Scientific Contributions Oil & Gas, Vol. 49. No. 2, June: 609 - 622

SCIENTIFIC CONTRIBUTIONS OIL AND GAS

Testing Center for Oil and Gas
LEMIGAS

Journal Homepage:http://journal.lemigas.esdm.go.id
ISSN: 2089-3361, e-ISSN: 2541-0520

Investigation of Insulation Effect on Wax Deposition Using a Flow Assurance Simulator

Astra Agus Pramana and Inggrialianthari Rezkhi Trinugrahandini

Universitas Pertamina,
Teuku Nyak Arief Street, RT.7/RW.8, Grogol Selatan, Kebayoran Lama Subdistrict, South Jakarta City, 12220, Indonesia

Corresponding author: Astra Agus Pramana (astraagus.p@universitaspertamina.ac.id)

Manuscript received: March 30th, 2026; Revised: April 13th, 2026
Approved: May 04th, 2026; Available online: June 15th, 2026; Published: June 23th, 2026.

ABSTRACT - Wax deposition remains one of the most common and disruptive problems in oil and gas pipelines. To address this issue, various methods are developed for both onshore and offshore fields according to their field characteristics. Insulation is one of the mitigation methods that generally performs well, despite several implementation challenges. This study presents a wax-deposition model to assess the effectiveness of insulation as a mitigation method. The analyzed fluid flows from the MOON platform to the SELENA platform in Field W through a carbon-steel subsea pipeline. The pipeline is modeled over a simulated distance of approximately 0–1,900 m, with detailed wax-deposition analysis focused on the critical section of 0–700 m. Rubber and concrete are applied to evaluate their performance as pipeline insulation materials. This study uses five scenarios with two different materials. The results show that, in all cases, wax thickness reduction reaches 100%, while rubber insulation performs more effectively than concrete in reducing temperature decline and heat loss. In addition, other parameters, such as pressure, Wax Appearance Temperature (WAT), and flow rate, are analyzed in this study.

Keywords: insulation, wax deposition, OLGA, rubber, concrete

How to cite this article:

Astra Agus Pramana and Inggrialianthari Rezkhi Trinugrahandini, 2026, Investigation of Insulation Effect on Wax Deposition Using a Flow Assurance Simulator, Scientific Contributions Oil and Gas, 49 (2) pp. 609 - 622. DOI org/10.29017/scog.v49i2.2104.

INTRODUCTION

Oil and gas demand has been increasing in recent years. According to Statista data, global oil and gas demand reached 99.57 MBPD in 2022 and is expected to increase to 101.89 MBPD in 2023. In Indonesia alone, approximately 1.58MBPD of oil and gas was consumed in 2022. The increasing demand for oil and gas requires higher production levels. Therefore, it is important to implement a hydrocarbon production process from the reservoir to the surface that is both technically and economically effective, known as flow assurance (FA). One flow assurance method to increase oil and gas production is to mitigate flowline problems in production systems, including hydrate formation, slugging, scaling, corrosion, emulsions, asphaltenes, naphthenates, and wax deposition (Theyab 2018).

Wax deposition occurs when hydrocarbon components crystallize into solid precipitates due to changes in petroleum fluid-phase behavior and wax-deposition mechanisms (Mansoori 2009; Yang et al., 2020). This phenomenon is triggered by a decrease in fluid temperature to or below the wax Appearance temperature (WAT) during hydrocarbon production from the reservoir to the surface. Wax deposition can cause formation damage around the wellbore, leading to reduced permeability and porosity, as well as changes in fluid rheology and composition. Several methods are available to overcome this problem, including mechanical, thermal, and chemical approaches (Singh et al., 2004; Sousa 2019; Theyab 2021). These methods include insulation, inhibition, thermal remediation, pigging, and others. Insulation (or isolation) is a method used to control blockage in production pipelines caused by deposition by maintaining the fluid temperature above the cloud point using suitable insulating materials (Theyab 2018).

To ensure the effectiveness and efficiency of these methods, accurate prediction of wax content and appearance is required (Septiano et al., 2022; Tony et al., 2025). Failure in wax prediction can lead to unsuccessful mitigation processes. In more severe cases, failure to handle wax deposition may result in production shutdowns, plug-and-abandonment, and site restoration (Huang et al., 2015). As a preventive approach, OLGA software provides predictions of WAT, wax thickness, and wax appearance time (Schlumberger 2017). This paper discusses modelling a production pipeline with wax content in an oil and gas field using OLGA software, as well as the performance of different insulation materials in mitigating wax deposition, specifically on the SELENA–MOON platform system.

Previous studies in Indonesian oil and gas production have focused on improving hydrocarbon recovery, treating waxy crude oil, and predicting wax deposition through various approaches. Tobing and Eni (2013) discussed production improvement through alkali–surfactant–polymer injection at a laboratory scale, while Pramana and Pagpa (2023) evaluated the effectiveness of pour point depressant in waxy crude oil. In addition, Septiano et al. (2022) developed a machine-learning proxy model to predict the wax deposition rate in two-phase water–oil flow, and Pramana et al. (2025) investigated alternative insulation materials for production pipelines through simulation. These studies indicate that wax mitigation and production optimization remain important issues. However, the comparative evaluation of rubber and concrete insulation at different thicknesses under specific subsea pipeline conditions remains limited.

However, the comparative effect of insulation materials and thickness variations under a specific subsea pipeline condition remains limited. This study addresses this gap by using OLGA to evaluate rubber and concrete insulation scenarios in the SELENA–MOON pipeline, focusing on fluid temperature, heat loss, wax thickness, pressure, WAT, and flow rate. The novelty of this study lies in comparing variations in insulation materials and thicknesses using field-based fluid and pipeline data.

METHODOLOGY

The experiment was conducted to analyze the effect of insulation by comparing production pipeline conditions with and without wax deposition. The investigation focused on several wax deposition parameters, such as thickness, appearance time, location, and other factors affecting the phenomenon.

Data

To achieve the objective, the study used a case study approach based on Field W data, complemented by a literature review. This process involved data processing and analysis using simulation software. The field data were obtained from operational data, including fluid, production, and pipeline data, along with pipeline coordinates in the x- and y-directions. Field W is an offshore field located in Southeast Sumatra. Only operational data relevant to the flow assurance simulation were used in this study.

Methodology

The analysis and modelling of the obtained fluid were conducted using the RKS-Advanced method in Multiflash software, with Pressure–Volume–Temperature (PVT) analysis applied to a two-phase gas–liquid system. Based on the available fluid data, the main modelled fluid properties included a water cut of 99.23%, a total mass flow rate of 409.52 lb/s, a reported wax fraction of 53.14% in the fluid model input, a wax appearance temperature (WAT) of 106°F (41.1°C), and an ambient temperature of 77°F (25°C).

The original flowline modelling without insulation was carried out in OLGA using a wax-deposition case within a flow assurance model, which served as the base case. The simulation procedure was arranged into five scenarios: Scenario 1 was the base case without insulation; Scenarios 2, 3, and 4 applied rubber insulation with thicknesses of 0.1 in., 0.5 in., and 1.0 in., respectively; and Scenario 5 applied concrete insulation with a thickness of 0.5 in. The concrete case was used to compare the performance of rubber and concrete insulation at the same insulation thickness. The full pipeline model was simulated over approximately 0–1,900 m, while the detailed wax deposition analysis focused on the critical section of 0–700 m, where wax formation and changes in wax thickness were most significant. The investigation of wax deposition conditions was conducted based on model outputs, which showed changes in wax thickness along the pipeline distance and production time before and after insulation was applied. Error analysis was performed using the "output" feature of the OLGA program to identify errors during modelling and simulation.

The observed OLGA output parameters include fluid temperature or mixture temperature (TM), Wax Appearance Temperature (WAT/WAXAP), wax thickness (DXWX), heat loss rate (QM), maximum pressure (PTMAX), and pipeline geometry. TM represents fluid temperature, WAT/ WAXAP indicates the wax crystallization temperature, DXWX refers to wax thickness, QM represents heat loss, PTMAX indicates maximum pressure, and geometry represents the pipeline elevation profile.

RESULT AND DISCUSSION

This section presents the OLGA simulation results on wax deposition behavior under the base case and insulation scenarios. The analysis focuses on temperature, heat loss, wax thickness, pressure, and flow rate to evaluate the effectiveness of insulation in mitigating wax deposition.

Base case scenario

Based on the obtained fluid data, the fluid was modeled as a two-phase mixture of gas and liquid, with a water cut of 99.23% and a total mass flow of 409.52 lb/s. The fluid also contains 53.14% wax (paraffin) in the fluid model input. The ambient temperature, as one of the considerations in investigating the case, reaches 77°F (25°C), with a WAT of 106°F (41.1°C). This indicates a high likelihood of wax deposition as the fluid temperature decreases along the pipeline. Figure 1 shows wax deposition forming as the temperature drops close to the WAT at a pipeline distance of 350 m, and it continues to thicken to 0.08 inch as the fluid temperature passes the WAT.

As a result of turbulence caused by the lower location of the pipe geometry, wax thickness depletion occurs again along the pipeline between 560 m and 580 m. The wax thickens once again as the turbulence diminishes, the fluid flow stabilizes, and the fluid temperature moves closer to the

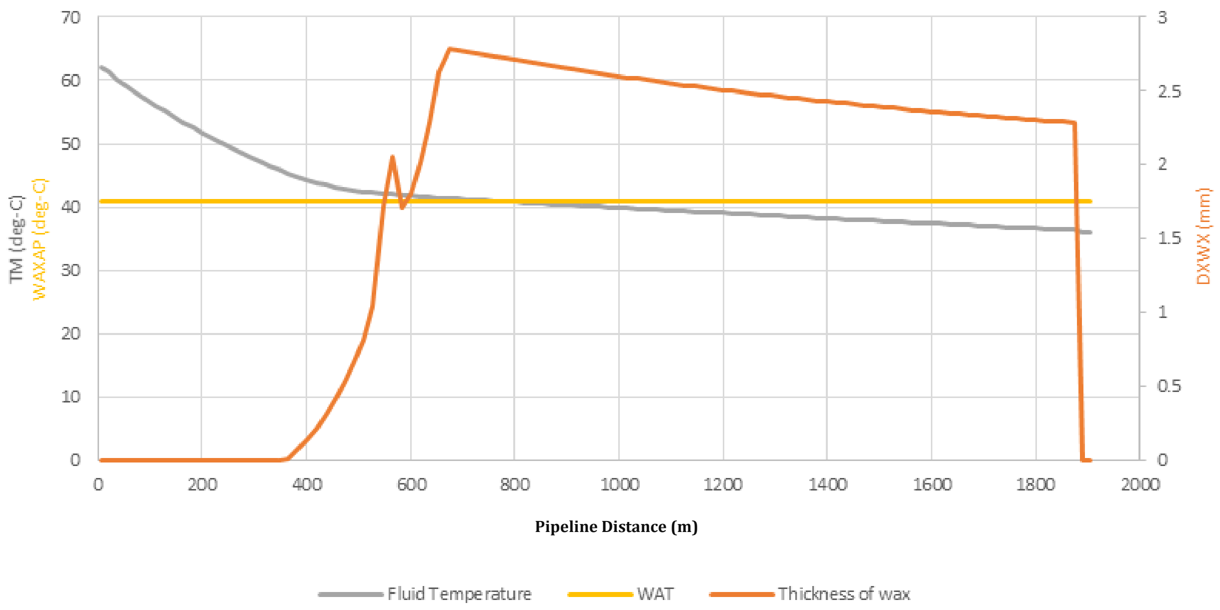

Figure 1. Wax deposition forming graph along the pipe.
That wax deposition begins when the fluid temperature approaches the wax appearance temperature (WAT) at approximately 350–400 m. Wax thickness then increases along the critical section and reaches its highest value around 650–700 m.

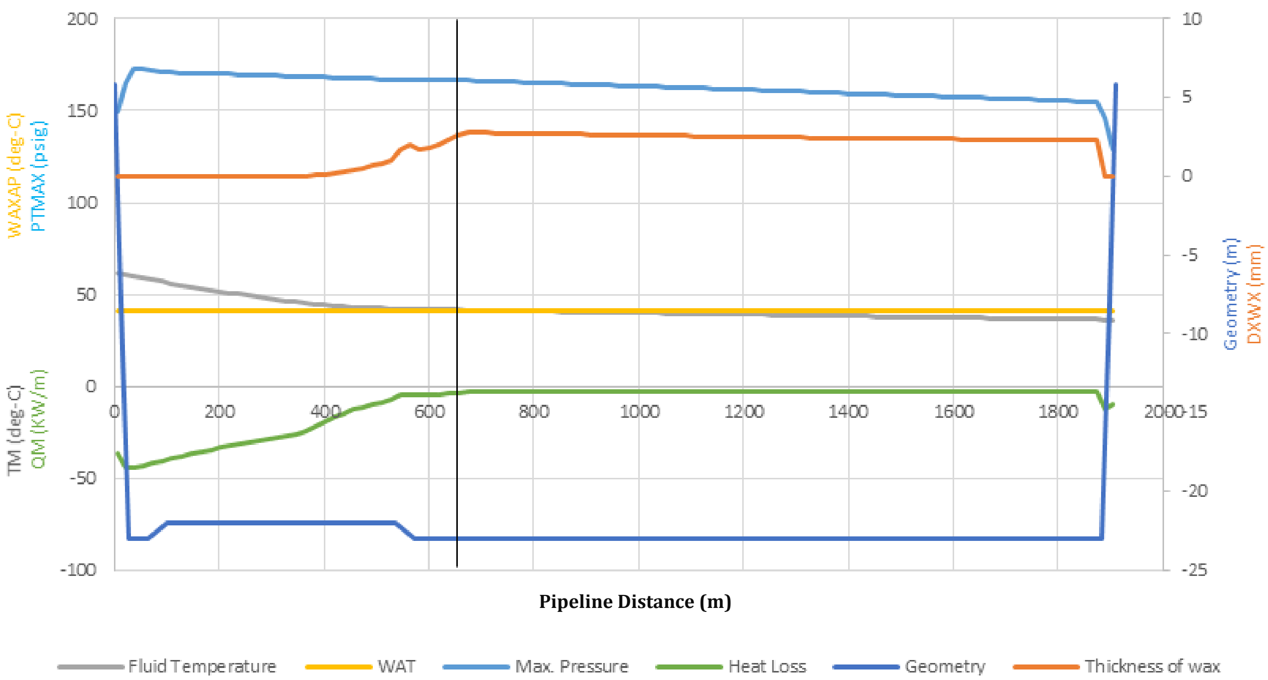

Figure 2. The base-case parameter conditions in the 20th year before insulation is applied.
The fluid temperature decreases along the pipeline and approaches the wax appearance temperature (WAT), which promotes wax formation in the critical section. Wax thickness increases around the 600–700 m section, while heat loss indicates thermal energy transfer from the fluid to the surroundings. Overall, the figure confirms that temperature decline and heat loss contribute to wax deposition in the uninsulated pipeline.

WAT; as observed at a pipeline distance of 674 m, it reaches 0.11 inch (2.79 mm). Figure 4 illustrates the general condition of the observed parameters for every 100 m along the pipeline.

Insulation result analysis

Rubber insulation

The carbon-steel pipeline was insulated with rubber, which affected the thickness of the wax. The temperature was evaluated at a pipeline distance of 400 m. The simulation results show that the change in wax thickness was influenced by the reduction in heat loss rate (from 18.9 kW/m to 4.74 kW/m) and by the increase in fluid temperature or the depletion of ΔT, making it less extreme than in the original scenario.

The fluid temperature in the initial scenario was 44°C, whereas it was effectively maintained at 60° C after insulation with a rubber material. The wax thickness in Scenario 2 is significantly influenced by the insulator, reducing it from 0.1 in (2.54 mm) to 0 in (0 mm), or around a 100% reduction compared to the initial scenario. In addition, the peak wax thickness, which previously formed at a pipeline distance of 675 m, no longer exists.

Scenario 3 represents a reduction in wax thickness that is as significant as in Scenario 2. Insulation with a thickness of 0.5 inch can handle wax deposition by reducing it to 0 inch (0 mm). In other words, this insulation causes the wax deposition to dissolve completely, or be 100% handled from the base case scenario (Figure 5). Due to a decrease in the temperature difference (ΔT) and reduced heat loss along the pipeline, the maximum wax thickness does not develop. This demonstrates that insulation with a thickness of 0.5 inch (Scenario 3) produces better results than 0.1 inch (Scenario 2). This important finding is reasonable, as each increase in rubber thickness results in its physical properties having a greater influence on changes in fluid temperature. As a

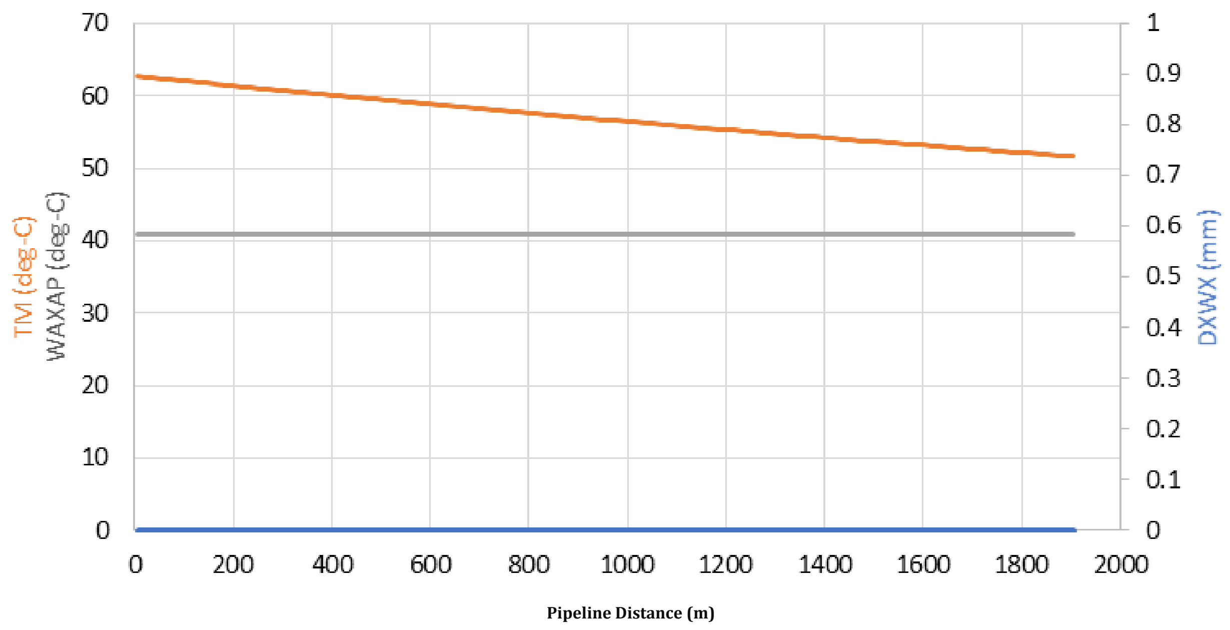

Figure 3. Wax deposition forming graph after 0.1 inch of rubber insulation applied.
The fluid temperature remains above the Wax Appearance Temperature (WAT) throughout the simulated distance, indicating that the insulation successfully reduces the temperature drop in the flowline. As a result, wax deposition does not form, as shown by the wax thickness remaining at 0 mm. This result indicates that 0.1-inch rubber insulation is already effective in preventing wax accumulation under the simulated pipeline conditions.

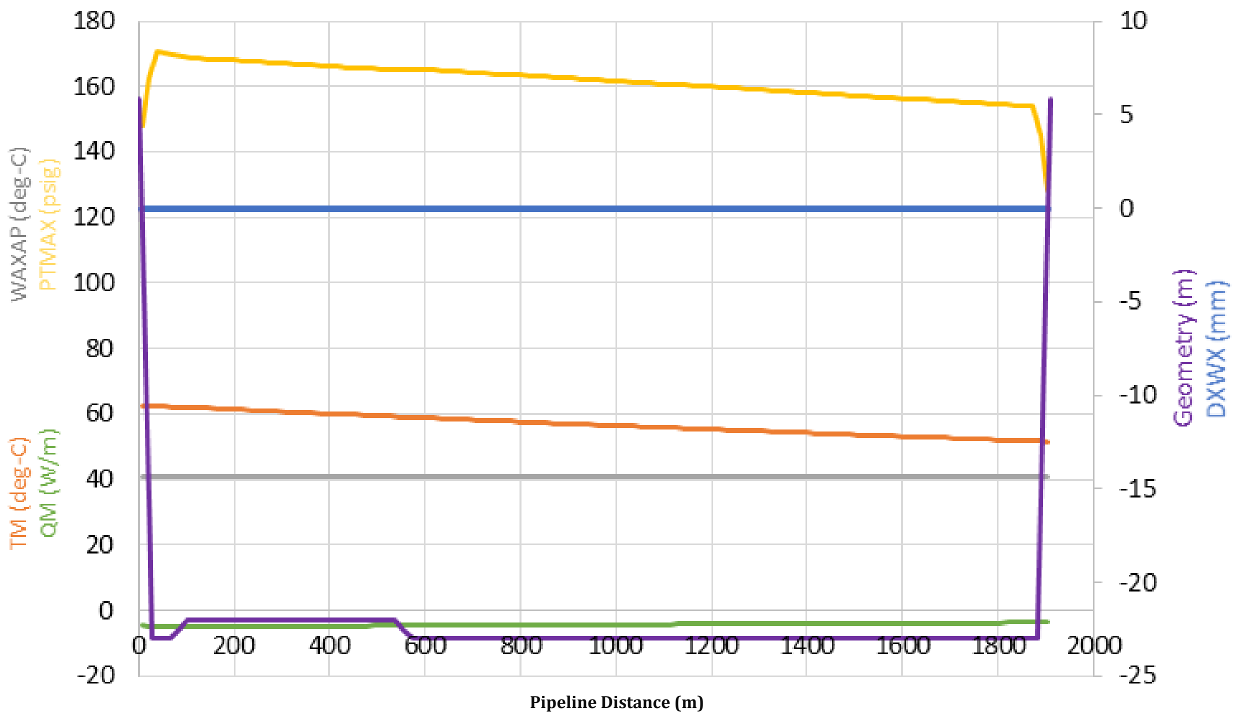

Figure 4. Condition of observed parameters after 0.1 in of rubber insulation applied.
The graph shows that the fluid temperature is maintained above WAT, while the wax thickness remains at 0 mm along the pipeline. This condition indicates that the insulation reduces heat loss and prevents the fluid from reaching the critical temperature for wax crystallization. The pressure trend remains relatively stable, and the geometry profile does not cause significant changes in wax formation. Therefore, this scenario confirms that thin rubber insulation can provide effective thermal protection against wax deposition.

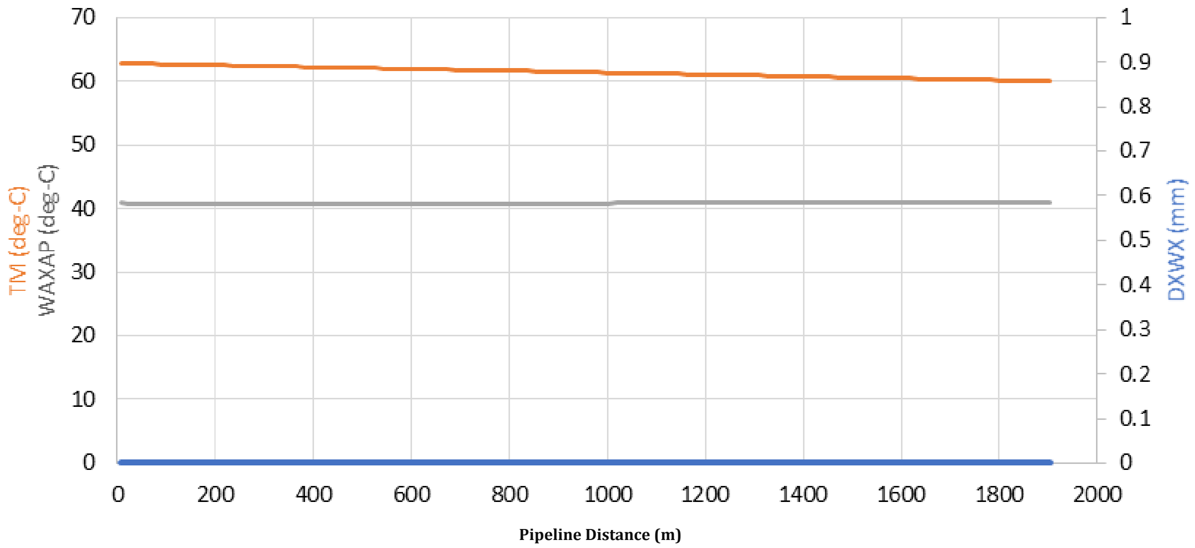

Figure 5. Wax deposition forming graph after 0.5 inch of rubber insulation applied.
The fluid temperature remains consistently above the Wax Appearance Temperature (WAT) along the pipeline, indicating that the insulation effectively maintains the thermal condition of the fluid. The wax thickness remains at 0 mm throughout the simulated distance, which confirms that wax formation is fully prevented in this scenario. Compared with the thinner insulation case, the 0.5-inch rubber insulation provides a more stable thermal margin and better protection against temperature decline.

result, the temperature drop along the pipe can be maintained more steadily and does not occur rapidly. Compared with the earlier scenarios, minor temperature fluctuations lead to wax dissolution and prevent accumulation over a longer period. Figure 6 displays the overall outcomes of the parameters observed in this scenario.

The application of 1 in thick insulation in Scenario 4 shows the same result as the previous scenario (Scenario 3), either for the fluid temperature parameter or wax thickness.

To be specific, the reduction of wax deposition is still totally effective (100%) as in the previous scenario, as well as the heat loss parameter, which relatively has the same result, and the dissolution of the wax deposition peak (Figure 7). This can be caused by the impact that has reached its maximum and is no longer visible in the resulting graph, since the physical characteristics of the insulator at decreasing temperature changes (ΔT) are no longer relevant. Given that installing insulation of this thickness would take more time and resources while having a roughly similar impact to the previous scenario, it is not advised to do so.

Figure 8 also displays the results for all parameters that were observed. Regardless of the importance of the results presented, the condition of reducing T from the initial condition indicates that insulation was successfully installed. This result is also influenced by the wax thickness, which was not too high before insulation was applied (base-case scenario). Meanwhile, the PTMAX parameters did not show a significant change after the insulation was installed with rubber material, with thicknesses of 0.1 in, 0.5 in, or 1 in.

Concrete insulation

The application of insulation with concrete material has quite a significant impact on the depletion of wax deposition thickness, but it is not as effective as rubber material in insulation. The research results on concrete insulation were based on the most effective rubber insulation thickness of 0.5 in. As shown in the results, the fluid temperature decreased to 59°C from the base case at a pipeline distance of 400 m. This result is 3 C lower than the rubber insulation case with the same thickness applied. It is shown on the chart that the temperature graph is steeper than that of Scenario

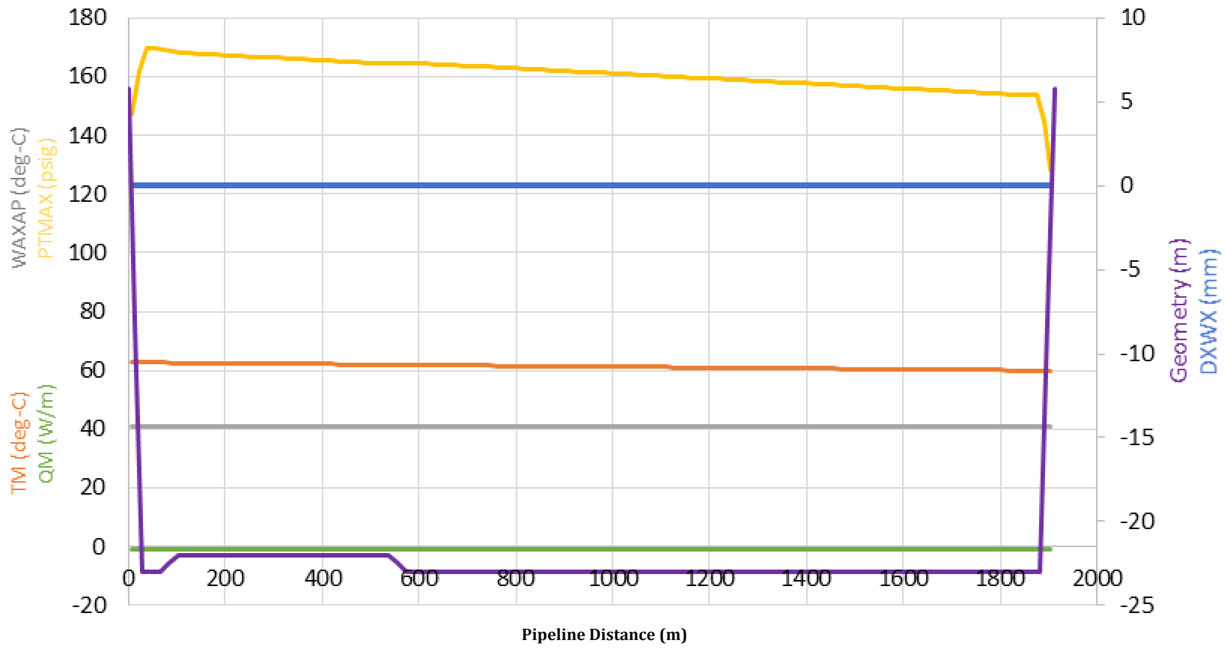

Figure 6. Condition of observed parameters after 0.5 inch of rubber insulation applied.
The fluid temperature remains above the wax appearance temperature (WAT), while wax thickness stays at 0 mm along the pipeline. The lower heat-loss profile indicates improved thermal stability, and the pressure trend remains relatively stable. These results confirm that 0.5-inch rubber insulation effectively prevents wax deposition and supports flow assurance performance.

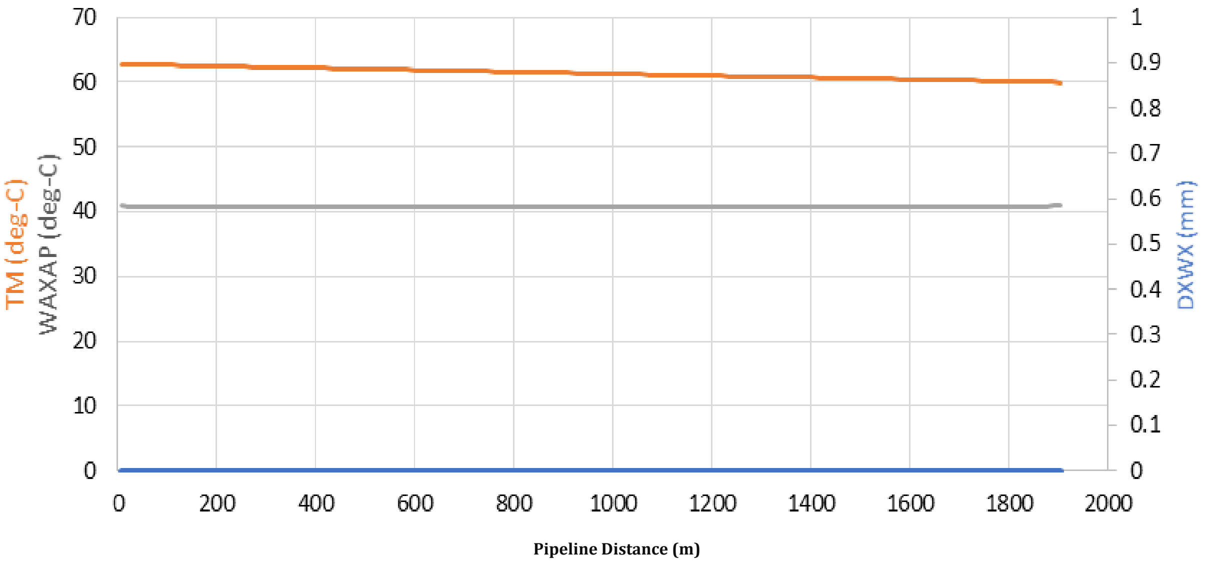

Figure 7. Wax deposition forming graph after 1 inch of rubber insulation applied.
The fluid temperature remains above the Wax Appearance Temperature (WAT) along the entire pipeline, indicating that the thicker rubber insulation effectively maintains the thermal condition of the fluid. The wax thickness stays at 0 mm throughout the simulated distance, which confirms that wax formation is completely prevented. However, the result is similar to the 0.5-inch rubber insulation case, suggesting that increasing the insulation thickness to 1 inch does not provide a proportional improvement in wax-deposition reduction.

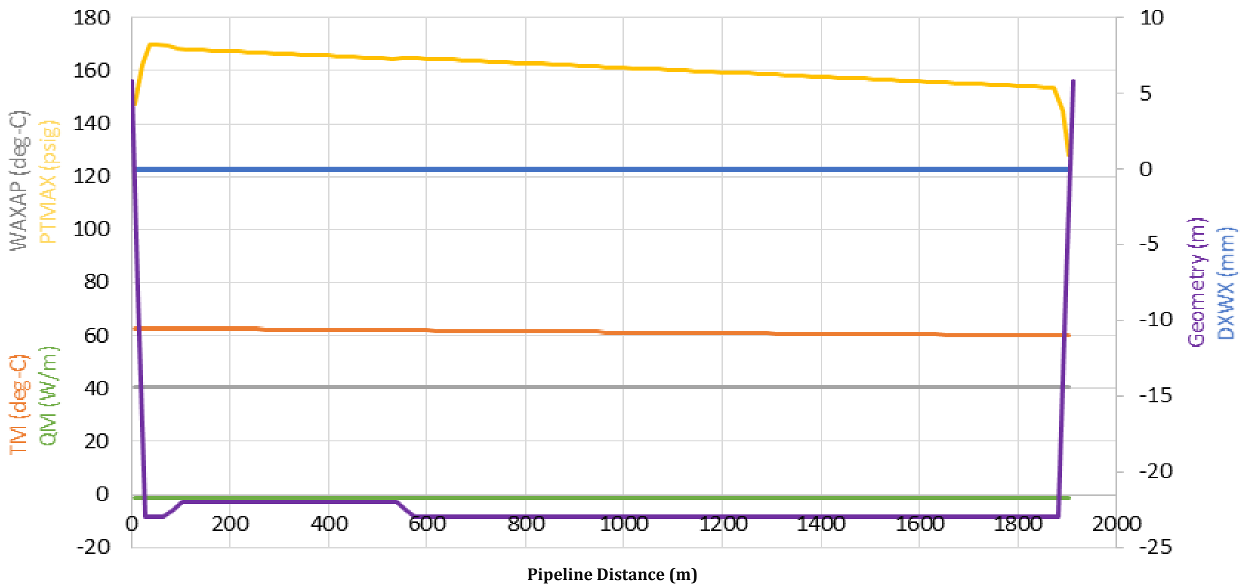

Figure 8. Condition of observed parameters after 1 inch of rubber insulation applied.
The fluid temperature remains above the Wax Appearance Temperature (WAT), while wax thickness stays at 0 mm along the pipeline. The heat-loss profile remains low, and the pressure trend shows no major change along the simulated distance. These results indicate that 1-inch rubber insulation effectively maintains the thermal condition of the fluid and prevents wax deposition.

3, which leads to larger ΔT. Nevertheless, no wax deposition was formed, and the wax deposition reduction is up to 100%, due to tolerable heat loss and ΔT. This event was mainly caused by the TM graph that does not reach WAT, as shown in Figure 9. As it was in the previous scenario, the other studied parameters are also influenced by concrete insulation. As shown in Figure 12, at a pipeline distance of 400, the PTMAX value dropped by 2.2 psig, and QM's value changed by (-15.68) KW/m from the initial scenario. The wax deposits that peaked in scenario 1 were fully resolved, as in scenarios 2 to 4, at a pipeline distance of 500-700 m.

These two factors failed to deliver better outcomes than insulator rubber. Even though all of these occurrences showed that wax deposits could be handled, and while concrete insulation and rubber both performed successfully, rubber's effectiveness was more clearly proved. Figure 10 and Tables 3 and 4 provide a comparison of all parameters impacted following the application of insulation.

The analysis at 400 m is a selected observation point used to compare the thermal and wax-deposition responses between rubber and concrete insulation. This location was not a separate insulated section, but was selected because it shows relevant changes in fluid temperature, heat loss, pressure, and wax thickness. The 500–700 m interval represents a selected observation section used to evaluate changes in wax thickness and thermal behavior along the critical wax-prone section.

Insulation effect on production

This experiment proved that both insulation materials successfully prevented wax deposition

Table 1. MAPE classification (Lasifa et al., 2021).

No.	MAPE percentage	Classification
1	<10%	Very Good
2	10% - 20%	Good
3	20% - 50%	Fair
4	>50%	Inaccurate

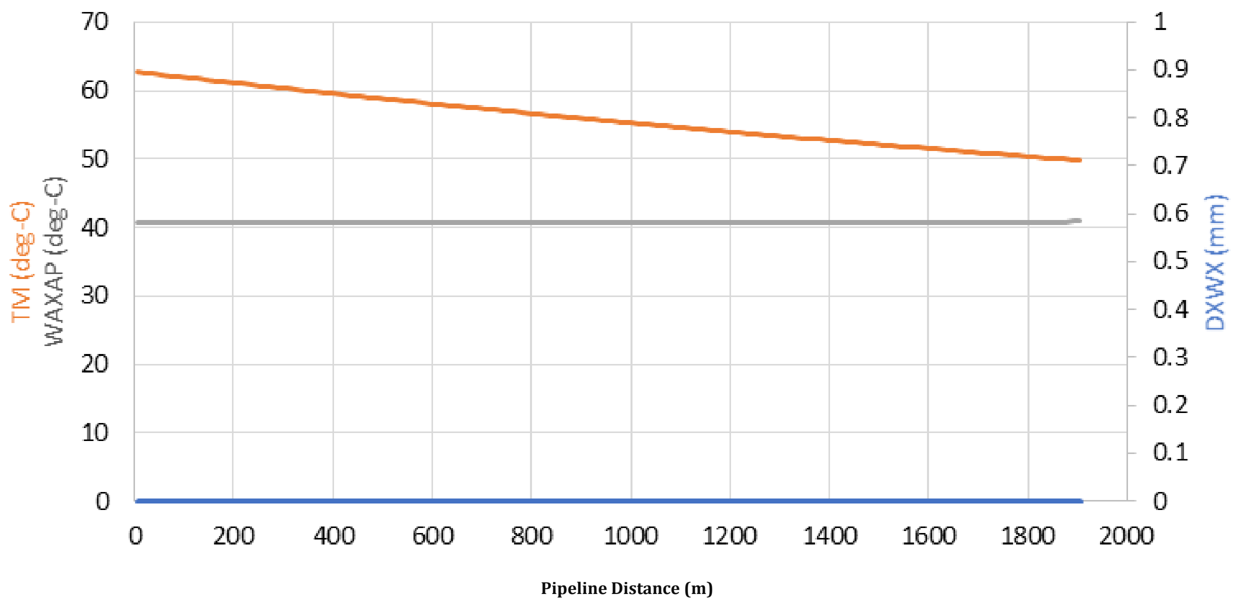

Figure 9. Wax deposition forming graph after 0.5 inch of rubber insulation applied.
The fluid temperature gradually decreases along the pipeline but remains above the wax appearance temperature (WAT). As a result, wax thickness stays at 0 mm throughout the simulated distance. This condition indicates that the applied insulation maintains a sufficient thermal margin to prevent wax formation along the pipeline.

Table 2. Parameter values of base case scenario.

Parameter	Pipeline distance of 400 m	Pipeline distance of 665 m
Fluid temperature	44°C	41°C
Heat loss	-18.9 kW/m	-3.3 kW/m
Wax thickness	0.14 mm	2.8 mm

Table 3. Parameter comparison of 0.5 in insulation effect at 400 m.

Parameter	Rubber Insulation	Concrete Insulation
Fluid temperature	62°C	59°C
Heat loss	-1.12 kW/m	-5.64 kW/m
Wax thickness	0 mm	0 mm
Pressure	165.6 psig	166.3 psig

Table 4. Parameter comparison of 0.5 in insulation effect at 500-700 m.

Parameter	Rubber insulation	Concrete insulation	Unit
Fluid temperature	62.03 – 61.73	58.81 – 57.36	°C
Heat loss	(-1.12) – (-1.11)	(-5.5) – (-5.3)	kW/m
Wax thickness	0	0	mm
Pressure	164.7–163.7	165.5–164.4	psig

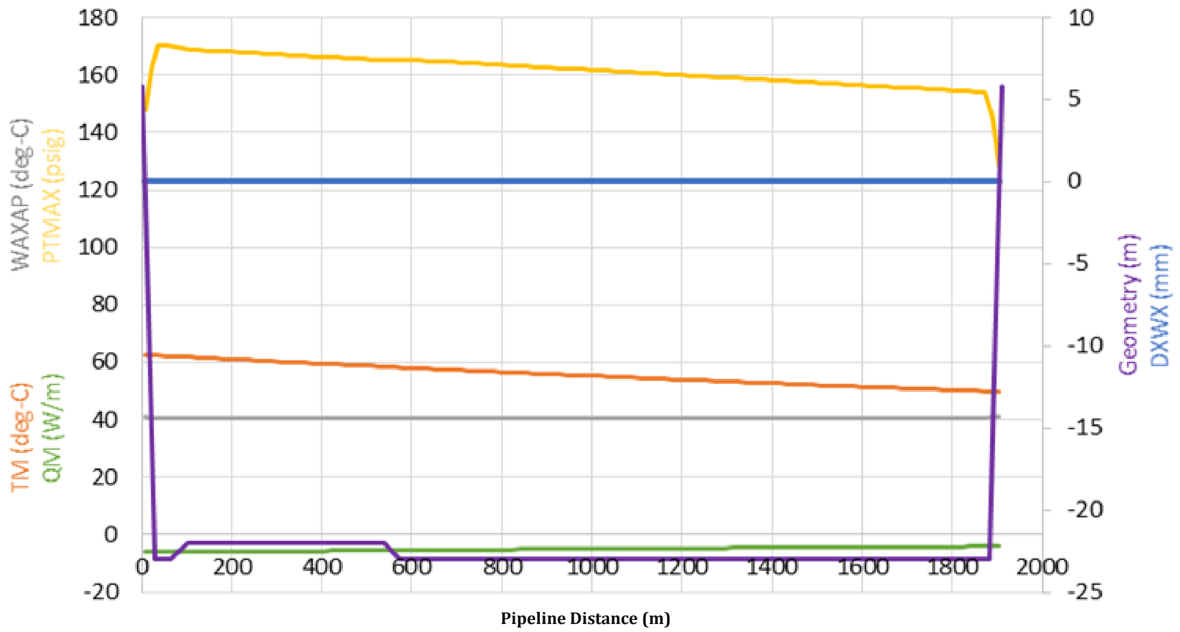

Figure 10. Condition of observed parameters after 0.5 inch of rubber insulation applied.
The fluid temperature remains above the Wax Appearance Temperature (WAT), while wax thickness stays at 0 mm along the pipeline. The heat-loss profile remains low and stable, indicating that the insulation helps maintain the thermal condition of the fluid. The pressure trend also shows no major fluctuation. These results confirm that 0.5-inch rubber insulation prevents wax deposition under the simulated condition.

formation in the pipeline. This can be investigated by examining wax thickness and heat loss, with a negative correlation between the two. For instance, if we investigate those parameters at a pipeline distance of 300 m, there is a difference in the results for insulation using rubber for each thickness, as well as for concrete along the pipe (Figures 11 and 12). We can also see that there is an unusual habit around 300 m to 600 m pipeline distance of pipe, which can be caused by a change of geometry in the pipeline that affects the observed parameters. In addition, wax deposition that formed early, before the temperature graph reached WAT, may be due to back pressure along the flowline, which cannot be interpreted in this experiment because of the software's limitations. This back-pressure phenomenon is considered common in deepwater pipelines. However, the pressure change was not particularly obvious. Therefore, it is necessary to directly observe the flow rate to determine whether production has increased. The oil flow rate in the initial scenario is 830.6 STB/D.

This indicates that the wax deposition has not interfered with production from the beginning to the study's time period (20th year). As a result, the applied solution does not significantly alter the production process. However, it is important to note that this paper considered only wax deposition, neglecting other forms of deposition, so other deposition mechanisms may occur along the pipeline in the field.

DISCUSSION

Although 0.1-inch rubber insulation already reduced the modeled wax thickness to 0 mm, the 0.5-inch rubber insulation provides a better thermal margin by maintaining a higher fluid temperature and lower heat loss along the pipeline. Therefore, 0.1-inch rubber insulation can be considered the minimum effective thickness in the simulation. In contrast, 0.5-inch rubber insulation is considered the most suitable option because it provides complete reduction in wax thickness and more stable thermal performance. The 1-inch rubber

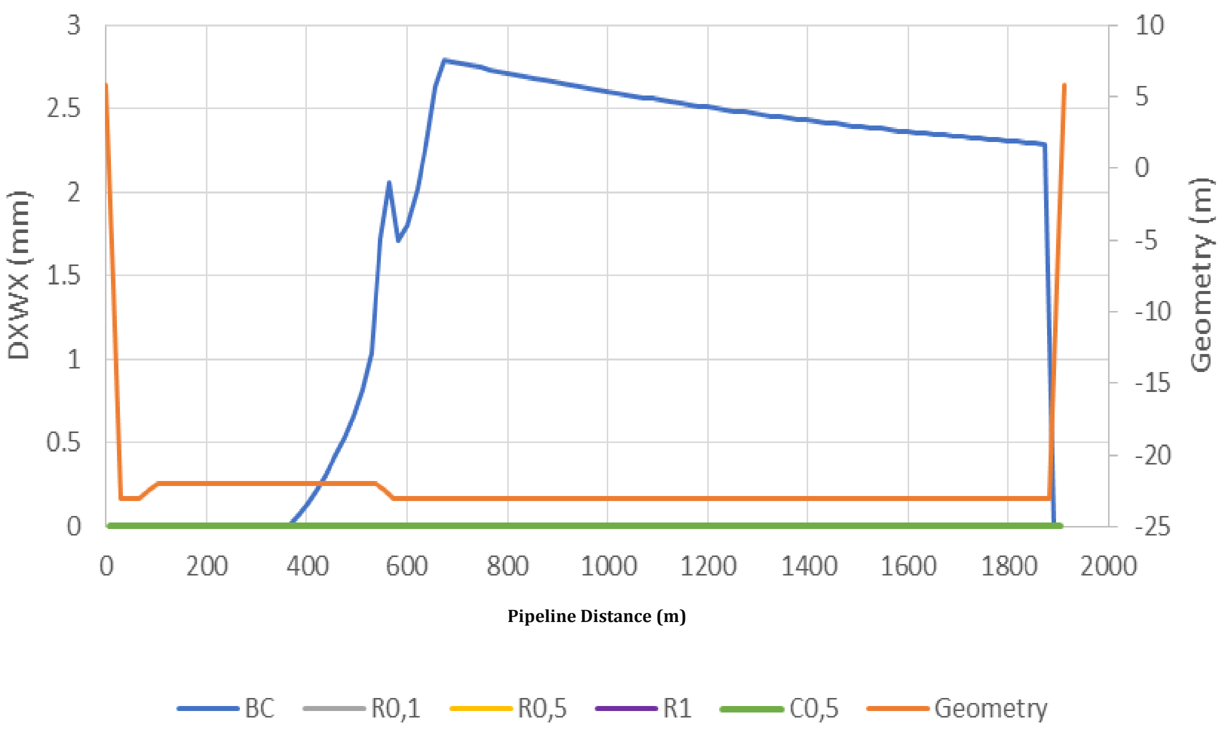

Figure 11. Wax thickness graph for each scenarios.
The base-case condition shows wax accumulation in the critical section, with the highest wax thickness occurring around the 600–700 m pipeline distance. In contrast, all insulation scenarios maintain wax thickness at 0 mm along the pipeline. This indicates that both rubber and concrete insulation effectively prevent wax deposition under the simulated conditions.

insulation produced a similar wax thickness response to the 0.5-inch case; therefore, the additional thickness may not provide a proportional improvement in the simulated results. Based on the input contained in the model within the OLGA software, where the parameters that can be input correlated to the flow rate are only the total flow rate, it is known that establishing the theoretical flow rate value in the software uses Equation 1 (Bendiksen, K. H., et al., 1991).

$$\psi = \left[\left(\frac{\partial R_s}{\partial p}\right)_T \frac{\partial p}{\partial t} + \left(\frac{\partial R_s}{\partial p}\right)_T \frac{\partial p}{\partial z}\frac{\partial z}{\partial t} + \left(\frac{\partial R_s}{\partial T}\right)_p \frac{\partial T}{\partial t} + \left(\frac{\partial R_s}{\partial T}\right)_p \frac{\partial T}{\partial z}\frac{\partial z}{\partial t}\right] (m_g + m_L + m_D) \quad (1)$$

where ψ, R_s, p, T, z, t, m_g, m_L, m_D, $\left(\frac{\partial R_s}{\partial p}\right)_T$, and $\left(\frac{\partial R_s}{\partial T}\right)_p$, are the calculated flow term in the OLGA model, the solution gas ratio, the pressure, the temperature, the axial distance along the pipeline, the time, the gas mass flow rate, the liquid mass flow rate, the dispersed-phase mass flow rate, the change of R_s with respect to pressure at constant temperature and teh change of R_s with respect to temperature at constant pressure, respectively.

Using this approach, the simulated flow rate values for various phases are obtained. Matching the value obtained from the simulation with the original data is important to assess the accuracy of the experimental result.

Matching is obtained using the flow rate parameter and the MAPE method. The actual field data for this parameter is 768.91 STB/D; the modelling findings show a flow rate parameter of 830.61 STB/D. Table 1 shows that the simulation model is classified as good or accurate based on its match with field data, as determined by the MAPE classification, as illustrated in the Equations 2 through 4.

$$\frac{1}{1}\sum_{x=1}^{n}\frac{|768{,}91 - 830{,}61|}{768{,}91} \times 100\% = 8{,}02\% \quad (2)$$

$$\frac{1}{1}\sum_{x=1}^{n}\frac{|98779{,}08 - 100149{,}75|}{98779{,}08} \times 100\% = 1{,}39\% \quad (3)$$

$$\frac{1}{1}\sum_{x=1}^{n}\frac{|1537 - 1568{,}15|}{1537} \times 100\% = 2{,}03\% \quad (4)$$

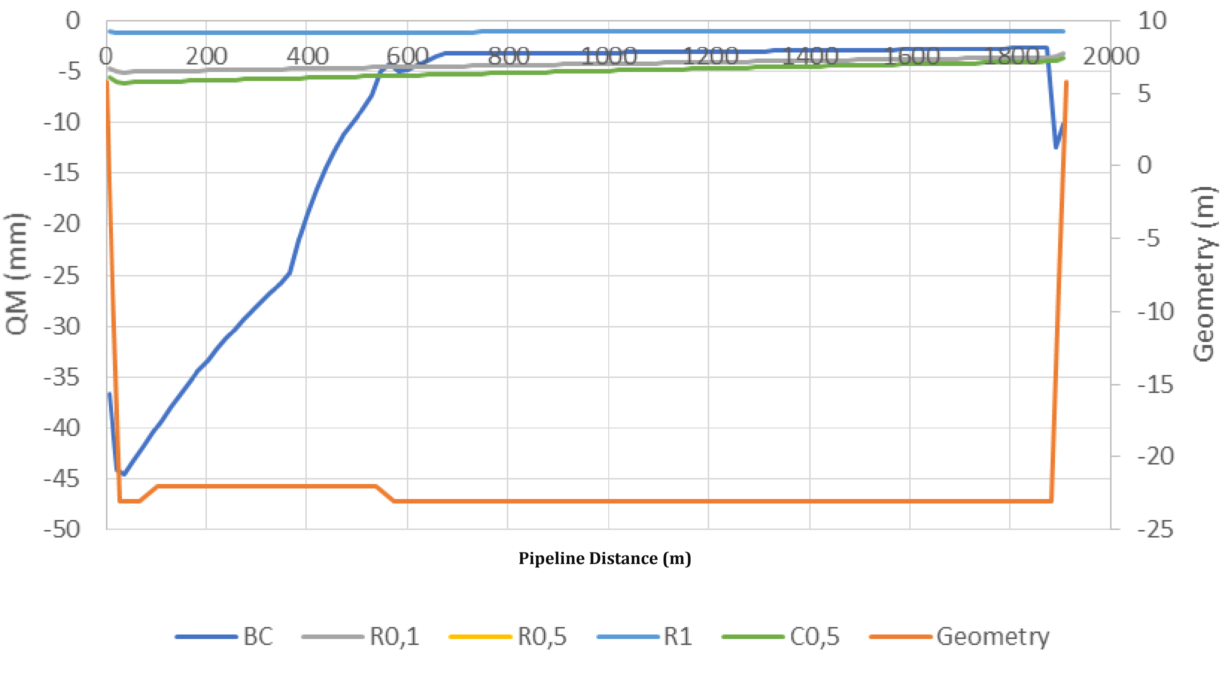

Figure 12. Heat loss graph for each scenarios.
The base-case condition shows higher heat loss along the pipeline, especially in the early section, which supports the decrease in fluid temperature and promotes wax deposition. After insulation is applied, the heat-loss values become lower and more stable. This indicates that both rubber and concrete insulation reduce thermal energy loss and help maintain the fluid temperature above the wax appearance temperature (WAT).

The error value in the experiment results for each flow rate is considered acceptable, as it is still below 10%. Errors that do not reach 0% are caused by varying data assumptions and by random data collection at the applied scale. Meanwhile, modelling is carried out with a rough time step of 15 minutes to 1 day over a 20-year simulation. As a result, some data may not be properly recorded.

CONCLUSION

The simulation results show that insulation affects fluid temperature, heat loss, and wax thickness. Applying insulation reduces heat loss, maintains the fluid temperature above the wax appearance temperature (WAT), and reduces wax accumulation along the pipeline. All insulation scenarios, including rubber insulation with thicknesses of 0.1 inch, 0.5 inch, and 1 inch, as well as concrete insulation with a thickness of 0.5 inch, reduced wax thickness by 100%. The 0.1-inch rubber insulation can be considered the minimum effective thickness in the simulation. In contrast, the 0.5-inch rubber insulation is considered the most suitable option because it provides complete reduction in wax thickness and more stable thermal performance. The 1-inch rubber insulation did not show a proportional improvement compared with the 0.5-inch case. The application of insulation did not significantly affect the flow rate because the initial wax thickness in the base case was relatively small.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to Universitas Pertamina for the support, facilities, and resources provided throughout this research.

DECLARATIONS

Author contribution

All authors contributed equally to the conception, research, analysis, and writing of this manuscript. All authors have read and approved the final version of the manuscript for publication.

Funding statement

None

Competing interest

The authors declare that there are no conflicts of interest related to this study or the publication of this manuscript.

The use of AI or AI-assisted technologies

None

GLOSSARY OF TERMS AND SYMBOLS

Terms & Symbol	Definition	Unit
WAT	Wax appearance temperature, the temperature at which wax begins to crystallize from hydrocarbon fluid	°C
TM	Mixture temperature, the temperature of the fluid mixture flowing inside the pipeline	°C
QM	Heat loss, the rate of thermal energy loss from the fluid to the surroundings along the pipeline	kW/m
DXWX	Wax deposition thickness parameter in OLGA simulation representing wax layer formation	mm / in
Q	Flow rate of produced fluid in the pipeline system	STB/D, lb/s
WC	Water cut, percentage of water content in produced fluid	%
ΔT	Temperature difference between fluid and surroundings along the pipeline	°C
k	Thermal conductivity, ability of material to conduct heat	W/m·K
ρ	Density, mass per unit volume of fluid	kg/m³
μ	Dynamic viscosity, resistance of fluid to flow	cP
P	Pressure inside the pipeline system	psig
$PTMAX$	Maximum pressure parameter observed along the pipeline	psig
$Flow\ Assurance$	Strategy to ensure continuous flow of hydrocarbons from reservoir to surface without blockage	-

$Wax\ Deposition$	Formation of solid wax crystals due to temperature drop below WAT	-
$Insulation$	Method to maintain fluid temperature by reducing heat loss in pipeline	-
$OLGA$	Dynamic multiphase flow simulator used for pipeline flow assurance analysis	-

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