Forecast of the Effect of Condensation Water on Reservoir Losses of Hydrocarbons in the T1-A Field of the Srednetungsky Field

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Abstract: Experimental PVT studies of the gas condensate mixture of the Srednetyungskoye field for the determination of the reservoir losses of hydrocarbons with the availability of condensation water have been conducted on recombined samples of separator gas, deposit water and saturated condensate. The bed samples were taken during field research of wells operating the T1-A deposit of the Srednetyungskoye oil and gas condensate field. T1-A bed has been sunk by all wells drilled in the field. The gas condensate pool was opened by thirteen wells, three of which (No. 225, 230, 240) made it possible to determine the position of the газоводяной контакт (ГВК) gas-water contact (GWC) of the deposit. Experimental modeling of phase behavior of gas-condensate bed systems at different thermodynamic states was carried out to determine the influence of condensation water on the value of condensate recovery during the development.

1. Introduction
The works on determination of thermodynamic properties and potential condensate content in formation gas at the exploration area of the Srednetyungskoye field in the Western Yakutia was carried out simultaneously with the expansion of the exploration drilling volumes. The first analytical studies were carried out by the East Siberian Laboratory (ESL) in cooperation with ОOO “Газпром VNIIgaz”. These studies were carried out to determine the parameters and indicators that are the basis for calculating the balance and recoverable reserves of condensate, ethane, propane, butane, non-hydrocarbon components, determining their potential content in formation gas, accounting for the production of condensate and natural gas components, research and arrangement of fields and condensate processing. It was difficult to research the beds with low-permeability reservoirs, because in order to obtain the necessary flow rates one has to create a large draw-down on the formation and the evaluation of true gas-condensate characteristics is very complicated.

2. Relevance
The influence of produced water and uneven input into the development of reserves of a large deposit leads to an inhomogeneous distribution of reservoir pressures and a significant differentiation of the current composition of raw materials extracted from different zones and areas, as a result, there is a need
to apply such methods and research tools that would allow timely and correct determination of all characteristics of the extracted raw materials for further forecasting of hydrocarbons

3. Formulation of the problem
The gas condensate deposit was discovered by thirteen wells, three of which (№№ 225, 230, 240) made it possible to determine the position of the gas-water contact (GWC) of the reservoir. In well №225 GWC was determined using geographic information systems геофизические исследования скважин (ГИС) well logging (GIS) at a depth of 2821.6 m (a.o. 2620,1 m), at the same depth, when testing formations on a cable (OPC), 100 liters GWS were obtained in one minute. The reservoir was tested in the column slightly higher than the GWC in the interval 2805-2815 m (a.o. 2603,4 m, a.o. 2613,4 m). Trial operation and gas condensation studies in the reservoir were carried out in well № 222 (interval 2690-2718 m, a.o. 2550,8-2578,8 m). During 21 days of trial operation, 16 million m$^3$ of gas was burned. The well worked stably. Wellhead parameters remained constant. The fall of reservoir and bottomhole pressures, the removal of rock and fluid was not observed [6]. The reservoir T1-A is a reservoir vault. The structural trap is completely filled - "to the castle". The height of the deposit is about 220 m.

In this way, an analysis of the gas compositions of the Lower Triassic and Upper Permian productive complexes shows that the gases of all the deposits have a close physicochemical characteristic. This circumstance may indicate the geochemical unity of the above deposits, and their comparison with the gases of the deposits of the central part of the Vilyuiski hemisineclise (Srednevilyuyski, Tolonski, Mastakhski, Sobolokh-Nedzhelinski, Badaranski and Nizhnevilyuyski) allows talking about the genetic connection of gases of different age deposits. The density ranges from 0,7539-0,7544 g/cm$^3$, the boiling point is 38-420°C. Molecular weight varies slightly.

4. Theoretical part
Experimental thermodynamic studies were carried out on the installation - $PVT$ ratios in order to determine the phase behavior of the reservoir system and reservoir condensate losses in the prediction of depletion of the field. Based on the results of experimental studies, the condensate drain recovery coefficient (КIK) was determined to justify the recoverable hydrocarbon reserves.

The study of gas condensate characteristics was carried out using a vertical louvered gas separator type ГЖ 6,3-1000-2-1 with a nominal throughput of $Q=1.0$ million m$^3$/day., according to the technological scheme of single-stage gas separation. The flow rate of the separated gas in the control mode was 340,0 thousand m$^3$/day, which does not exceed half the nominal throughput of the separator. Reservoir pressure and temperature were measured with an AMT-08 depth instrument. Reservoir pressure $P(\text{reservoir})=26,41$ MPa and temperature $+59,30$°C. The gas flow rate after exiting the separator was measured using ДИКТ – дифференциального измерителя критического истечения DICT - differential critical flow meter. At the end of the flow line, pressure and temperature measuring instruments are installed - a gauge and a thermometer.

The creation of a representative recombinated sample to justify the effect of formation water on the KIK was carried out taking into account measurements of the flow rates of gas, condensate and water. The determination of the volume of charged gas for separation was determined by the design features of the Chandler Engineering installation and the initial gas condensate factor [13].

5. Practical significance
The gas condensate factor (GCF) of the analyzed system is 110 cm$^3$/m$^3$, the density of the stable condensate is 0,765 g/cm$^3$, the molecular weight of the condensate is 119, and the reservoir temperature is 59,3°C. After loading gas and saturated condensate into the $PVT$ cell, reservoir conditions were created. The single-phase state of the mixture shows that the recombinated gas condensate sample is ready to study the thermodynamic properties. Figure 1 shows the dynamics of reservoir condensate losses in the T1-A deposit of the Srednetungsky field.
Figure 1. Dynamics of formation losses of hydrocarbons in the gas condensate system of the T1-A deposit of the Srednetungsky field.

So, from the graphical dependence it is clear that the condensation onset pressures determined by the contact and differential methods are equal to the current reservoir pressure, and amounted to 25.90 MPa.

The second type of experimental study of the reservoir gas system at the installation - PVT Chandler Engineering provides for maintaining a constant volume of the reservoir system (at a constant temperature), which is possible only if the amount of gas substance decreases, that is, gradual, slow in our case, release of the equilibrium bomb. This type of PVT study is called differential condensation.

Figure 2 shows a graphical distribution of the condensate of the T1-A deposit in the presence of formation water in the system.

Figure 2. Graphic distribution of condensate of the T1-A deposit in the presence of formation water in the system.

1 – reservoir condensate loss with and without water in the system g/m³,
2 – potential condensate content with and without water in the system, g/m³
Differential condensation, unlike contact condensation, is an irreversible process. So, 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. In this study, several experiments were carried out up to a pressure of 0.1 MPa, and the formation of a schedule of reservoir losses of stable condensate was carried out through volumetric shrinkage coefficients from the corresponding values on the initial table 2 of the precipitation of crude condensate.

**Table 1. T1-A formation condensate distribution balance.**

| № of development stages | Reservoir pressure, MPa | Total selection C₅H₁₂+ from the reservoir, g/m³ | Content C₅H₁₂+ formation gas content, g/m³ | Recovery factor K_recovery % |
|------------------------|------------------------|-----------------------------------------------|------------------------------------------|----------------------------|
| 0                      | 25.90                  | -                                             | 61.62                                    | -                          |
| 1                      | 23.41                  | 6.12                                          | 54.70                                    | 9.93                       |
| 2                      | 20.82                  | 12.03                                         | 45.79                                    | 19.52                      |
| 3                      | 18.23                  | 17.53                                         | 37.09                                    | 28.45                      |
| 4                      | 15.64                  | 22.58                                         | 28.64                                    | 36.64                      |
| 5                      | 13.05                  | 27.04                                         | 20.78                                    | 43.88                      |
| 6                      | 10.46                  | 30.89                                         | 14.13                                    | 50.13                      |
| 7                      | 7.87                   | 34.17                                         | 9.05                                     | 55.45                      |
| 8                      | 5.28                   | 37.08                                         | 5.64                                     | 60.18                      |
| 9                      | 2.69                   | 39.85                                         | 3.53                                     | 64.67                      |
| 10                     | 0.10                   | 44.99                                         | -                                        | 73.01                      |

In the hydrocarbon composition of the resinous part, aromatic cycles are dominant. Based on this, we can conclude:

- The condensation onset pressures determined by the contact and differential methods are equal to the current reservoir pressure and amounted to 25.90 MPa.
- The time of stabilization of vapor-liquid equilibrium at points ranged from 1 hour to 1.5 hours. This stabilization time value was established in the course of this study to achieve complete drainage of condensate into the graduated cylinder. At a pressure of 0.1 MPa in the cell, the RVT is recorded by measuring with a measuring piston, and then in the laboratory test tube, 22.00 cm³ of stable condensate. The density of the stable condensate deposited in the equilibrium bomb at the end of the experiment at a pressure of 0.1 MPa, measured at a temperature of +20°C, was – p420 = 0.7560 g/cm³. The volume of gas discharged from the PVT cell at the end of the experiment, recorded by a drum-type gas meter, was: 2098.14 – 1843.94 = 254.2 or 252 liters, which almost coincides with the volume of gas loaded into the bomb at the beginning of the experiment.

### 6. Conclusion

The performed experiments on the contact and differential condensation of the formation gas showed an intensification of the condensation process and a decrease in the KIK value. When conducting repeated experiments on contact condensation, the pressure of the onset of condensation was determined. So, from the graphical dependence it is seen that the condensation onset pressures determined by the contact and differential method are equal to the current reservoir pressure, if there is water in the reservoir gas condensate system, the condensation onset pressure increased by 0.4 MPa, the maximum condensation pressure shifted towards the onset of condensation. The nature of the “formation loss” curve indicates an intensification of the condensation process in the presence of condensation water in the well production, that is, large reservoir loss of condensate. In the presence of water, the final reservoir loss of condensate, respectively, the amount of condensate extraction decreased by 5%.
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