Results of the Study of the Productive Characteristics of Wells in the Development of Gas Condensate Deposits

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Abstract: Currently, to determine the productive characteristics and diagnose the state of the bottomhole zone of wells (BHZ) operating the gas condensate deposits of the Beregovoye field, studies are being carried out, which include a set of interrelated methods that differ in theoretical basis, technology and execution technique. The purpose of these studies is to obtain information on the thermobaric parameters of the formation fluid in the reservoir, on the productive characteristics of wells, on the filtration-volumetric and mechanical properties of the porous medium. In this case, the curve of the derivative of the pressure drop at the bottom of the well with respect to the logarithm of time, built in two logarithmic axes, is widely used. To construct this diagnostic curve, three types of data are used: pressure recovery curve (HPC); pressure stabilization curve at constant well flow rate and studies with arbitrary change in flow rate and bottomhole pressure. Using the curve of the derivative of the pressure drop over the logarithm of time, a very wide range of possible structure of the wellbore area, the shape of its drainage boundaries, fractures, double media, etc., is diagnosed. When determining the productive characteristics during the development of the reservoir, the nature of the pressure change over the reservoir area was studied. The frequency of measurement of reservoir pressure by wells was established taking into account the geological features of the Beregovoye field and the rate of formation gas withdrawal from the reservoir.

1. Introduction
An important information in determining the productive characteristics in the process of conducting research on non-stationary filtration modes is provided by the recording of the pressure recovery curve. With its help, the current reservoir pressures in the reservoir were determined, the map of isobars and current gas production was carried out. Each production well of the Beregovoye field was periodically surveyed to update the isobar map. The well was shut in once every three months to record the pressure build-up. The results of studies of well No. 011 of the Beregovoye field are of interest because it is located in the central, domed part of the gas reservoir. Therefore, it accounts for a significant part of the load: for technological reasons, it has a depression from 0.4 to 0.45 MPa. The recovery of its pressure during closing was recorded at its mouth with UMT manometers (TNVPO "Siam", Tomsk). The obtained results of removing the pressure build-up after stopping the well in a specific mode (with a specific washer diameter) determined the relationship between the drawdown and gas production rates. The form of the obtained diagnostic curve showed that the horizontal section...
of the curve corresponds to the BHZ area, in which radial filtration is realized. In this case, the value of the curve on the horizontal section is related to the parameter of conductivity \( \frac{k_h}{\mu} \) by an inversely proportional relationship: the higher the horizontal section, the lower the conductivity, and vice versa [1,2].

2. Relevance
The study of the productive characteristics of well No. 011 of the Beregovoye field is relevant as it is located in the central, domed part of the field. During operation, this well accounts for a significant part of the load: for technological reasons, it has a drawdown from 0.4 to 0.45 MPa. She is in a long-term operational fund. Since 2002, it has been periodically put into operation for the needs of the field: gas was taken from it for an autonomous power plant (AES), which supplies the field and drilling with electricity. The well is directional, with a zenith angle of 440 in the middle of the perforated interval. The reservoir was penetrated by perforation along the wellbore with PRK-42S charges, with a density of 12 holes per running meter. It opened the gas-water contact (GWC), but the formation of a cone of water during the operation of the well is prevented by an impermeable clay layer 2.5 m thick underlying the gas cap. Bottom water entering through the hardened space initiates active hydrate formation, as a result of which a constant supply of methanol is made to the gas pipeline [3].

3. Formulation of the problem
When studying the filtration characteristics of the reservoirs, a set of studies was used, which established the productive characteristics of the wells, as well as the initial and current temperature-pressure characteristics of the BT10 and BT11 formations of the Beregovoye field. In the process of pilot operation and further development, well testing was carried out by the service companies of the Urengoygskaya KORS and partly by the Tyumenburgaz branch. At gas-condensate and gas-condensate-water objects, the studies were carried out after the wellbore was completely cleaned from service water and the pressures were restored to stable ones, both during drilling in the open wellbore and in the production casing. Wells 012 and 013, with a similar design and geological section of the bottomhole formation zone, are also operated at the same cluster site with well No. 011 into a single gas-collecting reservoir. From all three wells, bottom water mixed with condensation water enters the plume gas pipeline. Produced water creates active hydrate formation; therefore, methanol is supplied to the gas pipeline. This fact also determines the interest in well No. 011, including the formulation of the problem of its study in an unsteady filtration mode [4].

4. Theoretical part
To monitor the process of reservoir exploitation, each production well of the Beregovoye field is periodically closed for a pressure build-up record, which is recorded in the electronic memory of the device. The recording results and the shape of the curve were processed in special programs (KomTEK, GDI-Effect). The current reservoir pressure, as well as some other reservoir parameters (permeability, skin factor) were calculated for an individual well, and the weighted average reservoir pressure in the reservoir was also determined. Recording pressure build-up at well No. 011 by wellhead parameters (without running a downhole tool) is an extremely economical and affordable way of geological - field control. Considering that the well stock of the Beregovoye field as of the date of the analysis was 63 wells located on 22 well pads with uniform coverage of the entire dome of the reservoir. Based on the analysis of the results by the Geological Field Service, it was proposed to close one well of the pad at the pressure build-up every month. In annual downhole surveys, wellhead measurements are monitored by a downhole recording of reservoir pressure build-up. As a result, it became possible to update the map of isobars and current selections on a monthly basis [5,6].

5. Practical significance
Based on the results of determining the effective permeability of the reservoir, the value of the piezococonductivity coefficient of the formation was estimated. In total, in 18 wells of the Beregovoye
field, the BT10, BT11 formations have been tested in 32 objects. To determine the hydrodynamic characteristics of these formations, the results of wells survey were used, in which commercial inflows were obtained. As of the date of the analysis of the field development in the wells that penetrated the BT10 and BT11 formations, a set of studies was performed on stationary and non-stationary filtration modes. Also, express studies were carried out with the determination of only the current reservoir pressure and temperature. The distribution of surveys of wells operating the BT10 and BT11 formations of the Beregovoye field is shown in Figure 1.

The presented materials show that a significant amount of research naturally falls on the initial period of development. At the same time, starting from the moment the deposits are exploited, there is an increase in the annual volume of research in proportion to the increase in the operating fund. For the first time, gas-dynamic studies at well 011 were carried out on May 27, 2002. The studies were carried out without lowering the downhole tool, by measuring the wellhead parameters with exemplary pressure gauges, and then calculating the bottomhole pressures (at the SIP) according to the formulas. After operation, the well was shut in at pressure build-up. It is known from the geological journal that the wellhead pressure (on the buffer and annular) was restored in the 2nd minute, after which the wellhead pressure slightly decreased (by 0.1 kgf/cm²).

According to the results during the processing of pressure build-up, the following formation parameters were determined: pressure at the wellhead (buffer) - 112.7 kgf/cm²; filtration coefficient "a" - 2.1026; Filtration coefficient "b" - 0.001076; filtration coefficient "A" (reservoir + wellbore) - 0.9339; filtration coefficient "B" (reservoir + wellbore) - 0.003044; well flow rate is free - 1747 thousand m³/day; well flow rate is absolutely free - 2982 thousand m³/day; reservoir permeability coefficient - 0.085 Darcy; skin effect - plus 2.5. In 2007, well No. 011 was re-examined. They were carried out with the descent of a downhole instrument of the AMT-08 type and measurement of depth parameters. Wellhead pressures were recorded with exemplary manometers. Based on the results of HPC processing, the following reservoir parameters were determined: pressure at the wellhead (buffer) - 111.0 kgf/cm²; reservoir pressure on self-supporting insulated wire - 122.96 kgf/cm²; filtration coefficients "a" - 0.0994 and "b" - 0.002297; well flow rate is free - 1699 thousand m³/day; permeability coefficient - 0.197 Darcy.

The wellhead pressure was restored at the 40th minute of the pressure build-up, the reservoir pressure recovered at the 90th minute of the build-up. The next well tests were carried out on the well in 2008 with an AMT-08 downhole tool and exemplary pressure gauges at the wellhead. Based on the
The results of hydrodynamic testing and pressure build-up treatment, the following formation parameters were determined: pressure at the wellhead (buffer) - 109.1 kgf/cm²; reservoir pressure on self-supporting insulated wire - 119.9 kgf/cm²; coefficients "a" - 1.4346 and "b" - 0.000371; well flow rate is absolutely free - 2637 thousand m³/day; the permeability coefficient was 0.220 Da; skin effect - plus 2.3.

The wellhead pressure was restored at the 80th minute of the pressure build-up, and the reservoir pressure at the 120th minute of the build-up. The next hydrodynamic tests were carried out on the well on 02.06.2009 with a downhole tool CAMT-02 and exemplary pressure gauges at the wellhead. A deep record of the pressure build-up curve for well No. 011 is shown in Figure 2.

![Figure 2](image_url)  
Figure 2. Diagram of the pressure build-up curve for well No. 011 of the Beregovoye field.

The well was closed after its development at the GFU on a 14 mm diaphragm. Based on the results of the pressure build-up treatment, the following formation parameters were determined: pressure at the wellhead (buffer) - 107.6 kgf/cm²; reservoir pressure on self-supporting insulated wire (Horner treatment) - 118.7 kgf/cm²; coefficient "a" - 0.6681 and "b" - 0.001396; well flow rate is free - 1742 thousand m³/day; well flow rate is absolutely free - 2955 thousand m³/day; permeability coefficient - 0.445 Da; skin effect - plus 2.2. The wellhead pressure recovery was recorded at the 120th minute of the pressure build-up. Reservoir pressure, as we can see from the above depth recording diagram, did not recover within 120 minutes of pressure build-up. According to the well test results, it can be seen that the bottomhole formation zone of the well has already been cleared of the drilling mud filtrate, and the inflow has begun in full volume of the bottomhole formation zone. With an increase in accumulated gas production from a reservoir and a drop in reservoir pressure, an increase in the duration of recovery of both wellhead and reservoir pressures is observed. The diagram below shows a different shape of the first minutes of the pressure build-up curve. The pressure build-up (in-depth) record dated 05/20/2010 is shown in Figure 3.
Figure 3. Pressure build-up curve for well No. 011 of the Beregovoye field as of the survey date of 20.05.2010.

The well was closed after its development at the GFU on a 14 mm diaphragm. Based on the results of the pressure build-up treatment, the following formation parameters were determined: pressure at the wellhead (buffer) - 105.2 kgf/cm²; reservoir pressure at the self-supporting insulated wire (Horner treatment) was 116.2 kgf/cm²; coefficient "a" - 1.1127 and "b" - 0.000862; well flow rate is free - 1859 thousand m³/day; well flow rate is absolutely free - 3360 thousand m³/day; permeability coefficient - 0.266 Da; skin effect - plus 2.1. According to the well test data from 06.10.2013, the wellhead pressure rise lasted 6.5 hours. The HPC record (buffer) dated 06.10.2013 is shown in Figure 4.

Figure 4. Pressure build-up curve for well No. 011 of the Beregovoye field as of the survey date of 06.10.2013.
The reservoir pressure recovery record increased to 8.5 hours, the reservoir pressure continued to recover. When processing the pressure build-up by the Horner method, the calculated reservoir pressure was 104.1 kgf/cm². It was decided to extend the pressure build-up time, after 12 hours a downhole tool was lowered into the well and the recovered pressure was measured, which turned out to be lower than the calculated one and amounted to 103.8 kgf/cm². The pressure build-up ratio record of well No. 011 of the Beregovoye field as of the survey date of 06.10.2013 is shown in Figure 5.

![Figure 5](image)

Figure 5. Pressure build-up curve for well No. 011 of the Beregovoye field as of the survey date of 06.10.2013.

The well was closed after its operation in the operational mode of the UKPG. Based on the results of pressure build-up treatment, the following formation parameters were determined: pressure at the wellhead (buffer) - 94.1 kgf/cm²; reservoir pressure (Horner treatment) - 103.8 kgf/cm²; coefficient "a" - 0.6879 and "b" - 0.001756; well flow rate is free - 1444 thousand m³/day; well flow rate is absolutely free - 2286 thousand m³/day; reservoir permeability coefficient - 0.425 Darcy; the skin effect was plus 2.0.

6. Conclusion

Thus, as a result of the research, it has been shown that during the last years of well operation, the formation is flooded due to the destruction of the cement stone of the column. Some scatter in the values of filtration coefficients "a" and "b", as well as absolutely free and free flow rate, can be explained as an error during well testing (technological and human factor). Additionally, in different years, the planned gas production rates changed significantly, respectively, the value of the created drawdown on the formation, the presence of drilling mud filtrate (FBR), man-made and formation waters coming from the formation changed. A certain influence is also exerted by the competent selection of restrictive diaphragms installed at the wellhead by the geological service of the field, depending on the changing technological and economic conditions of the field (economic crisis, a sharp reduction or increase in production, saving methanol, etc.) gas extraction and reservoir pressure drop, the duration of wellhead and reservoir pressure recovery in wells has increased significantly. If in 2007, before the field was put into commercial operation, the pressure recovery at the wellhead of most wells lasted from one to 10 minutes, then a year after the start-up, the duration of pressure build-up of about half of the well stock was up to 60 minutes (depending on the permeability of the
bottomhole formation zone). At present, the duration of wellhead pressure recovery in a strong well is from 30 to 60 minutes, in an average well from 2 to 4 hours, and weak wells with low permeability can be restored up to 2 days. Average statistically revealed that the duration of the formation pressure recovery is three times longer than the wellhead pressure. During operation, it was also discovered that after a long shutdown of the well at pressure build-up, weak and watered interlayers (in single wells there was a breakthrough of formation water) work for some time in the regime. Obviously, this is due to the restoration of pressure and the ability to remove the accumulated droplet liquid from the wellbore.

7. References
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