Feb. 6, 1951 C. C. BROWN 2,540,423

FORMATION TESTING DEVICE

Filed June 24, 1948 2 Sheets-Sheet 1

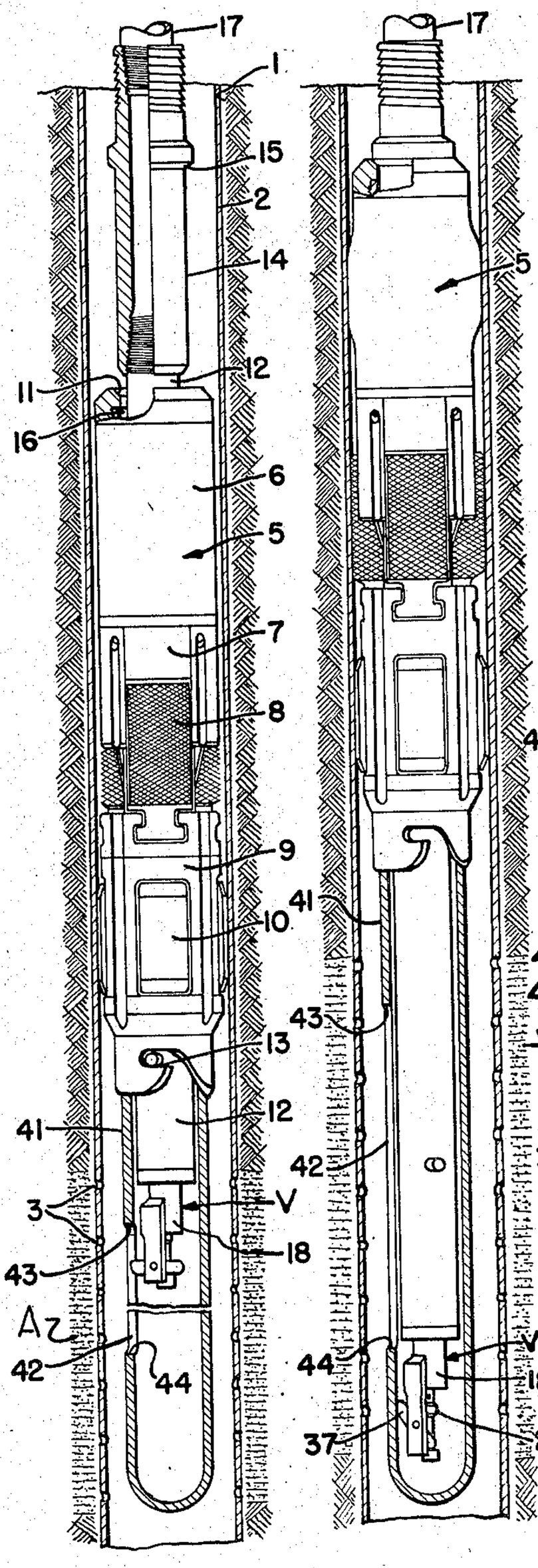

FIG. 1

FIG. 2

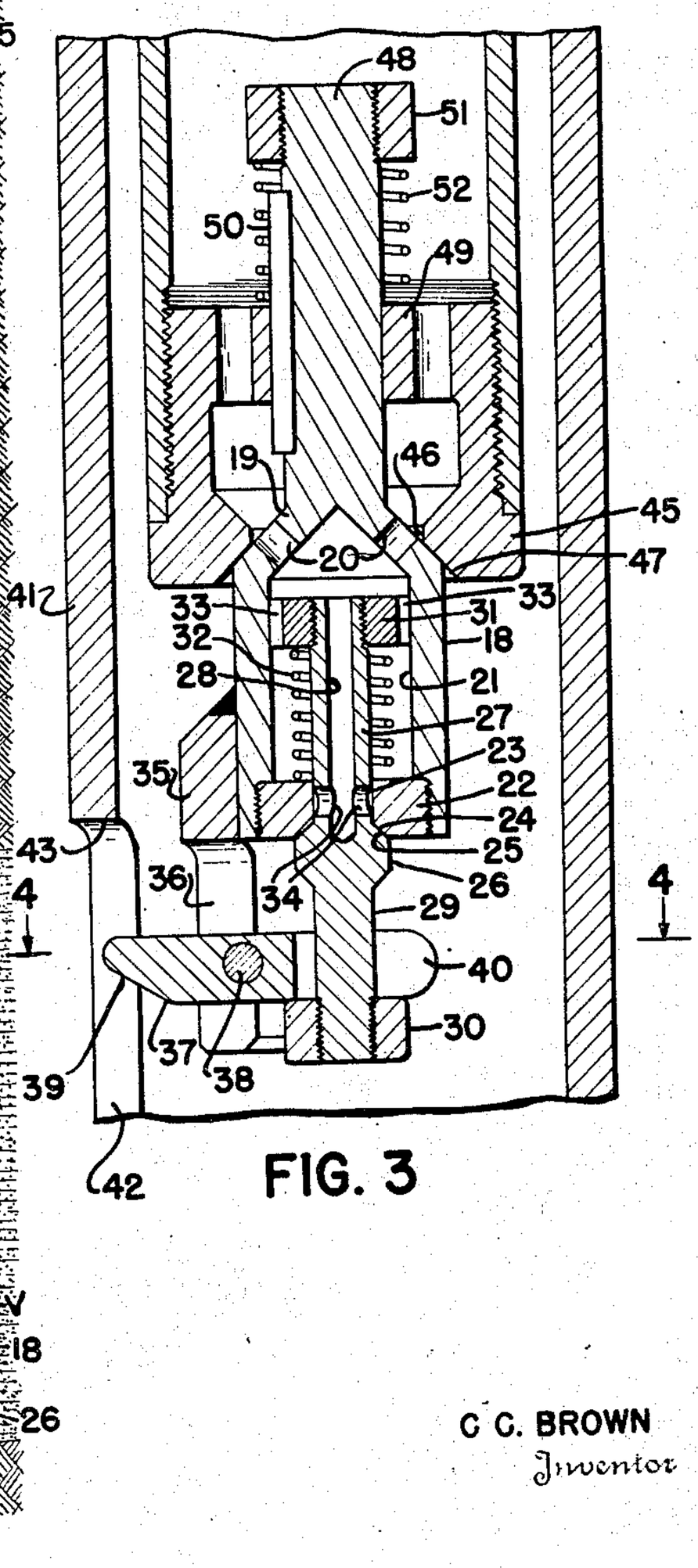

FIG. 3

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2 Sheets-Sheet 2

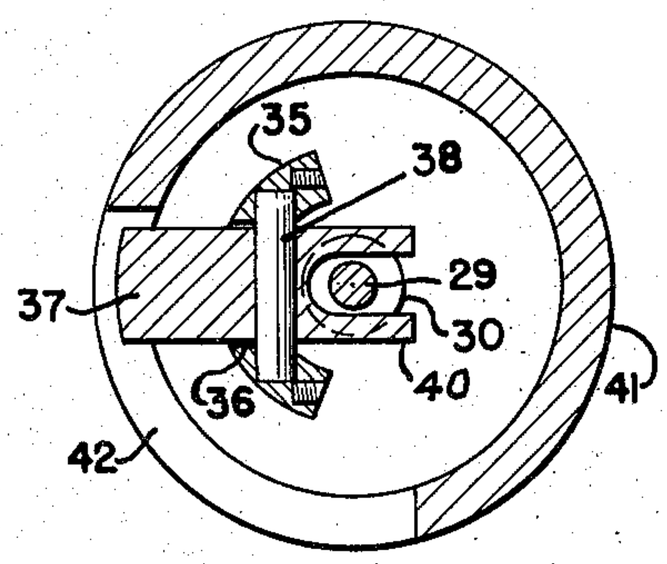

FIG. 4

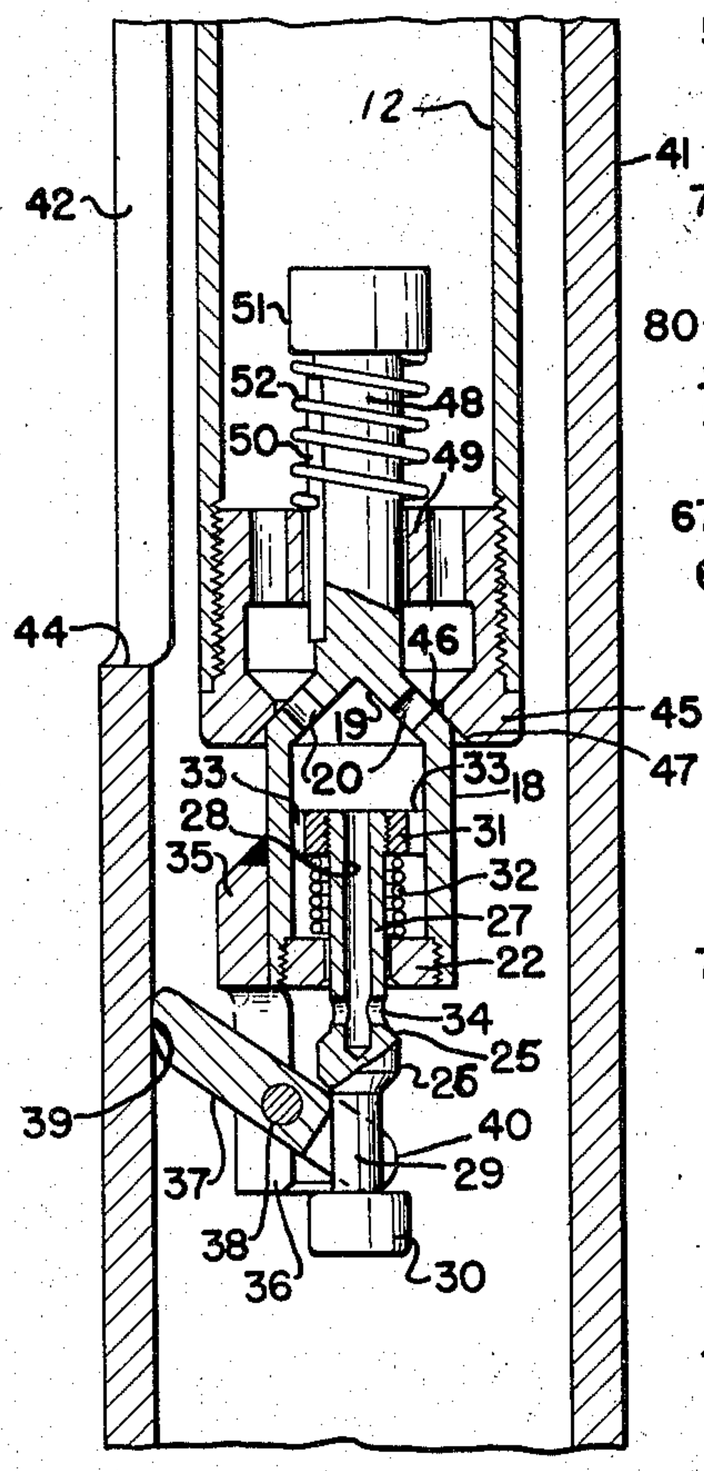

FIG. 5

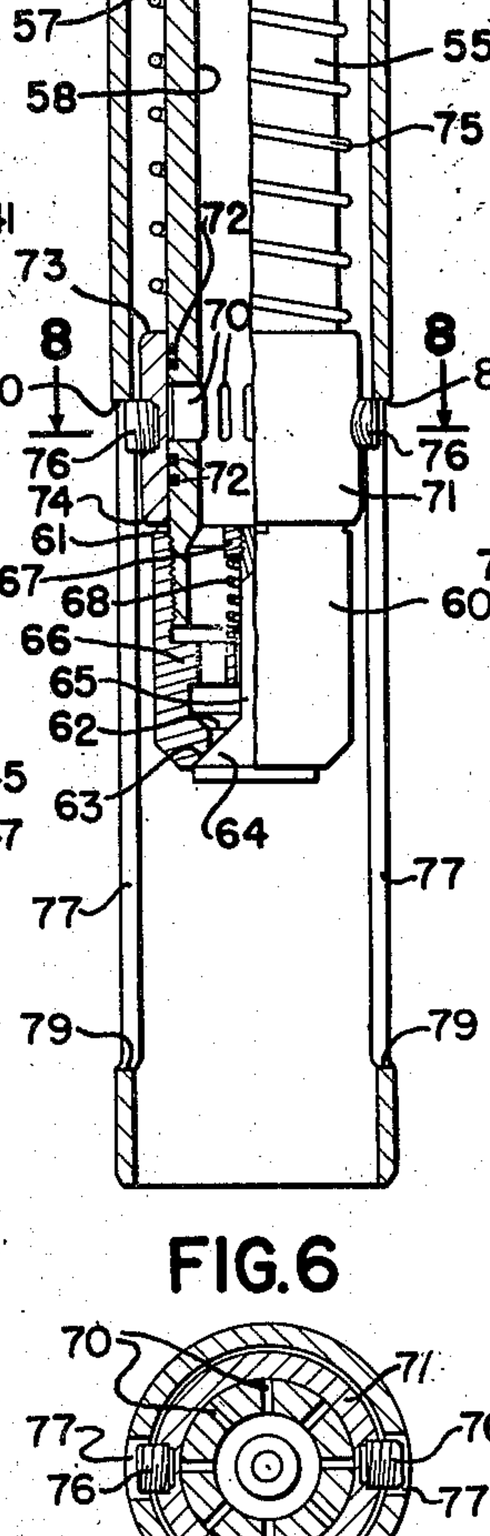

FIG. 6

FIG. 8

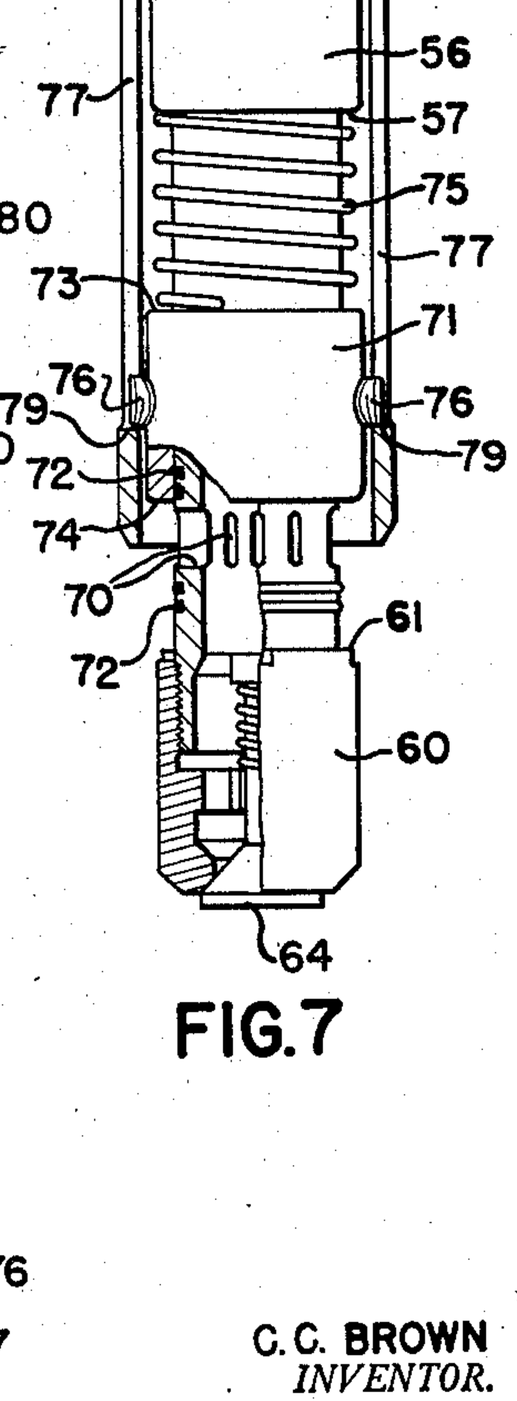

FIG. 7

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FORMATION TESTING DEVICE

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9 Claims. (Cl. 166—12)

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This invention relates to a device for testing earth formations for their contained fluid, such as oil, gas or water.

In wells drilled for the production of oil or gas, it is now common practice to test the various formations along the well for their productive possibilities before final completion of the well, in order that the formation having the best productive potentialities may be selected for final completion. Testing of such wells must normally be conducted while the borehole is filled with fluid such as weighted mud in order to prevent blowing-out of the well under the pressure of the formation fluid. The presence of such extraneous fluids makes for considerable difficulty in making adequate tests of the formations and obtaining accurate results from the tests.

Conventional testing devices employ a packer to seal off the well casing above the formation to be tested. The casing opposite the formation tested will ordinarily have been perforated to provide communication between the interior thereof and the formation under test. The packer will usually be run into the casing on a string of tubing which extends below the packer and has attached thereto a device, which, after the packer has been set, may be opened to provide communication between the interior of the tubing and the formation undergoing testing by suitable manipulation of the tubing. The tubing will normally be empty, so that upon being opened, the higher pressure fluids in the formation will flow into the interior of the tubing and discharge therethrough to the surface for measurement or other suitable determination of its character and volume.

Considerable difficulty of one sort or another has heretofore been experienced with such conventional testing devices and the present invention has for its principal objects the provision of improved forms of a formation testing device which are of relatively simple construction; which are easy to operate; and which permit the making of accurate tests of formations in the presence of hydrostatic fluid present in the well during testing.

More specifically this invention is directed to improved forms of a formation testing device which include a valve means connected to the lower end of the operating tubing which extends through a packer, said valve means being provided with operating means engageable with a suitable stop member carried by the packer so that the valve may be opened and closed by the

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relative longitudinal movement between the tubing and the packer employed in effecting setting and release of the packer. The valve structure may include independently operable check valve means to close the tubing against entrance of fluid from the well until opening of the test valve.

These and other more specific objects and advantages of this invention will become apparent from the following detailed description when read in conjunction with the accompanying drawings which illustrate useful embodiments in accordance with this invention.

In the drawings:

Fig. 1 illustrates one embodiment of the formation testing device in accordance with this invention, showing the device in a well with its parts in the closed position prior to the setting of the packer on which it is run;

Fig. 2 is a view similar to Fig. 1 showing the position of the parts when the device is opened to communication with the well;

Fig. 3 is an enlarged cross-sectional view of the valve mechanism by which the testing device is opened and closed, showing the valve in the closed position;

Fig. 4 is a cross-sectional view taken along line 4—4 of Fig. 3;

Fig. 5 is a view similar to Fig. 3 showing the formation test valve in its open position;

Fig. 6 is a longitudinal partly sectional view of another embodiment of the testing device in accordance with this invention, showing the position of the parts when the device is in the closed position;

Fig. 7 is a view similar to Fig. 6 showing the operating parts in the open position; and

Fig. 8 is a cross-sectional view along line 8—8 of Fig. 6.

Referring to the drawings: There is shown (Figs. 1 and 2) a well 1 lined with a casing 2 which has been perforated at 3 to provide communication between a formation 4, being tested, and the interior of the casing. The device, in accordance with this invention, will ordinarily be run in the well on one of the conventional production type well packers, indicated generally by the numeral 5. The latter consists of the usual sealing sleeve 6 which is ordinarily constructed of rubber or other rubber-like resilient material which, under end-wise compression will expand radially. Sealing sleeve 6 has connected to its lower end the usual conical mandrel 7 on which are slidably mounted slips 8 which are adapted to be expanded radially into gripping

engagement with the casing wall under downward expansive thrust of the mandrel. Slips 8 have their lower ends hingedly connected to a tubular cage 9 provided with compressible members 10 adapted to frictionally engage the casing. The upper end of sealing sleeve 6 is provided with an annular valve seat 11, and a tube 12 extends axially through the packer assembly. Tube 12, at a point adjacent its lower end, is connected to cage 9 by means of a conventional J-slot-and-pin connection, indicated at 13, by which tube 12 may be locked to the packer structure or released therefrom, as desired, by suitable manipulation of the tube. The upper end of tube 12 has connected thereto a tubular setting sleeve 14 carrying an annular valve ring 15 on the exterior thereof which is complementary in shape to seat 11 and adapted to cooperate therewith to open and close the annular opening 16 between the packer and tube 12 in response to appropriate longitudinal movement of the latter. The upper end of setting sleeve 14 is connected to the usual string of tubing 17 which it will be understood extends to the surface and serves not only for passage of fluid to and from the interior of the well but also as the tool for setting and releasing the packer in the conventional manner. It will be understood that the packer structure 5 may be of any of the conventional types which are adapted to be run on a string of tubing by the general arrangement described. The details of the particular packer employed do not, therefore, form a part of this invention.

The testing device, in accordance with this invention comprises a flow control valve, indicated generally by the letter V (Figs. 1 and 2), for opening and closing tube 12 to communication with the annular space between the tube and casing 2. Test valve V comprises a hollow generally cylindrical valve body 18 having a closed conical end wall 19 arranged in the lower end of tube 12, in a manner to be described hereinafter, and provided with a plurality of ports 20 which extend through end wall 19 to provide communication between the interior of tube 12 and bore 21 of body 18. Bore 21 is provided at its outer end with a seat bushing 22, having an axial port 23 therethrough provided at its outer end with a tapered seat 24. An annular valve 25, complementary in shape to seat 24 is mounted or formed about an intermediate portion of a cylindrical valve stem 26, the inner end portion 27 of which extends through port 23, in close sliding fit therewith, into bore 21 and is provided with an axial bore 28 extending from the inner end of end portion 27 to a point approximately opposite valve 25. The outer end portion 29 of valve stem 26 has a nut 30 mounted on the outer end thereof. Inner end portion 27 likewise has a nut 31 mounted on the inner end thereof, and a coil spring 32 surrounds end portion 27 and is mounted in compression between nut 31 and the inner end of seat bushing 22 to normally urge valve 25 toward seat 24. The outer edge of nut 31 is provided with a plurality of longitudinal slots 33 to permit passage of fluid past nut 31 through bore 21 of the valve body. A plurality of angularly spaced passageways 34 extend generally radially through the wall of inner end portion 27 at a point just inwardly of valve 25 and provide communication between the exterior of inner end portion 27 and bore 28 thereof. The position of passageways 34 on inner end portion 27 is such

that when valve 25 is in the closed position (Figs. 1 and 3), passageways 34 will be located within port 23, and will be closed off thereby due to the close fit of inner end portion 27 with port 23. In the open position of the valve (Figs. 2 and 4), passageways 34 will be below and outside of port 23 and will thus provide communication between the exterior of the valve and the interior thereof. Rigidly mounted on one side of the exterior of valve body 18 and depending therefrom is an arcuate bracket 35 having a narrow longitudinal slot 36 extending upwardly from the lower edge thereof. A dog or pawl 37 is rockably mounted in slot 36 on a pivot pin 38 extending transversely of the slot. The outer end of pawl 37 extends outwardly from slot 36 and is provided with a downwardly and inwardly sloping surface 39. The inner end of pawl 37 is provided with a U-shaped yoke 40 which encloses outer end portion 29 of the valve stem and rests on the upper face of nut 30. With this arrangement it will be seen that when the outer end of pawl 37 is pushed upwardly, yoke 40 will push downwardly against nut 30 against the action of coil spring 32 and pull valve 25 downwardly away from seat 24 and expose passageways 34. Coil spring 32 will act to close the valve whenever upward pressure against the outer end of pawl 37 is released. An actuating member for pawl 37 comprises a sleeve structure 41 which is rigidly connected to the lower end of the packer structure and extends generally concentrically with the lower end of tube 12 for a suitable distance below valve V. A slot 42 is cut longitudinally in one side of sleeve structure 40 into which the outer end of pawl 37 extends, the upper and lower ends of slot 42 forming abutments 43 and 44, respectively for engaging the end of the pawl in a manner to be described hereinafter. Slot 42 has a width such as to permit circumferential rotation of pawl 37 therein sufficient to accommodate that degree of rotation of tube 12 which occurs in effecting release of J-slot-and-pin connection 13.

It is normally desirable to close the lower end of tube 12 by means of a check valve, in order that fluid may be discharged from the tubing string while preventing uncontrolled entrance of fluid into the tubing from the bottom of the well. The embodiment of this invention illustrated particularly in Figs. 1 to 5, inclusive, provides such a check valve and conveniently employs test valve V as a portion of the check valve structure. In this embodiment, the lower end of tube 12 is provided with a valve seat bushing 45 which is screwed into the lower end of the tube and is provided with an axial port 46 having its outer end merging into a tapered seat 47 complementary to the outer face of end wall 19 of valve body 18. The diameter of seat 47 is such relative to end wall 19, that an annular portion of the latter below ports 20 will engage seat 47 and valve body 18 will thereby form the valve closure for port 46. Valve body 18 is provided with a stem 48 which extends axially through port 46 into the interior of tube 12. Stem 48 is slidable axially through a perforate spider 49 mounted transversely of seat bushing 45 and is held against rotation therein by means of a key 50. The inner end of stem 48 is provided with a nut 51 and a coil spring 52 is mounted about stem 48 in compression between nut 51 and the upper end of spider 49. The action of coil spring 52 is to normally urge and maintain valve body 18 into the closed position on seat 47.

The above-described embodiment is employed for testing formations in the following manner:

With the valve structure assembled on the lower end of a packer and connected to tubing string 17, as illustrated in Fig. 1, the device is lowered into the well casing. It will be understood that J-slot-and-pin connection 13 will be engaged (Fig. 1) at this time so that slips 8 will be held out of engagement with casing 2 during the lowering operation. At this time, also, pawl 37 will be out of engagement with the top or bottom of slot 42 and free for movement therein. Under these conditions valve V will, of course, be closed. The check valve in the lower end of tube 12, formed by port 46 and valve body 18, will also be closed as the tubing string will normally be kept empty of fluid when running into the well, so that there will be no pressure exerted on the upper face of end wall 19 which could open this valve against the resistance of coil spring 52. On the other hand, as the well casing will normally be filled with fluid, the check valve will prevent the entrance of such fluid into the tubing as the structure descends in the well. Fluid in the casing will be largely displaced through annular opening 16 at the upper end of the packer structure and will flow upwardly into the section of the casing above the packer.

When the string of tools has been lowered to the desired point in the well, as, for example, opposite formation A, tubing string 17 will be rotated in the appropriate direction to release J-connection 13, friction members 10 holding the packer structure against rotation in the usual manner during rotation of the tubing. With the J-connection then released, the tubing string will then be lowered to set the packer in the conventional manner, slips 8 being expanded into gripping engagement with the casing and sealing sleeve 6 expanded into tight-sealing engagement with the casing. In effecting the setting of the packer, valve 15 will descend upon seat 14 and close annular opening 16, thereby effectively sealing off the section of the well below the packer from that above the packer.

The descent of the tubing string in setting the packer will, of course, be accompanied by corresponding descent of the lower end of tube 12 and the valve mechanism carried thereby. Sleeve 41 being connected to the packer will remain stationary as the tubing descends. The descent of valve V will cause the end of pawl 37 which extends into slot 42 to strike abutment 44 at the lower end of the slot, forcing it in the upward direction (Figs. 2 and 5) causing it to pull stem 25 downwardly bringing passageways 34 below and out of port 23. It will be understood that the length of slot 42 will be so proportioned relative to the length of travel of tube 12 in setting the packer that the end of pawl 37 may descend below abutment 44 and slide down against the wall of sleeve 41 below the slot. The tapered face 39 on the end of the pawl is provided to permit this movement. The valve will thus be maintained in the open position so long as pawl 37 is thus held in the upward position by its contact with the inner face of sleeve 41.

With the valve thus opened, fluid from the formation under the formation pressure will flow through slot 42, thence through passageways 34, bore 28, and ports 20 into the interior of tube 12, and thence upwardly through tubing string 17 to the surface for handling and disposal in

the usual manner. As noted previously, tubing string 17 will normally be empty when running in the well, so that ordinarily there will be a substantial pressure differential favoring the flow of the formation fluids into the tubing.

The described device may be employed merely for testing the production possibilities of the formation or, if desired, it may be left in the well and the well permitted to produce through the valve until production ceases. In either event, whenever it is desired to remove the device, tubing 17 will be drawn upwardly from the top of the well to release the packer. This movement will lift the valve mechanism, bringing pawl 37 above abutment 44 and coil spring 32 will then expand, pulling valve stem 25 upwardly, thereby closing the valve and shutting off communication between the well and the tubing string. When the tubing string has been raised sufficiently, J-connection 13 will be re-engaged in the usual manner and the entire structure withdrawn from the well. It will be understood that the check valve formed by valve body 18 and seat bushing 45 may be employed, when desirable, to force or pump fluid down the tubing string into the well. The downward pressure of such fluid on end wall 19 will force the latter downwardly to open port 46 for this purpose.

Figs. 6, 7 and 8, illustrate another embodiment in accordance with this invention. The packer structure 5 and tube 12 will be the same as in the previously described embodiment and these parts are designated by the same numerals. In this embodiment the test valve includes a tubular body 55 which is coupled to the lower end of tube 12 by means of a collar 56 which forms a downwardly facing annular shoulder 57 about the exterior of the upper end of body 55. The latter has an axial bore 58 registering with the bore of tube 12 and provided with a choke bushing 59 forming a flow restriction in bore 58.

A check valve is provided for the lower end of body 55 and comprises a tubular collar 60, into the upper end of which the lower end of body 55 is screwed so that the upper edge of collar 60 forms an upwardly facing annular shoulder 61 about the exterior of body 55 spaced from shoulder 57. The lower end of collar 60 is provided with an axial port 62 having a downwardly and outwardly tapering seat 63. A valve 64 is arranged for opening and closing port 62 and is provided with a stem 65 extending axially through port 62 into the interior of collar 60 in which it is guided for sliding movement in a perforate spider 66. The upper end of stem 65 is provided with a nut 67 and a coil spring 68 is mounted in compression between nut 67 and the upper end of spider 66 to normally maintain valve 64 in the closed position against seat 63.

The lower portion of body 55 is provided with a plurality of circumferentially spaced ports 70 to provide communication between the exterior of body 55 and its bore 58. A sleeve valve 71 is mounted for sliding and rotative movement on the exterior of body 55 for opening and closing ports 70. Packing rings 72 are seated in appropriate grooves on body 55 above and below the ring of ports 70 to provide fluid tight seals between the exterior of the body and sleeve valve 71. The latter, being larger in diameter than body 55, forms upper and lower annular shoulders 73 and 74, respectively. A coil spring 75 is mounted about body 55 in compression between

shoulder 61 and shoulder 73 and normally urges sleeve valve 71 downwardly along body 55 to the position for closing ports 70. Shoulder 61 forms a lower stop to limit the downward movement of sleeve valve 71. Ports 70 are so positioned relative to shoulder 61, that when sleeve valve 71 rests on shoulder 61, ports 70 will be closed thereby. A pair of studs 76 extend diametrically from opposite sides of sleeve valve 71 into registering elongated slots 77 provided in a sleeve structure 78 which concentrically surrounds the the valve mechanism and is rigidly connected to the lower end of the packer structure. The width of slots 77 is only sufficient to accommodate studs 76 for easy sliding movement therein, body 55 being free to rotate relative to sleeve valve 71 during release of the packer. The upper and lower ends of slots 77 are closed by end walls 80 and 79, respectively, to form stops for studs 76.

This embodiment operates in the following manner: As in the previously described embodiment, the valve structure is lowered with the packer, J-connection 13 being engaged as before to prevent movement of tube 12 and the valve mechanism relative to the packer. The parts of the valve mechanism will be in the positions illustrated in Fig. 6. The pressure of coil spring 75 will hold sleeve valve 71 in the closed position over ports 70. J-connection 13 will be released to set the packer in the manner previously described, tube 12 and its attached valve mechanism being then lowered as the packer is set, sleeve 78 remaining stationary. The downward movement of tube 12 and the valve mechanism will first bring studs 75 into contact with stops 79 in the bottoms of slots 77, which will stop the downward movement of sleeve valve 71 while downward movement of tube 12 and valve body 55 will continue for a sufficient distance to bring ports 70 below the lower edge of sleeve valve 71 and thereby open bore 58 to communication with the casing (Fig. 7). This operation will also serve to compress coil spring 75. Ports 70, now being open, formation fluids will flow from the well through slots 77 and ports 70 into the interior of body 55 and thence upwardly through the tubing string to the surface.

When the packer is released to remove the structure from the well, the upward movement of the tubing effected in accomplishing this operation will raise studs 76 off of stops 79 and, as the tubing moves upwardly, coil spring 75 will expand to force sleeve valve 71 downwardly against shoulder 61 and close ports 70. J-connection 13 will then be re-engaged and the entire structure withdrawn from the well. The check valve at the lower end of body 55 will be available for use as desired in the manner previously described.

From the foregoing it will be evident that the devices in accordance with this invention will be opened for admission of formation fluids only when the packer becomes firmly set in the well. This is important, since it assures that the fluid discharging from the tubing is fluid from the formations undergoing testing and thereby permits an accurate test of the production possibilities of the tested formations. Moreover, the opening and closing of the test valve is effected by the very same operations employed for setting and releasing the packer, thereby eliminating the necessity for additional manipulations

of the tools which, in existing testing devices, is a common source of difficulty and error. Accordingly, it will be evident that the devices in accordance with this invention are of relatively simple construction, and are positive and efficient in operation. It will be understood that various alterations and changes may be made in the details of the illustrative embodiments within the scope of the appended claims but without departing from the spirit of this invention.

What I claim and desire to secure by Letters Patent is:

1. In a system for producing or testing formations along a well employing a packer for sealing the well above said formations and an operating tube extending through said packer for rotative and longitudinal movement relative thereto for setting and releasing said packer, a device for controlling communication between said tube and said well, comprising, valve means carried by said tube including port means and a relatively movable closure element therefor, a fixed element carried by said packer engageable with said closure element in response to relative longitudinal movement of said tube relative to said packer to open and close said port means, and independently operable check valve means closing said tube against entrance of fluid therein from said well.

2. In a system for producing or testing formations along a well employing a packer for sealing the well above said formations and an operating tube extending through said packer for rotative and longitudinal movement relative thereto for setting and releasing the packer, a device for controlling communication between said tube and said well, comprising, port means arranged in said tube below said packer, a closure element movably mounted on said tube for opening and closing said port means, an operating member connected to said closure element and extending laterally therefrom, and a fixed stop member supported from said packer in the path of movement of said operating member and engageable therewith upon relative longitudinal movement between said tube and said packer to open and close said port means.

3. In a system for producing or testing formations along a well employing a packer for sealing the well above said formations and an operating tube extending through said packer for rotative and longitudinal movement relative thereto for setting and releasing the packer, a device for controlling communication between said tube and said well, comprising, port means arranged in said tube below said packer, a closure element movably mounted on said tube for opening and closing said port means, an operating member connected to said closure element and extending laterally therefrom, and a fixed stop member supported from said packer in the path of movement of said operating member and engageable therewith upon relative longitudinal movement of said tube to open and close said port means, said stop member comprising a sleeve structure concentric with said tube and having a longitudinal slot closed at its lower end into which said operating member slidably extends.

4. In a system for producing or testing formations along a well employing a packer for sealing the well above said formations and an operating tube extending through said packer for rotative and longitudinal movement relative thereto for setting and releasing the packer, a device for controlling communication between the tube and

said well, comprising, valve means mounted on said tube below said packer including port means and a relatively movable closure element therefor, an operating member connected to said closure element and extending laterally therefrom, resilient means normally holding said closure element in the closed position, and a fixed element carried by said packer engageable with said operating member in response to relative longitudinal movement between said tube and said packer for opening and closing said port means.

5. In a system for producing or testing formations along a well employing a packer for sealing the well above said formations and an operating tube extending through said packer for rotative and longitudinal movement relative thereto for setting and releasing the packer, a device for controlling communication between said tube and said well, comprising, a generally cylindrical valve body mounted in the lower end of said tube having a bore communicating with the interior of said tube, an annular valve seat in the outer end of said valve body, an axially movable valve stem extending through said seat into said valve body, a valve closure mounted on said stem exteriorly of said seat, a passageway through said stem providing communication between the bore of said valve body and the exterior of said stem inwardly of said valve closure, resilient means arranged in said valve body to normally urge said valve closure toward said seat, an operating member connected to said valve stem, and a stop element rigidly supported from said packer engageable with said operating member in response to relative longitudinal movement of said tube for moving said valve closure relative to said seat.

6. A device according to claim 5 wherein said valve body is mounted for axial movement relative to the lower end of said tube to form an outwardly opening check valve therefor, and resilient means mounted in said tube and connected to said valve body to normally urge the latter into closing engagement with the lower end of said tube.

7. In a system for producing or testing formations along a well employing a packer for sealing the well above said formations and an operating tube extending through said packer for rotative and longitudinal movement relative thereto

for setting and releasing the packer, a device for controlling communication between said tube and said well, comprising, a tubular valve body having its lower end closed connected to the lower end of said tube below said packer, a plurality of circumferentially spaced ports in the wall of said body, a sleeve valve slidable on said body for opening and closing said ports, resilient means normally urging said sleeve valve to a position closing said ports, an operating member extending laterally outwardly from said sleeve valve, and a stop element rigidly supported from said packer engageable with said operating member in response to relative longitudinal movement of said tube for moving said sleeve valve relative to said ports.

8. A device according to claim 7 wherein the closure for the lower end of said valve body comprises a check valve normally closed against entrance therein of fluid from the well.

9. A formation testing or flow device for wells, comprising, an expandible packer adapted to be inserted in a well, an operating tube extending through said packer for rotative and longitudinal movement relative thereto for setting and releasing the packer, valve means mounted on said tube below the packer including port means and a relatively movable closure element therefor, an operating member connected to said closure element and extending laterally therefrom, a sleeve element extending below said packer generally concentrically with said tube, a stop member mounted on said sleeve element engageable with said operating member in response to relative longitudinal movement between said tube and said packer to open and close said port means, and an independently operable check valve closing said tube against entrance of fluid therein from said well.

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