Scientific Contributions Oil & Gas, Vol. 48. No. 3, October: 149 - 158

SCIENTIFIC CONTRIBUTIONS OIL AND GAS

Testing Center for Oil and Gas

LEMIGAS

Journal Homepage:http://www.journal.lemigas.esdm.go.id

ISSN: 2089-3361, e-ISSN: 2541-0520

Introducing Cork as an Alternative Insulator to Polyurethane in Field X Production Pipelines: A Simulation Study

Astra Agus Pramana[1], Adhikara Paramayoga[1], Utami Farahdibah[1], and M. Kurniawan[2]

Universitas Pertamina
Teuku Nyak Arief Street, South Jakarta, 12220, Indonesia

[2]Testing Center For Oil and Gas LEMIGAS
Ciledug Raya Street No. 10, Cipulir, Kebayoran Lama District, South Jakarta City, 12230, Indonesia.

Corresponding author: swinardhi@itb.ac.id.

Manuscript received: June 30th, 2025; Revised: July 29th, 2025
Approved: August 13th, 2025; Available online: October 16th, 2025; Published: October 16th, 2025.

ABSTRACT - This study investigates the role of insulation in mitigating wax deposition and compares the performance of two insulation materials, cork and polyurethane, when it is applied to production pipelines. The objective is to evaluate their effects on wax layer thickness, thermal energy retention within the production pipe, and reservoir fluid temperature relative to the Wax Appearance Temperature (WAT). The methodology involves fluid characterization using Multiflash PVT Modeling & Flow Assurance software, combined with dynamic multiphase flow simulations to model production pipelines and assess flow assurance performance. The novelty of this research lies in introducing cork as an alternative insulation material to polyurethane, providing new insights into sustainable and effective solutions for wax deposition control.

Keywords: wax deposition, insulation, polyurethane, cork, wax appearance temperature (WAT).

How to cite this article:

Astra Agus Pramana, Adhikara Paramayoga, Utami Farahdibah, and M. Kurniawan, 2025, Introducing Cork as an Alternative Insulator to Polyurethane in Field X Production Pipelines: A Simulation Study, Scientific Contributions Oil and Gas, 48 (3) pp. 149-158. DOI org/10.29017/scog.v48i3.1871.

INTRODUCTION

The global demand for crude oil and natural gas continues to rise, driving oil and gas companies to explore deeper offshore reserves. During the fluid lifting process, a significant decrease in fluid temperature occurs as the fluid travels from the reservoir to the surface, primarily due to the colder subsea environment. This temperature drop promotes wax crystallization and deposition, which may obstruct production pipelines if the minimum operating temperature is not maintained. Therefore, maintaining thermal stability in subsea pipelines is critical to ensure continuous production and to minimize flow assurance risks. Several strategies have been developed to mitigate wax deposition, one of which is the use of thermal insulation. For decades, insulation has been applied in production pipelines to reduce heat loss, delay wax appearance, and maintain flow efficiency. The effectiveness of this method, however, depends on the insulation material selected and the specific operating conditions of each field. A proper evaluation of insulation materials is therefore essential to ensure their suitability for field applications. This research investigates the effectiveness of insulation in production pipelines through dynamic simulations of fluid behavior. Specifically, it compares two insulation materials: polyurethane, which is widely used in the oil and gas industry, and cork, which has rarely been evaluated in this context despite its promising thermal and environmental properties. The study aims to assess the performance of these materials in terms of wax layer thickness, thermal energy retention, and reservoir fluid temperature relative to the Wax Appearance Temperature (WAT), using the dynamic multiphase flow simulator.

Unlike previous studies that mainly focused on conventional insulators such as polyurethane, this research introduces cork as an alternative insulation material in production pipelines. Cork has rarely been evaluated in the oil and gas sector, particularly for subsea production systems, even though it is lightweight, environmentally friendly, and has promising thermal properties. Therefore, this study provides a novel comparison between polyurethane and cork in terms of their effectiveness in reducing wax deposition and maintaining thermal stability, using the simulator for dynamic flow assurance evaluation.

METHODOLOGY

Data

The oil being used in this experiment has hydrocarbon and natural gas composition shown in the table 1 and 2 respectively below. The %mass of C6 to C9 is 0 or not found. It starts appearing at C10 with 0.01% to C15+ at 95.78%, where the number of compositions after C15 is added up and concluded at C15+. Meanwhile, its natural gas composition are of CO_2, N_2, and mostly methane gas of 95.05%.

Table 1. Hidrocarbon composition

Component	**% Mass**
C6 Hexane	0.00
C7 Heptane	0.00
C8 Octane	0.00
C9 Nonane	0.00
C10 Decane	0.01
C11 Undecane	0.01
C12 Dodecane	0.47
C13 Tridecane	1.57
C14 Tetradecane	2.16
C15+ Pentadecane +	95.78

Table 2. Natural gas composition

Component	% Mole
H_2S	0
CO_2	2.66
N_2	0.35
Methane	95.05
Ethane	1.12
Propane	0.44
iso-Butane	0.10
n-Butane	0.04
iso-Pentane	0.02
n-Pentane	0.01
Hexane	0.01
Heptane +	0.20

Table 3. Paraffin composition

Component	**% Mass**
N. Paraffins	51.67
Iso. Paraffins	1.47

Moreover, its paraffin composition is shown in Table 3 above, and its total wax content is 53.14%. This component is the main cause of the formation of wax deposition on the wall of production pipes.

Table 4. Fluids specific gravity

Parameter	
Oil	0.8560
Water	10.143
Gas	0.7206

Tabel 5. Production pipe characteristics

Parameter	**Unit**	
OD	in	16
Pipe Thickness	in	0.437
Pipe Length	in	1948
Depth of Pipe	m	21.33
Inlet Pressure	psig	150

Outlet Pressure	psig	120
Inlet Temperature	°F	145
Outlet Temperature	°F	126
Pipe Material		Carbol Steel
Density	kg/m3	7850
Heat Capacity	W/(m.°C)	500
Thermal Conductivity	J/(kg.°C)	50

The 1948 meter long production pipe applied to this field is made of carbon steel with an outer diameter of 16 inches and thickness of 0.5 in. The pressure and temperature at the inlet show greater values than the outlet.

Table 7. Ambience velocity

Ambience Data	
Wind Velocity	10 ft/s
Water Flow Velocity	3 ft/s

Ambience temperature has a large influence in decreasing the fluid temperature inside the production pipe. The big temperature gap between the inlet fluid temperature of 145°F and the ambience low seabed temperature of 77°F is causing temperature decrease. At certain distance from the inlet, the inside fluid temperature will be passing its WAT of 100°F and therefore initiating the formation of wax deposit.

Table 8. Production data

Parameter	Unit	
Gas/Oil Ratio	scf/stb	1998.93
Water Cut	%	99.23
Total Massflow Rate	lb/s	409.52

Table 9. Characteristics of cork insulation

Parameter	Unit	
Insulation Material		Cork
Density	kg/m3	110
Heat Capacity	W/(m.°C)	1600
Thermal Conductivity	J/(kg.°C)	40

To reduce the temperature decrease, two insulation products, namely cork and polyurethane, are applied separately along the production pipe from Platform A to Platform B, with the thickness of the installed insulation being 1 inch without an outer layer jacket. Table 9 and Table 10 above show that there is a quite significant difference in thermal conductivities of these two insulation products. Cork has thermal conductivity of 0.04 W/m·K and specific heat of 1800 J/(kg.°C) while polyurethane has lower values which are 0.025 W/m·K and 1400 J/(kg.°C) respectively. This means that polyurethane is a slightly better insulator but can store less heat per kg.

Table 10. Characteristics of polyurethane insulation

Parameter	Unit	
Insulation Material		Polyurethane
Density	kg/m3	65
Heat Capacity	W/(m.°C)	1570
Thermal Conductivity	J/(kg.°C)	0.83

Method

In Figure 1, it shows the steps in the research carried out, starting with a literature study from papers, books, journals, etc. to support the data used in the research. Other research data such as fluid and pipeline data are supporting data from the company. Before the simulation is carried out, the reservoir fluid data is entered into the PVT Modeling & Flow Assurance software to obtain the PVT table and wax table that will be needed in the production simulation process.

Then the pipeline data is put into the Dynamic Multiphase Flow software along with several other parameters such as ambience temperature as well as pipe diagrams and its characteristics. The next step is to simulate the insulation case with the help of Dynamic Multiphase Flow software. This simulation was carried out to determine changes in the thickness of the wax deposits and fluid temperature which is supported by several parameters such as the thickness of polyurethane and cork as an insulator to determine the thickness of wax deposits in this pipeline. This research will later discuss the simulation results of the two insulated pipelines respectively by using the existing data.

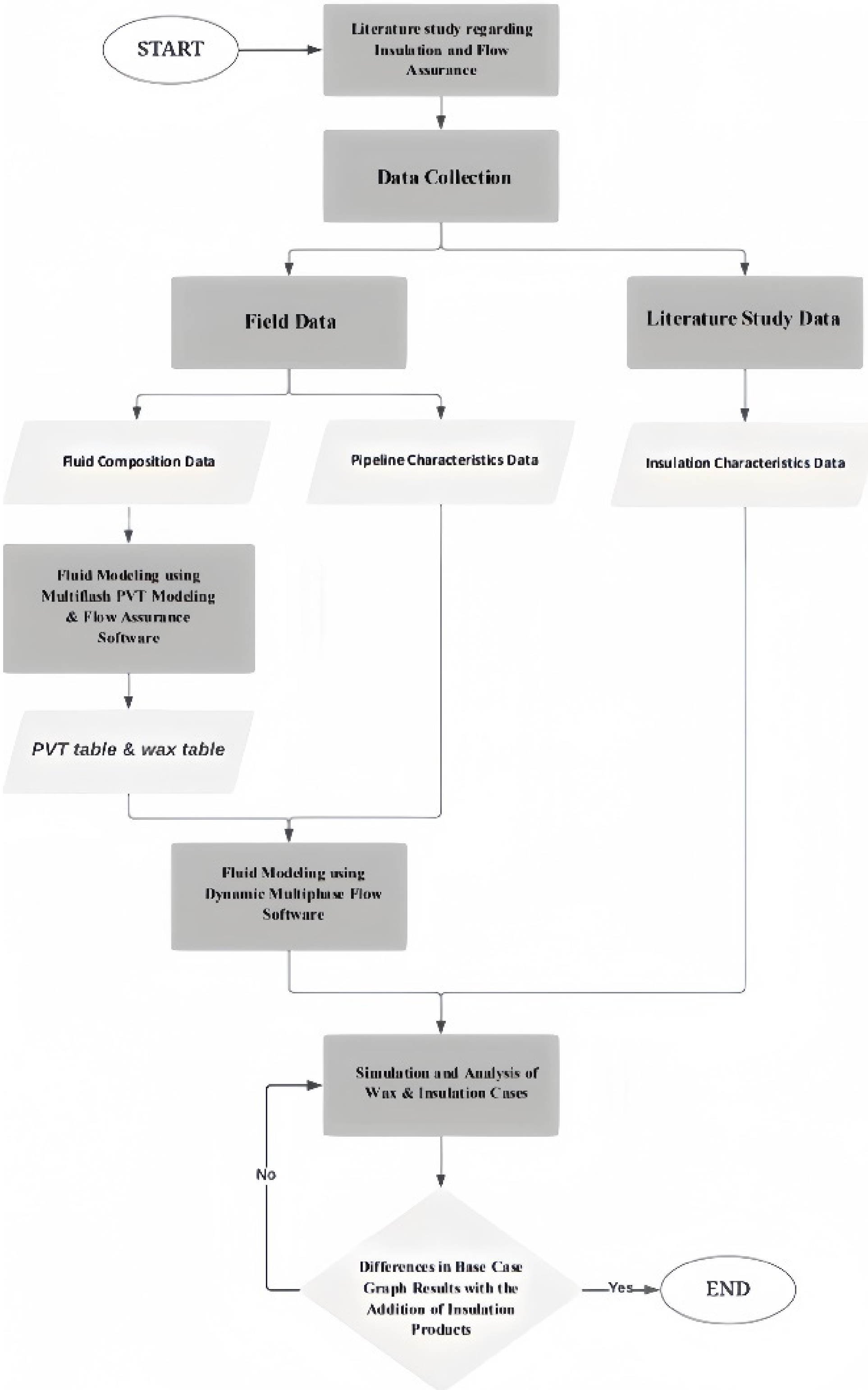

Figure 1. Research flow chart

 | DOI org/10.29017/scog.v48i3.1871

RESULT AND DISCUSSION

Results

Temperature change, as an indicator of heat loss, was simulated and plotted at Figure 2 for 800 days. Cork insulation was applied to the pipes starting from the beginning of the second year (>365 days) after previously not being applied in the production pipes. The results of the simulation are shown in Figure 2.

It can be seen in Figure 2 above that the blue curve shows the change in temperature of the fluid before and after the Cork is applied. The temperature began at 80°F, then it started increasing on day 365 and the temperature stabilized at 87°F on day 730. The increase from 80°F to 87°F means the cork insulation effectively retained more heat in the pipeline. However, since 87 °F is still below the WAT (100 °F), wax formation can still occur, though likely less severe than before. In short, the temperature rise demonstrates improved thermal efficiency but not yet enough to prevent wax precipitation completely.

In Figure 3, it can be seen that fluid temperature (green curve) decreases and reaches the WAT point at pipe length of 960.8 meters. The fluid temperature then it decreases to below 90°F at 1900m. The yellow curve represents the thickness of the wax deposits which started at 800m and increases up to the thickest point of 0.009 inches at pipe length of 1165 m.

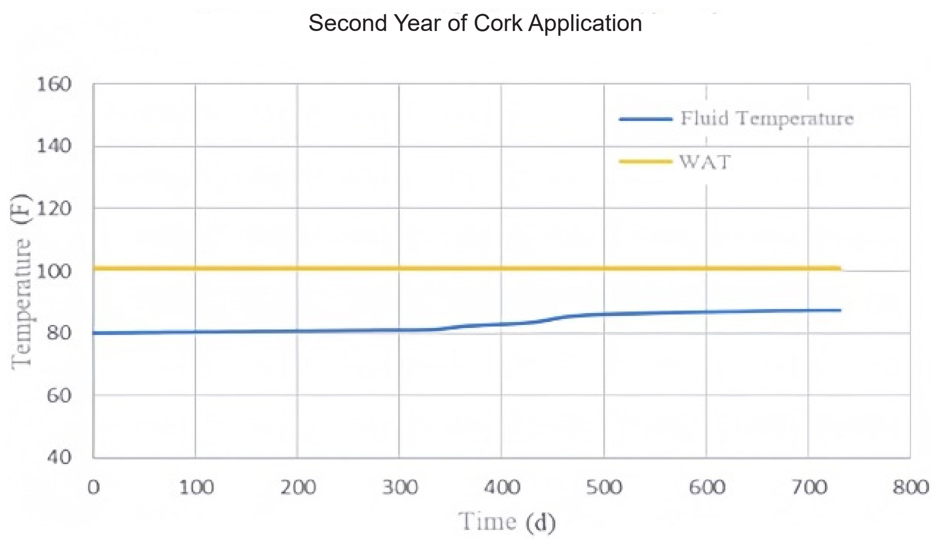

Figure 2. Changes in fluid temperature when cork insulation is applied in the second year (>365 days).

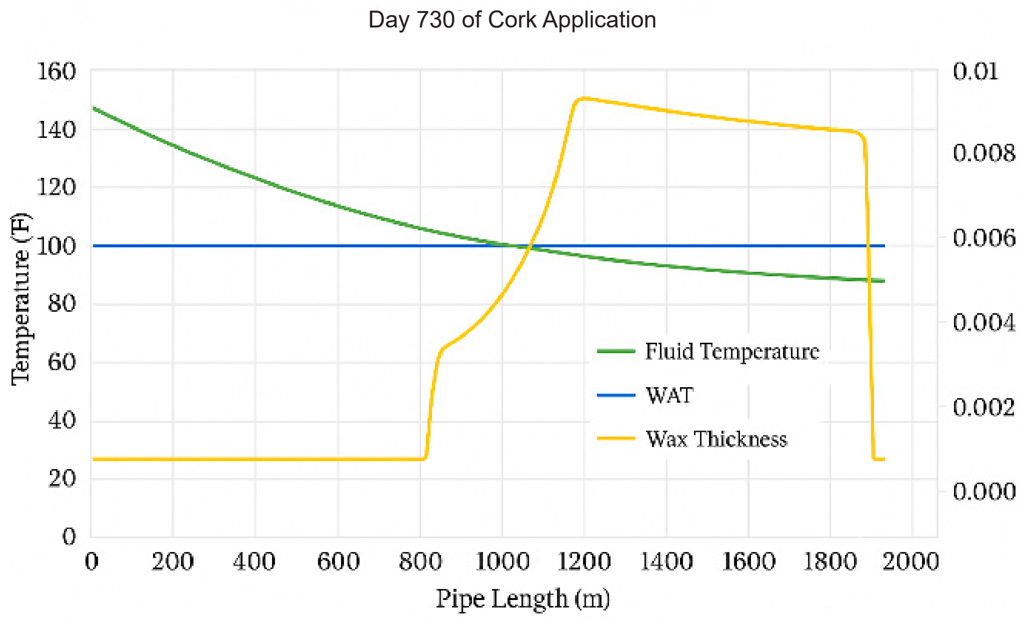

Figure 3. Simulation curve with cork insulation at day 730

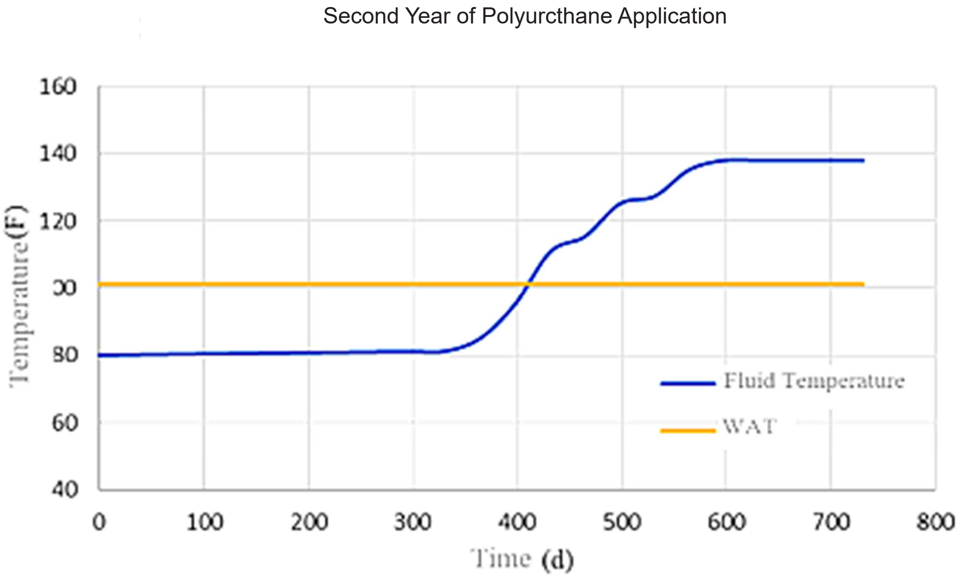

Figure 4. Changes in fluid temperature when polyurethane insulation is applied in the second year

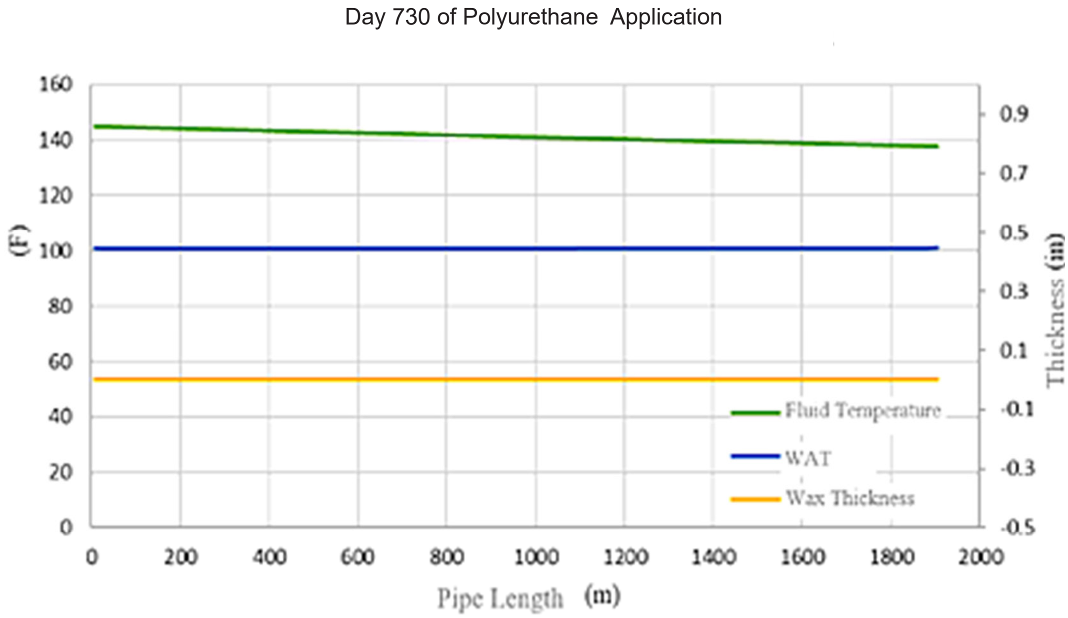

Figure 5. Simulation curve with polyurethane insulation at day 730

Similar to the previous simulation, the second insulator, namely Polyurethane or PUR, was applied to the pipe starting from the beginning of the second year after previously not having any application in the production pipe. The results of the simulation are shown in the Figure 4.

Figure 4 above shows changes in the fluid temperature graph when PUR insulation was applied in the second year, with data taken at the end of the production pipe or at the outlet. The blue curve shows the change in temperature of the fluid before and after PUR is applied. The fluid temperature changed significantly, which previously was still at 80 F, gradually increased, and on day 730 the temperature stabilized at 137 F, exceeding the WAT value shown in the yellow curve. After conducting a 730-day simulation using PUR as an insulator, the green curve shows that the fluid temperature remains above the WAT value. The WAT, represented by the blue curve, is 101 F, below which wax molecules begin to change phase and form precipitates. At a pipe length of 652 m, the fluid temperature is approximately 141 F. This indicates that PUR effectively maintains temperature stability and prevents the formation of wax deposits on the walls of the production pipe, as shown by the yellow curve.

Discussions

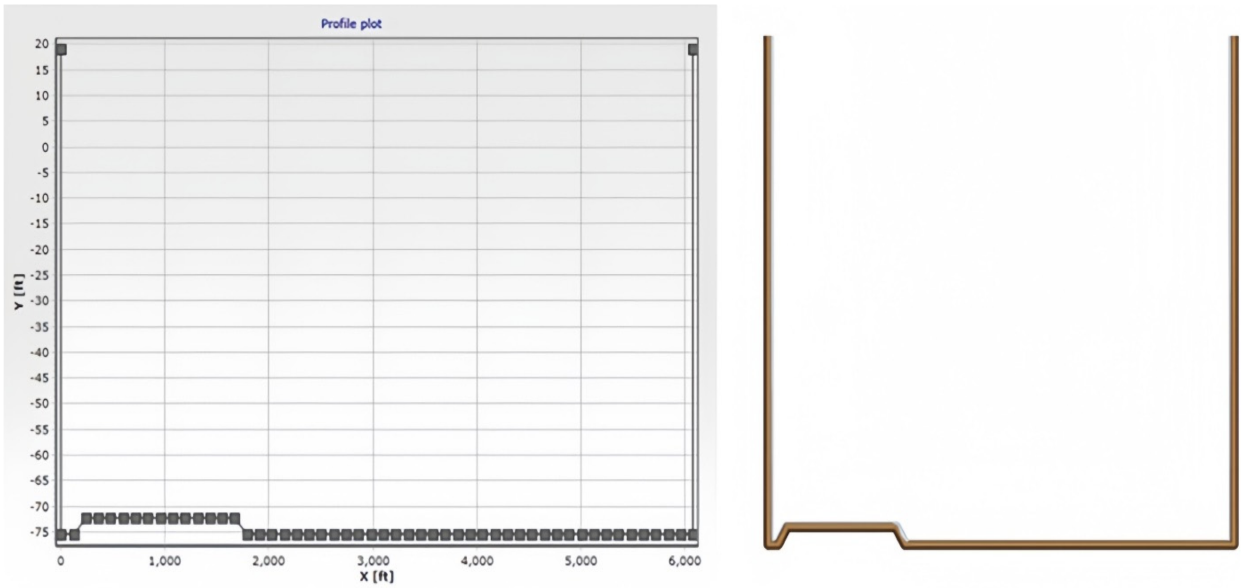

Figure 6. Production pipeline scheme

Figure 7. Production equipment scheme

The problem observed in this research, namely in reservoir fluid transportation in Field X, was the

formation of paraffin deposits on the walls of the production pipe for 730 days. This is caused by the high pour point value and the fluid temperature which touches the WAT value so that paraffin crystals form during the production process. The production equipment schematic shown in Figure 6 shows that the research was carried out at 2 measurement points, namely at the inlet and outlet. Meanwhile, Figure 7 shows a schematic of the production activities of this field on 2 platforms, namely Platform B as the outlet and Platform A as the inlet. Both platforms are installed at the same height, namely 19 feet above sea level, with a seabed depth of 21.33 meters below sea level. Changes in the shape of the pipeline from a pipe length of 67 meters which rose slightly to 539 meters which began to decline back to its original position because the production pipe was installed following the uneven geological shape of the seabed. As shown in Figure 8 above, after the production simulation test was carried out, a wax deposit with a thickness of 2.10974e-008 inches was formed at the 745th second along the pipe length between 467 and 912 meters. This precipitate formed because the wax content in the hydrocarbons was relatively high. The small thickness of the deposit indicates that the paraffin compounds were still in the binding stage between paraffin molecules, which had begun to change phase as the fluid temperature started to decrease. The simulation was then continued for a period of 730 days (approximately two years) to observe changes in the thickness of the wax deposits along the production pipe. At this stage, the insulation product had not yet been applied to the production pipe, allowing for a comparison of the wax deposit curves before and after the installation of the insulator.

The blue curve in the Figure above shows that on day 730, the WAT value of the fluid was 101°F. It can be seen that at a pipe length of 652 meters, the fluid temperature reached the WAT point and continued to decrease, resulting in the formation of wax deposits on the production pipe walls. The yellow curve represents the thickness of the wax deposits on the pipe walls, with the maximum thickness being 0.009 inches at a pipe length of 711 meters. At this thickness, the sediment formed would have minimal influence on the reservoir fluid's flow rate.

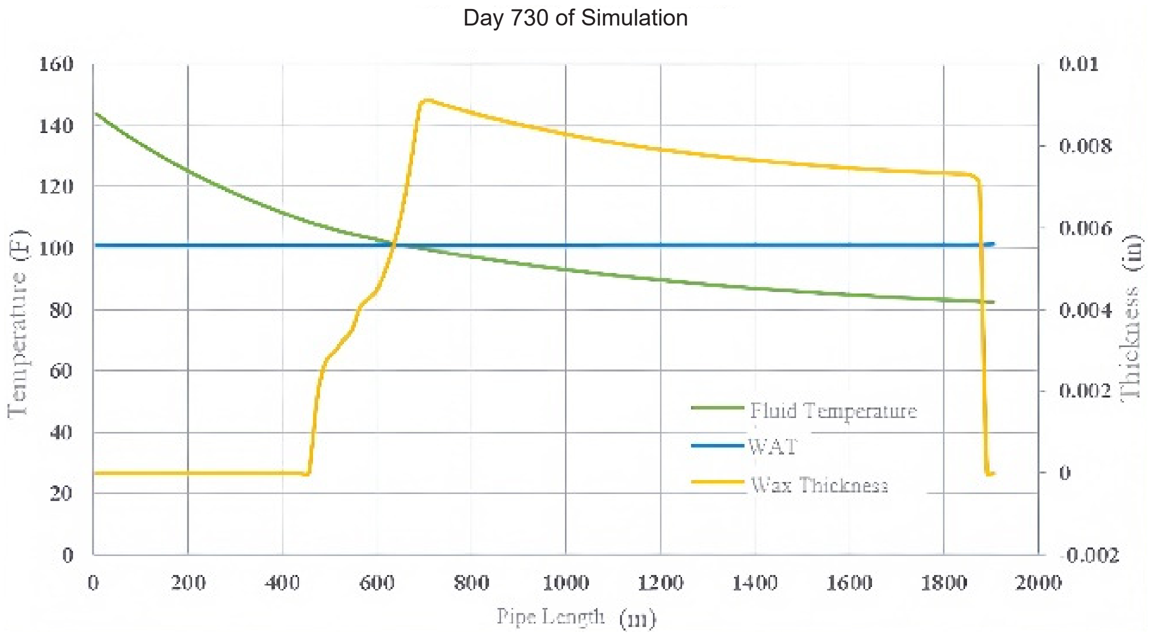

Figure 9. Day 730 simulation curve

A significant decrease in fluid temperature toward the WAT value causes the paraffinic molecules in hydrocarbons to begin changing phase and bonding with each other, resulting in crystallization. This phenomenon is illustrated by the yellow curve above, which shows that as the fluid temperature decreases, the wax deposit thickness curve increases significantly. This indicates that solid paraffin molecules start to precipitate and adhere to the inner walls of the production pipe.

The first simulation, shown in Figure 3, represents the application of Cork insulation to the production pipe. It shows that wax deposits begin to form along approximately 454 meters of the pipe. However, the thickness of the wax deposits remains constant at 0.009 inches. The Cork insulation product applied to the Field X production pipes can only maintain the fluid temperature for a relatively short period. Therefore, it can be concluded that this insulation product is less effective in preventing wax deposition, as it fails to maintain the fluid temperature above the WAT value.

The second simulation, which involves the application of Polyurethane (PUR) as an insulator, is shown in Figure 5. The results indicate that PUR successfully maintains temperature stability and prevents the formation of wax deposits on the walls of the production pipe, as illustrated by the yellow curve. The fluid temperature curve remaining above the WAT after the application of the PUR product confirms its effectiveness in maintaining thermal stability. This performance is due to the closed-cell structure of PUR insulation, which allows heat energy within the pipe to be retained and prevents its dissipation to the surroundings.

As discussed in the theoretical background, wax deposition is highly influenced by temperature. When the temperature falls below the WAT value, deposits begin to form, which reduces fluid mobility. However, this process is also affected by other parameters such as flow velocity, wax content, and frictional forces. Based on the simulation results, it can be concluded that PUR effectively minimizes heat loss and maintains the fluid temperature above the WAT value, thereby preventing the formation of wax deposits in the production pipe.

CONCLUSION

A production simulation was carried out at Field X for 730 days with the following conclusion: 1). Wax deposits on pipes with Cork insulation are formed with the highest thickness remaining the same as without the insulation applied, namely 0.009 inches, with a change in the position of the deposit formation which moves as far as 454 meters with the highest thickness being 1165 meters. The fluid temperature in the second year was stable at

87 F below WAT; 2). The PUR insulation product was successful in not forming wax deposits on the production pipe walls with the fluid temperature not touching the WAT and succeeded in maintaining a stable fluid temperature above the WAT value of 137 F on the 730th day.

In summary, polyurethane is a better insulator, had been used commercially and can avoid the formation of wax deposit. Cork, on the other side, is a weaker insulator and cannot avoid formation of wax deposit, though it has higher heat conductivity. A deeper research related to heat capacity and thermal conductivity is needed with many promising materials

ACKNOWLEDGEMENT

The authors would like to acknowledge Universitas Pertamina for the support and facilities provided during this research.

GLOSSARY OF TERMS

Symbol	Definition	Unit
WAT	Wax Appearance Temperature	
H_2S	Hydrogen Sulfide	
CO_2	Carbon Dioxide	
N_2	Nitrogen	
PUR	Polyurethane	
WAXAP	Wax Appearance Temperature	
DXWX	Thickness of wax layer deposited at wall	
QM	Heat loss per unit length from pipe wall to fluid	
QL	Volumetric flow rate oil	
TM	Fluid temperature	

REFERENCES

Ajayi, O.E. (2013). Modelling of controlled wax deposition and loosening in oil and gas production systems, Norwegian University of Science and Technology, Trondheim.

Burger, E., Perkins, T. & Striegler, J. (1981). Studies of wax deposition in the Trans Alaska Pipeline, SPE Journal of Petroleum Technology, pp. 1075–1086, SPE. DOI: 10.2118/8788-PA.

Cao, K., Pojtanabuntoeng, T., Esmaily, M. & Thomas, S. (2022). A review of corrosion under insulation: A critical issue in the oil and gas industry.

Cengel, Y.A. (2002). Heat transfer, second edition: A practical approach, McGraw-Hill Higher Education.

Chinwuba, I., Vivian, O. & Princewill, O. (2016). Evaluation of flow assurance in onshore production facilities in the Niger Delta.

Huan, Z., Zheng, S. & Fogler, H. (2015). Wax deposition: Experimental characterizations, theoretical modeling, and field practices, Taylor and Francis Group, USA.

Leiroz, A.T. & Azevedo, L.F.A. (2005). Studies on the mechanisms of wax deposition in pipelines, Offshore Technology Conference.

Kargarpour, M.A., Dandekar, A., Jain, A.K., Sharma, K., Negi, D.S., Sarkar, A., Tewari, D.C. & Theyab, M.A. (2017). Study of fluid flow assurance in hydrocarbon production – Investigation wax mechanisms, Journal of Petroleum Exploration and Production Technology. DOI: 10.18744/PUB.002061.

Karono, R. M. (2015). Hydrate Mitigation For Deep Water And Long Distance Pipeline Â€“Flow Assurance Approach. Scientific Contributions Oil and Gas, 38(2), 95-104. https://doi.org/10.29017/SCOG.38.2.544.

Masela, D., Subekti, H., & Candra, A. D. (2023). Pengaruh Perubahan Diameter Pipa dan Jenis Insulasi Terhadap Pressure Drop dan Heat Loss di Lapangan Panas Bumi. Lembaran publikasi minyak dan gas bumi, 57(3), 133-140. https://doi.org/10.29017/LPMGB.57.3.1597.

Matzain, A., Apte, M.S., Zhang, H., Volk, M., Redus, C.L., Brill, J.P. & Creek, J.L. (2001). Multiphase flow wax deposition modeling, ETCE, Houston. DOI: 10.1115/ETCE2001-17114.

Miranda, E.N. & Vidales, A.M. (1998). A relation between the thermal conductivity and the specific heat from entropy considerations, Universidad Nacional de San Luis.

Montero, F. (2020). Wax deposition analysis for oil and gas multiphase flow in pipelines.

Morris, W., Kaplan, K.B. & Brown. (1979), New technology in insulated offshore pipelines – Design and installation.

Olajire, A.A. (2021). Review of wax deposition in subsea oil pipeline systems and mitigation, Chemical Engineering Journal Advances. DOI: 10.1016/j.cejadv.2021.100144.

Phillips, D.A., Forsdyke, I.N., McCracken, I.R. & Ravenscroft, P. (2011). Novel approaches to waxy crude restart: Part 2 – An investigation of flow events following shutdown', Journal of Petroleum Science and Engineering. DOI: 10.1016/j.petrol.2011.04.003.

Rosvold, K. (2008). Wax deposition models', Norwegian University of Science and Technology, Trondheim.

Rygg, O.B., Rydahl, A.K. & Ronningsen, H.P. (1998). Wax deposition in offshore pipeline ja systems, North American Conference on Multiphase Technology, Banff.

Sierra-Perez, J., Gracie-Perez, S., Blanc, S., Gabarrell, X., Rives, & Boschmonart. (2017) The use of forest-based materials for the efficient energy of cities: Environmental and economic implications of cork as insulation material'. DOI: 10.1016/j.scs.2017.12.008.

Siljuberg, M.K. (2012). Modelling of paraffin wax in oil pipelines, Norwegian University of Science and Technology, Trondheim.

Singh, P., Venkatesan, R. & Fogler, H. (2000). 'Formation and aging of incipient thin film wax oil gels', AIChE, vol. 46, pp. 1059–1074. DOI: 10.1002/aic.690460517.

Theyab, M.A., 2017, 'Study of fluid flow assurance in hydrocarbon production – Investigation wax mechanisms', London South Bank University, London. DOI: 10.18744/PUB/002061.

Theyab, M.A. (2018). Fluid flow assurance issues: Literature review', Scientific Federation Journal of Petroleum, pp. 1–11, Ministry of Higher Education and Scientific Research of Iraq, Iraq.

Tony, B. (2025). Transient Simulation to Analyze Wax Deposition and Flow Pattern Behavior Along Tubing Under Esp Installation and Gassy Well Condition. Scientific Contributions Oil and Gas, 48(3), 51-60.

Vandragi, S., Lemma, T., Mujtaba, S. & Pedapati, S.(2021). Determination and analysis of leak estimation parameters in two-phase flow pipelines using OLGA multiphase software, Department of Mechanical Engineering, Universiti Teknologi petronas. DOI: 10.1016/j.suscom.2021.100564.

Venkatesan, R. & Creek, J.L. (2007). Wax deposition during production operations: SOTA', Offshore Technology Conference. DOI: 10.4043/18798-MS.

Xing, L. & Yeung, H. (2011). Investigation of slug flow induced forces on pipe bends applying Star-OLGA coupling', 15th BHR Group Multiphase Production Technology International Conference, pp. 327–344.

Zhu, T., Walker, J.A. & Liang, J. (2008). Evaluation of wax deposition and its control during production of Alaska North Slope oils', University of Alaska Fairbanks, Kansas. DOI: 10.2172/963363.