Experience in developing oil and gas deposits with horizontal wells located near the gas processing plant

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Abstract. In this work, four wells were analyzed at the Srednebotuobinskoye oil, gas and condensate field located in the Republic of Sakha (Yakutia). Production of oil reserves is complicated by the problem of gas breakthrough from the gas cap into the oil area of the reservoir, which leads to gasification of production wells up to their full shutdown. The field is characterized by the presence of a thin oil rim. That is why there is an urgent need to develop innovative technologies capable of ensuring higher oil recovery rates. The result of the conducted analysis is the object of implementation of the research results of this work.

1. Introduction
The object of research in the work is oil and gas deposits of Botuobinskoye horizon, located in Srednebotuobinskoye field. The peculiarity of oil and gas condensate field development is the direct dependence of hydrodynamic connection between oil and gas condensate objects. In accordance with the adopted project decision of the current field development project, oil reserves development of the Bt facility implies operation with horizontal wells with the length of more than 1250 meters. The geometry of the grid reflects the condition of in-line placement of wells: distance between rows of 500 meters, between wells in a row of 1000 meters. The rows of wells are shifted relative to each other, the gentle section of which is confined to the oil-saturated intervals of the deposit.

Well operation indicators, modes and conditions of their operation are essentially determined by the tasks of field studies, which are formulated as follows: justification of the optimal profile of horizontal well site location, taking into account the specific character of oil and gas saturation of the horizon. In the course of field development, the resource and energy potential of the formation is the uniform commissioning of objects in development.

2. Results and Discussion
The Srednebotuobinskoye oil and gas condensate field is located in Western Yakutia. In close proximity to the Srednebotuobinskoye field, the Taas-Yuryakhskoye, Bes-Yuryakhskoye, Irelyakhskoye, Mirminskoye, Severo-Nilbinskoye, Khotso-Murbaiskoye oil and gas condensate fields, which are at various stages of development (exploration, construction or development), have been
explored and are listed on the state balance sheet. According to the adopted scheme of oil and gas geologic zoning of the territory of the Siberian platform, the Srednebotuobinskoye field is timed to the Nepsko-Botuobinskoye oil and gas bearing region of the Leno-Tunguska oil and gas bearing province. A number of oil and gas fields have been discovered within the oil and gas bearing area, including the Chayandinskoye field, unique in terms of gas reserves with condensate. The Verkhnechonskoye, Talanskoye, Chayandinskoye, Yarakkinskoye, Severo-Talanskoye and Verkhnevylyuchanskoye fields are the largest in terms of oil reserves [1].

The Srednebotuobinskoye field is large in terms of both oil and gas reserves. The field is characterized by an intensive manifestation of block tectonics, which led to the formation of four large tectonic blocks: Central, Western, Eastern and Northern, complicated, in turn, by smaller order faults. All identified faults are considered hydrodynamic barriers. The proven oil and gas bearing capacity of the field is primarily associated with sediments of the Botuobin horizon, which contains the majority of oil and gas reserves. Gas deposits with condensate have been discovered in sediments of the Ulahan and Talakh horizons of the Kursk Vendian and Osin horizons of the Cambrian Bilir Formation. The prospects of oil and gas bearing are also connected with deposits of the Upper-Bbyuk Subformation, the Uspun Formation's Transfiguration Horizon, and the Jurassic-I-III Yuiriakh Formation's horizons. The proven productivity of the Central Tectonic Block of the Srednebotuobinskoye field is associated with sandstones of the Botuobinskoye horizon and with the Lower Cambrian carbonate sediments of the Bilir Formation - the Osinskoye horizon, the O-I and O-II formations. Oil and gas bearing capacity within the Northern Block was found in four horizons - Botuobin, Ulakhana I, Ulakhana II and Talakh. Within the Eastern Block III only the Botuobin production horizon was discovered, the Ulakhani horizon has a local distribution within the field and there is no oil content within the Eastern blocks [1]. The Talakh horizon has not been sufficiently explored within the northern block and its prospects have not been assessed within Eastern block III. The Botuobinskiy horizon is the main one at Srednebotuobinskiy field. Maximum oil flow rate was received in square No. Sbt-53 - 192 m³/day, maximum gas flow rate in square No. Sbt-86 - 1616 thousand m³/day, maximum water flow rate in square No. Sbt-7 - 144 m³/day.

When deciding on the field development strategy, one should take into account the fact that the practice of oil rim development is based on the organization of barrier flooding, regulation of oil and gas withdrawal rates and water injection in order to minimize losses associated with the introduction of oil into the gas part of deposits. The modern practice of oil rim development, which is covered with gas cap and underfloor water, presupposes wide application of horizontal wells. Important is the economic result, which predetermines the order of hydrocarbon reserves development, the order and rate of formation drilling, their status: main object or returnable object.

Thus, from the point of view of geological and technological conditions, within the limits of the Central Tectonic Block of Srednebotuobinskoye field the objects of development are Bt and O-I+II layers.

Extracting reserves from gas-oil and gas-condensate deposits is generally considered more difficult than developing oil fields. Specific features of these deposits (complex geological structure, presence of oil, gas, gas condensate and water in the reservoir) to a certain extent complicate the complex of problems associated with their development. It is especially typical for large gas and oilfields of Western Siberia (Samotlor, Fedorovskoye, Lyantorskoye, Variganskoye, etc.), including the area of Surgut arch, where 48% of current oil reserves of the fields under development fall on the share of oil and gas deposits. Analyses show that due to the high production of more geologically simple oil deposits, the prospects for oil recovery in this area will be primarily related to the development of complex gas and oil deposits. The main oil and gas reserves of the Surgut region's gas and oil deposits are concentrated at two sites - the Lyantorskoye and Fedorovskoye fields, which are characterized by a complex geological structure, small oil layer thicknesses and a large share of pore volume of oil-saturated layer. Extraction of these reserves with the highest oil recovery and lowest costs is one of the main problems in the development of fields of this type.

The tasks of rational development of gas-condensate (GKZ), gas-condensate oil (GKNZ) and oil
and gas (NGZ) deposits with bottom water are given, the generalization of world experience in the development of these deposits is given, the design theory is developed taking into account the geological and hydrogasdynamic features of NGZ and GKNZ and their classification, current problems of design and rational development of these objects are considered. The main difficulties in the development of oil and gas deposits are associated with technological difficulties of oil recovery, depending on the mode of their development. In this case, mainly show the modes of dissolved gas and the elastic-water pressure; the first has a dominant value and determines the final coefficient of oil recovery, in most cases insignificant. Due to the increasing world demand for oil and the depletion of large oil fields, there is increased interest in the development of oil and gas deposits and oil rims. As it is known, a rational method of oil rim recovery is considered to be the advanced oil rim development with saving of gas cap energy. However, as the world practice shows, sometimes the method of simultaneous extraction of oil and gas reserves from oil and gas deposits with preservation of gas and oil contact immovability is useful [2].

The oil and gas deposit of the Botuobinsky horizon is characterized by a complex geological structure, abnormally low formation pressure and temperature. Low reservoir pressure (50 kg/cm$^2$ less than hydrostatic pressure) [3] indicates that the reservoir has limited reservoir energy reserves and its long-term operation in the depletion mode is not expedient. Based on the results of field works performed during the development of Srednebotuobinskoye field we can conclude that geological conditions of hydrocarbons occurrence have an adverse effect on the efficiency of oil recovery process. Oil production under such conditions is inevitably accompanied by the extraction of significant volumes of associated formation water and top gas breakthrough [4].

Efficiency of gas-insulation measures in development of oil and gas deposits of Botuobinskoye horizon, as well as for other fields with hard-to-recover oil reserves, is an important problem for the near future. The regulation and control of oil reserves development processes and limitation of inefficient utilization of associated gas for flaring are of great importance. The assessment of the prospects of applying gas-insulation methods is connected with the creation of unconventional technologies, the physical nature of which is not only high technological efficiency, but also resource saving with a significant expansion of geological criteria of their applicability.

Analysis of the nature of gasification of oil producing wells and study of the causes shows that the main ones are:

- Gas breakthrough due to cone formation in monolithic areas, %
- Gas inflow by permeable interlayers with an outlet to the GNA, %
- Perforation of lawn saturated interlayers due to uncertainty, %
- Gas filtration by cone space, %
- Well operation in dissolved gas mode, %

Figure 1. Reasons for gasification of wells under conditions of gas and oil deposits development
The primitiveness of the process of gas and oil reservoirs development is determined by a 2-phase system, which is in equilibrium at initial formation conditions. In the process of development thermobaric parameters of the deposit are changed and the equilibrium is broken. General decrease of reservoir pressure (or decrease in some parts of the reservoir) leads to movement of CPC. Due to viscosity instability, the movement of the gas condensate downstream contributes to the breakthrough of gas tongue into the oil wells and the formation of cones [5].

Development of gas and oil deposits is complicated:
- by the difficulty of regulating the movement of G.N.A;
- equal saturation pressure (Pnas) and initial formation pressure (Рnas.н.);
- the unconditional proximity of the bottom of the GNK well when draining the oil rim;
- rapid gas breakthrough to the bottom of production wells and instability of oil displacement by gas, resulting in loss of reservoir energy;
- Possible SSC mobility in the vicinity of the well in the process of development and full hydrodynamic connection of the oil bed with the gas cap.

The growth of the gas factor is directly related to the location of wells relative to the gas content, the closer a well is to the gas content contour, the shorter is the gas-free period of well operation and the faster is the tightening of the gas cone. Only well №124 operates with relatively high (70-80 t/day) oil flow rate and stable gas factor (400 m3/t). For the rest of the wells the time of gas breakthrough from the wellhead (over 300 m3/t) is 1-2 days. Well №99 is an exception - where the breakthrough time was 18 days. The most probable reason is the influence of clay lintel, which is installed in close proximity to the HSS. Also it should be noted that the gas factor measured at wells (including during hydrodynamic studies), can not be the basis for the justification of parameters of the initial formation oil, because these parameters should be taken on the basis of experimental measurements (PVT) on the depth samples in the laboratory.

According to the analysis of field data, the current well flow rate for oil varies in the range from 3.5 to 204.6 tons per day, for liquids from 4 to 236 m3/day. The average oil flow rate is 90 tpd, fluid flow rate is 109.5 m3/day. Such a significant dispersion is related to the well construction and the wiring profile. Horizontal wells certainly justify themselves both from the point of view of productivity, which is four times higher than that of directional wells, and oil flow rate (HS - 110 tons per day, NPS - 30-40 tons per day).
Analysis of BT reservoir development showed that failure to achieve the design indicators for oil production and oil flow rates in 2017 becomes more significant: at actual values of 228.9 thousand tons, 101.4 tons per day and design values of 597 thousand tons and 42.0 tons per day respectively. The reason for the discrepancy between the design and actual indicators is the difference in the current production fund of about 30% (project - 41, fact – 28), due to the disconnection of wells due to high gas factor and the absence of new wells from drilling. Under the project, 39 new wells were planned to be commissioned, 9 wells were drilled, and 27 wells were commissioned (due to inaction and development of previous years). The water content of production wells under the project is 5.2%, actually from 5% to 25%. The wells are operated with high gas factor (~2000 m³/t), which is caused by imperfect technology of well construction and installation [6].

Despite the operation of wells on limited modes (underbalanced 1.0-3.0 MPa, downhole pressures up to 9.0-12.0 MPa at design Rzab – 4.0 MPa), unsatisfactory quality of cementing, fastening of couplings and packers led to the advance gas breakthrough of gas cap. The current gas factor is
considerable 328 m$^3$/t and exceeds the calculated value by 4 times. Since the beginning of development, 1106 thousand tons of oil and liquid have been produced at the field. The analysis of well operation indicators and field research results reflects a number of development process regularities, which were not confirmed before.

![Figure 5](image)

**Figure 5.** Dynamics of bottomhole formation pressure BT through the wells located near the SOC.

### 3. Conclusion

On the basis of the performed analysis of the experience in developing oil and gas deposits with a large gas cap and bedding bottom water, the reasons affecting the effective production of oil reserves were identified. The main reasons for high gas factor are gas breakthrough in horizontal wells behind the column space due to poor quality cementing and tightening of the upper gas cone in the areas of monolithic structure of the deposit. For the conditions of development of low-temperature deposits of the Srednebotuobinskoye field the main development indicators were analyzed during commissioning of new wells. It was found out that the optimal location of the horizontal well section should be closer to the water-oil contact. In addition, in the under-gas zones, it is necessary to reduce underbalance and optimize the parameters and profile of the hollow well. In consequence of operation of wells with increased underbalance up to 3.0-5.0 MPa leads to rapid growth of HF gas factor up to 1000 m$^3$/m$^3$ and higher. Based on the analysis of field data to ensure longer operation without gas breakthrough, the optimal underbalance is not more than 1.0 MPa. It is recommended to use the results of the study when developing oil reserves from under-gas zones of oil and gas fields.

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