Evaluation of Thermodynamic Researches of Layered Fluids in the Design and Development of Deposits of Hydrocarbon Raw Materials

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Abstract: At present, publications devoted to modern experimental equipment are widely used in domestic and foreign scientific journals aimed at specialists in the field of hydrocarbon processing. Thus, the installation of PVT ratios from Chandler Engineering allows us to conduct research in a wide range of pressures and temperatures and determine the phase processes of hydrocarbons. In the experimental work performed with natural mixtures and reservoir gas condensate systems, a pattern was found. At high reservoir pressures and temperatures, condensates are characterized by an increased content of high molecular weight hydrocarbons of complex structure, which affects phase processes. The parameters and indicators determined on this installation are the initial ones for calculating the balance reserves of ethane, propane, butane, non-hydrocarbon components in the formation gas, designing development and field development, as well as further processing of condensate. The main goal of the work is to determine the effect of contact condensation, which manifests itself when the deposits are unevenly developed by the area of the field on the development of hydrocarbon reserves based on experimental thermodynamic studies.

1. Introduction

In areas of the Far North, as practice has shown at the present stage, that the increase in liquid hydrocarbon reserves is associated with Achimov and Jurassic productive deposits. These deposits are located at great depths, characterized by a complex structure and the presence in the geofluidic system of increased reservoir pressure and temperature, as well as a complex hydrocarbon composition. Therefore, a detailed study of reservoir fluids of the Achimov deposits of the Urengoy field and the Jurassic stratum of the Pestsovoy field is of practical interest in the design of development, field development and processing of gas condensate. The research results showed that the condensate of the Jurassic deposit differs from the Achimov condensates.

The peculiarity of the Jurassic deposits in the Pestsovoye field is the abnormally high reservoir pressure Abnormal seam pressure (ASP), which is much higher than the Abnormal seam pressure (ASP) of the Achimov deposits. The reservoir pressure in the gas condensate reservoir of the \( \text{Yu}_3 \) layer in the depth interval 3910 - 3912 meters reaches 75.38 MPa, the reservoir temperature is 114°C. For the conditions of the \( \text{Yu}_0^9 \) reservoir, the initial pressure at a depth of 3849 meters was 75.37 MPa at a temperature of about 109°C. According to reservoir gas
studies at the PVT installation, a graph is plotted of changes in the current condensate content in the reservoir gas with decreasing pressure at the stages of field development, and a graphical dependence of the condensate content in the gas phase of the reservoir system. In repeated contact condensation experiments, the pressure of the beginning of condensation was determined. So, it is clear that the condensation onset pressures determined by the contact and differential method are much lower than the initial reservoir pressure. With an uneven selection of the gas condensate mixture, the condensation pressure increases, and the maximum condensation pressure shifts toward the beginning of condensation. Therefore, the nature of the «reservoir loss» curve indicates an intensification of the condensation process under conditions of uneven production of hydrocarbon reserves, those. large reservoir losses of condensate.

2. Results and discussion

The topic under consideration is relevant in connection with the fact that gas condensate deposits located at great depths are characterized by a complex structure and the presence of an Abnormal seam pressure (ASP) in the geofluidic system. Therefore, a detailed study of reservoir systems of complex hydrocarbon composition is of practical interest in the development, development of fields and the rational processing of gas raw materials. Therefore, a detailed study of reservoir systems of complex hydrocarbon composition is of practical interest in the development, development of fields and the rational processing of gas raw materials. The results of a study of the thermodynamic and physicochemical properties of the reservoir gas of the Yu³ and Yu⁰² deposits revealed their practical convergence. A feature of gas compositions is the high content of ethane (8.88 and 5.14 mol%) and propane (8.90 and 5.44 mol%). Condensates by fractional composition are heavy, the end of boiling of liquid hydrocarbons reaches 420°C, the density of the condensate fraction at the level of 0.802 g/cm³. This circumstance, obviously, is connected with the presence, to one degree or another, of hydrocarbons of the oil series. Obviously, harsh thermobaric conditions have become a favorable factor for the process of dissolution of liquid hydrocarbons during the transition to the gas phase of the largest part of the oil components. These condensates, characterized by high density and high paraffin content, occupy an intermediate position between oils and «pure» condensates. Condensates from peripheral wells located close to the outer contour of gas content or the area of development of oil rims fell into the region of oil-like condensates. The research data allow us to talk about the belonging of the studied fluids of the Yu³ and Yu⁰² formations to the common reservoir in connection with the proximity of their physicochemical characteristics. The Achimov deposits are stratigraphically confined to the Berrias-Valanginian age of the Lower Cretaceous system (lower parts of the Pokur Formation). According to the lithological composition, they are represented by sandstones and siltstones, as well as poorly permeable mudstones. The object of the study was samples of saturated condensate and gas of separation, taken from wells during field studies of productive formations Ach3-4 of the Urengoy field. In the study of the fluid, the thermodynamic and physicochemical properties of hydrocarbon mixtures were determined. So for a number of representative samples, the values of physicochemical parameters showed that the condensates of the Achimov deposits have a heavier composition. The molecular weight varies from 120 to 149. The density varies in the range of 0.8012 to 0.8296 g/cm³ [1,2,3].

Prediction of reservoir hydrocarbon losses due to uneven input of gas condensate deposits over the field’s area was carried out according to the approved methodology of Gazprom VNIIGAZ LLC, which allows the study of phase processes of gas condensates located in the Abnormal seam pressure (ASP) at a given temperature and pressure. Chandler Engineering's PVT is based on an integrated high-pressure pump, used to create pressure and accurately measure the volume of fluid deposited. The design of the PVT cell with an integrated digital video system makes it possible to accurately measure formation condensate losses in an automatic mode [4,5].

Before loading the separation gas into the PVT cell, its internal working volume was repeatedly purged with the test gas in order to displace air, if there could be one. The volume of the loaded separation gas is selected so that when the pressure in the PVT cell reaches reservoir pressure, the
position of the floating piston does not interfere with the movement of the magnetic stirrer. It is designed to mix crude condensate when reservoir conditions are reached with a view to its more rapid transition to the vapor phase. The calculation of the volume of the loaded separation gas is carried out by multiplying the geometric volume of the PVT cell by the pressure (Over pressure + Absolute pressure). It should take into account the compressibility factor for a given gas composition, pressure and temperature, and with the conversion of the final result to standard units. In carrying out this study, two complete experiments were carried out, from reservoir conditions (Reservoir pressure and Reservoir temperature) to a pressure in the apparatus of 0.1 MPa. The volume of crude (saturated) condensate that must be loaded into the PVT cell for this experiment was calculated by the formula: 
\[ V_{\text{load}} = \frac{V_g}{1000} \times CGF \] 
where CGF is the Condensate gas factor. The pressure in the container of crude condensate at room temperature is \( P_{\text{con}} = 60.18 \) MPa, which is almost equal to the reservoir pressure. Therefore, the 400 fluid container of crude condensate was cooled at the time of loading in order to reduce the loading pressure. The loading pressure, after checking the presence of the gas phase in the container, was set at 60.0 MPa. The pressure in the PVT cell was set below the loading pressure by no more than 0.1 MPa. After adjusting the parameters of the test gas to reservoir conditions – \( P_{\text{res}} = 60.0 \) MPa and \( T_{\text{res}} = 110^\circ\text{C} \), the remnants of the crude condensate were mixed, which, by this time, had not yet passed into the gas phase using a magnetic stirrer. After a while, at the end of mixing and turning off the magnetic stirrer, no liquid phase was observed in the periscope of the apparatus. In the subsequent experiment of contact condensation of the system, the process of which is reversible and which is carried out by lifting the floating piston of the PVT cell by releasing the buffer fluid from the apparatus hydraulic system, the pressure of the beginning of condensation was determined. After repeated repetition of this process, this parameter is finally fixed at the level of \( P_{\text{c.s.}} = 50.10 \) MPa. Differential condensation, unlike contact condensation, is an irreversible process. Therefore, to obtain several points for the formation of stable condensate, it is necessary to conduct several experiments of differential condensation, each time to the desired pressure point of the device or reservoir. The calculated phase diagram of the gas condensate system of the Achimov deposits of the Urengoy field is shown in Figure 1.

![Figure 1. Phase diagram of the gas condensate system of the Achimov deposits.](image_url)
The basis of thermodynamic studies of phase-unsaturated gas condensate systems was the determination of hydrocarbon losses at different stages of reservoir pressure reduction. Distinguish between differential, which simulates field development without maintaining reservoir pressure. The contact condensation study examines the process of reducing reservoir pressure with a constant mass of the system. Moreover, with contact condensation, reservoir fluid losses in the reservoir are greater than with differential modeling of the depletion reservoir development process. The effect of contact condensation is observed with the advanced development system of the underlying oil rim.

In case of uneven operation of the gas condensate deposit over the area, the effect of contact differential condensation may occur. In the course of the research, the degree of influence of contact condensation on the reservoir losses of hydrocarbons in the deposits and phase transitions of gas condensate systems was revealed. To solve the problem of the degree of influence of contact condensation on the condensate recovery coefficient, a series of experimental experiments was performed by the contact differential method on representative samples of separation gas and saturated condensate, taken from Achimov deposits that are under the conditions of Abnormal seam pressure (ASP) [6, 7, 10].

The essence of the experiments was to determine condensate losses under conditions of varying degrees of reservoir pressure reduction by contact differential condensation in modeling the development of a gas condensate reservoir. The pressure differential curves of reservoir condensate losses obtained by the contact-differential method for the phase-unsaturated gas condensate system of the Achimov deposits of the Urengoy field are shown in Figure 1.

![Figure 1. Pressure differential curves of reservoir condensate losses](image)

**Figure 2.** Dependence of reservoir hydrocarbon losses on the share of contact condensation.

During the study, the change in the gas-vapor mixture of the multicomponent formation system was determined by contact differential condensation, and the conditions for the transition of the gas mixture to the liquid phase were determined. The basic experiment is differential condensation, then in subsequent experiments the formation of the gas condensate system was carried out after reducing the pressure in the PVT cell by the contact method by 10%, 15% and 20% of the initial reservoir pressure. A significant effect of contact condensation of the system on reservoir condensate losses has been established in the direction of increasing subsequent pressure reduction. So, when the pressure value was reduced by the contact method by 10% of the initial reservoir pressure, the final condensate recovery factor in comparison with the baseline (0.70) decreased by 11% and amounted to 0.59. The experiment was repeated in a thermostatic cell of the PVT-ratios with varying degrees of reservoir pressure reduction by contact condensation. Subsequently, the rate of influence of the contact
condensation participation rate on condensate recovery factor slowed down. The reservoir loss of condensate with complete depletion of the reservoir when modeling the differential condensation process was 140 g/m³, with the participation of 10% contact condensation 167 g/m³, with 15% 180 g/m³. Thus, experimental studies of gas condensate systems of the Achimov deposits showed that when the field is unevenly put into development in different parts of the reservoir, due to the manifestation of contact condensation, an increase in reservoir losses of condensate occurs. Comparison of the obtained data showed that the magnitude of the effect of contact condensation on the phase transformations of gas condensate systems under uneven conditions depends on the thermobaric conditions of occurrence of the deposit and the hydrocarbon composition of the condensate.

3. Conclusion

Thus, the results of experimental studies of phase-unsaturated gas condensate systems of the Achimov deposits showed that contact condensation affects reservoir hydrocarbon losses. So, when the field is unevenly drilled over the area and subsequently put into development at different sites of the reservoir, the effect of contact condensation is manifest due to the unevenness, i.e., there is an increase in reservoir condensate losses in the reservoir. The magnitude of the effect of contact condensation on reservoir losses depends on thermobaric conditions and the hydrocarbon composition of the condensate. Under conditions of Abnormal seam pressure (ASP), there is a high probability of the existence of hydrocarbons at a high concentration of high-boiling components, especially in the zone after the transition of the hydrocarbon mixture through an unstable phase state. When the pressure is reduced by the contact method, which is 10% of the initial value in natural conditions, the largest change in the condensate extraction coefficient is observed in comparison with the differential condensation. Therefore, the obtained results of thermodynamic studies can be the source for predicting the balance reserves of ethane, propane, butane, non-hydrocarbon components in the reservoir gas, designing development and field development, as well as further processing of condensate at various stages of development.

4. References

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