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A Noninvasive Method of Hydrate Control Using Flow Rate Regulation

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Abstract
Hydrate is a major hazard to the deep-sea flow assurance. Chemical method and mechanical method are common means of controlling hydrates. This study explores the use of a noninvasive method of hydrate control which is flow rate regulation. The experimental study was carried out in a gas dominated system modelled in a 12meter closed flow loop that closely mimics the subsea flow line. Water and compressed natural gas were used as the hydrate former and were fed into the loop at 150pis. The temperature of the loop was reduced to hydrate formation temperature (4 to 10°C) while the hydrate forming process was monitored using the several temperature and pressure gauges around the loop. Flow rates considered in this study were 126.7 l/min, 136.2 l/min, 141 l/min, and 145.8 l/min. Four experimental runs were conducted with the four different flowrates. The pressure and temperature for experiments conducted with each flow rate was plotted. It was observed that increasing the flowrate of the loop shifted the hydrate formation curve leftwards, increasing the hydrate safe zone. Increased agitation prevented hydrate agglomeration. Thus, it is imperative for operators to produce at an optimum flow rate that prevents hydrate agglomeration and hydrate plug formation.

Keywords: *Flow assurance, Hydrate prevention, Flow regulation, Flow loop, Offshore production*

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1. Introduction

Clathrate hydrate formation is usually a cause of concern in most production facilities. Hydrates can occur in gas and gas/condensate wells and even in oil wells. A shut-in oil or gas well that has been producing water is a good candidate for hydrate formation. (Sloan, 1990). The thickness of the hydrate zone depends on operating regime, design, geothermal gradient in the well, fluid composition, and other factors. Clathrates are chemical substance consisting of a lattice of one type of molecule trapping another type of molecule. They are not chemical compounds as the sequestered molecules are never bonded to the lattice. Clathrate hydrates are formed at elevated pressure and cold temperature when hydrate formers are trapped in water molecule cages. These gas hydrates are formed by water molecules that make a loose 'cage' surrounding the molecules of gas. The most common natural gas hydrate formers are light end hydrocarbons such as methane (CH_4), ethane (C_2H_6), propane (C_3H_8), and other gases like carbon dioxide, nitrogen, hydrogen, xenon, acetone and others. Hydrate formation is also promoted by agitation and presence of nucleation sites (Carroll, 2009). Individual small guest molecules are entrapped in a cage of water molecule that has hydrogen bond between them. A molecule is free to rotate within the cavity of water molecules because they have no bonds between host and guest molecules (Carroll, 2009).

Hydrates usually form two crystallographic cubic structures known as the Structure I (sI) and Structure II (sII). A third hexagonal structure, Structure H exists but not form in hydrocarbon fluids (Sloan, 2008). Structure I hydrates are formed with smaller molecules such as CH_4, C_2H_6, CO_2 and H_2S. The water structures maybe 12 sided dodecahedrons (5^{12}) or 14 sided ($5^{12}6^2$) tetrakaidecahedrons. Structure II is formed with larger molecules such as C_3H_8, C_4H_{10} and N_2. This structure is a combination of smaller 12-sided (5^{12}) dodecahedrons and large 16 (5^{12} 6^4) sided hexakaidecahedrons. The structure consists of 136 water molecules in total. Clathrate hydrates can occur naturally in the permafrost. They are found in Norwegian continental shelf in northern headwall flank of the Storegga slide. They are also suspected to occur in large quantities on some outer planets, moons and trans-Neptunian objects, binding gas at fairly high temperature. About 6.4 trillion tones of methane is trapped in natural deposits of methane Clathrates on the deep ocean floor (Buffet and Acher 2004). Hydrates have lower density than ice. They contain about 10% hydrocarbons and 90% water and have a specific gravity of 0.98. Hydrates float in water since it is lighter than water but sinks in hydrocarbon liquid.

Methane is the most dominant component of naturally occurring hydrates. The amount of methane potentially trapped in natural methane hydrates deposits is about 1015 to 1017 cubic meters (Waite, 2009) which makes hydrates of major interest as potential energy resource. During petroleum production, hydrates can cause obstruction in pipes, reduce flow, increase back pressure of a system, and increase the differential pressure across the obstruction. Increased differential pressure can quickly accelerate a moving hydrate plug to velocities approaching the speed of sound, creating excessive forces. Moving hydrates can cause serious mechanical damage at downstream locations where restrictions (control valve), obstructions (closed valve) or sharp change of direction (elbow, tee) exist. Impact failures occur due to the mass and momentum of the hydrate hitting and fracturing the pipe or fittings. Since hydrates can plug the pipe, the pressure in pipe can be separated into two sections. The first part is upstream part that has high pressure and the other is downstream with low pressure. Thus, the difference in pressure can lead to rupture in the pipe segment by causing plug solid projectile which is very dangerous and can lead to loss of human lives (Chatti et al., 2005). Hydrates are not only a danger to oil and gas production installations, but they are also harmful to the people who work with them (Igboanusi, 2011). It is important to identify first these potential downstream locations as the likely points of failure if an impact occurs and to keep all workers away from the potential point of impact.

Several methods are being employed to curb the menace of hydrate deposition in pipelines. The commonly used methods include chemical treatment, mechanical method (or periodic cleaning of the line) and thermal treatment. This study examines the impact of flow rate regulation on hydrate formation. It is intended to study if hydrate formation will occur in all flow regimes.

2. Materials and methods

The experimental study was carried out in a 12inch closed hydrate loop designed by Odutola et al. (2017). The loop was situated in a temperature-controlled room and is fitted with several pressure and temperature gauges to monitor the hydrate formation process (Fig. 1). The loop was operated at temperatures of 0 to 10˚C and can withstand pressure up to 3500psi. The loop was also fitted with a variable screw pump (pump 1) that regulates the flow rate in the loop. Water and compressed natural gas of 90% methane were used as hydrate formers in the experiment conducted in the loop.

The experiment was conducted by first flushing the loop to rid it off any debris that may act as nucleation sites to promote hydrate formation. It is intended to only study the effect of agitation or flow rate regulation on hydrate formation. Experiments conducted in this loop are batch experiments in a constant volume batch experiment conducted in a gas dominated system. The hydrate formers, water and gas were fed into the loop and the loop was pressurized to 150psi. The cooling unit of the loop was switched on to regulate the loop temperature to hydrate formation temperature. The experiment was conducted for 2 hours at a constant flow rate, temperature and pressure readings were recorded at intervals of two (2) minutes during the 2-hour experimental run. Four different experimental runs were conducted with four different flow rates as from the control panel (126.7 L/min, 136.2 L/min, 141 L/min, and 145.8 L/min). Lower flow rates represented laminar flow while higher flow rates produced more agitation and represented turbulent flow.

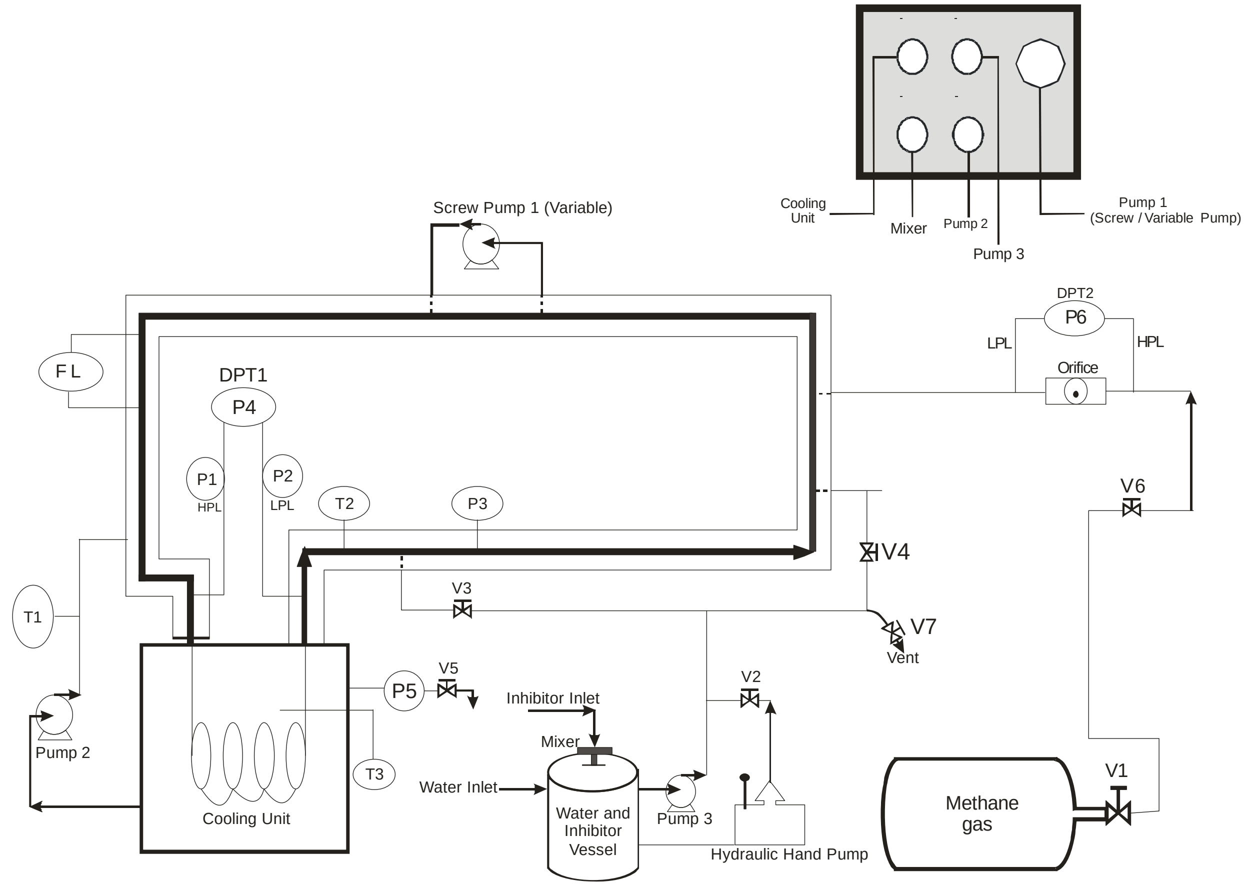

Fig. 1: Flow diagram of the mini fluid flow loop (Odutola et al., 2017)

3. Results and discussion

The effect of gas flow rate on hydrate formation was studied experimentally in the flow loop. The pressure and temperature readings recorded in each experiment conducted was plotted for the various flow rates considered (Fig. 2). From Fig. 2, it was observed that as the flow rate increases, the curve shift more to the left which is the hydrate forming zone while the right-hand side is the hydrate free zone. It was also observed that at the end of each experiment carried out, 185 ml of hydrate was formed. This means that the flow rate had little effect on the amount of hydrate formed. Fig. 3 is a plot of temperature against pressure for the different flow rates.

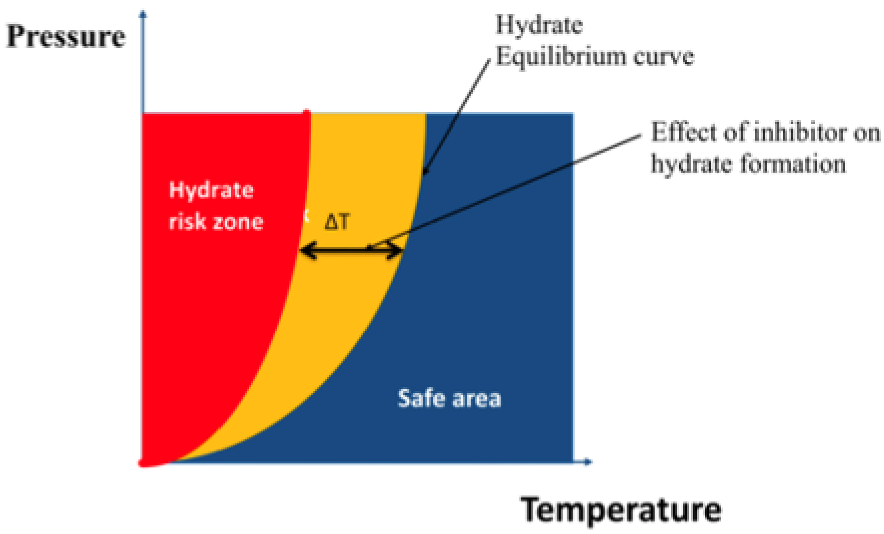

Fig. 2: Hydrate formation curve showing hydrate risk and hydrate free zones

Hydrate formation curve usually slopes downwards from right to left such that higher pressures will require relatively higher temperatures for hydrate formation. Odutola et al. (2015), while discussing the effect of methanol and ethanol in preventing hydrates, noted that the hydrate formation curve shifts to the left when proper hydrate inhibition is done. This study investigates the effect of flow rate on hydrate formation in an experimental flow loop. The pressure of the loop was plotted against temperature while changing the flow rates in each experimental run. The lowest flow rate considered in this study is 126.6l/min. The pressure-temperature curve from this flow rate is towards the far right of the chart (Fig. 3). As the flow rate increased to 136.2l/min, the hydrate formation curve shifted leftward, implying that the hydrate safe region has increased. Subsequent increase of the flow rate to 141.1l/min and 145.8l/min showed even move leftward movement, increasing the hydrate safe zone (Fig. 3). For instance, at a temperature of 10°C, hydrates will form at a pressure of 100psi with a flow rate of 126.6l/min. At the same temperature of 10°C, and higher flowrate of 136.2l/min and 141.8l/min, the hydrate formation pressure is 104psi. A further increase in the flow rate to 145.8l/min and a temperature of 10°C, the hydrate formation pressure is 114psi. This implies that, if the flow rate is left at 126.6l/min and a temperature of 10°C, the loop will experience hydrate problems at a pressure above 100psi. However, if the loop flowrate is increased to 145.8l/min, the loop can be safely operated at temperature of 10°C and pressure as high as 114psi. This could be because the agitation caused by increased flowrate prevents the agglomeration of the hydrate crystals and prevents hydrate plug formation.

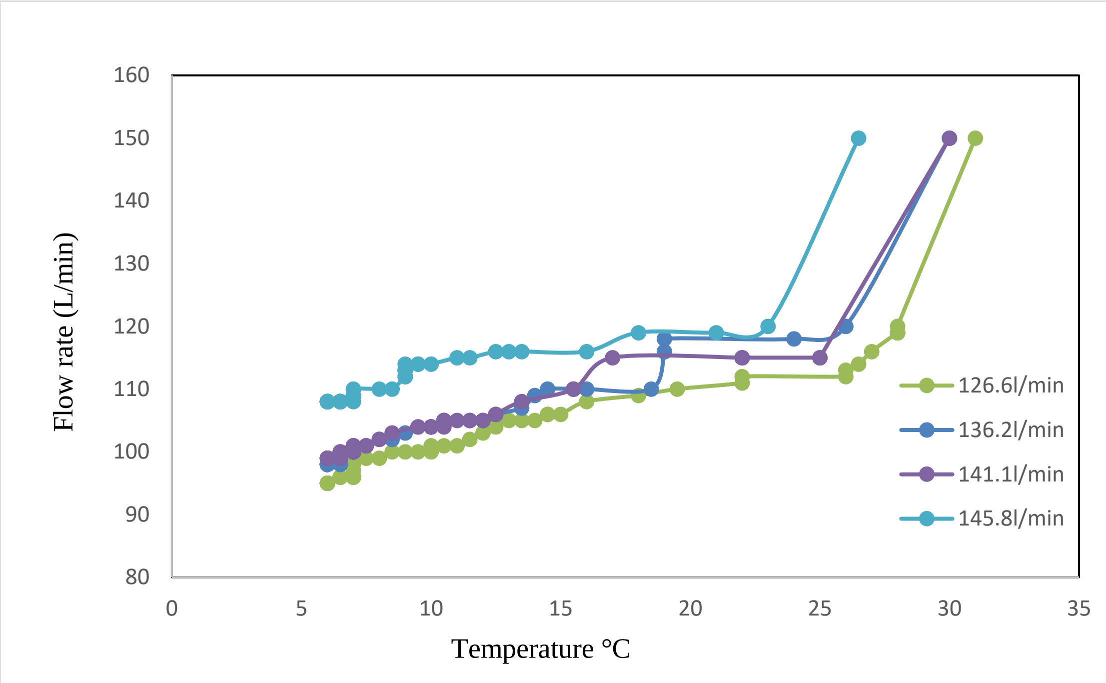

Fig. 3: Temperature vs pressure for the different flow rates

4. Conclusions

The effect of flow rate regulation on hydrate formation was studied. Constant volume batch experiments were conducted in a 12meters flow loop. The flow rates considered were 126.6, 136.2, 141.1 and 145.8l/min. It was observed that increasing the flow rate of the loop increased the hydrate safe zone. This implies that at higher flow rates, hydrate safe operations can be done at higher pressures. The best flow rate in this study was 145.8l/min as it increased the hydrate safe zone significantly.

References

Buffett. B. and Archer, D. (2004) Global inventory of methane clathrate: sensitivity to changes in the deep ocean, Earth and Planetary Science Letters, 227: 185–199.

Carroll, J.J. (2009) Natural gas hydrates: a guide for engineer, second edition. Amsterdam: Elsevier, XVII, 1-148.

Chatti, I.., Delahaye, A., Fournaison, L. and Petitet, J. (2005) Benefits and drawbacks of clathrate hydrates: a review of their areas of interest. Energy Conversion and Management, 46: 1333-1343.

Igboanusi, U.P. and Opara, A.C. (2011) The Advancement from Thermodynamic Inhibitors to Kinetic Inhibitors and Anti-Agglomerants in Natural Gas Flow Assurance. International Journal of Chemical and Environmental Engineering, 2(2): 131-134.

Odutola, T.O., Ajienka, J.A., Onyekonwu, M.O. and Ikiensikimama, S.S. (2017) Design, Fabrication and Validation of a Laboratory Flow Loop for Hydrate Studies. American Journal of Chemical Engineering. Special Issue: Oil Field Chemicals and Petrochemicals, 5(3-1): 28-41.

Odutola, T.O., Ikiensikimama, S.S. and Appah, D. (2015) LPG Hydrate formation and Prevention using Ethanol and Methanol, SPE 178333, presented at Nigeria Annual International Conference and Exhibition. Lagos, Nigeria.

Sloan, E.D. (1991) Natural Gas Hydrates. Journal of Petroleum Technology and Alternative Fuels, 43:1414–1417.

Sloan, E.D. and Koh, C.A. (2008) Clathrate Hydrates of Natural Gases, 3rdedition, CRC Press, Taylor & Francis Group, Boca Raton, FL 33487-2742.

Waite, W.F., Santamarina, J.C., Cortes, D.D., Dugan, B., Espinoza, D.N., Germaine, J., Jang, J., Jung, J.W., Kneafsey, T.J., Shin, H., Soga, K., Winters, W.J., Yun, T.S. (2009) Physical properties of hydrate-bearing sediments, Reviews of Geophysics, 47, RG4003.