GAS HYDRATES ON OFFSHORE PRODUCTION: A BRIEF REVIEW FOR THE DEVELOPMENT OF A PREDICTION METHODOLOGY

Manoela Bastos Alves[a], Reinaldo Coelho Mirre[a]

[a] Centro Universitário SENAI CIMATEC, Brasil, Av. Orlando Gomes, 1845, Piatã; Salvador/BA.

Abstract: This article presents a review of gas hydrate deposition prediction as a basis for the development of a methodology to predict gas hydrate formation in offshore production pipelines. Hydrates are crystalline structures that form between molecules of water and gases, such as methane and carbon dioxide, for example, under conditions of high pressure and low temperature. Knowing the conditions for hydrate formation is important in order to avoid flow obstruction during the oil and gas production phase. It was found that predictive systems are a new line of research that has been growing in recent years, allowing the prior identification of flow assurance problems, thus reducing the need for corrective agents, such as inhibitors. In addition, a methodology to predict the formation of hydrates during the production flow process was preliminarily proposed.

Keywords: gas hydrates; predictive system; flow assurance; oil and gas production.

HIDRATOS DE GÁS NA PRODUÇÃO OFFSHORE: UMA BREVE REVISÃO PARA O DESENVOLVIMENTO DE UMA METODOLOGIA DE PREDIÇÃO

Resumo: Este artigo apresenta uma revisão acerca da previsão de deposição de hidratos de gás como base para o desenvolvimento de uma metodologia para prever a formação de hidratos de gás em dutos de produção *offshore*. Hidratos são estruturas cristalinas que se formam entre moléculas de água e gases, como metano e dióxido de carbono, por exemplo, em condições de alta pressão e baixa temperatura. O conhecimento das condições de formação do hidrato torna-se importante para evitar a obstrução do fluxo durante a fase de produção de óleo e gás. Verificou-se que os sistemas preditivos são uma nova linha de pesquisa que vêm crescendo nos últimos anos, permitindo identificar previamente problemas de garantia de escoamento e, assim, reduzir a necessidade de agentes corretivos, como inibidores. Como resultado, foi proposta preliminarmente uma metodologia para prever a formação de hidratos durante o processo de escoamento da produção.

Palavras-chave: hidratos de gás; sistema preditivo; garantia de escoamento; produção de petróleo e gás.

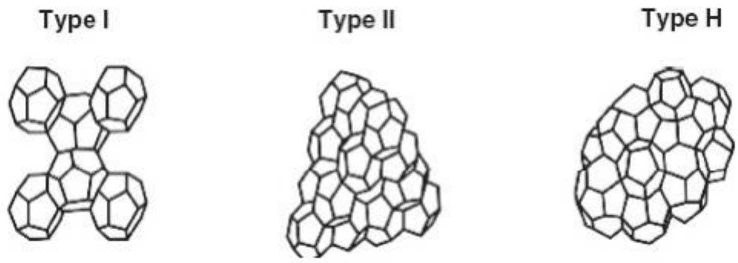
1. INTRODUCTION

The hydrocarbons are the main components of petroleum, but sulfur, oxygen and nitrogen are also present in smaller proportions. Nevertheless, the flow profile and challenges to ensure flow depend on the size of the molecular chain and the quantity of those. The existence and formation of hydrates is a challenge when proposing the exploration of natural gas in a cold area, like Siberia and Lake Baikal [1].

The hydrate is a problem that not only reaches cold areas, but also some types of offshore operations, because of the low temperature and high-pressure conditions. Therefore the general formula for the beginning of the formation of hydrates is: liquid water + gaseous hydrocarbon + high pressure + low temperatures [2].

The hydrates are composed of a natural gas molecule (10%) surrounded by water molecules (90%), which are connected by the van der Waals interaction, generating stability in the structure and the water's framework is known in the literature as "cage". This cage can be structured in three different ways: Type I, Type II, and Type H, as shown in Figure 1 [2].

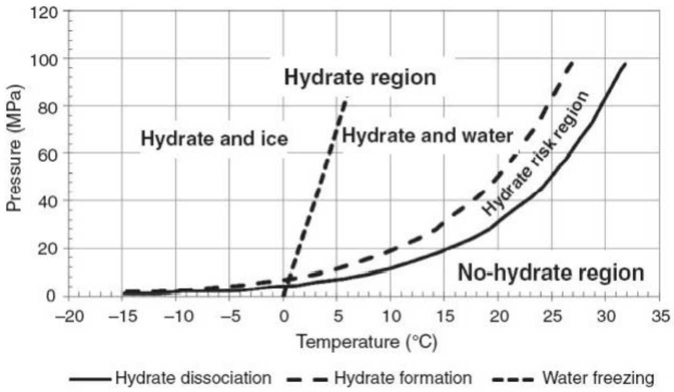
Figure 1. Types of gas hydrates structures [2].



During production the fluid conducts heat exchange and, consequently, cools down. So, if this condition is present in combination with high pressure, there will be a hydrate formation zone. This zone is present in the left side of the graph shown in Figure 2, where ice-hard or slushy gas hydrate can be formed [3].

In the right side of graph is the region where there is no hydrate formation because it has low pressures and high temperatures. Between these two zones there is a region with the possibility of forming gas hydrates [3].

Figure 2. Methane hydrate and water-phase envelope [3]



ISSN: 2357-7592

There are two main mechanisms of gas hydrate formation, nucleation and agglomeration. However, for hydrates to be a problem, there must be a deposition process and, consequently, the blockage of the pipeline [2].

1. Nucleation: this is the first step that gas hydrate crystals form at the interface between hydrocarbon and water, due to the low molecular weight ratio and the insolubility of both substances.
2. Agglomeration: two forces are responsible for the occurrence of this step. The first is the van der Waals interaction that holds the water molecules together to form the cage, and the second force is the pressure that holds the molecules together.
3. Deposition/growth: as a result of the gravitational force the gas hydrate particles deposit on the pipe wall. In doing so, blockage in the pipe starts.
4. Blockage: when there is a complete obstruction of the cross-section.

The formation and deposition of gas hydrate in the pipeline is a challenge for the oil and gas industry and because of that, a model or prediction system is of economic interest. There are numerous studies involving proposals for methodologies, models (phase equilibrium) and correlations. Van der Waals and Platteeuw developed a method in 1959 applied in the prediction of the phase state of the hydrate. In 1972, Parrish and Prausnitz modified the VDW-P, as van der Waals-Platteeuw's model is called, so this method could be applied to various types of gas, such as methane, ethane, and propane [5,6].

After this model, other models were developed. There are numerous studies about predictive systems for gas hydrates based at VDW-P and new lines of research have emerged, such as inhibitors that act in the nucleation process [1,5].

In the oil and gas industry, there are techniques to prevent the formation of gas hydrate in the pipeline, as to prevent it from occurring it is necessary to disfavor one of the essential conditions, such as temperature rise (with inhibitors or not) and thermodynamic inhibitors (change the thermodynamic conditions in the flow avoiding making the environment favorable) [3].

Therefore, this article performs a systematic review on the prediction of gas hydrate formation and deposition in order to guide the development of a methodology aimed at a model for predicting the formation of gas hydrates.

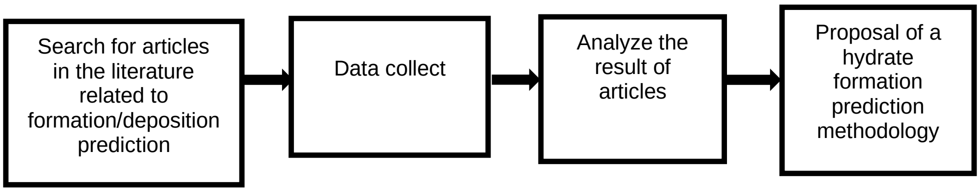
2. METHODOLOGY

The systematic review presented in this article deals with gas hydrate with a focus on predicting the formation/deposition process. First, a literature search was carried out, in which two databases were used: Science Direct and Scielo.

Afterwards, from the selected keywords, prediction, hydrate, formation, and deposition, the criteria of the articles to be selected was also established, so only articles that presented a predictive system related to the formation or process of hydrate deposition and obtained during 2017 and 2021 were considered in this review. So, the abstract and conclusion of the papers were read, and the dates collection happen.

After that there was the analyze, and there was a reading the articles and the development of a proposed methodology to be applied in a gas hydrate formation prediction system. Besides the papers, others works have been used as a basis, because this methodology needs a support in area of modeling and control.

Figure 3. Methodology for the systematic review



The guiding questions are an important step about the review because the search becomes more systematized.

Question 1: Are there models that enable predicting the conditions of hydrate formation or deposition in the oil production system?

Question 2: Are there computational models that enable predicting the conditions of formation or deposition of hydrates in the oil production system?

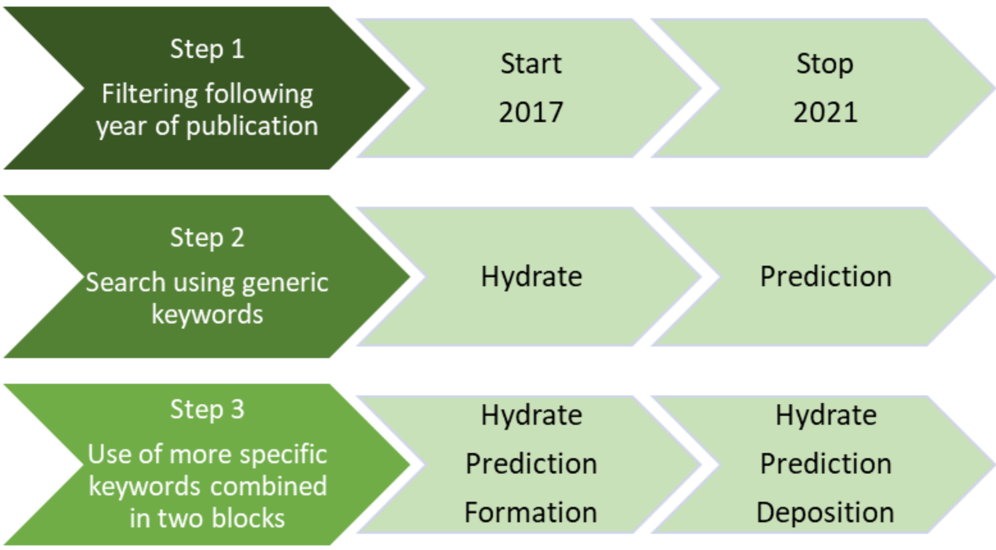
Question 3: Are there predictive models for hydrate formation in the oil production system that use machine learning tools?

3. RESULTS AND DISCUSSION

3.1 Search for articles

During the systematic review some strategies have been used for research using keywords (Figure 4). At first, a filter was applied referring to the years of publication, in the case of this review, articles from 2017 to 2021 were searched.

Figure 4. General approach to the research process



ISSN: 2357-7592

The use of keywords was done gradually, the first research has been carried out focusing on hydrates and prediction, and later two research blocks with higher level of restriction were implemented:

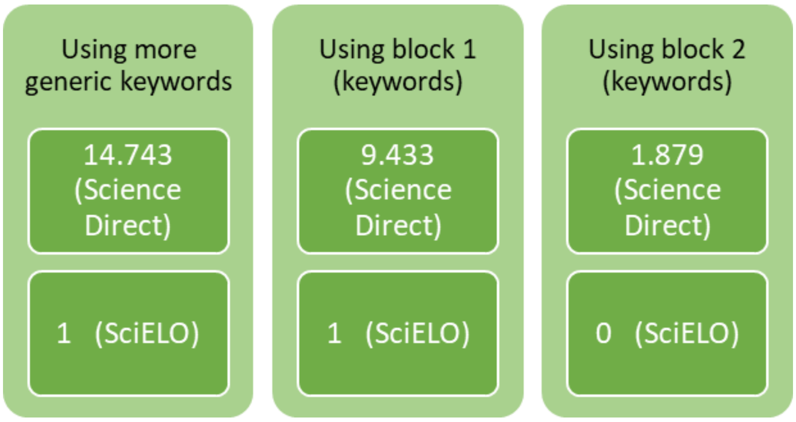
1- Block 1 (hydrate, prediction, and formation): in this block the focus was on the articles that computational and mathematical models were developed to predict the formation of hydrates.
2- Block 2 (hydrate, prediction, and deposition): these words were on the focus on predict the deposition of hydrates.

3.2 Data collect

A predictive process related to hydrates, there are a variety of scopes that can be applied, for example, prediction of reservoir conditions, of formation, of deposition, or phase equilibrium. But in this review, data collection is focused on the formation and deposition of hydrates.

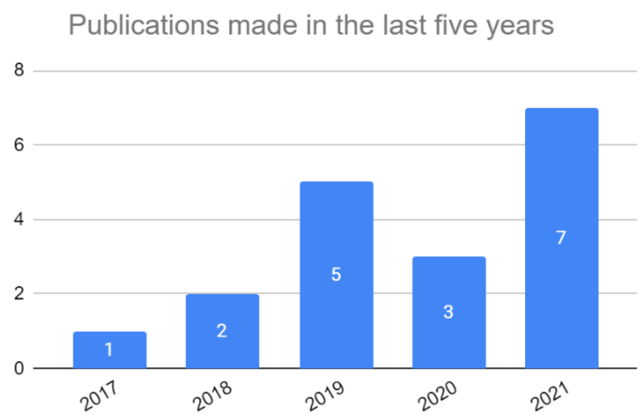
Two research platforms were used for the date collection: Science Direct and SciELO, but the first got better search results.

Figure 5. Quantity of articles found



There were a lot of results found, but when the exclusion criteria were applied, 18 articles were selected.

Figure 6. Publications in the last five years



3.3 Analysis and discussion

The research in the oil and gas industry have become interested in obtaining prior information on problems that add consequences and stop the production, and this situation generates high costs that could be previously identified and treated.

From 18 articles with the inclusion criteria, three were selected that presented characteristics more related to the proposed methodology that will be presented later.

Table 1. Articles selected for analysis

Publication	Year	Title	Authors
1	2014	Prediction of natural gas hydrate formation region in wellbore during deepwater gas well testing	WANG et al. [5]
2	2019	Prediction of hydrate deposition in pipelines to improve gas transportation efficiency and safety	ZHANG et al. [8]
3	2021	Prediction of methane hydrate formation conditions in salt water using machine learning algorithms	HONGFEI et al. [7]

All the publications presented in Table 1 have in common the parameters considered that lead the hydrate to form or deposit, in this case temperature and pressure, in addition to presenting a model to predict the formation or deposition of hydrates, that corresponds to guiding question 1.

However, the predictive system approach is different in each of the situations. Wang et al. [5] present a mathematical approach to deep water testing, in contrast with the papers 2 [8] and 3 [7], which used computational model.

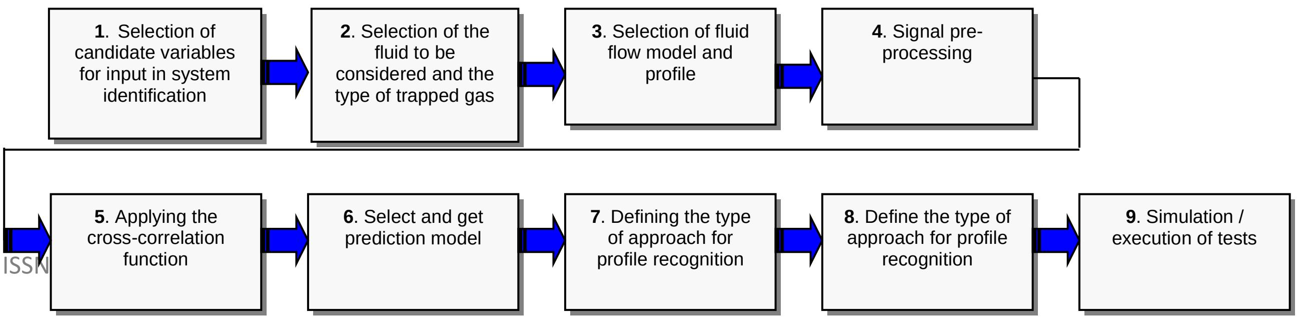
Zhang et al. [8] aims to develop a predictive computational system for the deposition of hydrates, in which a better efficiency in the results was obtained when compared to the base model used. Although Hongfei et al. [7] also uses a computational model, the approach is made by machine learning, and the article presents five algorithms for comparison purposes, in addition to aiming at a predictive system focused on the hydrate formation process.

Although Zhang et al. [8] and Hongfei et al. [7] correspond to the second guiding question, only Hongfei et al. is related to the third question.

3.4 Proposed methodology for predicting the formation of hydrates

A methodology for identification of a system, along with the recognition of signals, which will be measured by sensors from a thermodynamic model of gas hydrate formation, was proposed in Figure 7.

Figure 7. Methodology for the development of a prediction system



In the first step, there will be the selection of variables that are significant for the formation of the gas hydrate. Afterwards, it is necessary to choose that what type of gas hydrate will be studied (CO_2, CH_4, C_2H_6) for the prediction algorithm.

For a better understanding of the hydrate formation process, the second step is the choice of a thermodynamic model and a flow profile model. Thus, the data defined in the previous step will be applied in the pre-processing. Once the signals of variables for input in system are obtained, it will be analyzed if the amount of sample is sufficient to reach the desired results. Subsequently, a cross-correlation function will be applied to the candidate variables for input, if the function identifies the degree of linear relationship between the sampled signals, this parameter will be disregarded as a variable, and the cross-correlation function can identify whether the system under analysis will be represented well by the linear model [9].

The identification system will be obtained along with the recognition of the signals about de variables for input and obtaining the prediction model about gas hydrate, that will be used to map the signals (like pressure and temperature) captured in the flow process, and the simulations and tests will start until the results will be validated.

4. FINAL CONSIDERATIONS

This article presented the potential of a line of action that aims to ensure the flow of oil and gas production. The identification of which predictive systems can contribute to an adequate control and stability of production is supported by the growth of automation provided by Industry 4.0. From the literature review and the selection of works, it was possible to propose a methodology aimed at this objective. It is expected that, in the next step, the methodology will be tested to simulate production conditions and thus reduce problems related to the occurrence of hydrate formation and flowline obstruction.

Acknowledgments

To the Human Resources Program of the National Agency for Petroleum, Natural Gas and Biofuels, especially to the PRH 27.1 ANP/FINEP/SENAI CIMATEC, for the support and work opportunity in this research.

5. REFERENCES

[1] OLIVEIRA, M.C.K., GONÇALVES, M.A.L., MARQUES, L.C.C. **Fundamentos de garantia de escoamento**. Rio de Janeiro: Interciência, 2018.

[2] AL-SAFRAN, E.M., BRILL, J.P. **Applied multiphase flow in pipes and flow assurance:** oil and gas production. Society of Petroleum Engineers, Inc., 2017.

[3] FONTE, S.S.D., SIMONELLI, G., SANTOS, L.C.L. A review of the main techniques to avoid the formation of hydrates. **Brazilian Journal of Petroleum and Gas**. v.12, n.1, p. 061-073, 2018.

[4] KIM, N.R., RIBEIRO, P.R., BONET, E.J. Study of hydrates in drilling operations: a review. **Brazilian Journal of Petroleum and Gas**. v.1, n.2, p. 116-122, 2007.

[5] WANG, Z-Y., SUN, B-J., WANG, X-R. et al. Prediction of natural gas hydrate formation region in wellbore during deep-water gas well testing. **Journal of Hydrodynamics**. v.26, p.568-576, 2014.

[6] FAZLALI, A., GHALEHKHONDABI, V., RANJBARAN, T. Prediction of liquid propane hydrate formation conditions in the presence of light hydrocarbons (C_2-C_5): Experimental investigation and thermodynamic modeling. **Fluid phase Equilibria**. 2020. doi: https://doi.org/10.1016/j.fluid.2020.112756

[7] HONGFEI, X., ZEREN, J., ZHUORAN, Z. et al. Prediction of methane hydrate formation conditions in salt water using machine learning algorithms. **Computers and Chemical Engineering**. 2021. doi:

https://doi.org/10.1016/j.compchemeng.2021.107358

[8] ZHANG, J., WANG, Z., LIU, S., ZHANG, W., YU, J., SUN, B., Prediction of hydrate deposition in pipelines to improve gas transportation efficiency and safety. Applied Energy. V. 253, 2019. doi: https://doi.org/10.1016/j.apenergy.2019.113521

[9] CAJUEIRO, E., KALID, R., SCHNITMAN, L. **Inferindo posição de haste de bombeio mecânico a partir de corrente de motor.** Anais do XVIII Congresso Brasileiro de Inteligência Computacional, Fortaleza, CE, 2011, p. 1-8.