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Chemical Approach to Control Hydrate in Offshore Gas Production Facilities

Kate Odafe Idolor[1]
[1]Madonna University, Nigeria

Oluwaseun Francis Owolabi[2]
[2]Gateway ICT Polytechnic, Saapade, Nigeria

Abstract:- Hydrate formation presents a significant operational challenge in offshore oil and gas production, primarily due to the potential formation of hydrate plugs which obstruct fluid flow, thereby posing serious flow assurance risks. Additionally, these solid, crystalline, ice-like structures, composed of low molecular weight gases (such as methane, ethane, and propane) encapsulated in hydrogen-bonded water cages, can aggregate into larger masses capable of damaging or rupturing pipelines. Such formations typically occur under the high-pressure and low-temperature conditions prevalent in subsea flowlines and cold-weather operations. This study employs the Prosper simulation software to model these complex thermodynamic and hydrodynamic conditions and to predict the effective dosages of chemical inhibitors required to prevent hydrate formation. Specifically, our simulations suggest optimal dosages of 35% wt. methanol (MeOH) and 45% wt. monoethylene glycol (MEG) for gas stream 1, and 22% wt. MeOH and 33% wt. MEG for gas stream 2. Based on these findings, we advocate the use of Prosper simulation software as a predictive tool for the strategic administration of hydrate inhibitors in offshore gas production facilities. This research contributes to the ongoing development of chemical strategies for hydrate management, providing a basis for improved safety and efficiency in hydrocarbon extraction processes.

Keywords:- *Gas Hydrates, Pipeline Corrosion, Hydrate Management, PVT Analysis, Flow Assurance.*

I. INTRODUCTION

The formation and management of gas hydrates in the natural gas industry present formidable challenges, traceable to the pioneering work of Hammerschmidt in 1934 [1]. These hydrate compounds, primarily consisting of gases like methane, ethane, propane, isobutene, and carbon dioxide trapped within a crystalline water structure, manifest under specific conditions of high pressure and low temperature commonly encountered in subsea gas pipelines and processing facilities. Unlike ice, these hydrates have a lower density and form at temperatures significantly above the freezing point of water, behaving as a solid solution where gas acts as the solute within a solvent cage of water molecules without chemical bonding [2-4]

The operational challenges imposed by hydrates are multifold, ranging from the formation of plugs that obstruct pipeline flow to structural damages threatening the integrity of offshore platforms. The economic ramifications are equally severe, with potential losses amounting to millions of dollars per day due to interrupted production [5]. Moreover, traditional methods to manage hydrate formation, such as thermal and mechanical removal, are not only costly but also pose significant safety risks and environmental concerns [6-8].

Recent advancements in simulation technologies, such as the Prosper software, have revolutionized hydrate management by enabling precise predictions of hydrate formation conditions and optimizing the use of chemical inhibitors like Methanol, Monoethylene Glycol (MEG), and Triethylene Glycol (TEG) [9-12]. These inhibitors effectively shift the hydrate equilibrium, thus safeguarding operational conditions from falling within the hydrate formation envelope.

- *Significance of the Study*

This study's significance is anchored in its potential to enhance the safety, efficiency, and economic viability of gas production operations, particularly in offshore settings. By integrating advanced simulation tools with empirical research, this work aims to develop robust chemical methodologies for hydrate control, thus minimizing the operational disruptions and hazards associated with hydrate formations.

The utilization of chemical inhibitors based on simulation-guided strategies represents a critical advancement in the field. This approach not only helps in preempting the formation of hydrates but also contributes to the broader industry goal of maintaining uninterrupted flow assurance. Flow assurance is crucial in ensuring that hydrocarbons are transported efficiently from the reservoir to the point of sale without blockages, thereby optimizing production and minimizing downtime.

Furthermore, this research aligns with environmental sustainability goals by reducing the frequency and intensity of interventions required to manage hydrate formations, such as the use of pigs or the application of heat. Each of these traditional methods carries a carbon footprint and potential ecological impacts, which can be mitigated through the proactive chemical management of hydrates.

The outcomes of this study are expected to offer dual benefits: enhancing operational efficiency and reducing environmental impacts in offshore gas production. The strategies developed herein could serve as a benchmark for

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the industry, promoting safer and more sustainable practices across global operations.

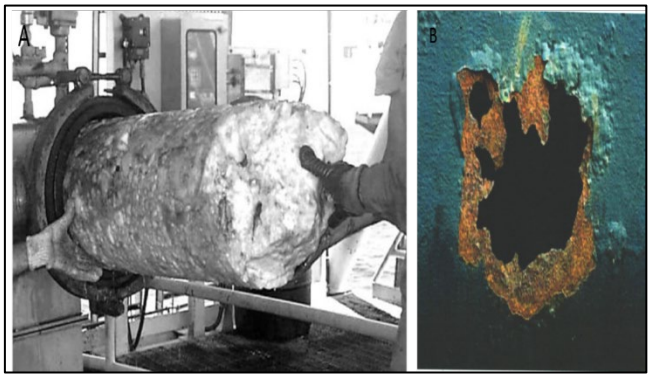

Fig 1 Effects of Hydrate Plug on Subsea Pipelines. A. Large Gas Hydrate Plug Formed in a Subsea Hydrocarbon Pipeline [1]. B. Corrosion in Subsea Pipelines [2].

II. METHODOLOGY

➢ *Collection of Well Data*

The study requires precise well data to manage hydrate formation effectively in offshore gas production facilities, using data from two distinct sources for different gas streams. Data for Gas Stream 1 were sourced from Shell Nigeria Limited at the Obigbo gas plants. This data set included operational temperatures, pipeline pressures, and the mole percentage composition of the gas. These parameters are critical for assessing the risk of hydrate formation and are used to model accurate predictions with Prosper simulation software [13-15]. For Gas Stream 2, data were obtained from Nalco Energy Services, encompassing similar operational parameters such as temperature, pressure, and detailed gas composition. This information is crucial for predicting potential hydrate formation under varying conditions [4].

➢ *Software for Hydrate Simulation*

To predict the hydrate forming temperature and pressure of a gas stream, the Prosper Simulation software was utilized [16]. The process begins with launching Prosper from the options menu, which allows for the selection and setup of the fluid description type. The method involves configuring the software to accurately represent the fluid dynamics and chemical properties of the gas stream being analyzed. This setup is crucial for ensuring that the simulations reflect real-world conditions and provide reliable data on hydrate formation risks under various operational scenarios.

Table 1 Fluid Description Asset-up and iPROSPER Software Equation of State Model

Fluid description – Type:	**Retrograde Condensate**
Fluid description – Method:	Equation Of State
Hydrates:	Enable Warning
Calculation type – Model:	Enthalpy Balance
EOS Model:	Peng Robinson
Optimization Mode:	Medium
Optimize Repeat Calculation:	Yes
Full Composition:	Yes
Allow Lumping:	No
Reference Temperature:	60°F
Reference Pressure:	0 psig
Phase detection Method:	Advanced
Path to surface – Separator Calculation Method:	Use Separator Train
First stage:	200 psig and 80°F
Second stage:	0 psig and 60°F
Target GOR method:	Use Separator fluids

➢ *PVT Data Input*

For the simulation, PVT (Pressure, Volume, Temperature) data is a critical component in assessing the physical properties and behavior of the gas streams under various operational conditions. In this study, the PVT data was entered into the Prosper simulation software by accessing a predefined sample directory (**Figure 2**). This directory provided baseline data which was then tailored according to the specific characteristics of the gas streams being analyzed, such as whether the gas was predominantly wet or dry. Adjustments to the PVT data included modifications based on the gas composition, as well as variations in temperature, pressure, and the boiling point differential. These changes are essential to accurately model the gas stream's behavior in the pipeline and predict hydrate formation conditions effectively. By fine-tuning the PVT settings to reflect the actual conditions of the gas streams, the simulation can provide more precise and reliable outputs.

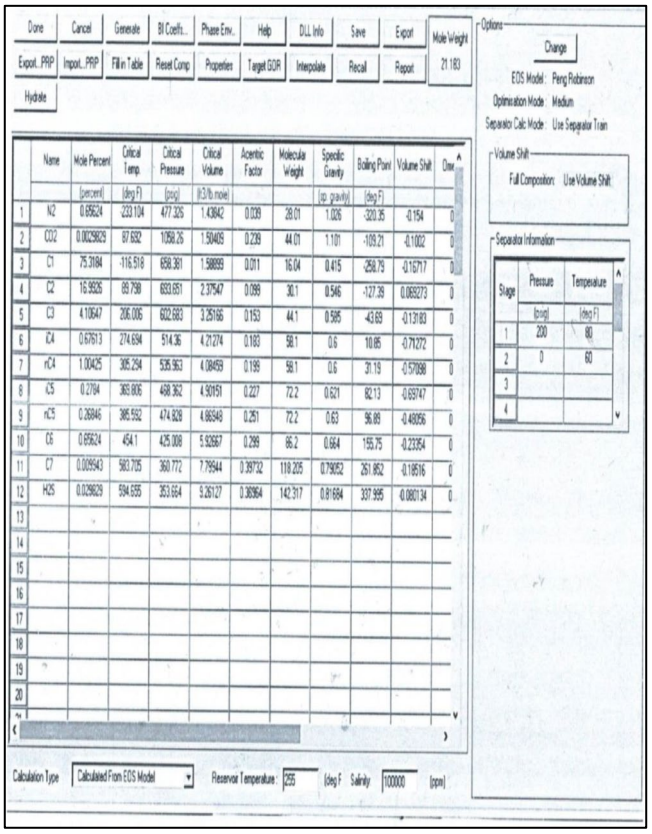

Fig 2 PVT Data of Dry Gas Stream Compisition 1 used in Prosper Software

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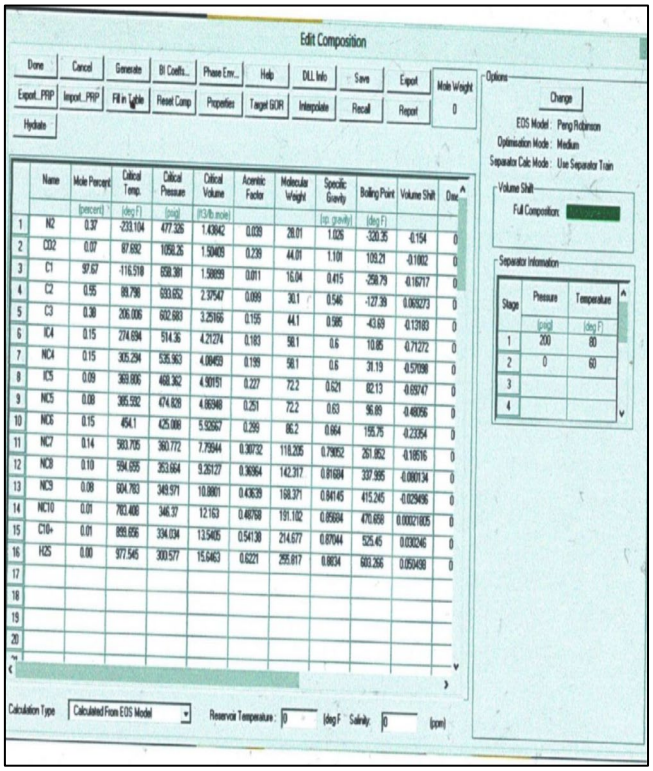

Fig 3 PVT Data of Dry Gas Stream Compisition 2 used in Prosper Software

➢ *Hydrate Curve Generation and Analysis*

In the PVT analysis phase within Prosper, a hydrate curve was generated to visually represent the potential for hydrate formation under various conditions. This curve was then stored within the Prosper file for further reference and analysis. During the simulation process, Prosper actively monitored the operating conditions—specifically pressure and temperature—to determine if they fell within the hydrate formation danger zone. The temperature range employed for the analysis spanned from 33°F to 80°F, with the simulation adjusting the temperature at each of the 10 incremental steps. This methodical variation allowed for a detailed examination of how temperature fluctuations influence hydrate stability within the specified range. The resulting hydrate curve is visualized in the output, providing a clear graphical representation of the conditions under which hydrates are likely to form. This visual tool is crucial for identifying critical thresholds and planning appropriate operational strategies to avoid hydrate-related complications.

➢ *Validation with Historical Data*

We validated the simulation model against historical data is crucial for ensuring its accuracy and reliability. This step involves comparing the hydrate formation predictions made by the Prosper simulation with actual instances of hydrate occurrence documented during past operations. By doing so, discrepancies can be identified and the model can be calibrated to better reflect real-world conditions. This validation process enhances the confidence in the simulation outputs, making them more actionable for operational planning and risk management.

III. RESULTS AND DISCUSSION

➢ *Impact of Inhibitor Concentration on Hydrate Formation Conditions*

We generated series of hydrate equilibrium curves, delineating the predicted hydrate formation temperatures and pressures for varying concentrations of chemical inhibitors—specifically methanol and glycol—in Gas Stream 1. These concentrations ranged from 0% (indicating no inhibition) to increments of 10%, culminating at 45%. The resulting data were visually represented across multiple figures (**Figures 4 and Figure 5**), illustrating the progressive shifts in hydrate formation conditions as the concentration of inhibitors increased.

A detailed analysis focused particularly on the conditions with 35% and 45% inhibitor concentrations. These scenarios were graphically superimposed onto the curve representing 0% inhibition (as displayed in **Figure 4**), to highlight the significant shift in the hydrate formation region. The comparative visualization clearly demonstrated that the presence of chemical inhibitors effectively alters the thermodynamic landscape of hydrate formation. Specifically, with increasing concentrations of methanol and glycol, the hydrate formation region is displaced to lower temperatures and higher pressures, thereby reducing the risk of hydrate formation under typical operational conditions. This shift is indicative of the inhibitors' efficacy in modifying the gas stream's thermodynamic environment, making it less conducive to hydrate formation. The results underscore the importance of selecting appropriate inhibitor dosages to optimize flow assurance while mitigating the risks associated with hydrate blockages in pipeline systems as also pointed out by Bavoh et al [14].

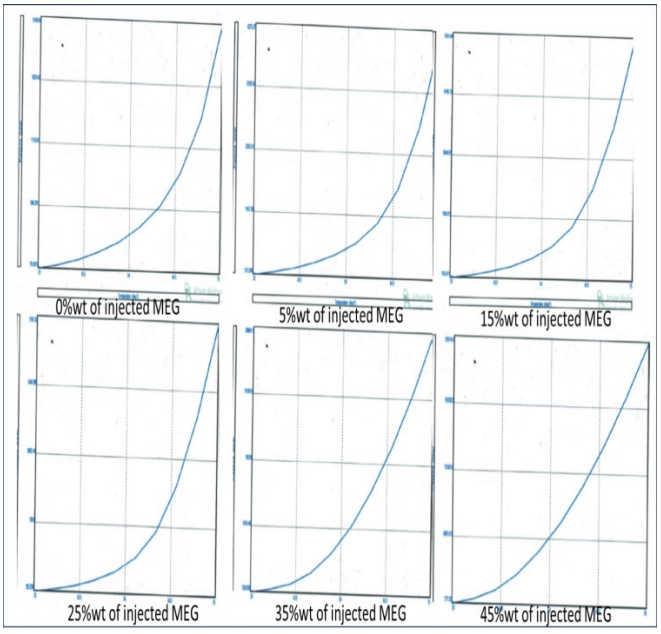

Fig 4 Hydrate Equilibrium Curves Delineating the Predicted Hydrate Formation Temperatures and Pressures for Varying Concentrations of Methyl Ethly Glycol (MEG) Chemical Inhibitor for Gas Stream 1

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➢ *Hydrate Management Through Inhibitor Modeling in Prosper Software.*

The Prosper simulation software was employed to assess hydrate formation under specific operational conditions for gas stream 1, defined by a pressure of 1500 psi and a temperature of 40°F. At this high pressure, the hydrate equilibrium temperature without inhibitors was predicted to be 70°F, placing the system within the hydrate formation region. Initial modeling efforts using varying concentrations of inhibitors—10% to 30% of methanol and 10% to 45% of MEG (monoethylene glycol)—were conducted. However, these concentrations proved insufficient, as indicated by the results displayed in Figure 5 for methanol and Figures 4for MEG, which showed that the system remained within the hydrate-prone conditions.

To safely operate outside the hydrate formation region, higher concentrations of inhibitors were needed. Injecting 35% wt. of methanol shifted the hydrate curve significantly to the left (**Figure 5)**, aligning the operating conditions to the right of the hydrate equilibrium curve, thus moving out of the hydrate forming region. The new hydrate equilibrium temperature at 1500 psi was adjusted to 37°F, comfortably below the operating temperature. Similarly, injecting 45% wt. of MEG shifted the hydrate equilibrium to a new low of 40°F, ensuring operational safety.

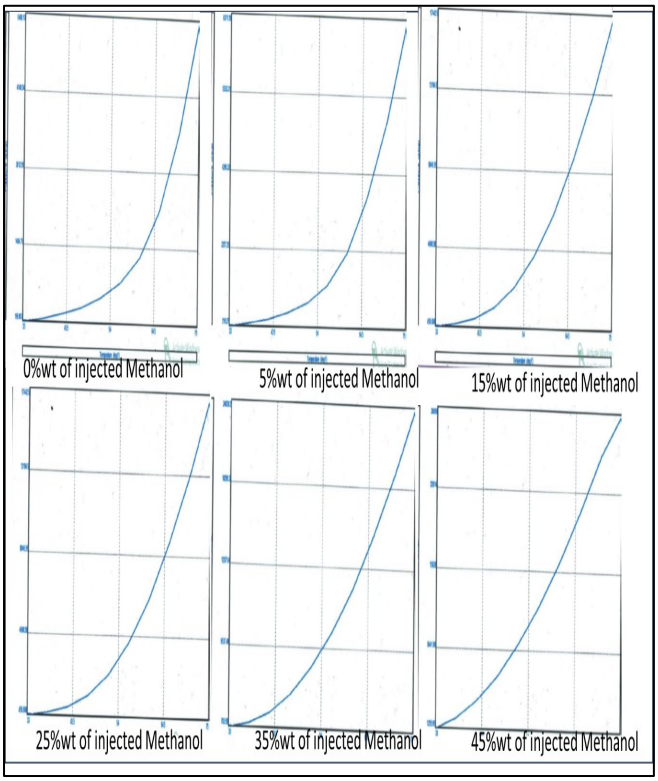

Fig 5 Hydrate Equilibrium Curves Delineating the Predicted Hydrate Formation Temperatures and Pressures for Varying Concentrations of Methanol Chemical Inhibitor for Gas Stream 1

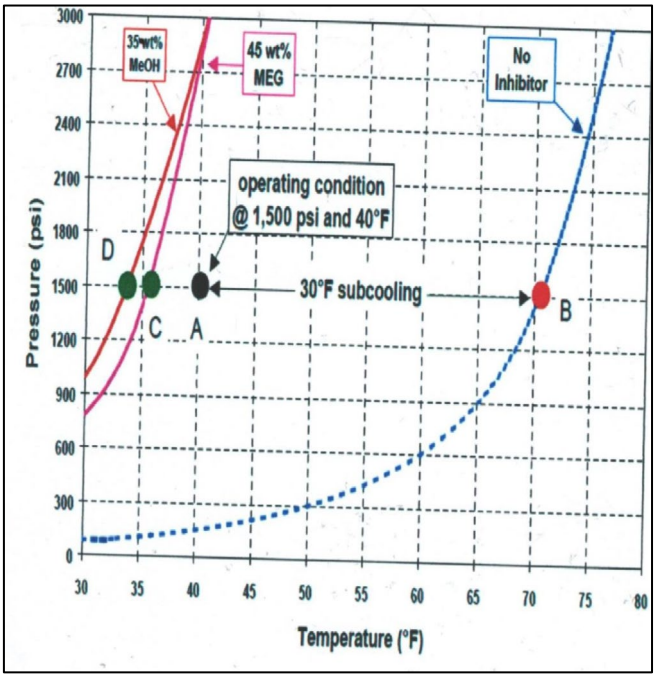

Fig 6 Hydrate Equilibrium Curves with and without Chemical Inhibitors for Gas Stream 1

The same simulation strategy was applied to gas stream 2 under identical operating conditions of 1500 psi and 40°F, which also initially placed the system within the hydrate formation region. Modeling with lower inhibitor concentrations of 0%, 10%, and 30% methanol and 10% and 20% MEG (**Figure 7**) did not achieve the desired shift in hydrate formation conditions. Ultimately, a 30% concentration of MEG and 30% methanol (**Figure 7**) were required to effectively move the hydrate formation conditions outside of the critical region.

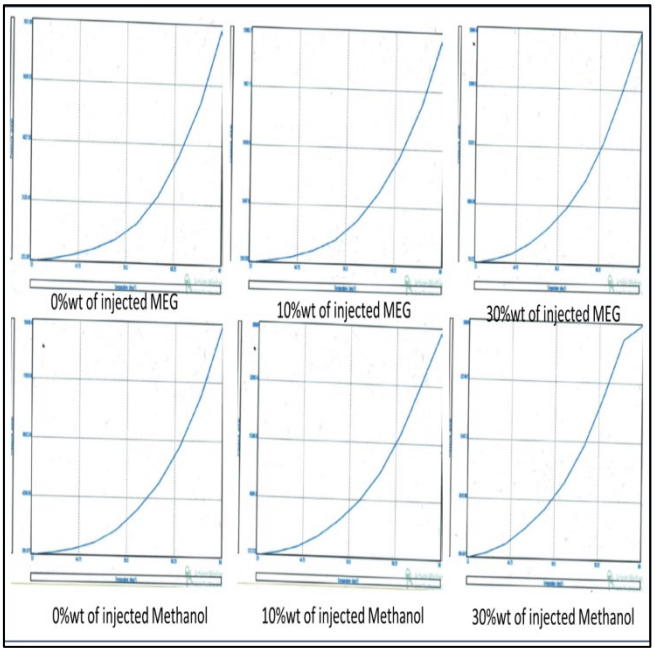

Fig 7 Hydrate Equilibrium Curves Delineating the Predicted Hydrate Formation Temperatures and Pressures for Varying Concentrations of MEG (Upper Panel) and Methanol Chemical (Lower Panel) Inhibitor for Gas Stream 2

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This enhanced modeling approach demonstrates the importance of accurately determining and applying sufficient inhibitor concentrations to ensure that the operational conditions in gas pipelines are maintained safely outside the hydrate formation thresholds.

IV. CONCLUSION

This study has thoroughly evaluated the efficacy of different hydrate inhibitors in offshore gas processing facilities using Prosper simulation software. Monoethylene glycol (MEG) emerged as the most effective inhibitor when compared to methanol and NaCl, owing to several significant advantages. Firstly, MEG can be regenerated and reused, which contrasts sharply with methanol that lacks this capability. This feature of MEG not only aligns with sustainable practices but also renders it economically advantageous despite its higher initial cost. Furthermore, MEG poses lower health, safety, and environmental risks, making it the preferred choice in the Exploration and Production (E&P) industry where safety is paramount.

The analysis determined that the optimal dosages of inhibitors for effective hydrate control are 35% methanol and 45% MEG for Gas Stream 1, and for Gas Stream 2, the dosages are 30% methanol and 30% MEG. These findings underscore the necessity of selecting appropriate inhibitor concentrations to balance efficacy and economic considerations in hydrate management.

RECOMMENDATIONS

Our study recommends the implementation of Gas Sweetening Processes. In facilities where acid gases like H_2S and CO_2 are present, gas sweetening processes should be implemented. These gases contribute to the potential for hydrate formation; therefore, removing them from the gas stream significantly reduces this risk. Our study also emphasizes continuous monitoring of production parameters is crucial. Real-time data acquisition and analysis can help in predicting and preventing conditions conducive to hydrate formation, thus ensuring uninterrupted gas flow and operational efficiency.

To further mitigate the risk of hydrate formation, dehydration of natural gas is recommended. Removing moisture from the gas stream effectively lowers the probability of hydrate formation, enhancing the reliability of pipeline operations. While kinetic inhibitors and anti-agglomerates offer potential benefits in managing hydrates, their limitations must be thoroughly evaluated to ensure they are feasible for production scenarios. This includes considerations of cost, environmental impact, and their integration into existing treatment systems.

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