

[54] INFLATABLE PACKER DRILL STEM
TESTING APPARATUS

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[73] Assignee: Schlumberger Technology Corporation, New York, N.Y.
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[21] Appl. No.: 410,945

[52] U.S. Cl. 166/106; 166/147; 166/187
[51] Int. Cl. E21b 43/00; E21b 33/127
[58] Field of Search 166/106, 127, 187, 129, 166/130, 183, 147

[56] References Cited

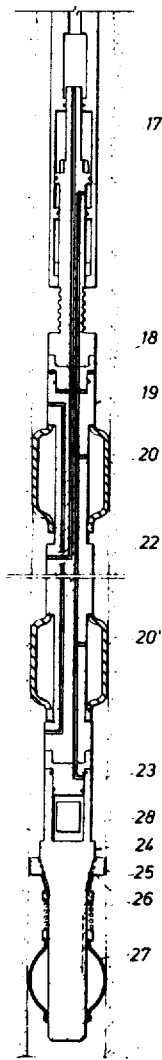
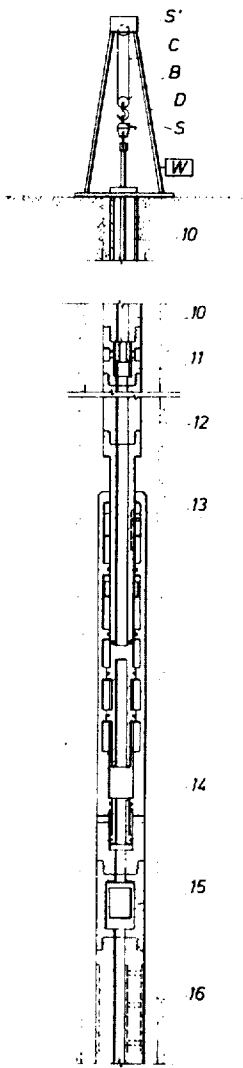
UNITED STATES PATENTS			
2,308,072	1/1943	Granger	166/183
3,032,116	5/1962	Barry	166/187
3,134,441	5/1964	Barry et al.	166/187
3,204,697	9/1965	Gaut	166/187
3,439,740	4/1969	Conover	166/187

Primary Examiner—James A. Leppink
Attorney, Agent, or Firm—David L. Moseley; William R. Sherman; Stewart F. Moore

[57] ABSTRACT

In accordance with an illustrative embodiment of the present invention, a drill stem testing apparatus that utilizes inflatable packer elements to isolate an interval of the borehole includes a uniquely arranged pump that is adapted to supply fluids under pressure to the elements in response to upward and downward movements of the pipe string extending to the surface. The pump includes an inner body structure connected to the packing elements and a telescopically disposed outer housing structure connected to the pipe string, said structures defining a working volume into which well fluids are drawn during downward movement, and from which fluids under pressure are exhausted and supplied to the packing elements during upward movement, the intake passages to the pump being backflushed during each upward movement to prevent clogging by debris in the well fluids. Uniquely arranged pressure equalizing and packer element deflating valve apparatus also is disclosed herein.

25 Claims, 18 Drawing Figures



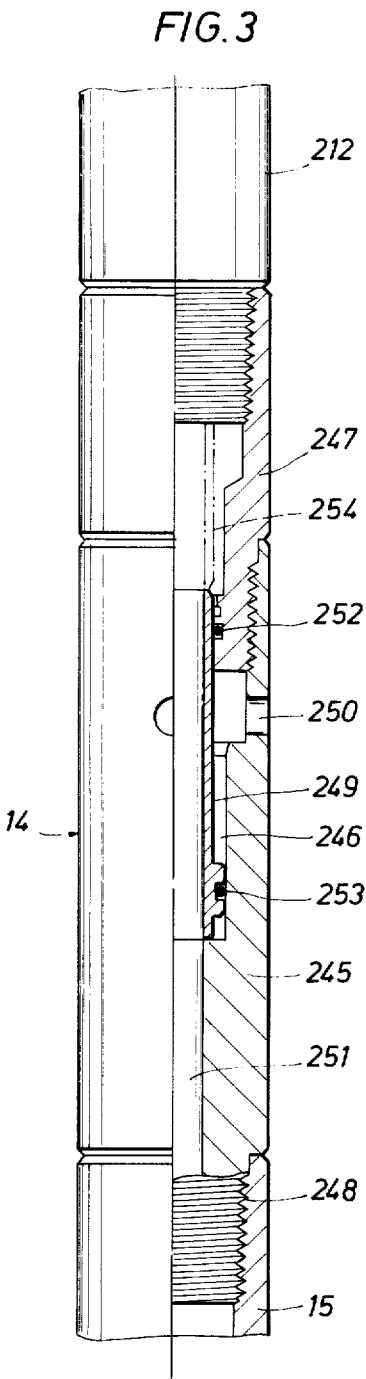
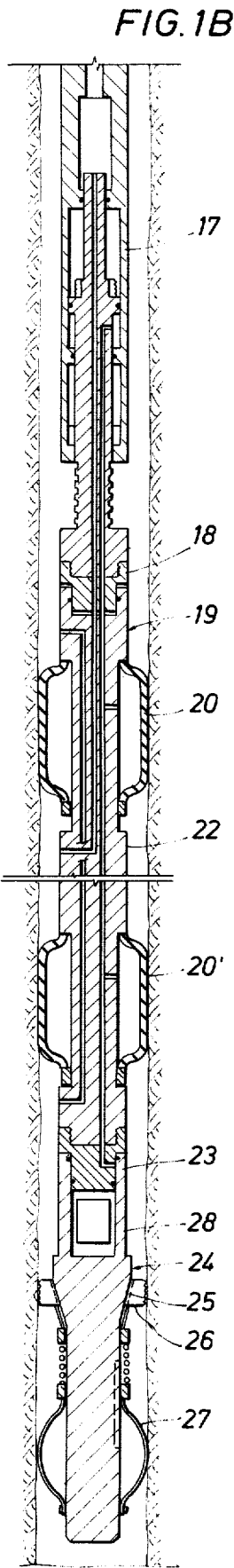
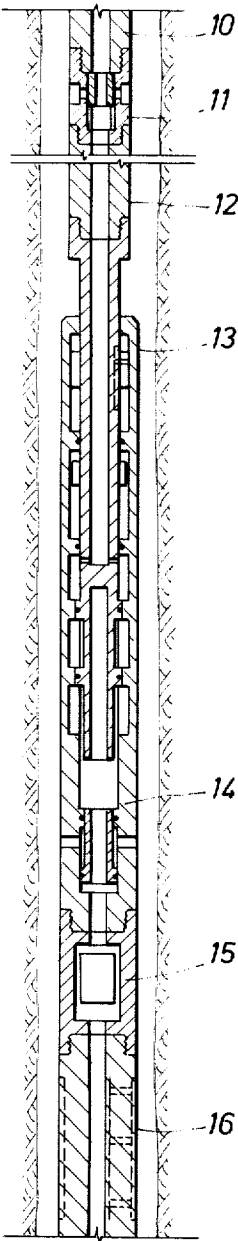
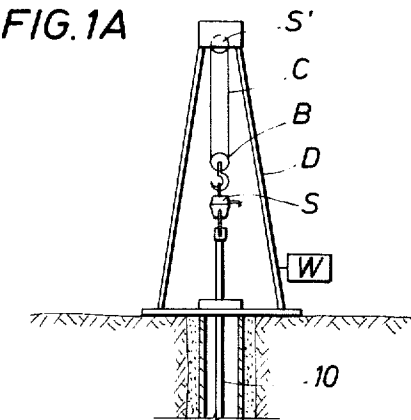


FIG. 2A

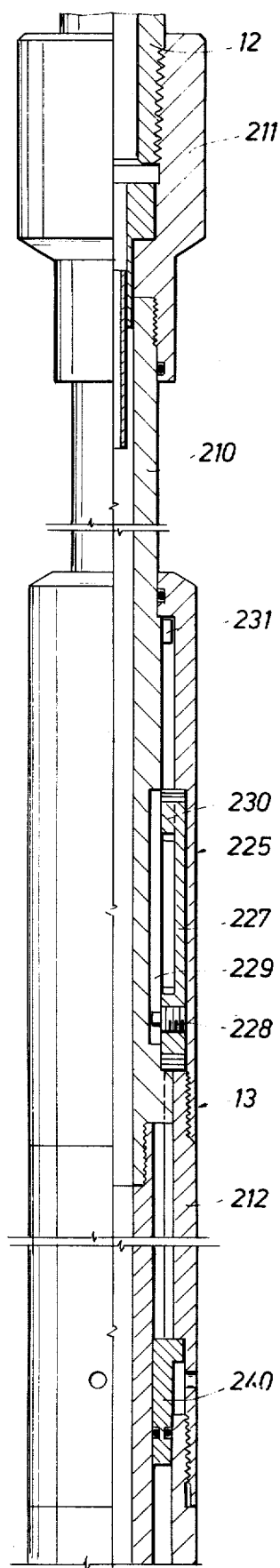


FIG. 2B

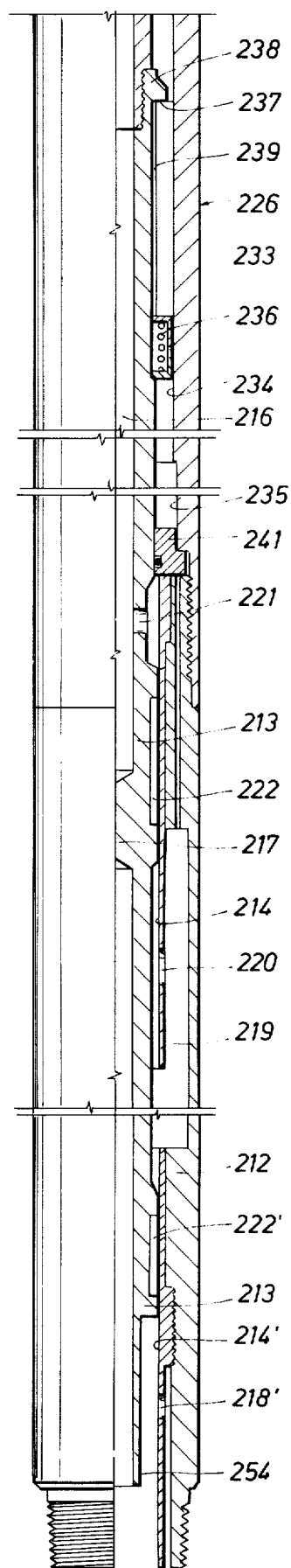


FIG. 4A

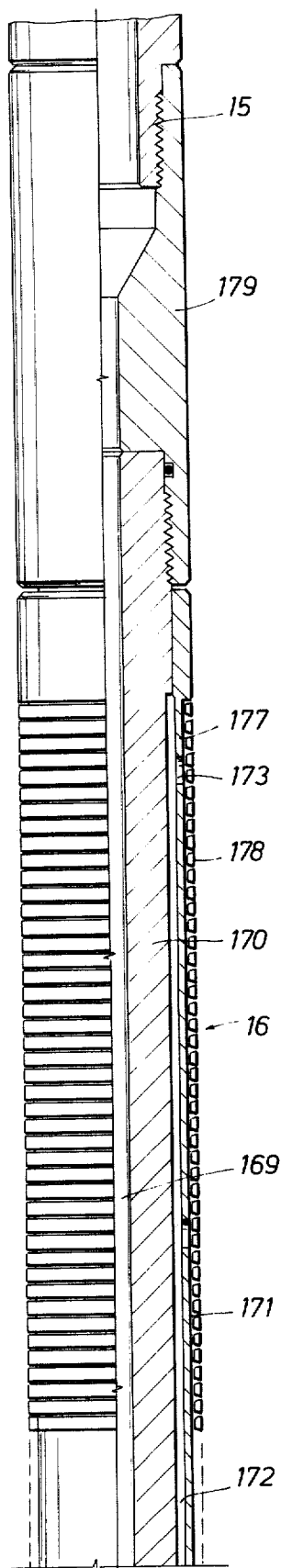


FIG. 4B

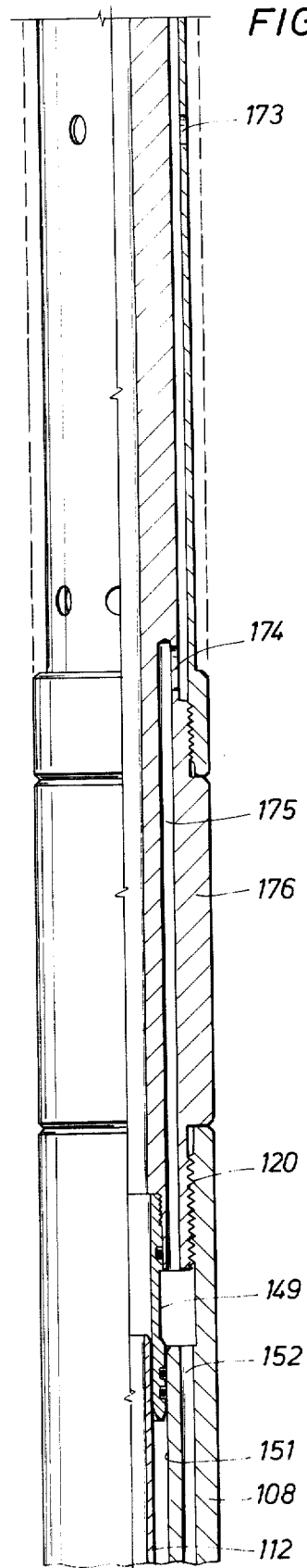


FIG. 5A

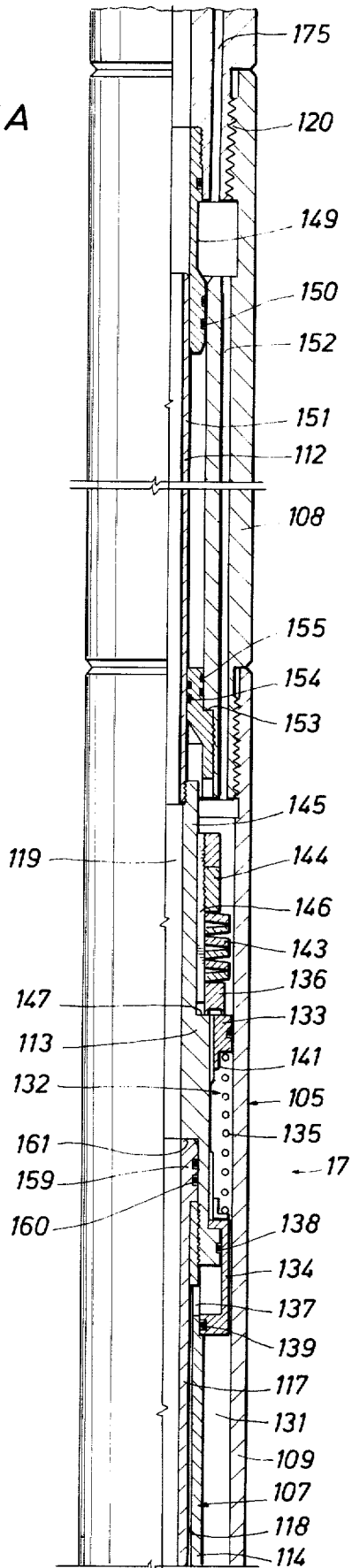


FIG. 5B

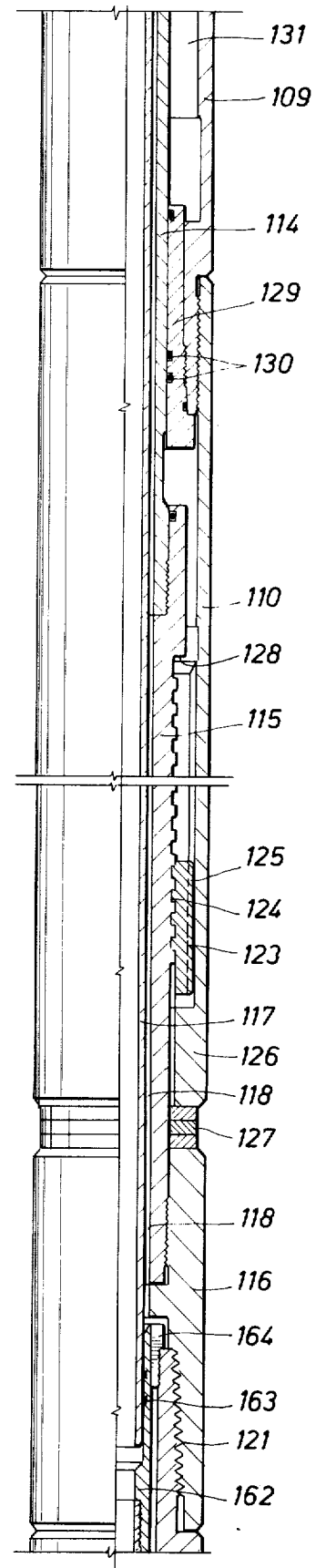


FIG. 6A

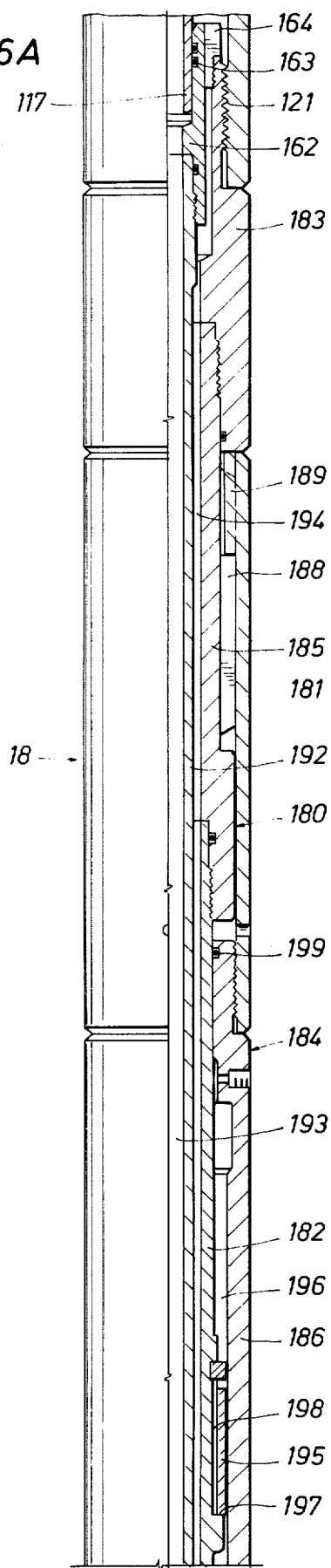


FIG. 6B

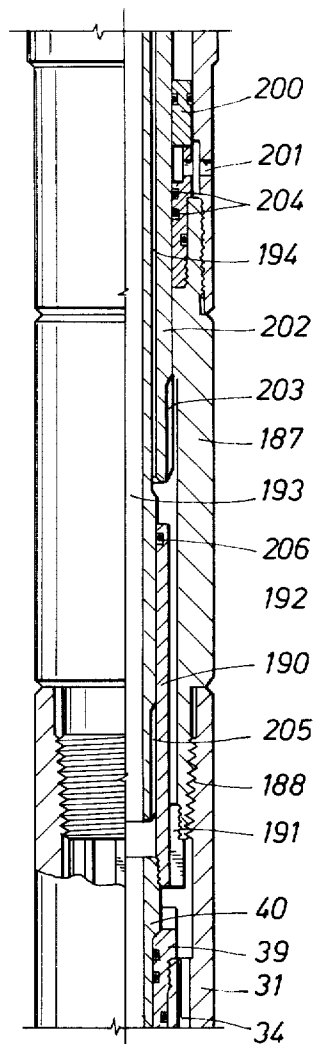


FIG. 7A

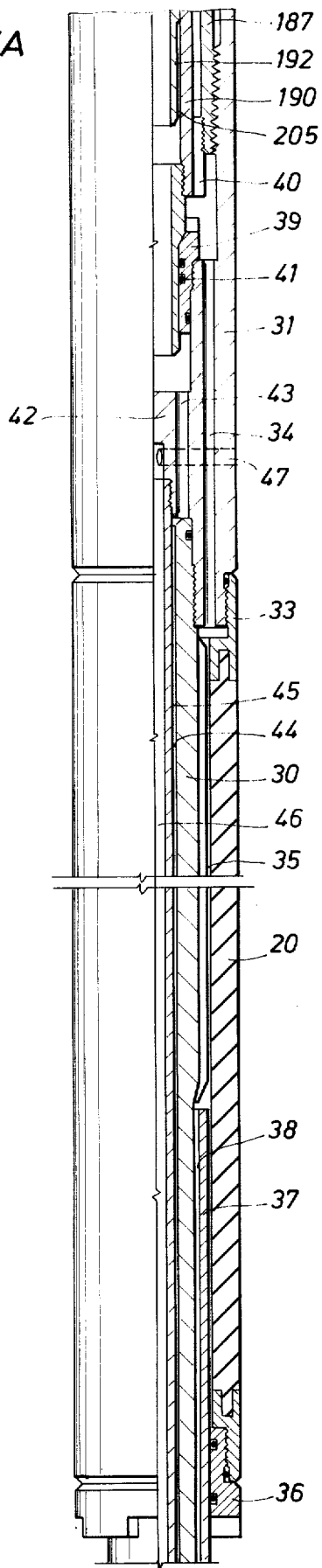


FIG. 7B

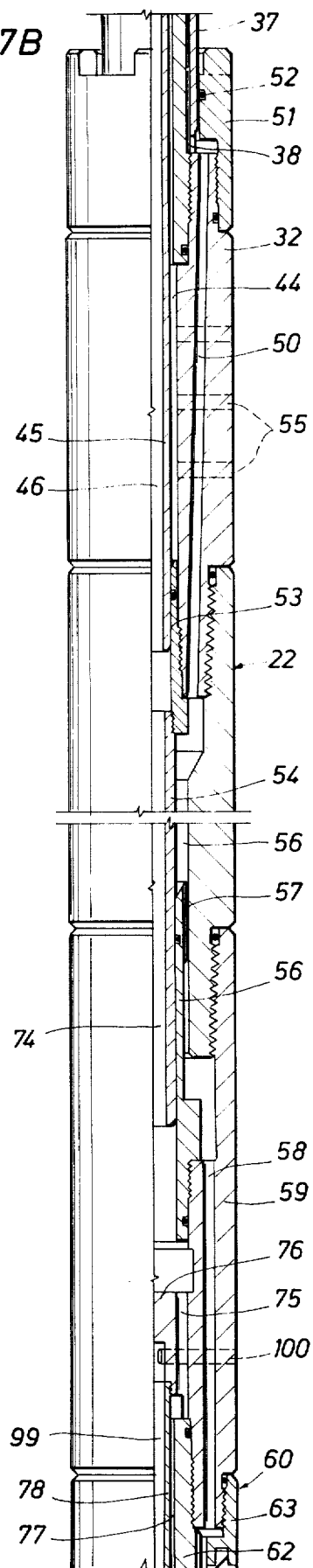


FIG. 7C

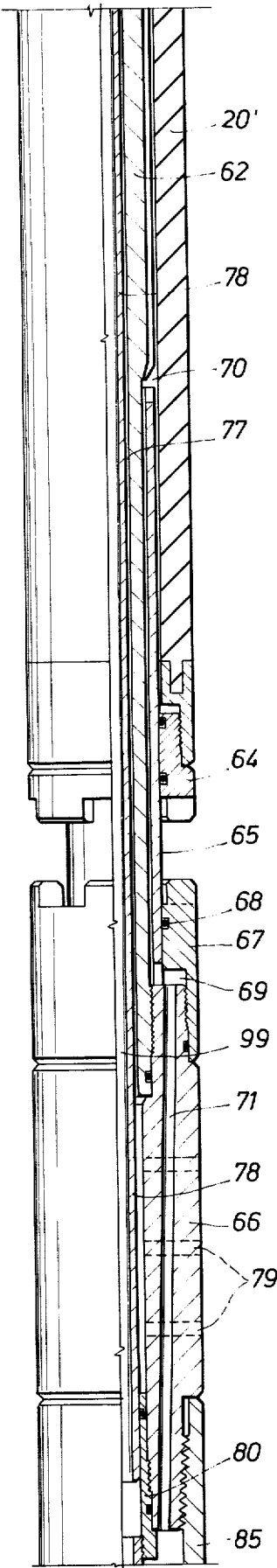


FIG. 8

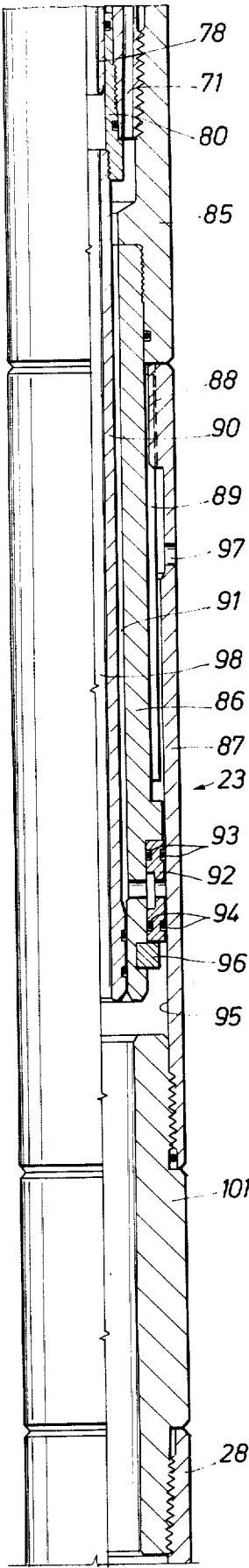


FIG. 9A

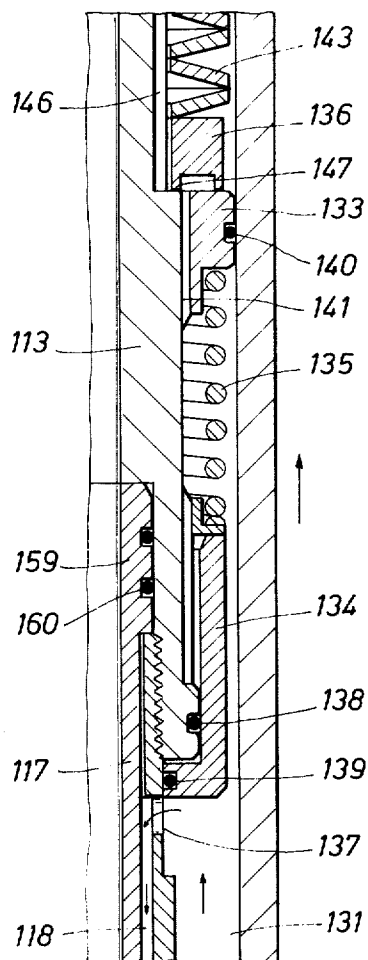


FIG. 9B

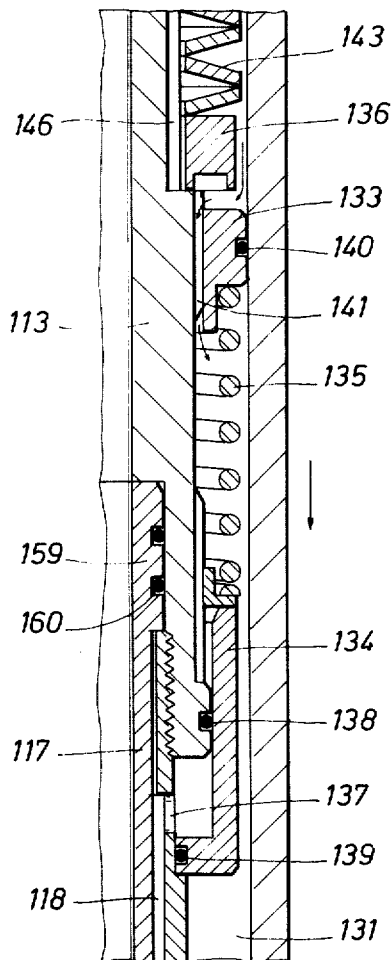
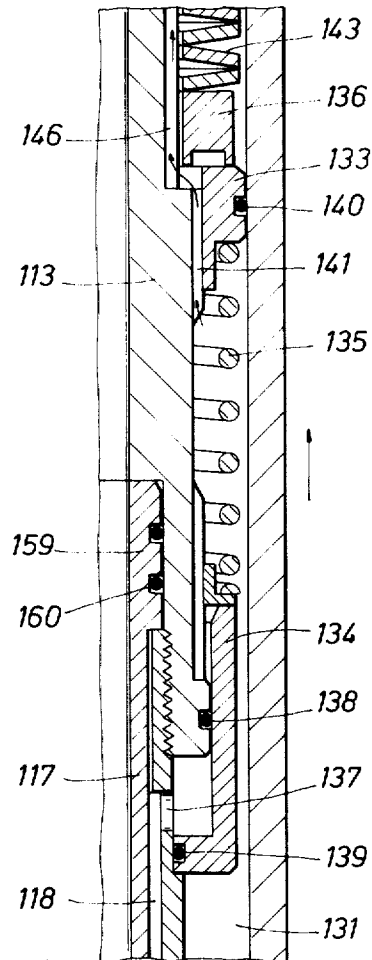


FIG. 9C



INFLATABLE PACKER DRILL STEM TESTING APPARATUS

This invention relates in general to drill stem testing, and particularly to new and improved drill stem testing apparatus including a packer assembly that incorporates spaced apart inflatable elements arranged for expansion in response to operation of a downhole pump in order to isolate an interval of the well bore undergoing test.

One typical testing system that utilizes inflatable packer elements is disclosed, for example, in U.S. Pat. No. 3,439,740, issued to G. E. Conover. The inflatable elements are expanded by a downhole pump that is actuated by rotation of the pipe string that extends from the tools to the surface. Such rotation causes a transversely oriented cam system to reciprocate a plurality of pistons or plungers which alternately draw in well bore fluids and supply them under pressure to the inflatable packing elements through fluid passages controlled by check valves. When a predetermined inflation pressure has been developed within the elements, a relief valve opens so that fluids are vented to the well annulus to prevent the development of excessive pressures. When it is desired to deflate the packing elements, further rotation is utilized to actuate an unloader valve and thereby bleed off the inflation pressure.

Although the foregoing inflatable packer system has had widespread use, it is considered to have a number of significant disadvantages. The pump is quite complex in structure and operation, and therefore is costly to manufacture as well as being subject to numerous maintenance problems. The intake ports through which fluids in the well bore are drawn into the pump can be blocked or become plugged by rock chips or other debris in the well, resulting in a failure of the pump to supply pressurized fluids. In this case the tools have to be removed from the well for appropriate cleaning before it is possible to complete the test. Moreover, it is highly desirable to provide for complete pressure equalization and the emptying of the packer elements of pressurized fluids upon completion of the test, so that the tools then can be moved through the well bore without excessive swabbing action which can cause damage to the packing elements.

It is one object of the present invention to provide new and improved drill stem testing tools that utilize inflatable packer elements to isolate the well interval to be tested.

Another object of the present invention is to provide a new and improved downhole pump for use in inflating inflatable packer elements, that is more simplified in construction and operation than heretofore has been provided in the art.

Yet another object of the present invention is to provide a new and improved pump system and associated structure of the type described, wherein the intake ports to the pump are backflushed during certain cycles of operation thereof so as to prevent plugging by debris in the well bore fluids.

A further object of the present invention is to provide new and improved drill stem testing equipment utilizing inflatable packers which can be fully deflated after completion of the test to obviate the problems in the prior art noted above.

These and other objects are attained in accordance with the concepts of the present invention through the

provision of drill stem testing apparatus including packer means having spaced apart elements arranged to be inflated and expanded into sealing contact with the surrounding well bore wall by fluid under pressure applied to the respective interiors thereof via appropriate inflation passages. A pump means arranged to be operated by manipulation of the pipe string at the surface is adapted to supply such fluids under pressure, and includes an inner body structure connected to the packer means and an outer housing structure coupled to the pipe string and telescopically disposed with respect to said body structure in such a manner that a working chamber is defined therebetween. A piston section of the housing structure provides the lower wall of the chamber, and intake and exhaust valves are located proximate the upper end of the chamber for respectively admitting well bore fluids thereto during downward movement of the housing structure, as said chamber expands in volume, and exhausting fluids under pressure to an inflation passage leading to the packer elements during upward movement of the housing structure as the chamber contracts in volume. Fluids coming into the chamber from the well bore are constrained to pass through an annular space between said housing and body structures that is constructed and arranged to have a greater transverse dimension than the working chamber of the pump, so that more fluids enter the intake passages and fill this space during upward movement of the housing structure than are required to fill the chamber during downward movement. Consequently, during such downward movement, the excess of well fluids is displaced back to the well annulus via the intake passages to cause a backflushing action to occur, with the result that the intake ports or passages do not become blocked.

The present invention further includes unique pressure equalizing valve apparatus that is actuated upon completion of a test to ensure that fluid pressure in the isolated intern is equalized with the hydrostatic head in the well to facilitate retraction of the packing element, as well as to provide communication between the respective interiors of the inflatable elements and the well bore, preferably above and below the packer assembly. Such communication ensures full deflation of the elements to avoid any problem relating to swabbing of the elements during longitudinal movement in the well bore. Of course such valve apparatus is selectively operable in order to enable expansion of the inflatable packing elements at various locations in the borehole during a single run of the equipment into the well.

The present invention has many other objects, features and advantages that will become more clearly apparent in connection with the following detailed description of a preferred embodiment, taken in conjunction with the appended drawings in which:

FIGS. 1A and 1B are schematic views of the string of drill stem testing tools, utilizing inflatable packers suspended in a well bore;

FIGS. 2A and 2B are detailed cross-sectional views with portions in side elevation, of the formation test valve assembly, FIG. 2B forming a lower continuation of FIG. 2A;

FIG. 3 is a sectional view of the pressure bleed-off valve that operates during expansion of the packing elements;

FIGS. 4A and 4B are sectional views similar to FIG. 2 of the screened fluid intake for the packer inflating pump;

FIGS. 5A and 5B are longitudinal sectional views, with portions in side elevation, of the pump assembly that is operated by vertical pipe motion to inflate the packing elements;

FIGS. 6A and 6B are cross-section views of the pressure equalizing and packer deflating valve sub; and

FIGS. 7A-7C are cross-section views of the inflatable packer assembly with upper and lower packer elements coupled by a spacer sub to enable a formation interval to be straddled and sealed off at each end;

FIG. 8 is a longitudinal sectional view of a pressure equalizing sub that can be connected to the lower end of the packing assembly; and

FIGS. 9A-9C are fragmentary sectional views showing the various operating positions of the valve assemblies that control the intake and supply of pressurized fluid to and from the pump assembly.

Referring initially to FIGS. 1A and 1B for a schematic illustration of the entire string of drill stem testing tools disposed in the borehole in position for conducting a test of an interval of the well, the running-in string 10 of drill pipe or tubing is provided with a reverse circulating valve 11 of any typical design, for example a valve of the type shown in U.S. Pat. No. 2,863,511, assigned to the assignee of this invention. A suitable length of drill pipe 12 is connected between the reverse circulating valve 11 and a multi-flow evaluator or test valve assembly 13 that functions to alternately flow and shut-in the formation interval to be tested. A preferred form of test valve assembly 13 is shown in my U.S. Pat. No. 3,308,887, also assigned to the assignee of this invention. The lower end of the test valve 13 is connected to a pressure relief valve 14 that is, in turn, connected to a recorder carrier 15 that houses a pressure recorder of the type shown in the assignee's U.S. Pat. No. 2,816,440. Of course the recorder functions to make a permanent record of fluid pressure versus lapsed time during the test in a typical manner. The recorder carrier 15 is connected to the upper end of a screen sub 16 that serves to take in and to exhaust well fluids during operation of the packer inflation pump assembly 17 to which the lower end of the screen sub is connected. The pump assembly 17, which together with the various other component parts of the tool string, will be described in considerably greater detail below, includes inner and outer telescoping members and a system of check valves arranged so that well fluids are displaced under pressure during upward movement of the outer member with respect to the inner member, and are drawn in via the screen sub 16 during downward movement. Thus a series of vertical upward and downward movements of the running-in string 10 is effective to operate the pump assembly 17 and to supply pressurized fluids for inflating the packers to be described below.

The lower end of the pump assembly 16 is coupled to an equalizing and packer deflating valve 18 that can be operated upon completion of the test to both equalize the pressures in the well interval being tested with the hydrostatic head of the well fluids in the annulus above the tools and to enable deflating the packer elements to their normally relaxed condition. Of course an equalizing valve is necessary to enable the packers to be released so that the tool string can be withdrawn

from the well. The valve 18 is connected to the upper end of a straddle-type inflatable packer system shown generally at 19, the system including upper and lower inflatable packers 20 and 20' connected together by an elongated spacer sub 22. The inflatable packers 20 and 20' each include an elastomeric sleeve that is normally retracted but which can be expanded outwardly by internal fluid pressure into sealing contact with the surrounding well bore wall. The length of the spacer sub 22 is selected such that during a test the upper packer 20 is above the upper end of the formation interval of interest, and the lower packer 20' is below the interval. Of course when the packer elements are expanded as shown in FIG. 1A, the well interval between the elements is isolated or sealed off from the rest of the well bore so that fluid recovery from the interval can be conducted through the tools described above and into the drill pipe 12.

The lower end of the packer system 19 can be connected to a slip joint and equalizing valve 23 which is, in turn, connected to an anchor 24 that may be of the hook-wall variety, an example of which is shown in U.S. Pat. No. 3,015,362, again assigned to the assignee of this invention. The anchor 24 typically comprises an expander cone 25 that is arranged to shift a set of normally retracted slips 26 outwardly into gripping contact with the well bore wall. During running, the slips are conditioned in the retracted position by a jay-slot and pin arrangement (not shown) which can be manipulated to a released condition due to the presence of drag springs 27 that frictionally engage the well bore wall. Through use of such an anchor it is possible to test well formations located at most any elevation in the borehole. If desired, another recorder carrier 28 can be positioned between the anchor 24 and the lower equalizing valve 23 and arranged to measure directly the formation fluid pressure in the isolated interval to enable a determination by comparison with the pressure readings of the recorder in the upper carrier 15 whether the test passages and ports have become blocked by debris or the like during the test. Although not shown in FIG. 1, it will be appreciated that other tools such as a jar and a safety joint may be incorporated in the string, for example between the test valve assembly 13 and the pump assembly 17, in accordance with typical practice.

As shown rather schematically in FIG. 1A, the pipe string 10 extends upwardly to the surface where it is suspended for handling within a derrick D by typical structure such as a swivel S, traveling block B and cable C extending between the traveling block and the crown block S' at the top of the derrick. The dead line of the cable has a transducer such as a load cell thereon to sense the weight of the drill string and the tools in the borehole. The output of the transducer is coupled to a weight indicator W that provides the rig operator with a visual indication of the precise amount of weight being supported by the cable and the derrick at all times. Of course the line end of the cable extends to a drawworks that is used in typical manner to raise and lower the pipe as desired.

Turning now to a more detailed description of the various component parts of the string of drill stem testing tools, reference initially will be made to the inflatable straddle packer system 19 shown in FIGS. 7A-7C. The system includes a body member or mandrel 30 having its upper end fixed to an upper sub 31 and its lower end fixed to a lower sub 32. An inflatable packer

element 20 surrounds the mandrel 30 and may be constituted by an elongated sleeve of elastomeric material such as neoprene that is internally reinforced by plies of woven metal braid or the like (not shown). The upper end of the element 20 is fixed to a collar 33 that is threaded to the upper sub 31, and may be retained with respect to the collar by means such as a frusto-conical ring that is forced against an inner surface of the element 20 by a lock nut or the like. Such structure is well known to those skilled in the art and need not be further elaborated here. One or more inflation ports or passages 34 extend vertically through the upper sub 31 and communicate with the annular space 35 between the inner wall surface of the sleeve 20 and the outer periphery of the mandrel 30. The lower end of the packer element 20 is also sealed and fixed with respect to an end cap 36 that is sealingly slidable along the mandrel 30, the lower portion of the mandrel being constituted by the combination with a passage sleeve 37 fitted around the mandrel 30 and laterally spaced therefrom to provide a continuation 38 of the passage space for inflation fluids. The upper sub 31 has a hollow seal sleeve 39 threadedly fixed therein and adapted to receive the lower end of an elongated flow tube 40 that extends upwardly within the equalizing and packer deflating valve assembly 18. The seal sleeve 39 carries seal rings 41 and is located in spaced relation above a transverse solid section 42 of the sub 31 which has, in addition to the inflation ports 34, a plurality of test ports 43 extending vertically therethrough. The ports 43 communicate with an annular fluid passage space 44 that is within the packer mandrel 30 but outside of a hollow flow tube 45 extending concentrically within the bore of the mandrel. The upper end of the flow tube 45 is threaded into the transverse section 42, and the bore 46 of the flow tube is opened to the well annulus outside the upper sub 31 by one or more laterally directed equalizing ports 47 that are angularly spaced in a transverse plane with respect to both the inflation ports 34 and the test ports 43.

The lower sub 32 as shown in FIG. 7B is threaded to the lower end of the packer mandrel 30 and has vertically extending inflation passages 50 whose upper ends are placed in communication with the annular sleeve passage 38 by a collar 51 that is threaded to the sub 32 and sealed with respect to the sleeve 37 by an O-ring 52. The flow tube 45 has its lower end received within a seal sleeve 53 that is threadedly fixed within the bore of the lower sub 32 and connected to another flow tube 54 that extends downwardly concentrically within the spacer sub 22. The annular fluid passage space 44 between the tube 45 and the mandrel 30 is communicated with the well annulus by a plurality of laterally directed ports 55 to enable formation fluids recovered during a test to enter the passage space 44 and pass upwardly through the tools. On the other hand the annular space 56 between the lower flow tube 54 and the spacer sub 22 continues a passage for inflation fluids that extend past an internal seal sleeve 56 at 57 and eventually communicates with vertically disposed inflation ports 58 in the upper sub 59 of the lower packer element assembly 20'. The lower assembly is substantially similar to the upper assembly 20 in its arrangement of an inflatable elastomeric packer element 61 (FIG. 7C) that surrounds a mandrel 62 with the upper end of the element fixed to a collar 63 and the lower end fixed to a movable end cap 64 that is sealingly slidable on an

outer sleeve 65 that surrounds the lower end portion of the mandrel. The lower end of the mandrel 62 is fixed to a lower sub 66, and a collar 67 carrying an O-ring seal 68 provides an internal recess 69 that communicates the inside 70 of the packer element 61 with one or more ports 71 that extend vertically throughout the sub 66. Thus it will be recognized that the respective interiors of the inflatable elements 20 and 20' are in continuous communication with one another so that fluid pressure applied thereto via the various intercommunicating passages 34, 35, 38, 50, 56, 58 and 70 will cause the elements to be expanded from their normally relaxed or retracted positions as shown in FIGS. 7A-7C to a substantially greater diameter where their outer peripheries come into sealing contact with an adjacent well bore wall. When expanded, the elements seal off the ends of an interval of the well bore to enable a formation test to be conducted.

Referring again to FIG. 7B, the intermediate flow tube 54 extends downwardly throughout the spacer sub 22, and its lower end extends through the seal sleeve 56 in a fluid-tight manner. Of course the bore 74 of the flow tube 56 communicates with the bore 46 of the upper flow tube 45 and thus with the well bore above the upper packing element 20 via the lateral ports 47. The lower end of the bore 74 also communicates with a series of ports 75 extending through an otherwise solid transverse section 76 of the upper sub 59, the ports 75 leading to an elongated annular flow path 77 located internally of the mandrel 62. Yet another, lower, flow tube 78 has its upper end fixed to the transverse section 76 and extends downwardly throughout the mandrel 62, with its outer wall defining the inner periphery of the annular flow path 77. The lower end of the flow path 77 is communicated with the well bore as shown in FIG. 7C by a plurality of lateral ports 79 through the wall of the lower sub 66, the lower end of the space between the tube 78 and the sub 66 being blocked by a seal sleeve 80 carrying appropriate O-rings. Accordingly, it will be recognized that the lateral ports 79 and 47 and the internal passages 46, 74, 75 and 77 provide for pressure equalization between the pressure of the fluids in the well bore above the upper packing assembly 20 and the pressure of the fluids in the well bore below the lower packing assembly 20' at all times.

The lower sub 66 of the lower packer assembly 20' is attached by a collar 85 to an inner tubular member 86 that is slidably received within an outer tubular member 87 as shown in FIG. 8, the two members being corotatively coupled by splines 88 and 89 and forming a slip joint and equalizing valve assembly 23. An inner sleeve 90 is concentrically disposed within the member 86 and is laterally spaced with respect thereto to provide a flow path 91 that communicates with the vertical ports 71 in the lower sub 66 of the packer assembly 20'. The lower end of the sleeve 90 has an outwardly directed flange that carries O-rings in sealing contact with the lower end portion of the member 86, and the flow path 91 is conducted through the wall of the member 86 by one or more ports. A ported ring 92 having upper and lower, inner and outer seals 93 and 94 is fixed between opposed shoulders of the member 86 and slidably engages the inner wall surface 95 of the outer member 87. It will be apparent that the ring 92 forms the remote lower end of the various intercommunicated inflation passages leading to and through to the

packing elements 20 and 20', and that the lower end of such passages remain closed as long as the member 86 and 87 occupy the mutually telescoped relative position shown in FIG. 8. On the other hand if the members are caused to extend, the ring 92 will be moved adjacent to a plurality of side ports 97 through the wall of the outer member 87 so that the lower end of the inflation passage is communicated with the well annulus to enable fluids to exit from the interior space of the elements 20 and 20'.

As previously mentioned, the internal sleeve 90 has its upper end threaded to the seal sleeve 80 that is fixed within the lower sub 66 of the lower packing assembly 20'. The bore 98 of the sleeve 90 is thus in fluid communication with the bore 99 of the lower flow tube 78 whose upper end is threaded into the solid section 76 of the upper sub 59 as shown in FIG. 7B. A counter-bore in the section 76 is opened to the well annulus by lateral ports 100 so that a pressure recorder housed in the carrier 28 attached to the collar 101 below the slip joint and equalizing valve 23 will "see" the pressures of fluids in the well annulus between the upper and lower inflatable packing element assemblies 20 and 20'. This pressure recorder, shown schematically in FIG. 2B, provides a second or "outside" recorder whose pressure record can be compared with the data gathered by the upper or "inside" recorder at 14.

Turning now to FIGS. 5A and 5B, a preferred embodiment of a pump assembly 17 that can be operated by manipulation of the pipe string 10 to cause expansion of the packer elements 20 and 20' is shown in greater detail. The pump 17 includes a housing 105 that extends downwardly in telescoping relation over a mandrel assembly 107 and is arranged for reciprocating motion with respect thereto between spaced longitudinal positions. The housing 105 is constituted by a series of threadedly interconnected tubular members including an upper sub 108, a cylinder section 109 and a splined section 110. The mandrel assembly 107 also comprises a number of interconnected, separate members including a flow tube 112, a valve section 113, a cylinder section 114 and a jack thread section 115 which has a pipe joint or collar 116 threaded on its lower end. Additionally, an elongated tube 117 is fixed concentrically within the members 114 and 115 and has its outer surface laterally spaced with respect thereto to provide an annular inflation fluid passage 118. The through bores of tube 117 and the mandrel sections 113 and 112 provide a central opening 119 for the passage of formation fluids through the pump assembly 17 from one end to the other. The upper sub 108 has an internal thread 120 for connection with the screen assembly 116 immediately thereabove, whereas the collar 116 has a similar thread 121 to adapt it for connection to the packer deflate and equalizing valve 18 located below the pump assembly 17.

Normally, that is when the tools are being lowered into the borehole, the housing 105 is locked in a lower position with respect to the mandrel assembly 107 by a clutch nut 123 (FIG. 5B) that is threaded at 124 to the mandrel section 115 and has a slidable spline connection 125 to the housing section 110. The clutch nut 123 engages above an inwardly extending shoulder 126 at the lower end of the housing section 110 to prevent upward movement, and several stacked thrust washers or bearings 127 can be located between the shoulder 126 and the upper face of the collar 116 to enable rota-

tion with relative ease. Rotation of the housing 105 with respect to the mandrel assembly 107 will cause the clutch nut 123 to feed upwardly until it comes into contact with a shoulder 128 on the mandrel, in which position the housing 105 is free to be moved upwardly and downwardly within limits along the mandrel assembly 107 in response to vertical motion of the pipe string 10 at the surface.

The lower end of housing cylinder section 109 is provided with a sleeve piston 129 that is sealed with respect to the mandrel cylinder section 114 by seal rings 130. The annular cavity 131 located above the sleeve piston 129 provides the working volume of the pump. The upper end of the cylinder space 131 is defined by a check valve system indicated generally at 132 which includes a fluid intake valve 133 and an exhaust valve 134. The intake valve 133 comprises an annular member that is pressed upwardly by a coil spring 135 against a valve seat ring 136, whereas the exhaust valve 134 is constituted by a stepped diameter sleeve that is pressed downwardly by the coil spring 135 in a lower position where it spans one or more fluid exhaust ports 137 that lead to the annular inflation passage 118 located between the hollow tube 117 and the inner surface of the mandrel cylinder section 114. Inasmuch as the valve sleeve 134 has a resultant transverse pressure area defined by the difference between the seal areas of the rings 138 and 139, it will be appreciated that a greater fluid pressure generated in the cylinder space 131 during upward movement of the housing 105 relative to the mandrel assembly 107 will shift the valve sleeve upwardly against the bias afforded by the coil spring 135 to a position uncovering the exhaust ports 137, as shown in greater detail in FIG. 9A, so that fluids under pressure can be supplied to the passage 118. On the other hand, during downward relative movement the spring 135 pushes the valve sleeve 134 closed, and a reduction in cylinder pressure below hydrostatic fluid pressure will cause the intake valve 133 to move away from the seat ring 136 as shown in FIG. 9B, thereby admitting well fluids into the cylinder space 131 and allowing it to fill during such downward relative movement. When the housing 105 reaches the bottom of its stroke, the spring 135 will push the intake valve 133 upwardly to closed position so that the pumping cycle can be repeated. As shown in FIG. 5A, the intake valve 133 carries a seal ring 140 that seals against the inner wall surface of the housing section 109, and is slidably arranged around a thickened wall portion of the mandrel section 113 which is longitudinally grooved at 141 to provide for fluid entry past the valve. The valve seat ring 139 may be provided with spaced apart, annular projections on its lower face that straddle the grooves 141 to provide a fluid tight interfit in the closed position of the valve, the inner projection resting on a mandrel shoulder 147 and the outer projection abutting the top surface of the valve element 133.

It should be noted at this point that the valve seat ring 136 is vertically movable to some extent, but normally is held in its lower position by a yieldable structure 143 that may comprise, for example, a series of Bellville washers located below an adjustable retaining nut 144 threaded on the mandrel section 113. The nut 144 and the washers 143 are located on a reduced diameter portion 145 of the mandrel section, the portion 145 having circumferentially spaced, longitudinally extending grooves 146 that provide for the passage of fluids inter-

nally of the nuts 144 and the washers 143. Thus it will be recognized that when the pressure generated in the cylinder space 131 reaches a certain predetermined maximum value, the seat ring 136 can be forced upwardly together with the valve element 133 to disengage the inner projection from the shoulder surface 147 as shown in FIG. 9C to allow pressurized fluids in the cylinder space 131 to vent out of via the grooves 146. This system dictates a maximum value of inflation pressure that can be supplied by the pump assembly 17 to the inflatable packer elements 20 and 20', which value is sufficient to fully expand them against the well bore wall while providing a protection against excessive inflation pressures that might otherwise result in damage. The magnitude of the pressure at which the seat ring 136 will move upwardly is set at a preselected value by adjustment of the preload in the washer springs 143 through appropriate vertical adjustment of the retainer nut 144.

The upper sub 108 of the housing assembly 105 provides fluids passages to the check valve system 132 and is, as previously mentioned, connected to the lower end of the screen assembly 16. As shown in FIG. 5A, a seal nipple 149 on the lower end of the screen assembly is sized to fit over the upper end of the tube 112 and carries seal rings 150 that engage the internal wall surface 151 of the sub 108. A plurality of vertically extending ports 152 serve to conduct fluids from the screen assembly 16 through the wall of the sub 108 and into the region above the check valve assembly 132. The lower portion of the sub 108 carries a seal sleeve 153 with a through bore that receives the tube 112. Seal rings 154 and 155 prevent fluid leakage between the ports 152 and the bore of the tube 112 during longitudinal relative movement. The seal rings 154 engage on a smaller diameter than do the seal rings 130 on the piston 129, so that during upward movement of the housing 105 relative to the mandrel assembly 107, a greater volume of well fluids will be brought into the pump assembly 17 than is required to fill the working volume of the pump during the next or subsequent downward movement. Thus, during each downward movement, not only is fluid supplied to fill the chamber 131, but also a certain amount of the fluids is forced back upwardly into the screen assembly 16 via the ports 152 to provide a back-flushing action to ensure that the screen assembly, to be described in detail herebelow, cannot become clogged by debris or other foreign matter in the well fluids.

The upper end of the lower flow tube 117 is provided with an enlarged head 159 that carries seal rings 160 and is interfitted between a shoulder 161 on the mandrel section 113 and the upper end face of the mandrel section 114. The lowermost end of the tube 117 is received by a flow coupling 162 (FIG. 5B) having seals 163 to prevent fluid leakage. The flow coupling 162 has an outwardly directed flange 164 at its upper end that is longitudinally grooved to provide for the flow of inflation fluids from the passage 118 into the annular area between the coupling and the body of the packer deflate and equalizing valve 18 connected immediately below the pump assembly 19.

The well fluids coming into the pump assembly 17 pass through the screen sub assembly 16 shown in FIGS. 4A and 4B, wherein inner and outer members 170 and 171 are rigidly fixed and laterally spaced to provide an annular passage space 172 that is placed in

communication with the well bore by a plurality of ports 173. The lower end of the passage space 172 is joined by a port 174 to a vertically disposed bore 175 that extends downwardly within the wall section of a connecting sub 176 to communicate the fluids to the interior of pump assembly 17. The seal nipple 149 is threaded to the lower end of the connecting sub 176 and sealingly interfits with the inner wall 151 of the upper sub 108 of the pump assembly 17 as previously described. The outer member 171 is provided with an external recess throughout a major portion of its length, and a screen element 178, formed of flat, spiral-wound wire or other suitable material, is positioned in the recess 177. The element 178 acts as a filter to prevent rock chips or other debris in the well fluids from coming into the pump assembly 17. A tool joint or collar 179 couples the upper end of the screen assembly 16 to the pressure recorder carrier 15 located immediately thereabove. The throughbore 169 of the member 170 continues the passage for the flow of formation fluids upwardly through the tools.

Turning now to the structural details of the pressure equalizing and packer deflating valve assembly 18 shown in FIGS. 6A and 6B, which assembly functions to enable the pressure of fluids in the isolated formation interval to equalize with the hydrostatic head of fluid immediately above the upper packer 20 upon completion of the test, as well as enabling the packer elements 20 and 20' to be deflated, so that the tools can be withdrawn from the well, the assembly comprises a mandrel 180 having an upper section 181 and a lower section 182, the upper section being provided with a collar 183 to adapt it for connection to the lower end of the pump assembly 17. The mandrel 180 is movable relatively within an outer member or housing 184 formed of threadedly interconnected sections 185, 186 and 187, the lower section or sub 187 being adapted by threads 188 for connection to the upper end of the packer assembly 19. The adjacent mandrel and housing sections 181 and 185 have interengaged splines 188 and 189 to prevent relative rotation and to provide limits for longitudinal relative movement. A valve sleeve 190 is fixed by threads 191 to the lower end portion 187 of the housing 184 and extends upwardly therein, and an elongated flow tube 192 whose upper end is connected to the flow coupling 162 extends downwardly into the valve sleeve 190. The central bore 193 of the flow tube 192 provides an upward passage for formation fluids that are recovered during the test, whereas the outer periphery of the tube is spaced inwardly of the inner wall surface of the mandrel 180 to provide a continuing inflation passage 194 leading from the pump assembly 17 to the packer assembly 19. The telescoping joint comprising the members 180 and 184 can be readily closed by downward movement of the mandrel 180, however upward movement to open position is delayed for a significant time interval by a hydraulic system including a metering piston 195 disposed within a chamber 196 located interiorly of the housing section 186. The piston 195 is sized to provide for a restricted leakage of hydraulic fluid from above to below it during upward movement, however the piston can move away from an annular seat surface 197 during downward movement so that hydraulic fluid can pass freely through external grooves 198 in the mandrel section 182 behind the metering piston. The chamber 196 is closed at its upper end by a seal ring 199 and at

its lower end by a floating balance piston 200 whose lower face is subject to the pressure of fluids in the well annulus via ports 201. The balance piston 200 functions to transmit the pressure of the well fluids to the hydraulic fluid below the metering piston 195 so that the pressure in this region of the chamber is never less than the hydrostatic fluid pressure in the well bore outside.

The lower end section 202 of the mandrel 180 is provided with external bypass grooves 203 that are arranged to communicate the inflation passage 194 with the well annulus via the ports 201 when the mandrel 180 is moved to its fully extended or open position with respect to the housing 184. Communication is by virtue of the fact that the upper ends of the grooves 203 will extend past the O-ring seals 204 to enable fluids to flow from the inflation passage 194 to the well annulus. Moreover the flow tube 192 is provided with similar grooves 205 that normally are positioned below a seal ring 206 on the valve sleeve 190. The upward movement that opens the inflation passage 194 to the well annulus also will position the upper ends of the grooves 205 above the seal ring 206 so that the formation fluid passage 193 is communicated with the well annulus. When this occurs, all pressures, that is to say the inflation pressure within the packer elements 20 and 20' and the pressure in the well bore interval between the packers 20 and 20' are equalized with hydrostatic pressure to enable the packers to deflate and return to their normal, relaxed positions whereby the tools can be withdrawn from the well.

The details of the test valve assembly 13 that is utilized to flow and shut-in the formation once it has been isolated by the packer assembly 19 in response to actuation of the pump 17 are shown in detail in my U.S. Pat. No. 3,308,887, to which reference is made herein. For purposes of completeness of this disclosure however, the tester as shown in FIGS. 2A and 2B includes a mandrel 210 that is connected to the pipe string 12 by a coupling 211. The mandrel 210 is telescopically disposed within a housing 212 whose lower end is threadedly connected to the upper end of the pressure relief valve assembly 14. The mandrel 210 is movable between an upper or extended position and a lower or contracted position within the housing 212 for the purpose of actuating a test valve to open and close a flow path through the tools. The valve assembly as shown in FIG. 2B comprises spaced upper and lower valve heads 213 and 213' that can simultaneously engage valve seats 214 and 214' in order to block fluid flow from within the housing below the lower valve head into the bore 216 above a transverse barrier 217 in the mandrel 210, and which are disengaged from the valve seats by downward movement in order to enable fluids to flow past the barrier via ports 218, an annular elongated sample chamber 219, and ports 220 and 221. Seals 222 and 222' prevent fluid leakage in the closed position. It should be noted that in the closed position, a sample of the fluids flowing upwardly through the tester will be trapped within the sample chamber 219 for recovery to the surface with the tools for later inspection and analysis.

In addition to the valve and sampler section described immediately above, the tester assembly 13 includes an index section 225 and a hydraulic delay section 226. The index section 225 comprises a sleeve 227 that is mounted for rotation relative to both the housing

212 and the mandrel 210 and which carries an index pin 228 that works in a channel system 229 formed in the outer periphery of the mandrel 210. The coaction of the index pin 228 with the channel system 229 as the mandrel 210 is moved vertically within the housing 212 causes the sleeve 227 to swivel between various angular dispositions in order to position one or more internal spline grooves 230 therein in such a manner that corresponding lugs 231 on the mandrel either can or can not pass therethrough. Thus the index system 225 functions basically to provide stops to downward movement of the mandrel 210 in certain positions thereof as will be further discussed herebelow. The delay section 226 (FIG. 2B) includes a metering piston 233 that is mounted on the mandrel 210 and is slidable within a stepped diameter cylinder 234 in the housing 212. The piston 233 is sized transversely in such a manner that hydraulic fluid in the cylinder 234 can leak or meter past the sleeve at a controlled rate during downward movement of the mandrel 210 until the sleeve enters the enlarged diameter portion 235 of the cylinder, whereupon the mandrel 210 can move quickly downwardly to its fully contracted position. The piston 233 is biased by a spring 236 upwardly against a seat 237 provided by a shoulder 238 on the mandrel 210 so that hydraulic fluid can pass only around the periphery of the sleeve during downward movement, however the sleeve can move away from the seat during upward movement. When disengaged from the seat, hydraulic fluid can bypass through recesses 239 internally of the sleeve so that the mandrel 210 can be moved rapidly upwardly to its fully extended position. The ends of the chamber 234 are sealed off by elements 240 and 241 to provide a closed system.

As previously mentioned, an overpressure relief valve assembly 14 is connected to the lower end of the tester housing 212 as shown in FIG. 3, and includes a ported sub 245 having a stepped diameter internal bore 246. The upper end of the sub 245 is connected by a coupling to the lower threaded end of the housing 212, and the lower end of the sub is threaded at 248 for connection to the upper end of the pressure recorder carrier 15. A valve sleeve 249 is longitudinally movable within the sub 245 between an upper position where the side ports 250 provide communication between the well annulus and the bore 251 of the sub, and a lower position as shown where seals 252 and 253 are engaged to prevent fluid flow through the ports. The valve sleeve 249 is sized and arranged to be pushed downwardly to the lower position by a lower end extension 254 (FIG. 2B) of the tester mandrel 210 when the said mandrel is disposed in its lowermost position relative to the housing 212, otherwise the valve sleeve is responsive to force due to pressure differences acting across the transverse cross-sectional area bounded by the seal rings 252 and 253. Thus when the valve sleeve 249 is in the lower closed position and the hydrostatic head of the well fluids outside the ports 250 exceeds the pressure of fluids in the bore 251 of the sub 245, a downward force is developed to keep the valve closed. On the other hand if there is a greater pressure of fluids within the bore 251, upward force is developed tending to shift the valve sleeve 249 upwardly to open position.

The valve assembly 14 operates to relieve excess pressures that may be developed in the annular well bore area between the packer elements 20 and 20' as they are inflated. It will be recognized that once the in-

flatable elements effect a seal with the well bore wall, and since the test valve 13 is not yet open, continued enlargement of the elements by further pumping action will tend to compress the entrapped well fluids therebetween and may raise the fluid pressure in the isolated interval to an excessive value. However, since such pressure acts upwardly on the valve sleeve 243, being communicated to the bore 251 by via the test ports 44 and the various passages 45, 43, 193 and 169, the valve sleeve is forced upwardly to vent fluid to the well annulus above the packer assembly 19 and thereby relieve such excessive pressure. Of course the valve sleeve 246 is forced downwardly to closed position by the end extension 254 of the tester mandrel 210 as the test valve is opened, and will be held in closed position throughout subsequent testing operations by the greater hydrostatic pressure in the well annulus acting through the ports 250 on the transverse pressure area of the valve element.

OPERATION

In operation, the various components of the tool string are in the end-to-end sequence as shown in FIGS. 1A and 1B of the drawings and connected to the drill string 10 preparatory to lowering into the well. The housing 105 of the pump assembly 17 is disposed in its lower position with respect to the mandrel assembly 107, with the clutch nut 123 also in its lower position where its function is to releasably lock the housing and mandrel in a mutually telescoped relationship. This disables the pump assembly 17 until such time as the clutch is released to enable relative longitudinal movement of the housing 105. Of course the inflatable packing elements 20 and 20' are both retracted, and the test valve assembly 13 is closed inasmuch as the mandrel 210 is in an upper or extended position relative to the housing 112, thereby disposing the valve heads 213 and 213' above the flow ports 220 and 218 to prohibit fluid flow. As the equipment is lowered into the borehole to setting depth, the drag springs 27 of the anchor assembly 24 frictionally engage the walls of the bore to prevent rotation as well as to provide a degree of restraint to vertical motion of the equipment. The pipe string 10 is either empty of fluids or may be provided with a column of water to act as a cushion as will be apparent to those skilled in the art. In any event, the pipe string 10 provides a low pressure region which can be communicated with an isolated section of the borehole to induce fluids to flow from the formation into the pipe string if they are capable of so doing.

When the packing assembly 19 is located opposite the formation interval to be tested, the interval is isolated by inflating the packing elements 20 and 20' into sealing contact with the surrounding well bore wall in the following manner. The pipe string 10 is appropriately manipulated to unjail the slip cage with respect to the body member of the anchor 24, and the equipment is lowered. The slips 26 are held against downward movement by the drag springs 27, so that the expander 25 shifts the slips outwardly into gripping contact with the wall of the borehole to prevent downward movement. Next the pipe string 10 is rotated to the right to feed the clutch nut 123 upwardly along the pump mandrel section 115 to the upper position where the housing 105 is free to be reciprocated with respect to the mandrel assembly 107. As the housing 105 is elevated, it will be recognized that the weight of all of the equip-

ment therebelow will resist upward movement of the mandrel assembly 107, so that pressure is generated within the chamber 131 above the piston 129. Such pressure will cause the check valve sleeve 134 to shift upwardly and uncover the ports 137, so that fluids under pressure are supplied via the inflation passage 118, 194 and 34 into the respective interiors of the packing elements 20 and 20'. The pressure causes the elements to inflate and bulge outwardly. When the pump housing 105 reaches the top of its stroke, thus having displaced its working volume of fluid into the inflation passage 118, the pipe string 10 is lowered to recharge the chamber 131 with well fluids. Of course the packer assembly 19 and the mandrel 10 of the pump assembly remain anchored against downward movement by the slips 26. As the housing 105 moves downwardly a reduction of pressure in the chamber 131 as it enlarges in volume during such downward movement enables the spring 135 to push the valve sleeve 134 downwardly to close off the passages leading to the packing elements 20 and 20'. As the pressure is further reduced by an increase in the working volume 131, the hydrostatic head of the well fluids present above the check valve assembly 132 forces the inlet valve 133 downwardly and away from the seat ring 136, thereby enabling the chamber to fill with well fluids as the housing 105 moves downwardly to the bottom of its stroke. When the chamber 131 is fully expanded, the absence of a pressure differential enables the spring 135 to push the inlet valve 133 closed. A second upward movement of the housing 105 will cause an additional volume of fluid under pressure to be displaced through the various inflation passages and into the packing elements 20 and 20' to increase their transverse dimension. In typical practice, dependent upon hole size in relation to the relaxed diameter of the packer elements 20 and 20', a series of seven to ten cycles of the pump 17 will be sufficient to cause the respective outer peripheries of the element to engage the well bore wall as shown in FIG. 2B. Continued actuation of the pump 17 in response to upward and downward pipe motion will continually increase the inflation pressure until the desired pressure is reached. Immediately after the elements actually engage the well wall, the assembly becomes firmly anchored against upward movement due to considerable frictional restraint between the packing elements and the surrounding well bore wall.

As previously noted, the difference in seal dimensions between the piston 129 and the mandrel assembly 107 on the one hand, and the seal collar 153 and the tube 112 on the other, are such that a greater volume of well fluid is drawn in through the screen sub 16 than is required for the displacement volume of the pump chamber 131, with the result that during each downward or suction stroke of the housing 105, a certain amount of excess fluid is discharged back to the well annulus via the screen to backflush and purge the openings in the screen element 178. Thus it is practically impossible for the screen to become plugged and result in a misrun as the case for prior art devices of this type.

When a predetermined maximum inflation pressure has been developed within the inflatable elements 20 and 20' through operation of the pump assembly 17 as described above, the inlet valve seat ring 136 will be forced upwardly and away from the mandrel shoulder 147 on each subsequent upward movement so that all

the fluids in the chamber 131 are vented through the screen sub lack to the well annulus, rather than being displaced into the inflation passage 118. Since the amount of force required at the surface to lift the pipe string 10 is directly related to the pressures developed within the chamber 131 and resisting upward movement of the piston 129, the amount of such force will increase until the pressures generated during the upward movements reach a magnitude sufficient to force the seat ring 136 upwardly, after which the force required to lift the pipe 10 during each pumping stroke will remain substantially constant. Thus the weight indicator at the rig floor can be observed by the tool operator and gives a positive indication of the performance of the downhole tools. That is to say, when the weight value stops increasing during each upward movement of the pipe string, the operator is assured that the packing elements 20 and 20' are fully expanded to the proper inflation pressure and can discontinue further operation of the pump assembly 17.

It should be noted at this point that upward movement is appropriate to open the pressure equalizing and packer deflating assembly 18, whereas downward movement is used to open the test valve 13. However, the operation of the respective hydraulic delay pistons 195 and 233 of these tools enables the pump assembly 17 to be actuated by repetitive downward and upward movements without opening the test valve or the equalizing valve because such movements occur during substantially lesser time intervals than is required for the delay pistons to meter to a released position. Thus the test and equalizing valves remain closed during operation of the pump assembly 17. Also, as previously mentioned, should an excessive "squeeze" fluid pressure tend to develop within the isolated interval of the well bore between the packing elements 20 and 20' due to expansion thereof subsequent to obtaining effective sealing action against the well bore wall, the excess pressure causes upward movement of the bleed valve element 249 so that the pressure is vented to the well annulus above the upper packing element 20 through the side ports 250. Of course the valve element 249 is shifted back to the lower closed position as the tester valve 13 is opened to initiate the test.

When it is desired to open the tester valve 13, the weight of the pipe string 10 is imposed upon the tools for the length of time necessary to overcome the hydraulic delay section 226. The mandrel 210 moves slowly downwardly during this time interval as the metering piston 233 approaches the enlarged diameter portion 235 of the chamber 234, and then moves rapidly downwardly to its fully contracted position. The valve heads 213 and 213' are thereby positioned below the test ports 220 and 218 to open a flow path through the sample chamber 217 and the mandrel ports 221 into the pipe string 12. Since the pipe string is initially at atmospheric or other low pressure, formation fluids in the isolated well interval between the expanded packing elements 20 and 20' will enter the ports 55 and flow upwardly through the passage 44, the ports 43, the bore 193 of the flow tube 192, through the central opening of the pump mandrel assembly 107, the bore 169 of the screen sub 16, through the pressure recorder carrier 15 and the excess pressure sub 14, and finally through the test valve assembly 13 into the pipe string 12. After a relatively short period of time necessary to draw down the pressure in the interval of the well bore

between the packing elements 20 and 20', the pipe string 10 is raised to shift the tester mandrel 210 upwardly and close the test ports 218 and 220. The formation is thereby shut-in to enable recordal by the gauge in the carrier 15 of pressure built-up data from which various formation and well fluids parameters can be determined as will be appreciated by those skilled in the art. Of course the tester valve can be repeatedly opened and closed as desired to gather further flow and shut-in pressure information, and each time the tester is closed a flowing sample of flowing formation fluids is trapped within the chamber 219. At all times during the test, of course the straddle bypass formed by the lateral ports 47, the bore 42 of the flow tube 45, the ports 75, the annulus space 77 and the lateral ports 79, remains open to ensure that the hydrostatic pressure of the well fluids above the upper packing element 20 is substantially equalized with the corresponding pressure of well fluids below the lower packing element 20'. The lower pressure recorder in the carrier sub 28 records the fluid pressure within the isolated interval between the elements 20 and 20' by virtue of being in communication therewith via the lateral ports 100, the bore 99 of the flow tube 78 and the bore 98 of the equalizing valve tube 90. The pressure record obtained thereby can, of course, be compared with the readings taken by the upper pressure recorder at 15.

When it is desired to terminate the test, a strain is placed in the pipe string 10, and the tension is maintained for a time sufficient to overcome the retarding action of the hydraulic delay piston 195 in the equalizing and deflate valve assembly 18. As the piston 195 reaches the upper end of the chamber 196, the equalizing grooves 203 and 205 are disposed above the respective seal rings 206 and 204 to communicate both the inflation passage 194 and the test passage 193 with the well annulus above the upper packing element 20 via the ports 201. In this manner, all the various pressures are equalized with one another, and the packing elements 20 and 20' will inherently deflate and retract to their original relaxed dimensions. Upward movement of the entire packing assembly 19 will cause extension of the lower equalizing sub 23 whereby the lowermost portion 91 of the inflation passage is communicated with the well annulus via the ports in ring 92 and the outer member ports 97. Further upward movement will unset the slips 26 of the anchor 24 from the well bore wall and cause them to be shifted inwardly by the slidable spline connections. Thus the equipment can be withdrawn intact from the well bore when the pressure records and the sample of formation fluids can be analyzed, or for that matter can be moved to another level in the well for additional tests.

Sincer certain changes or modifications may be made by those skilled in the art without departing from the inventive concepts disclosed herein, it is the aim of the appended claims to cover all such changes and modifications falling within the true spirit and scope of the present invention.

I claim:

1. Apparatus adapted for use in drill stem testing operations wherein normally retracted inflatable packer elements are expanded by pressurized fluid into sealing contact with the well bore wall in order to isolate an interval of the borehole, comprising: a body structure having concentrically disposed tubular members providing an annular inflation passage therebetween; a

housing structure telescopically disposed over said body structure and movable upwardly and downwardly with respect thereto; means on said housing and body structures defining a chamber that is contracted in volume during upward movement of said housing structure, and expanded in volume during downward movement of said housing structure; first passage and valve means enabling said chamber to fill with fluid during said downward movement and being normally closed during said upward movement; and second passage and valve means for conducting pressurized fluid from said chamber to said inflation passage during said upward movement and being normally closed during said downward movement.

2. The apparatus of claim 1 wherein said first valve means comprises a downwardly opening check valve element at the upper end of said chamber, said element being sealingly slidable with respect to said housing structure and engageable with a valve seat carried by said body structure.

3. The apparatus of claim 2 wherein said second valve means comprises a sleeve member movable vertically with respect to said body structure between an upper open position and a lower closed position, said sleeve member providing a resultant transverse pressure surface that is subject on its lower side to the pressure of fluids in said chamber and on its upper side to the pressure of fluids in said inflation passage.

4. The apparatus of claim 3 further including spring means reacting between said valve element and said sleeve member for urging said valve element upwardly toward its closed position and said sleeve member downwardly toward its closed position.

5. The apparatus of claim 1 further including rotationally releasably clutch means for preventing upward movement of said housing structure relative to said body structure during lowering of said apparatus into the borehole.

6. The apparatus of claim 5 wherein said clutch means includes a threaded section of said body structure, a nut member threaded to said section and being slidably splined to said housing structure, whereby rotation of said housing structure relative to said body structure functions to feed said nut member along said body structure from a position preventing relative movement to a position permitting such relative movement.

7. Apparatus adapted for inflating an inflatable packer element in a borehole, comprising: an elongated body structure including concentrically disposed inner and outer tubular members providing a formation fluid flow passage through the center of said inner member and an annular inflation passage between said inner member and said outer member; an elongated housing structure disposed over said body structure and movable with respect thereto between an upper position and a lower position; said housing structure having an inwardly directed piston section that is sealingly slidable against an outer wall surface of said outer member and defining the lower wall of an annular working chamber extending longitudinally between said housing and body structures; a suction passage leading into the upper end of said chamber for conveying fluid thereto; a discharge passage proximate the upper end of said chamber for supplying fluid under pressure from said chamber to said inflation passage; first valve means for opening said suction passage during downward move-

ment of said housing structure to enable said chamber to fill during such downward movement, said first valve means being normally closed during upward movement of said housing structure; and second valve means for closing said exhaust passage during downward movement of said housing structure and for opening said exhaust passage during upward movement to enable displacement of fluids under pressure from said chamber to said inflation passage during such upward movement.

8. The apparatus of claim 7 wherein said first valve means includes an annular valve element movably mounted on said body structure and sealingly slidable against an inner wall surface of said housing structure; said valve element coacting with a valve seat carried by said body structure and being movable downwardly away from said valve seat during downward movement of said housing structure and upwardly against said valve seat during upward movement of said housing structure.

9. The apparatus of claim 8 further including spring means for urging said valve element in an upward direction and against said valve seat.

10. The apparatus of claim 8 further including means for limiting the pressure that can be developed within said chamber during upward movement of said housing structure to correspondingly limit the magnitude of inflation pressure to be applied to said inflatable packer element.

11. The apparatus of claim 10 wherein said limiting means includes a vent passage leading from the upper end of said chamber, said valve seat being mounted for limited vertical movement with respect to said body structure, said vent passage being normally closed by coengageable means on said body structure and said valve seat; and yieldable means applying a selected closing force to said valve seat tending to maintain said coengageable means engaged, the development of a predetermined pressure within said chamber overcoming said yieldable means and forcing disengagement of said coengageable means to enable fluid to vent from said chamber via said vent passage.

12. The apparatus of claim 7 wherein said second valve means includes a valve sleeve movable vertically relative to said body structure between an open position and a closed position with respect to said discharge passage, spring means urging closing movement of said valve sleeve, and pressure responsive means for shifting said valve sleeve to its open position during upward movement of said housing structure.

13. The apparatus of claim 12 wherein said pressure responsive means includes a resultant transverse pressure surface with one side exposed to the pressure of fluids in said chamber and the other side exposed to the pressure of fluids in said inflation passage, whereby a greater pressure of fluids in said inflation passage acts together with said spring means to hold said valve sleeve closed, and a greater pressure of fluids in said chamber forces said valve sleeve against the bias afforded by said spring means to open position.

14. The apparatus of claim 7 wherein said suction passage extends from a location in communication with the well bore externally of said housing structure whereby said chamber is supplied with fluids from the well bore; and further including screen means for preventing the entry of debris in the well fluids into said suction passage.

15. Apparatus for use in inflating an inflatable packer element in a borehole, comprising: an elongated body structure providing a downwardly extending inflation passage arranged to convey fluid under pressure to said packer element; an elongated housing structure disposed in telescoping relation on said body structure and movable upwardly and downwardly with respect thereto between contracted and extended relative positions, intermediate portions of said body and housing structures being laterally spaced to define a first chamber means, said housing structure having an inwardly extending piston section that is sealingly slidable on an exterior surface of said body structure to define the lower end of said first chamber means; means on said body structure defining the upper end of said chamber means including first check valve means for admitting fluids into said first chamber means during downward movement of said housing structure, and second check valve means for enabling fluid under pressure to be exhausted from said first chamber means to said inflation passage during upward movement of said housing structure; second chamber means between said housing and body structures providing a suction passage leading to said first chamber means and being defined in part by an inwardly directed shoulder on said housing structure that is sealingly slidable on an exterior surface of said body structure that is of a lesser diameter than said first mentioned exterior surface, whereby said second chamber means has a greater lateral dimension than said first chamber means; and means for communicating said second chamber means with the well bore externally of said housing structure said second chamber means expanding to a greater volume during upward movement of said housing structure than the maximum volume of said first chamber means so that during downward movement of said housing structure an amount of well fluids equal to the difference in the volumes of said first and second chamber means is displaced via said communicating means to the well bore.

16. The apparatus of claim 15 further including screen means for filtering out debris in the well fluids entering said communicating means, the displacement of said amount of well fluids from said second chamber means to the well bore during downward movement of said housing structure serving to backflush said screen means and maintain it clear of debris.

17. Apparatus adapted for isolating an interval of a borehole, comprising: packer means including at least one inflatable element; pump means for supplying fluid under pressure to said inflatable element to expand said element into sealing contact with a well bore wall; check valve means for trapping developed pressures within said element to maintain said element in sealing contact; first selectively operable means above said packer means including a normally closed valve for releasing said developed pressures to enable said element to deflate; and second selectively operable means below said packer means providing an additional valve for releasing said developed pressures to insure complete deflation of said element.

18. The apparatus of claim 17 wherein said first means includes inner and outer members arranged for longitudinal movement between mutually extended and contracted relative positions, said members defining a portion of an inflation passage leading from said pump means to said packer means, said valve being normally closed in the mutually contracted position of

said member and open in the extended relative position.

19. The apparatus of claim 18 further including means for retarding longitudinal relative movement from said contracted position to said extended position to provide a time delay in the opening of said inflation passage.

20. The apparatus of claim 18 wherein said second means includes inner and outer members movable between mutually contracted and extended relative positions, said additional valve being closed in said contracted position and open in said extended position.

21. Valve apparatus disposed between a packer means including at least one inflatable element, and a pump means operable to supply fluid under pressure to said element to effect expansion thereof into sealing contact with a well bore wall, comprising: an inner body structure including concentric tubular members that are laterally spaced throughout their length to provide an annular inflation fluid passage; an outer body structure within which said inner body structure is movable from a mutually contracted relative position to a mutually extended relative position; and valve means on said body structures for opening said inflation passage to the exterior of said outer body structure in said mutually extended relative position and for preventing communication between said inflation passage and the exterior of said outer body structure in said mutually contracted position.

22. The apparatus of claim 21 wherein the inner one of said concentric tubular members has a hollow throughbore to provide a fluid flow passage; and further including an additional valve means operable only in said extended position of said body structures for communicating said throughbore with said inflation passage and thus with the exterior of said outer body structure.

23. The apparatus of claim 22 further including means for retarding longitudinal movement of said inner body structure relative to said outer body structure from said contracted position to said extended position to provide a time delay to opening of both of said valve means.

24. Apparatus for use in isolating an interval of a well bore, comprising: packer means including an inflatable element mounted on a body member and adapted to be expanded outwardly of said body member by fluid under pressure supplied to the interior of said element, said element when expanded coming into sealing contact with the surrounding well bore wall to isolate a region of the well bore from the hydrostatic pressure of fluids thereabove; and means for venting the pressures that may be developed in the well bore below said element during expansion thereof to the well bore above said element, including a fluid passage leading from said isolated interval to the well annulus above said element, and valve means for normally closing said fluid passage, said valve means having a transverse pressure area with one side exposed to the pressure of fluids in said passage and the opposite side exposed to the hydrostatic head of well bore fluids above said inflatable element in such a manner that a developed pressure within said passage in excess of said hydrostatic head will shift said valve means from closed to open position and thereby bleed off said excess pressure.

25. The apparatus of claim 24 further including means movable into contact with said valve means for shifting said valve means from said open position to said closed position.

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