May 27, 1969 B. P. NUTTER 3,446,280

ACTUATING MEANS FOR WELL TOOLS

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Fig. 2A

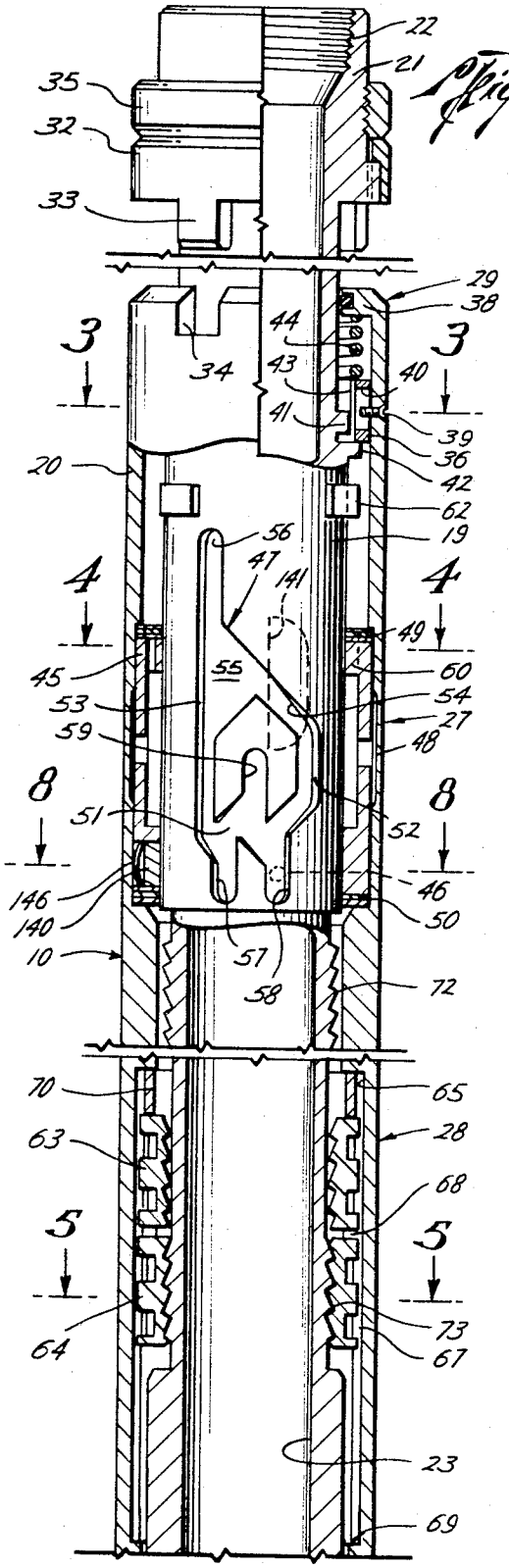
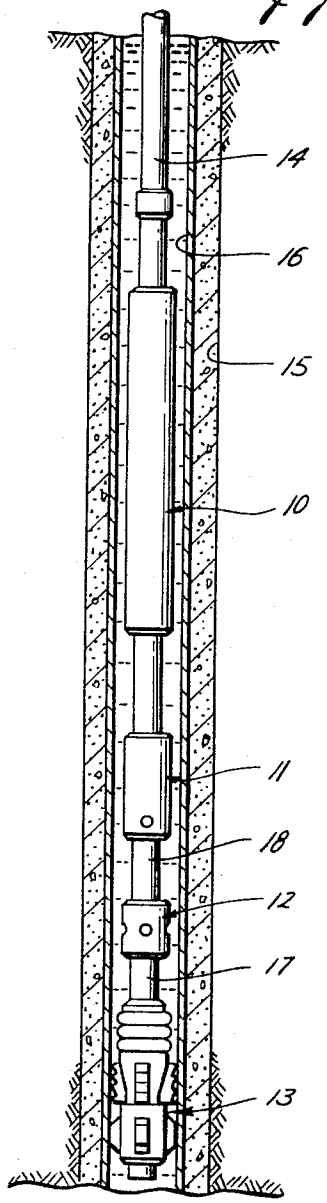



Fig. 1




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Fig. 2B

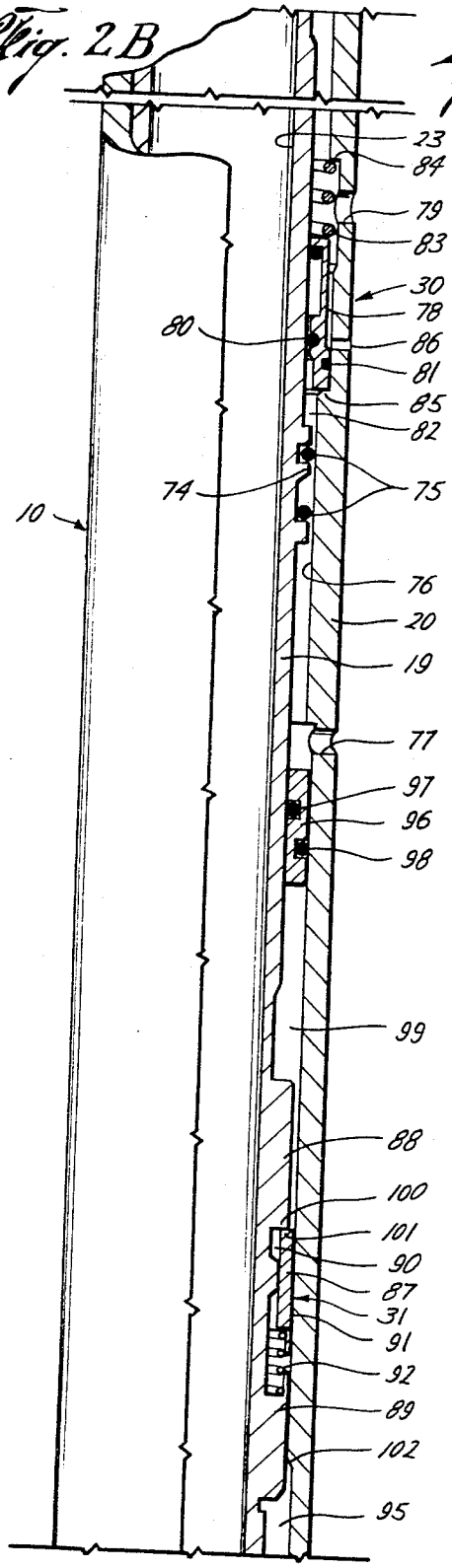
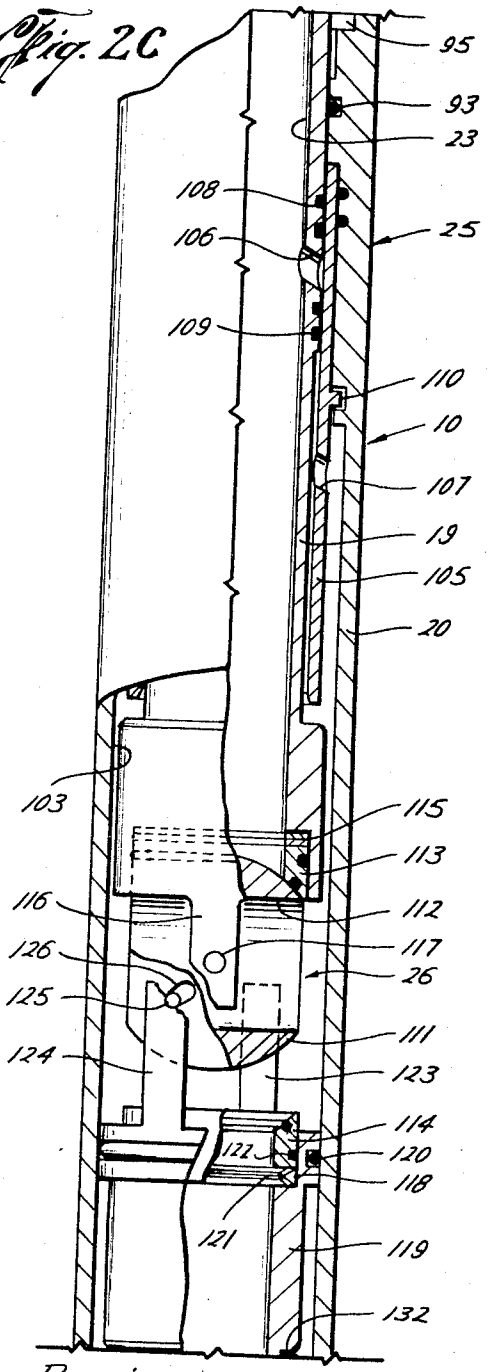



Fig. 2C




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Fig. 2D

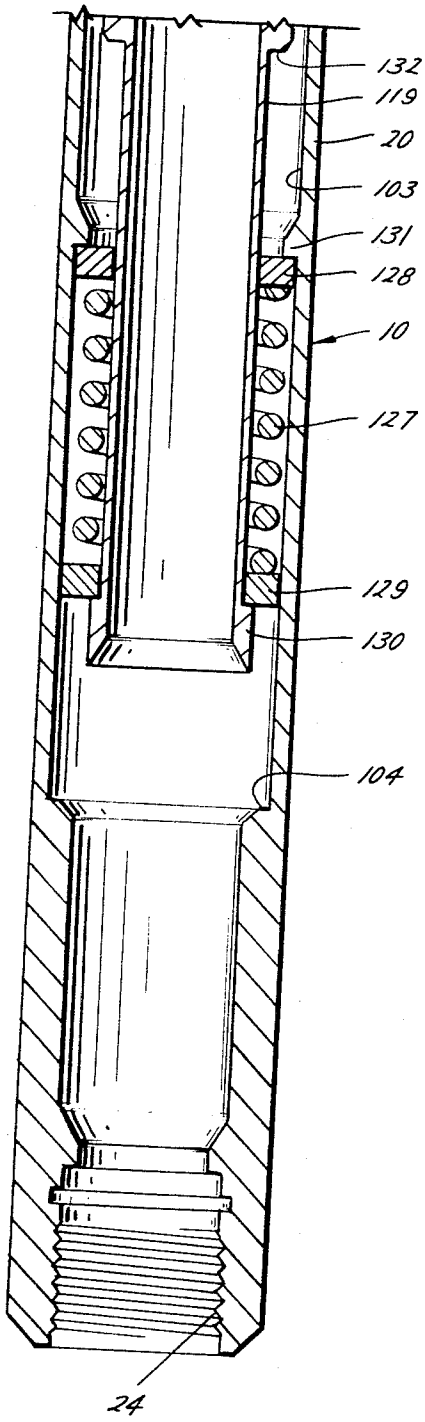



Fig. 3

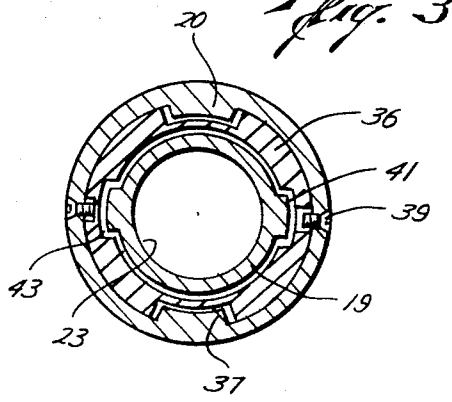



Fig. 4

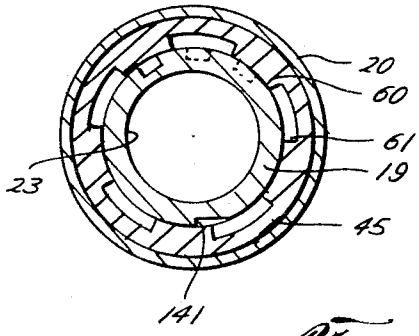
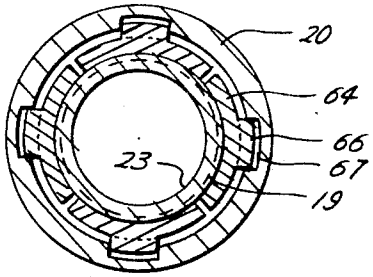



Fig. 5




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ACTUATING MEANS FOR WELL TOOLS

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Fig. 6A

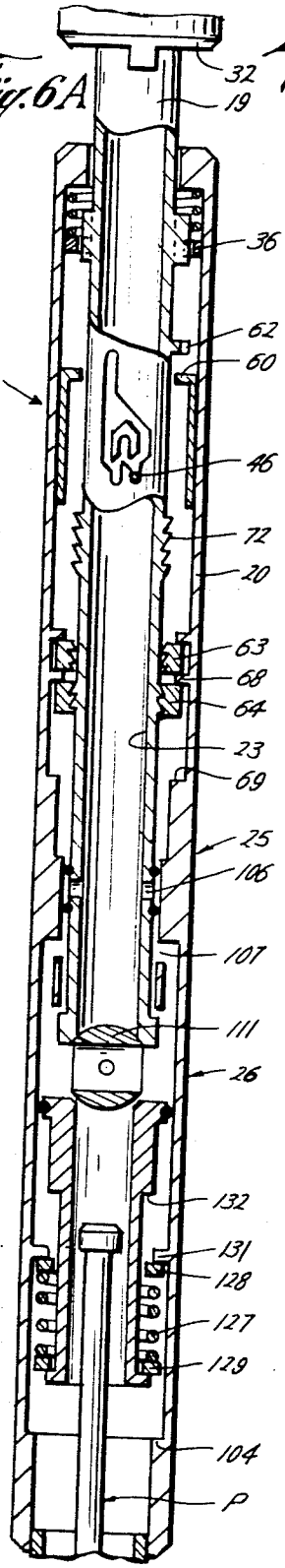



Fig. 6B

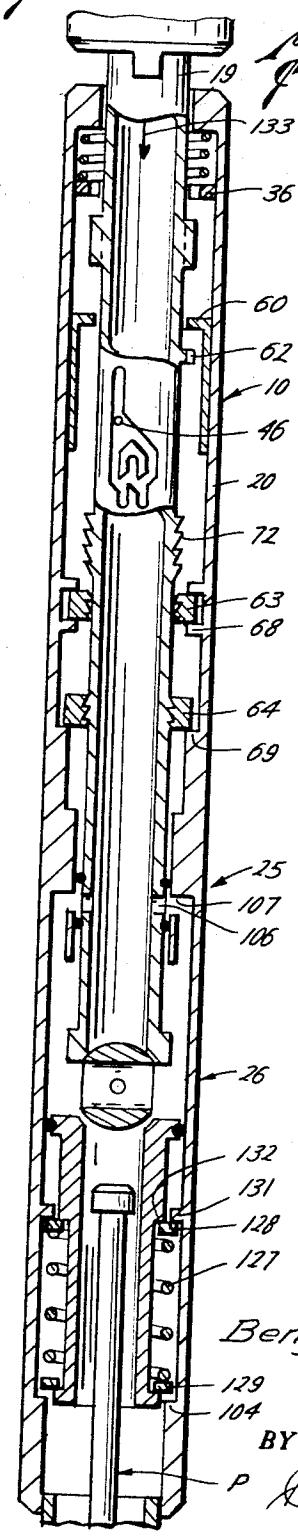
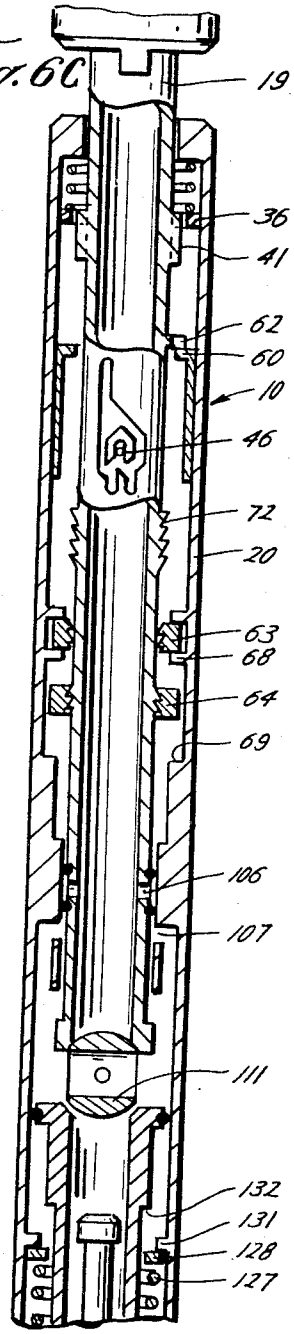



Fig. 6C




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Fig. 6D

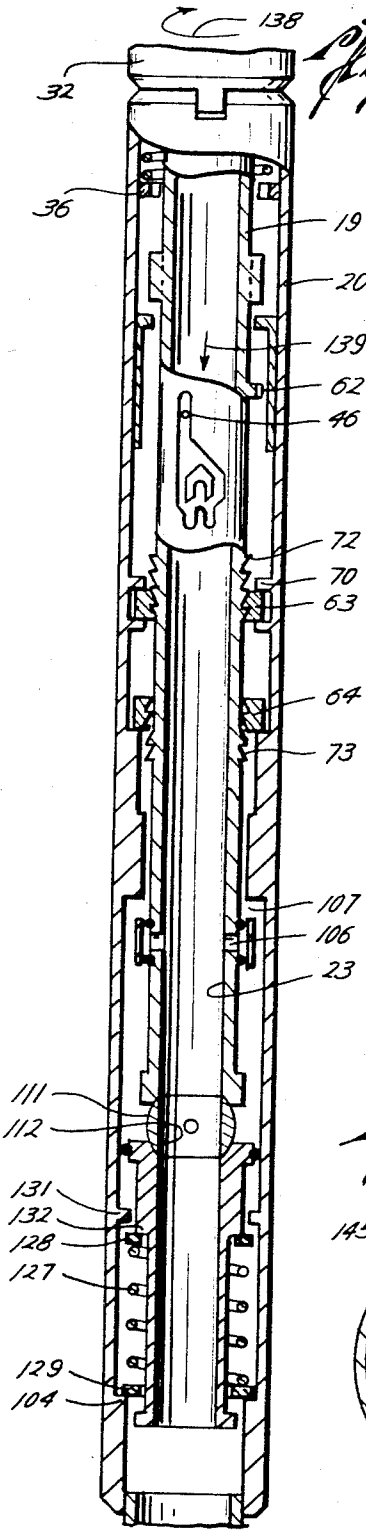



Fig. 7

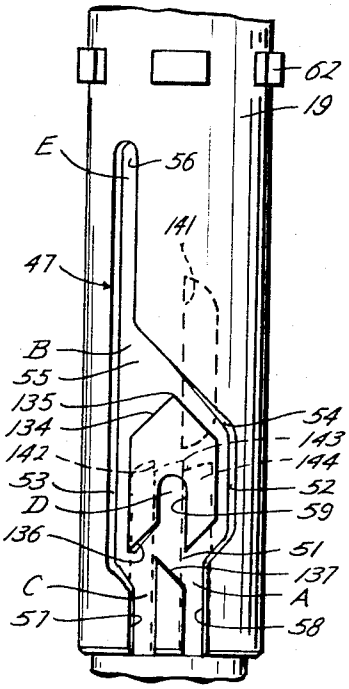



Fig. 8

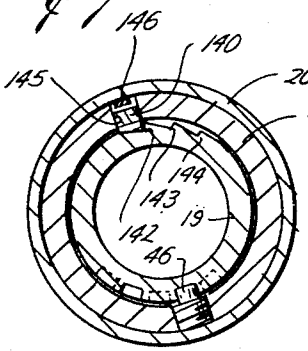
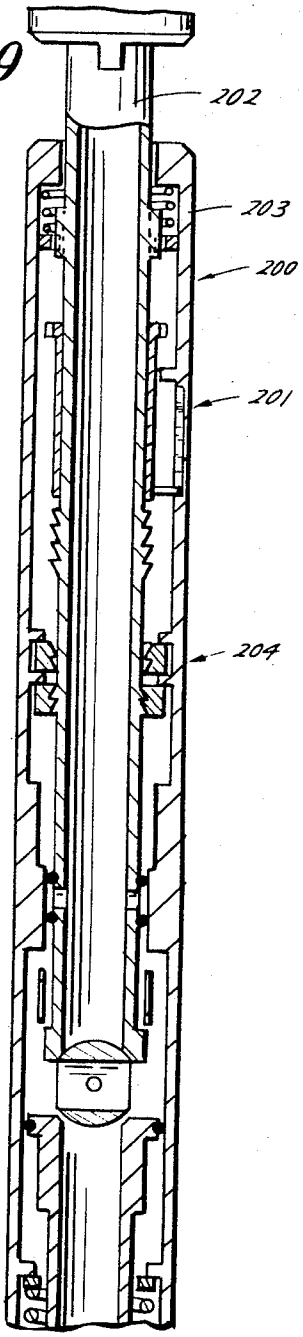



Fig. 9




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United States Patent Office 3,446,280
Patented May 27, 1969



3,446,280

# ACTUATING MEANS FOR WELL TOOLS

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Filed Oct. 26, 1967, Ser. No. 678,281
Int. Cl. E21b 23/00, 33/12
U.S. Cl. 166—152 28 Claims

## ABSTRACT OF THE DISCLOSURE

The particular embodiments described herein as illustrative of the invention are directed to actuating means for well tools having relatively rotatable inner and outer telescopically arranged members. To accomplish this, the disclosed tools include a threaded member, such as a nut, that is disposed in the annular space between the telescoped members between two spaced stops on one of the members such as, for example, the outer member. Threads on the other member, for example the inner member, are normally engaged with the threaded member. So long as the threaded member remains engaged with the threads, the other member cannot be moved over a first longitudinal span any greater than allowed by the spaced stops. A circuitous groove system on one member receives a lateral guide member loosely mounted on the other and, in response to relative telescoping movement of the two members, will permit the two members to be placed in various selected longitudinal positions within this first longitudinal span to perform various operations. Once, however, it is desired to move the members to a position outside of the limits of this first longitudinal span, the telescoped members are rotated relative to one another to disengage the threaded member from the threads. This will permit the telescoped members to then be moved in a different longitudinal span for performing still further operations.

Accordingly, as will subsequently become apparent, this invention relates to well tools; and, more particularly, this invention pertains to new and improved actuating means for selectively placing well tools into a plurality of distinctive operating positions with only a minimum of different manipulations.

It is customary to employ a number of different full-bore tools coupled into one string for such well-testing and well-completion operations as testing earth formations under both flowing and static conditions, squeeze cementin, acidizing, and fluid fracturing. As is typical, such a string of full-bore tools includes a full-bore packer for packing-off the well bore, a bypass valve for selectively controlling communication between the well bore annulus and the interior of the tubing string, and a selectively operable valve for controlling communication into the lower end of the tubing string. To shift these tools into position to conduct such operations as well as to go from one operation to another, the tubing string is generally used to manipulate each of the tools into various relative positions.

It will be recognized, of course, that as the number of operations to be performed by a particular string of tools increases, a correspondingly increasing number of different manipulations of the tubing string are required to move the tools into their various operating positions. In general, the only basic manipulative movements are limited to either a longitudinal shifting in either vertical direction or else rotation in one or the other rotative direction.

Those skilled in the art recognize, however, that it is not always feasible to use even all four of these basic manipulations. For example, many operators object to so-called "left-hand" torque since rotation in this direction



may inadvertently unthread one or more of the collars coupling the tubing string. Moreover, it is not too desirable to operate a well tool by continued "right-hand" rotation where only a predetermined number of revolutions establishes the particular operating positions of the tool. For, in addition to the possibility that some of this right-hand torque may only further tighten the collars coupling the tubing string, the inherent capability of the tubing string, to absorb a certain amount of torque usually makes it quite difficult, if not altogether impossible, to determine from the surface whether a predetermined number of rotations have been faithfully translated through the tubing string to a tool several thousands of feet therebelow. In such instances, it is best not to over-rotate the upper end of the tubing string just to be sure that a particular number of rotations have in fact reached the tool at the lower end of the string.

Thus, for these and other reasons, whenever several operating positions must be assumed by the tools, at least some manipulative movements must be duplicated and the operator must depend upon variations and degrees in these few movements to distinguish which operative positions the tools are in. Accordingly, many well tools of this nature are so arranged that they are operated by shifting the tool mandrels into various longitudinally spaced positions, with only a minimum number of these operating positions being reached by rotating the tubing string. Typical of such control arrangements is a so-called "J-slot" system in which a lateral pin projecting from one of the relatively movable members of a tool is received within a labyrinth arrangement of grooves formed on an adjacent surface of another member. By providing several longitudinally spaced branch portions in such J-slot systems, a variety of distinct operating positions are obtained by shifting the well tool mandrel longitudinally in either direction either with or without an accompanying rotative movement.

Although such J-slot systems are widely used, they are nevertheless still recognized as having certain disadvantages. For example, it is difficult to devise compatible J-slot arrangements for each of several tools in a common string that will enable one tool in the string to be moved into some of its operative positions without simultaneously shifting at least one of the other tools into an unwanted position. This problem becomes even more complicated when it is realized that it is sometimes desired to move two tools in conjunction with one another at one point in a given sequence of operations; but, at other points in the same sequence, it may be preferred that only one of these tools move without a corresponding movement of the other tool.

Accordingly, it is an object of the present invention to provide new and improved well tools having control or actuating means which permit these tools to be selectively placed in a plurality of distinctive operating positions with only a minimum of different manipulations. This and other objects of the present invention are obtained by providing first position-establishing means including a selectively releasable stop member between inner and outer telescoped members arranged to limit their longitudinal movement to a first span of travel. Second position-establishing means are provided and include a fixed shoulder on one of the telescoped members that is adapted for engagement with a shoulder rotatably mounted on the other of the telescoped members, with one of these shoulders having a circuitous system of channels or grooves arranged to receive a lateral guide projecting from the other telescoped member. The groove system and guide member are arranged to respond to longitudinal movement of the telescoped members to selectively orient the shoulders into angular alignment for abutment with one another whenever the telescoped members are at a predetermined

position within the first span of travel permitted by the stop means. Once a second span of longitudinal travel is to be covered by the telescoped members, the releasable stop member is released to enable the telescoped members to be moved to this different span of longitudinal travel. In this manner, first and second valve means that are operable by longitudinal movement of the telescoped members can be selectively operated by reciprocation of the telescoped members without one of the valve means being inadvertently operated.

The novel features of the present invention are set forth with particularity in the appended claims. The operation, together with further objects and advantages thereof, may best be understood by way of illustration and example of certain embodiments when taken in conjunction with the accompanying drawings, in which:

FIGURE 1 shows a typical string of well tools in a well bore including a tool employing the principles of the present invention;

FIGURES 2A–2D are successive elevational views, partially in cross-section, of one embodiment of a well tool arranged in accordance with the present invention;

FIGURES 3–5 and 8 are cross-sectional views taken along the lines 3—3, 4—4, 5—5 and 8—8 respectively, in FIGURE 2A;

FIGURES 6A–6D are somewhat schematic views of the well tool shown in FIGURES 2A–2D and depict its successive operating positions;

FIGURE 7 is a developed view of a typical groove system for the positioning means of the present invention; and

FIGURE 9 is a schematic view similar to FIGURE 6A but showing still another embodiment of a well tool with positioning means in accordance with the present invention.

Turning now to FIGURE 1, a number of full-bore well tools **10–13** are shown tandemly connected to one another and dependently coupled from the lower end of a string of pipe, such as a tubing string **14**, suspended in a cased well bore **15**. At the lower end of these tools, a conventional full-bore packer **13** is arranged for selectively packing-off the casing **16**. A typical hydraulic holddown **12** is coupled to the mandrel **17** of the packer **13** and arranged to engage the casing **16** to secure the mandrel against upward movement whenever the packer is set and fluid pressure within the tubing string **14** exceeds the hydrostatic pressure of the well control fluids in the well annulus. A typical bypass valve **11**, coupled by a tubing sub **18** above the holddown **12**, is suitably arranged to open and facilitate shifting of the tools **10–13** within the fluid-filled well bore **15** by diverting a substantial portion of the fluids through the central bore of the retracted packer **13**. Connected at the upper end of the string of tools **11–13** is a tool **10** incorporating the principles of the present invention. Although the tools **11–13** may be those shown on page 3057 of the 1960–61 "Composite Catalog of Field Equipment and Services," it will be understood, of course, that other tools of a similar nature may be used in conjunction with the tool **10**.

Turning now to FIGURES 2A–2D, successive elevational views, with each being partially cross-sectioned, are shown of the tool **10**. It will be recognized, of course, that for ease of manufacture and assembly of tools of this nature, they are customarily made of interconnected tubular sections. However, to facilitate the following description, various portions of the tool **10** have been shown as integral members rather than of such interconnected sections. The tool **10** includes a tubular member **19** telescopically disposed within a tubular housing **20** and arranged in accordance with the present invention for selective longitudinal movement therein between an extended position as shown in FIGURES 2A–2D, one or more intermediate positions, and a fully-telescoped position, all of which are subsequently described with reference to FIGURES 6A–6D. A threaded collar **21** (FIGURE 2A)



on the upper end of the mandrel **19** has threads **22** arranged for coupling to the tubing string **14** (FIGURE 1), with the central bore **23** (FIGURES 2A–2D) of the mandrel having substantially the same internal diameter as that of the tubing string. Similarly, threads **24** (FIGURE 2D) on the lower end of the housing **20** are arranged for coupling the tool **10** to other well tools therebelow such as, for example, the bypass valve **11** shown in FIGURE 1.

In general, the tool **10** includes first and second valve means **25** and **26** (FIGURE 2C) of a suitable nature that are each selectively opened and closed by shifting the mandrel **19** between different longitudinal positions with respect to the housing **20**. Although others may, of course, be used, the valve means **25** and **26** are preferably those shown in a copending application, Ser. No. 620,841, filed by the applicant on Mar. 6, 1967. For establishing these various longitudinal positions, the selectively operable positioning means **27** and **28** (FIGURE 2A) of the present invention are provided. Clutch means **29** are also provided in the present invention to permit selective application of torque from the mandrel **19** through the housing **20** to the other tools **11–13** when the mandrel is in certain ones of its positions. Biasing means **30** (FIGURE 2B) are preferably provided to maintain a downward force on the housing **20** to assist in keeping the packer **13** seated while the mandrel **19** is being moved as well as to apply an upward force on the mandrel to keep the clutch means **29** engaged whenever the mandrel is in its uppermost extend position with respect to the housing. Movement-retarding means **31** (FIGURE 2B) are also provided to retard downward travel of the mandrel **19** with respect to the housing **20**.

Turning now to FIGURE 2A, the uppermost portion of the tool **10** is shown. As seen there, the clutch means **29** are arranged to co-rotatively secure the mandrel **19** to the housing **20** only when the mandrel is either in its lowermost or fully-telescoped position or else is in its two uppermost positions in relation to the housing. In all other relative positions, the mandrel **19** is free to rotate relative to the housing **20**. To accomplish this, the clutch means **29** include an annular member **32** that is co-rotatively secured over the collar **21** on the upper end of the mandrel **19** and has one or more depending lugs **33** thereon adapted for reception in a corresponding number of upwardly facing longitudinal slots **34** in the upper end of the housing **20** whenever the mandrel is in its lowermost position relative thereto. A threaded ring **35** is threadedly secured to the collar **21** above the member **32** to retain the annular member in position as well as to facilitate its removal for disengaging the lugs **33** from the slots **34** after the tool **10** is removed from the well bore **15**.

The clutch means **29** further include an annular member **36** slidably mounted in the housing **20** and co-rotatively secured thereto by external longitudinal grooves thereon adapted to receive complementary inwardly-projecting housing splines **37** (FIGURE 3) below an inwardly-directed housing shoulder **38** above the annular member. Stop means, such as inwardly-projecting screws **39** in the housing **20** that are received in longitudinal slots **40** in the annular member **36**, are provided to limit the longitudinal travel of the annular member. External longitudinal splines **41** (FIGURE 2A) on the mandrel **19** and immediately above an external shoulder **42** thereon are adapted for reception in complementary longitudinal spline grooves **43** (FIGURE 3) in the internal wall of the annular member **36**.

Means, such as a spring **44** between the housing shoulder **38** and the upper end of the annular member **36**, are provided to normally urge the annular member downwardly against the shoulder or stop **42** but permit it to retrogress should the mandrel splines **41** not be in registry with their complementary grooves **43** as the mandrel **19** is being moved upwardly. It will be understood,

of course, that even though the mandrel splines **41** may not initially be in alignment with the spline grooves **43**, rotation of the mandrel **19** in either direction will quickly bring the splines into orientation with their grooves and the spring **44** will then urge the annular clutch member **36** downwardly over the splines as the mandrel moves further upwardly. It should also be noted that further upward travel of the mandrel **19** is halted when the upper end of the mandrel shoulder **42** engages the lower ends of the housing splines **37**.

Accordingly, it will be appreciated that so long as the mandrel **19** is in its extended position (as seen in FIGURES 2A–2D) with respect to the housing **20**, the mandrel is co-rotatively secured thereto by the clutch means **29**. Downward movement of the mandrel **19** into its several intermediate positions with respect to the housing **20** will, however, shift the mandrel splines **41** out of the spline grooves **43** and allow the mandrel to be rotated relative to the housing until the mandrel reaches its fully-telescoped or lowermost position. The mandrel **19** will then be again co-rotatively secured to the housing **20** once it is moved to this lowermost position and the lugs **33** enter the slots **34**.

The upper or first position-establishing means **27** of the invention are comprised of a sleeve member **45** that is rotatively mounted inside of the housing **20** and has an inwardly projecting lateral guide or pin **46** which has its distal end disposed in a circuitous system of grooves **47** formed on the exterior of the mandrel **19**. To secure the sleeve **45** against shifting longitudinally relative to the housing **20**, the sleeve is confined between opposed shoulders such as provided by a circumferential recess **48** formed around the interior housing wall. Bearings or wear rings **49** and **50** are placed between the upper and lower ends of the sleeve **45** and the opposed housing shoulders to facilitate the rotation of the sleeve with respect to the housing.

It will be appreciated, therefore, that since the guide pin **46** remains in the groove system **47**, the mandrel **19** can be moved longitudinally in relation to the housing **20** only so far as is permitted by the particular arrangement of the groove system. As best seen in the developed view in FIGURE 7, the groove system **47** includes an irregularly shaped but generally transverse lower groove **51** joined at its opposite ends by upwardly directed, parallel, longitudinal grooves **52** and **53**, with the upper end of the groove **53** being connected to the upper end of the groove **52** by a converging inclined groove **54** and an enlarged portion **55**. A longitudinal groove **56** is aligned with the groove **53** and continues further upwardly from the junction of the enlarged portion **55** and the grooves **52** and **53**. Thus, it will be appreciated that the maximum longitudinal distance which the mandrel **19** can be moved in relation to the housing **20** is represented by the longitudinal spacing between the uppermost end of the longitudinal groove **56** and the lowermost ends of two short longitudinal grooves **57** and **58** extending downwardly from the opposite ends of lower transverse groove **51**. An intermediate position of the mandrel **19** with respect to the housing **20** is also provided by centrally located longitudinal groove **59** that extends upwardly a short distance from the middle of the lower transverse groove **51**. The significance of the depicted configuration of the groove system **47** will subsequently become more apparent.

The upper end of the sleeve **45** is inwardly enlarged as best seen in FIGURES 2A and 4 to provide an annular shoulder **60**. Circumferentially spaced longitudinal slots **61** (FIGURE 4) around the inner portion of the shoulder **60** are arranged to pass outwardly directed lugs **62** (FIGURES 2A and 4) on the mandrel **19** whenever these lugs are aligned with the slots. Thus, by appropriately locating the guide pin **46** in relation to the shoulder slots **61** (all of which are on the sleeve **45**) on the one hand as well as arranging the circumferential spacing of the longitudinal grooves **52** and **53** in relation to the lugs **62** (all of which are on the mandrel **19**) on the other hand, whenever the guide pin is in either of the circumferentially spaced grooves **52** and **53**, the lugs **62** will be aligned with the slots **61** and, as the mandrel **19** is moved longitudinally in relation to the housing **20**, the lugs **62** will pass through the slots **61** in the shoulder **60**. The centrally located groove **59** is suitably arranged, however, so that when the guide pin **46** is in the position D (FIGURE 7) the lower surfaces of the lugs **62** will be abutted against the upper face of the shoulder **60** since the lugs will not be in registration with the slots **61**. This will, of course, allow downward forces on the mandrel **19** to be transmitted through the lugs **62** and the sleeve **45** to the housing **20** without such forces having to be carried by the guide pin **46**. Thus, only when the guide pin **46** is in the above-described position D are the lugs **62** engaged on top of the sleeve **45** to transmit downward loads therethrough to the housing **20**. In all other positions of the mandrel **19**, the lugs **62** are either above or below the sleeve shoulder **60** or else, when the guide pin **46** is in either of the grooves **52** or **53**, the mandrel lugs are passing through the shoulder slots **61** in the sleeve **45**. Accordingly, the position-establishing means **27** will orient and bring together the opposed shoulders defined by the lugs **62** and upper face of the sleeve shoulder **60** whenever desired without requiring rotation of the mandrel **19** in relation to the housing **20**.

Since the sleeve **45** cannot shift longitudinally relative to the housing **20**, the guide pin **46** will, of course, remain in the same transverse plane as the mandrel **19** and groove system **47** are moved longitudinally in relation thereto. As will subsequently be described in greater detail, a straight longitudinal movement of the mandrel **19** will move the groove system **47** relative to the guide pin **46**. Any rotational movement of the mandrel **19** will be accommodated by the pin **46** and sleeve **45** rotating as required by the slot system **47**.

Thus, assuming for example that the mandrel **19** is pushed straight downwardly from its position shown in FIGURE 2A, when the mandrel has moved sufficiently to bring the upper wall of the inclined groove **54** against the guide pin **46**, continued downward movement of the mandrel **19** will rotate the pin and sleeve **45** accordingly. It will be recalled that the guide pin **46** is so oriented in relation to the shoulder slots **61** and the groove system **47** is so orientated relative to the mandrel lugs **62** that as the mandrel **19** is lowered to move the longitudinal groove **52** downwardly in relation to the guide pin **46**, the shoulder slots will be properly aligned to permit the mandrel lugs to pass freely therethrough. Similarly, whenever the mandrel **19** is moved upwardly to move the groove **55** in relation to the guide pin **46**, the mandrel lugs **62** will again pass through the shoulder slots **61**.

The lower or second position-establishing means **28** of the present invention are seen in FIGURE 2A below the position-establishing means **27** and are comprised of radially expansible gripping means such as two segmented split-nuts **63** and **64** placed at longitudinally spaced positions in a housing recess or the annular clearance space **65** between the mandrel **19** and housing **20**. As best seen in FIGURE 5, means, such as longitudinal splines **66** on each of the segments of the nuts **63** and **64** are complementarily interlocked in grooves **67** in the internal wall of the housing **20**, are provided to co-rotatively secure the split-nuts to the housing. As seen in FIGURE 2A, to limit the longitudinal travel of the lower split-nut **64**, means, such as inwardly-directed spaced housing shoulders **68** and **69** above and below the nut, respectively, are also provided. The longitudinal travel of the upper split-nut **63** is similarly limited by an annular spacer **70** that is placed between the upper end of the nut and an inwardly directed housing shoulder **71** spaced above the nut.

Oppositely directed buttress threads **72** and **73** are longitudinally spaced around the mandrel **19** and respectively arranged for selective engagement with complementary threads in the nuts **63** and **64** in certain longitudinal positions of the mandrel. The upper mandrel threads **72** are faced upwardly and, in the tool **10** depicted in FIGURES 2A–2D, are preferably so-called "left-hand" threads arranged to threadedly engage the downwardly facing threads in the upper split-nut **63**. With this arrangement, downward longitudinal movement of the mandrel **19** will allow the upper mandrel threads **72** to be ratcheted freely into the upper split-nut **63** but prevent upward longitudinal movement of the mandrel until it is rotated in a clockwise or right-hand direction to unthread the upper mandrel threads from the upper split-nut. Similarly, the lower mandrel threads **73** are faced downwardly and are preferably so-called "right-hand" threads. To accommodate the lower mandrel threads **73**, the threads in the lower split-nut **64** are faced upwardly. Thus, release of the mandrel threads **73** from the lower split-nut **64** for downward movement of the mandrel **19** can be accomplished only by rotating the mandrel in a clockwise direction to unthread these members. It will be appreciated, of course, that by facing the mandrel threads **73** and those in the lower split-nut **64** in opposite directions, upward movement of the mandrel **19** will cause the lower mandrel threads to freely ratchet through the lower split-nut.

For reasons that will subsequently become more apparent, the lower mandrel threads **73** are normally engaged with the lower split-nut **64** and the upper threads **72** are normally disengaged from the upper split-nut **63** and spaced a particular distance thereabove. Thus, with the lower mandrel threads **73** engaged with the lower split-nut **64** as shown in FIGURE 2A, the mandrel **19** is free to travel longitudinally with respect to the housing **20** only so far as is permitted by the spacing between the housing shoulders **68** and **69** respectively above and below the lower split-nut. Similarly, as will also subsequently become apparent, whenever the upper mandrel threads **72** are threadedly engaged with the upper split-nut **63**, the mandrel **19** will be secured in its lowermost telescoped position and cannot be returned to its intermediate or extended positions since the upper split-nut is held by the spacer **70** and the co-engagement of the lugs **33** and slots **34** prevent further rotation of the mandrel with respect to the housing **20**. It will be recalled that the lugs **33** cannot be disengaged from the slots **34** until the tool **10** is returned to the surface and the threaded collar **35** is removed to permit disengagement of the clutch member **32**.

Turning now to FIGURE 2B, the intermediate portion of the tool **10** is shown in which are located the pressure-biasing means **30** and the movement-retarding means **31**. The pressure-biasing means **30** are comprised of an enlarged-diameter shoulder **74** on the mandrel **19** that is fluidly sealed, as by O-rings **75**, within a reduced-diameter portion **76** of the housing **20** above an external housing port **77** and an annular slidable piston member **78** that is around the mandrel above its enlarged-diameter shoulder **74** and below another external housing port **79**. O-rings **80** and **81**, respectively, inside and outside of the slidable piston **78** fluidly seal the piston to the mandrel **19** and housing **20** so as to provide a fluid-tight annular space **82** between the piston and the enlarged-diameter mandrel shoulder **74**, which space is normally at atmospheric pressure. A spring **83** between an inwardly directed housing shoulder **84** and the upper end of the piston **78** normally urges the piston downwardly against a shoulder **85** defined by the upper end of the reduced-diameter housing portion **76**.

It will be recognized that well control fluids will enter the ports **79** and **77** above the piston **78** and below the enlarged-diameter mandrel portion **74** as the tool **10** is being used. Inasmuch as the annular space **82** is normally at atmospheric pressure, the hydrostatic pressure of the well control fluids will therefore tend to lift the mandrel **19** by a force equal to the difference between the hydrostatic and atmospheric pressures multiplied by the annular cross-sectional area of the enlarged-diameter mandrel shoulder **74** itself. The cross-sectional area of the mandrel **19** itself will, of course, be subjected to both upwardly and downwardly acting pressure forces. Similarly, the piston **78** will be urged downwardly against the housing shoulder **85** by a force equal to the difference between the hydrostatic and atmospheric pressures multiplied by the annular cross-sectional area bounded by O-rings **75** and **81**.

Thus, since the mandrel **19** is urged upwardly by this unbalanced pressure force, a force at least greater than this upwardly directed pressure force must be applied to the mandrel in order to move it downwardly relative to the housing **20**. Similarly, it will be appreciated that the downwardly acting pressure force on the piston **78** is effective through the housing shoulder **85** to impose a corresponding downwardly directed force thereon which will be transmitted through the housing to the mandrel **17** of the packer **13** (FIGURE 1) to assist in keeping the packer seated.

Although the piston **78** could be made an integral portion of the housing **20**, it is preferred to make it a separate member as shown in FIGURE 2B and to provide a small lateral port **86** in the housing immediately above the normal position of the external O-ring **81**. In this manner, should well control fluids leak into the enclosed annular space **82**, as the tool **10** is being removed from the well bore **15**, any excessive pressure in the enclosed space **82** will be vented through the port **86** whenever this trapped pressure is sufficient to lift the piston **78** against the restraint of the spring **83** a sufficient distance to move the O-ring **81** above the port **86**. This arrangement also ensures that the mandrel **19** can be returned upwardly should fluids leak into the space **82** after the mandrel is lowered. Otherwise, the piston **78** could just as well be made an integral portion of the housing **20**.

The movement-retarding means **31** are comprised of a sleeve **87** loosely disposed between longitudinally spaced, enlarged-diameter portions **88** and **89** of the mandrel **19**, with only a limited annular clearance **90** being left between the mandrel and sleeve and a very minute annular clearance **91** being left between the sleeve and inner wall of the housing **20**. Means, such as a compression spring **92** between the sleeve **87** and the lower enlarged-diameter mandrel portion **89**, normally urge the sleeve upwardly against the upper enlarged-diameter mandrel portion **88**. An O-ring **93** (FIGURE 2C) around the internal wall of an inwardly facing shoulder **94** in the housing **20** fluidly seals the mandrel **19** and housing relative to one another and defines a fluid-tight space **95** therebetween below the sleeve **87**. An annular piston **96** (FIGURE 2B) having internal and external O-rings **97** and **98** is provided just below the housing **77** to fluidly seal the housing **20** relative to the mandrel **19** above the sleeve **87** and define a second fluid-tight space **99** therebetween in communication with the space **95** only by way of the annular clearance spaces **90** and **91** inside of and around the sleeve **87** respectively. A suitable hydraulic fluid, such as an oil or the like, fills the fluid-tight spaces **95** and **99**.

It will be appreciated that the hydrostatic pressure of the well control fluids will be effective through the port **77** against the piston **96** to maintain the oil in the spaces **95** and **99** at the same pressure. Accordingly, the speed of longitudinal movement of the mandrel **19** with respect to the housing **20** will be governed by the rate at which the oil can be displaced from one of the other of the fluid-tight spaces **95** and **99**. Downward movement of the mandrel **19** with respect to the housing **20** will, of course, maintain the lower face **100** of the upper enlarged-diameter mandrel portion **88** tightly engaged against the adjacent upper face of the sleeve **87**. By appropriately machining the abutting surfaces **100** and **101** of the shoulder **88** and sleeve **87**, a metal-to-metal seat is effected to close

the internal annular space **90** and make the minute external annular clearance space **91** the only flow path by which oil can be transferred from the lower space **95** to the upper space **99** as the mandral **19** is moved downwardly. In this manner, the time required to move the mandrel **19** downwardly with respect to the housing **20** will be directly related to the dimensions of the external annular clearance space **91** and the viscosity of the oil in the fluid-tight spaces **95** and **99**. If it is desired, the lower space **95** may be slightly enlarged, as at **102**, so that whenever the mandrel **19** has moved downwardly at this controlled rate a predetermined distance with respect to the housing **20**, it can continue moving further downwardly with added relative freedom. In any event, the combined effect of the pressure-biasing means **30** and the movement-retarding means **31** is to keep the mandrel **19** in its elevated position until a substantial weight is applied to it for a prolonged time.

To permit fairly rapid upward movement of the mandrel **19** with respect to the housing **20**, the internal clearance space **90** between the sleeve **87** and mandrel is made somewhat larger than the external clearance space **91**. It will be understood, of course, that the spring **92** is not sufficiently strong to keep the sleeve end **101** abutted against its mating surface **100** on the shoulder **88** whenever the mandrel **19** is being moved upwardly. Thus, whenever the mandrel **19** is pulled upwardly with respect to the housing **20**, the sleeve **87** will shift slightly downwardly and move the seating surfaces **100** and **101** apart so as to allow oil from the upper space **99** to pass relatively free between these surfaces, through the larger annular clearance **90**, and on into the lower fluid-tight space **95**.

Turning now to FIGURES 2C and 2D, the lowermost portion of the tool **10** is shown in which are located the first and second valve means **25** and **26** (FIGURE 2C). The internal diameter of this portion of the housing **20** is preferably increased to provide an enlarged bore, as at **103**, below the enclosed space **95** and above an upwardly directed housing shoulder **104** (FIGURE 2D) near the lower end of the housing.

The first valve means **25** (FIGURE 2C) are preferably arranged as a telescoping sleeve valve adapted to control fluid communication between the enlarged housing bore **103** and the internal bore **23** of the mandrel **19** so long as the second valve means **26** therebelow are closed. These first valve means **25** include a coaxially arranged tubular member **105** that is dependently secured within the housing **20** and extended downwardly into the enlarged housing bore **103**. Lateral ports **106** in the mandrel **19** are adapted to be moved into registry with corresponding lateral ports **107** in the coaxially arranged tubular member **105** whenever the mandrel is moved into one of its intermediate longitudinal positions with respect to the housing **20**. O-rings **108** and **109** respectively above and below the mandrel ports fluidly seal the mandrel **19** relative to the tubular member **105** to block flow through the ports **106** and **107** whenever they are not in registration in the other positions of the mandrel. If desired, the sleeve **105** may be rotatably mounted in relation to the housing **20**, as by a retainer ring **110** mounted in opposed complementary circumferential grooves in the sleeve and housing. To ensure that the ports **106** and **107** are angularly oriented, a suitable longitudinal spline and groove (not shown) are provided in the sleeve **105** and mandrel **19** to co-rotatively secure the two members to one another.

The second valve means **26** preferably include a spherical valve member **111** having an axial passageway **112** therethrough along on of its central axes that is sized to correspond at least approximately to the internal mandrel bore **23**. The ball member **111** is operatively disposed between a pair of opposed, longitudinally spaced, annular seats **113** and **114** having complementary spherical seating surfaces. One of the valve seats **113** is coaxially mounted with biasing means **115** in a complementary counterbore in the lowermost end of the mandrel **19** between a pair of depending longitudinal lugs **116** (only one seen) on the lower end of the mandrel **19** and extending downwardly on opposite sides of the seat. The ball member **111** is pivotally supported between the free ends of these depending lugs **116** about another of its central axes by appropriately located transverse pivots **117** (only one seen) that are so positioned that (with the aid of the biasing means **115**) the ball member will remain seated on the seat **113** as the ball moves between its open and closed positions. The axis of these pivots **117** is, of course, perpendicular to the central axis of the passageway **112** so that as the ball member **111** is pivoted, the passageway will move into and out of registration with the valve seat **113**.

The other valve seat **114** is coaxially mounted in an upwardly facing, complementary counterbore **118** in the upper end of an elongated tubular member **119** that is loosely disposed immediately below the ball member **111** in the enlarged housing bore **103** and fluidly sealed therein by an O-ring **120** around its upper end. The valve seat **114** is preferably supported in its receptive counterbore **118** by a spring **121** and fluidly sealed therein by an O-ring **122**.

Two pairs of upwardly extending lugs **123** and **124** (only one lug of each pair being seen) are arranged on opposite sides of the upper end of the tubular member **119** to straddle the valve seat **114** and the ball member **111**, with each of these lugs being laterally displaced from the central axis and extended upwardly alongside the opposite sides of the depending lugs **116**. Each associated set of the lugs **116**, **123** and **124** are so arranged that their opposed longitudinal edges are in juxtaposition with one another. Inwardly projecting transverse pins **125** (only one seen) on the free ends of the lower lugs **124** are disposed parallel to the axis of the pivots **117** but longitudinally spaced therebelow and slightly offset to one side. The free ends of these pins **125** are each confined within fairly short, inclined grooves **126** (only one seen) formed in the adjacent external surfaces of the ball member **111**. It will be noted that the pivots **117** normally support the ball member **111** off of the lower seat **114** so as to leave an annular clearance therebetween so long as the ball member is in its closed position as seen in FIGURE 2C.

Accordingly, it will be appreciated that whenever the ball member **111** is moved toward the tubular member **119** and valve seat **114**, the ball will be pivoted by the pins **125** and slots **126** about its pivots **117** in a clockwise direction as seen in the drawings. It will be realized, of course, that the cooperative engagement of the juxtaposed edges of the lugs **116**, **123** and **124** will prevent the mandrel **19** and tubular member **119** from rotating relative to one another and limit their relative motion to rectilinear travel. The inclined grooves **126** must, of course, be of sufficient length to accommodate the transverse pins **125** whenever the ball member **111** has rotated midway between its fully-closed and its fully-open positions.

Biasing means are provided such as a compression spring **127** (FIGURE 2D) that is disposed around the tubular member **119** between spaced, annular abutment members **128** and **129** slidably disposed thereon and supported by an external shoulder **130** on the lower end of the tubular member **119**. An inwardly directed housing shoulder **131** is suitably located to normally engage the upper face of the upper abutment **128** whenever the tool **10** is in the position shown in FIGURES 2A–2D.

It will be noted that in this position of the tool **10**, the lower face of the lower abutment **129** is spaced above the housing shoulder **104** a distance equal to the longitudinal spacing of the ports **106** and **107** when they are in the position shown in FIGURE 2C. Similarly, this same longitudinal spacing is maintained between the upper face of the upper abutment **128** and the lower face of an

enlarged-diameter portion or shoulder **132** at the upper end of the tubular member **119**. The shoulder **132** is, of course, suitably sized to pass freely through the annular housing shoulder **131**. Moreover, for reasons that will subsequently become apparent, these longitudinal spacings are preferably about equal to the longitudinal spacing between the upper face of the housing shoulder **69** and the lower face of the lower split-nut **64** (FIGURE 2A) when this split-nut is engaged with the mandrel threads **73**.

Accordingly, it will be appreciated that when the mandrel **19** is in its extended position with respect to the housing **20** as shown in FIGURES 2A–2D, both valve means **25** and **26** will be closed. However, by moving the mandrel **19** downwardly with respect to the housing **20** the above-mentioned longitudinal distance to its intermediate positions (with the guide pin **46** at B in FIGURE 7 to be subsequently described in greater detail), the first valve means **25** will be opened to provide fluid communication from the enlarged housing bore **103**, through the clearance between the ball **111** and valve seat **114**, and the ports **106** and **107**, and on into the central bore **23** of the mandrel **19**. The second valve means **26** are, of course, still closed in this intermediate position of the mandrel **19**. Similarly, as will be subsequently described with greater detail, once the lower split-nut **64** is released from the threads **73**, further downward movement of the mandrel **19** (to bring the guide pin to E in FIGURE 7) will reclose the first valve means **25** and open the second valve means **26** as the mandrel reaches its lowermost, telescoped position. In this latter position, a full-opening passage is provided through the tool **10** since the passageway **112** in the ball member **111** will have been rotated into alignment with the central mandrel bore **23**.

It will be appreciated, therefore, that so long as the lower split-nut **64** remains engaged with the mandrel threads **73**, the mandrel **19** can be moved longitudinally a distance equal to the spacing between the lower split-nut and the housing shoulder **69**. This distance is also equal to the longitudinal spacing between the two positions of the guide pin **46** represented at A and B in FIGURE 7. Thus, by simply moving the mandrel **19** downwardly in relation to the housing **20** the ports **106** and **107** will be opened. Similarly, by returning the mandrel **19** to its initial extended position (as shown in FIGURES 2A–2D) the ports **106** and **107** will again be reclosed. Thus, the lower split-nut **64** cooperates with the housing shoulders **68** and **69** to allow the mandrel **19** to be reciprocated sufficiently to selectively open and close the first valve means **25** without opening the second valve means **26**.

Turning now to FIGURES 6A–6D, the tool **10** is schematically represented to illustrate its various positions during the course of a typical operating sequence. To facilitate the explanation of the positioning means **27** and **28** of the invention, the movement-retarding means **31** and biasing means **30** have not been shown in FIGURES 6A–6D. It will be understood, however, that downward travel of the mandrel **19** will be regulated by the movement-retarding means **31** until the top of the sleeve **87** has entered the enlarged space **102** (FIGURE 2B). Similarly, it should be kept in mind that the biasing means **30** will be effective to provide an upwardly directed force on the mandrel **19** and to apply an equal, but downwardly directed, force on the housing **20** during the entire operation of the tool **10**.

In FIGURE 6A, the tool **10** is shown with the mandrel **19** being in its uppermost extended position with respect to the housing **20** as already described with reference to FIGURES 2A–2D. The first and second valve means **25** and **26** are closed to block fluid communication through the mandrel bore **23** as the tools **10–13** are moved into position in the cased well bore **15** (FIGURE 1). It will also be noted from FIGURE 6A that although the upper clutch member **32** is disengaged, the lower clutch member **36** is engaged to permit rotation to be applied from the tubing string **14**, through the tool **10**, and onto the other tools **11–13** therebelow. Accordingly, with the tool of the present invention secured in the position depicted in FIGURE 6A, the tools **10–13** can be brought into position at any desired depth in the cased well bore **15**.

Once the tools **10–13** have reached a desired position in the well bore **15**, they are momentarily halted and the tubing string **14** is manipulated as required to set the packer **13** and close the bypass valve **11**. Although other tools may utilize different movements for their operation, it is preferred to arrange the bypass valve **11** and packer **13** so that the position-establishing means, such as J-slot systems (not shown), in each tool will work in cooperation to close the bypass valve as the packer is being set. Accordingly, with the tools **11** and **13** having cooperative J-slot systems arranged in this manner, the tubing string **14** is picked up slightly and torqued in a clockwise direction to "unjay" the bypass valve and packer. Then, by slacking-off at least part of the weight of the tubing string **14**, the packer **13** will be set and the bypass valve **11** closed. It will be recalled that the mandrel **19** cannot move downwardly relative to the housing **20** until the upward force provided on the mandrel by the biasing means **30** is overcome.

Once the packer **13** is set, it will be appreciated that it is capable of supporting the full weight of the tools **10–12** and tubing string **14** thereabove. The housing **20** of the tool **10** will, of course, now be fixed relative to the casing **16** until the packer **13** is unseated. It will be recalled, moreover, that the biasing means **30** will also be effective to maintain a substantial downward force through the housing **20** to aid in holding the packer **13** seated. Thus, the mandrel **19** of the tool **10** is now capable of being moved relative to the now-stationary housing **20** by corresponding motions of the tubing string **14** to bring the tool into its various operating positions.

Accordingly, as shown in FIGURE 6B, application of sufficient weight to the mandrel **19** for setting the packer **13** will carry the mandrel a short distance downwardly (as shown by arrow **133**) until the lower split-nut **64** engages the upwardly facing shoulder **69**. This downward movement will, however, be retarded by the motion-retarding means **31** and furthermore will require sufficient weight on the mandrel **19** to at least overcome the upwardly directed force on the mandrel provided by the biasing means **30**. It will be noted from FIGURE 6B, however, that this initial downward travel of the mandrel **19** will open only the valve means **25** and disengage the lower clutch member **36**. Thus, by virtue of the positioning means **28** of the present invention, downward motion and rotation of the tubing string **14** in these first two operating positions of the tool **10** will be effective only to set the packer **13**, close the bypass valve **11**, and open the valve means **25** without introducing any risk whatsoever that the valve means **26** might be opened prematurely by over-movement of the mandrel **19**.

It will also be appreciated from FIGURE 6B that further downward travel of the mandrel **19** relative to the housing **20** is not possible so long as the lower nut **64** is abutted on the housing shoulder **69**. On the other hand, upward travel of the mandrel **19** is unimpeded should, for example, it be necessary to re-engage the lower clutch member **36** to apply rotation from the tubing string **14** through the housing **19** to the tools **11–13**.

Once the valve means **25** are open, the guide pin **46** will be at its position B as shown in FIGURE 7. The mandrel **19** cannot, however, be moved further downwardly so as to bring the guide pin **46** to its position at E since the lower face of the lower split-nut **64** will be abutted against the housing shoulder **69**.

A typical testing operation usually includes one or more measurements of the so-called "shut-in pressure" of the formation interval being tested. To measure this and other pressures, one or more pressure recorders (shown

schematically at P) are provided below the valve means **25** and **26**. If desired, these pressure recorders P may be arranged as shown in a copending application, Ser. No. 620,943, also filed by the applicant on Mar. 6, 1967, for selective release from the tool **10** by opening of the valve means **26**. In any event, to obtain a shut-in pressure, the mandrel **19** is pulled upwardly to reclose the valve means **25**. Once the guide pin **46** is in its position at B in the groove system **47**, upward movement of the mandrel **19** will bring the guide pin into the upper end of the longitudinal groove **53**. By extending the lower wall **134** of the recess **55** to a termination, as at **135**, beyond the lower end of the groove **56**, a straight upward pull on the mandrel **19** will be certain to carry the guide pin **46** into the groove **53** rather than the groove **52**.

The mandrel **19** is, therefore, picked-up until the guide pin reaches its position at C in the short slot **57**. This will, of course, also return the upper face of the split-nut **64** back into engagment with the housing shoulder **68** and reclose the ports **106** and **107**. It will also be recalled that once the guide pin **46** is in the groove **53**, the sleeve **45** will be appropriately positioned to align the mandrel lugs **62** with their respective shoulder slots **61** and allow the lugs to move above the shoulder **60**.

Although the valve means **25** are closed by the time the guide pin **46** reaches its position at C and the initial shut-in pressure measurement is started, it is desirable to maintain a downward force on the packer **13** while the measurement is being taken. Thus, as already discussed, the sleeve shoulder **60** is appropriately located in relation to the lower surfaces of the mandrel lugs **62** so that a slight downward movement of the mandrel **19** will bring the lugs **62** into engagement with the shoulder **60**. Once the mandrel lugs **62** are engaged on the shoulder **60**, a downward force on the tubing string **14** will be transmitted through the sleeve **45** to the housing **20** and on downwardly to the tools **11–13** therebelow. It should also be noted that in this position, the mandrel splines **41** are re-engaged with the slots **40** in the annular member **36** to permit rotation to be transmitted through the tool **10** to the tools **11–13** if desired. It will be recalled that the mandrel lugs **62** are not in registration with the shoulder slots **61** when the guide pin **46** is in the groove **59**.

As best seen in FIGURE 7, the upper surface of the transverse groove **51** is inclined and extended, as at **136**, over the groove **57** to prevent the guide pin **46** from re-entering the groove **53** when the mandrel **19** is moved downwardly to relocate the guide pin from its position C to its position D. Thus, a straight downward movement of the mandrel **19** will bring the surface **136** into engagement with the guide pin **46** and rotate the sleeve **45** sufficiently to bring the guide pin into its position D in the grooves **59**. This will still leave the valve means **25** closed and, as best seen in FIGURE 6C, allow a downward force to be applied through the lugs **62** and sleeve **45** to the housing **20**.

Once an adequate initial shut-in pressure measurement has been taken, the usual test procedure is to reopen the test valve and allow the well to flow for a period of time. Accordingly, it will be appreciated from FIGURE 7 that by raising the mandrel **19** slightly, the guide pin **46** will be engaged against the lower, downwardly-inclined surface **137** of the transverse groove **51** to rotate the sleeve **45** sufficiently to return the guide pin to its position at A. Then, as in the initial operation, a downward movement of the mandrel **19** will again reopen the valve means **25** (position B).

Accordingly, by alternately lowering and raising the mandrel **19**, any number of shut-in and flowing tests can be made. Moreover, each longitudinal movement of the mandrel **19** will provide a pronounced and easily detected indication at the surface when the mandrel reaches one extreme or another.

Once all tests are completed, it is usually preferred to open the full bore of the tool **10** either to conduct further completion operations or to recover the pressure recorders P. Accordingly, in keeping with the principles of the present invention, to continue further downward travel of the mandrel **19**, it is necessary to first unthread the lower mandrel threads **73** from the lower nut **64**. It will be realized, of course, that unthreading rotation of the mandrel **19** would ordinarily tend to move the mandrel on downwardly and leave the lower split-nut **64** shouldered on its associated lower housing shoulder **69**. It should be noted, however, that as a matter of operating technique, it is preferred to relieve some of the downward load on the mandrel **19** while rotating the tubing string **14**. This is done by picking up the tubing string **14** somewhat but still leaving sufficient weight on the mandrel **19** to overcome the biasing means **30** which added weight will, of course, slowly overcome the movement-retarding means **31**. Thus, a sufficient time is assured to allow the lower split-nut **64** to climb the mandrel threads **73** before the movement-retarding means **31** are overcome.

Accordingly, as best seen in FIGURE 6D, rotation of the mandrel **19** in the appropriate direction (as shown by arrow **138**) in cooperation with the movement-retarding means **31** will instead allow the nut **64** to climb the mandrel threads **73** and leave the mandrel in subtantially the same longitudinal position as before. The nut **64** cannot, of course, rotate by virtue of the splines **66** (FIGURE 5) but it will nevertheless climb the threads **73** as the mandrel **19** rotates relative to the split-nut.

Once the lower split-nut **64** is freed from the lower mandrel threads **64**, the mandrel **19** is then free to travel on downwardly as permitted by the movement-retarding means **31**. Once the upper end of the sleeve **87** clears the enlarged-diameter housing portion **102**, the mandrel **19** will then move rapidly downwardly (as shown by arrow **139**) into the position depicted in FIGURE 6D. This sudden movement will provide a substantial shock that is easily detected at the surface. As seen in FIGURE 6D, movement of the mandrel **19** into this position will simultaneously coengage the upper mandrel threads **72** with the upper split-nut **63**, move the mandrel ports **106** below the sleeve ports **107**, and pivot the ball member **111** into a position where its passageway **112** is coaxially aligned with the mandrel bore **23**. Then, if necessary, the tubing string **14** is rotated one or two rotations to insure engagement of the upper clutch member **32**. Once the clutch member **32** is engaged, this will also provide a positive indication at the surface that the ball member **111** is open and that the mandrel **19** and housing **20** are co-rotatively secured.

It will be appreciated that to pivot the ball member **111** into its open position, the ball member must move downwardly relative to the tubular member **119** with sufficient force that the camming action of the transverse pins **125** in the solts **126** will rotate the ball member about its pivots **117**. This upward force is, of course, provided by the spring **127** which, as best seen in FIGURES 6C and 6D, is progressively compressed until it develops a resisting force that is sufficient to rotate the ball member **111** against the frictional forces imposed by the upper valve member **119** will be restrained by the force of the spring **127** cannot develop an upwardly acting force until the lower abutment **129** has engaged the housing shoulder **104**. Then, as the mandrel **19** is moved further downwardly as seen in FIGURE 6D, the spring **127** is progressively compressed to develop a correspondingly increasing upwardly directed bias through the upper abutment **128** to the shoulder **132** of the tubular member **119**.

Accordingly, as the downward force **139** on the mandrel **19** increases, downward movement of the tubular member **119** will be restrained by the force of the spring **127** as the shoulder **132** tends to move the abutment **128** below the housing shoulder **131**. In some instances, the resulting force of the spring **127** will be sufficient to pivot the ball member **111** before the tubular member **119**

moves downwardly far enough to shift the abutment **128** below the shoulder **131**. However, to emphasize the function of the spring **127** in supplying the rotational bias to the ball member **111**, the abutment **128** is shown slightly below the housing shoulder **131** in FIGURE 6D. It will also be recognized that as the ball member **111** rotates, it will move slightly downwardly into seating engagement with the lower seat **114**. Thus, once the ball member **111** is rotated, the seats **113** and **114** will be tightly seated around the opposite ends of the passage **112** to prevent entrance of fluids in the mandrel bore **23** into the enlarged space **103**. It will also be noted that since the ports **106** and **107** are no longer in registration, solids or fluids in the mandrel bore **23** are similarly blocked from entering the enlarged space **103**.

Once the tool **10** is in the position shown in FIGURE 6D, the mandrel **19** will be prevented from traveling upwardly by the co-engagement of the upper mandrel threads **72** in the upper split-nut **63**. Release of the threads **72** from the nut **63** could, of course, be accomplished by rotation of the mandrel **19** were it not for the engagement of the upper clutch member **32** which now prevents further rotation of the mandrel relative to the housing **20**. Thus, once the mandrel **19** reaches its lowermost telescoped position shown in FIGURE 6D, the tool **10** is locked in this position with the ball valve means **26** open and the sleeve valve means **25** closed. This will provide a substantially continuous and uninterrupted passage from the tubing string **14** for introduction of various well tools (not shown), completion fluids such as cement or fracturing fluids requiring high flow rates, and for other reasons that may be encountered during the course of typical remedial or well-completion operations. The tools **10–13** must be retrieved to the surface in order to return the mandrel **19** to its original position. To do this, the upper clutch member **32** is quickly released by removing the threaded collar **35** and shifting the annular member upwardly to disengage the lugs **33** from the slots **34**.

The annular spacer **70** is, of course, employed to prevent the mandrel **19** from being picked upwardly once the ball valve **111** is opened and the upper mandrel threads **72** have become engaged with the upper split-nut **63** as shown in FIGURE 6D. It will be appreciated, therefore, that by omitting this spacer **70**, the mandrel **19** could be moved upwardly a sufficient distance to disengage the lugs **33** from their receptive slots **34**. This movement would, however, be insufficient to allow either the ball member **111** to be rotated back into its closed position or for the ports **106** and **107** to realign as shown in FIGURE 6B so long as the mandrel **19** was not rotated. Yet, once the lugs **33** were free of their slots **34**, the mandrel **19** could be rotated sufficiently to disengage the upper split-nut **63** from the mandrel threads **72** and permit the valve means **25** and **26** to be alternately opened and closed as many times as desired between the positions shown in FIGURES 6B and 6D. Moreover, with the spacer **70** omitted, once the mandrel **19** is rotated sufficiently to disengage the upper split-nut **63** from the upper mandrel threads **72**, the mandrel could also be returned to any of the positions shown in FIGURES 6A and 6C as well.

Omission of the spacer **70** is not too desirable, however, where the bypass valve **11** and packer **13** are of the types described above in reference to FIGURE 1. For example, following a so-called "squeeze job," it is almost essential to rapidly flush-out the excess cement remaining in the tubing string **14** by applying pressure to the well control fluids in the well annulus and forcing these fluids up into the lower end of the tubing string and on upwardly therein. Access to the tubing string **14** is typically gained by either unsetting the packer **13** or, as a last resort, opening the bpyass valve **11** should the packer not be readily unseated. It will be realized, of course, that in either event, the ball valve means **26** must be left open to permit a high flow rate of these fluids to be maintained. With bypass valves and packers of the types described, however, the tubing string **14** usually must be at least partially rotated and then picked up with considerable force to either open the bypass valve **11** or unseat the packer **13**. These motions could, therefore, serve to reclose the ball valve means **26** and prevent the desired flushing operation if either the packer **13** or bypass valve **11** were not completely free of foreign matter and readily movable. Thus, unless the packer **13** and bypass valve **11** are of a style requiring only a straight upward pull to unseat the packer or open the bypass valve, it is preferred to include the spacer **70** so that the ball member **111** will unquestionably remain securely locked in its open position once the tool **10** is moved into the position depicted in FIGURE 6D.

It will be appreciated from the foregoing description that the depicted arrangement of the groove system **47** of the position-establishing means **27** allows the sleeve valve means **25** to be selectively opened and closed by reciprocation of the mandrel **19**. Moreover, by appropriately locating such stops as the surfaces **134** and **136** adjacent to the entrance of one of the grooves (e.g., groove **59**), as the mandrel **19** is moved to reposition the guide pin **46** (e.g., from position C to position D), longitudinal movement of the mandrel will result in the guide pin reaching the subsequent position.

It will be realized, however, that the proper functioning of the position-establishing means **27** of the present invention requires that the mandrel **19** be moved longitudinally with little or no rotation so long as the lower split-nut **63** is engaged with the lower mandrel threads **73**. Those skilled in the art will understand, however, that torsional forces will often be developed in the tubing string **14** as the tools **10–13** are being positioned in the well bore **15**. Thus, even though no rotation is deliberately imparted to the tubing string **14** at the earth's surface during the operation of the tool **10**, sufficient torsional forces may have been stored by the tubing string to impart at least a partial rotation to the mandrel **19** as it is being moved longitudinally from the surface.

It will be realized, therefore, that should the mandrel **19** rotate in a clockwise direction as it is being raised to shift the guide pin **46** from its position at B to its position at C, the guide pin could clear the end **135** of the surface **134** and re-enter the groove **52** rather than being moved into the groove **53** (FIGURE 7). Should this occur, the guide pin **46** would return to its position at A without the operator's knowledge. Then, when the mandrel **19** was again lowered to supposedly shift the guide pin **46** from its position at C to its position at D, the guide pin would instead be returned to its position at B. Thus, instead of closing the valve means **25** to take a shut-in pressure measurement, the valve means **23** would be reopened. Similar malfunctions due to residual torsional movements of the mandrel **19** could just as well occur at other points in the operating sequence of the tool **10**.

Accordingly, to ensure positive operation of the position-establishing means **27**, stop means, such as an inwardly biased key **140** on the sleeve **45** and a plurality of vertically dispose dstops or shoulders **141–144** on the mandrel **19**, are provided to prevent inadvertent rotation of the mandrel from bringing the guide pin **46** into an incorrect position as the tool **10** is being operated. As best seen in FIGURE 8, the key **140** is mounted upright in a longitudinal sleeve recess **145** diametrically opposite the guide pin **46**. It should be noted that although the key **140** has been shown in FIGURE 2A to better illustrate the invention, the key is actually angularly oriented as shown in FIGURE 8. An arcuate spring **146** or similar biasing means behind the key **140** normally urges the key into contact with that portion of the mandrel **19** diametrically opposite the groove system **47** thereon.

The first stop shoulder **141** on the mandrel **19** is at about the same level as the enlarged portion **55** of the groove system **47** and is about diametrically opposite therefrom. It will be appreciated moreover from FIGURES 2A, 4 and 7 that the vertical shoulder surface **141** is so arranged in relation to the key **140** that whenever

the guide pin **46** is in either the groove **56** or enlarged groove portion **55**, the mandrel **19** cannot rotate in relation to the sleeve **45** sufficiently far in a clockwise direction that the guide pin can pass the terminal groove surface **135** and re-enter the groove **52**. Thus, once the guide pin **46** is in the position B shown in FIGURE 7, inadvertent rotation of the mandrel **19** in a clockwise direction will only bring the key **140** against the shoulder **141** and keep the sleeve **45** and guide pin correctly oriented in relation to the groove system **47**. Rotation of the mandrel **19** in a counterclockwise direction will only bring the guide pin **46** against the common wall of the grooves **53** and **56** which serves as a stop to prevent misalignment of the guide pin and groove system **47**.

The other stop shoulders **142–144** are similarly arranged at the same level of the transverse groove **51** to successively prevent re-entry of the guide pin **46** into either the groove **53** or groove **59** once the guide pin has entered the groove **57**, the groove **59** or the groove **58** as the tool **10** is operated. Thus, for example, once the guide pin **46** is in its position C (FIGURE 7), counterclockwise rotation of the mandrel **19** cannot reposition the guide pin into groove **53** since the shoulder **142** will engage the key **140** and hold the groove surface **136** above the pin so as to guide the pin to its position at D as the mandrel is lowered. Similarly, the shoulder **143** keeps the guide pin **46** from re-entering the groove **57** from the groove **59** and the shoulder **144** keeps the guide pin from re-entering the groove **59** from the groove **58**.

Turning now to FIGURE 9, a schematic representation similar to FIGURE 6A is shown of a tool **200** that is arranged in the same way as the tool **10** but for the first position-establishing means **201**. A comparison of FIGURES 6A and 9 will show that the position-establishing means **201** for the tool **200** are reversed from that shown at **27** for the tool **10**. As previously mentioned with respect to FIGURES 6A–6D, the movement-retarding means and biasing means are employed with the tool **200** but are not shown in FIGURE 9.

As seen in FIGURE 9, the tool **200** has a mandrel **202** that is disposed in a housing **203** for longitudinal movement between an extended position and a fully-telescoped position as determined by the position-establishing means **201**. It will be seen, therefore, that except for the reversal of the elements comprising the position-establishing means **201**, the tool **200** is otherwise like the tool **10**. Second position-establishing means **204** arranged in the same manner as those at **28** in the tool **10** are also included with the tool **200**. It should be noted, however, that as shown in FIGURE 12 of the aforementioned copending application, Serial No. 620,943, the position-establishing means **204** could also be reversed with the other position-establishing means being arranged either as at **204** in FIGURE 9 or as at **28** in FIGURE 2A in the present application.

Accordingly, it will be appreciated that the present invention has provided position-establishing or control means for ensuring that telescopically related members of a well tool can be reliably moved into a known relation with a minimum of manipulations. By arranging position-establishing means in accordance with the principles of the present invention, a longitudinal movement of the supporting string will suffice to selectively position the telescoping members in a well tool between two selected positions without risking the inadvertent movement thereof to a third position. Moreover, by providing means, such as the disclosed stop shoulders, improper operation of the position-establishing means is prevented even where the supporting string is inadvertently rotated as by an accumulated torque in the string. Then, once it is desired to move these members to a third position in relation to one another, rotation of the supporting string will permit further longitudinal movement of the string to shift the telescoped members to their third position.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects; and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

**1.** A well tool comprising: first and second relatively rotatable members telescoped together for reciprocating movement relative to one another between longitudinally-spaced positions; first means operable by relative longitudinal movement of said telescoped members between first and second ones of said spaced positions; second means operable by relative longitudinal movement of said telescoped members toward a third one of their said spaced position; first position-establishing means responsive to reciprocating movement of said telescoped members in their said first spaced position upon alternate movements of said telescoped members in one direction and for selectively positioning said telescoped members in their said second spaced position upon intervening movements of said telescoped members in said one direction; and second position-establishing means normally stopping said telescoped members from moving from their said second spaced position to their said third spaced position and responsive to relative rotation between said telescoped members to free said telescoped members for movement toward their said third spaced position.

**2.** The well tool of claim **1** further including: means for retarding movement of said telescoped members in said one direction.

**3.** The well tool of claim **1** wherein said first position-establishing means include: a first shoulder on said first telescoped member; a second shoulder rotatably supported on said second telescoped member and adapted for engagement with said first shoulder whenever said shoulders are angularly aligned and said telescoped members are in their said first spaced position; and guide means coupling said shoulders and operable upon reciprocating movement of said telescoped members to bring said shoulders into angular alignment for co-engagement once said telescoped members reach their said first spaced position.

**4.** The well tool of claim **3** wherein said guide means are comprised of: a guide member fixed in relation to one of said shoulders; and means fixed in relation to the other of said shoulders and including a groove adapted to receive said guide member and defining cam surfaces cooperable with said guide member for bringing said shoulders into angular alignment as said telescoped members approach their said first spaced position and for moving said shoulders out of alignment as said telescoped members are moved away from their said first spaced position.

**5.** The well tool of claim **1** wherein said second position-establishing means are comprised of: means for releasably gripping one of said telescoped members at a first location thereon and releasable therefrom only upon relative rotation between said telescoped members; and stop means on the other of said telescoped members and adapted to engage said gripping means whenever said telescoped members are in their said second position to prevent their further movement toward their said third position until said gripping means are released.

**6.** The well tool of claim **5** wherein said first position-establishing means include: a first shoulder on said first telescoped member; a second shoulder rotatably supported on said second telescoped member and adapted for engagement with said first shoulder whenever said shoulders are angularly aligned and said telescoped members are in their said first spaced position; and guide means coupling said shoulders and operable upon reciprocating movement of said telescoped members to bring said shoulders into angular alignment for co-engagement once said telescoped members reach their said first spaced position.

**7.** The well tool of claim **6** wherein said guide means are comprised of: a guide member fixed in relation to one

of said shoulders; and means fixed in relation to the other of said shoulders and including a groove adapted to receive said guide member and defining cam surfaces cooperable with said guide member for bringing said shoulders into angular alignment as said telescoped members approach their said first spaced position and for moving said shoulders out of alignment as said telescoped members are moved away from their said first spaced position.

8. A well tool comprising: inner and outer relatively rotatable tubular members telescoped together for reciprocating movement between longitudinally-spaced positions; first valve means selectively operable in response to movement of said telescoped members between a first one and a second one of their said spaced positions; second valve means selectively operable in response to movement of said telescoped members toward a third one of their said spaced positions; and position-establishing means operatively coupling said telescoped members including first and second stop means for respectively positioning said telescoped members in their said first and second positions, means responsive to reciprocating movement of said telescoped members for alternately guiding said telescoped members to their said first spaced position and then to their said second spaced position upon consecutive movements of said telescoped members in the same longitudinal direction, and means responsive to relative rotation between said telescoped members for inactivating one of said stop means to free said telescoped members for movement toward their said third spaced position.

9. The well tool of claim 8 wherein the other of said stop means include: a first shoulder on one of said telescoped members, and a second shoulder rotatably supported on the other of said telescoped members and adapted for engagement with said first shoulder whenever said shoulders are angularly aligned and said telescoped members are in their said first spaced position, said guide means coupling said shoulders and being selectively operable upon reciprocating movement of said telescoped members to bring said shoulders into angular alignment for co-engagement once said telescoped members reach their said first spaced position.

10. The well tool of claim 9 wherein said guide means are comprised of: a guide member fixed in relation to one of said shoulders; and means fixed in relation to the other of said shoulders and including a groove adapted to receive said guide member and defining cam surfaces cooperable with said guide member for bringing said shoulders into angular alignment as said telescoped members approach their said first spaced position and for moving said shoulders out of alignment as said telescoped members are moved away from their said first spaced position.

11. The well tool of claim 8 wherein said one stop means include: a plurality of threads on said inner member, a threaded nut threadedly engaged with said threads, means co-rotatively securing said nut to said outer member without restricting longitudinal travel of said nut in relation thereto, and a shoulder on said outer member adapted for engagement with said nut once said telescoped members reach their said second spaced position so long as said nut has not been disengaged from said threads.

12. The well tool of claim 11 further including: movement-retarding means between said telescoped members for delaying their travel in said longitudinal direction.

13. The well tool of claim 11 wherein the other of said stop means include: a first shoulder on one of said telescoped members, and a second shoulder rotatably supported on the other of said telescoped members and adapted for engagement with said first shoulder whenever said first and second shoulders are angularly aligned and said telescoped members are in their said first spaced position, said guide means coupling said shoulders and being operable upon reciprocating movement of said telescoped members to bring said first and second shoulders into angular alignment for co-engagement once said telescoped members reach their said first spaced position.

14. The well tool of claim 13 wherein said guide means are comprised of: a guide member fixed in relation to one of said first and second shoulders; and means fixed in relation to the other of said first and second shoulders and including a groove adapted to receive said guide member and defining came surfaces cooperable with said guide member for bringing said first and second shoulders into angular alignment as said telescoped members approach their said first spaced position and for moving said first and second shoulders out of alignment as said telescoped members are moved away from their said first spaced position.

15. The well tool of claim 14 further including: movement-retarding means between said telescoped members for delaying their travel in said longitudinal direction.

16. Apparatus adapted for use in a well bore and comprising: packing means adapted for packing-off a well bore in response to a downward force thereon and including a fluid passage adapted for providing fluid communication through said packing means; inner and outer relatively rotatable tubular members telescoped together for reciprocating movement between longitudinally-spaced positions, said outer telescoped member being coupled to said packing means and in fluid communication with said fluid passage, said inner telescoped member being adapted for connection to a pipe string; first valve means responsive to movement of said telescoped members between a first one and a second one of their said spaced positions for selectively opening and closing fluid communication between said fluid passage and a pipe string connected to said inner telescoped member; second valve means normally closing the interior of said inner member and responsive to movement of said telescoped members toward a third one of their said spaced positions to open the interior of said inner member; and position-establishing means coupling said telescoped member including first and second stop means respectively adapted for transmitting downward forces from a pipe string connected to said inner telescoped member to said packing means whenever said telescoped members are in their said first and second spaced positions, guide means responsive to reciprocating movement thereof for alternately positioning said telescoped members in their said first spaced position and then in their said second spaced position upon successive movements of said telescoped members in the same longitudinal direction, and means responsive to relative rotation between said telescoped members for releasing said second stop means to free said telescoped members for movement toward their said third spaced position.

17. The well bore apparatus of claim 16 further including: pressure-measuring means adapted to be supported in relation to said outer tubular member below said second valve means and for passage through the interior of said inner member and said second valve means.

18. The well bore apparatus of claim 16 wherein said first stop means include: a first shoulder on one of said telescoped members, and a second shoulder rotatably supported on the other of said telescoped members and adapted for engagement with said first shoulder to transmit downward forces to said packing means whenever said shoulders are angularly aligned and said telescoped members are in their said first spaced position; and said guide means include a guide member fixed in relation to one of said shoulders, and a groove fixed in relation to the other of said shoulders and defining cam surfaces cooperable with said guide member for angularly aligning said shoulders as said telescoped members approach their said first spaced position and for angularly misaligning said shoulders as said telescoped members are moved away from their said first spaced position.

19. The well bore apparatus of claim 16 wherein said second stop means and releasing means include: a plurality of threads on said inner member, a threaded nut threadedly engaged with said threads, means co-rotatively securing said nut to said outer member without restricting longitudinal travel of said nut in relation thereto, and a shoulder on said outer member adapted for engagement with said nut to transmit downward forces to said packing means whenever said telescoped members are in their said second spaced position so long as said nut has not been disengaged from said threads.

20. The well bore apparatus of claim 19 wherein said first stop means include: a first shoulder on one of said telescoped members, and a second shoulder rotatably supported on the other of said telescoped members and adapted for engagement with said first shoulder to transmit downward forces to said packing means whenever said shoulders are angularly aligned and said telescoped members are in their said first spaced position; and said guide means include a guide member fixed in relation to one of said shoulders, and a groove fixed in relation to the other of said shoulders and defining cam surfaces cooperable with said guide member for angularly aligning said shoulders as said telescoped members approach their said first spaced position and for angularly misaligning said shoulders as said telescoped members are moved away from their said first spaced position.

21. A well tool comprising: inner and outer relatively rotatable tubular members telescoped together for reciprocating movement between longitudinally-spaced positions; first valve means selectively operable in response to movement of said telescoped members between a first one and a second one of their said spaced positions; second valve means selectively operable in response to movement of said telescoped members toward a third one of their said spaced positions; and position-establishing means operatively coupling said telescoped members and including a sleeve member between said telescoped members and rotatably supported by one of said telescoped members, a first shoulder fixed on the other of said telescoped members, means on said sleeve member defining a second shoulder thereon adapted for engagement by said first shoulder whenever said shoulders are angularly aligned and said telescoped members are in their said first spaced position as well as defining a clearance on each side of said second shoulder adapted to pass said first shoulder whenever said shoulders are angularly misaligned and said telescoped members are in their said second spaced position, guide means coupling said other member and said sleeve member and responsive to reciprocating movement of said telescoped members for alternately aligning and misaligning said shoulders whenever said telescoped members are being moved between their said first and second spaced positions, abutment means on said outer member, and stop means releasably coupled to said inner member adapted to engage said abutment means whenever said telescoped members are in their said second spaced position and releasable from said inner member upon relative rotation between said telescoped members to free said telescoped members for movement toward their said third spaced position.

22. The well tool of claim 21 wherein said guide means include: a guide member fixed to and projecting from one of the said sleeve and said other telescoped members; and groove means on the other of said sleeve and said other telescoped members adapted to receive said guide member for movement relative thereto and including first and second and third longitudinal groove portions circumferentially spaced from one another, said first and third groove portions being angularly oriented to respectively align said first shoulder with one of said clearances when said guide member is therein and said second groove portion being angularly oriented to align said first shoulder with said second shoulder when said guide member is therein, a first transverse groove portion interconnecting adjacent portions of each of said longitudinal groove portions, a second transverse groove portion interconnecting other adjacent portions of said first and third longitudinal groove portions, said first transverse groove portion having first surface portions cooperable with said guide member for directing said guide member from said second longitudinal groove portion into said first longitudinal groove portion upon a first movement of said telescoped members in one longitudinal direction, said second transverse groove portion having second surface portions cooperable with said guide member for directing said guide member from said first longitudinal groove portion into said third longitudinal groove portion upon a first movement of said telescoped members in the other longitudinal direction, and said first transverse groove portion having third surface portions cooperable with said guide member for directing said guide member from said third longitudinal groove portion into said second longitudinal groove portion upon a second movement of said telescoped members in said one longitudinal direction followed by a second movement of said telescoped members in said other longitudinal direction.

23. The well tool of claim 22 further including means for preventing said guide member from being directed back into said first longitudinal groove portion upon said second movement of said telescoped members in said one longitudinal direction.

24. The well tool of claim 23 further including means for preventing said guide member from being directed back into said third longitudinal groove portion upon said second movement of said telescoped members in said other longitudinal direction.

25. The well tool of claim 24 further including means for preventing said guide member from being directed back into said second longitudinal groove portion upon said first movement of said telescoped members in said one longitudinal direction.

26. A well tool comprising: inner and outer relatively rotatable tubular members telescoped together for movement between longitudinally-spaced first, second, third and fourth positions; first valve means selectively operable in response to movement of said inner member between said third and fourth positions and said second position; second valve means selectively operable in response to movement of said inner members between said second position and said first position; and position-establishing means operatively coupling said telescoped members and including a sleeve member between said telescoped members and rotatably supported by said outer member, a first shoulder fixed on said inner member, means on said sleeve member defining a second shoulder thereon adapted for engagement by said first shoulder only when said shoulders are angularly aligned to halt said inner member in said third position as well as defining clearances on opposite sides of said second shoulder respectively adapted to pass said first shoulder whenever said shoulders are angularly misaligned and as said inner member is moved between said fourth and second positions, an inwardly-projecting guide member on said sleeve member, groove means on said inner member receiving said guide member for movement therein and responsive to successive reciprocating movements of said inner member for aligning said first and second shoulders to bring said shoulders into engagement and halt said inner member in said third position only on alternate reciprocations of said inner member and for aligning said first shoulder and one or the other of said clearances only on intervening reciprocations of said inner member to enable said inner member to move between said second and said fourth positions, abutment means on said outer member, and stop means releasably coupled to said inner member adapted to engage said abutment means and halt said inner member in said second position only on said intervening reciprocations of said inner member, said stop means being releasable from said inner member upon

rotation thereof to free said inner member for movement from said second position to said first position.

**27.** The well tool of claim **26** further including: clutch means co-rotatively securing said telescoped members whenever said inner member is in said third position and releasable whenever said inner member is in said second position.

**28.** The well tool of claim **27** further including: second clutch means co-rotatively securing said telescoped members only whenever said inner member is in said first position.



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U.S. Cl. X.R.

166—150, 226, 240