Tests during drilling of layers with abnormally low formation pressure

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Abstract
Based on results of test status monitoring in the process of wells drilling in which there are zones with abnormally low formation pressures (ALFP) the authors raised the problem of creating an improved design of layer tester, which would expand the range of technical and because of this - the technological capabilities for testing facilities in ALFP areas. Methodologically, the problem was solved through the analysis of existing designs of testers, study of their weaknesses with a view to their removal with the acquisition of functionally new qualities. As a result of an improved structure of layer tester for ALFP a new technological approach to facilities testing in wells with zones (ALFP) is offered.
Key words: ABNORMALLY LOW FORMATION PRESSURE, LAYER TESTER FOR ALFP, SET OF TEST TOOLS, LAYOUT OF TEST TOOL

Formulation of the problem in general view and its connection with important practical tasks

The complexity for deposits tests, characterized by an abnormally low formation pressures at the stage of prospecting and exploration works is inherent not only at the layers opening by drilling, but also when they are tested by layers testers in order to obtain reliable data regarding the value of formation pressure, hydrodynamic parameters and producing capacity of collector. A major factor in this case is on the one hand minimizing the time gap between the layer opening by drilling and its testing. On the other hand the inability to achieve a smooth decline in downhole pressure to drive the flow from layer and a high-cycle selection of fluid from layer and its delivery to the surface, followed by recovery of the initial pressure drawdown after each study cycle makes the use of standard configurations of the test tool unsuitable under ALFP conditions. In addition, when receiving the inflow from layer, as the practice of ALFP collectors tests showed, there is a gradual attenuation of the inflow from layer in time and, in some cases, until the complete termination of inflow, due to the constant decrease in drawdown pressure as the level rising in drill tubes. In such cases, often only one flushing liquid filtrate without signs of formation fluid enters drill pipes. To obtain positive results it is necessary to carry out several successive descents of layer tester to clear the layer from the filtrate and obtain reliable information. But this operation is very long term, requires a lot of material and money expenses and is ineffective because in intervals between each test, there is penetration of washing liquid filtrate into the later and its re-plugging.

Analysis of recent research and publications, which started solution to the problem

The solution of existing well testing problem during the drilling process under ALFP conditions is the development of new designs of layer tester and technologies that are able to provide:

- implementation of the wells washing during descent and ascent of test tool;

-next downside of level in the test tool and smooth reduction in pressure at the bottomhole to the value of given drawdown pressure;

- carrying out several open and closed testing cycles with measurement at the mouth of the lauer fluid inflow volume at each open cycle of test;

- transportation of received formation fluid inflow to the surface by backwashing of well after each open test cycle with the recovery of the layer pressure in the under-packer space of well;

-implementation of several layer test cycles with the recovery of the original given layer drawdown pressure after each cycle;

- direct and backwash of well with simultaneous recovery of layer pressure.

Known designs of multicycle layer testers [1,2,3] due to a number of design flaws can not be used for qualitative testing of collectors with ALFP to obtain reliable results about layers performance at the stage of drilling.

Isolation of previously unsolved aspects of the problem, which this article is devoted to

The main disadvantage of standard multicycle layer testers is the inability to:

- to carry out the well washing at descent and ascent of test tool;

- implementation of a smooth transfer of given drawdown pressure and warning due to this, the destruction of collector;

- carrying out the cyclic removing on the fluid type surface (oil, condensate, layer water) the reservoir fluid, washing liquid filtrate in attenuation or complete termination of flow from layer;

- to carry out the recovery of drawdown pressure to the originally given value after each cycle of open test period and the removal of fluid obtained from the layer from drill pipes on the surface.

Currently there are no analogues of multicycle layer testers, which would fully meet the technical requirements of test of collectors with ALFP in Ukraine, Russia and other CIS countries.

Therefore, **the aim of work** is to carry out theoretical and experimental studies to create such multicycle layer tester, which would allow to improve the technological approach to the test in the process of facilities drilling in ALFP areas.

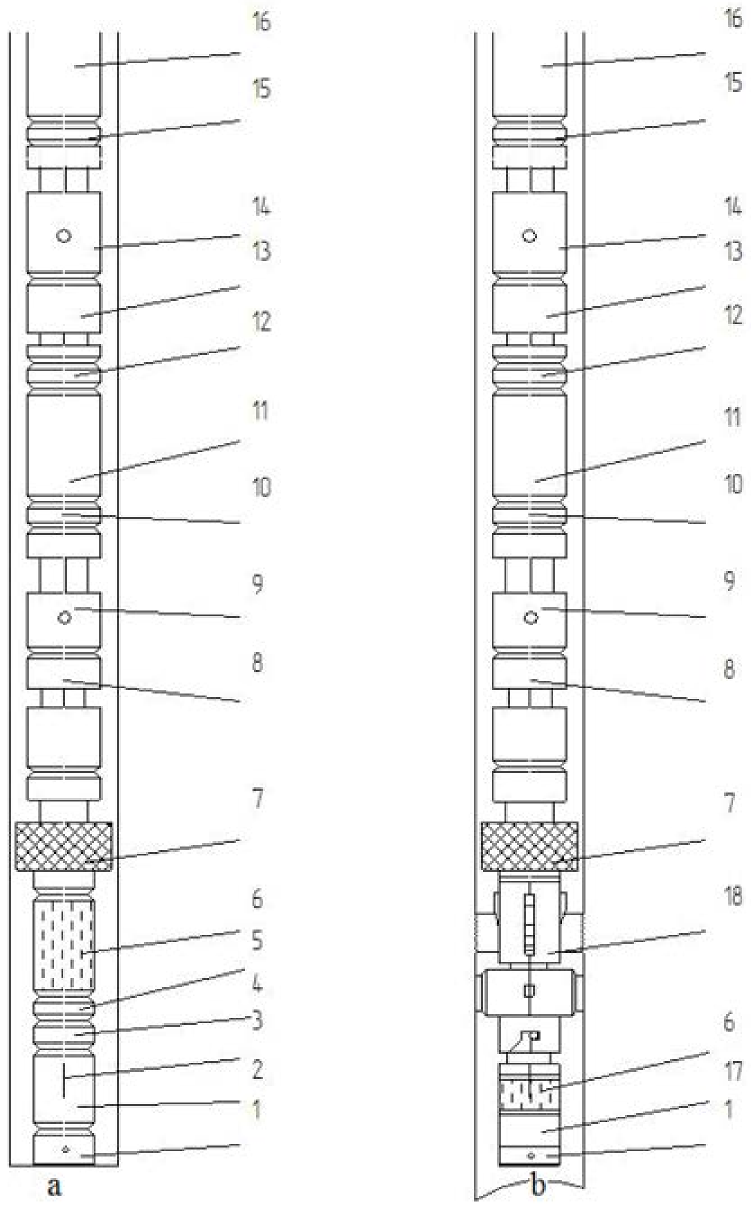
Presentation of the main research material

Specialists of Ukrainian State Geological Institute (USGI) developed design of multicycle layer tester for testing while drilling in areas characterized by ALFP. The basis of the development of multicycle layer tester for ALFP was the design protected by a.s. USSR № 1645488 [4], which authors are also scientists of USGI.

Due to the developed design of layer tester for ALFP, it became possible to offer a bit different technology of low permeable collectors with ALFP testing in the process of drilling, the use of which provides reliable evaluation results of layers with ALFP on performance.

Depending on geological and technical conditions, distance of testing layer from downhole, technological scheme provides two types of test tool layout: with shank bearing against the downhole (Fig. 1a), and with bearing against the drilled formation wall using slips mechanical anchor (Fig. 1b).

Test tool layout according to the scheme shown in Fig. 1a, is used in the testing of facilities located at a distance from downhole to 50-70m in the presence of reliable sites (according to the bore bit), ensuring the packering tightness at a differential pressure on packer to 25.0 MPa and comprises (bottom - up): blank plug 1, bearing shank made of steel or alloy drill pipes 2 with downhole pressure gauge 3, adapter 4, left adapter 5, filter 6, packer 7 with a rubber seal element appropriate to diameter of well, jar hydraulic 8, equalizing valve 9, drilling mud drill collar 11 with adapters 10,12, sample chamber 13, wash-check valve 14, adapter 15 and drill string 16.



1-blank plug; 2- bearing shank; 3- gauge; 4,10, 12,15- adapter; 6- filter; 5-left adapter; 7- packer; 8- jar hydraulic; 9- equalizing valve; 11- drilling mud drill collars; 13- sample chamber of layer tester; 14-wash-check valve of layer tester; 16- drill string; 17- drill pipe; 18-slips anchor

Figure 1. Scheme of the test tool layout in testing of objects with ALFP while drilling

When testing a layer with ALFP removing it from the downhole greater than 70-100m, test tool layout according to the scheme shown in Fig. 1b is applied. The test tool layout without bearing shank differs from the layout shown in the scheme of Fig. 1a, by the presence of bearing slips anchor 18 and drill pipe 17.

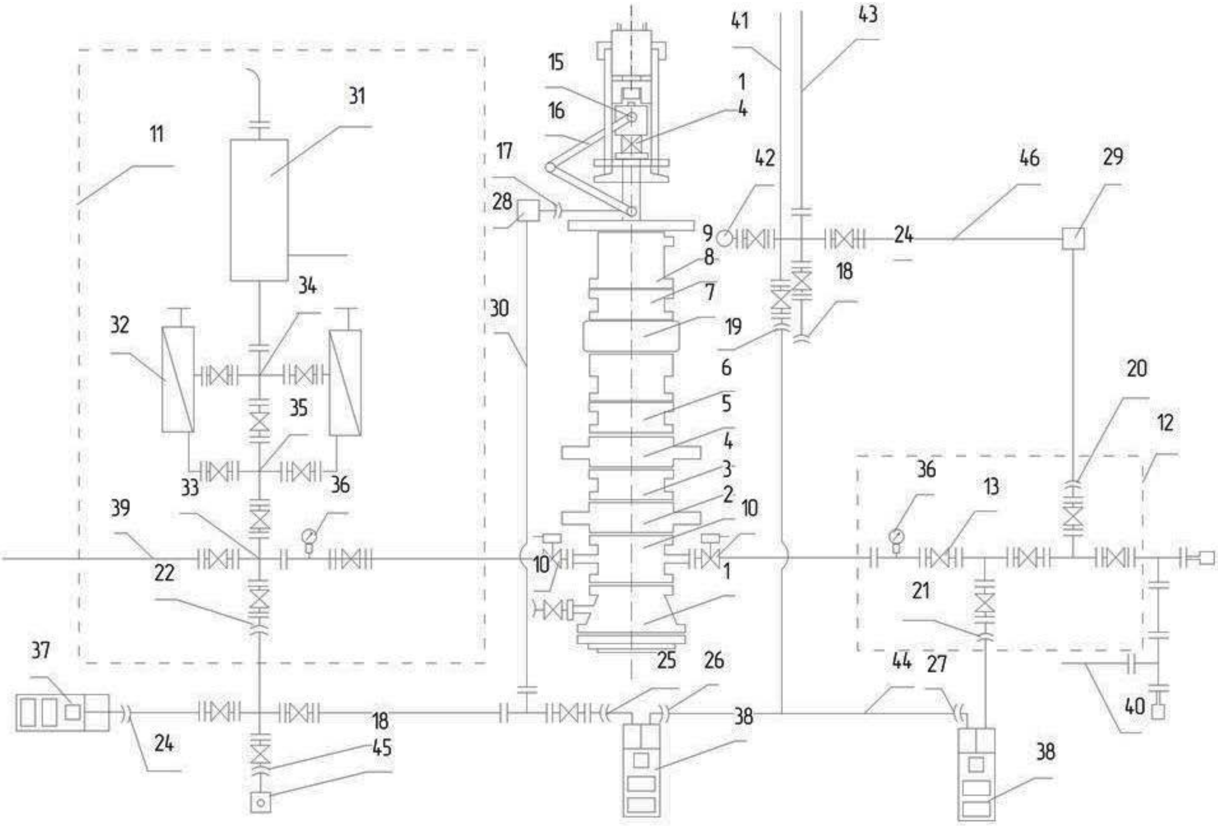
Given the above, wellhead equipment and estuarine aboveground equipment must meet the following basic requirements:

- possibility to wash the well at any depth during running the test tool, removing gas patches and aligning parameters of washing liquid;
- axial movement of the drill string in the range of 5-6 meters without disconnecting diverter line from the production wellhead of acetabular type;
- rotation of drill string at a fixed discharge-bit line with a simultaneous formation fluid tap-off from the well to the measuring tank or gas meter;
- supplying the compressed air by compressor to the drill string for pressurizing before setting the packer followed by its discharging to cause the inflow from layer;
- measurement of layer fluid flow volume over time, transporting obtained fluid through drill pipes to the surface, followed by the level decrease in pipes to cause the inflow;

- carrying out well testing in the mode of multiple (two - three) cycles of pressure drawdown change, transporting the obtained layer fluid flow volume through the drill pipes to the surface after each cycle and the subsequent reduction in the washing liquid level in drill pipes for well transition to the other test mode;
- enabling the washing liquid filing into the internal cavity of drill string and the annulus, inflow damping from the layer, direct and backwashing;
- degassing the washing liquid with specified parameters during well washing;
- controlling the pressure in the pipe and annulus, both during the layer testing, and during the well washing.

To implement set requirements for the scheme of wellhead and ground well piping during testing of objects with ALFP in the process of drilling a typical well piping arrangement is developed.

Typical piping arrangement (Fig. 2) is based on acting and subsidiary companies NJSC "Nadra of Ukraine" schemes of well wellhead. In general piping scheme includes three major components, which are mounted to the top of the well drilling.



1-surface wellhead; 2- crossbar; 3- blowout preventer of blank jaw; 4- spool; 5- jaw blowout preventer for drill pipes; 6- spool; 7- universal blowout preventer; 8- spool; 9- detachable trough; 10- hydraulic check; 11- choke manifold; 12- kill manifold; 13-choke; 14- ball valve; 15- production wellhead; 16- esturial floating manifold; 17,18,19,20,21,22,23,24,25,26,27- quick-coupled junction box; 28,29- pipe-rotative knee; 30- discharge valve bit line; 31- mud degasser; 32- throttling restriction; 33,34,35- crossbar; 36- gauge; 37- compressor; 38- cementing tank; 39,40- preventer pipe blowout; 41- utility line manifold; 42- stand-pipe; 43- circulating pumps manifold; 44- intake line of cementing tank; 45- gas counter; 46- discharge valve tubular line

Figure 2. Scheme of wellhead and ground well piping during testing in the drilling of objects with ALFP

The first component of the piping scheme includes wellhead part, namely: surface wellhead 1, crossbar 2 with preventer pipe blowouts 39 and 40, blowout preventer of blank jaw 3, intermediate crossbar 4, jaw blowout preventer for drill pipes 5, intermediate crossbar 6, universal blowout preventer 7, intermediate crossbar 8 and detachable trough 9.

The second component of piping includes choke manifold 11, which is mounted with preventer pipe blowout 39 and consists of related to preventer blowout of crossbars 33, 34 and 35, throttling restrictions 32, valves 13 with manual control and mud degasser 31.

The third component of piping is manifold 12, which is mounted into preventer pipe blowout 40 and includes pipe-rotative knee 29, chokes 13 with manual control and gauge 36 with phase separator and cutout and charging device. In addition, the preventer pipe blowout 40 through the choke 13 and quick-coupled junction box 20 and discharge valve tubular line 46, crossbar 47 and choke 13 is connected with circulating pumps manifold 43 and drill stand-pipe 42. Circulating pumps manifold ends with choke 13 with quick-coupled junction box 18.

Before starting the work on the well testing the stationary discharge valve bit line 30 with pipe-rotative knee 28 and elbow with quick-coupled junction box 17, T-pipe 29 and choke 13 with quick-coupled junction box 25 for connection to the discharge valve bit line (pipe blowup) of cementing tank 38. Discharge valve bit line 30 through the crossbar 48 with chokes 13 and quick-coupled junction box 22 is connected with crossbar 33 of choke manifold 11. Crossbar 48 is equipped on one side with choke 13 with quick-coupled junction box 18, on the other side - with choke 13 with quick-coupled junction box 24.

During layer testing the mouth of well is tied by production wellhead 15 of swivel type that is by its lower part through a ball valve 14 connected with the drill string and using elevator is suspended on the hook-block of tackle system. The esturial floating manifold 16 is connected with the run off side elbow of production wellhead by quick-coupled junction box, also, in turn, it is connected with the discharge valve bit line 30 by quick-coupled junction box 17. Accordingly, gas counter 45 and compressor 37 are connected to the discharge valve bit line 30 by quick-coupled junction boxes 18 and 24, and from the T-pipe 29 cementing tank 38 is connected by quick-coupled junction box 25. The second cementing tank is connected to a T-pipe of preventer pipe blowout 40 of kill manifold 12 by quick-coupled junction box 21. The intake line 44 of cementing tanks (CT) is collected from the high-pressure pipes 44 (intake line CT), T-pipe and is connected to the utility line manifold 41 by quick-coupled junction box 19.

Layer tester is the main part of test tool layout (Fig. 1) for testing of objects with ALFP during drilling. Designed layer tester for ALFP replaces three nodes in standard layout of test tool at once: the circulation and shutoff rotating valves and layer tester.

Layer tester for ALFP contains three components: wash-check valve, core barrel, equalizing valve.

Wash-check valve by the operation principle is axial and is actuated by axial movement of the drill string. During the descent of test tool into the well the valve is in open position, connecting tube side with the annular, which ensures the filling of drill pipes with washing liquid and the possibility of well washing during the descent and ascent of test tool and lowering the level in drill pipes by compressor. During the packer installation by axial discharge of drill string to predetermined value and valve shafts moving into the lower end position the circulation holes are overlapped tightly, isolating annulus from internal cavity of drill string. Along with overlapping of circulation holes in valve body the intratubal cavity of drill string through the radial holes of hollow valve shaft is combined with packer-type test area, allowing the transmission of pressure drawdown to layer and inflow initiation. After completion of the test open period by tension of drill pipes to a predetermined value the valve is provided in open position, and filing the washing liquid into the well annulus he obtained inflow of layer fluid is removed through the drill string to the surface. After removal of formation fluid to the surface the level in drill pipes is reduced again and bringing the valve in the closed position, the inflow from the layer with other drawdown value is caused again. There is a recovery of formation pressure during all the period of layer fluid transportation to the surface and re-lowering in pipes in the downhole. In this case it is possible to carry out layer tests in the multicycle mode, each time changing the drawdown value.

The core barrel is located between the washing and cutout and equalizing valves, descended into the well, and ascended to the surface in closed position. To equalize the pressure drop in the sample chamber with pressure in the annulus area the movable shaft of core barrel is equipped with equalizing valves system of versatile action. It provides pressure equalization in the sample chamber during lowering and lifting the test tool to a safe value.

Equalizing valve is installed in the bottom of layer tester and is intended to equalize pressure drop in the lower-packer zone with under-packer during descent and ascent of test tool and packer removal from the place of its installation after completing a test. During descent and ascent operations the valve is in the open position. Premature opening of equalizing valve during operations when opening the wash-check valve to remove layer fluid by backwash is warned by rolling equipping with hydraulic time relay, which slows shaft movement up by moving up the tool. The delay time length of equalizing valve opening depends on the magnitude of axial tensile force on drill string and is regulated by a calibrated spring braking piston of time relay.

Of course, before test performing the set of depth equipment of facilities testing under ALFP should be subjected to scrutiny, with particular attention to the layer tester packer and hydraulic jar.

Testing technology includes the following steps.

1. Before installing the packer the well washing is carried out to complete removal of polluted downhole patch of washing liquid located above the packer installation space.

Washing is carried out before the wellhead equipment by the head with ball valve and swivel manifold with discharge valve bit line (Fig. 2) by supplying washing liquid by circulating pumps through the stand pipe and square driving stem. In the absence of gas contamination of washing liquid, which is determined by the results of final well washing before descending layer tester, washing after the descent of the latter may not be held.

2. After the wellhead equipment by piped blowout the level in drill pipes is reduced using compressor and, if necessary compressor together with cementing tank is used.

3. The acetabular head valve is closed and at the overpressure in slot the packer is set by unloading the drill string to a value provided by work plan to the test.

4. The pressure reduction in lower-packer well space (test interval) is carried out by a smooth discharge of excess wellhead pressure. Pressure discharge is produced though the control choke with the direction of compressed pipe environment (compressed air, polluted liquid) to the degassing unit or through preventorny blowout into the pit. During the discharge after each wellhead pressure lowering of 20-25 atm, the well is shut and pressure change is recorded during 2-3 minutes. If after the last well closing there is an increase in wellhead pressure, further discharge is stopped and the well is converted into an open test period mode.

5. In the process of excess pressure discharge tin drill pipes he washing liquid level in the well annulus is controlled. Reducing the level in well annulus indicates the leak of packering or drill string or layer tester.

While reducing the level in annulus it is necessary to increase the load on packer (2-3 divisions of weight indicator) and, if the level continues to drop, further test is stopped, packer is removed and, after well washing, the test tool is raised to the surface.

6. In case of signs of the work of formation in the course of discharging the excess pressure on the mouth, hold the volume measurement of reservoir inflow, using a flow rate meter (gas meter, beaded meter pneumometric tube).

If in discharging process the wellhead pressure reduces to zero, the well is left in the inflow for all time of test open period, set by work plan to the test, and the layer fluid inflow by volume of displaced air from pipes is controlled during all time of test open period.

7. In case of reducing the inflow intensity of layer fluid at test open period by more than two times, or its complete termination by the axial tension of drill string to a certain height, at the same time the layer tester washing channel of wash-check valve is brought to the open position, connecting the annulus with tubular and the inlet - to the closed position, disconnecting the internal cavity of drill string with lower-packer tested area. In this case it is possible, simultaneously with the removal of obtained from the layer production, to hold the layer pressure recovery by well backwashing (closed testing period) with its registration by depth gauge.

8. By providing a long-term (more than 4 hours) safe time of tool stay at the bottomhole it is possible to carry out layer tests in the multicycle mode with transportation the obtained layer fluid to the surface after each mode. It is advisable to set with transition to another mode the pressure drawdown that could be different from the initial drawdown value, and, the latter must change from the less value to the maximum possible, and originate from the collector type and its physical properties.

9. In the case of gas obtaining from layer its removal is carried out through the drill string with a washing liquid degassing using the degassing unit, and clean gas is sent into prevent pipe blowout and burnt in the flame.

10. To close the well at the bottomhole after completion of open period test, with the aim of removing the layer pressure recovery curve, the drill string is raised slowly, controlling the pressure at the slot. At the time of instantaneous wellhead pressure increase, which indicates the washing valve opening, a further ascent of test tool is stopped. When lifting the tool it should be monitored that the pipe tension at the same time would not exceed its own weight by more than 2-3 divisions by weight indicator. The presence of equalizing valve in layout prevents premature opening of valve equalizing channels that provides its delay until a predetermined value of tensile load on drill pipes. After opening the layer tester washing valve the well backwashing is carried out to remove the layer fluid from drill string with simultaneous recording in lower-packer zone.

The duration of closed period test is set depending on the intensity of inflow from the layer and duration of the safe time of tool motionless stay in bottomhole.

To obtain the interpreted pressure recovery curve the length of closed period test in the study of low-permeability layers with ALFP with low productivity should be 1.5-2 times higher than the length of open period test.

11. After the last closed period test and the layer fluid replacement by washing liquid in drill pipes the packer is removed from the place of its installation hy axial movement of drill-rod string up. Tensile load on test tool to the value of 50 kN is above its own weight (the operation load of equalizing valve hydraulic brake) results in the opening of radial holes of equalizing valve, provides combination of upper-packer space with lower-packer and alignment of lower-packer pressure with upper-packer. The packer is removed by subsequent tension of drill string, the well is washed and test tool is raised to the surface.

12. Test tool ascent is carried out with constant topping up the borehole into annulus, avoiding reduction of pigging and tight pulls.

In the process of test tool ascent to the surface the pressure in sample chamber of core barrel is balanced with pressure in the annular space of borehole and gradually reduces to a safe level (2.0 - 5.0 MPa) due to gauge bypass.

13. After layer tester ascent to the surface the pressure measurement is performed in the sample chamber and the layer fluid is collected into containers, using sampling facilities. After that the test tool dismantled into its component parts, the cartograms are removed of depth gauges and according to the results of their recordings, such as the obtained layer fluid and its volume coming from the layer into drill pipes, final processing of tests results is performed to determine the productive characteristics of test horizon, the value of layer pressure and layer filtration parameters.

Conclusions

The advantage of this technology and means is that their application will allow: to determine the accurate productive characteristics of collector, the amount of layer pressure and optimum pressure drawdown in the process of wells drilling under ALFP conditions by smooth pressure drawdown transfer to layer to cause the inflow of layer fluid, circular fluid transportation to the surface in the process of inflow and subsequent recovery of drawdown.

An integral part of achieving efficiency through the use of technology and means for its implementation is the reduction of unsuccessful tests of collectors with ALFP with simultaneous increase in the reliability of test results and a decrease in the number of non-production facilities, tested under production strings.

Application of the technology and means for its implementation provides reliability of oil and gas potential evaluation of low permeability collectors with ALFP at the step of drilling of prospecting, geological exploration and parametric wells and can be implemented by enterprises that carry out prospecting and geological exploration works.

The solution to this problem is essential and promising in testing of objects with an abnormally low formation pressures.

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