PREVENTION OF FORMATION OF HYDRATES OF GAS DURING WELLS DRILLING OPERATIONS

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Summary:

Formation of hydrates is observed during drilling and construction of wells, more frequently in gas wells located offshore (deep sea water). Hydrates of natural gas can clog chokes and kill lines, and obstruct the opening or closure of blow out preventer (BOP), seal well override valve and immobilize well string. Because of that, this work was mainly focused in the selection and adaptation of a prediction method to avoid hydrate formation, to let us analyze their risk and be applicable to imperative conditions specifically during offshore drilling operations.

The results obtained with the application of the computer program HID. Bas reflects the effect gas composition exercise over initial P-T conditions in gas hydrates formation, during offshore deep sea water drilling. Also it is evident the effect in hydrate formation of water depth, drilling fluid density in the hydrostatic well column and temperature variation of fluids inside the wells. This program represents and innovative reference tool, that permits linking characteristics of a drilling system in the context of hydrate formation, with the purpose of establishing the planning of inhibitory treatments, and contingency plans for well control in case a hydrate formation is in development.

Introduction:

A hydrate is defined a solid and crystalline material, with similar appearance to ice, formed by water and small molecules of gas. Gas hydrates have been studied by oil industry for over 60 years, but it is until now, that most investigations have been
targeted to problems such as: Oil transportation, removal and prevention of hydrates plugs in transmission lines.

In recent years, oil and gas industry, have continued its expansion of exploration and drilling in deep sea waters all around the globe. Deep sea water drilling are characterized by extreme conditions of operations where temperatures of 30 °F (-1°C) and pressure near 5800 psi (400 bar) are common, in addition to the fact that the surface of the formation is not very consolidated, narrow margin in mud weight, shallow gas zones, among others. This implies that operative and services companies face technical challenges each time, more and more complex, and excellent conditions for hydrate to form. Offshore drilling operators are aware of this problem and some operational solutions and formulations of mud drilling have been proposed and applied, using mud drilling (WBM or OBM) with inhibitors in hydrate formation.

Despite that fact, that hydrate formation represents a dangerous potential in offshore drilling operation, very few data have been published about formation of gas hydrates in mud drilling, and it is very hard to find literature and technical references that describes real case studies of field work. According to Baker & Gomez¹, all drilling operations should be evaluated and analyzed the risk of hydrates formation, considering all periods of change in pipes and/or drilling bits.

Because of all previously exposed surges the reason of the present work, to develop a program with a prediction method to avoid hydrates formation, which allows us to describe the problematic of gas hydrates during wells drilling operations, by adapting the Gravity Method of Katz, to predict P-T conditions where hydrates forms, so it will apply to conditions that we normally encounter during offshore drilling operations combined with application of basic principles of drilling. This model is programmed in Visual Basic 6.0 very ease to use, to prevent the problem that will cause these compounds and take proper safety measures to inhibit their formation if this were possible.
The results of this work will contribute to improve the comprehension of the underneath problem in gas hydrates during drilling operations through development of a computer program, that handles a very simple and easy to adapt method, avoiding the complex and sophisticated methods of thermodynamic models that describes in more detail the kinetics of hydrates formation, this offering a new reference tool to promote a better knowledge of gas hydrates.

**Procedures:**

One of the main difficulties to estimate the conditions of hydrates formation is the selection of the right method to estimate the P-T couple that it will determine if it will be or not the formation of hydrates during drilling operations. Without any doubt, the best method to determine formation conditions of hydrates is to measure experimentally the pressure and temperature of a relevant composition. However, such experimental efforts consume great deal of time and are relatively expensive, due to the fact to infinite number of conditions for hydrate formation to which these measures are necessary. Because of this, several interpolation methods are required among experimental results, even an extrapolation beyond data obtained might be required.

To study the characteristics of evaluated methods, such as: Gravity of Gas of Katz, K-factor of Katz and Baillie Wichert, an evaluation matrix was generated to compare quantitatively the pros and cont of each method, to finally select the method that would apply to this work. The method selected was the Method of Gravity of Gas of Katz, after that, a comparison was made among results of several correlations to estimate the conditions of formation of hydrates by this method; the correlations analyzed were: Berge, Motiee, Hammerschmidt and Makogon.

Besides these methods, several assumptions were considered during the development of the program HID. Bas, so the mathematic model applied in the design
of the program was valid and the obtained results reproduce with the highest fidelity possible the experimental results that must be obtained in each case. Among these assumptions are: (a) by simplicity it is assumed that wells drilled are verticals; (b) gas mixtures do not contain hydrogen sulphide (H2S) or its percentage is so low that it is considerable negligible; (c) heavier gas components than n-butane are not included in the analysis; (d) a hydrostatic pressure gradient during formation of 0.45 psi/ft is assumed and in sea water of 0.433 psi/ft; (e) formation temperatures of hydrates below solidification point of water are not considered, and (f) in this work are not considered the real effects of composition of drilling mud in the condition of formation of hydrates, because of this, the results obtained are just an approximation of the P-T conditions of formation of hydrates and as such must be utilized.

Results:

In Venezuela, a study was made about “Stability of Hydrates” applied in one of the big LNG Project; four reservoirs were selected for this study. About the conditions of these reservoirs and their data we have the following:

Table 1. Conditions of each reservoir and PVT data.

<table>
<thead>
<tr>
<th>Field A</th>
<th>Field B</th>
<th>Field C</th>
<th>Field D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir Temperature (°F)</td>
<td>182</td>
<td>167</td>
<td>156</td>
</tr>
<tr>
<td>Bottom Hole Pressure (psi)</td>
<td>3909</td>
<td>3999</td>
<td>4099</td>
</tr>
<tr>
<td>Water Saturation (bbls/MMscf)</td>
<td>0.54</td>
<td>0.34</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Tabla 2. Gas Gravity, for each reservoir

<table>
<thead>
<tr>
<th>Gravity of Gas</th>
<th>Field A</th>
<th>Field B</th>
<th>Field C</th>
<th>Field D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.80</td>
<td>0.567</td>
<td>0.56</td>
<td>0.552</td>
</tr>
</tbody>
</table>
Among each of the fluids of these reservoirs a study of formation of hydrates was made applying the designed program HID.bas, and to measure the dispersion the results have been compared with the results obtained with commercial software used by a major oil company. Following is shown on Figure 1, the comparison between equilibrium curves obtained from the reference prediction program of hydrates formation and the program proposed in this work HID.bas. As you will see on Figure 1, similarity between these curves of equilibrium of hydrates (calculated by the consulted software) for fields B, C an D, lays in that specific gravities of these three fluids is very similar among them, as you can see in Table 2. on the other hand curve of equilibrium for reservoir A, is very different of each other; stability zone of hydrates for this fluid is wider that for the rest of fluids, due to higher concentrations of hydrates formers. At given pressure hydrates in fluid of Field A, begin to crystallize at higher temperatures than the other three fluids. For instance, at pressures of 2500 psi, hydrates could begin to form at temperature below 74 °F on the fluid in Field A, but for the other three reservoirs hydrates begin to form at temperatures below 64 °F.

Figure 1. Hydrate Equilibrium Curves for the studied reservoirs.

Note: Continuous lines represents “Equilibrium Curves of Hydrates” calculated by the software (*) (According to specifications of commercial software its uncertainty factor is ±1 °F); Dotted lines represent “Equilibrium Curves Hydrates” calculated by HID.bas
Comparing curves in Figure 1, we have that for reservoirs A and C, the calculated curves by both programs matches very well with differences of only 1 °F approximately. But for the fluid of Field A we can observe a minor variation for pressures between 750 and 1500 psi, because the program HID.bas calculates formation temperatures minor to the ones calculated by the commercial software at these pressures. The Equilibrium Curve of Hydrates for reservoir D, calculated by the program HID.bas for the given pressures, estimates initiating temperatures of hydrates formation lesser than the ones calculated by the commercial software with a difference of 2 °F until 2000 psi, beyond this point the curves begin to mach each other. Finally, for Field B, you can see that at pressure higher than 1500 psi, the proposed program HID.bas calculates temperatures of hydrates formation (≈2°F) higher than the commercial software at the same pressures.

Two wells in deep sea water, in areas widely separated geographically have experienced formation of hydrates during drilling operations, Baker & Gomez¹, describe expensive special procedures of removal of such hydrates. This data were input in program HID.bas and the results are shown below:

**Case 1: West Coast United States**

Water Depth=1150 feet  
Drilled Depth= 7500 feet  
Mud Density= 14.2 lb/gal  
Mud Drilling entry in standard conditions @60°F, 14.7 psi  

Baker & Gomez¹ in this report did not mention which was the composition of the gas that was found in that area, but it is presumable that the values were near the region of hydrates formation for that gas.

Here it goes Figure 2. Curve of Equilibrium of Hydrates, Gas Gravity 0.91. HID.bas
Here it goes Figure 3. Conditions of Formation of Hydrates, Gas Gravity 0.91

The Figure 2, shows curve of equilibrium of hydrates for a gas with a gravity of 0.91, obtained from the application of program HID.bas, where you can see that the range of best probability of formation of hydrates for this composition is between 65 and 85 °F, and in the system is required pressure between 1000 and 6000 psi. In the Figure 3 we can see a zone of high probability for hydrates to form, not only inside the well, but in the porous system of the formation, due to the fact that the high temperature of sea water in the line of mud was 54 °F and between 1000 and 3000 feet (shadowed are in yellow in Figure 3) because the geothermic gradient curve (blue, brown) of the formation, is to the left of the Curve formation of hydrates (red, blue). Besides, when drilling mud circulates through the well, we can validate (Figure 3) that at higher depths (> 3500 feet), the risk of hydrates formation in case that a gas influx to the well occurs is very high, for this gas composition in particular.
Case II: Gulf of Mexico

Water Depth = 3100 feet
Drilled Depth = 7679 feet
Baker & Gomez1 in his report do not mention which was the density of mud used in this well. A density of drilling mud of 14 lb/gal was assumed.

Here it goes Figure 4. Curve Equilibrium of Hydrate, Gravity of gas 0.718

In the Figure 4, we can see the Curve Equilibrium of Hydrate for a gas which gravity is 0.718, obtained from the program HID.bas, where we can notice that the
range of best probability for hydrates to form for this composition is between 70 and 90°F, and the pressure required in the system are 2000 and 7000 psi.

In wells drilled in the Gulf of Mexico the appearance of gas hydrates plugs are very common, we can infer this from Figure 5; conditions of temperature in the system are critical (with temperature of almost 40 °F at sea bottom) because of this a great deal of planning is required to prevent hydrates formation. We can observe from Figure 5, that due to great depth of water, temperature of sea water in the line of mud is approximately 40°F, a very low temperature that obviously propitiates the gas hydrate formation, not only inside the well where is evident a great possibility of hydrate formation between temperature of 60 and 80 °F, but also in the formation in the interval between 3000 and 6000 feet, where appearance of saturated stratus of hydrates are not rare. For this well in particular, the mud was submitted to a previous pre-heating, but nevertheless it was also obstructed with hydrates plugs.

Conclusions:

With the application of the program HID.bas, we can obtain an excellent estimation of conditions in which hydrates forms, as a function of depth gas composition and mud density, through the application of the Katz Gas Gravity Method, linking parameters of hydrates formation with depth and temperatures variations inside the well, in offshore areas. This work also validate the proper functioning of Motiee and Makogon correlations for gases with $\gamma_g \geq 0.6$ and the correlation of Berge for a $0.5 < \gamma_g < 0.6$.

The program HID.bas, let us visualize the behaviour and effect of drilling fluids in the formation of hydrates during deep water drilling. For this reason, these fluids must be specially crafted to inhibit hydrates, and adapted to each configuration of the drilling system. Application of HID.bas, shows that natural gas hydrates can be manipulated safely in deep water wells, through a detailed analysis of the conditions
of formation of gas hydrates, to establish an appropriate strategy of inhibitions treatments, and avoid plugging or obstruction problems.

**Gratitude:**

I like to thank Central University of Venezuela, to my academic tutor Prof. Edgar Parra, who conceived this work and thanks to his guidance it is now materializado in these pages. To Prof. Yuri Makogon, Prof. John Carroll, Prof. Enrique Rondón and engineers Maria Llamedo, Richard Rengifo and Elio Ponce.

**Bibliographical References:**


