Improving the cost-performance ratio of well construction using a multi-stage hydrostatic pressure tester

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Abstract. The article considers the issue of improving the cost-performance ratio of well drilling through the use of a device for drill and production pipes, which allows for multi-stage hydrostatic pressure testing during preparatory work in the well before liner completion, well lining and other technological operations. The authors present the results of a patent analysis on the problem under study and prove the need to create a device with a simpler design with a reduced probability of breaking and allowing multiple pressure testing of pipes in the well without lifting them to the surface. The article presents a scheme of the device and the technology of its operation in the well. The results of factory tests of a prototype device with a diameter of 105 mm showed its efficiency and practicality for technological processes during the drilling and exploitation of deep oil and gas wells.

1. Work timeliness
Well construction is a capital-intensive and time-consuming process requiring large investments, including expenses for unforeseen operations to eliminate the consequences of accidents and complications arising during the drilling and completion of wells. Therefore, it is very important to use new technologies and technical means to improve the cost-performance ratio of well construction.

In technological operations using a drill string and production string: lowering the liner, drilling sidetracks, repair and insulation work, treating the bottom-hole zone (BHZ), developing wells, it is necessary to test the strings with internal pressure for leaks. Existing testing technologies and applied devices (valves) do not allow repeatedly conducting leak tests, and when the valve is actuated, it is necessary to lift it from the well and replace to resume circulation of the working fluid and conduct subsequent pressure testing. All this leads to additional costs of time, money and to well appreciation.

2. Literature and patent analysis on the studied issues
Analysis of scientific and technical literature and patents for inventions showed that a large number of technical solutions related to operations for pressure testing of drill and production pipes in wells is based on the use of valves of various designs. Table 1 in chronological sequence shows the evolution of technical solutions to improve the design of valves for pressure testing of pipes inside the well with overpressure.
Table 1. Brief description of devices for pressure testing of strings in well

| Name                                                                 | Characteristics                                                                                                                                       | Drawbacks                                                                                      |
|----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| Controlled valve for blocking filter well [1]                       | Valve for blocking the filter part of the well with a packing element, made in the form of a cylindrical body with a valve seat in the upper part and a movable sleeve with a valve head and a closed zigzag groove on its outer surface, which includes fixed body pins; the groove is made of alternating in size sides of isosceles V-shaped sections equipped with leaf springs that allow the sleeve to rotate in only one direction with axial displacement | Complex design and low reliability                                                             |
| Device for pressure testing of pipe string in well [2]              | The device consists of a housing, a shutter and a plate. The housing has a central channel, a membrane, side channels and return channels for lowering the string into the well, the membrane calibrated for a certain pressure is destroyed, passing liquid through the side channels. | A large spread of destructive pressure, which affects the accuracy of the tests.               |
| Device for pressure testing of drilling string pipes [3]            | Device for pressure testing of drill pipes, comprising a housing with connecting threads and a stationary sleeve with axial and peripheral holes and a movable sleeve with a saddle for a wireline ball both located in the housing’s cavity, the movable sleeve being fixed in the initial position relative to the housing by shear elements. | The complexity of housing manufacturing                                                        |
| Device for pressure testing of drilling pipes [4]                  | Device includes a housing, a saddle, a cap with a rod, a spring and a locking device made in the form of interacting rod, sleeve with a labyrinth track and a ball, where the rod and sleeve of the locking device have non-circular cross-section and are connected together by a pin in a movable manner. | Inability to use in case of contamination of the solution with sludge.                       |
| Device for pressure testing of drilling pipes [5]                  | Device of a more simplified design consists of a housing with a bore, a sleeve with an axial channel, and a restriction plate with a saddle under the sleeve, which is freely installed in the bore of the housing and has peripheral axial channels covered by a membrane, and the saddle of the restriction plate has a seal. | Disposable                                                                                     |
| Device for pressure testing of pipes in well [6]                   | Device includes a housing, a spring-loaded sleeve with radial holes and a locking element mounted in the cavity of the housing concentrically to its inner surface, and a saddle for the locking element; the distinctive feature is that to increase the reliability of the device, the spring-loaded sleeve has a fitting in the upper part, and a saddle for the locking element is located in the lower part of the housing. | Low reliability due to the spring that during deformation loses its elasticity, and the valve fails |
| Device for pressure testing of pipes in well [7]                   | Device consists of a housing, a spring-loaded sleeve with radial holes and a locking element, the sleeve being installed in the cavity of the housing concentrically to its inner surface, and a saddle for the locking element, made in the form of a transition pipe with radial holes. | Contributes to a sharp change in pressure in the pipe string, which can lead to their destruction |
| Device for pressure testing of drilling pipes [8]                  | Device consists of a hollow body with connecting elements, with a sleeve with a saddle for a wireline ball mounted on shear elements and a restrictive sleeve located under it, rigidly connected to the body and having central and peripheral axial channels. The device is equipped with a spring, one end of which is fixed in the axial channel of the restrictive sleeve, and the other is freely placed in the axial channel of the sleeve with a saddle. | The need for additional operations for the delivery of the locking element for pressure testing of pipes |
| Device for pressure testing of drilling pipes [9]                  | Device comprises a housing and a stationary sleeve with axial peripheral holes and a movable sleeve with a saddle for a wireline ball both located in the housing’s cavity, the movable sleeve being fixed in the initial position by shear elements. The device is equipped with valves in the form of a ring to overlap the holes of the stationary sleeve, and the housing has radial channels. | Complexity of housing manufacture, due to the presence of radial channels which requires milling and drilling operations |
Table 1. Ending

| Name | Characteristics | Drawbacks |
|------|-----------------|-----------|
| Device for pressure testing of drilling string in well [10] | Device consists of a hollow body with an annular groove on the inner surface with connecting threads mounted in the cavity of the body with the possibility of axial movement of the sleeve with slots and with a saddle in the lower part under the wireline shut-off element. The slots of the sleeve go to its upper end as windows, with rotary latches located in them in the sleeve's wall above the end of its slots. The sleeve location enables interaction of the latch with the housing wall above its groove in the initial position, and in the working position it allows the latch to be placed in the groove of the housing | Complex design, instable operation |
| Device for blocking the cavity of the drilling string [11] | Device consists of a housing, a saddle and a wireline shut-off element containing movably mounted sleeves, one of sleeves being equipped with a poppet spring-loaded valve; in the shutter housing there are side windows in one of which a spring-loaded rotary lock is placed, and in the other a spring-loaded axis of the poppet valve is located | Unsatisfactory reliability. Insufficient impermeability of evacuated cavity. Disposable |
| Device for pressure testing of drilling pipes [12] | Two sleeves are movably mounted in the housing cavity. In the cavity of the inner sleeve, there is a valve made in the form of a bushing spring-loaded relative to the outer sleeve with windows in its wall. The bushing and the outer sleeve have spring-loaded clamps, and the inner sleeve for their placement on the inner and outer surfaces is made with annular grooves | Low reliability during repeated pressure tests of the pipe string in small-diameter wells |
| Pressure test packer [13] | Device includes a housing, a sealing assembly with a sealing element, a lower sleeve and a sealing chamber, a bypass device, a check valve and a valve assembly. The valve assembly has shear elements, a ball valve and a seat under it in the form of a cylindrical sleeve. The housing has an annular collar restricting the movement of the lower sleeve, an annular groove, a stepped annular undercut and radial holes for installing shear screws. The bypass device is made in the form of a spool with an internal step recess, a spring and an adjusting nut. It sets the spring force and stroke length of the spool. The seal chamber is formed by a sealing element and an annular groove of the housing | Design complex to fabricate. Pressure test requires filling the annulus with the working medium |
| Device for pressure testing of pipe string in well [14] | Device includes a housing and a shutter. The housing is provided with an internal cylindrical bore, and the shutter is made in the form of a central rod with a channel made in the form of a lifter saddle, a cylindrical part, a narrow cylindrical part and a stop placed from top to bottom, while a hollow sleeve is installed on the cylindrical part of the central rod with the possibility of limited downward movement with radial windows at the bottom, which on top is equipped with a self-sealing cuff that allows fluid to pass from the bottom up, and is fixed in the transport position relative to the center ceiling elements rod shear element sealingly closing the channel, connecting spaces above and below the self-sealing cuff when the gate is extracted. Into the radial windows of the hollow sleeve dies are installed with the possibility of radial movement inward and interaction in the working position with the inner cylindrical bore of the housing and the cylindrical part of the central rod | Design complexity. Operation of the design requires upward and downward movements. The device passes through only from bottom up |

The analysis showed that the designs were improved by complicating design with the addition of new structural elements and complicating production with the need for high-precision milling and drilling operations. The implementation of a large number of structural parts and interconnected elements is known to increase the likelihood of their breaking. In addition, most of the technical developments presented have a considerable drawback: after pressure testing of the pipes and “actuation” of the valve to resume circulation of the working fluid, subsequent pressure testing of these
pipes in the well can be achieved only after raising their wells and replacing the necessary elements (saddle, plug, pins, etc.) of known valves. This drawback leads to the need for additional technological operations, which increases the duration of the main works and increases their cost.

3. Technology of multi-stage pressure testing of pipes in well

The authors developed a device [15], which is equipped with a die sleeve equipped with an additional female ring. When pressure testing the string, a wireline ball is placed in the inner cavity of the pipes, which is designed to overlap the central channel of the die sleeve. When testing a pipe string for leaks, with a central channel blocked by a wireline ball, an internal test pressure (Pt) is created. The time and pressure value is determined by the technological regulations for pressure testing. After the leak test of the string, by excess pressure (Rs) in the pipes of 1.5 times, the wireline ball is "extruded" from the central channel of the die sleeve.

After extruding the wireline ball from the die sleeve of the proposed device, the circulation of the flushing fluid in the well is restored according to the accepted technology.

Then, in case of necessary additional pressure testing of pipes in a well, caused, for example, by their partial replacement, the next wireline ball is dropped into the pipe cavity, which is pumped to the seating face of the die sleeve, and then the calculated internal test pressure (Rt) is created. After the pressure test, according to the technology above, the circulation in the well is restored by creating an excess pressure that is 1.5 times higher than the calculated pressure of the pressure test (Rt) and extruding another wireline ball from the die sleeve of the device. This technological technique is new and can be assessed as essential, since it has positive effect on the solution of the formulated problem. Wireline balls after pressure testing of the pipes and forcing them through the die sleeve are accumulated in a container, which is a mechanical extension of the device body.

4. Multi-stage hydrostatic pressure tester

Multistage pressure testing of pipes is achieved by using a cylindrical die sleeve coaxially located with an annular gap in the device body and having strictly maintained geometric dimensions, in particular, in terms of the inner (d_in) and outer diameters (d_out) of the die sleeve, which are assigned according to the calculation results, taking into account the diameters of the wireline balls (d_b), the yield strength (σ_y) of the die sleeve metal, the testing overpressure (P_t) and the overpressure required to “extrude” the wireline ball (P_e).

The device for multi-stage pressure testing of pipes in a well (Figure 1) includes a housing 1, with die sleeve 2 placed therein, and a container body 3 for accommodating spent wireline balls. In the inner part of the housing 1, a thread M_1 was made for screwing up with the die sleeve 2. The screwing of the die sleeve 2 in the housing 1 is made until it stops with its end ledge 4, using the o-ring 5. The housing 1 and the container body 3 are interconnected by threaded connection 6. In the lower part of the container body 3, through longitudinal holes 7 are made, providing unhindered passage of the process fluid. The device housing 1 and the container body 3 are provided with threads 8 and 9 for incorporating the device into the pipe arrangement lowered into the well.

The figure shows a device for multi-stage crimping of pipes in a well in working condition. Three spent wireline balls 10 are shown in the container body 3. One wireline ball 11 is located in the inner cavity of the die sleeve and adjusting ring 12 is shown. An excess pressure P_t is created in the inner cavity of the pipes; in the annular space between the die sleeve and the cylinder wall, the excess pressure in the pipes is leveled up along the threaded channel to pressure P_e.
5. **Testing of multi-stage hydrostatic pressure tester**

A prototype device with a diameter of 105 mm was manufactured at an industrial enterprise in Tyumen. In order to verify the operability of the device and adjust it to the calculated operating parameters, the authors conducted preliminary factory acceptance tests, which showed the promise of using the developed device for multi-stage pipe testing in field conditions. At the same time, the need for more accurate manufacturing of mating (moving) parts of the device and the use of wear-resistant components (balls) was noted.

![Figure 2. Pressure tester in operating state](image1)

![Figure 3. Photo of the pressure tester with wireline balls](image2)

![Figure 4. Press for pressure adjustment](image3)

6. **Advantages of multi-stage hydrostatic pressure tester**

- Possibility of multiple pressure testing of drill pipes without lifting;
- The ability to conduct direct and reverse flushing while drilling;
- Simplicity and reliability of the design;
- To determine the place of leakage of drill pipes, it is not necessary to activate the device and completely raise the drilling tool;
- Saving time by reducing the number of trips;
- Cost saving in terms of the installation of new devices.

The expected economic effect from the introduction of the device is conditioned by a reduction in unproductive time by an average of 8 hours when drilling one well. With the cost of one hour of drilling rig operation of 30,000 rubles, the economic effect of the use of the proposed device is 240,000 rubles per well.

7. **Conclusions**

The device [15] developed by the authors allows for multiple pressure testing of pipes in a well without lifting them to the surface by simplifying the design of the device, pre-adjusting the device for pressure testing, increasing the reliability of the work by the absence of complex movable elements, as well as reducing the time of pressure testing.

The number of stages of pipe pressure testing, without lifting them to the surface, according to the proposed technology, can be limited only by the number of wireline balls and the volume of the container.
for collecting them, which is included as a component of the present device, while the absence of interconnected moving parts in the device ensures its high reliability.

References

[1] Baboshkin N N, Pinkenson D B and Potekhin L F 1965 Controlled valve for blocking filter well Authorship certificate no 287864 USSR, IPC E21B43/00
[2] Efremov Yu V, Starikov A A and Halyk-zade E A 1968 Device for pressure testing of pipe string in well Authorship certificate no 369242 USSR, IPC E21B17/00
[3] Ivanitsky E A., Strue Ya M and Tychinsky R D 1971 Device for pressure testing of drilling string pipes Authorship certificate no 370334 USSR, IPC E21B17/00
[4] Yadullaev N N and Vinitsky Yu N 1978 Device for pressure testing of drilling pipes Authorship certificate no 610973, USSR, IPC E21B17/00
[5] Karash E B, Abdulzade A N G, Tarnovsky V P and Nazarov S B 1980 Device for pressure testing of drilling pipes Authorship certificate no 973796 of the USSR, IPC E21B34/06
[6] Kuskov A I 1981 Device for pressure testing of pipes in well Authorship certificate no 794167 USSR, IPC E21B17/00
[7] Kurtov V D 1981 Device for pressure testing of pipes in well Authorship certificate no 794166 USSR, IPC E21B17/00
[8] Karmalsky V B and Spiridonov O N 1985 Device for pressure testing of drill pipes in well Authorship certificate no 1344890 USSR, IPC A1E21B17/00, 34/06
[9] Zelenin V M andMalikov I V 1985 Device for pressure testing of drill pipes Authorship certificate no 1314004 USSR, IPC E21B17/00
[10] Krykh B V 1986 Device for pressure testing of drill string in well Authorship certificate no 1411424 USSR, IPC E21B17/00, 34/06
[11] Krykh B V 1988 Device for blocking the cavity of the drilling string Authorship certificate no 1530739 USSR, MKI E 21B17/00
[12] Ishmukhametov A T and Kushnarev V I 1990 Device for pressure testing of drill pipes Authorship certificate no 2018633 RF, IPC E21B34/10
[13] Verzhbitsky A S, Sgibnev A D and Kuznetsov V G 2000 Pressure test packer Authorship certificate no 2153570 RF, IPC E21B33/12
[14] Makhmutov I Kh, Strakhov D V, Osnos V B et al 2006 Device for pressure testing of pipe string in well Authorship certificate no 2278944 RF, IPC E21B17/00
[15] Korabelnikov M I, Aksenova N A, Lipatov E Yu and Korabelnikov A M 2019 The method of multistage pressure testing of pipes in the well and a device for its implementation Authorship certificate no 2691037 RF, IPC E21B33/10