Problems of hydrate formation in production oil products from gas condensate wells

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Abstract. One of the most important problems in gas production at fields is hydrate formation - a process in which hydrates, settling on the inner walls of technological equipment, reduce their throughput, and therefore it may be necessary to stop the entire technological process for the purpose of unscheduled repairs, which leads to significant economic losses. The article presents the results obtained in the course of research, analytical work, namely: the assessment of the share of hydrocarbon production by region; analyzes of the main methods of combating hydrate formation; development of a methodology for comparing methods of combating hydrate formation among themselves; determining the most acceptable geography for the application of a particular method; forecast of the popularity of the method for 5 years.

1. Introduction
Currently, the oil and gas industry is the leading industry in Russia [1]. Oil and gas are of great importance for the development of the national economy of the country. Natural gas and heavy residues from oil refining are a cheap and convenient form of energy and domestic fuel. Oil serves as a raw material for the production of a large number of types of energy fuel: gasoline, kerosene, jet and diesel fuels for internal combustion engines, fuel oil, various types of lubricants, bitumen, synthetic fatty acids, etc. Today Russia is the largest producer of a driver and supplier of hydrocarbons in the global oil and gas market. Figure 1 shows the distribution of hydrocarbon production volumes by the largest enterprise of PJSC Gazprom in the Russian Federation in 2018 [2].

![Figure 1. Volumes of hydrocarbon production by PJSC Gazprom [1].](image-url)
According to figure 1, a hydrocarbon production diagram was drawn up, clearly showing in which regions the largest amount of hydrocarbons is produced (figure 2).

Figure 2. Shares of hydrocarbon production volumes by region.

Technological processes of production, storage, transportation and processing of oil and gas can be complicated by the formation of hydrates [3-4]. Hydrates are solid crystalline compounds formed as a result of the interaction of water with hydrocarbons under certain temperature and pressure conditions, mainly due to Van der Waals forces [5-7]. This compound is very unstable and any violation of the equilibrium state of hydrate formation will lead to their decomposition. The phenomenon of hydrate formation is characterized by a sharp decrease in the transfer capability of pipelines, which in turn can lead to an emergency shutdown of pipeline operation. [8].

2. Methods to combat hydrate formation.

To date, to prevent the formation of hydrates and eliminate the already formed hydrate plugs, there are a number of methods [9-10], which are divided into three groups according to the mechanism of action. The classification of existing methods is shown in figure 3.

Figure 3. Classification of methods to combat hydrate formation.
The chemical method [9] involves the introduction of inhibitors into the gas flow. Inhibitors are chemicals that slow down or eliminate hydrate formation [11]. Methanol, glycols, calcium chloride solution and others are used as inhibitors. The advantages of this method are applicability in the Far North, high manufacturability, and relative cheapness. The disadvantages are the toxicity of substances, which can lead to poisoning of people, the environment, the possibility of corrosion of equipment and pipelines.

The technological method [9-14] consists in maintaining a hydrate-free mode of the process. This can be achieved by selecting the appropriate working flow rates of the well, at which the temperature at the wellhead will be higher than the equilibrium temperature of hydrate formation. Also, this method can be implemented through the introduction of the so-called “smart” wells - these are wells equipped with sensor systems and/or control valves that allow you to control the operating parameters. This innovation will allow to remotely, timely and quickly respond to all changes in the parameters of the mining process and prevent the emergence of conditions for the formation of hydrates. Smart wells are very widespread in the world, but in Russia these wells are not yet in great demand (figure 4). This method is well applicable in fields with a warm, temperate climate.

It is also possible to avoid hydrate formation by heating the gas at specialized stations using steam, or in heat exchangers with other heat carriers. These heaters are installed in places of possible hydrate formation. This method is applicable only for short sections of pipelines and requires significant operating and economic costs.

To destroy the already formed hydrates, the pressure reduction method is used. It is based on a short-term pressure drop below the hydrate decomposition pressure and is applicable only in emergency situations.

The physical method involves the mechanical removal of hydrates by scraping, or by heating the section of the pipeline where hydrates are formed. The application of this method is due to the partial or complete shutdown of equipment, which leads to large economic losses. In this connection, today the physical method is practically not used anywhere.

3. Methodology and comparison of methods to combat hydrate formation.
In the course of the research work, a methodology for comparing the technological and chemical methods with each other was developed. The methodology is as follows: assessment criteria are assigned - economic, impact on human health, environmental (damage to nature as a result of an accident), temperature criterion (the effectiveness of the method under different temperature conditions, from low
to high temperatures). In the course of the analysis, it was assumed that all criteria are equal. A comparison diagram of the methods is shown in figure 5.

![Figure 5. Analysis of methods to combat hydrate formation.](image)

The temperature criterion was formed in such a way that the use of the chemical method is possible both in extremely negative and extremely positive temperatures, and the technological one - only in extremely positive ones.

Based on the comparative analysis, it can be concluded that when all the evaluation criteria are taken into account, these methods are approximately equivalent. However, it should be noted that at the present stage in Russia, the key factor for choosing a method for combating the formation of hydrates is temperature, since most of the production of hydrocarbons occurs in harsh climatic conditions (see figures 1, 2).

Let’s carry out a comparative analysis of the inhibitors used in practice. The following inhibitors are mainly used in production: glycols, methanol, calcium chloride and others. The choice of inhibitor depends on its ability to lower the equilibrium temperature of hydrate formation, cost, industrial regeneration, water solubility and toxicity.

Figure 6 shows diagrams of comparative analysis of inhibitors by various parameters. Each parameter was assessed on a 5-point scale: 1 point - unsatisfactory, 5 points - excellent.

![Figure 6. Results of the analysis.](image)
According to figure 6, it can be said that the most preferred inhibitor is methanol [15-17] (largest area of the figure).

Thus, in the course of the research work, a map of the Russian Federation was proposed, which marked the zones where the most optimal use of chemical (zone A) and technological (zone B) methods (figure 7).

![Figure 7. Map of distribution of hydrocarbon production volumes in the Russian Federation.](image)

4. Conclusion

In the conclusion of the review study, the following conclusions were formulated:

- To date, the most optimal methods for preventing hydrate formation are chemical and technological.
- A comprehensive comparison of chemical and technological methods shows that the technological method is the most environmentally friendly, but at the same time, it is much more expensive than the chemical one, and much less effective at low temperatures.
- Comparison of chemical inhibitors showed that it is best to use methanol, but one should take into account its high toxicity (refers to substances of the 3rd hazard class).

Taking into account the above conclusions, a forecast was made according to which, over the next five years, the most common method of combating hydrate formation will be chemical, and the most widely used inhibitor is methanol.

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