storage of gas, even in small quantities, carry a significant risk of fire or explosion. However, replacing the current system of gas delivery through road transport and storage with a domestic natural gas pipeline system offers inherent advantages in terms of safety and ease of use [Cera/IHS, 2007].

Previous field studies conducted by Mahmoud Hassan et al. [2008] have demonstrated the feasibility of supplying natural gas for domestic use in the city of Benghazi. This can be achieved by designing a natural gas transmission pipeline that connects to the existing Brega-Benghazi pipeline, which passes near the city. The proposed design involves two feeding points and two lines with two tracks extending from the feeding points to two metering and pressure reduction stations (PMRS) numbered 1 and 2. Each station has a maximum gas flow rate of 60,000 m3/hr, as depicted in Figure 1. The first PMRS is located at the northeastern border of the city close to the electrical power plant, while the second PMRS is situated in the southern part of the city near the cement factory. It is anticipated that the gas capacity transferred by the proposed pipeline will be sufficient to meet the domestic gas consumption needs of approximately 100,000 customers [Mahmoud Hassan et al., 2008].

For the purpose of this study, the focus is on the gas line route from the feeding point to PMRS No. 2, as indicated by the red line in Figure 1. This specific segment will be used for the design steps of the proposed natural gas transmission pipeline. The design process involves collecting secondary data on a sales gas pipeline and conducting an empirical study to determine the gas's properties and physical characteristics, which will be utilized in the design of the gas transmission pipeline.

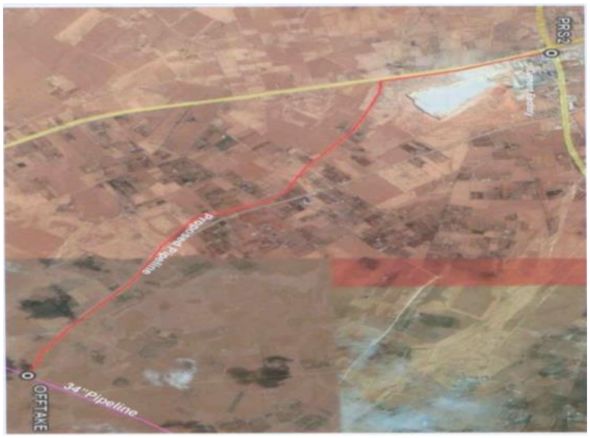

Figure (1) PRMS& Off Takes Locations for Benghazi City (Mahmoud H. et al., 2008)

2. Methodology

The gas data and other relevant information utilized in the design process of the gas pipeline were obtained from [GGTDC, 2023], as outlined in the following list. The subsequent sections provide a comprehensive description of the pipeline design procedure and the specific equations employed in each design step.

Table (1) Gas composition

No.	component	Mole Fraction (Y_i)	Molecular weight (M_i) g/mol
1	carbon dioxide	0.024	44
2	Nitrogen	0.058	28
3	methane	0.8368	16
4	Ethane	0.0883	30
5	propane	0.0271	44
6	I-Butane	0.0054	58
7	N-Butane	0.0066	58
8	I-Pentane	0.0026	70
9	N-Pentane	0.0019	72
10	Hexane +	0.0015	86

Gas sales pressure, temperature and flow rate:

The gas data which are pressure, temperature and gas capacity as gained from (GGTDC), also the distance between the feeding point and delivery point of the gas through pipeline as gained from (GGTDC) are as the following :

- Inlet pressure = 17 bar (246.56 psia)
- Minimum Outlet delivery pressure = 11 bar (159.54 psia)
- Inlet flowing temperature (T_f) = 70 F0
- Gas capacity = 53000 m3 / hr (44.92 MSCF/D)
- Base pressure and temperature (P_b = 14.7 psi , T_b = 60 F0)

Other needed data:

Distance between the feeding point and delivery point of the gas = 11 km = 36089.24 f_t = 6.8mile

The terrain is flat and accessible, so there is no effects for elevation on pipe pressure and the pipeline will be designed as horizontal pipe.

2.1. Calculation of Gas Properties

2.1.1 Determination of Apparent Molecular Weight

The molecular weight (M_a) of the gas can be estimated from the following Formula:

$$M_a = (Y_i x\ M_i) \qquad (1)$$

Where: Yi is the mole fraction of component I in gas mixture, Mi is the molecular weight of component i [E.shahi ,2016].

2.1.2 Determination of Gas Gravity (G)

The gas gravity (G) can be calculated from the following formula:

$$G = \frac{M_a}{M_{air}} \qquad (2)$$

Where: M_{air} is the molecular weight of the air which equal to 28.96 g/mol [E.shahi ,2005].

2.1.3 Determination of Gas compressibility Factor, Z

The gas compressibility factor can be evaluated using Katz and standing chart based on the psedo-reduced temperature and pressure as the following:

2.1.3.1 Calculation of the pseudo-critical temperature (T_C) and pressure (P_C) using the following correlation:

$$P_C = 677 + 15G - 37.5G^2 \qquad (3)$$

Where G is the gas Gravity, P_C critical temperature (psi)

$$T_C = 168 + 325G - 12.5G^2 \qquad (4)$$

Where T_C is the critical temperature (R^0) [Lyons and Plisga, 2011].

2.1.3.2 Calculation of the pseudo-reduced temperature (T_r) and pressure (P_r)

$$T_r = \frac{T}{T_C} \qquad (5\text{-A})$$

$$P_r = \frac{P_{avg}}{P_C} \qquad (5\text{-B})$$

Where: T is the flowing inlet temperature of the gas (R^0), $P_{avg.}$ is the average pressure of the gas which can be estimated from the following equation :

$$P_{avg} = \frac{2}{3}\left(\frac{P_1^3 - P_2^3}{P_1^2 - P_2^2}\right) \qquad (6)$$

Where: P_1, P_2 are the inlet and outlet flowing pressures of the gas through the pipe (psi)

[Lyons and Plisga, 2011; H.Dale Beggs ,1984].

2.1.3.4 Determination of Gas Density (ρ)

The gas density can be calculated from the following Formula:

$$\rho = \frac{P_{avg} M_a}{ZRT} \qquad (6)$$

where : ρ is the gas density (b/ft^3), P_{avg} is the average pressure of the gas (psi), M_a is apparent molecular weight of the gas(b/mol), z is gas deviation factor, T is inlet flowing temperature of gas (R^0), R is the gas constant which equal to (10.73 ft^{3}psi / mol. R^0) [Lyons and Plisga, 2011].

2.1.3.5 Determination of Gas Viscosity (μ)

The viscosity of natural gas mixture can be determined by the correlation developed by Lee,et .al in (1966) as shown in equation (8) below which:

$$\mu_g = K.10^{-4} e(X\rho_g^Y) \qquad (7)$$

Where: $K = \frac{(9.4+0.02M)T^{1.5}}{209+19M+T}$,

$$X = 3.5 + \frac{986}{T} + 0.01\,M,\ Y = 2.4 - 0.2\,X$$

μ_g : dynamic viscosity of gas mixture (c_p), M : molecular weight of gas mixture, T :gas Temperature (R^0), ρ_g : gas density (g /cm^3) [H. Beggs , 1984].

2.2 Pipeline Sizing

2.2.1. Determination of Pipe Diameter

The inside pipe diameter (d) can be estimated using Weymouth equation as shown in equation (9) below:

$$Q_g = 1.1\, d^{2.67}\left[\frac{P_1^2 - P_2^2}{LZGT_1}\right]^{1/2} \qquad (8)$$

[Maurice Stewart, 2016].

where : Q_g is the flowing gas flow rate (capacity) (MSCF/D), d is the inside pipe diameter (inch) , P_1 and P_2 are the flowing inlet and outlet gas pressures through the pipe (psi) , L is the length of the pipe (ft), Z is the gas deviation factor , G is the gas gravity, T_1 is inlet gas temperature (R^0).

2.2.2. Determination of Gas velocity in pipeline

The gas velocity at any point in a pipeline can be estimated from the equation (9-A) below:

$$u = 0.002122\left(\frac{Q_b}{D^2}\right)\left(\frac{P_b}{T_b}\right)\left(\frac{ZT}{P}\right) \qquad (9\text{-A})$$

Where: u: Gas velocity (ft/s), Q_b: Gas flow rate, measured at standard condition (ft^3/day), D: Pipe inside diameter (in) , P_b : base pressure (psia), T_b: base temperature (R^0), P: gas pressure (psia),T: Average gas flowing Temperature (R^0) Z: Gas compressibility factor at flowing temperature [E. Shashi Menon ,2016].

The upper limit of gas velocity in a pipeline can be approximately calculated from the following equation:

$$U_{max} = \frac{100}{\sqrt{\rho}} \qquad (9\text{- B})$$

[E. Shashi Menon ,2016].

where: U_{max}: maximum or erosional velocity (ft/s), ρ: gas density at flowing temperature (Ib/ft^3).

2.2.3 Determination of pipe Nominal Thickness

The nominal wall thickness of pipe can be calculated using Barlow equation (10) below:

$$t_{NOM} = \frac{P_d\,D}{2\epsilon_w \eta \delta_y F_t} + C_a \qquad (10)$$

[Boyun Guo and Ali Ghalambor ,2005]

where, t_{Nom} : nominal wall thickness (mm) , P_d : Design internal pressure (psi) D: internal inside diameter of pipe (mm) , ϵ_w : weld efficiency factor for pipe

δ_y : specified minimum Yield strength of pipe , η : design factor, F_t : temperature derating factor , and C_a : corrosion allowance thickness (mm).

2.2.4 Determination of pipe schedule number

The schedule number of the pipe can be calculated from the following Formula**:**

$$Sn = 1000X\frac{P}{S} \qquad (11)$$

[Boyun Guo and Ali Ghalambor ,2005]

Where: Sn: pipe schedule number, P: design internal pressure (psi)

S: Specified minimum yield strength of pipe (psi).

2.2.5 Determination of Reynolds Number and Friction Factor

The Reynolds number for the gas flow in pipeline can be evaluated from the equation (12-A) below:

$$N_{Re} = \frac{20QG}{\mu D} \quad \text{(12-A) [Maurice, 2016]}$$

Where: N_{Re} : Reynolds number, Q: gas flow rate (MSCF/D), μ: gash viscosity (cp), and D: pipe inside diameter (inch).

The friction factor of the pipe for turbulent flow can be estimated from the equation (12-B) below:

$$f^{0.5} = \frac{1}{2\log\left(\frac{D}{\varepsilon}\right)+1.14} \quad \text{(12-B)}$$

[Saeid Mokhatab et al ,2006]

Where, f: friction factor of pipe, D: pipe inside diameter (in), ε : pipe roughness (inch)

2.2.6 Determination of gas pipeline design pressures

2.2.6.1 Maximum allowable pipeline operating pressure (MAOP)

The maximum of allowable operating pressure pipeline can be calculated from the following formula:

$$MAOP = 2 \times F \times SMYS \times \frac{t}{D} \quad (13)$$

Where, MAOP: maximum of allowable operating pressure pipeline (psi)

F: design factor for natural gas pipelines, t: pipe wall thickness (mm)

D: pipe inside diameter (mm)

SMYS: specified minimum yield strength of pipe material (psi)

[E. Shashi Menon, P.E.,2005]

2.2.6.2 Pipeline Bursting pressure (BP)

The bursting pressure of pipeline can be evaluated from the following formula:

$$BP = 2 \times (SUTS) \times \frac{t}{D} \quad (14)$$

Where: BP is the bursting pressure of gas pipeline (psi), SUTS is the specified ultimate tensile strength of pipe material (psi), t is the pipe inside diameter (mm), t :pipe wall thickness (mm),

[E. Shashi Menon, P.E.,2005]

2.2.6.3 Plastic collaps pressure (P_Y)

The plastic collapse pressure of the gas pipeline (psi) can be estimated from the following formula:

$$P_Y = 2 \times SMYS \times \frac{t}{D} \quad (15)$$

2.2.6.4 Hydro test pressure (H_T)

The maximum hydro test pressure of pipeline (psi) can be evaluated from the following formula:

$$H_T = 1.25 \times MAOP \quad (16)$$

2.2.6.5 Pressure drop (ΔP)

The pressure drop of the gas through the pipeline (psi) can be calculated from the following formula:

$$\Delta P = P_1 - P_2 \qquad (17)$$

Where: P_1, P_2 are inlet and outlet pressure of the gas through the pipeline [E. Shashi Menon, P.E.,2005].

3. Results and Discussion

3.1. Results of Gas Properties

3.1.1 Apparent Molecular Weight:

By applying the equation (1) using the mole faction and the molecular weights of all the components in gas mixture, the estimated values are summarized in table (2) below; the resulted total apparent molecular weight of the gas mixture is 21.0414 g/mol.

Table (2): Gas Apparent molecular weight estimation

Number	Compound	Mole Fraction (Y_i)	Molecular weight g/mol	(Y_i*M_i)
1	carbon dioxide	0.024	44	1.056
2	Nitrogen	0.058	28	1.624
3	methane	0.8368	16	13.38
4	Ethane	0.0883	30	2.649
5	propane	0.0271	44	1.1924
6	I-Butane	0.0054	58	0.3132
7	N-Butane	0.0066	58	0.3828
8	I-Pentane	0.0026	70	0.182
9	N-Pentane	0.0019	72	0.1368
10	Hexane +	0.0015	86	0.129
Total		1		21.0452

Based on the gas compositions outlined in Table (2), it is evident that the gas predominantly consists of methane and ethane, with higher concentration levels, along with other hydrocarbon and acid gases in lower quantities. Therefore, based on this composition data presented in Table (2), it can be concluded that the gas is classified as a dry gas that meets the necessary criteria for designing gas transmission pipelines.

3.1.2 Gas Gravity (G)

Using the equation (2), the obtained gas gravity (G) value was 0.726 as the following:

$$G = \frac{21.0452}{28.9625} = 0.726$$

3.1.3 Gas Compressibility Factor (Z)

Firstly, by allying the equations (3, 4,), obtained values of pseudo-critical temperature (T_C) and pressure (P_C) are: 397.36 R^0 , 668.124 Psi

$$P_C = 677 + 15 * 0.726 - 37.5 * 0.726^2 = 668.124\ Psi$$

$$T_C = 168 + 325 * 0.726 - 12.5 * 0.726^2 = 397.36\ R^0$$

Secondly, using equations (5-A, 5-B, 6), the resulted values of the pseudo-reduced temperature (T_r) and pressure (P_r) are: 1.33, 0.3085

$$T_r = \frac{70+460}{397.36} = 1.33 \quad ,$$

$P_{avg} = \frac{2}{3}\left(\frac{246.56^3 - 159.54^3}{246.56^2 - 159.54^2}\right) = 206.15\ Psi$,

$P_r = \frac{206.15}{668.124} = 0.3085$

Thirdly, using the obtained values of T_r, P_r and by referring to Katz and Standing chart [H.Dale Beggs,1984] the estimated value of gas compressibility factor (z) of the gas was 0.960.

3.1.4 Gas Density (ρ)

By applying equation (6), the estimated value of gas density (ρ) was 0.794 b/ft^3 as the following:

$$\rho = \frac{206.15*21.0452}{0.96*10.73*530} = 0.794\ \text{b/ft}^3$$

3.1.5 Gas Viscosity (μ)

Firstly, the constants K,X,Y in equation (7) were estimated and the obtained values were 103.16,5.606,1.278 as the following:

$$K = \frac{(9.4+0.02*21.0452)520^{1.5}}{209+19*21.0452+520} = 103.1\ ,$$

$$X = 3.5 + \frac{986}{520} + 0.01 * 21.0452 = 5.606$$

$$Y = 2.4 - 0.2 * 5.606 = 1.278$$

Then by substituting the obtained values of K, X, Y constants into equation (7), the calculated value of gas viscosity was 0.010536 cp as the following: $\mu_g = 103.16.10^{-4} e(5.606 * 0.01272^{1.278}) = 0.010536\ cp$

3.2. Results of Pipeline Sizing

3.2.1. Pipe inside Diameter

The pipe inside diameter was calculated by applying Weymouth equation (8), the obtained value of pipe inside diameter was 12 inch as the following:

$$44.92 = 1.1\, d^{2.67}\left[\frac{246.56^2 - 159.54^2}{(36089.24)(0.96)(0.726)(530)}\right]^{1/2},$$

$d^{2.67} = 793.143,$

$d = 12.187\ inch \cong 12.0\ inch$

Therefore, The Pipe Inside diameter will equal to 12 inch (309.8mm).

3.2.2. Gas velocity in pipeline

According to equations (9-A,9-B), the estimated values of entering, outlet and erosional (maximum) gas velocity in pipeline were (38.61 ft/s, 59.67 ft/s ,112.22 ft/s) as the following :

For entering gas velocity, P = P_1 = 246.56 psia, T= T_1 = 530 R^0, Z = 0.960, D = 12 inch, Q_b = 53000m^3/hr (44920256.07 ft^3/day).

$u_1 = 0.002122\left(\frac{44920256.07}{12^2}\right)\left(\frac{14.7}{520}\right)\left(\frac{0.960*530}{246.56}\right) =$ 38.615 ft/s = 11.76 m/s .

For outlet gas velocity, P = P2 = 159.54 psia, T= T_1 = 530 R^0 , Z = 0.960

$u_2 = 0.002122\left(\frac{44920256.07}{12^2}\right)\left(\frac{14.7}{520}\right)\left(\frac{0.960*530}{159.54}\right) =$ 59.67 ft/s = 18.18 m/s.

For erosional gas velocity, by applying equation (9-B) for gas density (ρ = 0.794 b/ft^3),

$$U_{max} = \frac{100}{\sqrt{0.794}} = 112.22\frac{\text{ft}}{\text{s}} = 34.20\ \text{m/s}$$

Typically, in cases where the gas contains certain amounts of sand or other impurities, it is recommended to maintain an operational gas velocity below 50% of the erosional gas velocity. This precaution is necessary to prevent vibration, noise, and long-term erosion of the pipe interior. Upon evaluating the obtained values of the entering, outlet, and erosional gas velocities, it is evident that these values fall within the acceptable range. Therefore, the gas velocities meet the required criteria, indicating that the operational gas velocity remains within the acceptable limits to ensure the avoidance of vibration, noise, and pipe interior erosion over an extended period of time.

3.2.3 Results of Pipe Nominal Thickness

By applying Barlow equation (10), the estimated value of pipe nominal thickness was about 4mm as the following:

P_d = P_1 = 246.56 psia, D (pipe inside diameter) = 12 inch (304.8mm) ,For the proposed design of pipeline E_w =1.0 for steel pipe seamless Arc weld (SAW or DSAW), F_t (temperature derating factor) = 1.0 for temperature under 250 F^0. The recommended value of corrosion allowance thickness C_a is 1/16 inch (1.58 mm). The design factor (η) for the proposed design of pipeline is 0.72 for gas lines [E.W. McAllister, 2002]. δ_y: Specified minimum Yield strength of pipe(SMYS) is 25000 psia for Pipe specification API 5L Type (seamless Arc weld) according to ASME B31.8-2016 standard for materials and equipment specification

$$t_{NOM} = \frac{(246.56)*(304.8)}{2*1*0.72*25000*1} + 1.58 = 3.66\,mm \cong 4.0\,mm$$

According to ASME B31.3 Pipe sizing, the estimated value of pipe wall thickness (4 mm)

is in compliance with ASME B31.8 code for 12 inch, X -60 grade for steel pipes.

3.2.4 Results of Pipe Schedule Number

The estimated value of schedule number (Sn) of the designed pipe was 10.0 as the following:

P = P_1 (Gas entering pressure) = 246.56 psia, Specified minimum yield strength of pipe(S) = 25000 psia

$$Sn = 1000 * \frac{246.56}{25000} = 9.86 \cong 10.0$$

According to the nominal pipe size tables presented in Pipe Properties [E. Shashi Menon, P.E. 2005], a 12-inch nominal size pipe with a schedule number of 10 has a thickness of 4.57 mm. This calculated value aligns with the thickness obtained using the Barlow equation. The schedule number denotes the pressure rating of pipes, indicating their capacity to withstand pressure. It is crucial to determine the schedule number when ordering pipes to ensure the appropriate selection for the intended application.

3.2.5 Results of Reynolds number and friction factor

By applying equations (12-A, 12-B), the estimated values of Reynolds number and friction factor were 5158.807, 0.01318 as the following:

$$N_{Re} = \frac{20*44.92*0.726}{0.010536*12} = 5158.807$$

The Reynolds number is used to predict the fluid pattern, since the estimated value was greater than 2100, an indication that the gas flow regime is turbulent.

For the pipe fraction factor, for carbon steel pipe (non-corroded) $\varepsilon = 0.001968$,

$$f^{0.5} = \frac{1}{2\log(\frac{12}{0..001968})+1.14},$$

$$f = \sqrt{\left(\frac{1}{2\log(\frac{12}{0.001968})+1.14}\right)} = 0.01318$$

3.2.6 Results of Gas Pipeline Design Pressures

3.2.6.1 Maximum allowable pipeline operating pressure (MAOP)

By applying the equation (13), the evaluated value of MAOP was 1133.85 psia as the following:

Design factor for natural gas pipelines (F= 0.72), for API 5L (Note 2) grade X60 steel pipes, SMYS of the selected pipe material = 60 000 psi.

$$MAOP = 2 \times 0.72 \times 60000 \times \frac{4}{304.8} = 1133.85\, psi\ (78.17\ bar)$$

3.2.6.2 Pipeline Bursting Pressure (BP)

According to equation (14), the estimated value of bursting pressure of designed pipe was 1968.5 psi as the following:

For API 5L (Note 2) grade X60 steel pipes, SUTS of the selected pipe material = 75 000 psi,

$$BP = 2 \times (75000) \times \frac{4}{304.8} = 1968.5\, psi\ (135.72\ bar)$$

3.2.6.3 Plastic Collaps Pressure (P_Y)

By applying the equation (15), the calculated value of collaps pressure was 1574.8 psi as the following:

$P_Y = 2 \times 60000 \times \frac{4}{304.8} =$
$1574.8\ psi\ (108.57\ bar)$

3.2.6.4 Hydro Test Pressure (H_T)

According to equation (16), the evaluated maximum hydro test pressure of the designed pipeline (H_T) was 1417.31 psi as the following:

$H_T = 1.25 \times 1133.85 =$
$1417.31\ psi\ (97.72\ bar)$

3.2.6.5 Gas Pressure Drop (ΔP)

By applying equation (17), the estimated value of gas pressure drop was 87.02 psi as the following:

$\Delta P = 246.56 - 159.54 =$
$87.02\ psi\ (\ 6\ bar)$

As shown from the pressure drop value, the gas pressure in pipeline is decreased and this drop of pressure is mainly due to frictional effects. Table (3) below summarize all the results of the design parameters.

4. Conclusion and Recommendation

The design of the gas transmission pipeline involved the utilization of relevant design equations from ASME and API codes/standards. These equations were employed to estimate crucial parameters such as the appropriate diameter, wall thickness, schedule number, and pressure ratings. The gas properties were also calculated using appropriate equations tailored to the specific requirements.

Based on the design process, several significant design parameters were obtained, including a pipe inside diameter of 12 inches, a pipe wall thickness of 4mm, a pipe schedule number of 10, a maximum allowable operating pressure of 1133.85 psi, and a burst pressure of 1968.5 psi. To ensure accuracy and precision, it is recommended to employ an appropriate simulation program to simulate the designed pipeline. This simulation process will aid in verifying that all the obtained design parameters align with the simulation results, thereby confirming the reliability and functionality of the designed gas transmission pipeline.

Number	Parameter	value /unit
1	Flow capacity , Q	53000 m^3 / hr (44.92 MSCF/D)
2	Inlet Pressure,P1	17 bar (246.56 psia)
3	Out Pressure,P2	11 bar (159.54 psia)
4	Inlet Temperature , T	70 F^0
5	Pressure Drop (Δp)	87.02 psi (6 bar)
6	Apparent Gas Molecular weight (M_a)	21.0452 g/mol
7	Gas Gravity , G	0.726
8	Gas Density ,ρ	0.794 b/ft^3
9	Gas Viscosity , μ	$0.010536\ cp$
10	Gas deviation factor , Z	0.960
11	Pipe diameter , D	12 inch (309.8 mm)
12	Pipe thickness , t	0.157 inch (4 mm)
13	Pipe length , L	11 km (36089.24 ft)
14	Inlet gas velocity	36.58 ft/s (11.49 m/s)
15	Out let gas velocity	56.53 ft/s (17.23 m/s)
16	Erosional (maximum) gas velocity	116.33 ft/s (35.45 m/s)
17	Reynolds number , N_{Re}	5158.807
18	Pipeline Specified Minimum Yield Strength	60000 psia
19	Pipeline Specified Ultimate Tensile Strength	75000 psia
20	Pipeline Maximum Allowable Operating Pressure	$1133.85\ psi\ (78.17\ bar)$
21	Pipeline Bursting Pressure (BP)	$1968.5\ psi\ (135.72\ bar)$
22	Pipeline Hydro test pressure	$1417.31\ psi\ (97.72\ bar)$
23	Schedule Number	10.0

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