Justification of Condensate Recovery during Development of Productive Layers in Termokarstovoye Field

E I Inyakina¹, M D Z Alsheikhly², R K Katanova³

¹FGBOU VO Tyumen Industrial University, 36 Volodarskogo Str., Tyumen, 625000, Russia
²Kirkuk University, Faculty of Engineering, Al-Sayada St., Kirkuk, 36001, IRAQ
³FSBEI HE North-Eastern Federal University. M.K. Ammosova, Polytechnic Institute (branch), 14 Oyunskogo Str., Mirny, 678175, (Sakha) Yakutia

E-mail: rose941101@mail.ru

Abstract: The tendency of the growth of the share of natural gas in the structure of the fuel and energy balance in Russia has led to active involvement in the industrial development of gas and gas condensate fields located in extreme natural and climatic conditions. Development of Yamalo-Nenets Autonomous Okrug fields, in which more than 65% of the explored reserves of Russia are concentrated, is a fundamentally new stage in the theory and practice of design, construction, and operation of such fields. Justification of condensate recovery during the development of U1 and U2 formations is relevant because the structure of the Termokarstovoye field contains deposits of both massive and reservoir types. It is advisable to develop massive type gas condensate formations simultaneously either with vertical wells or double-barreled wells with horizontal ending. Development of productive layers U1 and U2 are being depleted by wells with horizontal opening of the formation. Moreover, three wells with two horizontal boreholes exploit the U1 formation and two vertical wells are located in the dome zone of the object I. The placement of double-barreled well number 111 is quite justified, since it is located at the edge of the structure of the U1 formation, close to the internal gas-bearing contour. The conducted studies significantly allow increasing condensate recovery and the productivity of gas condensate wells, due to the creation of favorable conditions for the removal of condensate to the surface.

1. Introduction

The thermokarst license area is located in the northeastern part of the West Siberian Plain. In order to study reservoir properties and gas condensate characteristics to justify condensate recovery in the development of Jurassic deposits, the reporting results were analyzed. Core studies and reservoir fluid properties were carried out both by the Tyumen Central Laboratory and the Novosibirsk Scientific Center of “Sibgeonaft” Research Center LLC. The illumination of productive sediments by core measurements has increased significantly due to the implementation of a wider range of additional petrophysical studies. With the standard definitions of reservoir properties performed on the core a wide range of special studies to simulate the reservoirs.
The main productive horizons of the Termokarstovoye field represented by a core and first of all U1 is quite fully (in section and area). So, this is provided the necessary petrophysical basis for a reliable assessment of the estimated reservoir parameters.

2. Formulation of the problem

The illumination of the U1 and U2 formations by core material is extremely unsatisfactory, which reduces the reliability of the estimation of the calculated parameters of the indicated formations using petrophysical connections along the nearby layers. The cores were taken from all wells. The coring was 678 m, the total coring was 382.1 m, which corresponds to 56.36% to the coring and 1.45% to the total well depth (24028 m). At the same time, directly within the productive horizons J1 and J2, the total penetration with coring was 326.7 m, and the volume of the removed core was 173.23 m or 53.02%. According to their lithological-petrophysical and reservoir properties, the analyzed formations can be divided into two complexes. Layer J2, which has a local distribution and is practically not illuminated by core material, is conditionally assigned. The dependence of the change in reservoir properties by facies conditions of sedimentation is common to all layers. The obtained results of the granulometric analysis generally indicate the deteriorated reservoir properties of the U1 formation due to the content of fine-silt and clay fractions in the rock.

3. Theoretical part

With a generally higher content of the sand fraction, the J1 formation is also characterized by a lower content of the fine-grained component, the proportion of which is significant. Taking into account significant differences in the characteristics of productive rocks, petrophysical justification of the well log data interpretation technique was carried out further with differentiation by groups of layers U1 and U2. Formation J1 with coring was penetrated by six wells with total core drilling of 69.9 m; linear offset - 31.05 m, which is 46.61% of the total footage. Reservoir rocks are more often represented by gray sandstones, fine-grained with clay carbonate-argillaceous and clay-carbonate cement and more rarely, gray coarse-grained siltstone with carbonate cement. The reservoir properties determined using core samples through four wells. Fifty two core samples have been investigated to measure porosity which ranged from 8.5 to 11.8%, on average - 15.3%. Fifty core samples have been investigated to measure the permeability, the values ranged from 0.22X 10^3 to 24.4 X 10^3 μm^2 and averaged 3.2 X 10^3 μm^2. Residual water saturation determined using twenty two samples and varied from 41.1 to 88.4%, and averaged 64.4%. High coefficients of residual water saturation cause a lower resistivity of rocks of the U1a formation.

According to well logging data, reservoir properties were estimated in 9 wells. Porosity according to 51 definitions ranged from 13.3 to 18.5%, on average 15.9%. According to permeability, 51 definitions were given; the values ranged from 0.32 X10^3 to 10.73 X 10^3 μm^2, on average - 2.35 X 10^3 μm^2. There are 48 definitions of the residual water saturation coefficient - from 34 to 100%, on average - 61%. The average values of porosity, permeability and water saturation obtained from core and well log data for the u1 formation of the same order.

The investigated layer U2 is a small sand package, allocated in the northern part of the field in the area of wells №166 and №171, contoured from the west, south and east by a clay zone. Core was taken in three wells. Total Interval with coring 6.8 m; linear removal of 4.7 m, which is 69.1% of the total coring. No core was taken from the reservoir interval. The reservoirs turned out to be gas saturated only in well №166 (interval True vertical depth 2891.4 ÷ -2898.8 m), the thickness is 5.3 m. The degree of reliability of the initial data for the U2 formation is extremely low. Therefore, implausible average values of net and gas-saturated thicknesses were obtained. The effective thickness was determined for 5 wells, gas-saturated intervals were found in only one well.

4. Practical significance

Currently, the gas condensate reservoirs of the Termokarstovoye field are being conducted in depletion drive mechanism. This type of mechanism ensures the simultaneous production of gas and
condensate, a high gas recovery factor, the possibility of varying the rates of gas and condensate extraction within a wide range. As of 01.01.2017, the field reached its maximum design level of gas production and is in the stage of continuous production. There are 5 gas condensate deposits under development, grouped into two production facilities. The accumulated withdrawal of dry gas amounted to 4.097 billion m³ (dry topped gas - 3.994 billion m³), the cumulative withdrawal of condensate amounted to 0.914 million tons.

As of 01.01.2017, the average daily production of separation gas (SOG) during the development period fluctuated significantly due to commissioning work at the Complex Gas Treatment Unit (CGTU). The maximum daily level of dry gas extraction was 7.462 million m³. Maintaining the "plateau" for the extraction of gas separation is carried out by reducing the wellhead pressure in the wells. Drop of wellhead pressure for the current year, on average, for object I, 0-9.0 abs.atm., for object II -13.0 abs.atm. Figure 1 shows the dynamics of separation gas production and the dynamics of the wellhead pressure decrease for the current year.

![Figure 1. Separation gas production, dynamics of wellhead pressure changes.](image)

On the change in the specific output of DEK was influenced by a number of factors: Technology of gas preparation for transportation (change in separation conditions during equipment debugging), changes in the potential condensate content in reservoir gas with a decrease in reservoir pressure during development [1,2,3]. Reservoir condensate losses and reservoir condensate supply were estimated based on the results of studies at the PVT unit. The creation of a representative recombined sample to substantiate the effect of formation water on the condensate recovery factor was executed taking into account the measurements of the flow rates of gas, condensate and water. The determination of the volume of the charged separation gas was determined by the design features of the Chandler Engineering unit and the initial condensate-gas factor [4,5].

Gas condensate studies were implemented in most cases with violations of the requirements for wells operating regime during gas condensate studies. The wells worked unstable in terms of liquid hydrocarbon production, which distorted the picture when the reservoir mixture was recombined in the PVT unit. Low-quality samples, respectively, increased the error in determining the composition and properties of the reservoir mixture and, in particular, the pressure of the beginning of condensation.

According to thermodynamic studies, the pressure of the beginning of condensation of the gas-condensate mixture (Well 173, U1 reservoir) ranges from 18.8 MPa to 27.4 MPa (Well 172, U2 reservoir). Thus, there are no clear-cut regularities in the dynamics of the pressure of the onset of
condensation or the final condensate recovery factor in the reservoirs. Figure 2 shows the results of PVT studies of the reservoir mixture sampled from the U1 reservoir.

![Figure 2](image.png)

**Figure 2.** Results of PVT-studies of gas-condensate mixture.

There are doubts about the accuracy of the estimation of the condensate recovery factors also because that under the conditions of the PVT bomb, all physical processes that can occur in a real reservoir (taking into account the reservoir properties, the presence of residual water saturation, etc.) are not reproduced. So, from the results of PVT-studies of the gas-condensate mixture, it can be seen that the pressures of the beginning of condensation, determined by the differential method, are equal to the current reservoir pressure [6,7,8].

When designing a development, the pressure of the beginning of condensation for all deposits in the absence of residual oil saturation is logical to take less than the initial reservoir pressure. Figure 3 shows the reserves by saturation pressure (initial reservoir pressure minus pressure of the beginning of condensation) and condensate recovery factor, depending on the initial potential condensate content and reservoir depth. The theory of such formations suggests as the second way of migration of the upward flow along the section. At great depths, the upward flow of a mixture of hydrocarbons is in a single-phase supercritical state. Such hydrocarbon traps can be diagnosed for both gas reservoirs and light oil reservoirs. In the current case, these are, most likely, gas condensate reservoirs. That is, from the supercritical state with a decrease in pressure during development, they pass into a gas state with the release of condensate in liquid form. The rising stream has the same composition. As it rises, the temperature and reservoir pressure decrease, so the difference between the pressure of the onset of condensation and the initial reservoir pressure decreases and for the uppermost reservoir it can be equal to zero. Further migration of the hydrocarbon flow into the upper layers could lead to the theory of oil and gas condensate reservoirs.

Based on the described scenario of the reservoirs of Termokarstovoye field as the first approximation for the pressure of the beginning of condensation of gas formation, it was decided to take a pressure value close to the initial formation pressure in the U1 reservoir, and for the lower U2 reservoirs - less than the initial formation pressure. Moreover, the pressure reserve will be greater when produced layers are deeper. It is proposed to predict the value of the pressure of the beginning of condensation, the dynamics of the component composition and physicochemical properties, the
coefficients of recovery and loss of condensate in the reservoir by calculating the phase states of reservoir mixtures.

Figure 3. Condensate recovery factors based on the results of PVT studies.

The obtained PVT properties can be used to substantiate the final condensate recovery factor during field’s development in depletion drive using hydrodynamic models. In the calculations of differential condensation, it is proposed to focus on the pressure of the onset of condensation within the initial reservoir pressure, and in the upper layer U1 it should be equal to the minimum initial reservoir pressure [9, 10].

5. Conclusion
Thus, since the gas condensate studies were performed in violation of the requirements for the technological modes of well operation, and the results of PVT studies of the recombined samples vary within a fairly wide range, the condensate recovery factor value for the final pressure of 0.1 MPa was predicted when substantiating the current condensate recovery based on the results of calculating phase states. Real profitable condensate recovery factors for the injection pressure were refined based on the results of calculations of development indicators on a permanent three-dimensional three-phase geological and technological model. Thus, the final condensate recovery factor according to the results of thermodynamic studies varied from 0.455 to 0.792, the average value for reservoirs for sampling close to representative is from 0.508 to 0.719.

6. References
[1] Alexandrova E M, Ivanova M S, Inyakina E I, Katanova R K, Tomskiy K O 2019 Study of oil characteristics of two-phase deposits Materials of the All-Russian youth scientific conference with the participation of foreign scientists (Novosibirsk)
[2] 2007 Research report “Technological scheme for the development of productive horizons J11, J12 of the Termokarstovoye field”: Scientific Research Center “Sibgeonaft” LLC (Novosibirsk)
[3] Inozemtseva A A, Inyakin V V, Krasnov I I etc. 2015 Measures to increase the productivity of wells and limit the inflow of formation water. *Materials of the scientific and technical conference* (Tyumen) pp 90-94

[4] Tomskaya V F, Alexandrova E M, Krasnov I I and other 2019 Substantiation of modes and conditions of wells operation at the Srednebotuobinskoye field. *Scientific forum* (Siberia) Vol 5 pp 11-12

[5] Ivanova M S, Inyakina E I, Krasnov I I, Inyakin V V 2019 Influence of mining and geological conditions on the development of hydrocarbon reserves. *Mining journal* 2 pp 10-12

[6] Petrenko V I, Zinoviev V V, Zlenko V Ya et al. 2011 Geological and geochemical processes in gas condensate fields and underground gas storage (M.: Nedra)

[7] Ostrovskaya T D, Inyakina E I, Krasnov I I 2018 Influence of water on the extraction of hydrocarbons from the reservoir during the development of a gas condensate field. *Scientific forum. Siberia* 2 pp 5-7

[8] Inyakina E I, Krasnov I I, Inyakin V V 2017 Experience in the development of oil and gas condensate fields with complicated geological and physical characteristics. *Oil and Gas: Experience and Innovation* 1 pp 41-56

[9] Inyakina E I, Katanova R K, Alheikhli M D Z 2019 Methodology for predicting the current condensate content and hydrocarbon losses in the reservoir. *Oil and Gas: Experience and Innovation* 2 pp 20-41