

July 9, 1963

T. L. CROWE

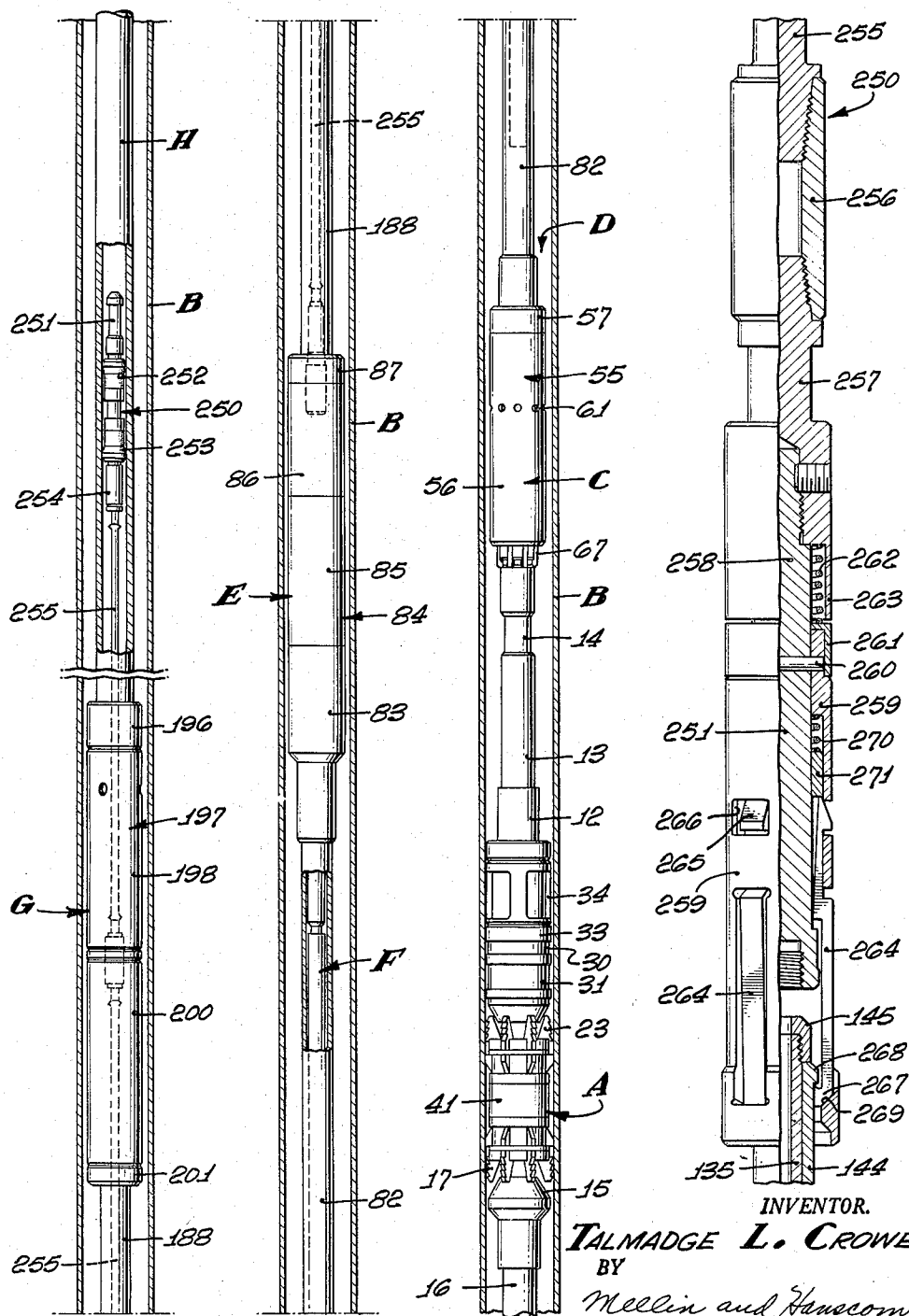
3,096,823

WELL BORE TESTING AND PRESSURING APPARATUS

Filed April 28, 1959

10 Sheets-Sheet 1

Fig. 1. Fig. 1a. Fig. 1b. Fig. 4.



INVENTOR.
TALMADGE L. CROWE
 BY
Mellin and Hunscomb
 ATTORNEYS.

July 9, 1963

T. L. CROWE

3,096,823

WELL BORE TESTING AND PRESSURING APPARATUS

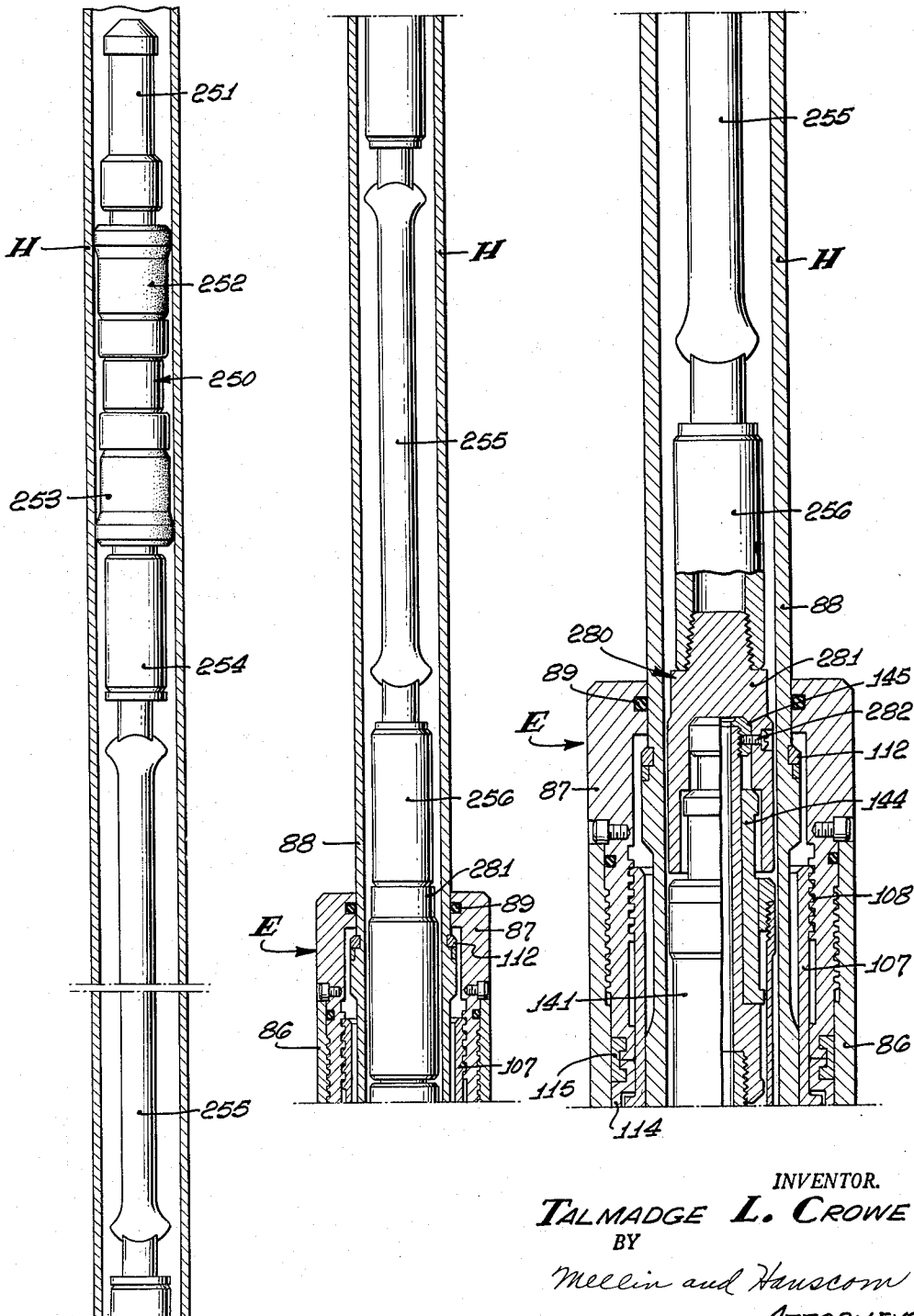
Filed April 28, 1959

10 Sheets-Sheet 2

FIG. 2.

FIG. 2a.

FIG. 3.



INVENTOR.

TALMADGE L. CROWE

BY

Mellin and Hauscorn

ATTORNEYS.

July 9, 1963

T. L. CROWE

3,096,823

WELL BORE TESTING AND PRESSURING APPARATUS

Filed April 28, 1959

10 Sheets-Sheet 3

Fig. 5.

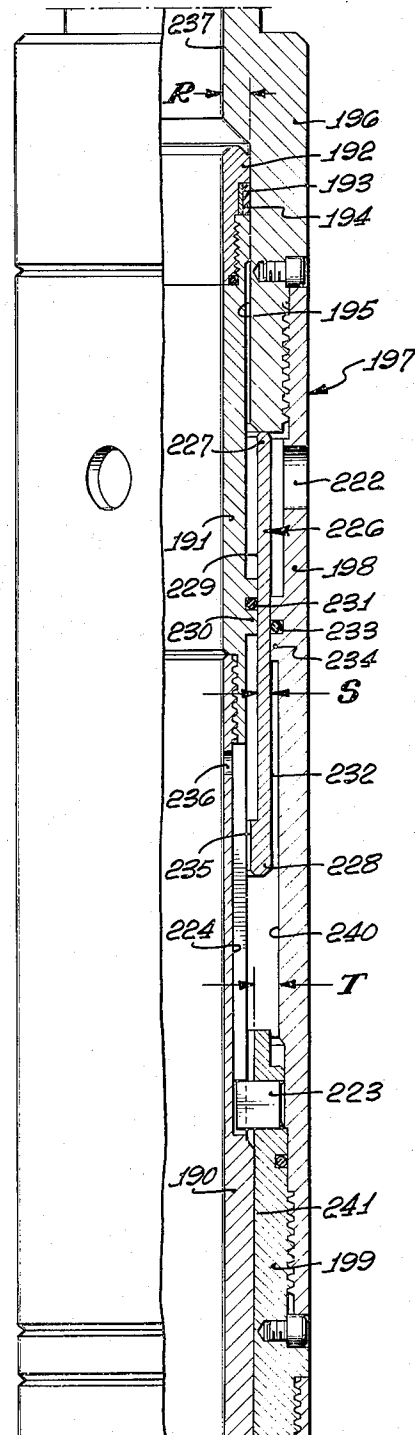
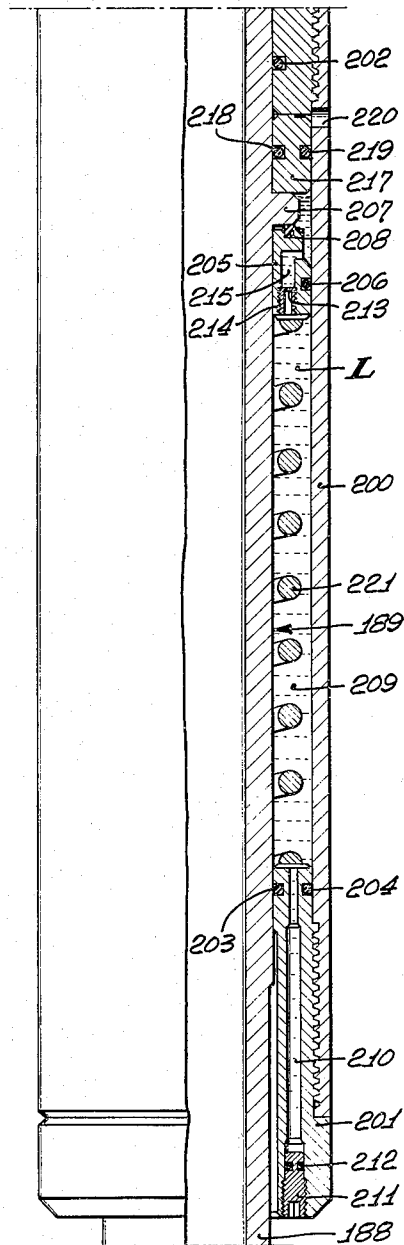


Fig. 5a.



INVENTOR.

TALMADGE L. CROWE
BY

McClintock and Hanson
ATTORNEYS

July 9, 1963

T. L. CROWE

3,096,823

WELL BORE TESTING AND PRESSURING APPARATUS

Filed April 28, 1959

10 Sheets-Sheet 4

FIG. 6.

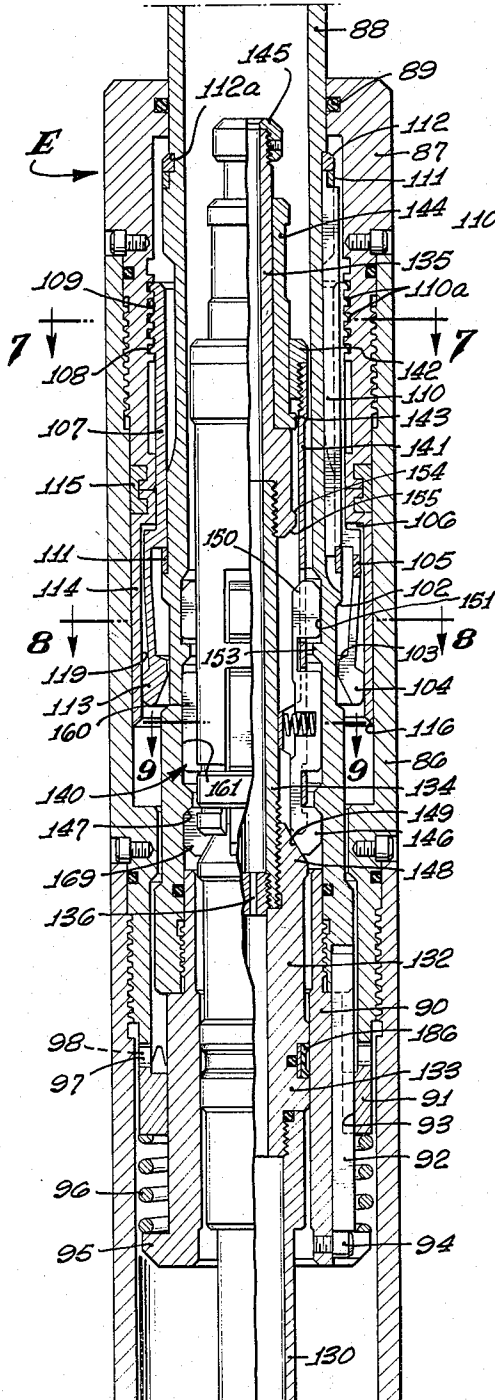


FIG. 7.

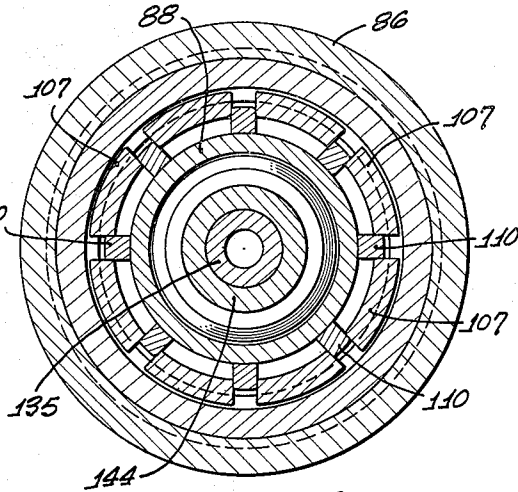
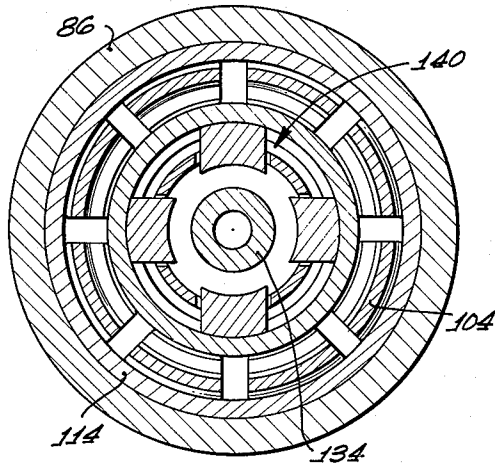


FIG. 8.



INVENTOR.
TALMADGE L. CROWE
 BY
Mellin and Hanson
 ATTORNEYS.

July 9, 1963

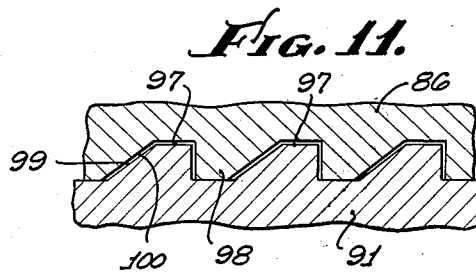
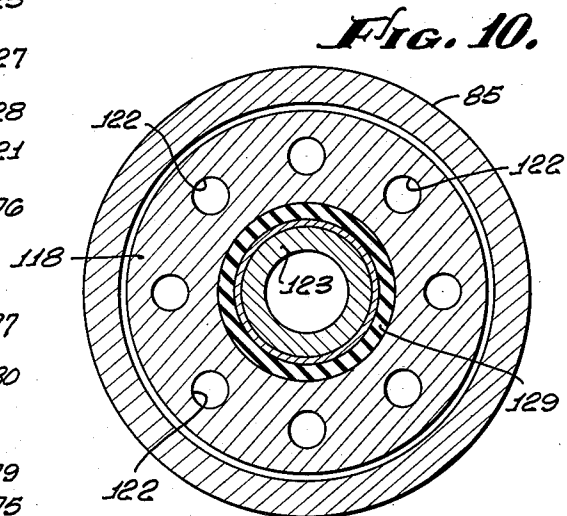
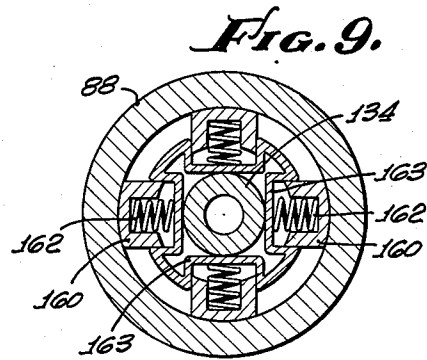
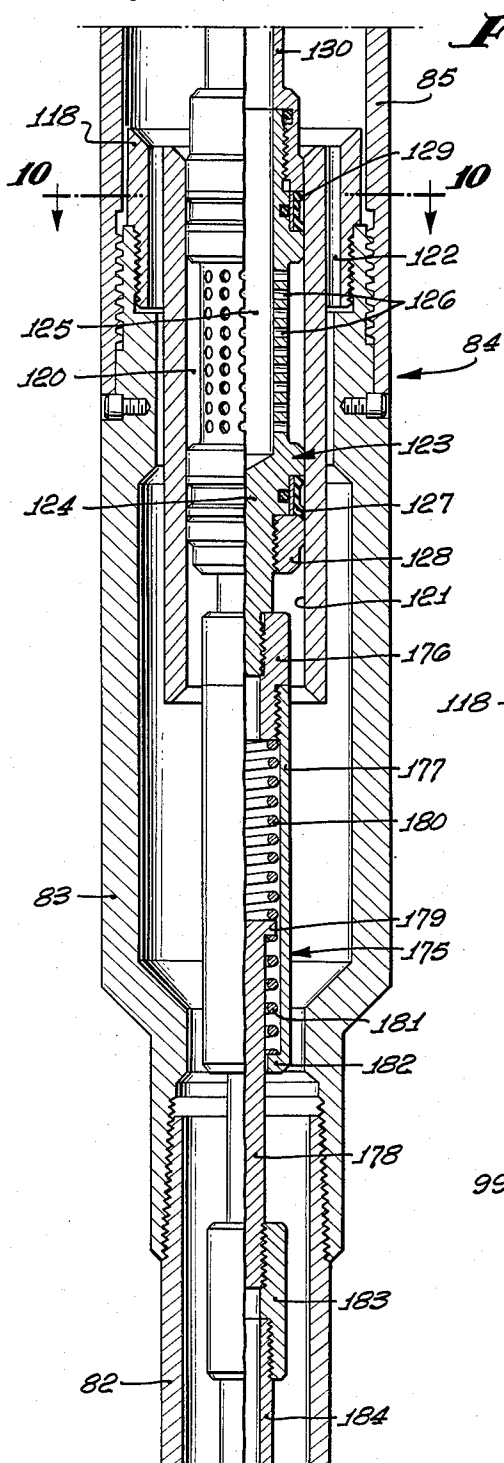
T. L. CROWE

3,096,823

WELL BORE TESTING AND PRESSURING APPARATUS

Filed April 28, 1959

10 Sheets-Sheet 5



INVENTOR.
TALMADGE L. CROWE
 BY
Mellin and Hanscom
 ATTORNEYS.

July 9, 1963

T. L. CROWE

3,096,823

WELL BORE TESTING AND PRESSURING APPARATUS

Filed April 28, 1959

10 Sheets-Sheet 6

Fig. 12.

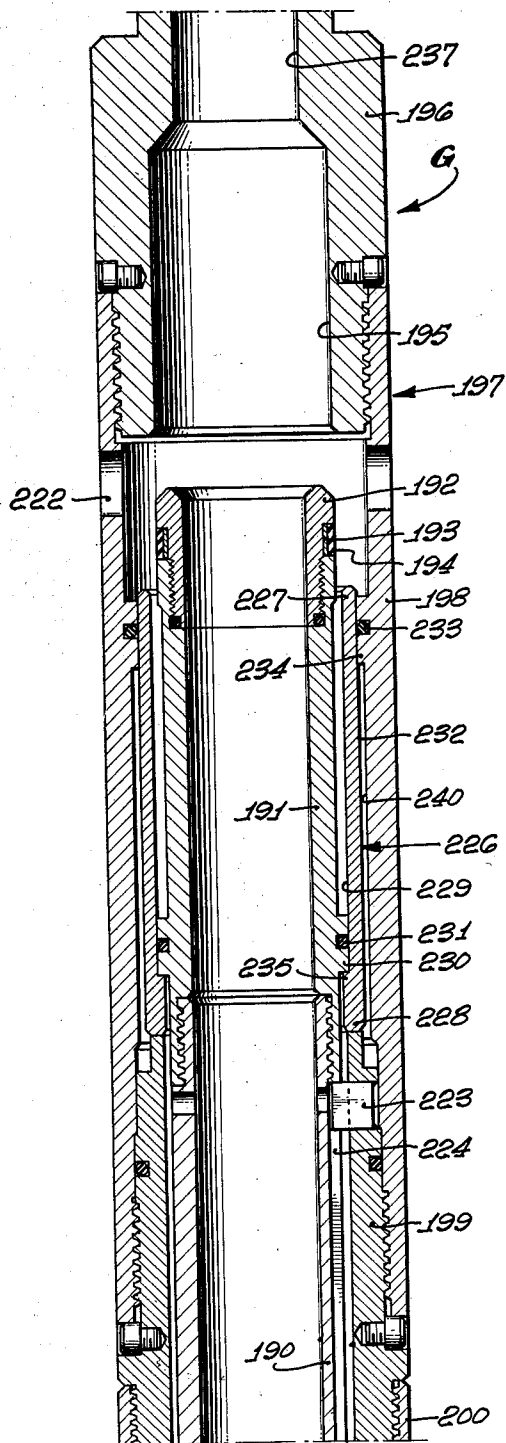
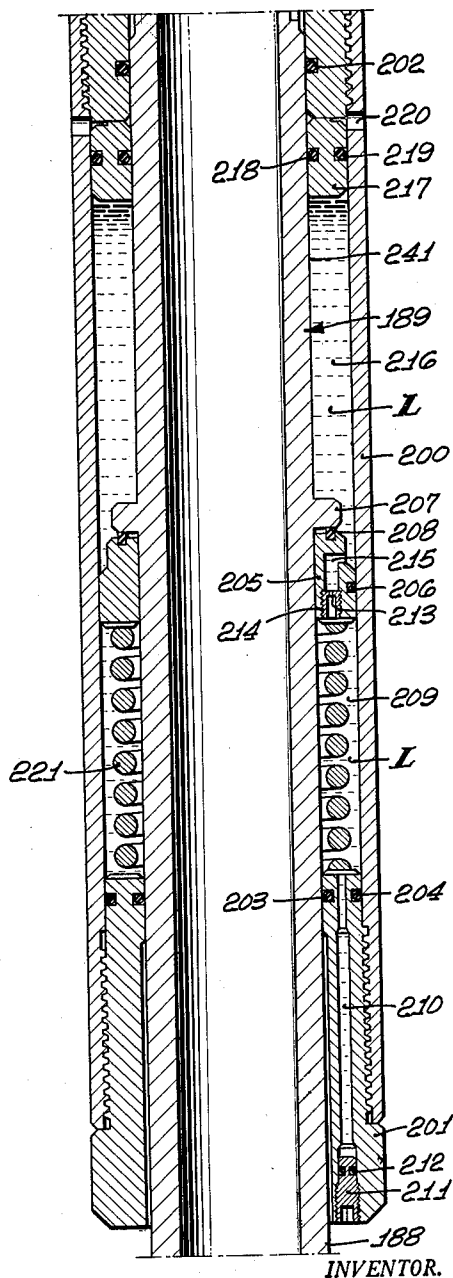


Fig. 12a.



INVENTOR.

TALMADGE L. CROWE
BY

Meelin and Hancock
ATTORNEYS.

July 9, 1963

T. L. CROWE

3,096,823

WELL BORE TESTING AND PRESSURING APPARATUS

Filed April 28, 1959

10 Sheets-Sheet 7

Fig. 13.

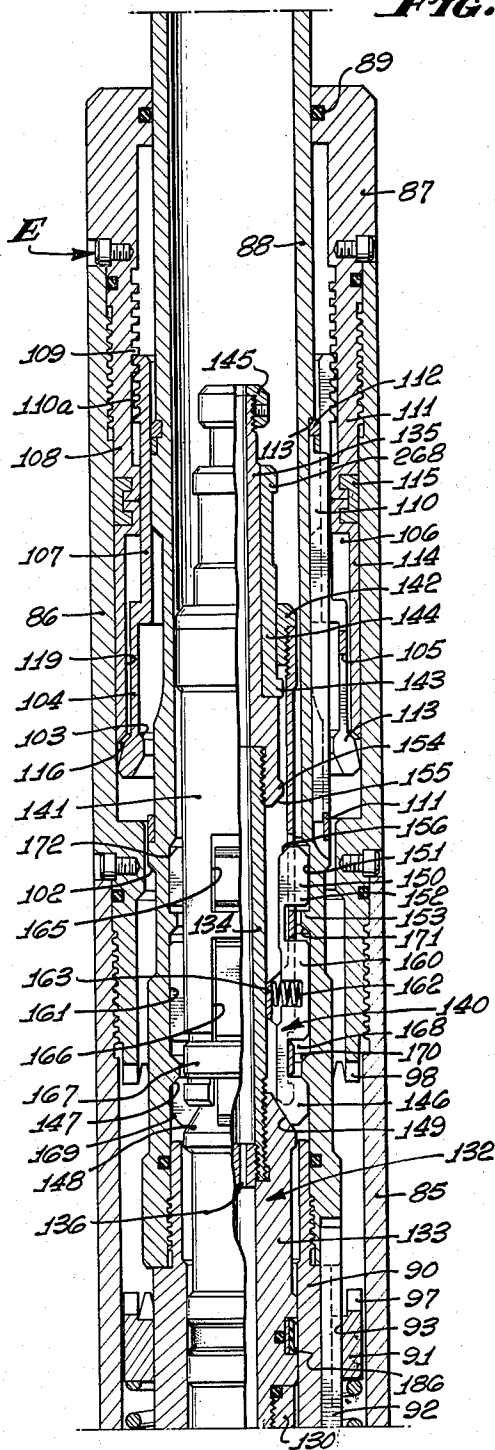
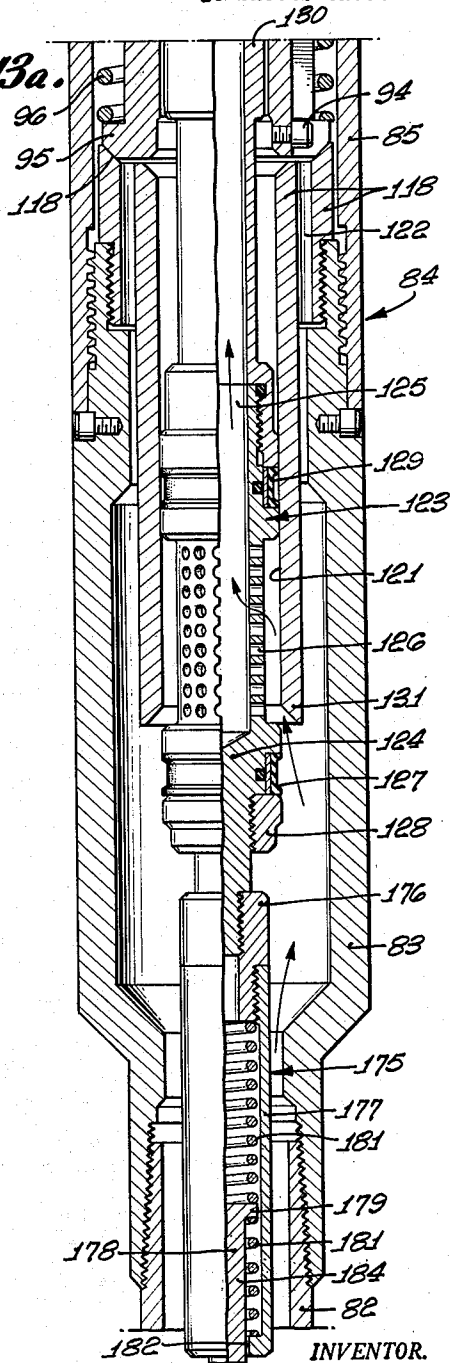


Fig. 13a.



INVENTOR.
TALMADGE L. CROWE
BY

Meelin and Hanscom

ATTORNEYS.

3,096,823

10 Sheets-Sheet 8

Fig. 16.

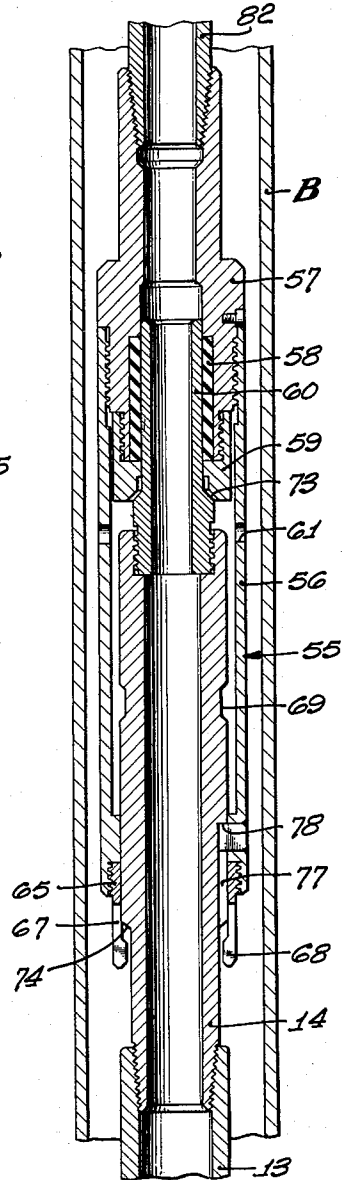
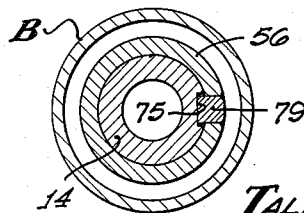


Fig. 17.



TALMADGE L. CROWE
BY

Mellin and Hanson
ATTORNEYS.

July 9, 1963

T. L. CROWE

3,096,823

WELL BORE TESTING AND PRESSURING APPARATUS

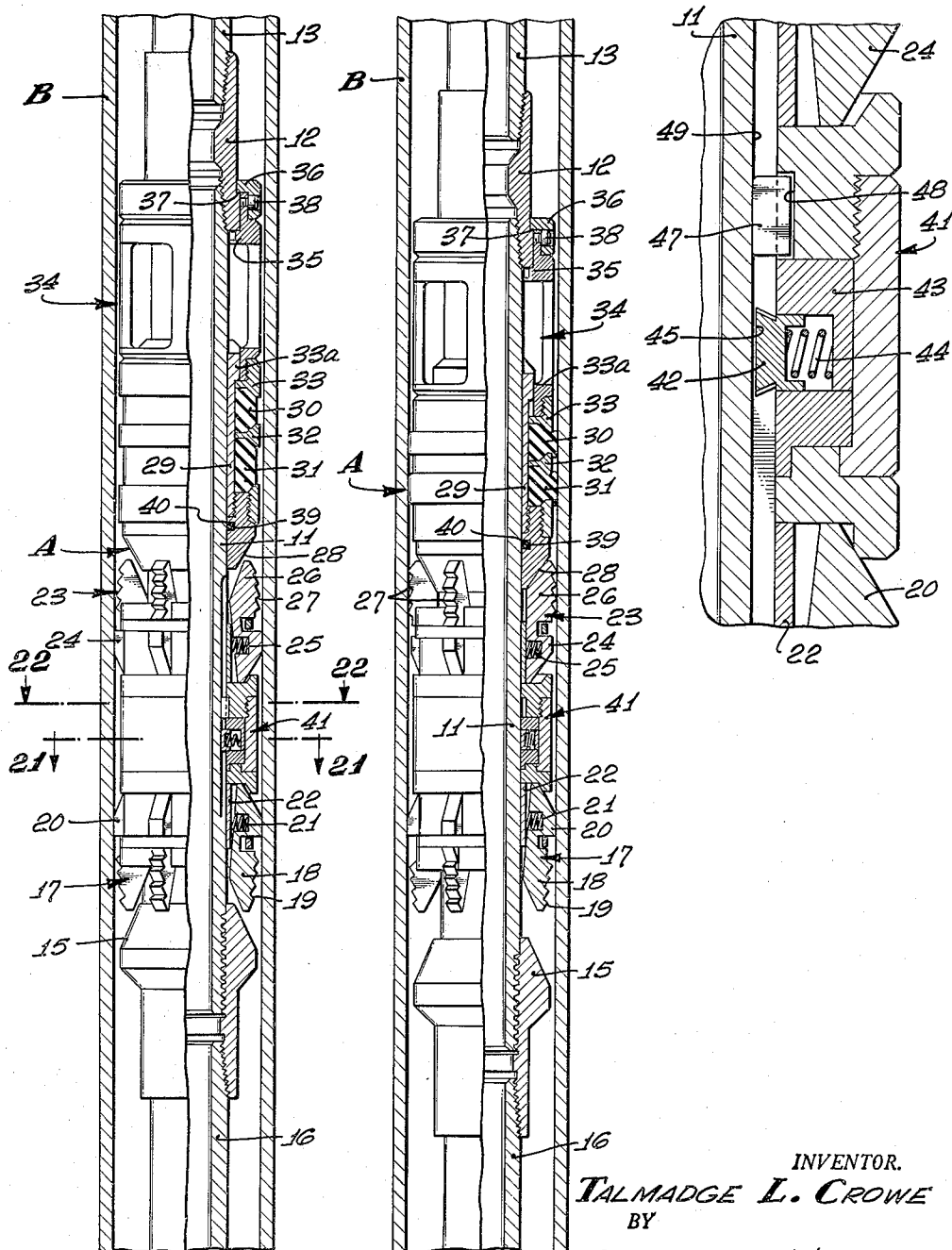
Filed April 28, 1959

10 Sheets-Sheet 9

Fig. 18.

FIG. 19.

Fig. 20.



INVENTOR.
TALMADGE L. CROWE
BY

McEllin and Hanscom
ATTORNEYS.

July 9, 1963

T. L. CROWE

3,096,823

WELL BORE TESTING AND PRESSURING APPARATUS

Filed April 28, 1959

10 Sheets-Sheet 10

Fig. 21.

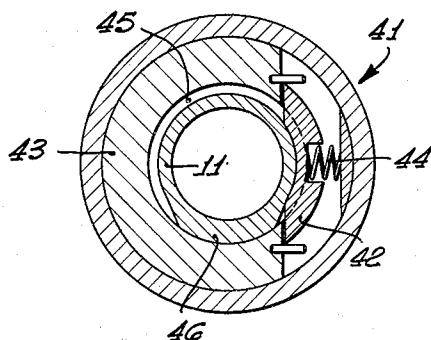


Fig. 22.

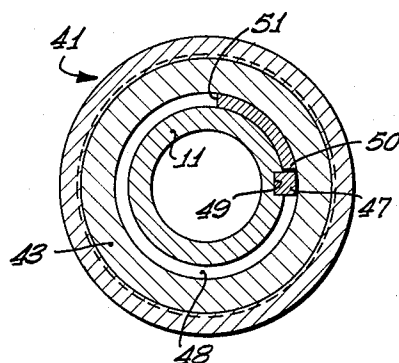


Fig. 23.

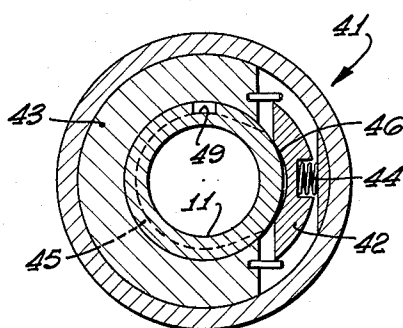
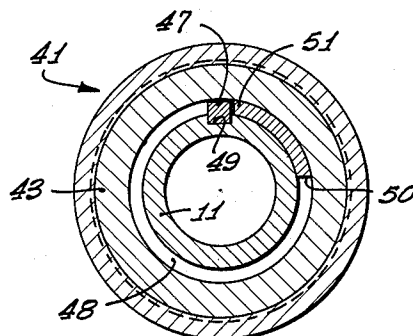


Fig. 24.



INVENTOR.

TALMADGE L. CROWE

BY

Mellin and Hanscom

ATTORNEYS.

1

3,096,823

WELL BORE TESTING AND PRESSURING APPARATUS

Talmadge L. Crowe, Houston, Tex., assignor to Baker Oil Tools, Inc., Los Angeles, Calif., a corporation of California

Filed Apr. 28, 1959, Ser. No. 809,383
41 Claims. (Cl. 166—150)

The present invention relates to subsurface well apparatus, and more particularly to apparatus capable of performing testing operations in a well bore, and also various types of treatments therein, such as cement squeezing, acidizing and fracturing.

Testing equipment has been used to test the productivity of a formation zone or the effectiveness of a cement job in a well bore. When the test indicated a need for subsequent well treatment, the testing equipment was removed from the well bore and other apparatus, such as a well packer, run in the well bore on a tubular string to perform the subsequent treatment, such as a hydraulic fracturing operation, acidizing of the well, squeeze cementing, or perforating or additional perforating. Following such treatment, the other apparatus was removed from the well bore and the testing equipment again lowered therein to perform the testing operation. The testing equipment and subsequent treatment equipment was alternately used until the desired satisfactory well condition was realized. Such repeated running-in and removal of different types of equipment in the well bore is both time consuming and costly.

An object of the present invention is to provide an improved apparatus which can be run in the well bore and used for alternately testing the well bore and performing a suitable pressuring operation therein without the necessity for removing the apparatus from the well bore.

Another object of the invention is to provide an apparatus adapted to be run in a well bore on a tubular string and of being anchored in packed-off condition in the well bore against movement in both upward and downward directions, so as to function selectively as a testing tool or a squeeze packer, the passage through the apparatus being selectively blocked when the apparatus is being used as a tester or opened fully when the apparatus is being used as a squeeze packer, the open passage being unobstructed throughout the length of the apparatus.

A further object of the invention is to provide a retrievable apparatus adapted to be run in a well bore on a tubular string and of being anchored in packed-off condition in the well bore against movement in both upward and downward directions, the apparatus being set in the well bore and released in response to manipulation of the tubular string and adapted to have a full straight-through opening when the apparatus is in use for forcing fluent materials into the formation, and to have a barrier therein when the apparatus is to be used as a tester, the barrier being inserted in place and removed without the necessity for withdrawing the apparatus from the well bore.

Yet another object of the invention is to provide apparatus for testing well formations and the like, adapted to be lowered in a well bore on a tubular string, in which circulation in either direction can be established through the tubular string without subjecting the well formation to pressure or, if a pressure recorder is used, without also subjecting the recorder to the pressure of the circulating fluid. This enables the fluid in the tubular string developed from the test to be reversely circulated from the tubular string without subjecting the formation to pressure or the recorder to pressure. It also enables the fluid developed from the test to be reversely circulated from the tubular string while a shut-in test is being per-

2

formed and recorded on the pressure recorder, thereby saving substantial time.

Still a further object of the invention is to provide testing and pressuring apparatus to be disposed in a well bore and embodying a retrievable plug or mandrel valve portion adapted to be latched in place to enable the tool to function as a tester and to be removed when another operation, such as a well pressuring operation, is to be performed, the mandrel valve portion being positively held in place and readily retrieved, when desired.

An additional object of the invention is to provide a tester valve adapted to be disposed in a well bore, in which positive assurance is had that the valve has been shifted from closed to opened position.

Another object of the invention is to provide a tester valve that can be shifted from opened to closed position in a simple manner, as by merely moving a portion of the valve in a straight line path, as upwardly.

Yet a further object of the invention is to provide a tester valve capable of being alternately opened and closed an infinite number of times while disposed in the well bore.

A further object of the invention is to provide testing and pressuring apparatus to be disposed in a well bore, and embodying a retrievable plug or tester mandrel valve portion capable of release from the remainder of the apparatus for withdrawal from the well bore with assurance that there is no pressure differential imposed upon it which might hamper its releaser or damage parts of the apparatus.

Yet another object of the invention is to provide testing apparatus to be disposed in a well bore on a tubular string and embodying a retrievable mandrel tester valve portion, assurance being had that the fluid in the tubular string can be unloaded therefrom into the well bore during removal of the tubular string, in the event the mandrel portion cannot first be released and retrieved through the tubular string. Accordingly, the sections of the tubular string will be dry as they are removed from the hole, avoiding spilling of the fluid on the surface equipment and personnel.

A further object of the invention is to provide an unloading valve adapted to be attached to a tubular string and opened and closed without the necessity for rotating the tubular string, motion and effort being transmittable through the valve, to operate other equipment in the well bore secured to the valve, without changing the condition of the valve.

This invention possesses many other advantages, and has other objects which may be made more clearly apparent from a consideration of a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIGURES 1, 1a and 1b together constitute a side elevational view of an apparatus embodying the invention disposed in a well casing, a portion of the apparatus being shown in longitudinal section, FIG. 1a constituting a lower continuation of FIG. 1 and FIG. 1b constituting a lower continuation of FIG. 1a;

FIGS. 2 and 2a are side elevational views of a running-in tool secured to the tester valve portion of the apparatus and disposed within the tubular string, FIG. 2a constituting a lower continuation of FIG. 2;

FIG. 3 is a longitudinal section of the lower portion of the retrieving tool attached to the retrievable mandrel and barrier portion of the tester valve apparatus;

FIG. 4 is a side elevational view and longitudinal section through the lower portion of the apparatus for retrieving a mandrel or barrier from the apparatus;

FIG. 5 and 5a together constitute a combined side elevational view and longitudinal section through the upper unloader valve, which is disclosed in closed position, FIG. 5a constituting a lower continuation of FIG. 5;

FIGS. 6 and 6a together constitute a longitudinal section and side elevational view through the tester valve portion of the apparatus, the valve being in closed position, FIG. 6a constituting a lower continuation of FIG. 6;

FIG. 7 is an enlarged cross-section taken along the line 7—7 on FIG. 6;

FIG. 8 is an enlarged cross-section taken along the line 8—8 on FIG. 6;

FIG. 9 is an enlarged cross-section taken along the line 9—9 on FIG. 6;

FIG. 10 is an enlarged cross-section taken along the line 10—10 on FIG. 6a;

FIG. 11 is a longitudinal section of a fragment of an overload release or ratchet type of clutch forming part of the tester valve apparatus;

FIGS. 12 and 12a together constitute a longitudinal section through the upper unloader valve in open condition, FIG. 12a constituting a lower continuation of FIG. 12;

FIGS. 13 and 13a together constitute a longitudinal section, with parts shown in side elevation, through the tester valve in open condition, FIG. 13a constituting a lower continuation of FIG. 13;

FIG. 14 is a longitudinal section through the lower equalizer valve in open condition;

FIG. 15 is another view of the valve disclosed in FIG. 14, with the inner mandrel portion in side elevation;

FIG. 16 is a view similar to FIG. 14 of the equalizer valve in closed condition;

FIG. 17 is a cross-section taken along the line 17—17 on FIG. 14;

FIG. 18 is a combined side elevational view and longitudinal section through the retrievable well packer portion of the apparatus, with the slips and packing structure in retracted position;

FIG. 19 is a view similar to FIG. 18 disclosing the packer anchored in packed-off condition against downward movement in the well casing;

FIG. 20 is an enlarged fragmentary longitudinal section through the control unit or clutch portion of the packer disclosed in FIGS. 18 and 19;

FIG. 21 is an enlarged cross-section taken along the line 21—21 on FIG. 18;

FIG. 22 is a cross-section taken along the line 22—22 on FIG. 18;

FIG. 23 is a view similar to FIG. 21 illustrating the clutch control unit in a released position;

FIG. 24 is a view similar to FIG. 22 illustrating the parts in another relative position.

The apparatus disclosed in the drawings is adapted to be used in the performance of a test in a well bore and to force fluent materials under pressure into the well bore. As shown, the apparatus includes a lower packer A adapted to be anchored in packed-off condition in a well casing B, or other conduit string, against movement in both an upward and a downward direction. The upper end of the well packer is connected to an equalizer valve C which can be opened to provide communication between the interior of the valve and the surrounding annulus D, or closed to prevent such communication. The equalizer valve is attached to a tester valve E which can be placed selectively in an open or closed position and which may embody a pressure recorder F. The tester valve is connected to the lower end of an upper unloader valve G, which, in turn, is connected to the lower end of a tubular running-in string H, such as a string of drill pipe or tubing extending to the top of the well bore and by means of which the well

packer A, equalizer valve C, tester valve E and unloader valve G are controlled.

The tester valve E can have its passage blocked to restrict the flow of fluid through it, as during the performance of a formation test, or the passage may be fully opened so that an unrestricted flow path is provided that continues through the equalizer valve C and the lower packer A, as well as through the upper unloader valve G, to facilitate the pumping of fluent substances downwardly through the entire apparatus, or to permit the passage therethrough of other equipment, such as casing perforating devices (not shown), which may be withdrawn through the apparatus and the tubular string H to the top of the well bore.

The well packer A is of a type that can be anchored in packed-off condition in the well casing B against longitudinal movement in both an upward and downward direction therewithin, to withstand pressures imposed thereon within the well casing from above, as well as pressures imposed thereon from below. Specifically, the well packer is of the type disclosed in the patent to Martin B. Conrad, 2,802,534, and particularly FIGS. 11 and 12 thereof. As shown in FIGS. 18 to 24, inclusive, the well packer A includes an upper body 11 having a body sub 12 attached thereto, by means of which the packer is attached to a tubular connector 13 which is, in turn, threadedly secured to the inner mandrel 14 of the equalizer valve C. A lower expander 15 is secured to the lower end of the body 11 and may have a tail pipe 16 attached thereto which extends downwardly in the well casing B to any desired distance. This lower expander is adapted to coact with a set of lower slips 17, to anchor the packer in the well casing against upward movement therewithin. As shown, the lower slips 17 are of the rocker type, and include lower anchor portions 18 having upwardly facing external wickers or teeth 19 adapted to grip the wall of the well casing. The slips also include drag portions 20 adapted to frictionally engage the wall of the well casing B, being urged thereagainst by helical springs 21 engaging the drag portions 20 and a slip-retaining assembly 22. When the springs 21 urge the drag portions 20 outwardly into full engagement with the wall of the well casing, the anchor portions 18 are out of engagement with the well casing. When the lower expander 15 moves relatively behind the anchor portions 18 of the slips, the latter are rocked outwardly into anchoring engagement with the wall of the well casing B and are held thereagainst by the lower expander.

The slip supporting assembly 22 also carries a set of upper segmental slips 23 having lower drag portions 24 urged into frictional engagement with the wall of the well casing by helical springs 25 and upper anchor portions 26 having downwardly facing wickers or teeth 27 adapted to engage the wall of the well casing. The upper anchor portions 26 coact with an upper expander 28 slidable on the tubular body 11 of the tool. When this upper expander moves downwardly within the upper slips 23 it rocks the anchor portions 26 outwardly into gripping engagement with the wall of the well casing, the upper slips pivoting on the upper portions of the drag portions 24, as fully described in Patent No. 2,802,534.

The upper expander 28 is secured to the lower end of a thrust or booster sleeve 29 slidable on the body 11, and this thrust or booster sleeve has one or a plurality of packing elements 30, 31 therein made of rubber or rubber-like material. The lower packing sleeve 31 engages the upper expander 28 and an intervening spacing ring 32, which, in turn, engages the lower end of the upper packing sleeve or ring 30, the upper end of which engages an upper abutment 33 that is slidable on the booster sleeve 29. This booster sleeve has an upper, outwardly extending flange 33a adapted to engage the upper abutment 33, which is prevented from moving longitudinally of the body 11 by being secured to a sleeve-

5

like cage or skeleton structure 34 which is swivelly mounted on the body sub 12. Thus, the cage 34 has a lower shoulder 35 engaging the lower end of the sub 12 and is prevented from moving downwardly of the sub by a cap 36 engaging an upper sub shoulder 37, this cap being secured to the cage in any suitable manner, as by means of one or more screws 38.

The packing sleeves or structure 30, 31 normally occupies a retracted position and are expanded outwardly against the wall of the well casing when the upper abutment 33 moves toward the upper expander 28 (which actually constitutes a lower abutment), which will shorten the packing sleeves and effect their expansion into sealing engagement with the wall of the well casing B, as well as with the exterior of the booster sleeve 29. Leakage through the interior of the booster sleeve is prevented by a side seal ring 39 mounted in a groove 40 in the upper expander 28 and slidably sealing against the periphery of the packer body 11.

The upper and lower sets of slips 23, 17 may be locked in a neutral position, in which they are both out of anchoring engagement with the wall of the well casing, by a releasable clutch or control unit 41 adapted to releasably couple the slip mounting structure 22 to the body 11 of the tool. Release of the clutch or control unit will permit the body 11 of the tool and the expanders 15, 28 to move longitudinally with respect to the upper and lower sets of slips, so as to either anchor the lower slips 17 against the well casing or the upper slips 23 against the well casing.

The control unit 41 includes a clutch dog 42 which is movable radially in the clutch housing 43, that forms part of the slip assembly 22, this clutch dog being urged inwardly against the body 11 by a helical compression spring 44. The body has an arcuate groove 45 therein (FIGS. 20, 21 and 23) in which the dog 42 is received to couple the entire slip assembly 22 to the body 11 of the tool, which will prevent the upper or the lower expanders 28, 15 from expanding the slips into engagement with the well casing. The dog 42 is shifted out of the groove 45 upon rotation of the body 11 of the tool with respect thereto, which will bring a bridge or cam portion 46 of the body opposite the dog 42 and shift it radially outwardly, whereupon the dog will slide along the smooth periphery of the body, which can then move longitudinally in both directions with respect to the surrounding slip assembly 22. The dog 42 is positively located, so as to be able to move into the arcuate clutch groove 45 in the body 11, or is held in a position in which it engages the smooth periphery of the body, by a locating device in the form of a key 47 mounted in a recess 48 in the clutch housing structure and slidable in a longitudinal keyway 49 in the body. Turning of the body 11 in one direction will engage the key 47 with a housing stop 50 at one end of the recess 48 (FIG. 22), which will locate the dog 42 in alignment with the clutch groove 45. Turning of the body in the opposite direction will bring the key 47 into engagement with another housing stop 51 at the other end of the recess 48 (FIG. 24), resulting in the bridge piece 46 shifting under the dog 42 to cam and hold it out of the groove 45.

By turning the body 11 so that the bridge piece 46 is opposite the dog 42, the clutch 41 is released, whereupon the body 11 of the tool is lowered, carrying the cage 34, packing device 29 to 33, and upper expander 28 downwardly with it. The drag portions 20, 24 resist downward movement of the slip assembly 22 and the slips 23, 17 themselves. Accordingly, the upper expander is moved downwardly behind the upper slips 23, engaging their anchor portions 26 and expanding them into anchoring engagement with the well casing B. Further downward movement of the upper expander 28 cannot occur, since it is wedged within the slips 23. As a result, continued downward movement of the body 11 and cage 34 will shift the upper abutment 33 toward the low-

6

er abutment or expander 28, expanding the packing sleeves 30, 31 against the well casing B. The well packer is now anchored in packed-off condition in the well casing against downward movement therewithin (FIG. 19).

The well packer A can also be anchored in packed-off condition in the well casing B against upward movement therewithin. After the packer has been anchored in packed-off condition against downward movement in the well casing, such as disclosed in FIG. 19, fluid under pressure can be imparted through the body 11 of the tool and will act on its lower portion, whereupon the body of the tool can be moved upwardly, the fluid pressure carrying the upper expander 28 upwardly away from the upper slips 23, but the packing structure 30, 31 remains sealed against the well casing. This packing structure slides along the well casing until the lower expander 15 moves upwardly behind the lower slips 17, expanding them outwardly into engagement with the well casing B and holding them anchored thereagainst. Pressure can now be imposed through the well packer A, which will be anchored in packed-off condition against upward movement therewithin, since the pressure around the body below the well packer A will urge the upper expander 28 toward the upper abutment 33 to hold the packing structure 30, 31 in sealing engagement against the wall of the well casing.

When the well packer A is released from the well casing, the pressure differential, either in the annulus D above the packing structure 30, 31, or the annulus below the packing structure, is relieved, and the body 11 of the tool rotated so as to locate its arcuate or circumferential groove 45 in alignment with the clutch dog 42. The body 11 of the tool is then either raised or lowered, as the case may be, to the position in which the dog moves radially into the groove 45, in which position both upper and lower slips 23, 17 are out of wedging engagement with their respective expanders 28, 15 and have been rocked by the springs 25, 21 to bring their anchor portions 26, 18 out of contact with the well casing, the slips then occupying the position illustrated in FIG. 18. The body 11 is then coupled to the entire slip structure 22 and cannot be moved relative thereto for the purpose of expanding the upper or lower slips against the well casing. The entire well packer A can now be moved in either an upward or a downward direction within the well casing B, the packing structure 30, 21 having been returned to its retracted position.

As stated above, the well packer A is connected to an equalizer valve C thereabove, which has the purpose of relieving the pressure differential in the annulus D above the well packer when the latter is to be released, and which is closed when a formation test is to be performed or fluid under pressure forced through the apparatus. The tubular connector member 13 secured to the upper body 11 of the packer is attached to the inner mandrel 14 of the equalizer valve, which is telescoped within an outer valve housing 55 which includes a lower housing member 56 threadedly secured to an upper housing member 57. This upper housing member has a suitable seal sleeve and seat 58 held therein by a threaded nut 59 adapted to coact with a tubular valve head 60, threadedly attached to the upper end of the inner mandrel 14, for the purpose of closing side equalizer or circulating ports 61 in the valve housing 55 below the seal sleeve 58. When the valve housing 55 is moved downwardly relative to the mandrel 14, the seal sleeve 58 is disposed over and in sealing engagement with the periphery of the tubular valve head 60, as shown in FIG. 16, in which the ports 61 are closed. On the other hand, upward movement of the housing 55 relative to the inner mandrel 14 will dispose the seal sleeve and seat 58 substantially above the tubular valve head 60, whereupon the circulating ports 61 are opened, as disclosed in FIGS. 14 and 15.

The equalizer valve C is releasably held in its opened or closed conditions and may be releasably locked in its

closed condition so as to preclude its being forced to the opened condition in the event that fluid under pressure is being pumped through the apparatus. A latch device is provided between the housing 55 and the mandrel 14. As disclosed, the latch device includes a latch sleeve 65 threadedly attached to the lower end of the housing member 56 and having longitudinal slots 66 therein to provide spring-like legs 67 terminating in feet 68 that are adapted to extend inwardly into a circumferential groove 69 in the periphery of the mandrel 14. The lower side 70 of the groove is tapered so as to coact with the companion upwardly and inwardly tapered surfaces 71 on the feet, in order to cam the latter out of the groove 69. As shown most clearly in FIG. 15, the latch feet 68 are in the circumferential groove 69, which releasably latches the valve C in opened condition. However, when a sufficient downward force is imposed on the housing 55 and the latch sleeve 65, the lower ends 71 of the feet 68 engage the lower tapered side 70 of the groove, which cams the feet out of the groove, whereupon the housing 55 can telescope downwardly over the mandrel 14 until the sleeve valve seal 58 is disposed fully over the tubular valve head 60, as determined by engagement of the nut 59 with a companion shoulder 73 on the valve head. At this time, the feet 68 are disposed below a downwardly facing shoulder 74 on the mandrel 14, the feet having sprung inwardly and being adapted to engage this shoulder to releasably retain the valve in the closed position, such as disclosed in FIG. 16. Upon exertion of sufficient upward force on the housing 55, the lower shoulder 74 will cam or force the legs 67 in an outward direction, allowing the housing to move upwardly relative to the mandrel 14 to again open the valve, the feet 68 then springing into the upper groove 69 and releasably holding the valve in the opened position.

The valve C can be locked in its closed position and cannot be opened regardless of the amount of upward force imposed on the outer housing 55. To accomplish this purpose, the exterior of the mandrel 14 is provided with a longitudinally extending control slot or groove 75 which merges into a diagonal portion 76 which, in turn, opens into a longitudinal locking slot portion 77 that has an upper end 78. The housing has a pin 79 secured thereto extending into the control slot device 75, 76, 77, this pin being movable by the housing 55 in longitudinal slot portion 75 and engaging the lower tapered side 80 thereof, which will steer or move it into the locking slot portion 77. When disposed in the upper longitudinal slot portion 75, the pin does not interfere with the telescopic movement of the housing 55 relative to the mandrel 14, so that the valve parts can be moved between their opened and closed conditions. However, after the housing 55 has been moved downwardly of the mandrel 14 to close the valve, the pin 79 will be disposed in the locking slot portion 77. Accordingly, any tendency to open the valve, as by moving the housing 55 upwardly, will be prevented by the pin 79 shifting into the upper end 78 of the locking slot portion. It is only upon turning of the housing 55, so as to move pin 79 into alignment with the upper longitudinal slot or groove 75, that a sufficient upward force can be taken on the housing to release the latch dogs 68 from the lower shoulder 74 and shift the housing 55 upwardly of the mandrel 14 back to the valve opening position.

The upper housing member 57 of the equalizer valve is threadedly attached to a tubular connector member 82 which is, in turn, threadedly attached to the lower housing section 83 of the external member or housing 84 of the tester valve E, which is adapted to control the upward flow of fluid from the region below the well packer through the upper unloader valve G and into the tubular string H. The lower section of the valve housing is threadedly attached to an intermediate housing section 85 which is, in turn, threadedly attached to an upper housing section 86 threadedly secured to an upper housing

head 87. A tubular control mandrel member 88 is telescopically disposed within the housing member, leakage of fluid therebetween being prevented by a suitable side seal 89 mounted in the upper housing head 87 and adapted to slidably and sealingly engage the periphery of the mandrel member 88. This mandrel member extends downwardly within the housing and has a lower mandrel section 90 adapted to be releasably clutched or coupled to the housing 84, in order that the turning effort of the mandrel 88 can be transmitted to the housing.

As shown, a clutch member 91 is slidable axially on the lower mandrel section 90, the latter having a longitudinally extending clutch key 92 secured thereto and received within a keyway 93 in the clutch member. The key 92 is prevented from dropping out of the lower mandrel section 90 by a cap screw 94 threaded into the latter and extending across the bottom end of the key. The lower mandrel section has an outwardly directed flange 95 providing a spring seat for a compression spring 96 which engages the clutch member 91 and tends to hold the axial teeth 97 on the latter in engagement with companion axial teeth 98 provided on the lower end of the upper housing section 86. The leading faces 99 of the clutch member teeth and the companion trailing faces 100 of the housing teeth are tapered, as disclosed most clearly in FIG. 11, such that right-hand rotation can be transmitted from the mandrel 88 through the clutch to the housing 84, the spring 96 preventing the clutch teeth 97, 98 from being disengaged from each other by the camming action of the sloping tooth faces 99, 100 upon one another. Such clutch release will occur in the event that sufficient torque is transmitted between the mandrel 88 and housing 84, as to overcome the holding force of the spring 96.

The control mandrel member 88 is movable downwardly within the housing for the purpose of disengaging the clutch member teeth 97 from the housing teeth 98, and also for the purpose of opening the tester valve (as described hereinafter). However, the extent of downward movement of the control member 88 is at first limited by engagement of a stop shoulder 102 on this member with the inwardly extending heel portions 103 of latch elements or legs 104 depending from a latch sleeve 105 disposed in the annular space 106 between the mandrel 88 and the housing section 86. This latch sleeve includes upwardly extending arms 107 terminating in externally threaded latch heads 108 which are engageable with companion internal threads 109 on the upper housing head 87. The upper surfaces 110a of the external latch head threads are tapered in a downward and outward direction so as to permit the heads to ratchet in an upward direction along the companion internal threads 109 in the housing head. However, the threaded heads 108 can only move downwardly along the housing thread 109 upon being rotated in a right-hand direction by the control mandrel member 88. Such rotation is transmitted from the control mandrel member through a plurality of longitudinal keys 110 secured to the mandrel member 88 by upper and lower retaining rings 111 encompassing the upper and lower ends of the keys 110, as well as the control mandrel member 88 itself. The upper retainer ring 111 and the keys 110 are prevented from moving upwardly by an inherently retractable split holding ring 112 disposed above the keys and retaining ring and engageable with a downwardly facing shoulder 112a on the control mandrel member 88.

The latch legs 104 and the heels 103 of the latch feet 113 at the lower terminals of the latch legs are held in an inward position by engagement of the latch feet 103 with the inner surface of a holding sleeve 114 disposed within the housing 86 and which is connected to the upper housing head 87 by a two-piece coupling ring 115. This holding sleeve terminates in a beveled end 116 located a predetermined distance below the upper ends of the latch feet 113 when the heads 108 are in their uppermost position in the threads 109 (FIG. 6). Such predetermined

distance is preferably less than the length of the companion threads 109 in the upper housing head. When the sleeve 105 is in its uppermost position, the control mandrel 88 can only move downwardly to the extent at which its stop shoulder 102 engages the upper ends or heels 103 of the latch feet 113. However, upon turning the control mandrel 88 to the right through suitable rotation of the tubular string H, the teeth 97 of the clutch member are cammed by the faces 99, 100 out of engagement with the teeth 98, the teeth ratcheting over each other and, in effect, disengaging the clutch. The control mandrel 88 can be turned to the right, which motion will be transmitted through the keys 110 to the latch arms 107 and heads 108, causing the latter to thread downwardly along the internal threads 109 in the housing head and shift the latch feet 113 down along the holding sleeve 114 until they are disposed below the lower beveled end 116 of the latter, which will then permit the latch legs 104 to spring inherently in an outward direction, so that the heels 103 are no longer disposed inwardly of the stop shoulder 102. When this occurs, the restraint against downward movement of the control mandrel member 88 within the housing 84 is removed, and the former can then be moved downwardly in a straight line without any rotation being required, its keys 110 merely sliding through the slots between the latch arms 107 and latch heads 108. Such downward movement to a maximum extent is limited by engagement of the mandrel flange 95 with the upper end of a valve seat member 118 threadedly attached to the lower housing section 83.

The control mandrel member 88 can be elevated within the housing 84 by merely taking a straight line upward pull thereon, the elevation continuing until the lower retaining ring 111 engages the transverse surface 119 on the latch sleeve 105, then shifting the latter upwardly within the housing 84, the external threads 110a ratcheting upwardly freely along the internal threads 109, until the control mandrel member 88 has been shifted to its uppermost position. The upward movement of the latch sleeve 105 will cause the latch feet 113 to engage the lower beveled end 116 of the holding sleeve 114, which will shift the latch feed 113 inwardly once again to a position below the stop shoulder 102 on the mandrel 88, and thereby limit the extent of downward movement of the mandrel within the housing because of the interference to such movement by the heels 103.

The tubular control mandrel member 88 is moved downwardly and upwardly within the housing 84 for the purpose of opening and closing the passage 120 through the valve seat 118, which is elongate, and which has an internal cylindrical seating surface 121 which actually is the wall of the central passage therethrough. Longitudinal by-pass passages 122 are provided around the valve seat 118 between it and the lower housing member 83, such by-pass passages extending through the upper portion of the valve seat and opening through its upper end. The passage 120 through the valve seat is adapted to be closed by a valve head 123, having a closed lower end 124 and which has a central passage 125 opening through its upper end, there also being a plurality of side ports 126 through the valve head establishing communication between its interior and exterior.

The valve head 123 has a lower side seal 127 below the ports 126 held thereon by a nut 128 threaded on the valve head 123, and also an upper side seal 129 above the ports 126 which is held thereon by the lower end of a connector tube 130 threaded on the upper end of the valve head. The upper and lower seals 129, 127 slidably seal against the wall or cylindrical seat 121 of the valve seat 118, and when they are both disposed within the latter fluid is incapable of flowing from the housing 84 into and through the ports 126 to the interior of the valve head 123 and thence upwardly through the connector tube 130. However, when the lower seal 127 is disposed below the lower end 131 of the valve seat 118 then the ports

126 are open and fluid can pass from the interior of the housing 84, through the ports 126 into the valve head 123 and upwardly through the connector tube 130.

The upper end of the connector tube 130 is threadedly secured to the lower end of a retrievable body or mandrel 132 that may be releasably contained within the control mandrel member 88. The retrievable mandrel or body 132 includes a lower body member 133 attached to the connector tube 130, which, in turn, is threadedly attached to an intermediate body or mandrel member 134, which is, in turn, threadedly secured to a tubular upper body or mandrel member 135. The lower end of the intermediate mandrel member 134 may have an orifice 136 threadedly secured therein, in order to restrict the rate at which fluid can flow upwardly through the valve head ports 126 when the latter are opened, through the connecting tube 130 and lower mandrel member 133 into the intermediate body member 134 and upper body member 135, into the control mandrel member 88 thereabove for continued upward passage through the upper unloader valve G into the tubing string H that extends to the top of the hole.

The retrievable mandrel structure 132 is releasably secured to the control mandrel member 88 by circumferentially spaced locating and holding dogs, latches or keys 140 which are carried by a latch sleeve 141 surrounding the mandrel 132, and which is movable to some extent longitudinally thereof. The upper end of the latch sleeve has a nut or head 142 secured thereto and which extends inwardly thereof, this head being engageable by an outwardly directed flange 143 on the lower end of a retrieving sleeve 144 slidably mounted on the upper tubular mandrel section 135, this latter section having an upper head 145 suitably attached thereto. Each latch or key 140 is elongate in form and has a lower holding dog 146 adapted to be disposed below and engage a downwardly facing shoulder 147 on the control mandrel member 88, which shoulder is inclined in an inward and upward direction. The lower mandrel member 133 has an expander 148 formed on its upper portion which tapers in an upward and inward direction for engagement with companion tapered surfaces 149 on the dogs 146, in order to urge and hold the dogs outwardly and under the control mandrel shoulder 147, and thereby prevent upward movement of the retrievable mandrel within the control member.

Downward movement of each elongate latch or key 140 is prevented by its upper portion 150 adapted to fit within an internal locking groove 151 in the control member 88, and when fitting in this groove to have its downwardly facing transverse shoulder or surface 152 engageable with a companion upwardly facing shoulder or surface 153 defining the lower end of the groove 151 and which preferably extends normal to the axis of the control mandrel member 88. When the locking portions 150 are disposed in the groove 151 they will prevent any substantial further downward movement of the retrievable mandrel 132 within the control mandrel member 88, since an upper expander 154 on the upper mandrel section 135, which has an external surface 155 tapering in a downward and inward direction, will engage companion surfaces 156 at the upper, inner corners of the locking elements and hold the latter outwardly in the locking groove 151.

The latch or key members 140 also have intermediate locating portions 160 which are adapted to fit within a companion elongate locating groove 161 in the control member 88 between the upper groove 151 and the downwardly facing retainer shoulder 147. It is only when each intermediate portion 160 is disposed opposite the locating groove 161 that the latches or keys can extend outwardly into the grooves since the intermediate groove 161 is substantially longer than any other groove in the tubular string H and in the apparatus thereabove that will be capable of receiving the intermediate portions of the keys. When the keys 140 reach such position, they will be urged outwardly by helical compression springs

162 which engage spring seats 163 extending across the latch sleeve 141 and also the intermediate locating portions 160 of the latches or keys.

It will be noted that the upper downwardly holding portions 150 of the keys extend through upper openings or windows 165 in the sleeve 141; whereas the intermediate portions 160 will extend through lower slots 166 in the sleeve opening through its lower end. Outward movement of the dogs 146 and the intermediate portions 160 of the keys is limited by their engagement with a retainer ring 167 which encompasses the latch sleeve 141 and which fits within grooves 168 formed between the intermediate portions 160 of the keys and the dogs 146 therebelow.

The lower outer ends 169 of the dogs 146 are tapered in a downward and inward direction so as to shift the dogs inwardly past grooves in the tubular string H, the upper unloader valve G and in the control mandrel member 88. Similar tapered surfaces are not required on the intermediate portions 160 of the keys 140 since they are too long in extent to be able to shift into any groove above the elongate grooves 161 in the control member 88, which are designed to receive them. The lower side 170 of the locating groove 161 is tapered in a downward and inward direction so as to cam the dogs 146 inwardly, enabling them to move downwardly past the intermediate groove 161, whereas the upper side 171 of the intermediate groove is tapered in an upward and inward direction so as to cam the intermediate portions 160 of the keys, as well as the dogs 146 inwardly as they ride past the upper end of the groove 161. Similarly, the upper end 172 of the upper locking groove 151 is tapered in an upward and inward direction for engagement with different portions of the keys 140, in order to cam the latter inwardly when the apparatus is to be retrieved from the control mandrel member 88, and through the upper unloader valve G and tubular string H to the top of the well bore.

The retrievable mandrel apparatus 132, including its latches or keys 140, is secured to the connector tube 130 which is attached to the valve head 123. The lower end of the latter may carry the pressure recorder F, of any known and suitable construction, through the agency of a shock absorber 175 (FIG. 6a). This shock absorber includes a top adapter 176 threadedly secured to the lower end of the valve head 124 and has the upper end of a spring housing 177 attached thereto. Telescopically disposed within the housing 177 is a mandrel 178 having an upper head 179 thereon on which the lower end of the helical upper compression spring 180 rests, the upper end of the spring engaging the lower end of the adapter 176. Surrounding the mandrel 178 is a lower helical compression spring 181, the upper end of which engages the mandrel head 179 and the lower end of which engages an inwardly directed flange 182 of the spring housing 177, which serves as a spring seat. Thus, the mandrel 178 is mounted for yieldable movement within the upper housing 177 and is adapted to move therewith.

The lower end of the mandrel 178 is threadedly attached to a bottom adapter 183 which, in turn, is threadedly attached to a support 184 for the pressure recorder F, which will extend downwardly through the tubular connector member 82. The shock absorber mechanism 175 and the pressure recorder F are adapted to move through the valve seat 118, as well as through the control mandrel member 88, unloader valve G and the tubular string H.

The retrievable mandrel device 132 with the valve head 123 connected thereto, and if desired the pressure recorder F suspended from the lower end of the valve head, may be lowered through the tubular string H, passing through the upper unloader valve G and into the control or mandrel member 88, which is then in its upper position within the tester valve housing 84. When the intermediate portions 160 of the latches or keys 140 come

opposite the intermediate groove 161 in the control mandrel member 88, the keys will be urged by the springs 162 outwardly into the groove 161, with the upper portions 150 of the keys in the upper groove 151, and the lower dogs 146 below the downwardly facing holding shoulder 147. The retrievable mandrel 132 can only move downwardly to the extent limited by engagement of the upper expander 154 with the upper ends 156 of the keys or latches. When in this position a side seal 186 on the lower mandrel member 133 will sealingly engage the control mandrel member 88 to prevent fluid from passing between the control and retrievable mandrels 88, 132. The latching of the tubular mandrel 132 in place will dispose both of the valve head seals 127, 129 within the valve seat 118, so that the ports 126 are closed, preventing fluid from passing into the valve head 123 and thence upwardly through the connector tube 130, lower mandrel member 133, orifice 136, intermediate mandrel member 134 and upper mandrel member 135, and through the upper unloader valve G and tubular string H.

The valve is opened by rotating the control mandrel member 88 in a right-hand direction within the tester housing 84. As stated above, the rotating action will disengage the clutch member 91 from the housing by the ratcheting of the teeth 97, 98 over each other, the right-hand rotation of the control mandrel member 88 being transmitted through the keys 110 to the latch sleeve 105, causing the latter to thread downwardly in the housing 84 until its feet 113 are below the lower end 116 of the holding sleeve 114, the latch feet then spring outwardly into the enlarged housing space below the control sleeve 114, which will then permit the control mandrel member 88 to move downwardly and thereby shift the lower valve seal 127 below the cylindrical valve seat 118, the extent of downward movement being limited by engagement of the lower end 95 of the control mandrel member with the upper end of the valve seat 118. Fluid will now flow through the ports 126 and through the entire tester valve E into the upper unloader valve G and the tubing string H. When it is desired to close the tester valve it is merely necessary to move the control mandrel member 88 upwardly, the threaded heads 108 on the latch sleeve 105 merely ratcheting freely upwardly along the internal threads 109 in the housing head 87, the lower seal 127 again moving within the valve seat 118, the parts thus being returned to the positions illustrated in FIGS. 6 and 6a.

The valve E can be opened and closed as many times as desired merely by rotating the control mandrel member 88 within the housing member to release the latch feet 113 and its heels 103 from the mandrel member, whereupon the valve is shifted to the open position by straight line downward movement of the control member, re-closing of the valve being effected merely by taking a straight line upward pull on the control mandrel member 88 to shift it upwardly within the tester valve housing 84, carrying the entire retrievable mandrel 132 and valve head 123 attached to the latter upwardly with it.

The upper end of the control mandrel member 88 is secured to a connector tube 188 which is, in turn, attached to the inner mandrel portion 189 of the upper unloader valve G. This mandrel portion or member includes a lower mandrel section 190 threadedly attached to an upper mandrel section 191, the upper end of which is threadedly secured to a mandrel head 192 that defines a groove 193 with the upper section 191 in which a suitable side seal 194 is disposed adapted to sealingly engage a cylindrical seat 195 provided on an upper sub 196 of a valve housing 197 surrounding the mandrel 189, and which is telescopically related thereto. This upper sub 196 is threadedly secured to the upper end of an upper housing section 198, the lower end of which is threadedly secured to a housing coupling 199 threadedly attached to the upper portion of a housing cylinder 200, the lower end of which is threadedly attached to a lower

cylinder head 201. The housing coupling 199 is slidable along the mandrel section 190, leakage of fluid therebetween being prevented by a side seal 202 on the housing coupling slidably and sealingly engaging the periphery of the mandrel. Similarly, leakage of fluid between the lower cylinder head 201 and the mandrel 189 is prevented by an inner side seal 203 on the head slidably and sealingly engaging the periphery of the mandrel. Leakage of fluid through the threaded connection between the cylinder head 201 and the housing cylinder 200 is prevented by an external side seal ring 204 on the cylinder head engaging the wall of the cylinder.

An annular orifice or valve member 205 is mounted on the mandrel 189 and within the cylinder 200, this orifice or valve member having a side seal ring 206 on its outer portion slidably and sealingly engaging the inner wall of the cylinder. This orifice member engages an outwardly directed stop flange 207 on the mandrel 189, leakage of fluid between the orifice valve member and the stop flange being prevented by a suitable seal ring 208 on the valve member engaging the flange. The annular space 209 between the mandrel 189 and cylinder 200, and the lower cylinder head 201 and the orifice valve member 205 is filled with a liquid L, such as oil, through a longitudinal filling passage 210 in the head 201, the lower end of which is closed by a plug 211 threaded in the head and having inner and outer seal rings 212 engaging the wall of the passage to prevent leakage of fluid from the latter. The liquid preferably fully fills the annular space 209 and is adapted to be forced by the lower cylinder head 201, when the outer housing 197 is moved upwardly relative to the inner mandrel 189, through a relatively small orifice opening 213 in an orifice plug 214 threaded in the valve member 205, through an enlarged passage 215 in the latter, and into the annular space 216 within the cylinder 200 above the valve member 205. The liquid will fill the orifice plug 214, passage 215 and space 216, as well as the space 209 below the valve member 205. The fluid is prevented from moving out of the upper end of the cylinder by a floating annular piston 217 on the mandrel 189 adjacent to the housing coupling 199, which has an inner side seal ring 218 slidably and sealingly engaging the periphery of the mandrel 189 above the flange 207, and an outer seal ring 219 slidably and sealingly engaging the cylinder wall. Above the floating piston 217, the upper end of the cylinder 200 has a side port or bleeder hole 220 which will permit the hydrostatic head of fluid to act upon the piston 217, so that the external pressure acts through the piston 217 on the liquid in the cylinder 200.

The unloader valve G is disposed in the closed position illustrated in FIGS. 5 and 5a and tends to be held in such position by a helical compression spring 221 within the cylinder 200 and engaging the cylinder head 201 and the orifice valve member 205. When the housing 197 is moved upwardly along the mandrel member 189, the cylindrical seat 195 is elevated above the seal ring 194, to open side ports 222 in the housing and permit fluid to pass between the interior and the exterior of the unloader valve. Such extended movement of the housing 197 upwardly along the mandrel 189 can only occur upon exertion of sufficient force to overcome the force of the spring 221, and also requires substantial time as a result of the necessity for forcing the liquid in the cylinder 200 through the relatively small orifice 213 to the other side of the valve member 205. When sufficient force is exerted, about 20 seconds to two minutes might be required to displace all of the liquid or oil L in the cylinder 200 on the lower side of the orifice 213 through the latter into its upper side, before the valve can be shifted to its fully open position, such as illustrated in FIGS. 12 and 12a. Thus, substantial tensile force can be imposed on the tubular string H and the unloader valve G to which it is connected without opening such valve, provided that such force is not maintained for any extended period. As an example,

if the force is only exerted for about 3 to 5 seconds, insufficient time will elapse for enough liquid L to be displaced through the orifice 113 to effect a disengagement between the cylindrical valve seat 195 and the seal ring 194 and opening of the housing ports 222.

Torque can also be transmitted from the housing 197 to the mandrel 189 for all relative telescopic positions of these members. Thus, the housing has a key 223 secured to its coupling 199 and extending inwardly into a longitudinal keyway 224 in the mandrel 189. It is evident that regardless of the opened or closed position of the valve G there is a torque transmitting connection always available for transmitting the turning effort imparted by the tubular string H to the housing 197 to the mandrel member 189 for transmission to the apparatus therebelow.

A pressure balancing device is also incorporated in the upper unloader valve G so that pressure within the valve will not tend to inadvertently shift it to an opened condition, and also to counteract a portion of the external pressure that might tend to shift the valve to an opened condition. As shown, a balance sleeve 226 is disposed between the mandrel 189 and housing 197, the upper end 227 of this balance sleeve being adapted to engage the upper housing sub 196 and the lower end 228 of the sleeve being adapted to engage the upper end of the housing coupling 199. The inner surface 229 of this sleeve is slidable along an outwardly directed flange or piston portion 230 on the upper mandrel member 191, leakage of fluid between these parts being prevented by a suitable seal ring 231 mounted on the piston portion and sealingly engaging the inner surface 229 of the sleeve. Similarly, leakage of fluid between the exterior surface 232 of the sleeve and the upper housing section 198 is prevented by an internal seal ring 233 mounted in an inwardly directed flange 234 on the housing member and sealingly engaging the external surface or periphery 232 of the balance sleeve 226. The sleeve may occupy an upper position, such as disclosed in FIG. 5, across the ports 222 when the valve G is closed, but has a lower inwardly directed flange 235 adapted to be engaged by the outer flange 230 on the upper mandrel section 191 to move the sleeve 226 downwardly clear of the ports 222 and against the upper end of the housing coupling 199 when the valve is shifted to its opened position.

The lower surface of the sleeve 226 is subject to the fluid pressure within the valve G, such fluid pressure passing through a side port 236 in the lower mandrel section 190 below the mandrel piston 230. When a pressure differential exists internally of the unloader valve, such pressure can pass through the port 236 and act upwardly on the balance sleeve 226 to urge it to its upper position against the lower end of the housing sub 196. As disclosed in FIG. 5, the valve is in closed position. Fluid pressure internally of the valve will act on the housing 197 over the internal area R between the cylindrical seat 195 and the inner surface 237 of the sub, such fluid under pressure also acting in an upward direction over the cross-sectional area of the balance sleeve 226 and the inwardly housing flange 234, designated as the area S in FIG. 5. Internal fluid pressure is acting in a downward direction on the outer housing 197 over the annular area T between the inner surface 240 of the upper housing section 198 and the surface 241 of the mandrel 189 against which the housing coupling seal ring 202 seals. If the areas R plus S are made substantially equal to the area T, then the internal pressure will have no effect in attempting to shift the valve to an opened position. By making the area T a little greater than the sum of the areas R and S, the internal pressure can be availed of to hold the valve G in its closed position.

It will be noted that the unloader valve G has a passage straight through its mandrel 189 and that it is shifted to its opened position by taking an upward pull on the tubular string H and the valve housing 197 of a sufficient duration to displace the liquid L in the cylinder 200

15

through the orifice 213 to the upper side of the orifice valve member 205 and the mandrel stop flange 207. Reclosing of the valve will occur upon imposing a sufficient downward force on the housing 197 to displace the liquid L from the upper side of the orifice valve member 205 through the orifice 213 and around the seal 208 and through the clearance space between the member 205 and mandrel 189, into the annular cylinder space 209 below the orifice valve member. Such downward force on the liquid is imposed by the housing from its coupling member 199 through the annular balance piston 217.

The apparatus is initially run in the well casing B with the well packer slips 17, 23 in their neutral position and the packing 30, 31 retracted. The equalizer valve C is held in its open condition by the latch feet 68 being disposed within the latch groove 69 of the inner mandrel 14. Because of the fact that the apparatus is being initially run in the well casing, the retrievable mandrel 132 is already latched in place within the control mandrel member 88, the threaded heads 108 being disposed in their uppermost threaded position within the housing 84 and the latch feet 113 located within the holding sleeve 114 so as to cause the stop shoulder 102 of the control member 88 to engage the latch heels 103 and prevent the lower tester seal 127 from being shifted out of the valve seat 118, thereby insuring that the tester valve E is in the closed position. The pressure recorder F may also be connected to the tester valve head 123, extending therebelow. In addition, the upper unloader valve G may be in a closed position, such as illustrated in FIGS. 5 and 5a.

When the location in the well casing B is reached at which the well packer A is to be set, the tubing string H is rotated, the rotation being transmitted through the upper unloader valve housing 197, through the key 223 to its mandrel member 189, and from the latter through the control mandrel 88 of the tester valve E. From the latter, the turning effort is transferred through the clutch member 91 to the housing 84, continuing on through the connector tube 82 to the equalizer valve housing 55, the turning effort being transmitted from the lock pin 79 of the latter to the mandrel 14, and from the mandrel through the tubular connector 13 to the body 11 of the well packer A. The turning effort continues until the locator key 47 is shifted into engagement with the stop 51 at the other end of the clutch housing 43, which will insure that the bridge piece 46 has cammed the clutch dog 42 out of the clutch groove 45 in the body 11. The tubular string H can now be moved downwardly, such downward movement being transmitted through the upper unloader valve G and the tester valve E to the outer housing member 55 of the equalizer valve C. Since the drag portions 20, 24 of the packer resist downward movement of the mandrel 14, the latch feet 68 may be cammed out of the lock groove 69, so that the housing 55 telescopes over the mandrel 14 and disposes the housing seal 58 over the tubular valve head 60, to close the equalizer valve ports 61. Continued downward movement will be transmitted through the tubular connector 13 and body 11 of the tool A to the cage 34 and the packing structure 30, 33, shifting the upper expander 28 downwardly within the upper slips 23, expanding the anchoring portions 26 of the latter outwardly into engagement with the well casing B. Continued downward motion will then move the upper abutment 33 toward the upper expander 28 and shorten the packing rings 30, 31, expanding them outwardly into sealing engagement with the wall of the well casing. The well packer A is now anchored against downward movement in the well casing B and will relieve the formation to be tested of the hydrostatic head of fluid in the well casing.

The tester valve can now be opened by turning the tubular string H to the right, the turning effort being transmitted through the unloader valve housing 197 and its key 223 to its mandrel section 189, which is connected to the control mandrel member 88. The taking of several revolutions, such as three or four complete revolutions,

16

will result in the threading of the latch sleeve 105 downwardly of the housing 84 to dispose the latch feet 113 below the holding sleeve 114, enabling them to spring outwardly and their heels 103 to shift out of the path of the stop shoulder 102. When the latch feet 113 have been disposed below the holding sleeve 114, the tubular string H, upper unloader valve G and the control mandrel 88, together with the retrievable mandrel 132 and the valve head 123 connected thereto, can then move downwardly, to the extent limited by engagement of the lower end 95 of the control mandrel with the upper end of the valve seat 118. At this time, the lower seal ring 127 of the valve head will be disposed below the valve seat 118, opening the head ports 126 and permitting any formation fluid that might be under sufficient pressure to flow into the casing B and up through the well packer A and the closed equalizer valve C into the housing 84 and then inwardly through the valve head ports 126 to its interior, and through connector tube 130 and the retrievable mandrel 132 for discharge into the control member 88 and for continued upward flow through the upper unloader valve G into the tubing string H. The fluid under pressure will also flow around the pressure recorder F, if one is used, the desired pressure-time diagram being secured.

When the tester valve E is to be closed, it is merely necessary to take an upward pull on the tubular string H. The hydrostatic head of fluid will retain the well packer A anchored in packed-off condition against downward movement in the well casing B, and will resist upward movement of the parts connected to it. The equalizer valve C will also remain in its closed condition, since its latch feet 68 are then disposed below the lower shoulder 74 on the inner mandrel 14. The taking of an upward strain on the tubular string H will be transmitted through the unloader valve housing 197 through the liquid L to the mandrel member 189, and from the latter to the control or mandrel member 88 of the tester valve E, elevating the latter, together with the retrievable mandrel 132 latched therewithin and the valve head 123 to dispose the lower head seal 127 back in the valve seat 118. The movement of the control mandrel member 88 upwardly to a sufficient extent will dispose its shoulder 102 above the latch feet 113 and heels 103 of the latch sleeve 105, the lower retaining ring 111 engaging the latch sleeve 105 and moving it upwardly within the housing 84, its threaded heads 108 springing inwardly with their threads ratcheting past the housing threads 109, until the apparatus occupies the position illustrated in FIGS. 6 and 6a, the tester valve then being closed.

The control mandrel member 88 can be moved upwardly to re-close the valve in the matter of several seconds, there being insufficient time during which an upward strain is being imposed on the unloader valve G for sufficient fluid L to be displaced through the orifice 213 and thereby move the elongate cylindrical valve seat 195 from engagement with the mandrel seal ring 194. As a result, the ports 222 of the unloader valve will remain closed. However, if it is desired to open these ports, the upward strain will be maintained for a sufficient period until enough liquid L is displaced through the orifice 213 to move the valve seat 195 completely from engagement with the seal ring 194 and fully open the ports 222, the valve then being in the position illustrated in FIGS. 12 and 12a. When in this position, the tester valve E will still be closed, as well as the equalizer valve C therebelow. The well packer A will also remain anchored in packed-off condition in the well casing B. The formation test sample that has been secured during the time that the tester valve E was opened can now be recovered by circulating fluid down through the annulus D between the tubing string H and casing B, this circulating fluid passing through the unloader valve ports 222 to its interior and pumping the test sample upwardly through the tubing string H to the top of the well bore. During the recovery of the test sample, the circulating pressure is not being imposed upon

the formation, since the tester valve E is closed. Such closed condition also prevents the pressure recorder F from being subjected to the circulation pressure. Accordingly, the shut-in pressure data can be secured on the recorder F during the time that the formation sample is being recovered, thereby saving valuable rig time.

The apparatus can be removed from the well casing. An upward strain is taken on the tubing string H to open the equalizer valve C by pulling its housing 55 upwardly along the mandrel 14. Before this will occur, the spring force of the latch legs 67 will be overcome, the downwardly facing shoulder 74 camming the feet 68 in an outward direction. Also, the lock pin 79 will be placed in the upper longitudinal control slot 75, which will permit upward movement of the valve housing 55 along the mandrel to the port opening position.

Opening of the equalizer valve C will balance the pressure above and below the well packer A, permitting an upward pull to return the packing 30, 31 to its retracted position, elevating the upper expander 28 from the upper slips 23 and moving the body 11 back to the position in which the clutch dog 42 reenters the groove 45. As assurance that the slips 17, 23 are again in their neutral position relative to the upper and lower expanders 28, 15, a turning effort is imparted to the body 11 of the tool until the stop member 47 engages the other stop face 50 of the clutch housing 43, which will assure the alignment of the clutch dog 42 with the clutch groove 45 and its entry thereto. The entire apparatus can now be moved in the well casing to another location therewithin, or removed entirely from the well casing.

In the event that the formation test has indicated that another operation should be performed in the well bore, such as a squeeze cementing operation, the retrievable mandrel 132, and the parts 123, 175, F, attached thereto, can be released from the control mandrel member 88 and elevated through the upper unloader valve G and the tubing string H to the top of the well bore. A suitable retrieving tool 250 is disclosed in FIG. 4 which is adapted to be pumped down through the tubing string H for engagement with the head 145 of the upper retrievable mandrel member 135 and the control sleeve 144 that surrounds it. As shown, the retrieving tool includes a mandrel 251 having an upper swab cup 252 mounted thereon adapted to seal against the wall of the tubing H by pressure from above, and a lower swab cup 253 mounted thereon that is adapted to seal against the wall of the tubular string when pressure from below is imposed upon it. The lower portion of the mandrel is connected to a sucker rod coupling 254 which is, in turn, connected to a suitable length of sucker rod 255 that is attached by a coupling 256 to an adapter 257 threadedly secured to a retrieving mandrel 258. Surrounding the mandrel is a latch housing or sleeve 259 connected thereto by a shear pin 260. This shear pin is held in assembled position by an encompassing cap 261, there being a compression spring 262 bearing against the upper end of the cap and also upon the lower end of the adapter 257, the spring being enclosed by a depending adapter skirt 263.

The latch sleeve 259 carries a plurality of circumferentially spaced elongate latch elements 264 having upper fingers 265 extending through upper openings 266 in the latch sleeve and lower foot portions 267 extending inwardly and which are adapted to be disposed under the outwardly extending upper flange 268 of the control sleeve 144. The latch sleeve 259 has an inner holding surface 269 tapering in a downward and inward direction, adapted to coact with companion surfaces at the lower ends 267 of the latch elements 264 in order to hold them under the flange 268 of the control sleeve 144. The latch elements 264 are urged in a downward direction within the latch housing 259 by a spring 270 disposed in the housing and bearing against the upper end of a thrust ring 271 which, in turn, engages the upper ends of the latch elements,

the upper end of the spring bearing against the latch housing or sleeve 259.

The retrieving tool 250 is pumped down through the tubing string H until the lower end of the mandrel 251 engages the upper head 145 of the retrievable mandrel 135. When this occurs, the latch elements 264 will slip over the control sleeve flange 268 and be disposed therebelow. The retrieving mandrel 251 will shift the retrievable mandrel 132 downwardly, so that its expander 148 is shifted away from the latch dogs 146, whereupon the taking of an upward pull on the retrieving apparatus 250 will cause the latch sleeve 259 to move upwardly to urge and hold the latch feet 267 inwardly and under the control sleeve flange 268. The control sleeve will then move upwardly with the retrieving tool 251, its lower flange 143 engaging the nut 142 of the latch sleeve 141, this sleeve then contacting the keys 140 and elevating them along the control mandrel member 88, the various tapered surfaces on the latter camming the keys inwardly and releasing them from their companion grooves. The control sleeve 144 will engage the head 145 of the inner mandrel member 135 and will elevate the entire mandrel 132, the tester valve head 123 and the pressure recorder F, if one is used, with it, the entire apparatus passing upwardly through the control mandrel member 88 and the unloader valve G into the tubing string H thereabove.

When the retrieving mandrel 251 reaches the retrievable portion of the tester valve apparatus E, the lower swab cup 253 will be disposed in the tubing string above the unloader valve G. During the downward pumping of the retrieving tool 251 through the tubing string H, the unloader valve G will be in its open condition. Accordingly, upon the grasping of the retrievable mandrel sleeve 144 by the latch feet 267, it is only necessary to establish reverse circulation around the exterior of the tubing string H, the circulating fluid under pressure passing through the ports 222 and acting upwardly on the lower swab cup 253 to force the latter upwardly in the tubing string H, carrying the entire retrieving tool 250 and the retrievable mandrel 132, valve head 123 and pressure recorder F upwardly with it, until the top of the well bore is reached.

The well packer A can again be anchored in packed-off condition in the well casing B by suitable manipulation of the apparatus, as described above, the equalizer valve C closed, and its lock pin 79 placed in the upper locking slot portion 78 of the mandrel, so that the equalizer valve cannot be opened as a result of taking an upward pull on its housing 55, or under the influence of internal pressure in the equalizer valve. The upper unloader valve G is placed in its closed position by again telescoping its housing 197 downwardly over its mandrel 189. Fluid under pressure may then be pumped down through the tubular string H, the closed upper unloader valve G, and the tester valve E, which now has a fully open passage therethrough, the fluid under pressure passing down through the equalizer valve C and through the well packer A to a position therebelow. The upward pressure acting on the well packer A will shift its body 11 upwardly, the expander 28 following upwardly and retaining the packing sleeves 30, 31 packed-off against the wall of the well casing B. Upward movement of the body can continue until the lower expander 15 engages the lower slips 17 and expands them outwardly into anchoring engagement with the wall of the well casing. The necessary squeeze cementing, hydraulic fracturing, or other pressuring operation, can now be performed.

Following completion of the pressuring operation, it may be desired to perform another formation test with the apparatus still remaining in the well bore. Accordingly, the retrievable mandrel portion 132 of the tester valve is secured to a running-in tool 280 (FIG. 3), which may consist of the same swab cup and sucker rod arrangement 251-256 as used in the retrieving tool. However, the lower rod coupling 256 is secured to a different adapter 281 which is releasably attached to the head 145

of the upper mandrel or body member 135 by means of a shear screw 282. The upper unloader valve G may be opened and the running-in tool 280 with the retrievable mandrel 132, valve head 123 and pressure recorder F depending therefrom all pumped down through the tubing string H, until the valve head 123 enters the valve seat 118 and the latches 140 are disposed in their mating grooves 151, 161 in the control member 88. When this occurs, reverse circulation can be instituted, the fluid under pressure passing down through the annulus D between the tubing H and the casing B and then through the open unloader valve ports 222, acting upwardly on the lower swab cup 253 to shift the adapter 281 upwardly. Such upward movement will move the expander 148 behind the dogs 146 which are then engaged with the shoulder 147 on the control mandrel member 88, and which cannot, therefore, move upwardly. When sufficient pressure is imposed on the lower swab cup 253, the shear screw 282 will be disrupted and the entire running-in tool 280 pumped upwardly through the tubing string H to the top of the well bore.

The upper unloader valve G can now be re-closed by moving the outer housing 197 downwardly over the mandrel 189 and the fluid in the tubing string H removed by a swabbing action. When sufficient fluid has been removed, or all of the fluid substantially fully removed, from the tubing string H, the well packer A can be anchored against downward movement in the well casing B, the valve C closed, and the tester valve E again opened to conduct another formation test.

If such test indicates the need for further work in the well bore, the retrieving tool 250 can again be pumped down through the tubing string H, latched on to the retrievable sleeve member 144, and the mandrel 132 again removed from the tester valve E in the manner described above. The well packer A can again be anchored in packed-off condition in the well casing and another pressuring operation performed. The use of the apparatus for testing and pressuring purposes can take place as often as is deemed necessary, without removing the main assemblage of different apparatus from the well casing. For that matter, other equipment can be lowered through the apparatus after the retrievable mandrel portion 132 and the pressure recorder F have been removed, such as a perforating gun, in the event that the well casing B below the well packer is to be perforated or additionally perforated.

In retrieving the mandrel 132, valve head 123 and pressure recorder F, assurance is had that release can be effected by balancing the pressure both above and below this portion of the equipment. Such balancing is readily accomplished by opening the upper unloader valve G as well as the lower equalizer valve C. In the event difficulty is encountered in removing the retrievable mandrel member 132 and its valve mechanism, then the entire apparatus can be withdrawn from the well casing B, the upper unloader valve G first being opened to insure that the fluid in the tubing string H will drain into the well casing as the tubing is elevated therewithin and disconnected at the top of the well bore. Accordingly, the pulling of a "wet" job is precluded.

The inventor claims:

1. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be anchored in the well bore against upward and downward movement therewithin and having a fluid passage; a tester valve above and connected to said packer and communicable with said packer passage, said tester valve being shiftable between opened and closed conditions to selectively permit fluid to flow from said packer passage through said valve or prevent such flow; and said tester valve including a portion detachably secured in said tester valve and removable therefrom through the tubular string to provide a substantially unobstructed passage through said tester valve; an unloader valve above and connected to

said tester valve and adapted to be attached to the tubular string, said unloader valve being shiftable between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow, said unloader valve having a passage through which said tester valve portion can move.

2. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be set in the well bore and having a fluid passage; a tester valve above and connected to said packer and communicable with said packer passage, said tester valve having inner and outer members telescopically movable with respect to each other to open and close the valve to selectively prevent fluid from said packer passage to flow through said valve, permit such flow and then prevent such flow; and an unloader valve above and connected to one of said members, said unloader valve having inner and outer members telescopically movable with respect to each other without rotation between opened and closed conditions to selectively prevent fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to permit such flow, one of said unloader valve members being adapted for connection to the tubular string whereby said one unloader valve member can be shifted longitudinally and without rotation relative to said other unloader valve member upon longitudinal non-rotary movement of the tubular string.

3. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be anchored in the well bore against upward and downward movement therewithin and having a fluid passage; a tester valve above and connected to said packer and communicable with said packer passage, said tester valve being shiftable between opened and closed conditions to selectively permit fluid to flow from said packer passage through said valve or prevent such flow; said tester valve including a portion detachably secured in said tester valve and removable therefrom through the tubular string to provide a substantially unobstructed passage through said tester valve; an unloader valve above and connected to said tester valve and adapted to be attached to the tubular string, said unloader valve being shiftable between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow, said unloader valve having a passage through which said tester valve portion can move; said unloader valve embodying means for resisting opening of said unloader valve during shifting of said tester valve between opened and closed conditions.

4. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be set in the well bore and having a fluid passage; a tester valve above and connected to said packer and communicable with said packer passage, said tester valve having inner and outer members telescopically movable with respect to each other to open and close the valve to selectively prevent fluid from said packer passage to flow through said valve, permit such flow and then prevent such flow; an unloader valve above and connected to one of said members, said unloader valve having inner and outer members telescopically movable with respect to each other without rotation between opened and closed conditions to selectively prevent fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to permit such flow, one of said unloader valve members being adapted for connection to the tubular string whereby said one unloader valve member can be shifted longitudinally and without rotation relative to said other unloader valve member upon longitudinal non-rotary movement of the tubular string; said unloader valve embodying means for

21

resisting telescopic movement between the inner and outer members of said unloader valve to a position opening said unloader valve.

5. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be set in the well bore and having a fluid passage; a tester valve above and connected to said packer and communicable with said packer passage, said tester valve having inner and outer members telescopically movable with respect to each other to open and close the valve to selectively prevent fluid from said packer passage to flow through said valve, permit such flow and then prevent such flow; and an unloader valve above and connected to one of said members, said unloader valve having inner and outer members telescopically movable with respect to each other without rotation between opened and closed conditions to selectively prevent fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to permit such flow, one of said unloader valve members being adapted for connection to the tubular string whereby said one unloader valve member can be shifted longitudinally and without rotation relative to said other unloader valve member upon longitudinal non-rotary movement of the tubular string; said unloader valve embodying time delay means for retarding telescopic movement between the inner and outer members of said unloader valve to a position opening said unloader valve, whereby said tester valve can be shifted between opened and closed conditions without opening said unloader valve.

6. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be set in the well bore against upward movement therewithin and having a fluid passage; an equalizer valve above and connected to said packer and having a passage communicating with said packer passage, said equalizer valve being shiftable between opened and closed conditions to selectively permit fluid to flow between its interior and the annulus surrounding the tubular string or to prevent such flow; a tester valve above and connected to said equalizer valve, said tester valve being shiftable between opened and closed conditions to selectively permit fluid to flow from said passages through the tester valve or prevent such flow; an unloader valve above and connected to said tester valve and adapted to be attached to the tubular string, said unloader valve being shiftable between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow; and means releasably locking said equalizer valve in its closed condition to prevent its opening upon exertion of an upward force thereon tending to open said equalizer valve.

7. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be set in the well bore and having a fluid passage; an equalizer valve above and connected to said packer and having a passage communicating with said packer passage, said equalizer valve having inner and outer members telescopically movable with respect to each other between open and closed conditions to selectively permit fluid to flow between the interior of said equalizer valve and the annulus surrounding the tubular string or to prevent such flow; a tester valve above and connected to said equalizer valve and communicable with said passages, said tester valve having inner and outer members telescopically movable with respect to each other to open and close the tester valve to selectively permit fluid from said passages to flow through said tester valve or to prevent such flow; and an unloader valve above and connected to one of said tester valve members, said unloader valve having inner and outer members telescopically movable with respect to each other

22

without rotation between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow, one of said unloader valve members being adapted for connection to the tubular string whereby said one unloader valve member can be shifted longitudinally and without rotation relative to said other unloader valve member upon longitudinal non-rotary movement of the tubular string.

8. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be set in the well bore against upward movement therewithin and having a fluid passage; an equalizer valve above and connected to said packer and having a passage communicating with said packer passage, said equalizer valve being shiftable between opened and closed conditions to selectively permit fluid to flow between its interior and the annulus surrounding the tubular string or to prevent such flow; a tester valve above and connected to said equalizer valve, said tester valve being shiftable between opened and closed conditions to selectively permit fluid to flow from said passages through the tester valve or to prevent such flow; an unloader valve above and connected to said tester valve and adapted to be attached to the tubular string, said unloader valve being shiftable between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow; said unloader valve embodying means for resisting opening of said unloader valve during shifting of said equalizer valve and tester valve between opened and closed conditions; and means releasably locking said equalizer valve in its closed condition to prevent its opening upon exertion of an upward force thereon tending to open said equalizer valve.

9. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be set in the well bore against upward movement therewithin and having a fluid passage; an equalizer valve above and connected to said packer and having a passage communicating with said packer passage, said equalizer valve having inner and outer members telescopically movable with respect to each other between opened and closed conditions to selectively permit fluid to flow between the interior of said equalizer valve and the annulus surrounding the tubular string or to prevent such flow; a tester valve above and connected to said equalizer valve and communicable with said passages, said tester valve having inner and outer members telescopically movable with respect to each other to open and close the tester valve to selectively permit fluid from said passages to flow through said tester valve or to prevent such flow; an unloader valve above and connected to one of said tester valve members, said unloader valve having inner and outer members telescopically movable with respect to each other between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow, one of said unloader valve members being adapted for connection to the tubular string; said unloader valve embodying means for resisting telescopic movement between the inner and outer members of said unloader valve to a position opening said unloader valve; and means releasably locking said inner and outer members of said equalizer valve to each other to prevent opening of said equalizer valve upon exertion of an upward force thereon.

10. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be set in the well bore against upward movement therewithin and having a fluid passage; an equalizer valve above and connected to said packer and having a passage communicating with said packer passage, said equalizer valve having inner and

outer members telescopically movable with respect to each other between opened and closed conditions to selectively permit fluid to flow between the interior of said equalizer valve and the annulus surrounding the tubular string or to prevent such flow; a tester valve above and connected to said equalizer valve and communicable with said passages, said tester valve having inner and outer members telescopically movable with respect to each other to open and close the tester valve to selectively permit fluid from said passages to flow through said tester valve or to prevent such flow; an unloader valve above and connected to one of said tester valve members, said unloader valve having inner and outer members telescopically movable with respect to each other without rotation between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow, one of said unloader valve members being adapted for connection to the tubular string whereby said one unloader valve member can be shifted longitudinally and without rotation relative to said other unloader valve member upon longitudinal non-rotary movement of the tubular string; said unloader valve embodying time delay means for retarding telescopic movement between the inner and outer members of said unloader valve to a position opening said unloader valve, whereby said equalizer valve and tester valve can be shifted between opened and closed conditions without opening said unloader valve; and means releasably locking said inner and outer members of said equalizer valve to each other to prevent opening of said equalizer valve upon exertion of an upward force thereon.

11. In apparatus adapted to be secured to a tubular string and lowered in a well bore to perform a test therein: a tester valve having a passage therethrough and comprising inner and outer members telescopically movable with respect to each other to selectively open or close said passage and close said passage after it has been opened; and an unloader valve above and connected to one of said members, said unloader valve having inner and outer members communicating with said passage and telescopically movable with respect to each other without rotation between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow, one of said unloader valve members being adapted for connection to the tubular string whereby said one unloader valve member can be shifted longitudinally and without rotation relative to said other unloader valve member upon longitudinal non-rotary movement of the tubular string.

12. In apparatus adapted to be secured to a tubular string and lowered in a well bore to perform a test therein: a tester valve having a passage therethrough and comprising inner and outer members telescopically movable with respect to each other to selectively open or close said passage and close said passage after it has been opened; and an unloader valve above and connected to one of said members, said unloader valve having inner and outer members communicating with said passage and telescopically movable with respect to each other without rotation between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow, one of said unloader valve members being adapted for connection to the tubular string whereby said one unloader valve member can be shifted longitudinally and without rotation relative to said other unloader valve member upon longitudinal non-rotary movement of the tubular string; said unloader valve embodying means for resisting telescopic movement between the inner and outer members of said unloader valve to a position opening said unloader valve.

13. In apparatus adapted to be secured to a tubular

string and lowered in a well bore to perform a test therein: a tester valve having a passage therethrough and comprising inner and outer members telescopically movable with respect to each other to selectively open or close said passage and close said passage after it has been opened; and an unloader valve above and connected to one of said members, said unloader valve having inner and outer members communicating with said passage and telescopically movable with respect to each other without rotation between open and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow, one of said unloader valve members being adapted for connection to the tubular string whereby said one unloader valve member can be shifted longitudinally and without rotation relative to said other unloader valve member upon longitudinal non-rotary movement of the tubular string; said unloader valve embodying time delay means for retarding telescopic movement between the inner and outer members of said unloader valve to a position opening said unloader valve, whereby said tester valve can be shifted between opened and closed conditions without opening said unloader valve.

14. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be set in the well bore and having a fluid passage; an equalizer valve above and connected to said packer and having a passage communicating with said packer passage, said equalizer valve being shiftable between opened and closed conditions to selectively permit fluid to flow between its interior and the annulus surrounding the valve or to prevent such flow; a tester valve above and connected to said equalizer valve, said tester valve being shiftable between opened and closed conditions to selectively permit fluid to flow from said passages through the tester valve or prevent such flow; an unloader valve above and connected to said tester valve and adapted to be attached to the tubular string and having a passage therethrough communicable with the tubular string, said unloader valve being shiftable between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow; said tester valve including barrier means within and releasably latched to a portion of said tester valve, said barrier means being adapted for release and removal from said portion of the tester valve and through the unloader valve passage and tubular string to open the passage through said tester valve.

15. In apparatus for testing a well bore and adapted to be secured to a tubular string extending to the top of the well bore: a well packer adapted to be set in the well bore and having a fluid passage; an equalizer valve above and connected to said packer and having a passage communicating with said packer passage, said equalizer valve having inner and outer members telescopically movable with respect to each other between opened and closed conditions to selectively permit fluid to flow between the interior of said equalizer valve and the annulus surrounding said equalizer valve or to prevent such flow; a tester valve above and connected to said equalizer valve and communicable with said passages, said tester valve having inner and outer members telescopically movable with respect to each other to open and close the tester valve to selectively permit fluid from said passages to flow through said tester valve or to prevent such flow; an unloader valve above and connected to one of said tester valve members and having a passage communicable with the tubular string, said unloader valve having inner and outer members telescopically movable with respect to each other between opened and closed conditions to selectively permit fluid to flow between the interior of said unloader valve and the annulus surrounding the tubular string or to prevent such flow, one of said unloader valve members being adapted for connection to the tubular string; said

25

tester valve including barrier means within said tester valve members and releasably latched to one of said tester valve members, said barrier means being adapted for release and removal from said one tester valve member and through the unloader valve passage and tubular string to open the passage through said tester valve.

16. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members adapted to occupy one relative position opening said passage in response to relative longitudinal movement between said members in one direction and adapted to occupy another relative position closing said passage in response to relative longitudinal movement between said members in the opposite direction; and holding means on said members for preventing substantial longitudinal movement between said members and responsive to relative rotation between said members to enable said members to move relatively in one of said directions to place said members in one of said relative positions, said holding means being constructed and arranged to permit said members to move relatively longitudinally in the other of said directions without relative rotation between said members to place said members in the other of said relative positions.

17. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members adapted to occupy one relative position opening said passage in response to relative longitudinal movement between said members in one direction and adapted to occupy another relative position closing said passage in response to relative longitudinal movement between said members in the opposite direction; and holding means on said members for retaining said coengageable means in passage closing position and responsive to relative rotation between said members to enable said members to move relatively in one of said directions and shift said coengageable means to passage opening position, said holding means being constructed and arranged to permit said members to move relatively longitudinally and without relative rotation in the other of said directions to shift said coengageable means to passage closing position.

18. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members adapted to occupy one relative position opening said passage in response to relative longitudinal movement between said members in one direction and adapted to occupy another relative position closing said passage in response to relative longitudinal movement between said members in the opposite direction; and holding means on said members for preventing substantial longitudinal movement between said members, said holding means including threaded instrumentalities responsive to relative rotation between said members to shift a portion of said holding means along another portion of said holding means to a position permitting said members to move relatively in one of said longitudinal directions and shift said coengageable means from one of said positions to the other of said positions, said threaded instrumentalities being constructed and arranged to permit said members to move relatively and without rotation in the other of said longitudinal directions to shift said coengageable means back to said one of said positions.

19. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members adapted to

26

occupy one relative position opening said passage in response to relative longitudinal movement between said members in one direction and adapted to occupy another relative position closing said passage in response to relative longitudinal movement between said members in the opposite direction; and holding means on said members for preventing substantial longitudinal movement between said members, said holding means including threaded instrumentalities responsive to relative rotation between said members to shift a portion of said holding means along another portion of said holding means to a position permitting said members to move relatively in one of said longitudinal directions and shift said coengageable means from closed position to open position, said threaded instrumentalities being constructed and arranged to permit said members to move relatively and without rotation in the other of said longitudinal directions to shift said coengageable means back to closed position.

20. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members adapted to occupy one relative position opening said passage in response to relative longitudinal movement between said members in one direction and adapted to occupy another relative position closing said passage in response to relative longitudinal movement between said members in the opposite direction; releasable latch means threadedly attached to one of said members in a first location and engageable with said other member to prevent substantial longitudinal movement between said members to retain said coengageable means in one of said positions; means for rotating said latch means relative to said one of said members to thread said latch means along said one member to a second location disengaged from said other member permitting said members to move relatively in one of said directions and shift said coengageable means to the other of said positions; and means responsive to relative longitudinal movement between said members in the other of said directions for returning said coengageable means to said one position and said latch means to said first location.

21. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members adapted to occupy one relative position opening said passage in response to relative longitudinal movement between said members in one direction and adapted to occupy another relative position closing said passage in response to relative longitudinal movement between said members in the opposite direction; releasable latch means threadedly attached to one of said members in a first location and engageable with said other member to prevent substantial longitudinal movement between said members to retain said coengageable means in closed position; means for rotating said latch means relative to said one of said members and thread said latch means along said one member to a second location disengaged from said other member permitting said members to shift said coengageable means to open position; and means responsive to relative longitudinal movement between said members in the other of said directions for returning said coengageable means to closed position and said latch means to said first location.

22. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members adapted to occupy one relative position opening said passage in response to relative longitudinal movement between said members in one direction and adapted to occupy another

relative position closing said passage in response to relative longitudinal movement between said members in the opposite direction; latch means having an expansible and contractible threaded portion threadedly attached to one of said members in a first location and engageable with said other member to prevent substantial longitudinal movement between said members and retain said coengageable means in closed position; means on said other member for rotating said latch means relative to said one member and thread said latch means along said one member to a second location disengaged from said other member permitting said members to move relatively in one of said directions and shift said coengageable means to open position; and means on said other member engageable with said latch means to return said latch means without rotation to said first location during relative movement of said members in the other of said directions to return said coengageable means to a closed position.

23. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members adapted to occupy one relative position opening said passage in response to relative longitudinal movement between said members in one direction and adapted to occupy another relative position closing said passage in response to relative longitudinal movement between said members in the opposite direction; releasable latch means threadedly attached to said outer member in a first location and engageable with said inner member to prevent substantial longitudinal movement between said members to retain said coengageable means in one of said positions; means for rotating said latch means relative to said outer member to thread said latch means along said outer member and to a second location permitting said member to move relatively in one of said directions and shift said coengageable means to the other of said positions; and means responsive to relative longitudinal movement between said members in the other of said directions for returning said coengageable means to said one position and said latch means to said first location.

24. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members adapted to occupy one relative position opening said passage in response to relative longitudinal movement between said members in one direction and adapted to occupy another relative position closing said passage in response to relative longitudinal movement between said members in the opposite direction; latch means having an expansible and contractible threaded portion threadedly attached to said outer member in the first location and engageable with said inner member to prevent substantial longitudinal movement between said members and retain said coengageable means in closed position; means on said inner member for rotating said latch means relative to said outer member and thread said latch means along said outer member to a second location permitting said members to move relatively in one of said directions and shift said coengageable means to open position; and means on said inner member engageable with said latch means to return said latch means without rotation to said first location during relative movement of said members in the other of said directions to return said coengageable means to closed position.

25. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members for opening and closing said passage; latch means between said inner and outer members including a threaded portion

threadedly engaging said outer member in one location, said latch means also including a holding portion; means retaining said holding portion in an inward position for engagement by said inner member to prevent said members from moving longitudinally of one another to shift said coengageable means to passage opening position; means on said inner member for rotating said latch means to thread said latch means along said outer member to a position releasing said holding portion from said retaining means and allowing said holding portion to shift outwardly from its position to be engaged by said inner member, permitting said members to shift longitudinally of one another to shift said coengageable means to open position.

26. In a tester valve adapted to be disposed in a well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; coengageable means on said members for opening and closing said passage; latch means between said inner and outer members including a threaded portion threadedly engaging said outer member in one location, said latch means also including a holding portion; means retaining said holding portion in an inward position for engagement by said inner member to prevent said members from moving longitudinally of one another to shift said coengageable means to passage opening position; means on said inner member for rotating said latch means to thread said latch means along said outer member to a position releasing said holding portion from said retaining means and allowing said holding portion to shift outwardly from its position to be engaged by said inner member, permitting said members to shift longitudinally of one another to shift said coengageable means to open position; said threaded portion being expansible and contractible; and means on said inner member engageable with said latch means to return said latch means longitudinally and without rotation to its position wherein said threaded portion is at said one location and said holding portion is retained in said inward position.

27. In a tester valve adapted to be disposed in a well bore on a tubular string extending to the top of the well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; one of said members having a valve seat; barrier means within and releasably latched to the other of said members and having a valve head engageable with said seat to close said passage, said barrier means and its valve head being adapted for release and removal from said other of said members and through the tubular string; and means for shifting said members with respect to each other to shift said valve head with respect to said seat and selectively open or close said passage.

28. In a tester valve adapted to be disposed in a well bore on a tubular string extending to the top of the well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; one of said members having a cylindrical valve seat; barrier means within and releasably latched to the other of said members and having a valve head slidable in said cylindrical seat to close said passage, said barrier means and its valve head being adapted for release and removal from said other of said members and through the tubular string; and means for shifting said members longitudinally with respect to each other to shift said valve head within said seat to selective positions opening or closing said passage.

29. In a tester valve adapted to be disposed in a well bore on a tubular string extending to the top of the well bore: inner and outer members movable longitudinally with respect to each other and having a passage there-through, said inner member being within said outer member; one of said members having a cylindrical valve seat; barrier means within and releasably latched to the other

29

of said members and having a valve head slidable in said cylindrical seat to close said passage, said barrier means and its valve head being adapted for release and removal from said other of said members and through the tubular string; holding means on said members for preventing substantial longitudinal movement between said members to retain said valve head in passage closing position within said seat; and means for releasing said holding means to permit relative longitudinal movement between said members to shift said head along said seat to passage opening position.

30. In a tester valve adapted to be disposed in a well bore on a tubular string extending to the top of the well bore: inner and outer members movable longitudinally with respect to each other and having a passage therethrough, said inner member being within said outer member; one of said members having a valve seat; barrier means within and releasably latched to the other of said members and having a valve head engageable with said seat to close said passage, said barrier means and its valve head being adapted for release and removal from said other of said members and through the tubular string; said other of said members having an upper locking groove, a locating groove below said locking groove, and a downwardly facing shoulder below said locating groove; said barrier means including a mandrel, a laterally movable latch element carried by said mandrel, said element having an upper portion receivable in said locking groove, an intermediate portion receivable in said locating groove, and a lower portion adapted to be disposed below said shoulder when said upper portion and said intermediate portion are in said upper groove and locating groove, respectively, and means on said mandrel engageable with said lower portion to hold it laterally outwardly below said shoulder; and means for shifting said members with respect to each other to shift said valve head with respect to said seat and selectively open or close said passage.

31. In a tester valve adapted to be disposed in a well bore on a tubular string extending to the top of the well bore: inner and outer members movable longitudinally with respect to each other and having a passage therethrough, said inner member being within said outer member; means responsive to relative movement between said members for opening and closing said passage, said means comprising barrier means within and releasably latched to one of said members; said one member having an upper locking groove, a locating groove below said locking groove, and a downwardly facing shoulder below said locating groove, said barrier means including a mandrel, a laterally movable latch element carried by said mandrel, the element having an upper portion receivable in said locking groove, an intermediate portion receivable in said locating groove, and a lower portion adapted to be disposed below said shoulder when said upper portion and intermediate portion are in said upper groove and locating groove, respectively, and means on said mandrel engageable with said lower portion to hold said lower portion laterally outwardly below said shoulder.

32. In a tester valve adapted to be disposed in a well bore on a tubular string extending to the top of the well bore: inner and outer members movable longitudinally with respect to each other and having a passage therethrough, said inner member being within said outer member; means responsive to relative movement between said members for opening and closing said passage, said means comprising barrier means within and releasably latched to one of said members; said one member having an upper locking groove, a locating groove below said locking groove, and a downwardly facing shoulder below said locating groove, said barrier means including a mandrel, a laterally movable latch element carried by said mandrel, the element having an upper portion receivable in said locking groove, an intermediate portion receivable in said locating groove, and a lower portion adapted to

30

be disposed below said shoulder when said upper portion and intermediate portion are in said upper groove and locating groove, respectively, means on said mandrel engageable with said lower portion to hold said lower portion laterally outwardly below said shoulder, and means on said mandrel engageable with said upper portion for holding it laterally outwardly in said locking groove.

33. In a tester valve adapted to be disposed in a well bore on a tubular string extending to the top of the well bore: inner and outer members movable longitudinally with respect to each other and having a passage therethrough, said inner member being within said outer member; means responsive to relative longitudinal movement between said members for opening and closing said passage, said means comprising barrier means within and releasably latched to one of said members; said one member having an upper locking groove, a locating groove below said locking groove, and a downwardly facing shoulder below said locating groove, said barrier means including a mandrel, a sleeve slidable on said mandrel, circumferentially spaced laterally movable latch elements carried by said sleeve, each of said elements having an upper portion receivable in said locking groove, an intermediate portion receivable in said locating groove, and a lower portion adapted to be disposed below said shoulder when said upper portion and intermediate portion are in said upper groove and locating groove, respectively, and means on said mandrel engageable with said lower portions to hold said lower portions laterally outwardly below said shoulder.

34. In apparatus of the character described: a member having an upper locking groove, a locating groove below said locking groove, and a downwardly facing shoulder below said locating groove; a mandrel within said member; a laterally movable latch element carried by said mandrel, said element having an upper portion receivable in said locking groove, an intermediate portion receivable in said locating groove, and a lower portion adapted to be disposed below said shoulder when said upper portion and intermediate portion are in said upper groove and locating groove, respectively; and means secured to said mandrel and engageable with said lower portion to hold it laterally outwardly below said shoulder.

35. In apparatus of the character described: a member having an upper locking groove, a locating groove below said locking groove, and a downwardly facing shoulder below said locating groove; a mandrel within said member; a laterally movable latch element carried by said mandrel, said element having an upper portion receivable in said locking groove, an intermediate portion receivable in said locating groove, and a lower portion adapted to be disposed below said shoulder when said upper portion and intermediate portion are in said upper groove and locating groove, respectively; means secured to said mandrel and engageable with said lower portion to hold it laterally outwardly below said shoulder; and means secured to said mandrel and engageable with said upper portion to hold said upper portion in said upper locking groove.

36. In a valve adapted to be disposed in a well bore on a tubular string: inner and outer telescopically related members having a passage therethrough, one of said members having a side port which is closed when said members are in one relative telescopic position and open when said members are in another relative telescopic position; and means for retarding relative movement of said members to said another telescopic position comprising a cylinder provided by and between said members and adapted to contain a liquid, means providing a choke orifice in one of said members disposed in said cylinder, and means on the other of said members for forcing the liquid through said choke orifice in response to movement of said members toward said another telescopic position.

37. In a valve adapted to be disposed in a well bore on a tubular string: inner and outer telescopically related members having a passage therethrough, one of said members having a side port which is closed when said members are in one relative telescopic position and open when said members are in another relative telescopic position; and means for retarding relative movement of said members to said another telescopic position comprising a cylinder provided by and between said members and adapted to contain a liquid, said cylinder including spaced upper and lower cylinder heads on said outer member, a flow restricter having a choke orifice therein on said inner member and through which one of said heads can force the liquid when said members move toward said another telescopic position.

38. In a valve adapted to be disposed in a well bore on a tubular string: inner and outer telescopically related members having a passage therethrough, one of said members having a side port which is closed when said members are in one relative telescopic position and open when said members are in another relative telescopic position; and means for retarding relative movement of said members to said another telescopic position comprising a cylinder provided by and between said members and adapted to contain a liquid, said cylinder including spaced upper and lower cylinder heads on said outer member, a flow restricter having a choke orifice therein on said inner member and through which one of said heads can force the liquid when said members move toward said another telescopic position, one of said heads being slidable in said outer member, said outer member having a port through which fluid externally of said outer member can enter for urging said slidable head toward said other head.

39. In a valve adapted to be disposed in a well bore on a tubular string: inner and outer telescopically related members having a passage therethrough, one of said members having a side port which is closed when said members are in relative contracted position and open when said members are in relative extended position; and means for retarding relative movement of said members to said extended position comprising a cylinder provided by and between said members and adapted to contain a liquid, means providing a choke orifice on one of said members disposed in said cylinder, and means on the other of said members for forcing the liquid

through said choke orifice in response to movement of said members toward said extended position.

40. In a valve adapted to be disposed in a well bore on a tubular string: inner and outer telescopically related members having a passage therethrough, one of said members having a side port which is closed when said members are in relative contracted position and open when said members are in relative extended position; and means for retarding relative movement of said members to said extended position comprising a cylinder provided by and between said members and adapted to contain a liquid, said cylinder including spaced upper and lower cylinder heads on said outer member, a flow restricter having a choke orifice therein on said inner member and through which said lower head will force the liquid when said members move toward said extended position.

41. In a valve adapted to be disposed in a well bore on a tubular string: inner and outer telescopically related members having a passage therethrough, one of said members having a side port which is closed when said members are in relative contracted position and open when said members are in relative extended position; means for retarding relative movement of said members to said extended position comprising a cylinder provided by and between said members and adapted to contain a liquid, said cylinder including spaced upper and lower cylinder heads on said outer member, a flow restricter having a choke orifice therein on said inner member and through which said lower head will force the liquid when said members move toward said extended position; and spring means in said cylinder between said lower head and flow restricter.

References Cited in the file of this patent

UNITED STATES PATENTS

2,717,646	Johnston	Sept. 13, 1955
2,719,588	Huber	Oct. 4, 1955
2,726,723	Wilhoit et al.	Dec. 13, 1955
2,799,345	Baker	July 16, 1957
2,806,539	Green et al.	Sept. 17, 1957
2,831,542	Lynes et al.	Apr. 22, 1958
2,862,564	Bostock	Dec. 2, 1958
2,874,927	Conrad	Feb. 24, 1959
2,912,216	Conrad	Nov. 10, 1959
2,984,451	Conrad	May 16, 1961