On the possibility of operational management of reservoir pressure in a multilayer reservoir exploited by dual completion and injection method based on recording current gas factor of products extracted from each reservoir

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Abstract. The paper discusses the problem of operating complex and expensive telemetering equipment designed to monitor and control a multilayer field operation using the dual completion and injection method. The author offers an alternative to the applied wireless and wired data transmission (as the first type does not have the required range and the second does not have the required reliability) technology. It is a new method for monitoring and controlling reservoir pressure in real time based on recording the current gas factor of the products extracted from each layer using dual completion method and ensuring its relative stability due to the operational management of their reservoir pressure through the dual injection system. At the same time, it is proposed to use commercially available automated group measure unit equipped with corresponding sensors as the means of measuring gas/oil ratio. Testing the method of reservoir pressure management proposed by the author for the two-layer reservoir of the Tedinskoye field of Lukoil-Severneftegaz confirmed its effectiveness, which served as the basis for the development of an appropriate methodological guide and filing of a patent.

1. Introduction

When exploiting multilayer reservoirs using dual completion and injection method, ensuring the stability of reservoir pressure of each development target aimed to prevent it from falling below the initial one is a technically difficult problem [1].

For this purpose, it is necessary to equip the production facility with a pressure-sensitive system directly in the well against each layer as well as to ensure the real-time information transmission from them to the surface for processing and making appropriate decisions concerning the change of their operation or injection mode to provide pressure buildup [2].

Such a technical solution not only significantly increases the cost of the technological process itself but also reduces the reliability of the entire information and communication system designed for its control. It is stipulated by the fact that both wireless and wired systems [3] transferring information to the surface and used for these purposes are not appropriate. It is due to the fact that the first one has insufficient speed and long-range interaction, and the second one has a low operational resource
associated with poor reliability of wired electric inputs through the separation packers of dual completion and injection systems.

Studies have shown that this problem can only be solved by simplifying the monitoring and control system and building it not on traditional wire-based telemetry systems located in the well but on the surface control (which is much simpler and, most importantly, cheaper and more reliable) of some indirect parameters, the magnitude of which is quite dependent on reservoir pressure.

2. Materials and methods
As was established by studies [4], such a parameter is the current gas factor of gas/oil ratio, the value of which depends on the difference between the reservoir pressure $R_{lay}$ and the pressure of its saturation by associated petroleum gas $R_{sat}$.

Figure 1 shows the experimental dependence of gas/oil ratio on the relative difference between the reservoir pressure and oil saturation pressure of associated petroleum gas for the multilayer field of LLC Sheshmaoil of the Republic of Tatarstan exploiting the Ufa (1), Bobrikov (2) and Devonian (3) strata, composed of sand-clay rocks obtained by the author using the measuring unit "OZNA-LPIGF" and developed with her direct participation [5].

![Figure 1](image)

**Figure 1.** Dependence of gas/oil ratio on the relative difference between reservoir pressure $R_{lay}$ and oil saturation pressure with associated gas $R_{sat}$ for the multilayer field of LLC Sheshmaoil RT operating Bobrikovsky (1) and Devonian (2) strata.

The current gas ratio is:

$$GOR = \frac{V_{apg}}{Q_f},$$

(1)

where $V_{apg}$ is the volume of associated petroleum gas dissolved in the reservoir fluid, m$^3$; $Q_f$ is the weight of reservoir fluid saturated with associated petroleum gas, t.

The relative difference between the reservoir pressure $R_{lay}$ and the saturation pressure of oil associated gas $R_{apg}$ is equal to:

$$\frac{\Delta P}{P_{lp}} = \frac{P_{lp} - P_{apg}}{P_{lp}},$$

(2)

where $P_{lp}$ is layer pressure, MPa; $P_{apg}$ is the pressure of associated petroleum gas dissolved in the reservoir fluid, MPa.

The graphs shown in Figure 1 are typical dependencies that can be obtained for each specific layer of a multi layered reservoir based on laboratory studies of oil samples taken from products extracted from the corresponding reservoir (in this case from Bobrikovsky – 1 and Devonian – 2 strata).
The proposed method for monitoring and controlling reservoir pressure of a particular reservoir of a multizone oil reservoir is as follows (Figure 1).

Products extracted from each layer of a multi layered reservoir go to the ground-based automated group measure unit AGZU-GF, where the current gas factor is monitored on-line, the data from which are then transmitted to the Process control system SUTP. According to the program, as soon as the value of the current gas factor in the products coming from one of the three layers reaches a critical maximum (Figure 1), which will correspond to the deviation of the $\Delta P/P_{\text{lay}}$ parameter from the preset optimal value by an order of -10%. Afterwards the Process control system SUTP will send a command to the corresponding valve in the dual injection system, through which the increased flow of produced water injected through the repressuring system gets into this reservoir.

As soon as an increase in the $\Delta P/P_{\text{lay}}$ parameter by more than 10% from the set value is detected on the AGZU-GF measuring unit, the supply of the amplified flow through the corresponding valve will be stopped upon a command from the Process control system SUTP.

The proposed method of controlling reservoir pressure relative to the saturation pressure of associated petroleum gas makes it possible to set any limit of $\Delta P/P_{\text{lay}}$ regulation.

The proposed method for monitoring and managing reservoir pressures during the operation of a multi layered reservoir using a special device for field equipment is being implemented.

The developed device for field equipment consists of the following units and parts (Figure 2).

Two layers located at different depths, Devonian layer 5 at the depth of ~ 1700m and Bobrikovsky stratum 6 at the depth of ~ 1100m, were opened up zones of a perforated hole 3 in a production well cased with the casing 1 and fixed by a cement ring 2.

Each layer is operated by its deep-well pumping equipment, which includes an ESP unit (electric submersible pump) or sucker rod pump – 7, each of which is suspended on its tubing 8, and their operating intervals are separated using a separation packer 9 (for example, M1-X). Power and commands to the ESP unit are given via cable 10 from the control cabinet 11.

Each tubing passes through the tubing adaptor flange 12 at the mouth of the production well, where it is connected to the corresponding flow lines 13, which are linked to the ground-based AGZU-GF – 14, designed to measure oil, water and oil-associated gas flow rates as well as an accurate estimate of a current oil/gas ratio.

AGZU-GF is connected to the collector 15, and the data on measuring $Q_{\text{o}}, Q_{\text{w}}, V_{\text{oag}}$ and oil/gas ratio are supplied via cable 16 to the Process control system SUTP-(17), which in turn is connected to the power supply and control cabinet 11 by cable 18.

With the help of cables 19 the output of the control system is connected to the controlled gate valves 20 located on the discharge lines 21 and coming from the injection comb 22, to which the injected water from the repressuring system is supplied through the pipe 23 and through the valve 24 managed by the Process control system SUTP-(17).

The injection lines 21 in the tubing adaptor flange 25 located at the mouth of the injection well are connected to two tubings 26 through which water is pumped via two perforation interval zone 27, opening the casing 28, fixed by a cement ring 29. Each injection interval in the corresponding layer is isolated from the neighboring interval by the packer 30.
A method for monitoring and controlling reservoir pressure during operation, for example, a two-layer oil field using the dual completion and injection method, is implemented as follows (Figures 1, 2).

Before implementing the proposed method for monitoring and controlling a value of the reservoir pressure during the operation of a two-layer oil field using the dual completion and injection method, a calibration (exemplary) relationship between the gas factor of a particular reservoir (oil/gas ratio) and the relative difference in reservoir pressure ($P_{lay}$) and the saturation pressure are removed from this layer with associated petroleum gas ($R_{apg}$). It is required as well to lay it on the graph (Figure 1) for each layer separately. Then, the abscissa axis determines the value of the minimum allowed parameter value ($\Delta P/P_{lay}$) common for all reservoirs in one well and fixes the magnitude (oil/gas ratio) corresponding to each reservoir on the ordinate axis. The latter is used as a quantitative criterion applying a special control program and is loaded into database supporting the ground control station of the Process control system SUTP (Figure 2).

Then, it is put in a well that develops a two-layer reservoir using the dual completion and injection method and on which calibration curves shown in Figure 1 were taken into service.

The technological scheme of a production well developing a multilayer reservoir using the dual completion and injection method is shown in Figure 2.

In the casing 1, having the cement ring 2 outside, perforation 3 is made, which reveals two productive formations 5, 6 located at different depths from the surface.

The reservoir fluid is extracted from the upper reservoir by the plunger pump 7 (sucker rod pump), and from the lower reservoir by the sucker rod pump or by an electric centrifugal pump suspended on the corresponding tubing 8. The operation intervals of each of the two reservoirs are isolated from each other by means of a separation packer 9, and the electric centrifugal pump is controlled by force cable 10, which is passed through insulated electrical inputs through a separation packer 9 and is connected on the surface to the control cabinet 11.

The tubing 8 is mounted on the tubing adaptor flange 12, in which they are connected to two flow lines 13 linked to the ground-based measuring group unit 14 (AGZU-GF). It is intended for an
accurate assessment of the current gas factor of the extracted products (oil/gas ratio) along with measuring the flow rate of oil, water and gas from each of the two layers 5, 6 separately.

The products extracted from each of the two layers 5, 6 are sent from AGZU-GF to the production header 15, and data on oil, water and gas flow rates, including oil/gas ratio, are sent via cable 16 to the process control system 17 (SUTP). They are processed by appropriate computer programs by comparing the results obtained from oil/gas ratio with calibration graphs shown in Fig. 1.

If the parameter \( \Delta P/P_{lay} \) deviates from the set value in a smaller direction from the set value for one of the formations being developed, the corresponding shutter 20 is opened on the discharge line 21 upon the command from the process control system (17), providing enhanced injection of reservoir fluids from the comb 23 through the wellhead base plate 25. Further they are to a specific layer along the corresponding tubing 26 directly into the perforation interval zone 27 of the layer, whose relative parameter \( \Delta P/P_{lay} \) has decreased below the set minimum limit by 10%.

The process of intensive injection into this reservoir is carried out until the parameter \( \Delta P/P_{lay} \) reaches the initial value. Afterwards the corresponding shutter 20 is returned to its original position, upon a command from the process control system (17).

3. Results and Discussion

The proposed method of reservoir pressure control based on keeping its value sufficiently stable relative to the pressure of this layer (being saturated with oil-associated gas on the basis of ensuring a stable gas factor of this layer by controlling the value of its reservoir pressure through the repressuring system) was tested at the two-layer Tedinsky oil field of LLC “Lukoil-Severneftegaz”, where oil/gas ratio instability varied as follows ± 45–65% in some wells (for example, No. 146 and 142g) during the measurement process for 12-18 hours.

After the author and the specialists of LLC TuymazyNIPIneft studied the reasons for the established phenomenon, appropriate measures were taken to stabilize it by controlling reservoir pressure in these wells. It was ensured through neighboring focal injection wells, which ultimately reduced the instability of the recorded oil/gas ratio values in the 146 and 142g wells to ± 15–20%.

A patent application has been filed on the basis of the studied phenomenon and the offered method for stabilizing the recorded oil/gas ratio value in the wells of the two-layer Tedinskoye field. The author, together with the specialists of LLC TuymazyNIPIneft, developed and approved the corresponding methodological guide in 2016 [6], and the method for stabilizing the oil/gas ratio value during the operation of multilayer fields.

4. Conclusion

A method and field equipment have been developed for the operational monitoring and control of reservoir pressure during the operation of multilayer reservoirs using the dual completion and injection method based on several factors. The first one is the research findings and their testing under production conditions. The second one is real-time recording of the current gas factor by appealing to ground-based serial measuring installations without the use of expensive and unreliable wired and wireless telesystems used to transmit mode data operation of each of the reservoirs.

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