United States Patent [19]

Mignotte

[11] **3,797,572**

[45] **Mar. 19, 1974**

[54] **APPARATUS FOR SELECTIVE FORMATION TREATMENT**

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[73] Assignee: **Baker Oil Tools, Inc.,** Los Angeles, Calif.

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[21] Appl. No.: **284,340**

[52] **U.S. Cl.** **166/127,** 166/128, 166/133, 166/134, 166/146, 166/147

[51] **Int. Cl.** **E21b 23/06,** E21b 33/124

[58] **Field of Search** 166/146, 147, 157, 177, 166/186, 191, 126–131, 133, 134

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Primary Examiner—David H. Brown
Attorney, Agent, or Firm—Bernard Kriegel

[57] **ABSTRACT**

A selective formation treatment tool has a retrievable packer adapted to be set in a well casing above perforations in the casing, and a washing or treating fluid tool has opposed packers for progressively isolating the vertically spaced individual perforated casing sections as the washing or treating tool is progressively moved upwardly to confine the flow of fluid from the tool into the formation through the successive perforations.

20 Claims, 23 Drawing Figures

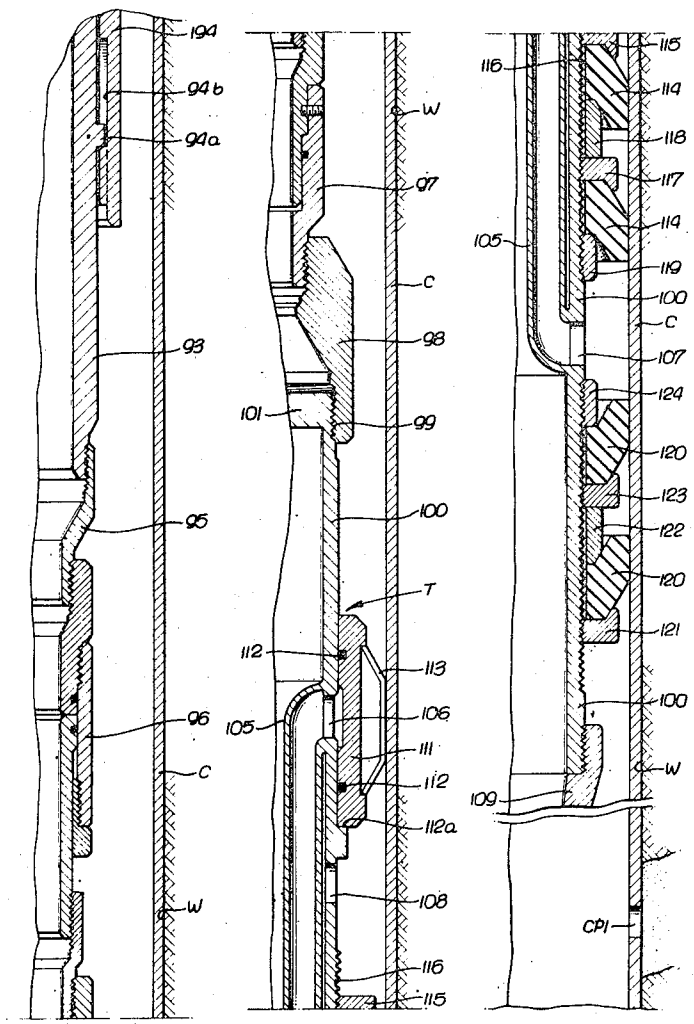


FIG. 1a.

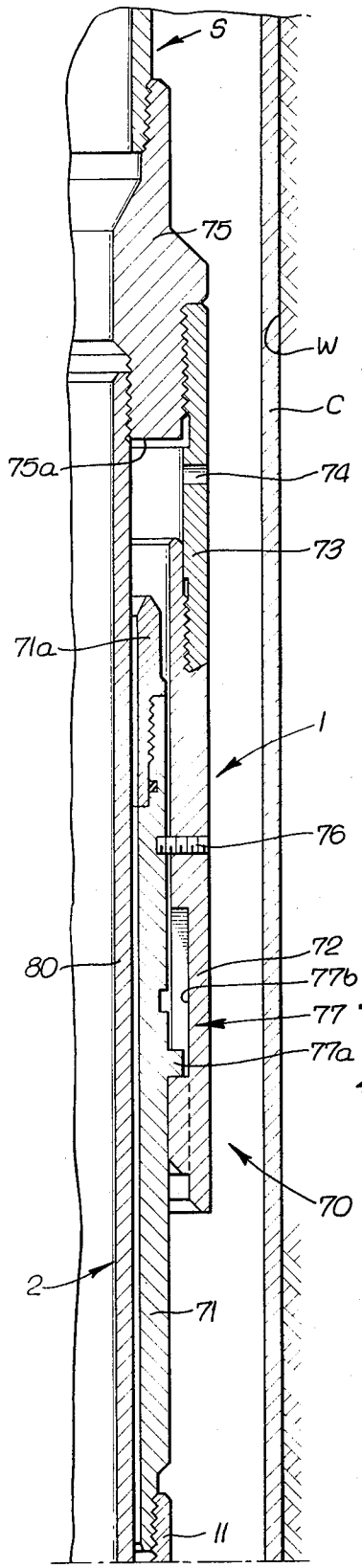


FIG. 1b.

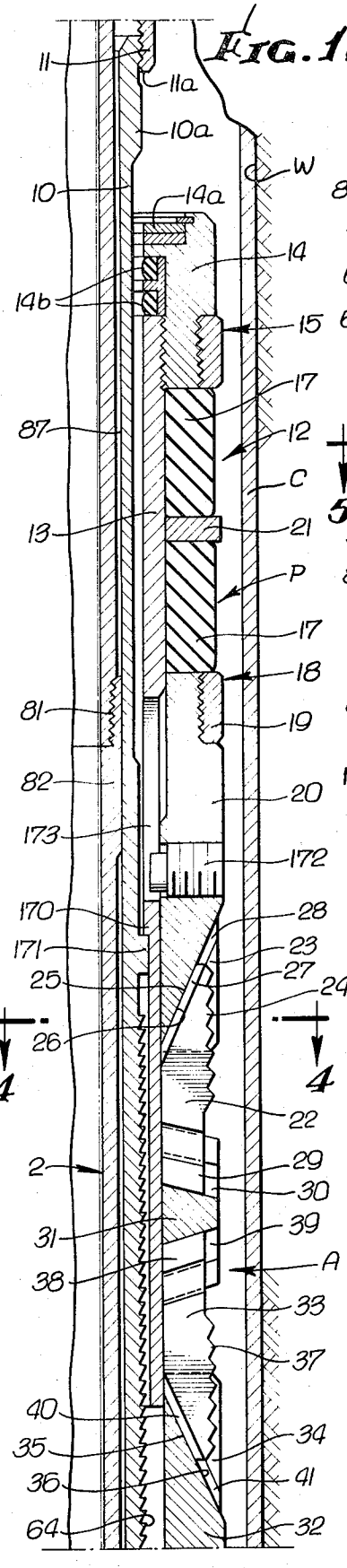


FIG. 1c.

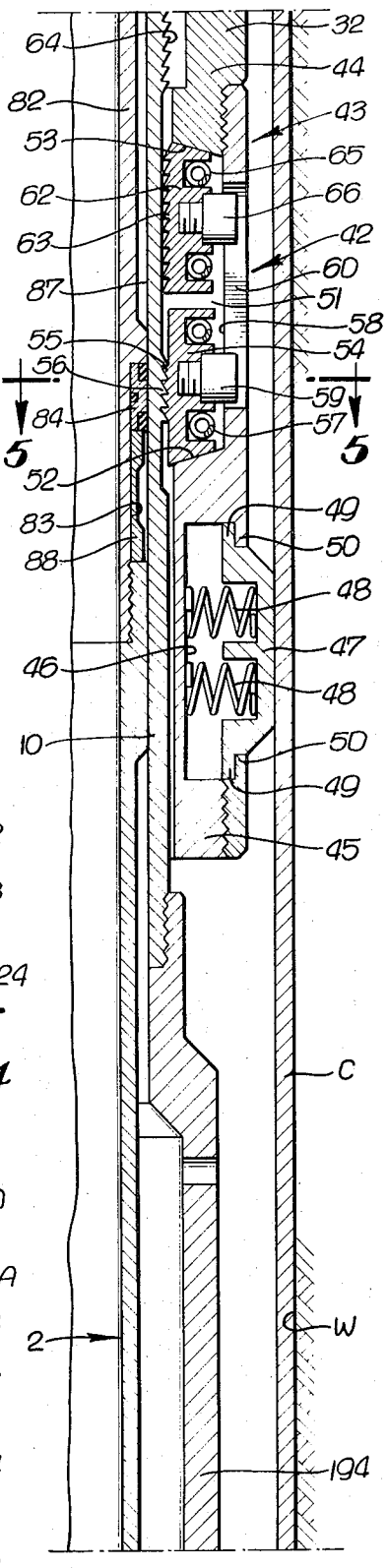


FIG. 1d.

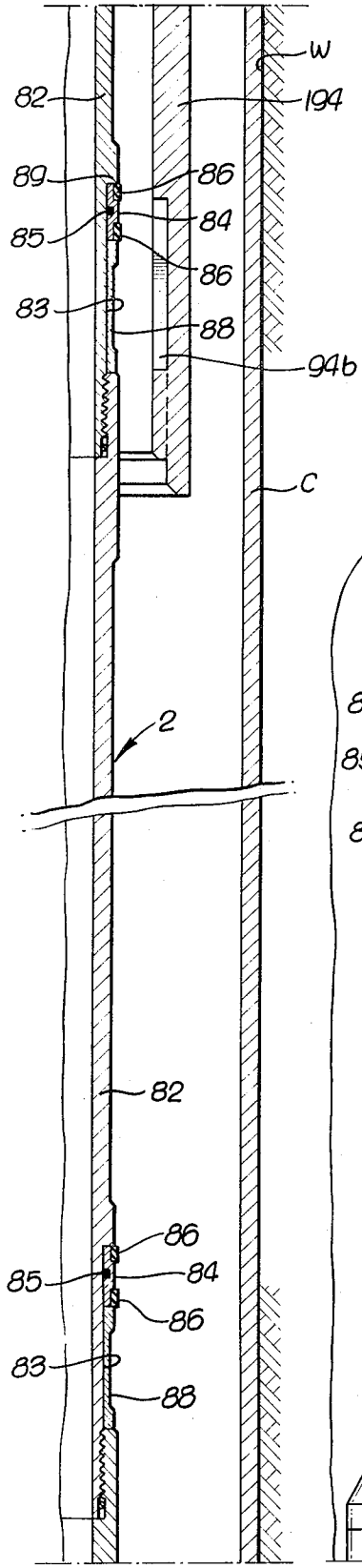


FIG. 1e.

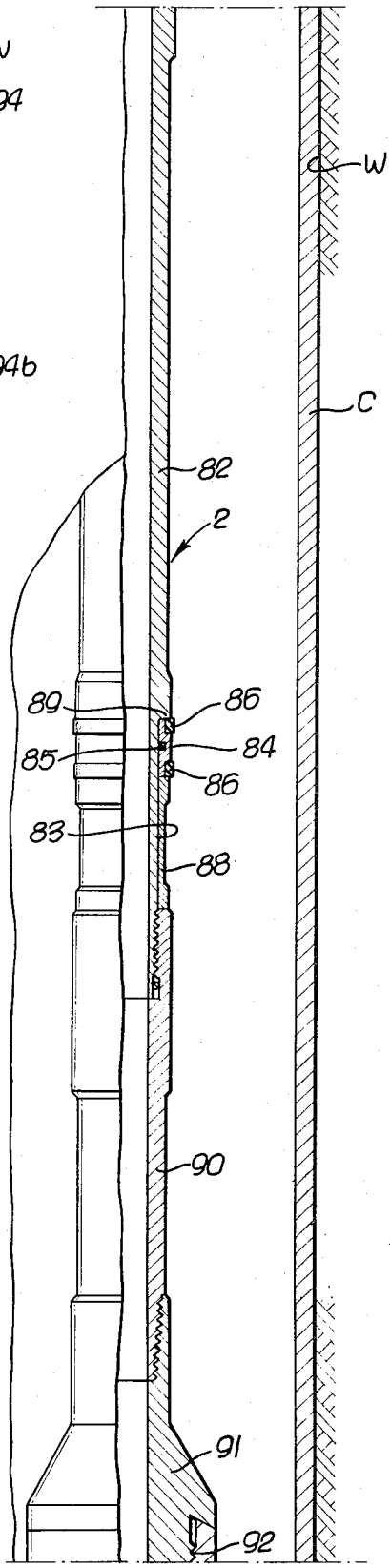


FIG. 1f.

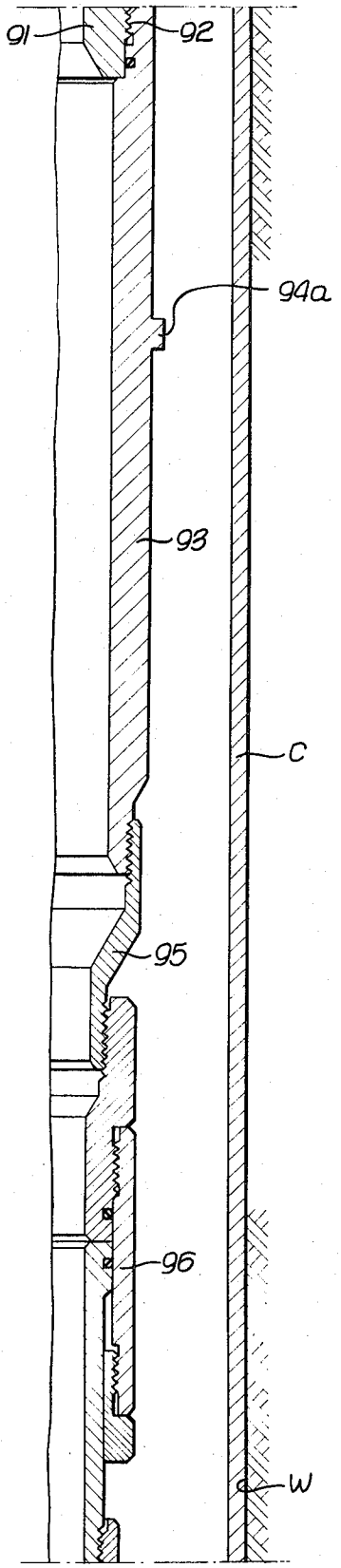


FIG. 1g.

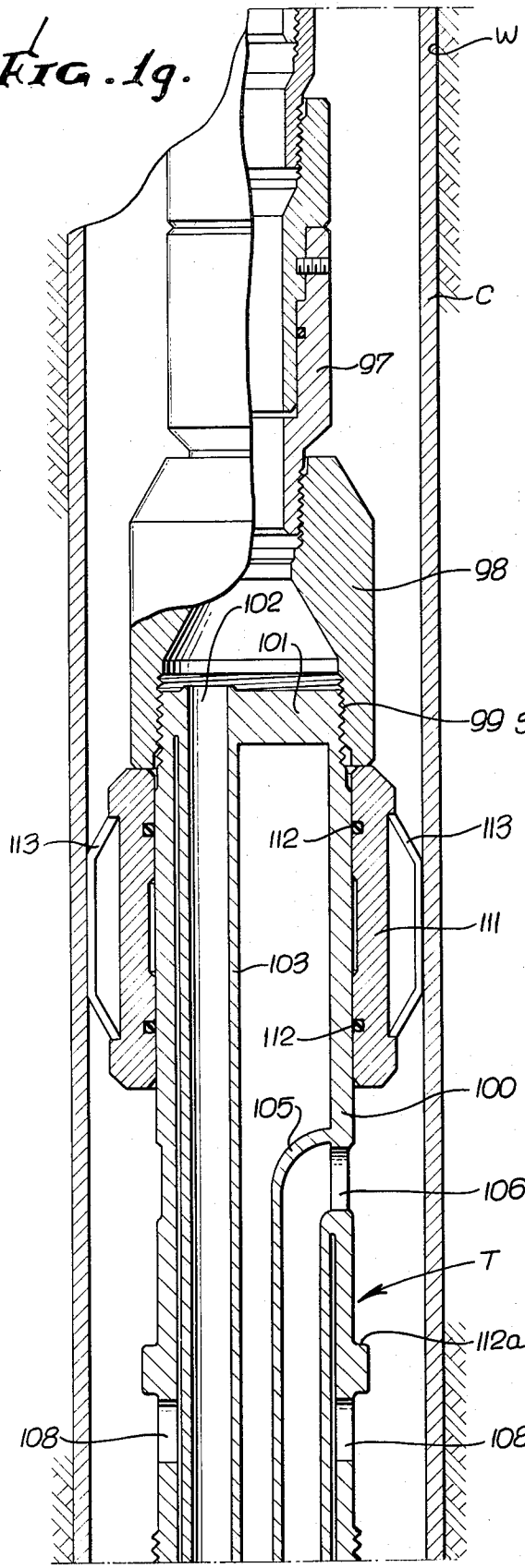

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FIG. 1h.

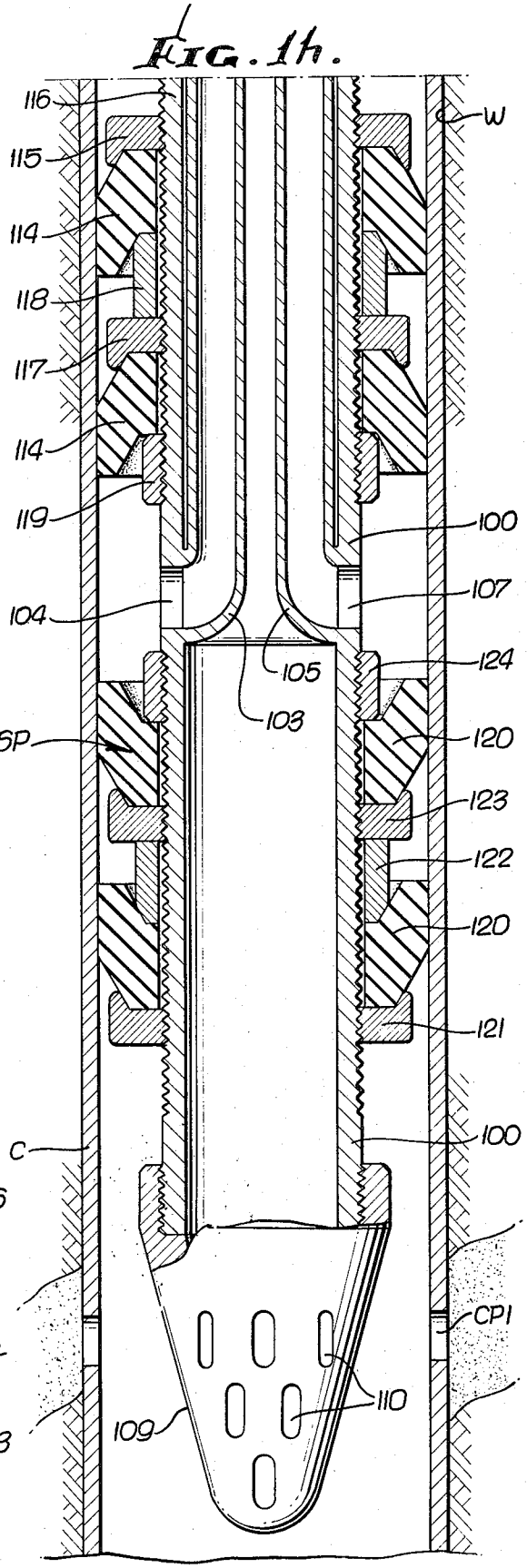

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FIG. 2a.

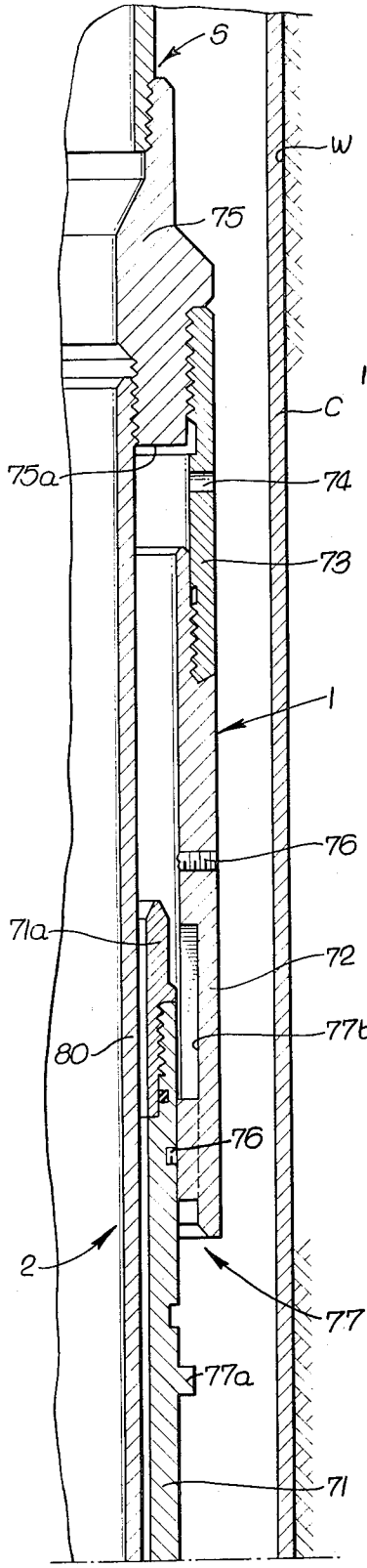


FIG. 2b.

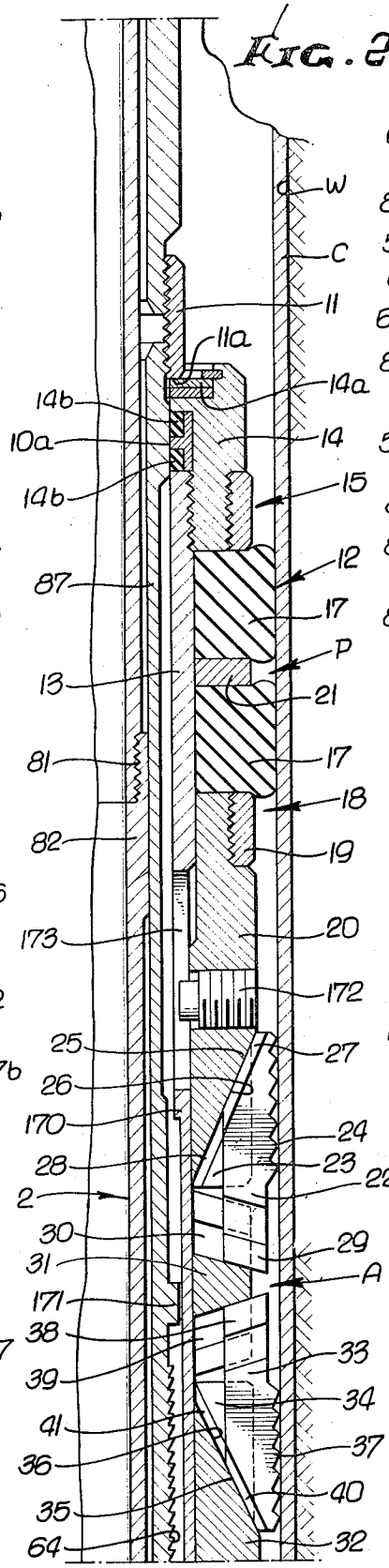


FIG. 2c.

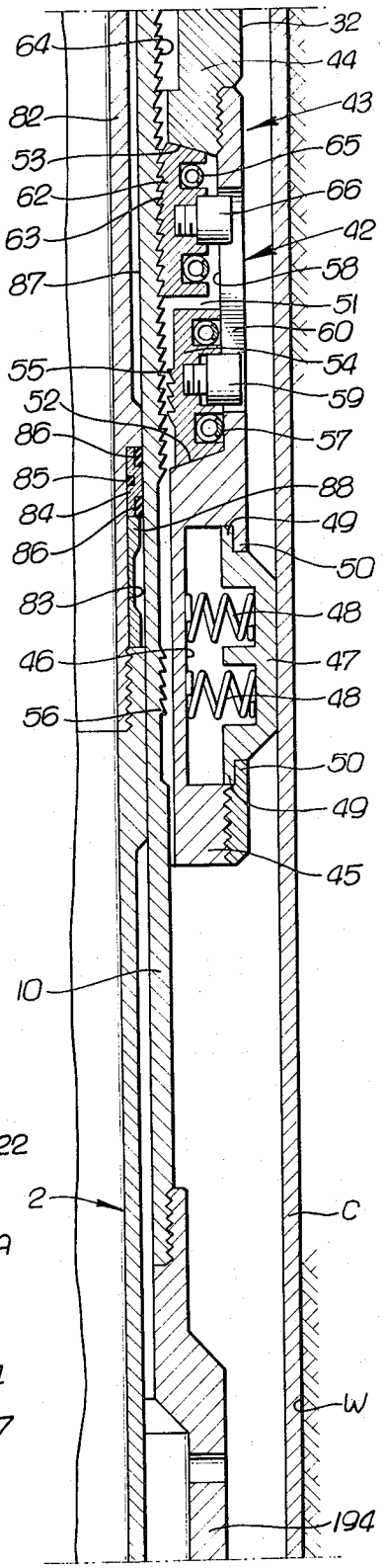


FIG. 2d.

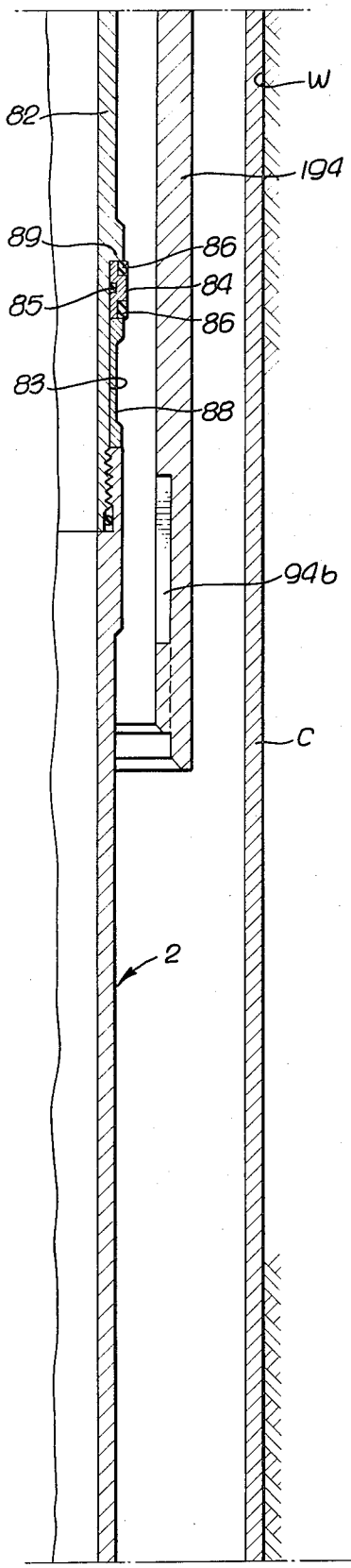


FIG. 2e.

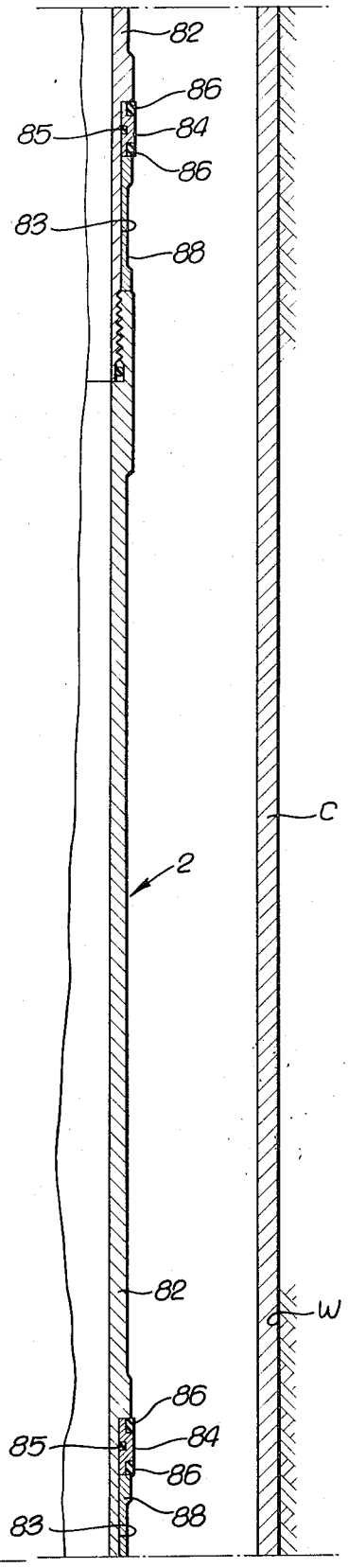


FIG. 2f.

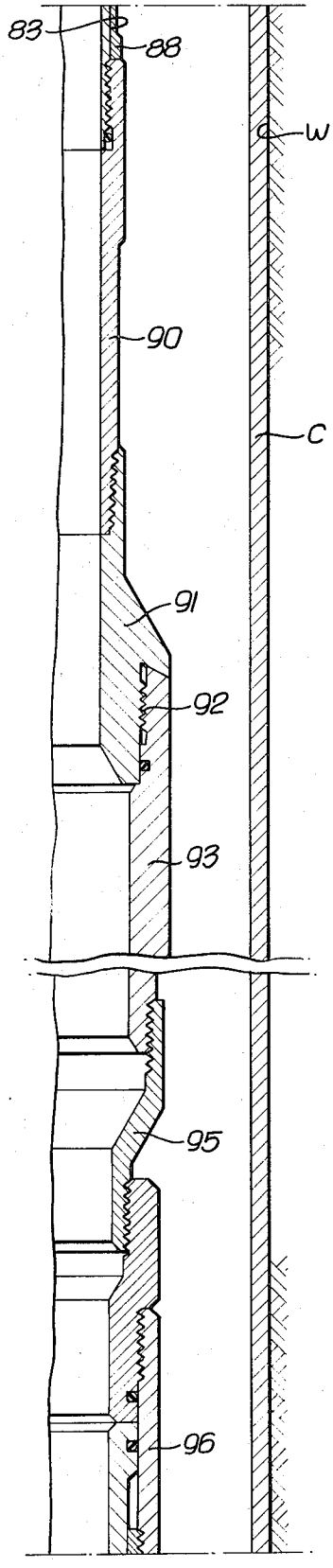


FIG. 2g.

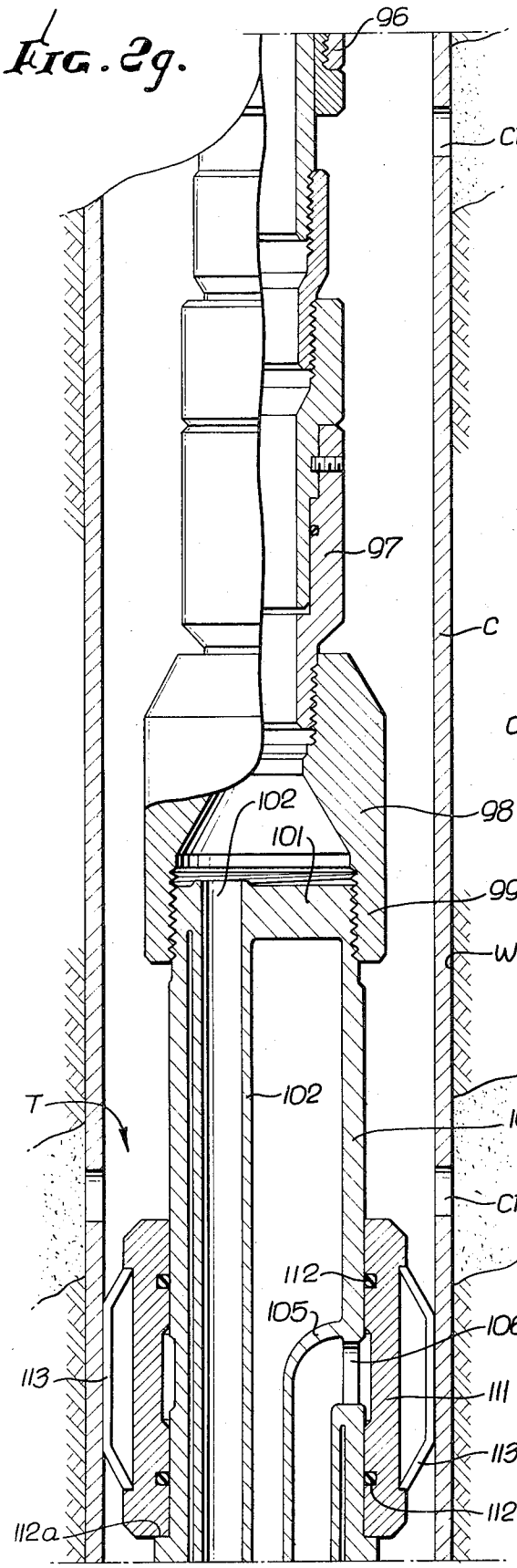

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FIG. 2h.

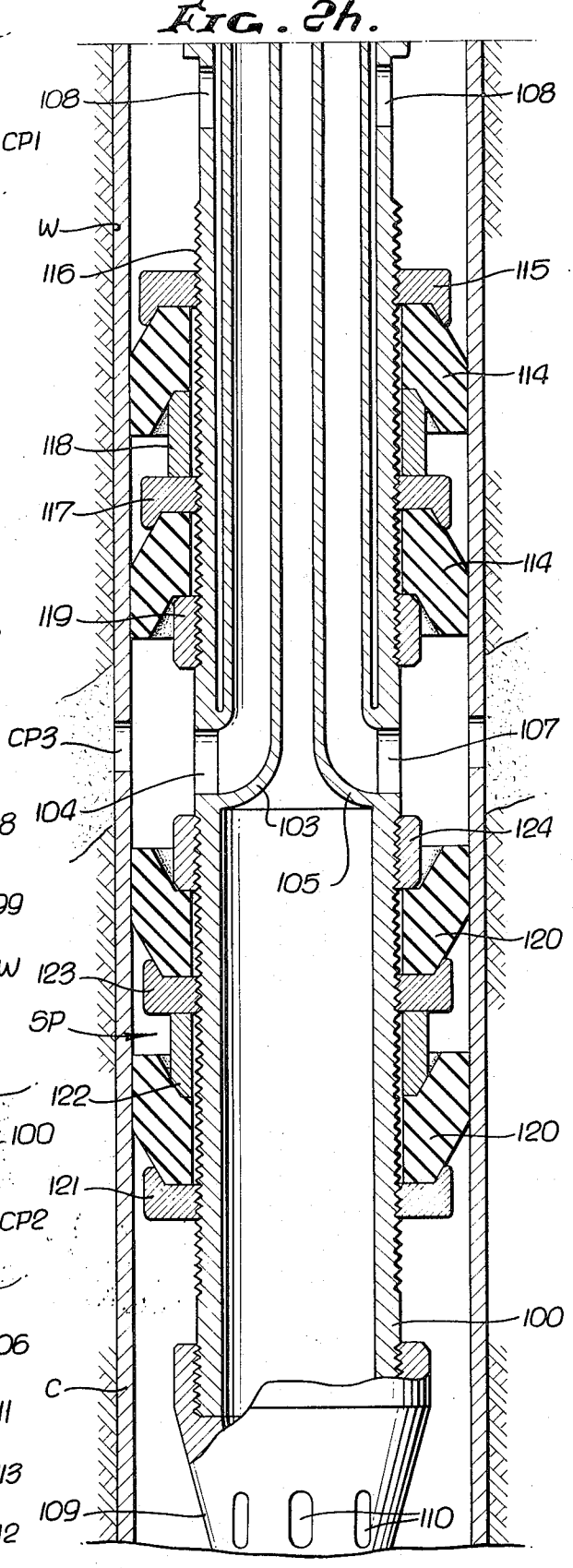

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FIG. 3a.

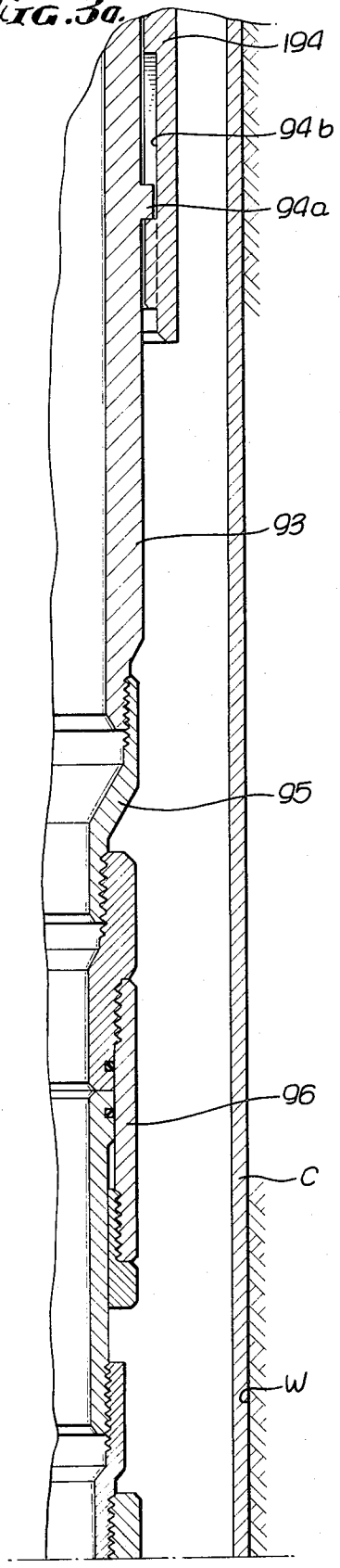


FIG. 3b.

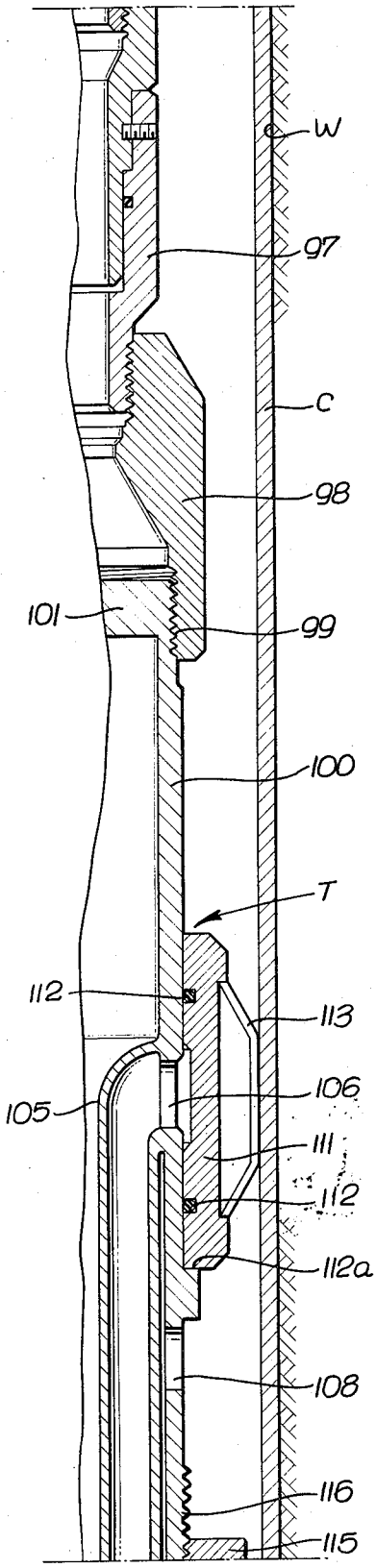


FIG. 3c.

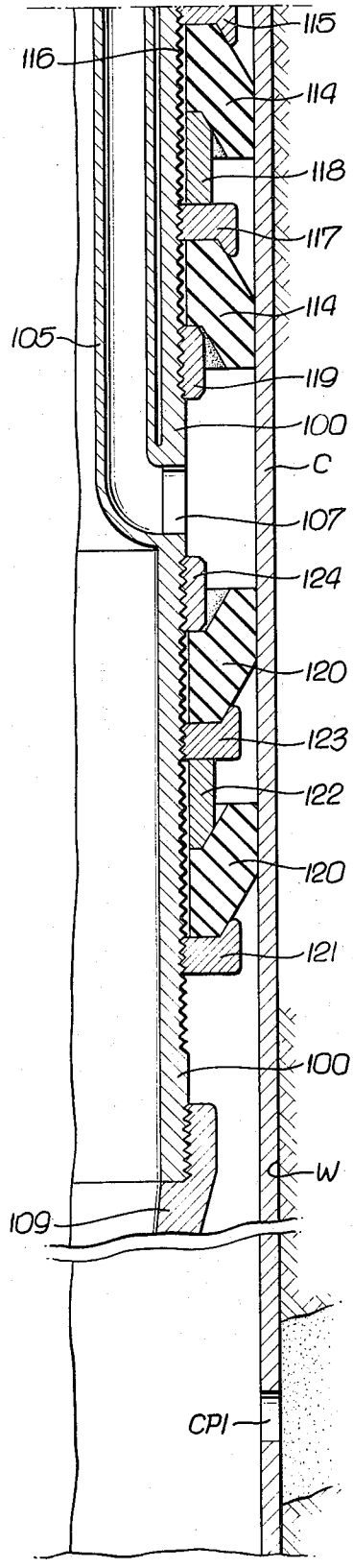


FIG. 4.

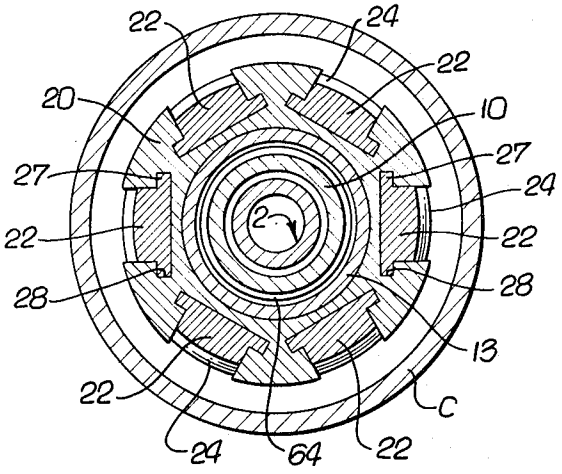
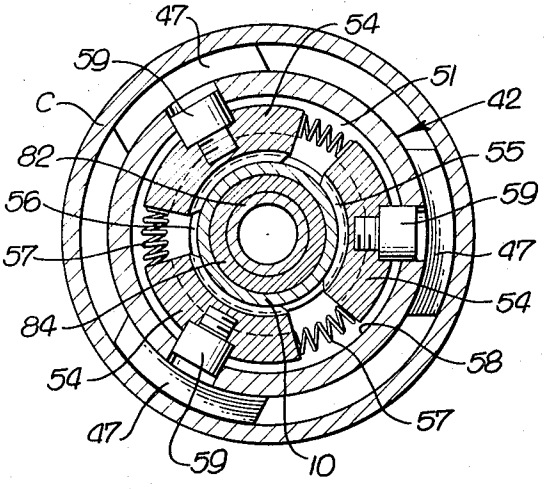


FIG. 5.



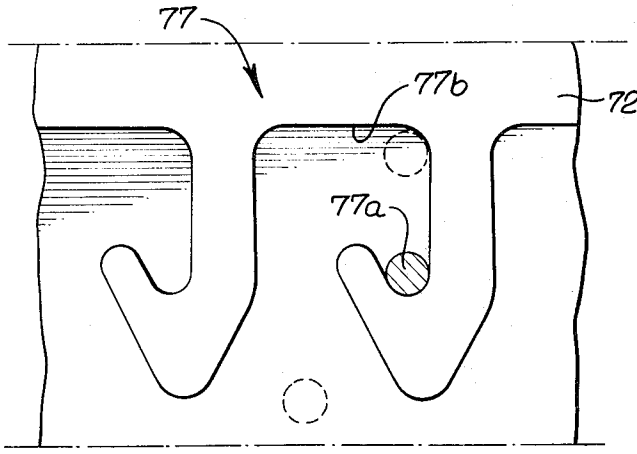
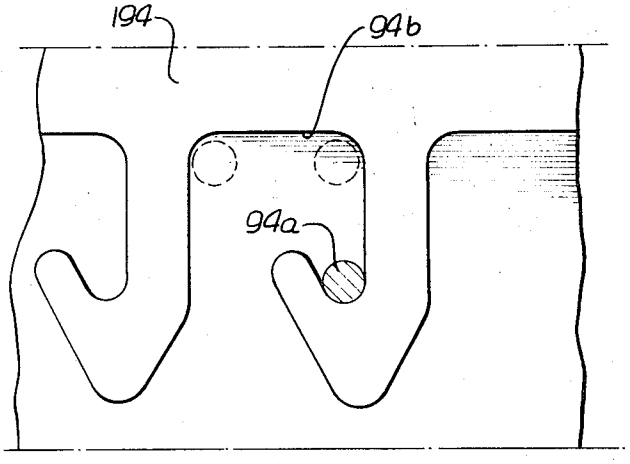


FIG. 6.

FIG. 7.



APPARATUS FOR SELECTIVE FORMATION TREATMENT

In the fluid treatment of earth formation or strata into which or through which a well casing has been set and perforated, a problem has existed in respect of distributing the treating fluid equally through all of the vertically spaced perforations, or at least assuring treatment of the formation or strata adjacent to all of the perforations to the best advantage.

Various tools and methods have been devised to assist in assuring or improving the distribution of treating fluid to all of the perforations, say for sand consolidation treatments, washing, acidizing, and other treatments where fluid is displayed from the top of the wall through a pipe string to the zone to be treated. One common procedure is to straddle the zone with packers, say, for example a straddle packer having opposed packers spaced apart a distance greater than the height of the zone to be treated, thereby exposing all of the perforations in the zone to the treating fluid. However, when the treating fluid reaches the zone to be treated it is applied simultaneously to the formation at all of the perforations, and the ability of the fluid to flow through the perforations is not uniform, due too variable conditions in the formation, so that the bulk of the treating fluid may flow through comparatively few of the perforations and the formation adjacent to other perforations may, therefore, not be adequately or suitably treated. This problem has persisted, even in the face of utilization of selective blocking materials or agents in an effort to divert fluid flow from the more open or permeable formation, where fluid may be lost, to the tighter or less permeable or blocked formation, during the treatment.

An example of such a well treatment is the consolidation of incompetent formation or sand, say, to prevent the sand from flowing into the well through the perforations with the well fluids. A typical sand consolidation treatment involves washing the formation or sand by pumping various fluids through the perforations, such as acid, diesel oil, alcohol, and aromatic oil, and then displacing a cementing material through the perforation, such as a resin containing a catalyst. When the excess resin and catalyst is flushed or washed from the interstices of the sand, the residual cementing material, at the points of contact between the sand particles, bonds the sand into an integrated or competent mass, through which well fluids may flow into the well without carrying entrained sand particles.

Clearly, due to the flow of excessive portions of the washing and cementing fluids into only certain of the perforations, the sand adjacent the other perforations may not be properly cemented together and may continue to flow into the well with the formation fluids following the treatment.

The present invention involves treating the formation or sand penetrated by a well casing which has been perforated at vertically spaced locations by isolating the vertically spaced perforations progressively so that the treating fluids can be separately applied to the individual perforations at each vertically spaced location.

More particularly, the invention provides a selective treatment tool including a retrievable packer adapted to be run into the well on a pipe string and set in the well casing above the uppermost perforations to isolate the perforated zone from the annulus above the packer.

Slidably carried by the packer is an elongated seal tube assembly which is connected to the pipe string and releasably connected to the packer. The seal tube carries a washing or treating tool which has opposed packing cups spaced apart so as to straddle the individual vertically spaced sets of perforations to isolate the respective perforations as the seal tube is shifted longitudinally with respect to the packer. The treating tool has a treating fluid passage opening between the opposed packer cups and communicating through the seal tube with the pipe string, whereby treating fluid can be injected into the formation successively through the vertically spaced sets of perforations, as the seal tube is moved progressively longitudinally relative to the casing.

The tool also includes means providing a circulating fluid passage enabling the circulation of fluids either down the pipe string into the casing between the opposed packers or down the casing and up the pipe string, and a valve is adapted to close the passage during treating or displacement of fluid into the formation. Additional by-pass passages allow the fluid in the well casing to by-pass the tool, as the tool is being run into the well and retrieved.

More specifically, the invention involves providing a retrievable packer having a seal bore therethrough, an elongated seal mandrel extending through the bore and being releasably connected to the packer body, so that the assemblage is adapted to be run into the well on a string of tubing or drill pipe which is manipulated to set the packer and release the pipe string and seal mandrel for longitudinal movement relative to the packer body. The lower end of the seal mandrel carries the washing or treating tool, including the opposed packer cups which are adapted to straddle the respective vertically spaced perforations. The seal mandrel and the packer also have cooperative control means co-engageable to release the packer when a treatment is completed or when it may be necessary to move the packer in the casing.

This invention possesses many other advantages, and has other purposes which may be made more clearly apparent from a consideration of forms in which it may be embodied. These forms are shown in the drawings accompanying and forming part of the present specification. They 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 descriptions are not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

FIGS. 1*a* through 1*h*, together, constitute a longitudinal section showing a selective wall treating tool made in accordance with the invention in condition for running into the well, FIGS. 2*b* through 2*h* being successive downward extensions of FIG. 1*a*;

FIGS. 2*a* through 2*h*, together, constitute a longitudinal quarter section generally corresponding to FIGS. 1*a* through 1*h*, but showing the tool with the packer set in the well casing and the sealing tube moved to a position at which the washing tool is located adjacent to a set of casing perforations which are straddled by the packing cups;

FIGS. 3*a* through 3*c*, together, constitute a fragmentary longitudinal section, showing the sealing tube shifted upwardly relative to the packer to engage a

lower control mechanism prior to release of the packer;

FIG. 4 is a horizontal section, as taken on the line 4—4 of FIG. 1*b*;

FIG. 5 is a horizontal section, as taken on the line 5—5 of FIG. 1*c*;

FIG. 6 is a planar development of the upper control mechanism for releasably connecting the sealing tube to the packer mandrel until the packer is set; and

FIG. 7 is a planar development of the lower control mechanism for connecting the seal tube to the packer for releasing the packer.

As seen in the drawings, a well casing C is set in a well bore W, the casing C being perforated at vertically spaced regions CP1, CP2 and CP3, so that fluids may flow or pass from the earth formation or strata outside the casing into the casing. From time to time, it is necessary or desireable to introduce various treating fluids into the formation from the casing for purposes such as improving the permeability of the formation, thereby enhancing the ability of the formation fluids to flow through the formation to the well, to consolidate incompetent sands, thereby preventing the sand from flowing into the well with the formation fluids, as examples.

However, the injection of the treating fluids into the formation through the perforations poses problems when the various perforations or the adjacent formation at the different levels or vertically spaced locations, may be partially plugged, if not wholly plugged, and the treating fluid tends to flow off through the formation which is most open or permeable, so that treating fluid is not displaced into the less permeable formations at the flow rates available.

Thus, the present invention provides packer means P, including anchor means A, adapted to be run into the well casing C on a pipe or tubing string S and to be set in sealing and anchoring engagement with the casing C above the uppermost perforations CP1. The packer P is initially interconnected to the pipe string S by a control head 1 which supports an elongated seal tube assembly 2 extending longitudinally through the packer P. At the lower end of the seal tube 2, is a washing or treating tool T which carries packing means SP which are axially spaced so as to straddle a set of casing perforations when positioned by shifting of the seal tube 2 relative to the packer P, whereby fluid is injectable into the formation through the single set of isolated perforations. Thus, as will be later described, fluid can be displaced through all of the perforations, but in separate isolated stages to better assure displacement of fluid through all of the perforations and better treatment of the formation, all while the packer seals off the annulus between the pipe string and the casing above the perforations to prevent fluid in the annulus from entering the perforations.

The packer P may be of any well known type adapted to be anchored and released by manipulation of the pipe string. The specific well packer P illustrated includes a tubular mandrel or body 10, the upper portion of which is threadedly secured to a body coupling 11 which is, in turn, attached by means of the control head 1, to the lower end of the string of tubing S, extending to the top of the well bore, and by means of which the apparatus is moved longitudinally in the well casing, is set therewithin, and is released therefrom. The well packer includes an upper packing structure 12 consisting of an elongate sleeve or body 13 slidable on the inner body or mandrel 10, with its upper end threadedly secured to the upper head 14 of the upper abutment 15, packing element 17 surrounding the sleeve 13, the lowermost of which engages a lower abutment 18, including a lower gage ring 19 threadedly mounted on the upper portion of an upper expander 20 which is adapted for relative sliding movement on the outer sleeve or body 13. A spacer ring 21 is provided between adjacent packing elements 17, the latter being made of a suitable pliant and elastic material, such as natural or synthetic rubber, capable of being expanded outwardly upon relative movement of the upper abutment 15 toward the lower abutment 18, but also being capable of inherently retracting when the abutments are subsequently moved relatively away from each other.

The well packer P is adapted to be anchored against downward movement in the well casing C by the coaction between the upper expander 20 and a set of circumferentially spaced upper slips 22 disposed in slots 23 in the expander. These slips have outer teeth 24 and inner tapered surfaces 25 adapted to engage companion downwardly tapering and inclined surfaces 26 in the expander. Relative downward movement of the expander 20 within the slips 22 will shift the latter outwardly to embed their teeth 24 in the wall of the well casing, whereas relative upward movement of the expander with respect to the slips will effect retraction of the latter from the casing. Such retraction will occur because of the provision of oppositely directed inclined tongues or flanges 27 on each slip which are disposed within companion grooves 28 in the sides of each slot (FIG. 4), forming a slidable spline connection therebetween. The slips themselves are movable longitudinally jointly, but can partake of independent lateral or radial movement, by virtue of the reception of T-shaped heads 29 of the slips in companion T-shaped slots 30 in a slip ring 31 encompassing and slidable relatively on the outer sleeve or body 13.

The well packer apparatus P is adapted to be anchored to the well casing C against upward movement therewithin by the coengagement between a lower expander 32 and a set of circumferentially spaced lower slips 33 disposed within companion slots 34 in the lower expander. Tapered inner surfaces 35 of the lower slips engage companion tapered surfaces 36 in the base of the slots 34 which are inclined in an upward and inward direction so that relative upward movement of the lower expander 32 within the lower slips will expand the latter outwardly toward the casing to embed their exterior teeth 37 therewithin. As is true of the upper slips, the lower slips have upper T-shaped heads 38 in companion slots 39 in the slip ring 31 to cause the lower slips to move jointly in a longitudinal direction while allowing them to shift independently laterally to and from the casing C. Relative downward movement of the lower expander 32 with respect to the slips 33 will effect retraction of the latter from the well casing because of the coaction between inclined oppositely directed tongues or flanges 40 of each slip in companion grooves 41 in the expander on opposite sides of the slot 34 in which the slip is disposed, forming a slidable spline connection therebetween.

A control mechanism 42 is provided between the inner mandrel or body 10 and the parts surrounding it, to releasably secure the several sets of slips 22, 33, and

packing structure 12 initially in their retracted positions, to permit expansion of the packing structure and sets of slips against the wall of the well casing, and to releasably retain the packing structure and slips in such outwardly expanded condition. As specifically illustrated in the drawings, the control mechanism or unit includes a control unit and drag block housing 43 surrounding and slidable relative to the inner body or mandrel 10. This housing includes an upper portion 44, integral with and depending from the expander 32 and threadedly secured to a lower control housing portion 45. The control housing portion 45 has a plurality of circumferentially spaced cavities 46 receiving drag blocks 47 urged outwardly into frictional engagement with the wall of the well casing by a plurality of helical compression springs 48 bearing against the base of the cavity and also against the blocks, outward movement of the drag blocks being limited by engagement of stop shoulders 49 with stop shoulders 50 on the housing above and below each drag block. The drag blocks 47 resist longitudinal movement of the housing 43 and lower expander 32 in the well casing, as well as rotary movement therein. However, when sufficient force is exerted, the drag blocks 47 will slide frictionally along the wall of the well casing C.

The lower housing portion 45 and the lower end of the housing portion 44 depending from the lower expander 32 define an internal circumferential groove 51, the lower side 52 of the groove tapering to a slight extent in a downward and inward direction and the upper side 53 of the groove tapering upwardly to a slight extent in an inward direction. Disposed within the groove are upper and lower clutch or lock structures. The lower lock structure includes a plurality of clutch segments or elements 54 having internal ratchet teeth 55 constituted by right-hand buttress threads adapted to mesh with companion right-hand buttress threads 56 on the body or mandrel 10. These segments are urged in an inward direction to releasably hold the buttress threads meshing with the body threads by a plurality of encircling helical tension springs 57. The segments 54 can move radially outward so that their teeth 55 are free from engagement with the lower buttress threads 56 on the body, since there is adequate lateral clearance between the outer surfaces of the thread segments and the outer base portion 58 of the groove in which they are located. Rotation of the segments 54 relative to the housing 42 is prevented by a guide screw 59 threadedly secured to each segment and slidably received within a longitudinally extending slot 60 in the housing. The buttress threads 55, 56 face in the direction disclosed in the drawings, so that the mandrel or body 10 can ratchet upwardly and without rotation through the segments 54, but cannot be moved downwardly except as a result of rotating the inner body or mandrel 10 relative to the segments, rotation of the segments being prevented or resisted by the frictional engagement of the drag blocks 47 against the wall of the well casing.

The right-hand buttress thread connection is preferably a multiple thread, with each thread having a comparatively large lead so that only a comparatively small number of turns of the body 10 within the segments 54 is required to effect full downward unthreading of the body from the segments, whereupon the body or mandrel 10 is free to continue its downward movement without rotation.

The control unit 42 of the mechanism also includes upper clutch segments or elements 62 having downwardly facing ratchet teeth in the form of multiple threads 63 which are preferably lefthand buttress threads and which are adapted to engage companion buttress left-hand threads 64 extending longitudinally along the body thereabove. Encompassing helical springs 65 engage the segments 62 and urge them inwardly, the segments being adapted to be shifted radially outwardly by the threads 64 upon downward movement of the body 10 and its left-hand buttress threads 64 therealong. Once the left-hand buttress threads 64 are engaged with the internal threads 63, the body 10 cannot move upwardly relative to the segments 62 unless the body or mandrel 10 is rotated. Rotation of the segments 62 relative to the housing 42 is prevented by guide screws 66 attached to the segments and received within the longitudinal slots 60 within the housing, the guide screws allowing radial inward and outward shifting of the segments 62 but preventing their rotation, in view of the resistance to rotation afforded by the drag blocks 47.

The left-hand threads 63, 64 are preferably multiple threads having a relatively large lead so that upon rotation of the inner mandrel or body 10, a lesser number of body turns is required to effect upward feeding of the body within the upper set of clutch segments 62, as described hereinbelow.

It is to be noted that the outer sleeve or body 13 extends downwardly within the sets of slips 22, 33 and terminates within the lower expander 32. Its downward position along the inner body or mandrel 10 is limited by engagement of a downwardly facing sleeve shoulder 170 with an external body flange 171 above its left-hand ratchet threads 64. It is further to be noted that relative rotation between the upper expander 20 and outer sleeve or body 13 is prevented by a radial pin 172 threadedly secured in the upper expander and extending into a longitudinal slot 173 in the sleeve, such pin and slot interconnection, however, permitting downward movement of the sleeve or outer body 13 within the upper expander 20 for the purpose of shortening the packing elements 17 and expanding them outwardly into sealing engagement with the wall of the well casing.

Initially, the parts of the apparatus occupy the relative positions illustrated in FIGS. 1*b* and 1*c*, in which the packing structure 12 is retracted as well as the upper and lower sets of slips 22, 33. The lowermost turn off the left-hand buttress thread 64 on the inner body or mandrel 10 is disposed above the upper clutch segments 62, whereas the lower buttress thread 56 is in full mesh with the companion internal threads 55 of the lower clutch segments 54, thereby locking the inner mandrel or body to the control unit housing 43 and the lower expander 32, preventing downward movement of the inner body 10 with respect thereto. The apparatus is connected to the tubular string S and is inserted in and movable downwardly within the well casing. Downward movement of the tubular string S and body 10 is transferred through the lower clutch members 54 to the housing 42 and results in the drag blocks 47 sliding frictionally along the wall of the well casing. The sleeve or outer body 13 is engaging the body flange 171 and cannot move downwardly therealong so as to inadvertently expand the packing elements 17 against the wall of the well casing. The upper expander 20 cannot

shift downwardly along the sleeve 13 in view of the engagement of its radial pin 172 with the sleeve at the lower end of the longitudinal slot 173. As a result, the upper and lower sets of slips 22, 33 are retained in their retracted positions by virtue of their tongue and groove interconnections 27, 28 and 40, 41 with their respective upper and lower expanders 20, 32. Thus, all of the parts externally of the body 10 are retained in their retracted positions allowing the tubular string and apparatus to be moved downwardly through the fluid in the well casing, the latter flowing upwardly through the tubular body into the tubing string and also relatively around the retracted parts.

When the setting location of the well packer P in the well casing C has been reached, the tubular string S and body 10 are rotated to the right to effect a downward unthreading of the lower buttress threads 56 on the mandrel from the lower clutch segments 54, since the lower clutch segments are prevented from rotating by the frictional engagement of the drag blocks 47 against the wall of the well casing. Inasmuch as the coengaging buttress threads are preferably multiple pitch, only a single turn, for example, is sufficient to complete unscrewing of the mandrel threads 56 from the threads 55 of the lower clutch segments 54, freeing the mandrel for downward movement with respect to the parts that surround it. The initial downward movement of the inner body or mandrel 10, as a result of moving the tubular string S downwardly, will cause the body coupling 11 to engage the upper head or abutment 15, shifting the packing structure 12 and upper expander 20 downwardly toward the lower expander 32, since downward movement of the latter is resisted by the frictional engagement of the drag blocks 47 against the casing. Such movement of the upper expander toward the lower expander will effect an outward expansion of the upper and lower sets of slips 22, 33 against the well casing, the left-hand buttress threads 64 shifting downwardly within the segments 62 and ratcheting freely through the latter. In this connection, it is to be noted that the inner mandrel 10 has moved downwardly without rotation within the upper clutch segments 62, and upon moving within the lower clutch segments 54 will merely cam the latter outwardly, and, in fact, hold them outwardly inasmuch as the left-hand threads 64 are of a different hand from the internal threads 55 of the lower segments.

The tubular string S and body 10 can move downwardly in the manner described until the tool takes some of the weight of the tubular string, which will insure that the upper slips 22 have engaged the wall of the well casing C. Thereafter, the tubing string and body can be pulled upwardly, the left-hand mandrel threads 64 meshing and locking with the segments 62 so that such upward pull is transmitted directly through the lower expander 32 to the lower slips 33 to insure embedding of their teeth 37 in the wall of the well casing. The tubular string S and body 10 can again be moved downwardly to apply an additional wedging force of the upper expander 22 within the upper slips 22 to insure their firm anchoring against the wall of the well casing.

The application of additional set down weight on the body coupling 11 and upper abutment 15 will shift the upper abutment toward the lower abutment 18 (which is prevented from moving downardly by the upper slips), to shorten the packing elements 17 and effect their expansion outwardly into firm sealing engagement with the wall of the well casing.

The anchored and packed-off condition of the well packer in the well casing is illustrated in FIGS. 2*b* and 2*c*, in which it is to be noted that the tool is prevented from moving upwardly in the casing by the wedging action of the lower expander 32 in the lower slips 33, the tool being prevented from moving in a downward direction by the wedging action of the upper expander 20 in the upper set of slips 22. The body 10 cannot move downwardly to any further extent in view of the anchoring of the upper slips 22 against the casing, and the firm compression of the packing elements 17 between the outer body 13 and the well casing. The body 10 cannot move upwardly because of the coupling action of the left-hand threads 64 with the upper set of clutch segments 62, which engage the housing extension 44 of the upper expander, the upper thrust being transmitted through the lower set of slips 33 to the well casing.

The control head 1, which, as previously described, connects the packer body or mandrel 10 to the pipe string S, constitutes upper control means 70 by which the packer mandrel 10 is releasable from the pipe string S, after the packer is set in the well casing C to allow freedom of longitudinal movement of the seal tube 2 with respect to the packer. More particularly, the control head 1 includes an inner control sleeve 71 threadedly connected to the coupling 11 and extending initially, as seen in FIGS. 1*a* and 1*b*, upwardly into an outer control sleeve 72 which is threaded to a sleeve 73, having a vent port 74, the sleeve 73, in turn, being threaded on a connector nut 75. This connector nut is threaded onto the tubing string S and threadedly receives the upper end of the seal tube 2. Thus, the tubing string S, the seal tube 2 and the outer control sleeve 72 are unitized.

The inner control sleeve 71 is releasably connected to the outer control sleeve 72 by means of one or more shear screws or frangible members 76, whereby the packer P is adapted to be run into the well casing and initially anchored therein. The shear screw 76 is adapted to transmit sufficient force to the packer mandrel 10 to force it downwardly relative to the outer body 13 to set the slips 22 and 33 upon engagement of the lower end 11*a* of the coupling 11 with suitable abutment ring means 14*a* carried by the abutment structure 15 of the packer. When the anchoring slips have been set in the casing C, thereby resisting further downward movement of the mandrel 10, the frangible connection provided by the shear screw or screws 76 is broken, then allowing the tubing S and the seal tube 2 to be shifted longitudinally relative to the packer P, further downwardly, causing engagement between an upper end ring 71*a* on the inner control sleeve 71 with the lower surface 75*a* of the connector sub 75. Downward force can then be transmitted to the packer mandrel to force it downwardly to firmly anchor the packer and deform the packing elements 17 into sealing engagement with the casing. Following release of upper control means 77, constituted by a pin 77*a* and a J-lock slot 77*b*, respectively, on and in the inner control sleeve 71 and the outer control sleeve 72, the tubing S and the seal tube 2 are free for upward movement relative to the set packer P. In order to enable pressurization of the fluid in the annulus to check the setting of the packer P, the mandrel 10 has cylindrical seal portion 10*a* below the coupling 11 which moves into the abut-

ment means 15 which contains suitable seal rings 14*b* engageable with the seal portion 10*a*. As will be hereinafter more clearly apparent, however, the seals 14*b* may not be necessary when the tool is so arranged that the seal tube 2 effectively provides a seal between itself and the packer mandrel 10.

This seal tube 2 comprises an upper tubular section 80 threaded into the connector sub 75 and extending longitudinally into the packer mandrel 10 when the control means 77 are engaged. At its lower end the tubular member 80 is threadedly connected at 81 to the upper end of a tubular seal tube extension unit 82 which has, at its lower end a reduced cylindrical portion 83. On this cylindrical portion 83 is a seal carrier ring 84 having an inner resilient seal ring 85 engageable with the cylindrical portion 83 of the unit 82, and outer seal ring means 86 are carried by the ring 84 and are sealingly engageable with the cylindrical sealing wall 87 which extends through the packer mandrel 10. A spacer sleeve 88 abuts with the ring 84 and with the upper end of a subjacent sealing tube unit 82 to hold the seal ring against a downwardly facing shoulder 89 on the seal tube unit 82. The seal tube 2 may be made up of any suitable number of such seal tube units 82 interconnected one below the other, depending upon the number of vertically spaced perforated sections of well casing through which fluid is to be displaced, as will be later described. In addition, the seal tube units 82 may be of selected length, depending upon the space between the perforated intervals of casing. The significant point is that the seal tube 2, including, in the form shown, the spaced seals 86 at the joint between the seal tube sections or units, provides a seal with the packer mandrel 10 to prevent communication between the casing above the packer P and the casing below the packer P, as the seal tube 2 is moved progressively upwardly, as will be later described.

At its lower end, the lowermost seal tube unit 82, as seen in FIG. 1*e*, is threadedly connected to a connector sub 90 which in turn is threaded into an enlarged sub 91 which supports at 92, an elongated tubular control member 93 having a pin 94*a* projecting radially therefrom and cooperable with a J-slot 94*b* formed within a lower control sleeve 194 which is threaded into the lower end of the packer mandrel 10 forming part of lower control means, whereby, when the packer P is to be released, the pipe string S can be effectively reconnected to the packer mandrel as will be later described.

In the illustrated device, the washing or treating tool T (FIGS. 1*g* and 1*h*) is supported beneath the control member 93 by a tubular assembly comprising a connector 95, a telescopic swivel 96, a safety joint 97 and a coupling 98 which is threaded at 99 onto the upper end of the elongated hollow body 100 of the tool T. The details of the swivel 96 and the safety joint 97 are not germane to the present invention and are well known in the art.

The tool body 100 has an upper head 101 providing an inlet 102 to an internal tube 103 which extends longitudinally within the body 100 and opens laterally through a port 104 in the body 100 to provide a treating fluid passage. The body 100 also contains a second tube 105 communicating through a lateral port 106 in the body 100 above the straddle packing elements SP, later to be described, and between the packing elements SP through a laterally opening port 107 to provide a circulating fluid passage, as will later be described. The body has additional laterally opening ports 108 above the straddle packing means SP which communicate between the casing and the interior of the body 100 at the lower end of which is a guide shoe 109 having suitable openings 110 which communicate with the interior of the body 100 and thus, with the lateral ports 108 to provide a by-pass passage, as will be later described.

The port 106 is adapted to be closed by a valve sleeve 111 having suitable internal ring seals 112 slidably and sealingly engageable with the external cylindrical portion of the body 100 between the coupling 98 and an external upwardly facing shoulder 112*a* on the body 100, located below the port 106. The valve sleeve 111 has means in the form of drag springs 113 frictionally and slidably engageable with the well casing C, whereby as the tool is being lowered within the well casing C the drag springs 113 normally maintain the valve sleeve 111 in an upper position, with the valve ports 106 open.

The straddle packing cups or means SP in the illustrated tool, comprise a pair of upper downwardly facing elastomeric packing cups 114 suitably mounted upon the body 100. The uppermost cup 114 is engaged in a recessed backup ring 115 mounted on a threaded section 116 of the body 100, and a similar backup ring 117 is threaded onto the body 100 and engages a spacer sleeve or ring 118, which maintains the upper cup 114 engaged in its backup ring 115. Correspondingly, a retainer ring 119 is threaded onto the body threads 116 and retains the lower cup 114 in its seat 117. Below the body ports 104 and 107 is a pair of lower, upwardly facing elastomeric packing cups 120, the lowermost of which seats in a backup ring 121 and is held in place by a spacer ring or sleeve 122, this spacer 122 being in turn engaged by a backup ring 123 threaded on the body 100 and receiving the uppermost cup 120 which is held in place by a ring 124 threaded on the body 100. Such packing cups are well known in the art and require no further specific description herein. However, it will be noted that the cups effectively form spaced sealing means engageable with the casing C and between which the ports 104 and 107 open.

The method of use of the above described apparatus to perform a fluid injection well treatment includes the following steps, with particular reference to the performance of sand consolidation treatment of the type in which epoxy material and a catalyst are injected through the casing perforations into the sand to cement the said particles together.

The assembly is made up as shown in FIG. 1*a* through 1*h*, with the packer assembly P held in a stretched out condition by the lower clutch element 54, and the shear screw 76 connecting the packer mandrel 10 to the running-in string of pipe S. Under these conditions, the assembly is lowered through the well casing C, the sleeve valve 111 being held by the bow spring 113 in the upper position. The fluid in the well casing below the tool is permitted to by-pass through the ports 110 upwardly through the tool body 100, and through the upper by-pass ports 108. The washing tool T is lowered downwardly, to a location below the lowermost casing perforation CP3, and at this location, the tool can be elevated slightly to close the sleeve valve 111, as the tool moves upwardly to position the circulating ports

106 between the seals 112 of the sleeve valve which remains stationary in the casing. At this time, fluid in the pipe string S can be pressurized, the fluid pressure being applied to the space between the packing cup means SP through the fluid treating port 104, and being trapped therein by the closed sleeve valve 111. The entire assembly can then be elevated to locate the various perforated zones CP3, CP2 and CP1, as fluid pressure bleeds off through the successive perforated zones when the perforations are straddled by the packing means SP. The tool can then be lowered to again locate the straddle packing means SP at the successive downwardly spaced perforations CP1, CP2 and CP3 and suitable injection fluids may be displaced through each of the isolated perforations. Typically, such fluids would include washing or cleaning fluids, such as hydrochloric acid, diesel oil, alcohol and aromatic oil adapted to clean the earth formation or sand in advance of displacement of the sand consolidating fluid. As the tool is being moved downwardly, the sleeve valve 111 will remain open enabling fluid to circulate, as desired, and if desired the well can be back-flushed by circulating fluid down the casing into the circulating port 106, then upwardly through the injection passage 104 into the pipe string S. At this point, it should be noted that in lieu of the valve means incorporated in the tool T, suitable circulating valve means, as well known, may be employed in the pipe string S, and if desired, the operation may involve back surging or "shocking" the formation, as is also well known.

The tool assembly is then moved with the packer P and the injecting tool T so that the latter is located above the uppermost casing perforation CP1. At this location, the packer P is to be set in anchoring engagement with casing C. To set the packer P as previously indicated, the pipe string S is manipulated by applying a downward weight and being rotated to release the lower latch or clutch dogs 54, which enables the packer mandrel 10 to move downwardly with respect to the drag device, whereby to expand or set the anchoring slips, all as previously described in detail. Thereafter, the shear screws 76 are broken or sheared and the packing rubbers 17 deformed into sealing engagement with the casing. At this point, the fluid in the casing can be pressurized to test the setting of the packer, and then the upper control means 77 is released by elevating the pipe string S and rotating the same to the right to disengage the pin 77*a* from the J-slot 77*b*. Such release of the control means 77 allows the pipe string S and seal tube 2 to be stroked downwardly through the sealing bore 87 of the packer mandrel 10 to locate the tool T below the lowermost perforations. As the tool T is then moved upwardly, the packing cup SP will straddle the lowermost set of vertically spaced perforations. Stroking of the seal tube and tool is stopped and the sand consolidating resin and catalyst can then be displaced through the treating port 104 and will be forced into the earth formation through the perforations. One of the seal rings 84 in the seal tube 2 will always be located within the sealing bore 87, so that fluid cannot flow upwardly through the packer, as the injection operation is repeated at each vertically spaced perforated casing section. Thereafter, suitable overflushing materials can be injected through the selectively straddled perforations.

When it is desired to release the packer P, the tubing S is further elevated to engage the pin 94*a* on the control sleeve 93 in the J-slot 94*b* and the tubing rotated to the right to connect the seal tube 2 to the packer mandrel 10, whereby continued rotation of the tubing to the right and subsequent elevation of the pipe string S will disengage the upper holding dogs or clutches 62 from the mandrel 10 and effect release of the packer, as the packer mandrel 10 moves upwardly and the slip elements are retracted and the packing rubbers allowed to retract as previously described. After the packer has been released fluid can be reverse circulated through the pipe string S, and then the tool assembly is removed from the well by pulling the pipe string.

I claim:

1. In selective well treating apparatus adapted to be run into a well casing on a pipe string for conducting treating fluid selectively to isolated, vertically spaced perforated casing sections: packer means having an elongated tubular mandrel provided with a bore therethrough, said packer having anchor means and sealing means expansible into anchoring engagement and retractable from anchoring engagement with the well casing, an elongated seal tube reciprocably extending through said bore of said mandrel, said seal tube and said mandrel having cooperative sealing means in mid bore, fluid injection tool means on said seal tube and including longitudinally spaced packing means sealingly engageable with said casing at locations above and below one of said perforated casing sections, and treating fluid passage means extending through said seal tube and said tool means to conduct treating fluid to the space between said longitudinally spaced packing means.

2. In selective well treating apparatus as defined in claim 1, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasable responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means.

3. In selective well treating apparatus as defined in claim 1, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasably responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means and said sealing means.

4. In selective well treating apparatus as defined in claim 1, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasable responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means and said sealing means, said packer means also having means for holding said anchor means and said sealing means expanded into engagement with said casing and releasable responsive to manipulation of said mandrel, and including means for connecting said seal tube to said mandrel to manipulate the same for causing retraction of said anchor means and said sealing means.

5. In selective well treating apparatus as defined in claim 1, said cooperative sealing means of said seal tube and said mandrel including a sealing surface in said mandrel bore and sealing members spaced longitudinally along said seal tube to be positioned in said sealing surface when said packing means are at said locations.

6. In selective well treating apparatus as defined in claim 1, said cooperative sealing means of said seal tube and said mandrel including a sealing surface in said mandrel bore and sealing members spaced longitudinally along said seal tube to be positioned in said sealing surface when said packing means are at said locations, said seal tube comprising a number of interconnected seal tube sections joined in end-to-end relation.

7. In selective well treating apparatus as defined in claim 1, said cooperative sealing means of said seal tube and said mandrel including a sealing surface in said mandrel bore and sealing members spaced longitudinally along said seal tube to be positioned in said sealing surface when said packing means are at said locations, said seal tube comprising a number of interconnected seal tube sections joined in end-to-end relations, and said sealing member of said seal tube including resilient seal elements mounted at the junctions of said seal tube sections.

8. In selective well treating apparatus as defined in claim 1, means defining a circulating passage communicating through said tool means with the space between said packing means and with the casing above said packing means, and including valve means for closing and opening said circulating passage responsive to manipulation of said pipe string.

9. In selective well treating apparatus as defined in claim 1, means defining a circulating passage communicating through said tool means with the space between said packing means and with the casing above said packing means, and including valve means for closing and opening said circulating passage responsive to manipulation of said pipe string, said valve means comprising a valve sleeve and means on said valve sleeve engageable with the casing to hold said sleeve stationary as said pipe string is moved vertically.

10. In selective well treating apparatus as defined in claim 1, means defining a circulating passage communicating through said tool means with the space between said packing means and with the casing above said packing means, and including valve means for closing and opening said circulating passage responsive to manipulation of said pipe string, and also including means defining a by-pass passage for communicating with said casing through said treating tool means above and below said packing means.

11. In selective well treating apparatus as defined in claim 1, means defining a circulating passage communicating through said tool means with the space between said packing means and with the casing above said packing means, and including valve means for closing and opening said circulating passage responsive to manipulation of said pipe string, said valve means comprising a valve sleeve and means on said valve sleeve engageable with the casing to hold said sleeve stationary as said pipe string is moved vertically, and also including means defining a by-pass passage for communicating with said casing through said treating tool means above and below said packing means.

12. In selective well treating apparatus as defined in claim 1, means defining a circulating passage communicating through said tool means with the space between said packing means and with the casing above said packing means, and including valve means for closing and opening said circulating passage responsive to manipulation of said pipe string, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasable responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means.

13. In selective well treating apparatus as defined in claim 1, means defining a circulating passage communicating through said tool means with the space between said packing means and with the casing above said packing means, and including valve means for closing and opening said circulating passage responsive to manipulation of said pipe string, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasable responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means, said packer means also having means for holding said anchor means and said sealing means expanded into engagement with said casing and releasable responsive to manipulation of said mandrel, and including means for connecting said seal tube to said mandrel to manipulate the same for causing retraction of said anchor means and said sealing means.

14. In selective well treating apparatus as defined in claim 1, means defining a circulating passage communicating through said tool means with the space between said packing means and with the casing above said packing means, and including valve means for closing and opening said circulating passage responsive to manipulation of said pipe string, and also including means defining a by-pass passage for communicating with said casing through said treating tool means above and below said packing means, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasable responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means.

15. In selective well treating apparatus as defined in claim 1, means defining a circulating passage communicating through said tool means with the space between said packing means and with the casing above said packing means, and including valve means for closing and opening said circulating passage responsive to manipulation of said pipe string, and also including means defining a by-pass passage for communicating with said casing through said treating tool means above and below said packing means, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releas-

able responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means and said sealing means, said packer means also having means for holding said anchor means and said sealing means expanded into engagement with said casing and releasable responsive to manipulation of said mandrel, and including means for connecting said seal tube to said mandrel to manipulate the same for causing retraction of said anchor means and said sealing means.

16. In selective well treating apparatus as defined in claim **1**, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasable responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means, said means releasably connecting said pipe string to said mandrel including a control head having a part connected to said seal tube and a part connected to said mandrel, and releasable means interconnecting said parts.

17. In selective well treating apparatus as defined in claim **1**, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasable responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means, said means releasably connecting said pipe string to said mandrel including a control head having a part connected to said seal tube and a part connected to said mandrel, and releasable means interconnecting said parts including frangible means.

18. In selective well treating apparatus as defined in claim **1**, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasable responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means, said means releasably connecting said pipe string to said mandrel including a control head having a part connected to said seal tube and a part connected to said mandrel, and releasable means interconnecting said parts including a J-slot and pin.

19. In selective well treating apparatus as defined in claim **1**, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasable responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means, said means releasably connecting said pipe string to said mandrel including a control head having a part connected to said seal tube and a part connected to said mandrel, and releasable means interconnecting said parts including frangible means breakable following expansion of said anchor means and a J-slot and pin disengageable following expansion of said sealing means.

20. In selective well treating apparatus as defined in claim **1**, said packer means having means initially holding said anchor means and sealing means retracted, said holding means being releasable responsive to manipulation of said mandrel, and including means releasably connecting said pipe string to said mandrel for manipulating the latter and releasable from said mandrel to allow longitudinal movement of said pipe string and seal tube following expansion of said anchor means and said sealing means, said packer means also having means for holding said anchor means and said sealing means expanded into engagement with said casing and releasable responsive to manipulation of said mandrel, and including means for connecting said seal tube to said mandrel to manipulate the same for causing retraction of said anchor means and said sealing means, said means releasably connecting said pipe string to said mandrel including a control head having a part connected to said seal tube and a part connected to said mandrel, and releasable means interconnecting said parts, said means for connecting said seal tube to said mandrel including control pin and J-slot means on said seal tube and said mandrel.

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