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| [22] | Filed | June 2, 1969 |
| [45] | Patented | June 15, 1971 |
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- [54] RETRIEVABLE PACKER APPARATUS FOR USE IN
A WELL BORE AND METHOD OF PROLONGING
ITS OPERATING LIFE**
11 Claims, 21 Drawing Figs.

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| [52] | U.S. Cl..... | 166/129,
166/134, 166/182 |
| [51] | Int. Cl..... | E21b 23/00 |
| [50] | Field of Search..... | 166/129,
134, 130, 182 |

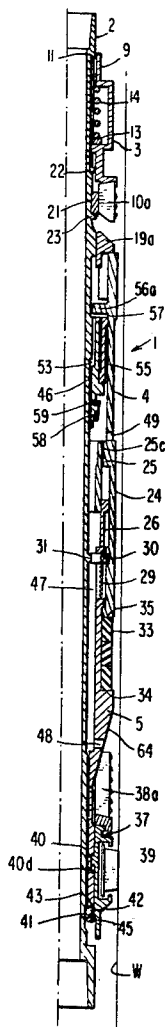
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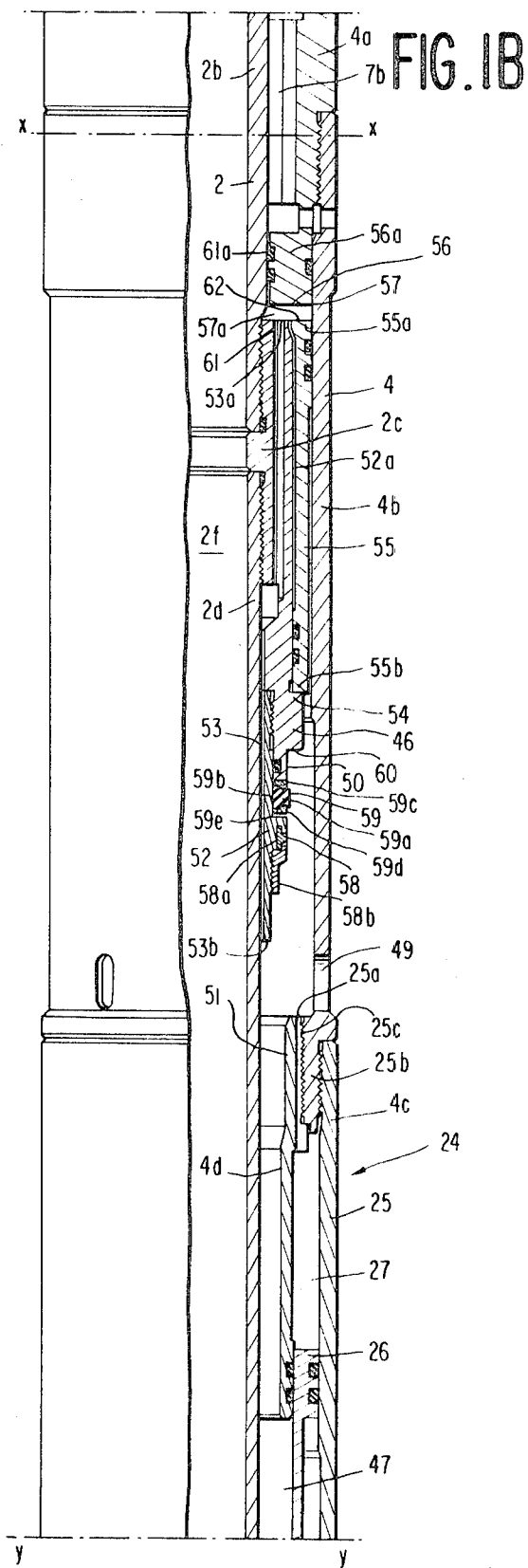
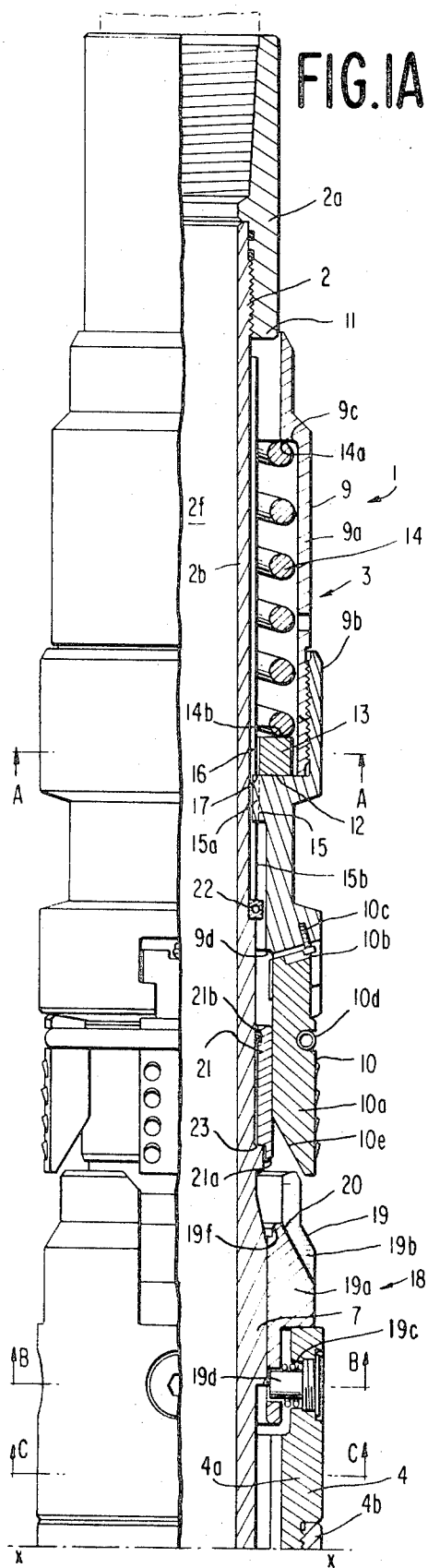
ABSTRACT: Retrievable packer apparatus for use in a well bore including an equalizing valve designed to release pressure in two stages. A ratchet mechanism prevents the relaxation of compressed packer elements until the complete release of upper slip segments has occurred. A floating sleeve, in conjunction with spaced abutments or stop means, provides a mechanism for radially collapsing slip expander blocks and, if necessary, applying a lifting or impact force to upper slips to ensure their release.

A selectively releasable ball coupling provides a mechanism for applying longitudinal force through a series of telescopically assembled components and selectively releasing the components for longitudinal movement relative to each other.

An equalizing valve carried by a packer mandrel is pressure balanced with respect to differential pressure acting beneath the set packer. Pressure acting beneath the set packer tends to augment the packer setting force.

A method of releasing an equalizing valve wherein the valve is released in two stages, the first stage involving the separation of a high pressure seal from a valve seat, and the second involving the subsequent release of a low pressure seal from the valve seat.





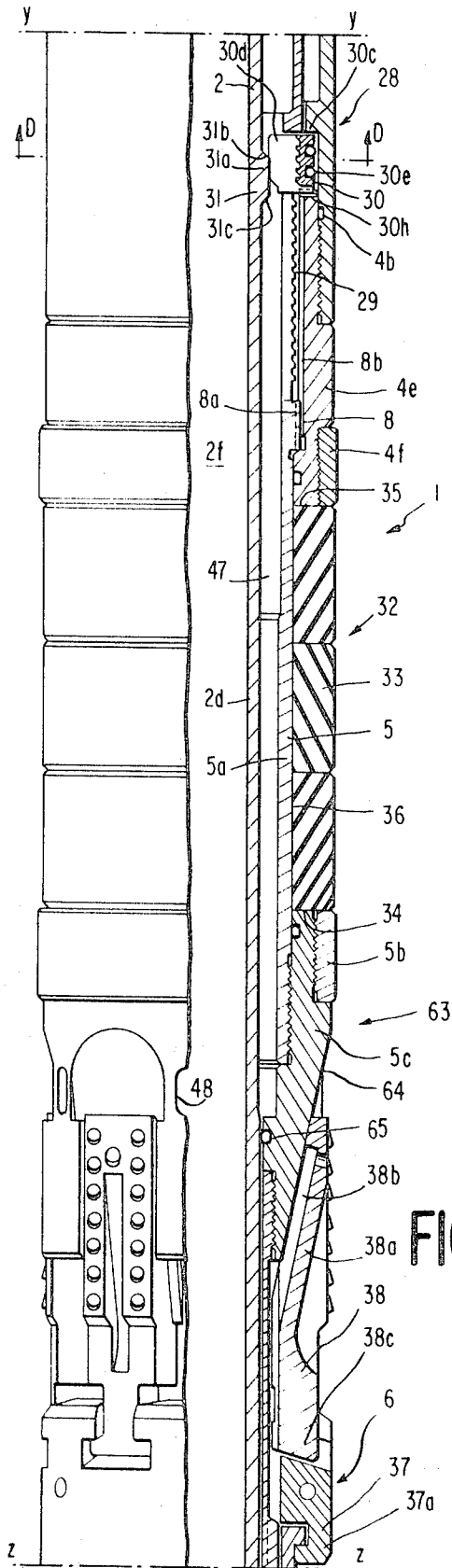


FIG. 1C

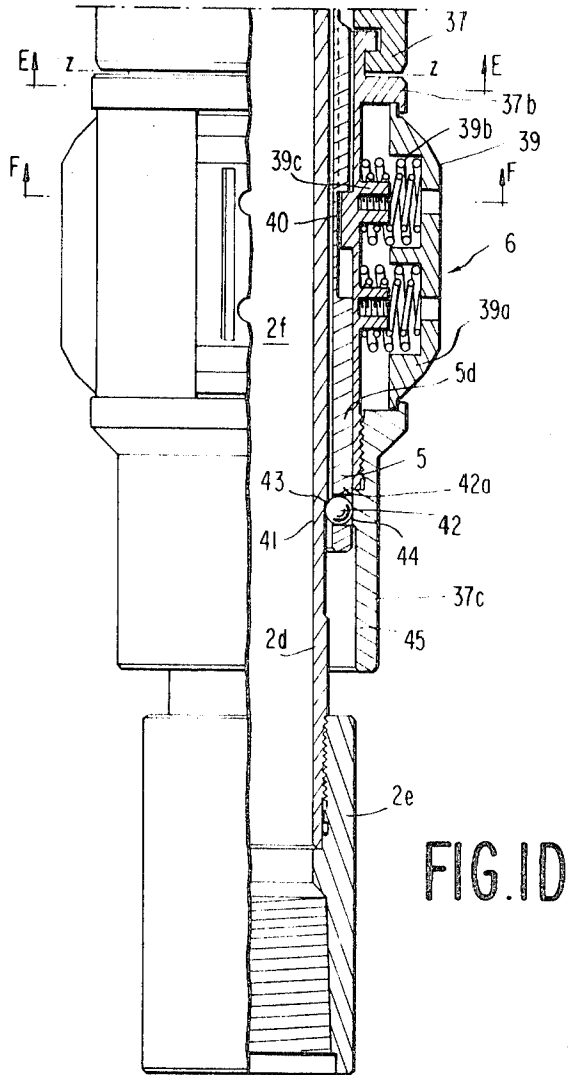


FIG. 1D

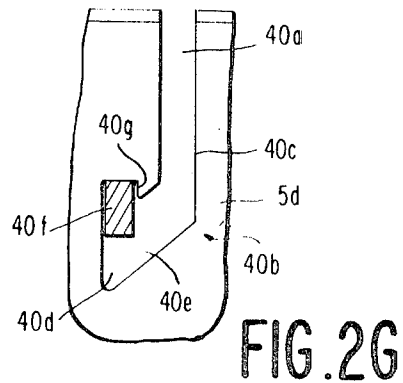


FIG. 2G

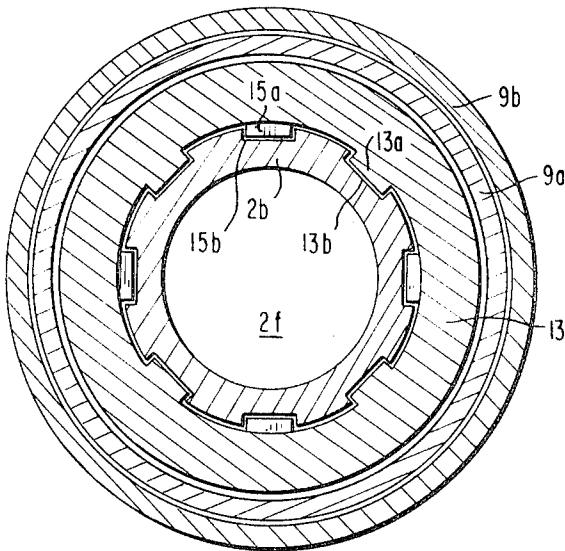


FIG. 2A

FIG. 2B

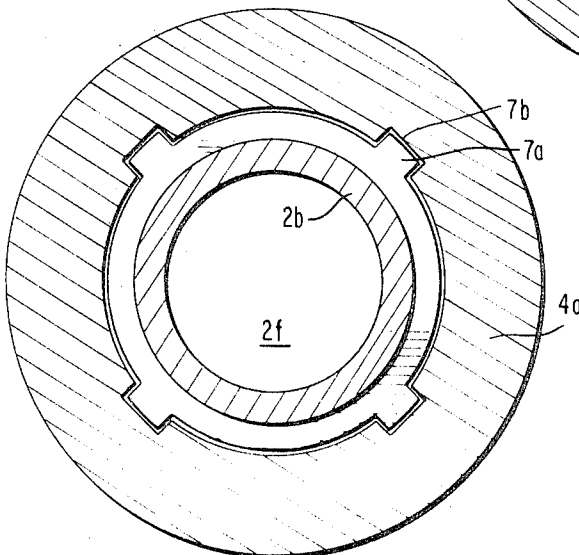
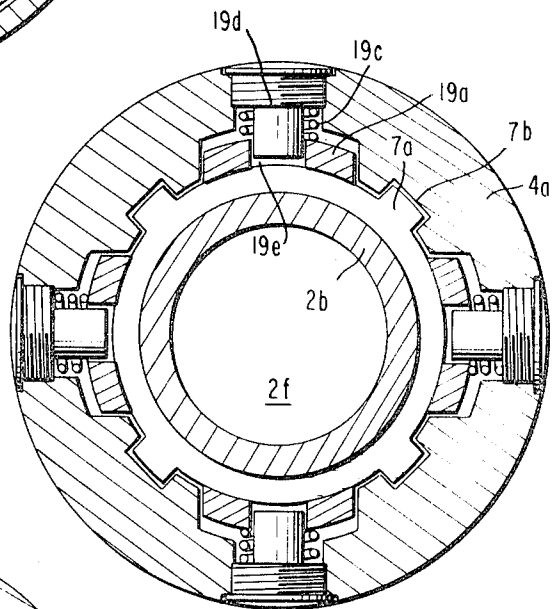
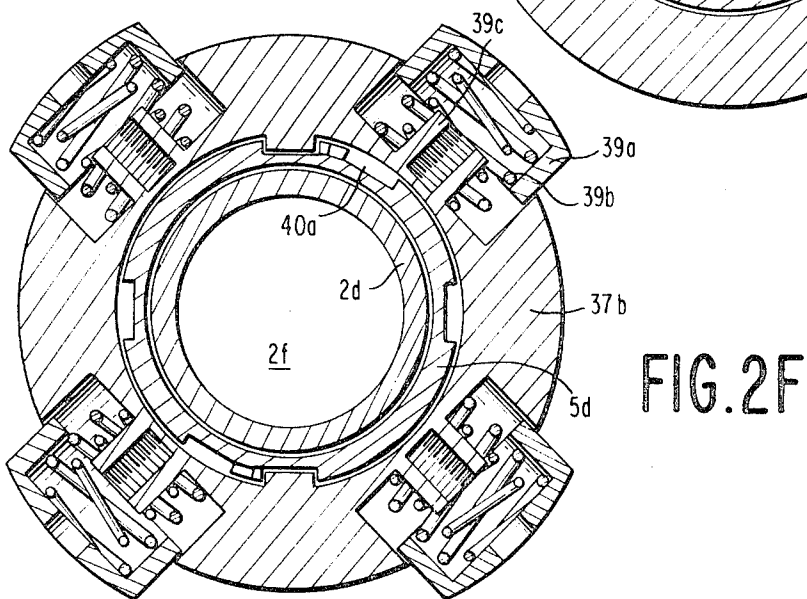
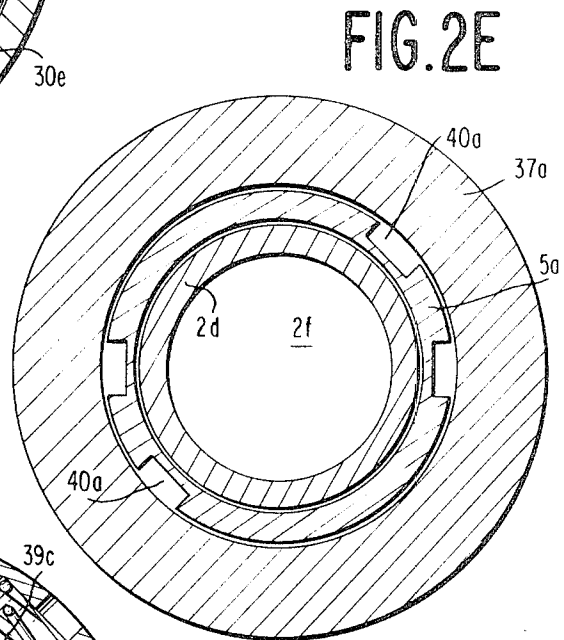
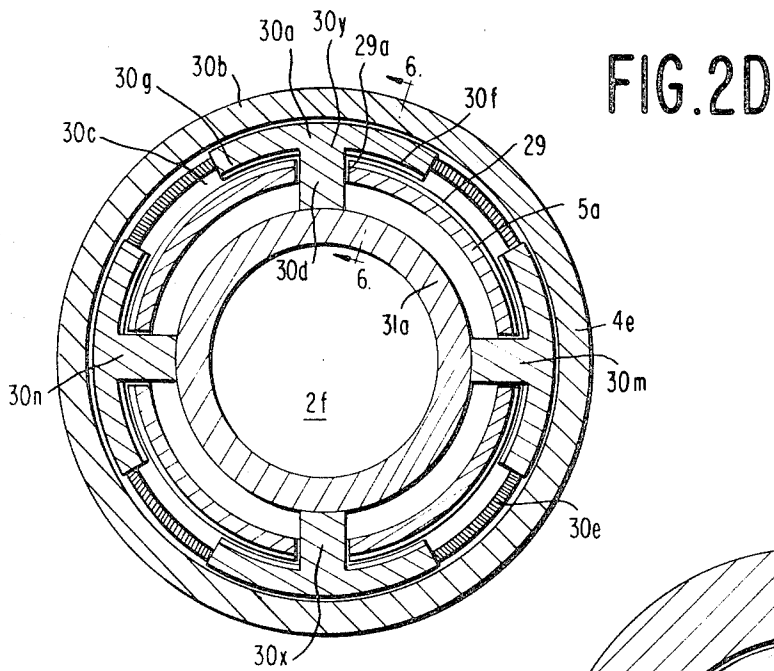
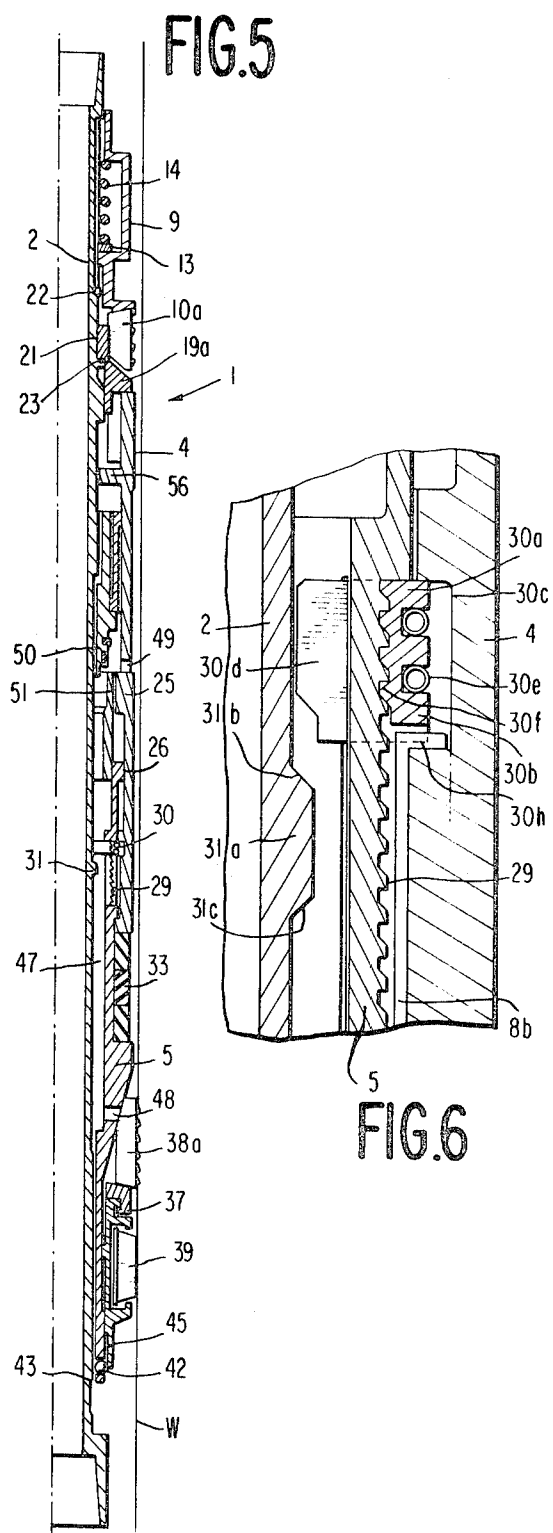
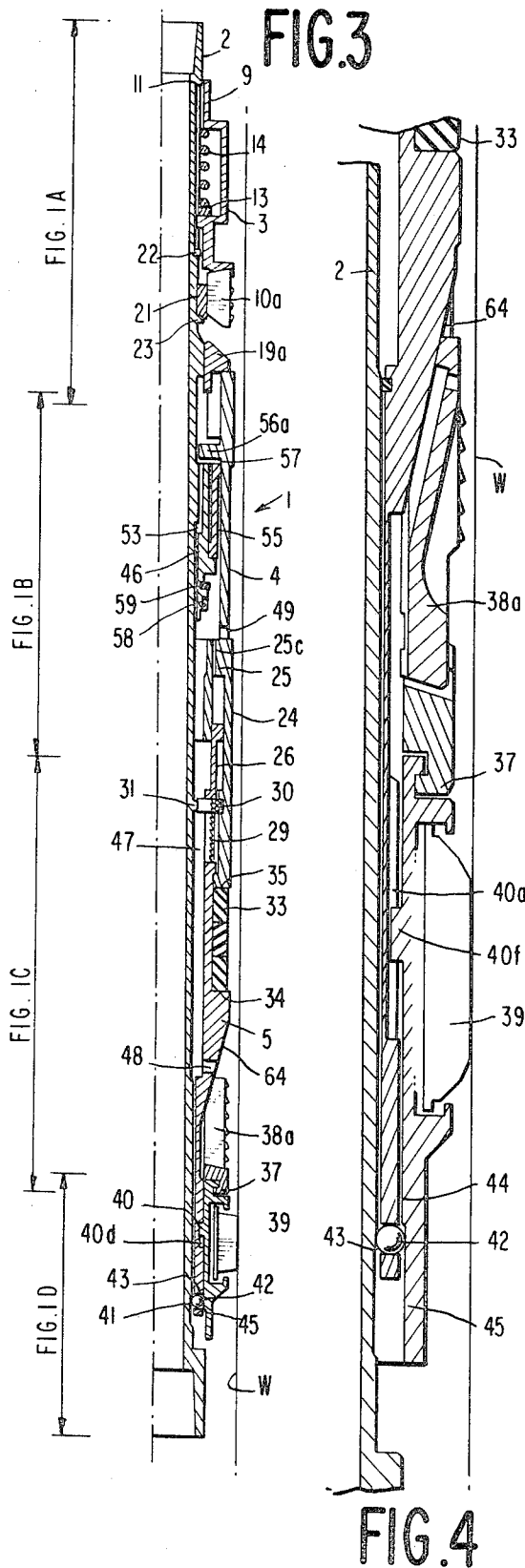


FIG. 2C





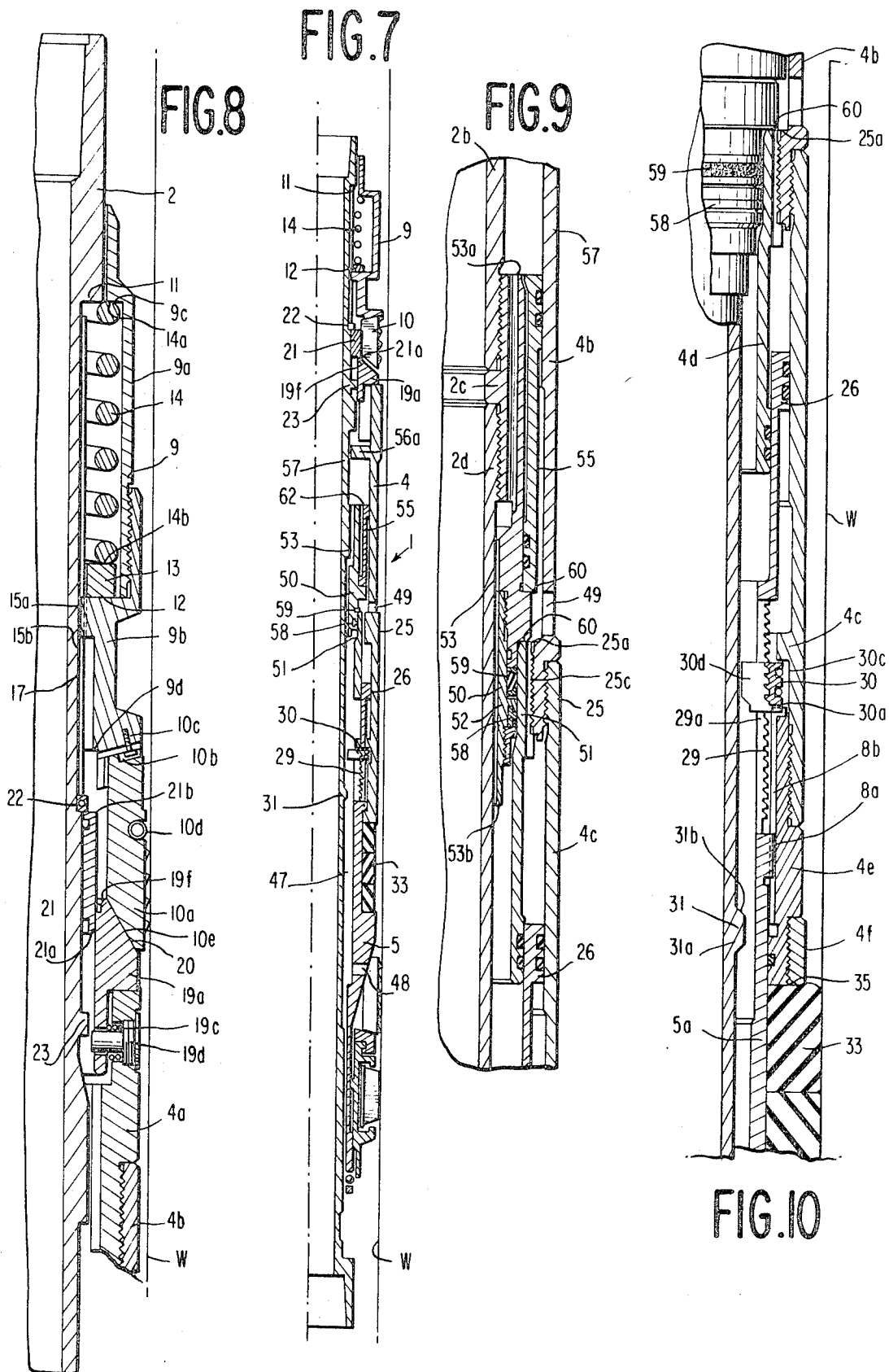


FIG. 11A

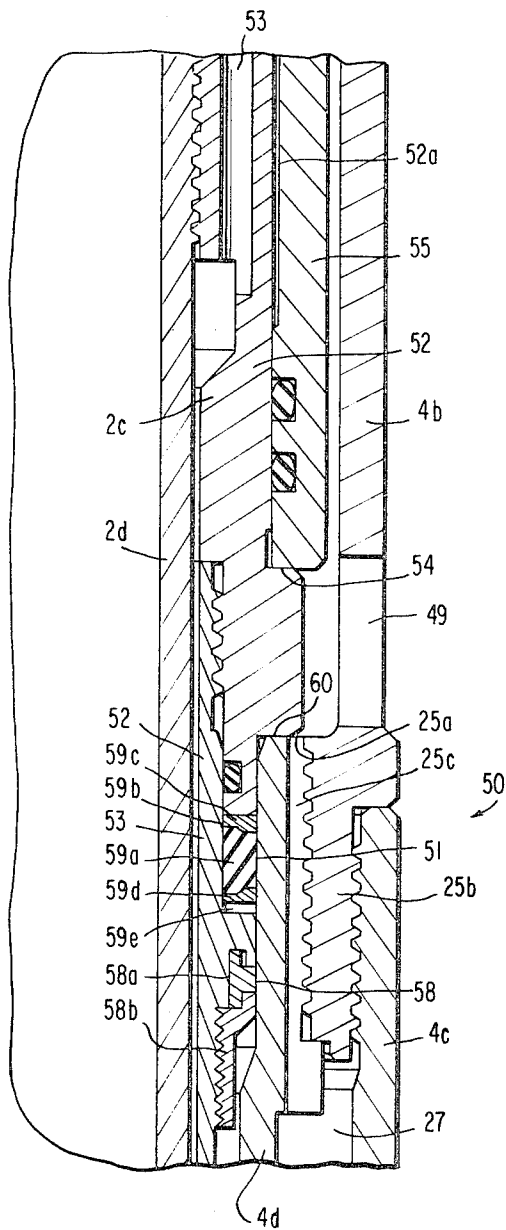
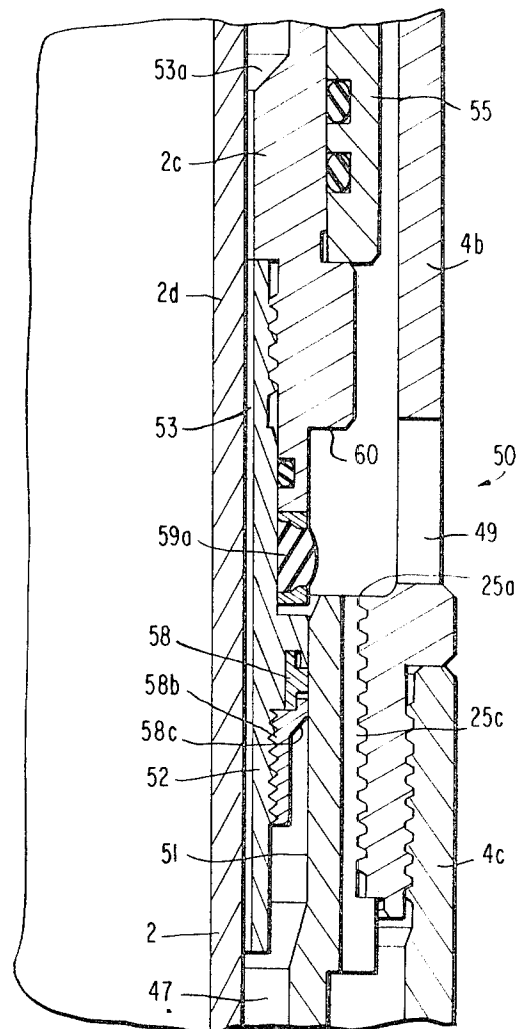


FIG. 11B



RETRIEVABLE PACKER APPARATUS FOR USE IN A WELL BORE AND METHOD OF PROLONGING ITS OPERATING LIFE

GENERAL BACKGROUND, OBJECTS AND SUMMARY OF INVENTION

The well packer art has developed over a span of several decades, with continuing efforts being made to improve the operational reliability of packer apparatus while simplifying packer structure and prolonging the operating life of the packer apparatus.

The extraordinary number of packers developed by the petroleum industry indicates the severity and continuing nature of the packer problem.

The present invention is concerned with a packer apparatus intended for use in well bores and designed to be retrievable. The packer is specifically designed for use in conjunction with conventional well operations such as squeeze cementing, formation testing, formation treating and similar operations.

Specifically, it is a principal object of the invention to provide a packer apparatus, the reliability of which is enhanced while structural complexity is minimized and operating life is prolonged.

It is a particular object of the invention to incorporate in a retrievable packer apparatus an equalizing valve which serves to equalize pressure across a packer while enhancing and prolonging the operating life of the equalizing valve so as to in turn extend the operating life of the packer apparatus itself.

It is a further object of the invention to provide a new method of releasing an equalizing valve in a well tool so as to avoid valve seal scouring, or at least tend to minimize such scouring.

Another object of the invention is to provide a retrievable packer apparatus including a mechanism for collapsing expander blocks associated with upper slips, while permitting an application of lifting force to the upper slips, if necessary.

A still further object of the invention is to provide a retrievable packer apparatus with a selectively controllable ratchet mechanism which serves to maintain a packer in its expanded condition until upper slips have been fully released so as to ensure that the contraction of the set packer does not inadvertently reset only partially released upper slips.

Another object of the invention is to provide a selectively releasable detent coupling between mutually telescoped components of the packer apparatus, which releasable coupling serves to permit the selective interlocking of components for the transmission of longitudinal force therethrough, and also serves to permit the selective releasing of the components for relative longitudinal movement.

Yet another object of the invention is to provide a retrievable packer apparatus wherein an equalizing valve carried by an actuating mandrel is pressure balanced in such a way as to ensure that differential pressure acting beneath the set packer does not tend to open the equalizing valve or move the actuating mandrel upwardly so as to release the packer.

A still further object of the invention is to provide such a retrievable packer apparatus wherein differential pressure acting beneath the expanded packer serves to augment the packer setting action.

An apparatus for accomplishing certain of the objects heretofore defined is characterized by an equalizing valve including sequentially releasable, high and low pressure seals. During the opening of the equalizing valve the high pressure seal is first released, with the low pressure seal remaining effective to prevent a high volume or high pressure flow of fluid across the high pressure seal which would tend to abrade or scour the high pressure seal.

Other objects of the invention are accomplished through a ratchet mechanism associated with mutually telescoping, packer setting components. The ratchet mechanism is controlled by mandrel movement so as to ensure that upper

packer slips are completely released before the ratchet will permit collapsing of the expanded packer elements.

Still additional objects of the invention are achieved by a mechanism for ensuring the release of the upper slips of the packer apparatus. This mechanism is characterized by a sleeve mounted for "floating" or limited longitudinal movement on a packer setting mandrel. The sleeve is designed to be withdrawn from radially expanding cooperation with slip expander blocks so as to permit their rapid collapse. If this action does not suffice to disengage the upper slips from locking cooperation with a well bore periphery, continued upward movement of the mandrel supporting the sleeve will cause the sleeve to impart a lifting or impact force to the upper slips to facilitate their complete release.

Other objects of the invention are provided by a detent-type, releasable coupling interposed between the actuating mandrel of the packer apparatus and a body means supporting a drag block and lower slip assembly. This detent mechanism provides a device for applying longitudinal force to the body means so as to move it downwardly through the well bore without causing packer setting action. A J-slot mechanism permits the detent mechanism to be selectively released in order to allow the actuating mandrel to move downwardly relative to the lower body means to complete the packer setting action.

Other objects of the invention are accomplished by interconnecting packer actuating, upper and lower body means by a piston and cylinder assembly in such a manner that differential pressure acting beneath the expanded packer will tend to augment the packer setting action.

Still further objects of the invention are accomplished by the utilization of pressure balancing surfaces in conjunction with the aforesaid equalizing valve so as to prevent differential pressure acting beneath the set packer form causing the equalizing valve to open and the actuating mandrel to move upwardly so as to tend to release the set packer.

THE DRAWINGS

In describing the invention, reference will be made to a preferred embodiment shown in the appended drawings.

In the Drawings:

FIGS. 1A through 1D, separated for illustration purposes by juncture lines X-X, Y-Y, and Z-Z, provide a partially sectioned, side elevational view of the packer apparatus of the present invention, illustrating packer components in the position they occupy while the apparatus is ready to be "run" into a well bore;

FIGS. 2A through 2F provide enlarged, transverse sectional views of the packer apparatus shown in FIGS. 1A through 1D as viewed along sections lines A-A, B-B, C-C, D-D, E-E, and F-F respectively;

FIG. 2G provides a transverse sectional view of one of a plurality of simultaneously operable, but circumferentially displaced J-slots interconnecting a lower body means and lower slip assembly of the packer apparatus as viewed along section line G-G of FIG. 1D;

FIG. 3 provides a fragmentary, reduced scale, vertically sectioned, elevational view of the packer apparatus, schematically illustrating the arrangement of principal components as they are disposed while the apparatus is being moved downwardly through a well bore;

FIG. 4 provides an enlarged, fragmentary, vertically sectioned view of a J-slot and ball detent mechanism incorporated in the packer apparatus and illustrating the disposition of the components when the J-slot permits substantial downward longitudinal movement of a packer assembly supporting the lower body means relative to a lower slip assembly so as to effect the setting of the lower slips of the packer apparatus;

FIG. 5 provides in a schematic format, similar to that of FIG. 3, an illustration of packer components after the lower slips have been set and the upper slips are about to be set;

FIG. 6 provides an enlarged, fragmentary view of a ratchet mechanism of the FIG. 5 assembly, as viewed along section line 6-6 of FIG. 2D, illustrating the manner in which a mandrel carried shoulder has permitted the interengagement of ratchet teeth, carried by an upper body means, with ratchet surface means carried by lower body means of the packer apparatus;

FIG. 7 provides, in a format similar to that of FIG. 3, a schematic illustration of packer components as the mandrel is moving downwardly to displace upper slip expander blocks radially outwardly and commence the closing of an equalizing valve;

FIG. 8 provides an enlarged, fragmentary view of upper slip setting components of the FIG. 7 assembly, illustrating the manner in which mandrel carried sleeve has moved slip expander blocks outwardly and further indicating the manner in which continued downward movement of the mandrel will apply resilient, slip setting force to upper slips of the packer apparatus;

FIG. 9 provides an enlarged, fragmentary view of the equalizing valve portion of the FIG. 7 assembly, illustrating the disposition of equalizing valve components after the mandrel has moved downward from the FIG. 7 position to effect full sealing of the equalizing valve and the equalizing valve has moved into force transmitting and packer setting engagement with the upper body means of the packer;

FIG. 10 illustrates the manner in which downward movement of the actuating mandrel of the packer apparatus serves to induce the longitudinal compression and radial expansion of the packer elements, with the FIG. 6 ratchet mechanism serving to prevent collapsing of the packer elements;

FIG. 11A illustrates the fully sealed equalizing valve of the packer apparatus in an enlarged, fragmentary, vertically sectioned format; and

FIG. 11B illustrates the FIG. 11A components when upward mandrel movement has released a high pressure seal, but a low pressure seal is still aligned with a valve set.

PRINCIPAL COMPONENTS OF THE PACKER APPARATUS

Principal components of the packer apparatus are illustrated in FIGS. 1A through 1D with structural interrelationships being clarified by the cross-sectional views of FIGS. 2A through 2G.

Prior to discussing the manner in which the components are assembled and mutually interact, it will be useful to tabulate these components in relation to reference numerals which will be used hereafter in describing the invention.

The principal components of the apparatus are as follows:

1. Overall Packer Apparatus
2. Mandrel Means
3. Upper Slip Assembly
4. Upper Body Means
5. Lower Body Means
6. Lower slip Assembly
7. First Spline Means Interconnecting Mandrel Means 2 and Upper Body Means 4
8. Second Spline Means Interconnecting Upper Body Means 4 and Lower Body Means 5
9. Elements of Upper Slip Assembly 3
10. Upper Slip Housing Means
11. Upper Slip Means Mounted on Upper Slip Housing Means
12. First Abutment Means Carried by Mandrel Means 2
13. Second Abutment Means Carried by Upper Slip Housing Means 9
14. Compression Ring Means
15. Longitudinally Compressible Helical Coil Spring Means
16. Third Spline Means Interconnecting Upper Slip Housing Means 9 and Mandrel Means 2

17. Fourth Spline Means Interconnecting Compression Ring Means 13 and Mandrel Means 2
18. Third Abutment Means Carried by Mandrel Means 2
19. Upper Slip Actuating Means
20. Upper Slip Expanding Means
21. Upper Slip Expanding Surface Means
22. Sleeve Means
23. First Stop Means
24. Second Stop Means
25. Piston and Cylinder Assembly Between Upper and Lower Body Means
26. Cylinder Means
27. Piston Means
28. Low Pressure Zone in Cylinder Means 25
29. Ratchet Means Between Upper and Lower Body Means
30. Ratchet Surface Means
31. Ratchet Teeth Means
32. Ratchet Teeth Disabling Means
33. Packer Assembly
34. Longitudinally Compressible and Radially Expansible Packer Means
35. Lower Packer Engaging Means
36. Upper Packer Engaging Means
37. Packer Supporting Wall Means
38. Elements of Lower Slip Assembly 6
39. Lower Slip Housing Means
40. Lower Slip Means
41. Drag Block Means
42. J-slot Means
43. Selectively Releasable Coupling Means
44. Ball Detent Means
45. Mandrel Carried Shoulder Means
46. Ball Restraining Means
47. Ball Releasing Recess Means
48. Equalizing Valve Means
49. First Passage Means
50. Second Passage Means
51. Third Passage Means
52. Sleeve Valve Means
53. Elements of Sleeve Valve Means
54. Seat Means
55. Valve Body Means
56. Fourth Passage Means
57. First Ledge Means
58. Piston Means
59. Second Ledge Means
60. Enclosure Means
61. First Relatively Rigid Seal Means
62. Second Relatively Deformable Seal Means
63. Packer Setting Abutment Means
64. Mandrel Pressure Balancing Means
65. Upwardly Facing Pressure Balancing Surface Means
66. Lower Slip Actuating Means
67. Lower Slip Expander Means

Having identified principal components of the apparatus, the structural relationships between these components will now be discussed.

STRUCTURAL INTERRELATIONSHIPS OF PRINCIPAL PACKER COMPONENTS

The manner in which principal components 1 through 64 are structurally interrelated is shown in FIGS. 1A through 1D, augmented by the cross-sectional views 2A through 2G.

Main Body Elements

Thus, overall packer apparatus 1 includes a central, generally tubular or cylindrical mandrel means 2. Mandrel means 2 is fabricated from threadably interconnected components 2a, 2b, 2c, 2d, and 2e which define an unobstructed central passage 2f of substantially uniform cross section.

Component 2a is adapted to be threadably connected to a conduit or tubing "string" extending upwardly to a well head. In a conventional manner, the conduit string connected to mandrel component 2a will serve to lower or raise the packer apparatus 1 through a well bore and effect the desired rotation of the mandrel 2 for packer setting purposes.

Mandrel component 2e is adapted to be threadably connected to other components of a conduit string to be positioned below the packer assembly 1, in accordance with the type of well operation involved.

Packer apparatus 1 also includes an upper slip assembly 3 which is mounted for longitudinal movement on an upper portion of mandrel means 2, as indicated generally in FIG. 1A.

A generally cylindrical or tubular upper body means 4 is telescopically mounted on mandrel means 2 beneath the upper slip assembly 3, when the packer is disposed in a well bore. Body means 4 is fabricated from threadably interconnected components 4a, 4b, 4c, 4d, 4e, and 4f, as shown generally in FIGS. 1A, 1B and 1C.

Upper body means components 4b, 4c, and 4d cooperate to provide a cylinderlike structure, the significance of which is subsequently discussed. The upper body means 4 is mounted for limited longitudinal movement on the mandrel means 2.

A lower body means 5 is mounted beneath the upper body means 4, when packer 1 is disposed in the well bore. Body means 5 is mounted for longitudinal movement on mandrel means 2, and is interconnected with the upper body means 4 for longitudinal movement relative to this upper body means.

Lower body means 5 is fabricated from threadably interconnected components 5a, 5b, 5c, and 5d as shown generally in FIGS. 1B, 1C and 1D.

A lower slip assembly 6, as shown in FIGS. 1C and 1D, is mounted for longitudinal movement on the lower body means 5.

As shown in FIGS. 1A and 1B, a first spline means 7 serves to interconnect the mandrel means 2 and the upper body means 4. First spline means 7 is defined by mandrel carried, radially outwardly projecting splines 7a which are slidably received within upper body carried, and longitudinally extending, spline grooves 7b.

Spline means 7 serves to permit limited longitudinal movement of mandrel means 2 relative to the upper body means 4 while substantially preventing relative rotational movement between the body means 4 and the mandrel means 2.

A second spline means 8, shown generally in FIG. 1C, serves to interconnect the upper body means 4 with the lower body means 5. Spline means 8 is defined by a plurality of circumferentially spaced, longitudinally extending, radially outwardly projecting spline lugs 8a carried by lower body means component 5a. Lugs 8a are slidably received within circumferentially spaced and longitudinally extending spline grooves 8b formed on upper body means component 4e.

Spline means 8 serves to permit limited longitudinal movement of upper body means 4 relative to lower body means 5 while substantially preventing relative rotational movement between these components.

Upper Slip Assembly

Upper slip assembly 3, as generally shown in FIG. 1A, includes an upper slip housing means 9 defined by threadably interconnected, generally cylindrical components 9a and 9b.

Upper slip means 10 are mounted on housing means 9. Slip means 10 are defined by a plurality of circumferentially spaced slip segments 10a which are mounted in conventional slip mounting socket 10b formed in housing means 9. Each slip segment 10a may be retained in its socket 10b by a retainer bolt 10c as generally shown in FIG. 1A. A coil spring 10d, extending circumferentially about the packer exterior, serves to bias the slip segments 10a radially inwardly but permit radially outward movement of the slip segments into gripping engagement with the periphery of a well bore. This gripping engagement impedes or prevents upper packer move-

ment, but does not prevent downward movement of the upper slip assembly.

Slip assembly 3 further includes first abutment means 11 defined by mandrel component 2a. Abutment means 11 is annular in character and faces downwardly within the well bore as shown generally in FIG. 1A.

A second, generally annular abutment means 12 is defined by housing segment 9b. Second abutment means 12 faces upwardly within the well bore.

A generally annular compression ring 13 shown in FIG. 1A is carried by the housing 9 and adapted to seat on the abutment 12.

A longitudinally compressible, helical coil spring 14 is interposed longitudinally between the compression ring 13 and the first abutment means 11. However, as is shown in FIG. 1A, with the packer in its storage or "run-in" position, the upper end 14a of the coil spring is held out of engagement with the abutment 11 by a housing shoulder 9c. Downward movement of shoulder or abutment 11, relative to housing 9, is necessary to bring this abutment 11 into engagement with the upper end 14a of spring 14.

A third spline means 15 serves to interconnect the housing 9 and the mandrel means 2. Spline means 15 is defined by radially inwardly projecting spline lugs 15a carried by housing 9 which are slidably received within longitudinally extending spline grooves 15b carried by mandrel component 2b. Spline means 15 is operable to permit limited longitudinal movement of housing 9 relative to mandrel 2, while substantially preventing relative rotary movement between these components.

A fourth spline means 16 shown in FIGS. 1A and 2A serves to interconnect the compression ring 13 with mandrel 2. Spline 16 is defined by radially inwardly projecting, compression ring carried, spline lugs 13a which are slidably received within longitudinally extending, mandrel carried, spline grooves 13b. Spline 16 permits limited longitudinal movement of compression ring 13 relative to mandrel 2 but substantially prevents relative rotational movement between these components.

As shown in FIG. 1A, the lower ends 17 of spline grooves 13b define third abutment means 17. This third abutment means is disposed beneath the compression ring when the packer 1 is located in a well bore. Abutment means 17 are operably to abuttingly engage and lift the compression ring 13, in response to upward movement of the mandrel 2 relative to housing 9, within the well bore. When this lifting action occurs, with the housing 9 restrained against upward movement because of the set slip segments 10a, continued upward movement of the mandrel 2 will induce upward movement of the compression ring 13. This compression will tend to compress the coil spring 14, thereby asserting resilient force on the shoulder 9c which is transmitted as a lifting or slip "unsetting" force through the housing 9 to the slip segments 10a.

Upper Slip Actuating Means

Packer 1 also includes upper slip actuating means 18 as shown generally in FIG. 1A.

Upper slip actuating means 18 includes upper slip expanding means 19 carried by the upper body means 4. The upper slip expanding means 19 provides a plurality of circumferentially displaced, downwardly and outwardly slipping, camming or slip expanding surfaces 20.

The slip expander means 19, as shown in FIGS. 1A and 2B, comprise a plurality of circumferentially spaced expander blocks 19a. These blocks are mounted for radially outward movement in slot portions 19b of upper body means component 4a. Each expander block 19a is biased radially inwardly toward mandrel means 2 by a coil spring 19c. Each such coil spring 19c is stabilized for defined radial movement, along with its associated expander block 19a, by an alignment plug 19d. Each alignment block 19d passes axially through its associated biasing spring 19c and telescopically through a stabilizing aperture 19e formed in the associated expander block

19a. Each block 19a provides an expander surface 20, as shown in FIG. 1A.

Upper slip actuating means 18 additionally includes a sleeve 21 mounted for limited longitudinal movement on mandrel means 2. Sleeve 21 is provided at its lower end with a downwardly and inwardly sloping, frustoconical camming surface 21a. Camming surface 21a is operable, in response to downward movement of mandrel 2 relative to expander means 19, to cammingly engage upwardly and outwardly sloping camming surfaces 19f formed on the expander blocks 19a. Thus, downward movement of the sleeve 21 will cause the cooperating camming surfaces 21a and 19f to facilitate the movement of the sleeve 21 axially between the expander blocks 19a and mandrel 2 so as to cause radially outward movement of the expander blocks 19a relative to the mandrel means 2.

Sleeve 21 is mounted for limited floating movement on the outer periphery of mandrel means 2, as generally shown in FIG. 1A. Upward movement of sleeve means 21 is limited by an annular stop ring 22 fixedly secured to mandrel means 2 above sleeve 21. Downward movement of sleeve 21 relative to mandrel 2 is limited by an annular shoulder or stop 23, also fixedly positioned on mandrel means 2.

Piston and Cylinder Assembly

As shown in FIG. 1B, upper body means 4 and lower body means 5 are interconnected by a piston and cylinder assembly 24.

Piston and cylinder assembly 24 includes cylinder means 25 defined by upper body means 4 and having an open lower end 25a when the packer is disposed in a well bore. Cylinder 25 is defined by radially spaced and generally parallel components 4c and 4d body means 4, interconnected by a cylinder head defining, lower end of upper body means component 4b. This cylinder head 25b is provided with one or more longitudinally extending relief passages 25c as generally shown in FIG. 1b.

Assembly 24 additionally includes an annular piston 26 defined by the upper end of lower body means component 5a. Piston 26 is telescopingly received within the annular open end 25a of annular cylinder 25.

The interior 27 of cylinder 25 defines a relatively low pressure zone, with the reference to the well bore pressure beneath the packer in its set or expanded condition.

Ratchet Mechanism

As shown in FIGS. 1C and 2D, packer 1 includes a ratchet means 28 which is operable to ratchetingly interconnect the upper body means 4 and lower body means 5. Ratchet means 28, when operable, is designed to permit downward movement only of the upper body means relative to the lower body means 5 when the packer 1 is located in a well bore, i.e. upward movement of body means 4 is prevented.

Ratchet means 28 includes a plurality of longitudinally extending, but circumferentially displaced, ratcheting surfaces 29 which are formed on the outer periphery of lower body means component 5a.

Ratchet teeth means 30 are carried by the upper body means 4. Ratchet teeth means 30, as shown in FIG. 2D, comprise a series of circumferentially displaced, teeth bearing lugs or segments 30a, each having a generally T-shaped cross section. The flangelike, circumferentially extending, head portion 30b of each segment 30a is secured within a recess 30c of body component 4c. This arrangement permits radial movement of the segments 30a relative to the body means 4, but prevents longitudinal movement of the segments 30a relative to the body means 4. The lower end of each recess 30c is defined by the upper end of component 4e, as shown in FIG. 1C.

The radially inwardly extending leg portion 30d of each segment 30a is guidingly and slidably received by a longitudinally extending slot portion 29a formed in lower body means component 5a. The various slot portions 29a, as shown in FIG. 2, are circumferentially interspersed with the ratchet teeth surface means 29.

A pair of coil spring assemblies 30e extend circumferentially about the ratchet segments 30a and engage these segments so as to tend to bias them radially inwardly.

As shown in FIG. 2D, the radially facing undersurfaces 30f and 30g on the circumferentially extending flanges of each segment 30a are provided with ratchet teeth designed to ratchetingly engage with the ratcheting surface means 29. Stabilized radial movement of segments 30a may be facilitated by radial guide slots 30h formed in the upper end of component 4e and slidably and guidingly receiving the lower edges of the radial segment legs 30d.

As will be apparent by reference to the enlarged view shown in FIG. 6, the cross-sectional nature of the ratchet teeth surfaces 30f and 30g and the mating, ratchet surface means 29 is such as to permit downward movement only of means 4 relative to body means 5, when the segments 30a are moved radially inwardly so as to cause the teeth 30f and 30g to ratchetingly engage the surfaces 29.

Ratchet means 29 is provided with a disabling means 31 carried by the mandrel means 2. As shown generally in FIG. 1C, disabling means 31 is defined by an annular shoulder 31a having an upwardly facing camming surface 31b and a downwardly facing annular camming surface 31c. With shoulder 31a fully engaged with the legs 30d of ratchet teeth bearing segments 30a, as shown in FIG. 1C, the teeth 30f and 30g of each segment are held out of ratcheting engagement with the surface means 29. However, downward movement of the mandrel means 2 relative to the upper body means 4 will cause the shoulder 31a to move downwardly out of engagement with the segment legs 30d so as to permit the springs 30e to bias the segments 30a into ratcheting engagement with the surface means 29.

When the shoulder 31 has moved downwardly out of alignment with the segments 30a, during the packer setting operation, it will be apparent that when the packer is to be released, the raising of mandrel 2 will cause the shoulder 31a to again engage the segment legs 30d and move the segments 30a out of locking or ratcheting engagement with the surface means 29.

Shoulder 31 is located on mandrel means 2 so as to engage the segments 30a on the upstroke of mandrel means 2 only after the sleeve 21 has been moved upwardly out of engagement with the expander blocks 19 and after the upper slip segments 10a have been substantially separated from locking cooperation with the expander surfaces 20. Indeed, shoulder 31 will engage segments 30a on the upstroke of mandrel 2 (with this engagement is facilitated by cam means 31b) only after the slip segments 10a have separated sufficiently from surfaces 20. This separation is such that the "relaxation" or expansion of packer elements, permitted by disengagement of the segments 30a from the ratchet surface means 29, cannot induce upward movement of body means 4 relative to lower body means 5 sufficient to reengage the expander surfaces 20 with the slip segments 10a and reset the upper slips.

Packer Assembly

As shown generally in FIG. 1C, packer 1 includes a packer assembly 32.

Packer assembly 32 includes one or more generally annular, longitudinally compressible and generally radially expandable packer elements 33. Packer elements 33 are disposed in superposed or stacked relation on lower body means 5. Annular shoulder 34 defined by lower body means 5 comprises a lower packer engaging means disposed beneath the packer elements 33 when packer 1 is located in a well bore.

Shoulder 34 is fixedly positioned on lower body means 5. A movable shoulder or upper packer engaging means 35 is carried by the upper body means 4. Shoulder 35 is disposed above the packer element 33 when the packer 1 is located in a well bore.

As is shown in FIG. 1C, the packer elements 33 are stabilized by a generally cylindrical wall 36 defined by body segment 5a.

The upper packer engaging shoulder 35 is operable to converge longitudinally with the lower shoulder 34 in response to longitudinally converging movement of the upper body means 4 and the lower body means 5. This convergence of shoulders 34 and 35 will induce longitudinal compression and generally radial expansion or "setting" of the packer elements 33 in a conventional and well-recognized fashion.

Lower Slip Assembly

The lower slip assembly 6 incorporated in packer 1 is shown generally in FIGS. 1C and 1D.

Lower slip assembly 6 includes lower slip housing means 37 defined by conventionally interconnected components 37a, 37b, and 37c. Lower slip housing means 37 is thus generally cylindrical in character and is mounted on the lower body means 5 beneath the packer assembly 32 when the packer is locked in a well bore.

Lower slip means 38 are carried by housing means 37 and project generally longitudinally upwardly from the housing 37 within a well bore. Lower slip means 38 is defined by a plurality of circumferentially displaced slip segments 38a. Slip segments 38a are constrained by circumferentially extending webs 38b and a circumferentially extending T-head 38c for controlled, radially outward movement. Slip segment structure and mounting arrangement of this nature are now well known and described, for example, in a U.S. Pat. 3,308,996 to Evans.

Lower slip assembly 6 is provided with drag block means 39 carried by housing 37. Drag block means 39, as shown in FIGS. 1D and 2F, is characterized by a plurality of circumferentially displaced drag blocks 39a. Each drag block is biased outwardly by a series of longitudinally spaced, helical spring assemblies 39b as shown in FIG. 1D. Each spring assembly 39b may be stabilized by a radially outwardly projecting boss 39c formed on housing component 37b.

Drag blocks 39a frictionally engage the inner periphery of the well bore as the packer 1 is moved longitudinally therethrough so as to tend to impede movement of the lower slip assembly 6 relative to the remainder of the packer apparatus.

A J-slot means 40, shown in FIGS. 1D, 2E and 2G, serves to controllably interconnect the housing 37 with the lower body means 5. J-slot means 40 is operable to selectively permit or prevent longitudinal movement of the body means 5 relative to the housing 37 through a longitudinal movement increment.

This longitudinal movement increment is defined by the "long," longitudinally extending, leg 40a of each of the two concurrently operable J-slot mechanisms 40b incorporated in the packer apparatus. In each of the two J-slot mechanisms, a radially outwardly facing, J-shaped slot 40c is formed in lower body means 5. Each such slot 40c includes the long leg portion 40a and a conventional "short" restraining leg 40d. Leg portions 40a and 40d are interconnected by the generally circumferentially extending leg portion 40e, inclining upwardly from leg 40d toward leg 40a.

In each J-slot mechanism 40b, a radially inwardly projecting lug 40f, carried by housing 37, is slidably received within the J-slot 40c.

When the lugs 40f are moved into the long J-slot legs 40a, by clockwise rotation of the body means 5 from the FIG. 2 position, the body means 5 is free to undergo the aforesaid longitudinal movement increment, downwardly relative to housing 37, as permitted by relative movement of lugs 40f "upwardly" through the long leg 40a.

As will be appreciated, rotation of the body means 5 so as to permit the lug to move into the leg 40a may be effected by picking the mandrel 2 upwardly and then rotating the mandrel 2 clockwise. The "pickup" on the mandrel 2 will move the restraining J-slot corner 40g out of engagement with the lug 40f, with the clockwise turning movement of the mandrel 2 then serving to shift the J-slot so as to bring the long leg 40a

into longitudinal alignment with the lug 40f. Rotary movement of the body means 5 in response to rotary movement of the mandrel 2 is permitted by the spline joints 7 and 8.

Force Transmitting Coupling

Packer 1 additionally includes a selectively releasable, longitudinal force transmitting coupling means 41 shown in FIG. 1D.

Detent coupling means 41 is interposed between the lower body means 5 and the mandrel means 2.

Coupling 41 includes a plurality of circumferentially spaced ball detents 42 carried by sockets 42a formed in the component 5d of lower body means 5. When unrestrained, the ball detents are operable to move radially outwardly of the sockets 42a and the lower body means 5.

A downwardly facing, annular shoulder 43 carried by the mandrel means 2 is operable to engage the ball detents 42 and transmit longitudinal force from the mandrel 2, through the ball detents 42 to the lower body means 5 when the ball detents 42 are disposed, as shown in FIG. 1D, in a radially innermost and confined position within the sockets 42a on the lower body means 5.

Ball means 42 are confined to the radially innermost, force transmitting, position shown in FIG. 1D by a generally cylindrical, inwardly facing, ball restraining surface 44 carried by the slip housing 37. With surface 44 located radially adjacent the ball detents 42, this surface 44 prevents radially outward movement of the detents 42 relative to the lower body means 5, assuming of course that the J-slot means are disposed as shown in FIG. 2G, so as to substantially prevent downward movement of body means 5 relative to slip housing means 37.

The coupling means 41 additionally includes a generally radially outwardly extending recess 45 carried by the slip housing 37 beneath the restraining wall 44. Recess 45, when located radially adjacent the ball detents 42, is operable to permit generally radially outward movement of the detents 42 relative to the lower body means 5. This radially outward movement of the detents 42 moves the detents out of force transmitting engagement with the shoulder means 43. Thus, with the ball means 42 moved outwardly into the recess 45, downward movement of mandrel 2 relative to lower body means 5 is permitted.

At this point it should also be recognized that the positioning of the J-slot lugs 40f in the long J-slot legs 40a will permit the lower body means 5 to move downwardly through gravity, or move downwardly with mandrel means 2 because of frictional interaction between these components, so as to effect camming and slip setting operation between the lower slip segments 38a and a lower slip actuating means subsequently described.

Equalizing Valve

Returning now from the lower end of the packer 1 to an intermediate packer portion, as shown in FIGS. 1B and 1C, it is appropriate to consider a highly significant equalizing valve means 46 incorporated in the packer apparatus 1.

Equalizing valve means 46 includes a first, generally annular, longitudinally extending first passage means 47 interposed radially between the mandrel means 2 and the interconnected upper and lower body means 4 and 5 respectively.

A series of circumferentially displaced ports 48 shown in FIG. 1C are carried by segment 5c of lower body means 5 and disposed beneath the packer assembly 32. Ports 48 define second passage means providing fluid communication between the longitudinally extending first passage means 47 and the well bore within which the packer 1 is disposed.

Another series of circumferentially spaced ports 49, carried by segment 4b of upper housing means 4, defines third passage means disposed above the packer assembly 32. Third passage means 49 is operable to provide fluid communication between the first passage means 47 and the well bore surrounding the body means 4. Third passage means 49 also provides continu-

ous fluid communication between cylinder cavity 27 and the well bore by way of relief passages 25c.

Equalizing valve means 46 includes sleeve valve means 50 carried by the mandrel means and disposed in sealing and sliding engagement with the upper body means 4. Sleeve valve means 50 is defined, in part, by segments 2b, 2c, and 2d of mandrel means 2 as shown generally in FIG. 1B.

A generally cylindrical seat 51 is carried by segment 4d of upper body means 4, and is operable to valvingly receive the sleeve valve means 50. Seat means 51 is interposed longitudinally between the second and third passage means 48 and 49 respectively. Valving cooperation between the valve means 50 and the seat 51 is effective to substantially block fluid communication between the second and third passage means 48 and 49.

The sleeve valve 50 is spaced longitudinally above the seat 51 when the packer 1 is located in a well bore and the mandrel 2 is blocked against downward longitudinal movement by the selectively releasable coupling means 41, as shown generally in FIGS. 1A through 1D.

The valve means 50 includes a generally annular, shoulderlike valve body 52 projecting radially outwardly of the mandrel 2 and defined by mandrel segment 2c.

One or more circumferentially spaced, longitudinally extending, fourth passage means 53 extend entirely through the body means 52 terminating at upper and lower ends 53a and 53b respectively.

A generally annular, first ledge means 54 projects radially outwardly of the valve body means 52 as shown generally in FIG. 1B. A generally annular piston 55 is telescopically mounted on body means 52 for relative longitudinal movement with respect to the body means 52. Piston 55 is operable to seat on ledge 54.

A second annular ledge 56, defined by the lower end of component 4a of upper body means 4 and projecting radially inwardly therefrom, is spaced above the upper end of piston 55 when the piston 55 is seated on ledge 54 as shown in FIG. 1B.

As is also shown in FIG. 1B, ledge 56 is defined by a radially inwardly projecting, annular shoulder portion 56a of upper body means 4 which provides slidable and sealing cooperation between the upper body means 4 and mandrel means 2.

Ledges 56 and 54 are operable to permit, but limit, longitudinal movement of the piston 55 relative to the valve body 52. The piston 55 of course is alternately engageable with either the ledge 54 or the ledge 56, depending upon the direction in which it has been moved.

Valve means 50 additionally includes an enclosure 57 defined by mandrel component 2b and upper body means components 56a and 4b. Enclosure 57 is operable to define a cavity 57a communicating with the upper end 53a of fourth passage means 53 and upper end 55a of piston 55. As shown in FIG. 1B, cavity 57a is closed except for its communication with passage means 53. Passage means 53 is disposed in continuous fluid engagement with the longitudinally extending first passage means 47.

At this point it is appropriate to consider the unique structure of a multistage, seal arrangement associated with the equalizing valve 46. This seal arrangement avoids scouring or abrasion of the valve seal means so as to prolong the operating life of the packer.

As shown in FIGS. 1B, 11A, and 11B, the valve seal arrangement includes a first relatively rigid, lower seal 58. Lower seal 58 may be fabricated, for example, from metal such as brass. This relatively rigid, annular seal 58 may be provided with a T-shaped cross section as shown in FIG. 1B, and secured in an annular recess 58a having a T-shaped cross section and extending circumferentially about the valve body 52. Seal ring 58 may be releasably secured by a threadedly mounted securing collar 58b.

The radially outwardly facing periphery 58c of ring 58 provides limited sealing cooperation with the seat 51, recognizing of course that the relatively rigid character of the seal 58 and

the nominal clearance between the seal and the seat 51 will yield a relatively low pressure seal.

Spaced somewhat longitudinally above the rigid seal 58 is a second, relatively deformable seal means 59.

Seal means 59 comprises an annular, resilient or deformable seal member 59a secured in a recess 59b on the lower end of valve body 52. The upper and lower edges of deformable seal 59a may be supported by antiextrusion rings 59c and 59d. Seal 59a may be mounted in recess 59b so as to leave a longitudinal gap or clearance 59e. This gap or clearance may accommodate longitudinal expansion of the seal element 59a resulting from the radial compression of the seal 59a which takes place when the seal element 59a valvingly and sealingly engages the seat 51.

The deformable nature of the seal 59 tends to provide an effective and relatively high pressure seal between the body means 52 and the seat 51.

Seal 58 is positioned on mandrel means 2 so as to be engageable with the seat means 51 at about the point in time when the sleeve means 21 engages the expander blocks 19.

The second or deformable seal means 59 is operable to sealingly engage the seat means 51 prior to the point in time where longitudinal convergence of packer setting shoulders 34 and 35 occurs.

Valve means 50 additionally includes a packer setting, shoulderlike abutment 60 carried by the valve body 52. Abutment 60 projects radially outwardly from valve body 52 and is disposed above the second seal means 59.

Packer setting abutment 60 is operable to abuttingly engage the upper end 25a of cylinder means 25. Once abutment 60 has engaged cylinder 25, longitudinally and downwardly directed force may be transmitted from the mandrel 2, through the ledge 60 and cylinder 25, to the shoulder 35 so as to induce axial to longitudinal compression of the packer elements 33.

Thus, after the valve seals 48 and 49 have seated against the seat 51, the shoulder 60 will engage the cylinder 25 and commence the packer setting or expanding action.

Pressure Balancing

Packer 1 additionally includes pressure balancing means 61 shown generally in FIG. 1B.

This pressure balancing arrangement comprises an annular surface means 62 defined by the upper ends of the valve body 52 and the piston 55. This annular area is equivalent to the annular area between the seat 51 and the inner cylindrical wall 62a of body segment 4b and is acted downwardly on, when the packer is set, by fluid pressure beneath the set packer and transmitted by passage means 47 and 53. This annular area is substantially equal to the cross-sectional area of a circle having a radius equal to the radius of the segment of the portion 2b of mandrel means 2 disposed in slidable and sealable engagement with segment 56. This circular area represents the net area of mandrel means and conduit string 2 acted upwardly on by pressure beneath the set packer. With this arrangement, the generation of pressure beneath the set packer assembly, either from a formation or from the pressure of fluid within the unobstructed cylindrical interior 2f of mandrel means 2, will not tend to induce upward movement of the mandrel means 2. Such upward movement of the mandrel means 2 of course would be undesirable as it would tend to open the equalizing valve 46 and permit unsetting of the packer.

This pressure balancing concept is significant with respect to "differential pressure" acting beneath the set packer assembly.

Pressure balancing to some extent is also provided when differential pressure is acting above the packer assembly, i.e. when the pressure of annulus fluids above the set packer elements 33 exceeds hydrostatic pressure and pressure of fluid in the well bore beneath the packer elements 33. Where such differential pressure exceeds above the packer assembly, the

pressure will act on the floating pistons 55 and tend to move the piston upwardly against the ledge 56. This differential pressure will thus be transmitted to the expander blocks 19, thereby tending to increase the holding action of the slips 10.

Such differential pressure acting above the packer elements 33 will, in effect, act upwardly on the mandrel 2 across an area substantially equal to the annular area between wall means 51 and wall means 52a of valve body means 52. This differential pressure will act downwardly on mandrel means 2 across an annular area extending between wall means 61a, sealingly engaged with segment 56a, and the normally smaller, outer diameter of the tubing string supporting the mandrel means 2. Where such differential pressure acting above the packer elements 33 produces a net upward force acting on the mandrel means 2, it may be necessary to increase tubing or string weight so as to overcome the raising force. However, as will be recognized, the condition most likely to be encountered is that where differential pressure will tend to act beneath the expanded packer elements 33, and in this event the pressure balancing surface means 62 provide a substantially fully pressure balanced mandrel structure.

As will be apparent by reference to FIG. 1B, pressure balancing surface means 62 is disposed in continuous fluid communication with the first passage means 47 by way of the fourth passage means 53.

As will also be apparent, the pressure balancing action of surface means 62 is effective only when the valve means 50 is sealingly engaged with the seat means 51 and the packer elements 33 are expanded into sealing engagement with the inner periphery of the well bore.

The third passage means 49 carried by the upper body means 4 provides continuous fluid communication between the well bore and the downwardly facing portion 55b of piston means 55. Thus, piston means 55 is continuously able to move upwardly into engagement with ledge 56 in response to a differential pressure acting above the set packer means 33, i.e. when the pressure in the passage means 49 exceeds the fluid pressure in the first passage means 47.

Lower Slip Actuating Means

In conclusion, packer apparatus 1 is provided with a lower slip actuating means 63.

As shown in FIG. 1C, lower slip actuating means 63 is defined by a series of circumferentially displaced, downwardly and inwardly sloping, slip expanding surface means 64. Each such surface means 64 is disposed in longitudinal alignment with and disposed above one of the slip segments 38a. Each such expander surface 64 is operable to induce radially outward movement of a slip segment 38a in response to longitudinally downward movement of the lower body means 5 relative to the lower slip assembly 6, as described generally in the aforesaid Evans patent.

Such downward movement of the lower housing means 5 may occur by gravity or as a result of frictional interaction between the downwardly moving mandrel means 2 and the lower body means 5 when the J-slot lugs 40f are located in the long legs 40a of the J-slots.

PACKER SETTING AND RELEASING SEQUENCE

The manner in which the retrievable packer 1 is both set and released within a well bore will now be described with reference to FIGS. 3-10.

Run-In

FIG. 3 illustrates the packer 1 with its components arranged to permit the apparatus to be run downwardly through a well bore to a location where the packer is to be set.

FIG. 3 also illustrates, for reference purposes, the relationships existing between FIGS. 1A-1D and the overall schematic representation of the packer 1 as set forth in FIG. 3.

In the "run-in" position shown in FIG. 3, the ball detents 42 are engaged with the shoulder 43, with the J-slot lugs 40f

being disposed in the J-slot legs 40d. The mandrel 2 is in an "upper" position. This disposition of components ensures that the lower slips, the packer elements, and the upper slips are all maintained in a contracted or "unset" condition.

Lower Slip Setting

When the desired location within a well bore W has been reached, downward movement of the conduit string, supporting the upper end of the mandrel 2 is interrupted. The conduit string is pulled upwardly and turned to the right, or clockwise, so as to, in essence, cause the long J-slot legs 40a to be moved into longitudinal alignment with the J-slot lugs 40f. The mandrel 2 is then moved downwardly, as shown in FIG. 4, so as to cause the expander surface means 64 to cammingly engage the lower slips 38a and cam these slip segments 38a radially outwardly into locking or "set" cooperation with the well bore W. The setting of lower slips 38a, i.e., their radially outward movement, is schematically illustrated in FIG. 5.

This action results because of the continuous frictional engagement between the outer periphery of the drag blocks 39 and the well bore W which longitudinally restrains the segments 38a. With this restraint present, as the mandrel is moved downwardly as permitted by the J-slot legs 40a, the lower body means 5, carrying the expander surface means 64, will move downwardly, either under the influence of gravity or through frictional interaction with the mandrel so as to induce the lower slip setting action.

This downward movement of the lower body means 5, possibly augmented by the downward thrust transmitted from mandrel shoulder 43 through ball detents 42, will serve to move the ball detents 42 into alignment with the recess 45 as shown in FIG. 4. With the ball detents disposed in the recess 45, the shoulder 43, in response to further downward movement, will cam the ball detents 42 radially outwardly out of force transmitting engagement with the mandrel means 2. This, of course, frees the mandrel means 2 for further downward movement.

As is also shown in FIG. 5, the initial downward movement of the mandrel means 2 relative to the body means 5, after the lower slip assembly 6 has been set, has served to move the ratchet disabling shoulder 31 downwardly out of engagement with the teeth bearing means 30, i.e. the segments 30a. This longitudinal displacement of the shoulder means 31 and the segments 30a, as shown in FIG. 6, serves to permit the springs 30e to move the ratchet teeth surface means 30f and 30g into ratchetting cooperation with the ratchet surface means 29.

At this point, it will be appreciated that with the components arranged as shown in FIG. 6, the upper body means 4 may move downwardly relative to the lower body means 5, by ratchetting the segments 30a downwardly over the ratchet surface means 29. However, the configuration of the ratchet teeth prevents upward movement of the body means 4 relative to the lower body means 5, when the components are arranged as shown in FIG. 6.

Upper Slip Setting

Further downward movement of the mandrel means 2 serves to cause the abutment means 22 to urge the lower camming end 21a of the expander sleeve 21 into camming cooperation with the upper cam end 19f of the expander blocks 19a as shown generally in FIG. 7. At about this point in time, the relatively rigid equalizing valve seal 58 telescopes within and sealingly cooperates with the valve seat 51, to the extent of providing a low pressure pseudo "seal."

Still further downward movement of the mandrel means 2 as shown in FIG. 8, will cause the sleeve 21 to move radially between the expander blocks 19a and the mandrel means 2, thereby displacing the expander blocks 19a radially outwardly. This expansion action takes place with the cam surfaces 10e of the upper slip segments 10a disposed in engagement with the slip expanding surfaces 20 as shown in FIG. 8. Thus, downward movement of mandrel means 2, effective to

move sleeve 21 radially beneath the expander blocks 19a, will take place with the expander blocks 19a and the slip segments 10a disposed in coaxing, or slip setting cooperation.

Continued downward movement of the mandrel means 2 will cause the shoulder 11 to engage the upper end of the spring 14a and move the spring end 14a downwardly. This downward movement of the spring end 14a, with the slip segments 10a at least partially set against the well bore W so as to restrain movement of the housing 9, will transmit resilient, downwardly directed force through the spring 14, compression ring 13 and body means 9, to the slip segments 10a thereby providing an intensified upper slip setting action.

In this connection, it will be recognized that this "setting" of the upper slip segments 10a serves to prevent upper movement of the upper slip assembly, although downward movement of the assembly 3 and the upper body means 4 will subsequently occur.

Closing of Equalizing Valve

Still further downward movement of the mandrel means 2 will cause the upper, high pressure, equalizing valve seal 59 to telescope within and set against the equalizing valve seat 51 as shown in FIG. 9. A slight additional increment of downward movement of mandrel means 2 relative to upper body means 4 will cause the packer setting shoulder 60 to abuttingly engage the upper end 25a of cylinder means 25, as is also shown in FIG. 9.

Packer Setting

Downward movement of mandrel means 2 beyond the FIG. 9 position, will induce downward movement of the body means 4 relative to the lower body means 5. Body means 5, of course, is restrained by the set, lower slip assembly 6.

As shown in FIG. 10, this downward movement of the upper body means 4 relative to the restrained lower body means 5 will cause the upper packer engaging shoulder 35 to converge with the restrained, lower packer means engaging shoulder 34 and cause longitudinal contraction and radial expansion of the packer elements 33 into sealing cooperation with the well bore W. During this downward, packer expanding movement of the body means 4, the ratchet segments 30a will ratchet downwardly over the surface means 29 as shown in FIG. 10. Ratchet segments 30a will secure the expanded packer elements 33 in their set or expanded condition with piston 26 having a substantial, upward travel distance available in cylinder 25, as shown in FIG. 10. The locking action of segments 30 at any axial position of mandrel means 2 may be facilitated by longitudinally displacing the ratchet teeth 30f and 30g of segments 30m and 30n by a half tooth increment with respect to segments 30x and 30y (See FIG. 2D).

With the packer set, differential pressure acting beneath the packer, acting through piston and cylinder means 24, will tend to intensify the packer setting action by inducing axial convergence of body means 4 and 5. Any such convergence, of course, will be secured by ratchet means 28.

Retrieval

Unsetting and retrieving of the packer 1 is effected merely by moving the mandrel means 2 upwardly within the well bore.

Opening of Equalizing Valve

The initial portion of the upper mandrel means movement serves to move the high pressure seal 59 upwardly out of the seat 51. After continued upward movement of the mandrel means 2 has displaced the deformable seal 59 above the valve seat 51, as shown in FIG. 11A, an additional increment of upward movement of the mandrel means 2 will serve to separate the low pressure, rigid seal 58 from the valve seal 51. At this point, the equalizing valve has been opened to restore fluid communication between the port means 48 and 49 thereby

equalizing pressure across the still expanded packer elements 33. However, contraction of the packer elements 33 is prevented by the ratchet teeth segments 30a.

Release of Upper Slips

Further upward movement of the mandrel means 2 causes the shoulder 23 to engage the sleeve 21 and move the sleeve 21 upwardly out of engagement with the expander blocks 19a. This action permits the expander blocks 19a to radially collapse and thus induce unsetting of the upper slip assembly. Since the equalizing valve is open at this point, differential pressure formerly acting beneath the packer will not be able to urge the packer upwardly and cause the slip segments 10a to cam the expander blocks 19a radially inwardly against sleeve 21 so as to impede upward sleeve movement.

If the upper slip assembly should not release at this point, continued upward movement of the mandrel means 2 will cause the abutment means 17 to engage the compression ring 13 and move the lower end 14b of the coil spring upwardly. This upward movement of the coil spring lower end 14b, with the slips 10a still partially set, will assert a resilient upward force on the slip segments 10a through the housing means 9, thereby tending to pull the slip segments 10a away from the expander blocks 19a so as to more positively induce unsetting of the upper slip assembly.

If this action should prove unsuccessful in effecting complete releasing or unsetting of the upper slip assembly, still further upward movement of the mandrel means 2 will cause the upper end 21b of the sleeve 21 to abuttingly engage a lifting shoulder 9d formed on housing means 9 as shown in FIGS. 1A and 8. With sleeve end 21b engaged with shoulder 9d, upward movement of the mandrel means 2 will exert a lifting, or upwardly directed impact force, on the slip housing means 9 so as to ensure the separation of the segments 10a from setting cooperation with the expander blocks 19a.

Release of Packer Elements

With the upper slip assembly now fully released, the terminal portion of the upward movement of the mandrel means 2 will cause the ratchet disabling shoulder 31 to cam back underneath the leg portions 30d of the teeth bearing segments 30a, and reassume the FIG. 1C position. This reengagement of the shoulder 31 with the segments 30a is facilitated by the camming shoulder 31b.

With shoulder 31 again interposed radially between the segments 30a and the mandrel means 2, the teeth surfaces 30f and 30g are separated from locking cooperation with the surface means 29. With the ratchet mechanism thus disabled, the packer elements 33 are free to longitudinally expand and radially contract so as to induce full packer release. This relaxation of the packer elements 33 will tend to induce upward movement of the body means 4 relative to the body means 5 and the mandrel means 2. However, since the slip segments 10a and the expander sleeve 21 have been fully separated from cooperable engagement with the expander block segments 19a, the relaxation of the packer elements 33 cannot possibly cause resetting of the upper slip assembly.

Release of Lower Slips

The terminal portion of the upward movement of mandrel means 2 will concurrently cause the J-slot lug means 40f to automatically cam back into the short J-slot leg means 40d and the expander surface means 64 to move upwardly, away from the drag block restrained, lower slip segments 38a. The automatic camming action of the J-slot means is effected by the sloping nature of the transition slot means 40e of the J-slot mechanism. The relative upward movement of the lower body means 5 and the lower slip assembly 6, necessary to effect this automatic repositioning of the J-slot means and separation of surface means 64 and segments 38a, may be effected by engagement of surface means 62 with abutment 56, with lifting force being transmitted from body means 4 to body means 5 at

abutment junction 65 shown in FIG. 16. Rotation of drag blocks 39 relative to the well bore (or torsional flexibility of the supporting conduit string) will permit the necessary relative rotation between the lower slip assembly 6 and the lower body means 5 to effect the automatic repositioning of the J-slot means in the FIG. 2G position for packer retrieval purposes.

As will also be appreciated, the ball detents 42, which are retained in the sockets 42a by the mandrel means 2 and the wall 45, will become reengaged with the restraining wall 44 in response to the terminal portion of the upward movement of the mandrel means 2 during the packer releasing sequence. The frictional interaction between the drag blocks 39 and the well bore W will tend to cause relatively upward movement of the body means 5 relative to the lower slip assembly during upward movement of the mandrel means 2 so as to restore the restraining surface 44 to radial restraining alignment with the ball detents 42.

ENHANCEMENT OF EQUALIZING VALVE OPERATING LIFE

The sequential releasing of the equalizing valve 50 has been described so as to make clear its structure and mode of operation.

However, the importance of this releasing action justifies some additional discussion with reference to FIGS. 11 and 11A.

As shown in FIG. 11, the equalizing valve 50 is disposed in a fully closed position, with seats 59 and 58 fully engaged with the valve seat 51.

During the releasing of the equalizing valve 50, shown in FIG. 11A, upward movement of the mandrel means 2 first serves to move the relatively deformable high pressure gasket or seal 59a upwardly out of sealing cooperation with the seat 51.

However, when seal 59a is released from seat 51, the rigid low pressure seal 58 remains seated within seat 51 so as to prevent a rapid upward flow of high pressure fluid across the seal 59a. Such a rapid upward flow of high pressure well fluid at the point in time when the seal 59a was releasing from the seat 51 would tend to produce seal abrasion and scouring. By preventing this high pressure flow during the releasing of the seal 59a, the operating life of the equalizing valve is substantially enhanced.

As will be apparent by reference to FIG. 11A, substantial upward movement of the seal 59a must take place before the low pressure rigid seal 58 separates from the seat 51. This ensures substantial separation of the seal 59a from high pressure fluid passing upwardly through the passage means 47 at the point in time when the seal 58 is axially separated from the seat 51.

As will be further noted, the low pressure seal 58 is supported by collar 58b with this collar 58b providing a fluid deflecting surface 58c disposed beneath the seal 58. Thus, as the seal 58 clears the seat 51, the deflecting surface 58c will tend to deflect high pressure fluid flowing upwardly through the passage means 47 upwardly and outwardly away from the relatively vulnerable seal 59a.

It will also be recognized that seal 58 is more of a flow limiting device than a true seal. Its function is to perform as a flow impedance device, having a high resistance to fluid flow induced wear. Seal 58 may engage seat 51 via an interference fit, or be provided with a small clearance or leakage path, but nevertheless will probably permit some leakage through passage means 47 when the "true" seal 59 is released.

SUMMARY OF ADVANTAGES AND SCOPE OF INVENTION

In describing the invention, reference has been made to a preferred embodiment, encompassing optimum advantages of the overall invention.

Within the overall invention, the equalizing valve structure provided with sequentially operable high and low pressure "seals" tends to prolong operating life of the packer by reducing abrasion and wear with respect to the high pressure seal.

The floating piston carried by the equalizing valve is effective in tending to augment the holding action of the upper slip assembly in response to differential pressure acting above the set packer.

The body arrangement comprising a central mandrel and upper and lower body means interconnected by spline joints, with movement between the upper and lower body means being controlled by the latching mechanism, provides an effective yet structurally reliable packer body arrangement.

The piston and cylinder interconnecting the upper and lower body means provides a positive "pressure assist" phenomena, whereby differential pressure acting beneath the set packer tends to intensify the packer setting action.

The floating sleeve and compression ring of the upper slip actuating mechanism provides a sequentially operable device for applying diverse slip releasing forces to the upper slip assembly so as to promote positive and reliable slip releasing action.

The detent-type, force transmitting arrangement and the lug and slot movement control mechanism provide a reliable structure for controlling longitudinal movement between the mandrel, lower body means, and lower slip assembly while transmitting longitudinal force between these components, as desired.

The manner in which the sleeve 21 is slidably mounted on the mandrel means 2 permits the equalizing valve to be opened before the upper slip assembly is released. In releasing the equalizing valve before the sleeve 21 is sought to be removed from cooperation with the expander blocks 19a, separation of the sleeve 21 and expander blocks 19a is facilitated.

The operation of the latch mechanism, in preventing packer contraction before the upper slips and upper slip expander blocks have been fully separated, ensures that the radial contraction and longitudinal expansion of the packer elements does not reset the upper slips.

Having described the invention with reference to a preferred embodiment, those skilled in the packer art and familiar with the disclosure of this invention may recognize additions, deletions, substitutions or other modifications, which would fall within the purview of the invention as set forth in the appended claims.

We claim:

1. A packer apparatus for use in a well bore, said apparatus comprising:
 - mandrel means operable, when disposed in a well bore, to be connected at an upper portion with support means;
 - an upper slip assembly mounted for longitudinal movement on said mandrel means;
 - body means mounted for longitudinal movement on said mandrel means;
 - packer means carried by said body means;
 - upper slip actuating means carried by said body means and operable to exert upwardly directed slip actuating force on said upper slip assembly in said well bore;
 - equalizing valve means including
 - first passage means interposed radially between said mandrel means and said body means,
 - second passage means carried by said body means, disposed beneath said packer means when said apparatus is disposed in said well bore, and providing fluid communication between said well bore and said first passage means,
 - third passage means carried by said upper body means, disposed above said packer means when said apparatus is disposed in said well bore, and operable to provide fluid communication between said first passage means and said well bore,
 - sleeve valve means carried by said mandrel means,

seat means carried by said body means and operable to valvingly receive said sleeve valve means, said seat means being interposed longitudinally between said second and third passage means, with valving engagement between said valve means and said seat means substantially blocking fluid communication between said second passage means and said third passage means,

said sleeve valve means being spaced longitudinally above said seat means when said apparatus is disposed in said well bore and said mandrel means is blocked against downward longitudinal movement relative to said body means,

said sleeve valve means including

valve body means projecting generally radially outwardly of said mandrel means,

fourth passage means extending longitudinally entirely through said valve body means,

first ledge means projecting generally radially outwardly of said valve body means,

piston means mounted for longitudinal movement on said valve body means and disposed, when in said well bore, with its lower end in continuous fluid communication with said third passage means,

second ledge means carried by said body means and projecting generally radially inwardly thereof,

said first and second ledge means being operable to permit but limit longitudinal movement of said piston means relative to said valve body means, with said piston means being alternately engageable with said first and second ledge means,

enclosure means defined by said mandrel means and said body means and operable to define a cavity communicating with the upper end of said fourth passage means and the upper end of said piston means when said apparatus is disposed in said well bore,

said fourth passage means being disposed in continuous fluid communication with said first passage means,

first, relatively rigid, seal means carried by said valve body means and operable to provide a relatively low pressure seal with said seat means,

second, relatively deformable, seal means carried by said valve body means above said first seal means when said apparatus is disposed in said well bore and operable to provide a relatively high pressure seal with said seat means, and

packer setting abutment means carried by said valve body means, disposed above said second seal means when said apparatus is disposed in said well bore, and operable to abuttingly engage said body means and transfer packer means compressing force longitudinally downwardly from said mandrel means to said body means.

2. A packer apparatus for use in a well bore, said apparatus comprising:

mandrel means operable, when disposed in a well bore, to be connected at an upper portion with support means;

an upper slip assembly mounted for longitudinal movement on said mandrel means;

upper body means disposed beneath said upper slip assembly when said apparatus is disposed in a well bore, said upper body means being mounted for longitudinal movement on said mandrel means;

lower body means mounted beneath said upper body means when said apparatus is disposed in said well bore, said lower body means being mounted for longitudinal movement on said mandrel means;

a lower slip assembly mounted for longitudinal movement on said lower body means;

first spline means interconnecting said mandrel means and said upper body means and operable to permit longitudinal movement of said mandrel means relative to said

upper body means while substantially preventing relative rotational movement between said upper body means and said mandrel means;

second spline means interconnecting said upper body means and said lower body means, said second spline means being operable to permit longitudinal movement of said upper body means relative to said lower body means while substantially preventing relative rotational movement between said upper and lower body means;

a piston and cylinder assembly interconnecting said upper body means and said lower body means, said piston and cylinder assembly including

cylinder means carried by said upper body means and having an open lower end when said apparatus is disposed in said well bore, and

piston means carried by said lower body means when said apparatus is disposed in said well bore, said piston means being telescopically received within said cylinder means,

said cylinder means defining a relatively lower pressure zone; and

ratchet means operable to ratchetingly interconnect said upper body means and said lower body means and permit downward movement only of said upper body means relative to said lower body means when said apparatus is disposed in said well bore, said ratchet means including longitudinally extending ratchet surface means carried by said lower body means,

ratchet teeth means carried by said upper body means and secured against longitudinal movement relative thereto, and

ratchet teeth disabling means carried by said mandrel means and operable, in response to downward movement of said mandrel means relative to said upper body means, to permit said ratchet teeth means to ratchetingly engage said ratchet surface means,

said ratchet teeth disabling means being operable, in response to upward movement of said mandrel means relative to said lower body means, to engage said ratchet teeth means and move said ratchet teeth means generally outwardly of said mandrel means and out of ratchetting engagement with said ratchet surface means subsequent to longitudinal separation of said sleeve means and said upper slip expander means, and subsequent to longitudinal separation of said sleeve means and said upper slip expander means, and subsequent to longitudinal separation of said upper slip means and said upper expander means.

3. A packer apparatus for use in a well bore, said apparatus comprising:

mandrel means operable, when disposed in a well bore, to be connected at an upper portion with support means;

a slip assembly mounted for longitudinal movement on said mandrel means;

upper body means disposed beneath said upper slip assembly when said apparatus is disposed in a well bore, said upper body means being mounted for longitudinal movement on said mandrel means; lower body means mounted beneath said upper body means when said apparatus is disposed in said well bore, said lower body means being mounted for longitudinal movement on said mandrel means;

said slip assembly including,

slip housing means,

slip means mounted on said slip housing means and operable to move generally radially outwardly of said mandrel means,

first abutment means carried by said mandrel means and facing generally downwardly when said apparatus is disposed in said well bore,

second abutment means carried by said slip housing means and facing generally upwardly when said apparatus is disposed in said well bore,

compression ring means carried by said slip housing means and adapted to seat on said second abutment means,

longitudinally compressible spring means interposed longitudinally between said compression ring means and said first abutment means, and

third abutment means carried by said mandrel means, disposed beneath said compression ring means when said apparatus is disposed in said well bore, and operable to abuttingly engage said compression ring means in response to upward movement of said mandrel means within said well bore and induce upward movement of said compression ring means tending to compress said spring means when said slip housing means is restrained against upward movement in said well bore by said slip means;

slip actuating means including

slip expanding means carried by said upper body means, said slip expanding means being mounted for generally radially outward movement on said upper body means and providing, when said apparatus is disposed in said well bore, slip expanding surface means,

sleeve means mounted for longitudinal movement on said mandrel means,

said sleeve means being operable, in response to downward movement of said mandrel means in said well bore relative to said upper body means, to engage said slip expanding means and induce generally radially outward movement thereof and being operable in response to upward movement of said mandrel means in said well bore relative to said upper body means, to engage and exert a lifting force on said slip housing means,

first and second stop means carried by said mandrel means, spaced longitudinally thereof, and operable to permit but limit longitudinal movement of said sleeve means;

ratchet means operable to ratchetingly interconnect said upper body means and said lower body means and permit downward movement only of said upper body means relative to said lower body means when said apparatus is disposed in said well bore, said ratchet means including longitudinally extending ratchet surface means carried by said lower body means,

ratchet teeth means carried by said upper body means and secured against longitudinal movement relative thereto,

ratchet teeth disabling means carried by said mandrel means and operable, in response to downward movement of said mandrel means relative to said upper body means, to permit said ratchet teeth means to ratchetingly engage said ratchet surface means,

said ratchet teeth disabling means being operable, in response to upward movement of said mandrel means relative to said lower body means, to engage said ratchet teeth means and move said ratchet teeth means generally outwardly of said mandrel means and out of ratchetting engagement with said ratchet surface means subsequent to longitudinal separation of said sleeve means and said slip expanding means, and subsequent to longitudinal separation of said slip means and said slip expanding means; and

a packer assembly including

longitudinally compressible and generally radially expandable packer means carried by said lower body means,

lower packer engaging means carried by said lower body means and disposed beneath said packer means when said apparatus is disposed in said well bore, said lower packer engaging means being fixedly positioned on said lower body means, and

upper packer engaging means carried by said upper body means and disposed above said packer means when said apparatus is disposed in said well bore,

packer supporting wall means,

said upper packer engaging means being operable to converge longitudinally with said lower packer engaging means in response to longitudinal converging movement of said upper and said lower body means and induce longitudinal compression and generally radial expansion of said packer means;

said ratchet teeth disabling means being engageable with said ratchet teeth means when packer means induced separation of said upper and lower packer engaging means is insufficient to cause movement of said upper body means sufficient to reengage said slip means and slip expander means.

4. A packer apparatus for use in a well bore, said apparatus comprising:

mandrel means operable, when disposed in a well bore, to be connected at an upper portion with support means;

a slip assembly mounted for longitudinal movement on said mandrel means;

body means mounted for longitudinal movement on said mandrel means;

said slip assembly including,

slip housing means,

slip means mounted on said slip housing means and operable to move generally radially outwardly of said mandrel means,

first abutment means carried by said mandrel means,

second abutment means carried by said slip housing means,

compression ring means carried by said slip housing means and adapted to seat on one of said abutment means,

longitudinally compressible spring means interposed longitudinally between said compression ring means and the other of said abutment means, and

third abutment means carried by said mandrel means and operable to abuttingly engage said compression ring means in response to longitudinal movement of said mandrel means within said well bore and induce longitudinal movement of said compression ring means tending to compress said spring means when said slip housing means is restrained against longitudinal movement in said well bore by said slip means;

slip actuating means including

slip expanding means carried by said body means,

said slip expanding means being mounted for generally radially outward movement on said body means and providing, when said apparatus is disposed in said well bore, slip expanding surface means,

sleeve means mounted for longitudinal movement on said mandrel means,

said sleeve means being operable, in response to longitudinal movement of said mandrel means in said well bore relative to said body means, to engage said slip expanding means and induce generally radially outward movement thereof,

first and second stop means carried by said mandrel means, spaced longitudinally thereof, and operable to permit but limit longitudinal movement of said sleeve means.

5. A packer apparatus for use in a well bore, said apparatus comprising:

mandrel means operable, when disposed in a well bore, to be connected at an upper portion with support means;

body means mounted for longitudinal movement on said mandrel means;

a slip assembly mounted for longitudinal movement on said lower body means;

spline means interconnecting said mandrel means and said body means and operable to permit longitudinal movement of said mandrel means relative to said body means while substantially preventing relative rotational movement between said upper body means and said mandrel means;

said slip assembly including

slip housing means mounted for longitudinal movement on said body means,
 slip means carried by said slip housing means,
 drag means carried by said slip housing means, projecting generally outwardly thereof, and operable to frictionally engage the inner periphery of said well bore, and
 lug and slot means interconnecting said slip housing means and said body means and operable to selectively permit and prevent longitudinal movement of said body means relative to said slip housing means through a longitudinal movement increment;
 selectively releasable, longitudinal force transmitting coupling means interposed between said body means and said mandrel means, said selectively releasable coupling means including
 ball means carried by said body means, fixedly positioned against longitudinal movement relative to said body means, and operable to move radially outwardly of said body means,
 shoulder means carried by said mandrel means and operable to engage said ball means and transmit longitudinal force from said mandrel means through said ball means to said body means when said ball means are disposed in a radially innermost position on said body means,
 ball restraining means carried by said slip housing means and operable to prevent radially outward movement of said ball means relative to said body means when said lug and slot means is operable to substantially prevent said increment of longitudinal movement of said body means relative to said slip housing means, and
 recess means carried by said slip housing means and operable to permit generally radially outward movement of said ball means relative to said body means out of force transmitting engagement with said shoulder means in response to said increment of longitudinal movement.
 6. A packer apparatus for use in a well bore, said apparatus comprising:
 mandrel means operable, when disposed in a well bore, to be connected at an upper portion with support means;
 an upper slip assembly mounted for longitudinal movement on said mandrel means;
 upper body means disposed beneath said upper slip assembly when said apparatus is disposed in a well bore, said upper body means being mounted for longitudinal movement on said mandrel means;
 lower body means mounted beneath said upper body means when said apparatus is disposed in said well bore, said lower body means being mounted for longitudinal movement on said mandrel means;
 a lower slip assembly mounted for longitudinal movement on said lower body means;
 first spline means interconnecting said mandrel means and said upper body means and operable to permit longitudinal movement of said mandrel means relative to said upper body means while substantially preventing relative rotational movement between said upper body means and said mandrel means;
 second spline means interconnecting said upper body means and said lower body means, said second spline means being operable to permit longitudinal movement of said upper body means relative to said lower body means while substantially preventing relative rotational movement between said upper and lower body means;
 upper slip actuating means carried by said upper body means;
 a piston and cylinder assembly interconnecting said upper body means and said lower body means;
 ratchet means operable to ratchetingly interconnect said upper body means and said lower body means and selectively permit downward movement only of said upper

body means relative to said lower body means when said apparatus is disposed in said well bore;
 a packer assembly carried by said lower body means and actuable by movement of said upper body means relative to said lower body means;
 selectively releasable, longitudinal force transmitting coupling means interposed between said lower body means and said mandrel means;
 equalizing valve means carried by said mandrel means and operable to selectively equalize pressure across said packer assembly;
 mandrel, pressure balancing means operable to pressure balance said mandrel means with respect to pressure acting therewithin; and
 lower slip actuating means carried by said lower body means.
 7. An apparatus as described in claim 6 wherein said equalizing valve means includes
 first passage means interposed radially between said mandrel means and said upper and lower body means;
 second passage means carried by said lower body means, disposed beneath said packer assembly when said apparatus is disposed in said well bore, and providing fluid communication between said well bore and said first passage means;
 third passage means carried by said upper housing means, disposed above said packer assembly when said apparatus is disposed in said well bore, and operable to provide fluid communication between said first passage means and said well bore;
 sleeve valve means carried by said mandrel means;
 seat means carried by said upper body means and operable to valvingly receive said sleeve valve means, said seat means being interposed longitudinally between said second and third passage means, with valving engagement between said sleeve valve means and said seat means substantially blocking fluid communication between said second passage means and said third passage means;
 said sleeve valve means being spaced longitudinally said seat means when said apparatus is disposed in said well bore and said mandrel means is blocked against downward longitudinal movement relative to said lower body means by said selectively releasable coupling means;
 said valve means including
 valve body means projecting generally radially outwardly of said mandrel means,
 first, relatively rigid, seal means carried by said valve body means and operable to provide a relatively low pressure seal with said seat means,
 second, relatively deformable, seal means carried by said valve body means above said first seal means when said apparatus is disposed in said well bore and operable to provide a relatively high pressure seal with said seat means, and
 packer setting abutment means carried by said valve body means, disposed above said second seal means when said apparatus is disposed in said well bore, and operable to abuttingly engage said upper body means and transfer packer means compressing force longitudinally downwardly from said mandrel means to said upper body means.
 8. An apparatus as described in claim 6 wherein said upper slip actuating means includes:
 upper slip expanding means carried by said upper body means;
 said upper slip expanding means being mounted for generally radially outward movement on said upper body means and providing, when said apparatus is disposed in said well bore, upper slip expanding surface means;
 sleeve means mounted for longitudinal movement on said mandrel means;

said sleeve means being operable, in response to downward movement of said mandrel means in said well bore relative to said upper body means, to engage said upper slip expanding means and induce generally radially outward movement thereof; and

first and second stop means carried by said mandrel means, spaced longitudinally thereof, and operable to permit but limit longitudinal movement of said sleeve means.

9. An apparatus as described in claim 6 wherein:

said ratchet means, operable to ratchetingly interconnect said upper body means and said lower body means and permit downward movement only of said upper body means relative to said lower body means when said apparatus is disposed in said well bore, includes

longitudinally extending ratchet surface means carried by said lower body means,

ratchet teeth means carried by said upper body means and secured against longitudinal movement relative thereto, and

ratchet teeth disabling means carried by said mandrel means and operable, in response to downward movement of said mandrel means relative to said upper body means, to permit said ratchet teeth means to ratchetingly engage said ratchet surface means,

said ratchet teeth disabling means being operable, in response to upward movement of said mandrel means relative to said lower body means, to engage said ratchet teeth means and move said ratchet teeth means generally outwardly of said mandrel means and out of ratchetting engagement with said ratchet surface means;

said selectively releasable longitudinal force transmitting coupling means, interposed between said lower body means and said mandrel means, includes

detent means carried by said lower body means, fixedly positioned against longitudinal movement relative to said lower body means, and operable to move radially outwardly of said lower body means,

shoulder means carried by said mandrel means and operable to engage said detent means and transmit longitudinal force from said mandrel means through said detent means to said lower body means when said detent means are disposed in a radially innermost position on said lower body means,

detent restraining means carried by said lower slip assembly and operable to prevent radially outward movement of said detent means relative to said lower body means when said J-slot means is operable to substantially prevent said increment of longitudinal movement of said lower body means relative to said lower slip assembly, and

recess means carried by said lower slip assembly beneath said detent restraining means when said apparatus is disposed in said well bore and operable to permit generally radially outward movement of said detent means relative to said lower body means out of force transmitting engagement with said shoulder means in response to said increment of longitudinal movement.

10. A packer apparatus for use in a well bore, said apparatus comprising:

mandrel means operable, when disposed in a well bore, to be connected at an upper portion with support means;

an upper slip assembly mounted for longitudinal movement on said mandrel means;

upper body means disposed beneath said upper slip assembly when said apparatus is disposed in a well bore, said upper body means being mounted for longitudinal movement on said mandrel means;

lower body means mounted beneath said upper body means when said apparatus is disposed in said well bore, said lower body means being mounted for longitudinal movement on said mandrel means;

a lower slip assembly mounted for longitudinal movement on said lower body means;

first spline means interconnecting said mandrel means and said upper body means and operable to permit longitudinal movement of said mandrel means relative to said upper body means while substantially preventing relative rotational movement between said upper body means and said mandrel means;

second spline means interconnecting said upper body means and said lower body means, said second spline means being operable to permit longitudinal movement of said upper body means relative to said lower body means while substantially preventing relative rotational movement between said upper and lower body means;

said upper slip assembly including,

upper slip housing means,

upper slip means mounted on said upper slip housing means and operable to move generally radially outwardly of said mandrel means,

first abutment means carried by said mandrel means and facing generally downwardly when said apparatus is disposed in said well bore,

second abutment means carried by said upper slip housing means and facing generally upwardly when said apparatus is disposed in said well bore,

compression ring means carried by said upper slip housing means and adapted to seat on said second abutment means,

longitudinally compressible spring means interposed longitudinally between said compression ring means and said first abutment means,

third spline means interconnecting said upper slip housing means and said mandrel means and operable to permit longitudinal movement of said upper slip housing means relative to said mandrel means while substantially preventing relative movement between said upper slip housing means and said mandrel means,

fourth spline means interconnecting said compression ring means and said mandrel means, said fourth spline means being operable to permit longitudinal movement of said mandrel means relative to said compression ring,

third abutment means carried by said mandrel means, disposed beneath said compression ring means when said apparatus is disposed in said well bore, and operable to abuttingly engage said compression ring means in response to upward movement of said mandrel means within said well bore and induce upward movement of said compression ring means tending to compress said spring means when said upper slip housing means is restrained against upward movement in said well bore by said upper slip means;

upper slip actuating means including

upper slip expanding means carried by said upper body means,

said upper slip expanding means being mounted for generally radially outward movement on said upper body means and providing, when said apparatus is disposed in said well bore, upper slip expanding surface means,

sleeve means mounted for longitudinal movement on said mandrel means,

said sleeve means being operable, in response to downward movement of said mandrel means in said well bore relative to said upper body means, to engage said upper slip expanding means and induce generally radially outward movement thereof,

first and second stop means carried by said mandrel means, spaced longitudinally thereof, and operable to permit but limit longitudinal movement of said sleeve means;

a piston and cylinder assembly interconnecting said upper body means and said lower body means, said piston and cylinder assembly including

cylinder means carried by said upper body means and having an open lower end when said apparatus is disposed in said well bore, and
 piston means carried by said lower body means when said apparatus is disposed in said well bore, said piston means being telescopically received within said cylinder means, 5
 said cylinder means defining a relatively lower pressure zone;
 ratchet means operable to ratchetingly interconnect said upper body means and said lower body means and permit downward movement only of said upper body means relative to said lower body means when said apparatus is disposed in said well bore, said ratchet means including longitudinally extending ratchet surface means carried by 10
 said lower body means,
 ratchet teeth means carried by said upper body means and secured against longitudinal movement relative thereto,
 ratchet teeth disabling means carried by said mandrel means and operable, in response to downward movement of said mandrel means relative to said upper body means, to permit said ratchet teeth means to ratchetingly engage said ratchet surface means, 20
 said ratchet teeth disabling means being operable, in response to upward movement of said mandrel means relative to said lower body means, to engage said ratchet teeth means and move said ratchet teeth means generally outwardly of said mandrel means and out of ratchetting engagement with said ratchet surface means subsequent to longitudinal separation of said sleeve means and said upper slip expanding means, and subsequent to longitudinal separation of said upper slip means and said upper slip expanding means; 30
 a packer assembly including 35
 longitudinally compressible and generally radially expandable packer means carried by said lower body means,
 lower packer engaging means carried by said lower body means and disposed beneath said packer means when said apparatus is disposed in said well bore, said lower packer engaging means being fixedly positioned on said lower body means, 40
 upper packer engaging means carried by said upper body means and disposed above said packer means when said apparatus is disposed in said well bore, and 45
 packer supporting wall means,
 said upper packer engaging means being operable to converge longitudinally with said lower packer engaging means in response to longitudinal converging movement of said upper and said lower body means and induce longitudinal compression and generally radial expansion of said packer means; 50
 said lower slip assembly including
 lower slip housing means mounted for longitudinal movement on said lower body means, said lower slip housing means being disposed beneath said packer assembly when said apparatus is disposed in said well bore, 55
 lower slip means carried by said lower slip housing means and projecting generally longitudinally upwardly therefrom when said apparatus is disposed in said well bore, 60
 drag block means carried by said lower slip housing means, projecting generally outwardly thereof, and operable to frictionally engage the inner periphery of said well bore, 65
 J-slot means interconnecting said lower slip housing means and said lower body means and operable to selectively permit and prevent longitudinal movement of said lower body means relative to said lower slip housing means through a longitudinal movement increment; 70
 selectively releasable, longitudinal force transmitting coupling means interposed between said lower body means and said mandrel means, said selectively releasable coupling means including 75

ball means carried by said lower body means, fixedly positioned against longitudinal movement relative to said lower body means, and operable to move radially outwardly of said lower body means,
 shoulder means carried by said mandrel means and operable to engage said ball means and transmit longitudinal force from said mandrel means through said ball means to said lower body means when said ball means are disposed in a radially innermost position on said lower body means,
 ball restraining means carried by said lower slip housing means and operable to prevent radially outward movement of said ball means relative to said lower body means when said J-slot means is operable to substantially prevent said increment of longitudinal movement of said lower body means relative to said lower slip housing means, and
 recess means carried by said lower slip housing means beneath said ball restraining means when said apparatus is disposed in said well bore and operable to permit generally radially outward movement of said ball means relative to said lower body means out of force transmitting engagement with said shoulder means in response to said increment of longitudinal movement;
 equalizing valve means including
 first passage means interposed radially between said mandrel means and said upper and lower body means,
 second passage means carried by said lower body means, disposed beneath said packer assembly when said apparatus is disposed in said well bore, and providing fluid communication between said well bore and said first passage means,
 third passage means carried by said upper body means, disposed above said packer assembly when said apparatus is disposed in said well bore, and operable to provide fluid communication between said first passage means and said well bore,
 sleeve valve means carried by said mandrel means,
 seat means carried by said upper body means and operable to valvingly receive said sleeve valve means, said seat means being interposed longitudinally between said second and third passage means, with valving engagement between said sleeve valve means and said seat means substantially blocking fluid communication between said second passage means and said third passage means,
 said sleeve valve means being spaced longitudinally above said seat means when said apparatus is disposed in said well bore and said mandrel means is blocked against downward longitudinal movement relative to said lower body means by said selectively releasable coupling means,
 said sleeve valve means including
 valve body means projecting generally radially outwardly of said mandrel means,
 fourth passage means extending longitudinally entirely through said valve body means,
 first ledge means projecting generally radially outwardly of said valve body means,
 piston means mounted for longitudinal movement on said valve body means,
 second ledge means carried by said upper body means and projecting generally radially inwardly thereof,
 said first and second ledge means being operable to permit but limit longitudinal movement of said piston means relative to said valve body means, with said piston means being alternately engageable with said first and second ledge means,
 enclosure means defined by said mandrel means and said upper body means and operable to define a cavity communicating with the upper end of said fourth passage means and the upper end of said piston means when said apparatus is disposed in said well bore,

said fourth passage means being disposed in continuous fluid communication with said first passage means, first, relatively rigid, seal means carried by said valve body means and operable to provide a relatively low pressure seal with seat means, 5

second, relatively deformable, seal means carried by said valve body means above said first seal means when said apparatus is disposed in said well bore and operable to provide a relatively high pressure seal with said seat means, 10

said first seal means being operable to sealingly engage said seat means as said sleeve means engages said upper expanding means, 10

said second seal means being operable to sealingly engage said seat means prior to the longitudinal compression of said packer means, 15

packer setting abutment means carried by said valve body means, disposed above said second seal means when said apparatus is disposed in said well bore, and operable to abuttingly engage said cylinder means and transfer packer means compressing force longitudinally downwardly from said mandrel means to said upper body means; 20

mandrel, pressure balancing means comprising

upwardly facing, pressure balancing surface means provided by said valve means when said apparatus is disposed in said well bore, said upwardly facing, pressure balancing surface means being operable to prevent in increase in pressure of well fluid beneath said packer means from applying a lifting force to said mandrel means when said packer means is generally radially expanded into sealing engagement with the periphery of said well bore and when said valve means is sealingly engaged with said seat means, said pressure balancing surface means being in continuous fluid communication with said first passage means by way of said fourth passage means; 35

said third passage means carried by said upper body means providing continuous fluid communication between said well bore and a downwardly facing portion of said piston means when said apparatus is disposed in said well bore, with said piston means being operable to move upwardly on said valve body means in response to pressure in said third passage means exceeding pressure in said first passage means to thereby cause said piston means to engage and apply upward force to said second ledge means; and 45

lower slip actuating means including

lower slip expander means carried by said lower body means and disposed above said lower slip means when 50

said apparatus is disposed in said well bore,

said lower slip expander means being operable to induce generally radially outward movement of said lower slip means in response to longitudinally downward movement of said lower body means relative to said lower slip assembly in said well bore.

11. A packer apparatus for use in a well bore, said apparatus comprising:

mandrel means operable, when disposed in a well bore, to be connected at an upper portion with support means;

body means mounted for longitudinal movement on said mandrel means and supporting packer means;

equalizing valve means including

first passage means interposed radially between said mandrel means and said body means,

second passage means carried by said body means, disposed beneath said packer means when said apparatus is disposed in said well bore, and providing fluid communication between said well bore and said first passage means,

third passage means carried by said body means, disposed above said packer means when said apparatus is disposed in said well bore, and operable to provide fluid communication between said first passage means and said well bore,

sleeve valve means carried by said mandrel means, and seat means carried by said body means and operable to valvingly receive said sleeve valve means, said seat means being interposed longitudinally between said second and third passage means, with valving engagement between said sleeve valve means and said seat means substantially blocking fluid communication between said second passage means and said third passage means,

said sleeve valve means being spaced longitudinally above said seat means when said apparatus is disposed in said well bore and said mandrel means is blocked against downward longitudinal movement relative to said body means,

said valve means including

valve body means projecting generally radially outwardly of said mandrel means,

first seal means carried by said valve body means and operable to provide a relatively low pressure seal with said seat means, and

second seal means carried by said valve body means above said first seal means when said apparatus is disposed in said well bore and operable to provide a relatively high pressure seal with said seat means.

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