Nov. 28, 1967 D. E. YOUNG 3,354,964

WELL BORE PACKING APPARATUS

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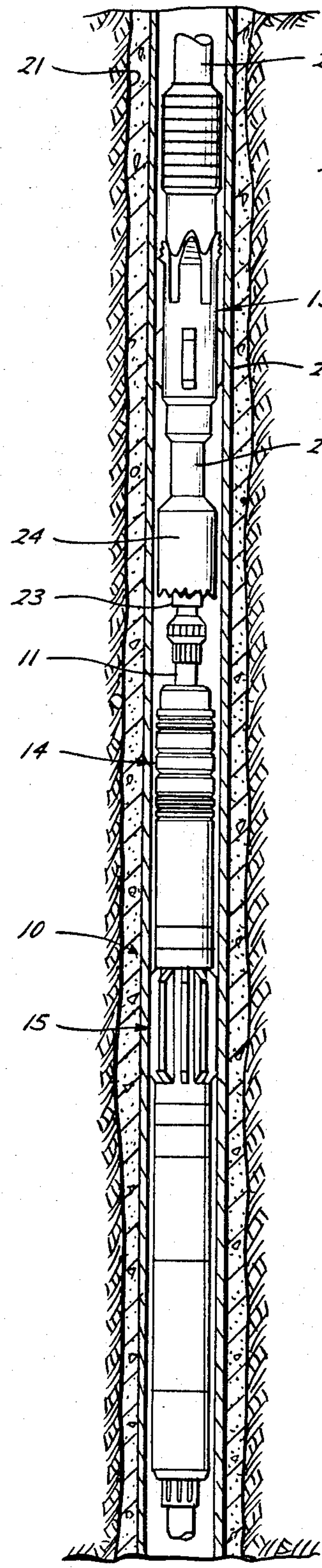
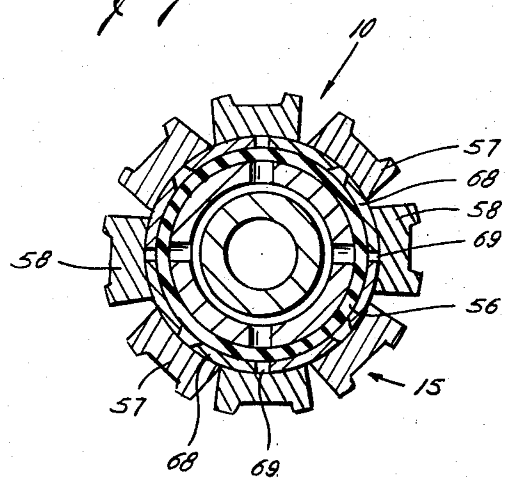


Fig. 1

Fig. 3



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WELL BORE PACKING APPARATUS

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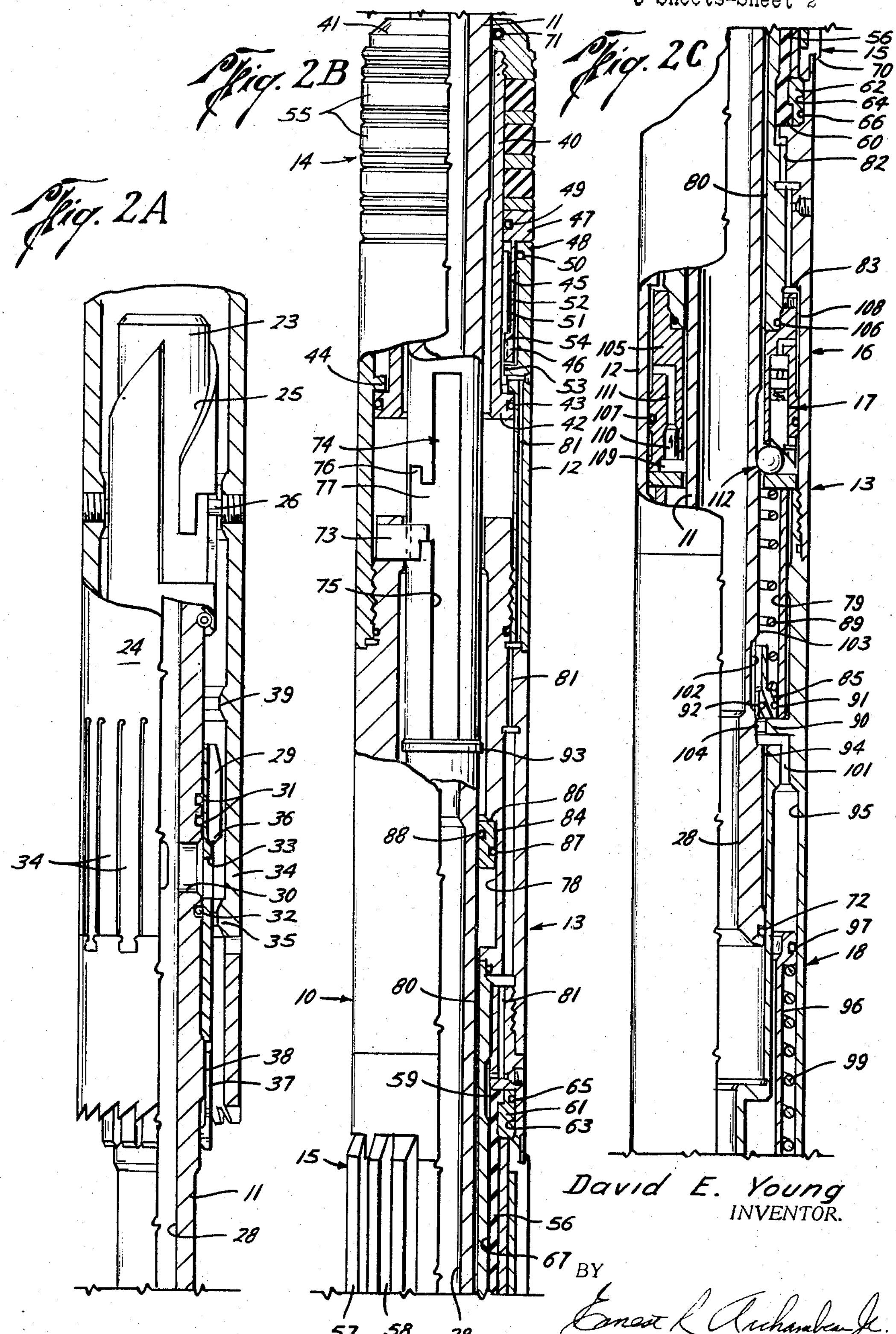

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Fig. 4A

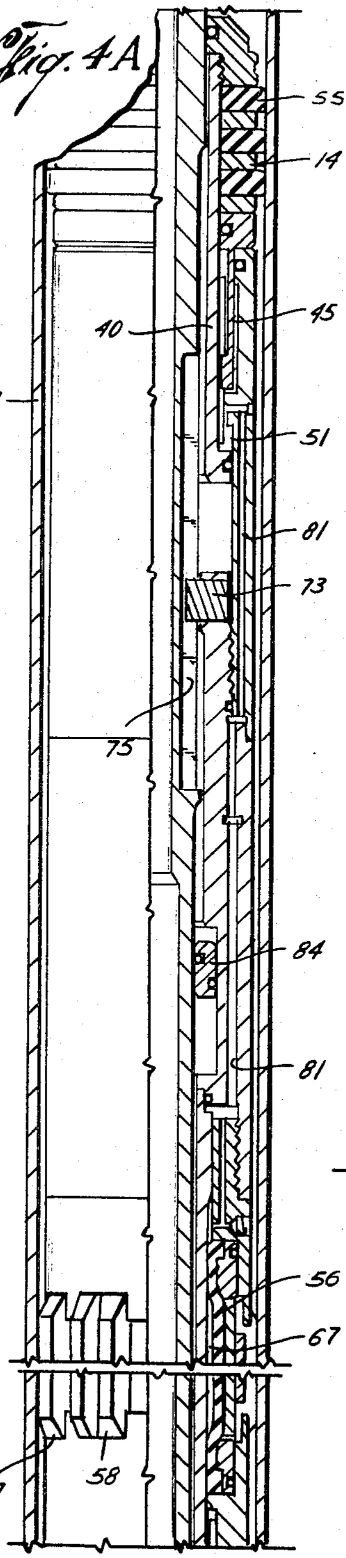

Fig. 4B

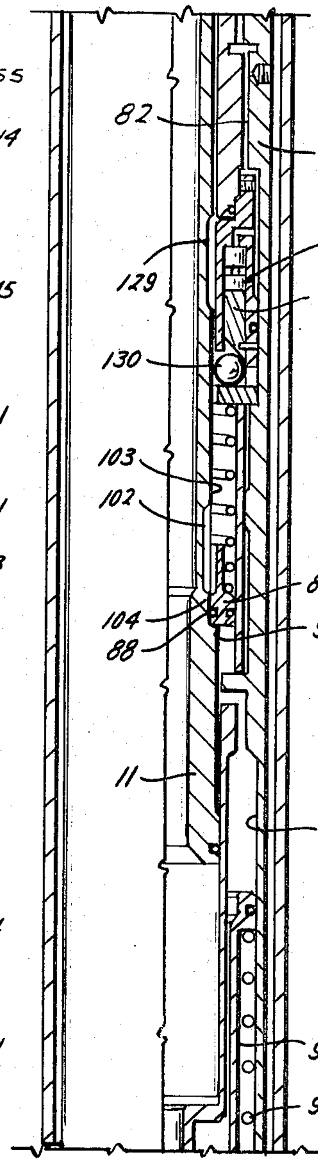

Fig. 4C

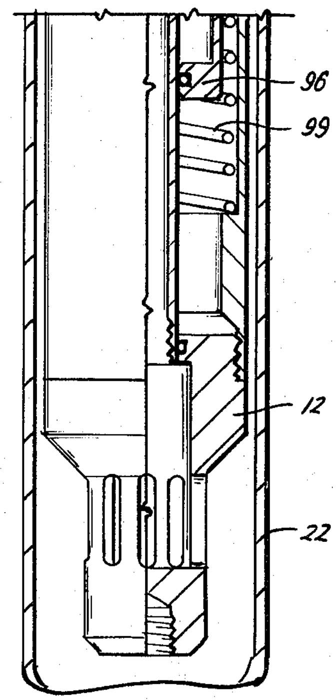

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Fig. 2D

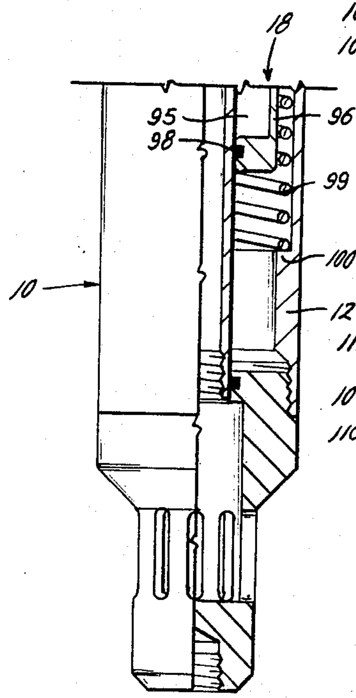


Fig. 5

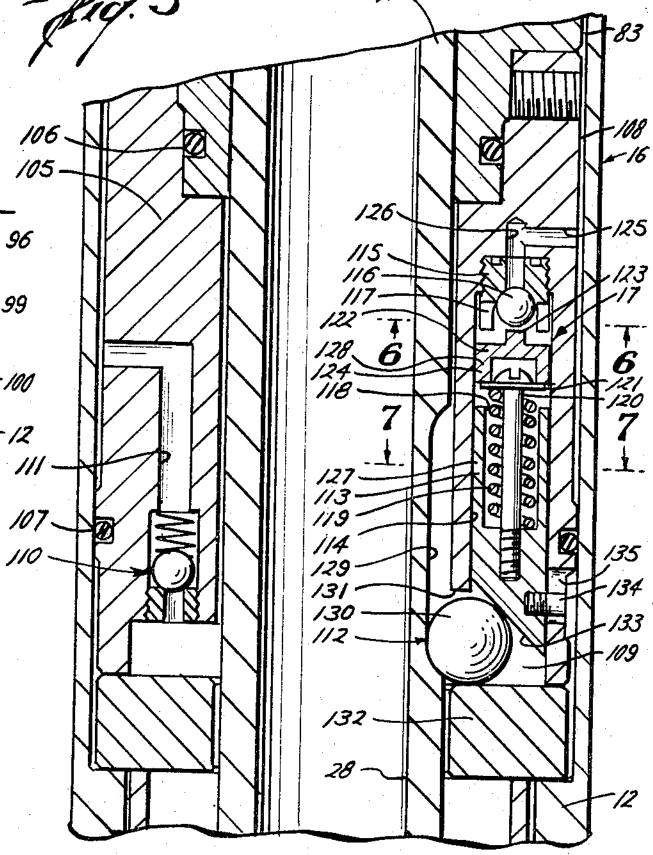


Fig. 7

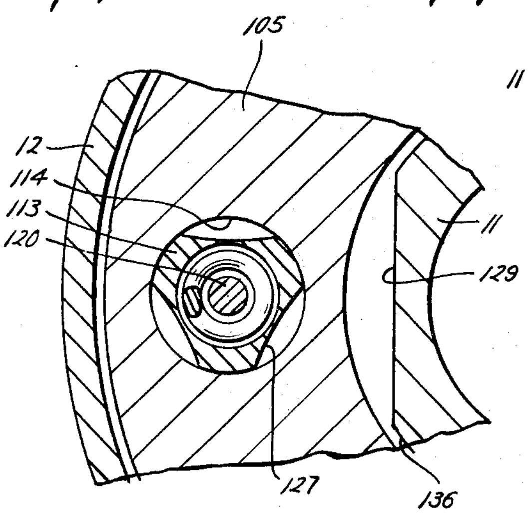
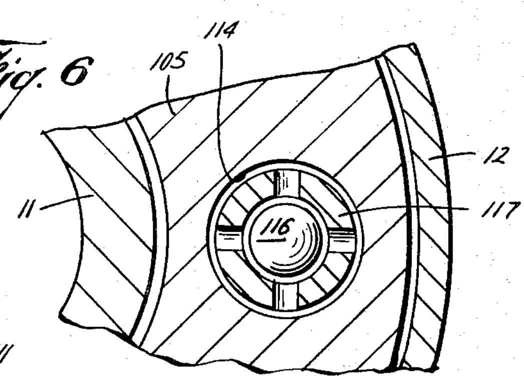


Fig. 6



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WELL BORE PACKING APPARATUS

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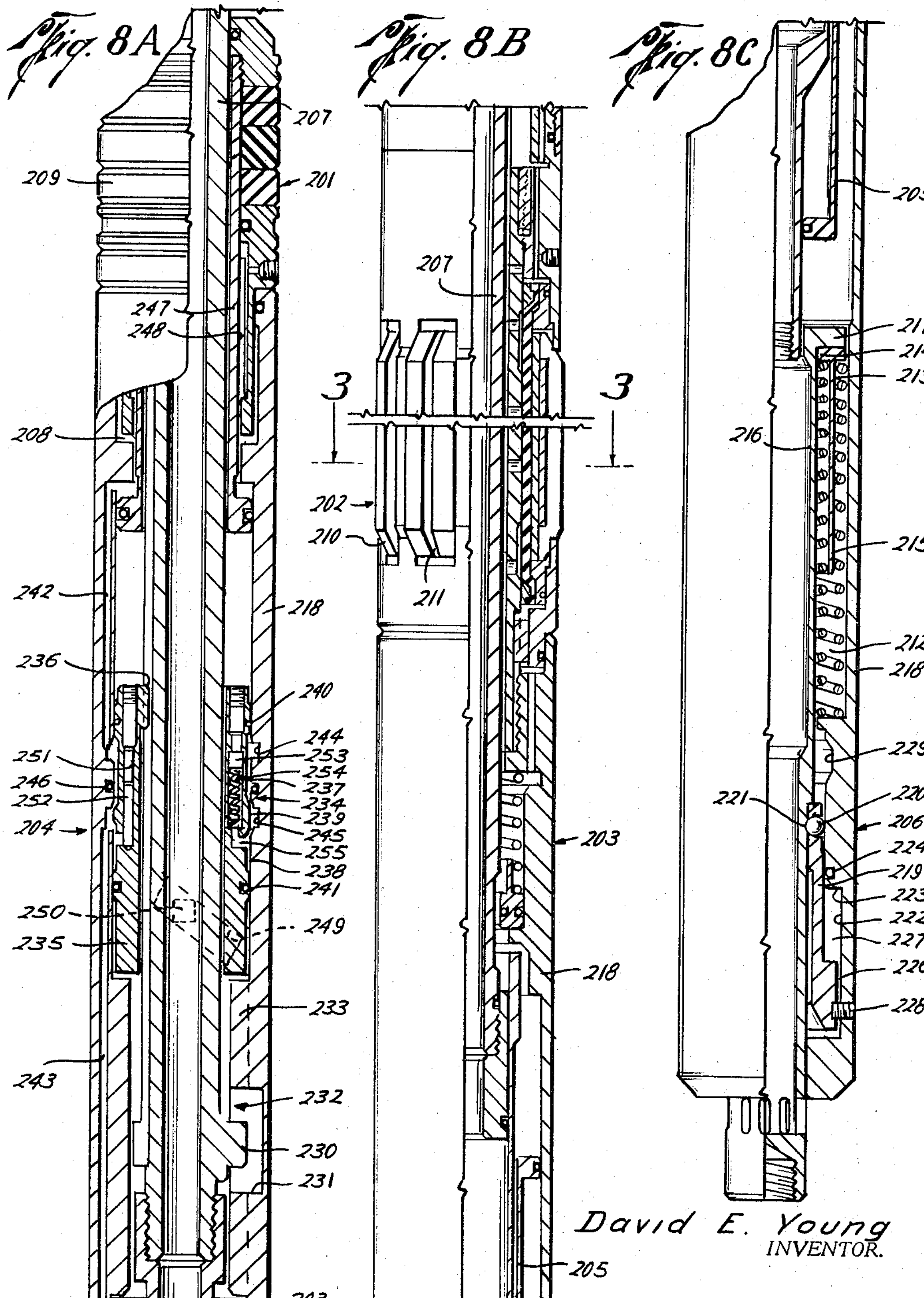

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3,354,964

WELL BORE PACKING APPARATUS

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Filed Dec. 10, 1965, Ser. No. 512,858

15 Claims. (Cl. 166—120)

This invention relates to apparatus for packing off a well bore; and, more particularly, to packing apparatus which, when set in place, will be anchored and sealingly engaged in the well against pressure differentials acting from either direction on the apparatus by forces proportionately related to the acting pressure differentials.

In conducting such well completion operations as acidizing, cementing, or fracturing, full-opening well packer dependently coupled from a tubing string is positioned at a particular depth in a cased well and the packer set to isolate the formation interval to be treated from the remainder of the well bore thereabove. Treating fluids are then pumped downwardly at high pressure through the tubing and packer and introduced into the formation being treated through perforations appropriately located in the casing.

In those instances where a well having several producing formations is being completed, a selectively operable bridge plug is usually dependently coupled beneath the full-opening packer. Such a bridge plug permits intervals of selected length to be packed-off for selective treatment of different formation zones with only a single trip into the well. It will be appreciated that during the course of such completion operations, these packing apparatus are usually subjected to high fluid pressures acting alternately from both above and below them. Thus, these packers and bridge plugs must be firmly sealed and securely anchored against pressure differentials acting in either longitudinal direction.

Accordingly, it is an object of the present invention to provide new and improved packing apparatus having hydraulically actuated packing means and wall-engaging anchoring members which are respectively maintained in sealing and anchoring engagement by forces proportionately related to pressure differentials between fluids in the well above and below the apparatus.

Packing apparatus arranged in accordance with the invention includes hydraulic means that are selectively operable for initially setting the packing element and anchoring the apparatus in the well bore with predetermined engaging forces and, thereafter, respond to pressure differentials across the packing apparatus to maintain the packing element and wall-engaging means in engagement with forces that are proportionately related to these differentials.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of 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:

FIG. 1 is a view of a full-bore packer and a bridge plug of the present invention and depicted as they would appear within a well bore;

FIGS. 2A–2D are successive, detailed cross-sectional views of one embodiment of a bridge plug having hydraulically actuated packing means and anchoring means in accordance with the present invention;

FIG. 3 is a cross-sectional view taken along the lines 3—3 of FIGS. 2B and 8B;

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FIGS. 4A–4C are successive views similar to FIGS. 2B–2D but depicting the bridge plug as it will appear when set within a well bore;

FIG. 5 is an enlarged view of the control means of the present invention;

FIGS. 6 and 7 are cross-sectional views taken respectively along the lines 6—6 and 7—7 in FIG. 5; and

FIGS. 8A–8C are views of an alternate embodiment of a bridge plug employing the principles of the present invention.

In general, the retrievable bridge plug **10** of the present invention is comprised of an actuating mandrel **11** that is telescoped within a tubular housing **12** and selectively movable therein between an intermediate neutral position (FIG. 2) and an operative position (FIG. 4) in which the mandrel is free to shift a limited distance either upwardly or downwardly relative to the housing. Pressure-developing means **13** are included which, as the mandrel **11** shifts relative to the housing **12**, will develop sufficient pressure to extend pressure-responsive packing means **14** and anchoring means **15** outwardly into firm engagement with an adjacent wall in a well bore. Control means **16**, including valve means **17** which are selectively operated by movement of the mandrel **11** into and out of an operative position, are provided to regulate the hydraulic pressure applied to the packing means **14** and anchoring means **15** to insure that they remain firmly engaged irrespective of further shifting of the mandrel until it is returned to its neutral position. Other pressure-developing means **18** are employed to develop a sufficient initial pressure to urge the anchoring means **15** against the well bore wall with sufficient force to secure the housing **12** for moving of the mandrel **11** relative thereto.

Since those skilled in the art will recognize that such a well tool is typically comprised of separate tubular elements threadedly connected to one another to facilitate its manufacture and assembly, the drawings have been somewhat simplified by showing some of these separate elements as a single member for purposes of greater clarity.

Turning now to FIG. 1, a typical full-bore packer **19** is dependently connected to a tubing string **20** and positioned within a well bore **21** having a casing **22** set therein. A retrievable bridge plug **10** arranged in accordance with the present invention is releasably coupled by a fishing neck **23** to an overshot **24** dependently connected beneath the packer **19**.

Matched J-slots **25** (FIG. 2A) are arranged on opposite sides of the fishing neck **23** to cooperatively receive inwardly projecting lugs **26** on the overshot **24** whenever it is lowered over the fishing neck. After the lugs **26** have entered the open upper end of the long portion of the J-slots **25**, the lugs are lockingly engaged in the closed short portion of the J-slots by a concerted application of counter-clockwise torque and a slight upward pull on the tubing string **20**. Conversely, the overshot **24** is selectively disengaged from the fishing neck **23** by lowering the tubing string **20** slightly, torquing it to the right, and then pulling upwardly. By employing such a releasable coupling, the bridge plug **10** can be set at the lower limit of a particular formation interval and the packer **19** uncoupled and subsequently set thereabove irrespective of the length of the tubing sub **27** connecting them.

Fluid communication through the mandrel bore **28** is selectively controlled by an annular valve member **29** which is slidably disposed around the mandrel **11** immediately around lateral bypass ports **30** therein and fluidly sealed thereto by O-rings **31** and **32** straddling the bypass ports. Lateral ports **33** are appropriately arranged in the slidable valve member **29** to register with the bypass ports **30** whenever the valve member is in the position illustrated in FIG. 2. The slidable valve member **29** is arranged to be shifted longitudinally by the overshot **24** so that the ports **30** and **33** are brought into register as the overshot is being engaged over the fishing neck **23** (FIG. 2A) and the bypass ports are covered by the valve member whenever the overshot is removed.

Whenever the overshot **24** is being removed, a group of dependent resilient fingers **34** spaced around the lower portion of the overshot have inwardly projecting shoulders **35** that engage a shoulder **36** on the sliding valve member **29** to pull it upwardly and close the bypass ports **30**. As the valve member **29** is pulled upwardly, depending resilient fingers **37** around the lower end of the valve member are cammed outwardly as they pass over an annular shoulder **38** around the mandrel **11**. After clearing the mandrel shoulder **38**, the lower ends of these fingers **37** then engage the annular shoulder to hold the slidable valve member **29** in its uppermost or port-closed position (not shown) after the overshot **24** has been removed. A shoulder **39** projecting inwardly from the central portion of the overshot **24** engages the valve member **29** and shifts it downwardly to its open position (FIG. 2A) whenever the overshot is coupled to the fishing neck **23**.

As seen in FIG. 2B, the pressure-responsive packing means **14** include a slidable sleeve member **40** having an outwardly enlarged upped end **41** and an outwardly enlarged lower end **42** that is telescopically fitted within the upper portion of the tubular housing **12** and fluidly-sealed thereto by an O-ring **43** below an inwardly projecting housing shoulder **44**. A shorter slidable sleeve member **45** is telescopically arranged around the central portion of the other setting sleeve **40** and has a lower end **46** extending into the housing **12** above the housing shoulder **44** and a projecting, outwardly enlarged upper end **47** that is shouldered on the upper housing end **48** and fluidly sealed to the inner sleeve by an O-ring **49**. An O-ring **50** in the upper housing end **48** fluidly seals the shorter outer setting sleeve **45** to the housing **12** and defines an enclosed space **51** between the setting sleeves **40** and **45** and the other O-rings **43** and **49**. An elongated external spline **52** extending longitudinally along the inner setting sleeve **40** is cooperatively received within complementary internal grooves **53** and **54** in the housing shoulder **44** and shorter outer sleeve **45** to co-rotatively secure the three members to one another and limit their relative movement to longitudinal telescopic travel.

Elastomeric packing means **14**, such as a plurality of stacked annular elements **55** mounted around the exposed portion of the inner sleeve, are arranged between the outwardly enlarged upper ends **41** and **47** of the sleeves **40** and **45** to be foreshortened thereby and expanded outwardly whenever the setting sleeves are relatively telescoped together. Conversely, longitudinal movement in the opposite direction of the sleeve ends **41** and **47** as the setting sleeves **40** and **45** expand allow the packing rings **55** to relax and return to their normal position.

Thus, it will be appreciated that, upon application of sufficient hydraulic pressure in the enclosed space **51**, the setting sleeves **40** and **45** will be telescoped. As the setting sleeves **40** and **45** contract, the elastomeric elements **55** will be foreshortened and expanded radially outwardly against the casing wall. By oppropriately selecting elements **55** having a particular elasticity and dimensions suitable for a given range of casing diameters, it can be readily determined that, for a given hydraulic pressure in the enclosed space **51**, the elements will be urged against the casing **22** with a force proportionately related to this hydraulic pressure. Accordingly, those skilled in the art will understand that by applying at least a predetermined hydraulic pressure in the enclosed space **51**, the elastomeric elements **55** will be sealingly engaged against the casing **22** with a force sufficient to withstand well bore pressure differentials up to a particular magnitude.

Mounted around the central portion of the housing **12** is the hydraulically actuated, radially expansible anchor **15** (FIGS. 2B–2C), with parts thereof as also shown in cross-section in FIG. 3. This anchor **15** includes an expansible elastomeric sleeve **56** encircling the central portion of the housing **12** with a plurality of elongated wall-engaging members **57** and **58** being longitudinally mounted uniformly around the periphery of the sleeve. The enlarged upper and lower ends **59** and **60** of the elastomeric sleeve **56** are secured by slidable annular retainers **61** and **62** within opposed peripheral recesses **63** and **64** around the housing **12**. O-rings **65** and **66** around the retainers **61** and **62** fluidly seal the sleeve ends **59** and **60** within the recesses **63** and **64** to provide a fluid-tight space **67** between the sleeve **56** and housing **12**.

Each of the casing-engaging members **57** and **58** is elongated and has a thick, arcuate cross-section(FIG. 3). Alternate ones of the casing-engaging members are centrally aligned and mounted on the outer convex surface of relatively thin, elongated, arcuate backing members **68**. A sufficient number of these mounted members **57** are disposed around the periphery of the elastomeric sleeve **56** that the backing members **68** substantially encompass the sleeve. The remaining casing-engaging members **58** are unmounted and alternately disposed between the mounted casing-engaging members **57** in such a manner that the unmounted members **58** straddle adjacent backing members **68** and cover the gaps **69** therebetween.

The ends of the casing-engaging members **57** and **58** are beveled, as at **70** (FIG. 2C), for reception within the opposed annular housing recesses **63** and **64**. It will be appreciated that, although the casing-engaging members **57** and **58** will move radially outwardly whenever the elastomeric sleeve **56** is inflated, the beveled ends of the members cannot escape from the housing recesses **63** and **64**.

By applying hydraulic pressure within the fluid-tight space **67**, the casing-engaging members **57** and **58** will be urged against the casing with a force proportionately related to this pressure. Thus, by appropriately selecting the materials and contact surface areas for causing-engaging members **57** and **58**, it can be readily determined that a particular hydraulic pressure in the fluid-tight space **67** will secure the bridge plug **10** against longitudinal shifting by pressure differentials in the well up to a particular magnitude.

The actuating mandrel **11** is movably disposed through the inner setting sleeve **40** and extends on downwardly into the housing **12**. O-rings **71** and **72** at each end of the mandrel **11** respectively fluidly seal the mandrel to the inner sleeve **40** and lower end of the housing **12**. To establish the longitudinal position of the mandrel **11** relative to the housing **12**, an outwardly projecting lug **73** on the mandrel is confined within an inwardly directed T-shaped slot **74** formed in the inner wall of the housing. As shown in FIG. 2B, the T-slot **74** has an elongated portion **75** extending longitudinally along the housing **12** and a shorter longitudinal portion **76** spaced apart therefrom and connected thereto by a transverse portion **77** extending between the centers of the longitudinal slot portions.

As will be seen from FIG. 2, so long as the mandrel lug **73** is confined in the shorter slot portion **76**, the mandrel **11** is substantially restrained from moving longitudinally relative to the housing **12**. However, by rotating the mandrel **11** in a clockwise direction to bring the lug **73** through the transverse slot portion **77** into the elongated slot portion **75**, the mandrel is then free to shift longitudinally relative to the housing **12** a distance determined by the length of the elongated slot portion.

Turning now to the pressure-developing means **13** for the bridge plug **10**, the housing **12** is formed in such a manner as to provide an annular chamber **78** (FIG. 2B) above the upper end of the anchor **15**. A similar annular chamber **79** (FIG. 2C) is also formed below the lower end of the anchor **15**. An annular clearance space **80** between the mandrel 11 and housing 12 provides fluid communication from the upper chamber 78 to the lower chamber 79. A longitudinal passage 81 through the housing 12 provides fluid communication from the fluid-tight space 67 under the elastomeric sleeve 56 to the enclosed space 51 between the setting sleeves 40 and 45. Similarly, another passage 82 through the housing 12 provides fluid communication from the fluid-tight space 67 to a valve chamber 83 below the elastomeric sleeve 56. Thus, the passages 81 and 82 interconnect the enclosed space 51 and fluid-tight space 67 to the valve chamber 83. Filling ports with closure members (not all shown) are provided at appropriate locations for introducing a suitable hydraulic fluid into the hydraulic system.

The upper end of the upper annular chamber 78 and the lower end of the lower annular chamber 79 are respectively closed by annular piston members 84 and 85 which are slidably mounted relative to both the housing 12 and mandrel 11. The upper slidable piston member 84 (FIG. 2B) is adapted to engage a downwardly directed shoulder 86 formed in the housing 12 at the upper end of the upper chamber 78. Annular grooves around the outer and inner surfaces, respectively, of the upper piston member receive O-rings 87 and 88 which fluidly seal the slidable piston member 84 relative to the housing 12 as well as to the mandrel 11.

The lower slidable piston member 85 (FIG. 2C) is biased downwardly by a spring 89 so that the lower piston member normally rests against an upwardly directed shoulder 90 formed in the housing 12 at the lower end of the lower chamber 79. Similarly, external and internal annular grooves around the piston member 85 receive O-rings 91 and 92 to fluidly seal the slidable piston member relative to both the housing 12 and the mandrel 11.

A shoulder 93 (FIG. 2B) located on the mandrel 11 a short distance above the upper slidable piston 84 is so arranged that whenever the mandrel shifts downwardly, the shoulder will engage the upper piston and force it downwardly. Similarly, a second shoulder 94 (FIG. 2C) is provided on the mandrel 11 to engage and shift the lower piston member 85 upwardly whenever the mandrel shifts in that direction. It will be appreciated, therefore, that with a suitable fluid in the above-described hydraulic system, longitudinal shifting of the mandrel 11 in either direction will develop a uniform pressure throughout the system that is related to the distance that the mandrel shifts. Thus, as previously described, this developed hydraulic pressure is employed to telescope the setting sleeves 40 and 45 for expanding the packing elements 55 and to press the casing-engaging members 57 and 58 against the casing 22.

The other pressure-developing means 18 include an annular compensating chamber 95 (FIGS. 2C–2D) that is formed in the housing 12 beneath the lower piston member 85 to maintain a supply of fluid in the hydraulic system as well as to compensate for thermal expansion of the hydraulic fluid. The lower end of this annular chamber 95 is closed by a slidable annular compensating piston member 96 having O-rings 97 and 98 around its outer and inner surfaces which fluidly seal the compensating piston relative to the housing 12. Means, such as a spring 99 engaged between the compensating piston 96 and an upwardly facing housing shoulder 100, are provided to accommodate thermal expansion of the hydraulic fluid as well as to bias the compensating piston against the hydraulic fluid.

Selectively controlled fluid communication is provided between the compensating chamber 95 and the remainder of the hydraulic system through a housing passage 101 and an annular clearance space formed by a reduced-diameter portion 102 around the mandrel 11. This reduced-diameter portion 102 is arranged to be normally in juxaposition with the lower piston 85 whenever the mandrel 11 is in its intermediate neutral position as determined by the mandrel lug 73 being confined within the shorter slot 74. When, however, the mandrel 11 has been so manipulated to shift the lug 73 into the longer slot 75 and the mandrel is shifted longitudinally only a slight distance in either direction, the inner O-ring 92 within the lower piston member 85 fluidly seals the piston to the mandrel at either 103 or 104 depending upon the direction in which the mandrel has been shifted.

Accordingly, it will be seen that so long as the mandrel 11 is in a "neutral" or intermediate position (as determined by the lug 73 being within the short slot 76), the mandrel is substantially restrained from shifting longitudinally in either direction and the upper and lower piston members 84 and 85 will be substantially in the positions illustrated in FIG. 2 with the mandrel shoulders 93 and 94 separated therefrom. When the mandrel 11 is in the above-mentioned intermediate position, the reduced-diameter mandrel portion 102 will permit free communication of hydraulic fluid from the compensating chamber 95 into the remainder of the hydraulic system above the lower piston 85. This communication will allow the fluid in the hydraulic system to expand as its temperature increases during a descent into a well bore. It will be recognized, of course, that when hydraulic pressure is to be developed in the system by shifting either piston 84 or piston 85, it is best to close the communication through portion 102 to the compensating chamber 95. Thus, by closing communication to the compensating chamber 95 as the mandrel 11 is first shifted, less travel of the mandrel is required to develop an effective hydraulic pressure.

When the bridge plug 10 is being set, it will be apparent that as the mandrel lug 73 is being shifted within its T-slot 74, means must be provided to hold the housing 12 fixed relative to the mandrel 11. Moreover, after the bridge plug 10 has been set, the housing 12 must remain anchored to the casing 22 with at least a minimum holding force whenever the mandrel 11 is not sufficiently displaced to coact with one of the pistons 84 and 85 or is shifting through its intermediate position to one of its other positions. Although conventional spring-biased drag blocks could be successfully employed for this purpose, it is preferred to instead select a spring or springs, as at 99, that have an effective spring rate to bias the compensating piston 96 with sufficient force to develop a slight hydraulic pressure in the hydraulic system.

By developing a predetermined hydraulic pressure in the system in this manner, the casing-engaging members 57 and 58 will be urged against the casing 22 with sufficient holding force to permit movement of the mandrel 11 relative to the housing 12 but without unduly limiting the positioning of the bridge plug 10. Moreover, once the casing-engaging members 57 and 58 are extended against the casing 22, it will be appreciated that subsequent shifting of the mandrel 11 will be immediately effective to develop additional hydraulic pressure since the elastomeric sleeve 56 will already be inflated.

It will, of course, be recognized that since the well bore pressure is acting against both the compensating piston 96 and elastomeric sleeve 56, the pressure in the hydraulic system will be equal to the sum of the well bore pressure plus the pressure developed by the spring 99. Thus, the spring rate of the spring 99 will directly determine the force with which the casing-engaging members 57 and 58 are urged against the casing 22. It will be further understood that the pressure developed in the hydraulic system by the action of the spring 99 against the compensating piston 96 is not sufficent to significantly foreshorten the packing elements 55. Accordingly, as the bridge plug 10 is being moved into position within the well bore 21, the anchoring means 15 will serve as drag blocks but the packing means 14 will remain substantially retracted.

When the bridge plug 10 is to be set in a well, the mandrel 11 is appropriately manipulated by the tubing string 20 to shift the mandrel lug 73 into the elongated slot portion **75** of the T-slot **74**. Once the mandrel lug **73** is in the longer slot portion **75**, the mandrel **11** is free to shift either upwardly or downwadrly to engage either the lower piston **85** or upper piston **84** and develop a hydraulic pressure in the system for actuating the pressure-responsive anchor means **15** and packing means **14**. Thus, once the mandrel **11** is lowered or elevated, the bridge plug **10** will be firmly anchored and sealingly packed-off.

It will be appreciated, however, that unless the mandrel **11** remains in one of its displaced positions, the developed hydraulic pressure will vary as the mandrel shifts relative to the housing **12**. Thus, for example, after the overshot **24** is released from the fishing neck **23**, the mandrel **11** will assume a position (within the limits established by the length of the slot portion **75**) that will be dictated by the magnitude and direction of whatever, if any, pressure differential there may be across the bridge plug **10**. Thus, with a low pressure differential, there will be a proportionately low pressure developed in the hydraulic system.

Although the effective holding force to be applied by the anchor means **15** need not be any greater than that developed by the shifting of the mandrel **11** in response to any given pressure differential, it will be realized that to maintain an effective seal with the packing elements **55** they must be held firmly engaged against the casing **22**. Accordingly, the bridge plug **10** includes control means **16** for selectively regulating the hydraulic pressure being applied to the pressure-responsive means **14** and **15** whereby the applied pressure will be maintained even though the developed pressure decreases but will still be increased upon further increases of the developed pressure. Moreover, it will be recognized that until the pressure-developing means **13** have been actuated to set the packing means **14** and firmly engage the anchoring means **15**, the control means **16** must communicate the slight pressure developed in the compensating chamber **95** to the anchoring means to secure the housing **12** for movement of the mandrel **11** relative thereto.

To accomplish these purposes, an annular valve body **105** is disposed in the valve chamber **83** below the anchoring means **15** and fluidly sealed therein to the housing **12** by O-rings **106** and **107**. In this manner, the valve chamber **83** is divided into an outer sealed space **108** and an inner sealed space **109**. The outer sealed space **108** is connected to the anchoring means **15** by the housing passage **82** and also to the enclosed space **51** between the setting sleeve **40** and **45** by way of the fluid-tight space **67** under the elastomeric sleeve **56** and the housing passage **81**. As shown, this inner sealed space **109** within the valve body **105** may be a continuation of the annular clearance **80** communicating the upper and lower chambers **78** and **79** of the pressure-developing means **13**. Thus, it will be appreicated that the valve body **105** isolates the pressure-responsive means **14** and **15** from the pressure-developing means **13**.

Accordingly, to provide selective fluid communication from the pressure-developing means **13** to the pressure-responsive means **14** and **15**, a conventional spring-biased unidirectional check valve **110** is disposed in a longitudinal passage **111** through one side of the valve body **105** between the inner and outer sealed spaces **108** and **109**. By selecting a check valve **110** that will open under a slight pressure differential and appropriately arranging it in the passage **111**, substantially unrestricted fluid communication is provided from the pressure-developing means **13** to the pressure-responsive means **14** and **15**. On the other hand, the check valve **110** will prevent fluid communication from the pressure-responsive means **14** and **15** back to the pressure-developing means **13**. Thus, before the bridge plug **10** is set, whatever hydraulic pressure that is developed by the compensating piston **96** will be readily transmitted from the compensating chamber **95** to the anchoring means **15** by way of the check valve **110** and its associated fluid passage **111**.

As previously mentioned, when the bridge plug **10** is to be set, the mandrel **11** is rotated to shift the lug **73** from the shorter slot portion **76** to the longer portion **75** of the T-slot **74**. Once the mandrel lug **73** is in the longer slot portion **75**, the mandrel **11** is then shifted (by the tubing string **20**) in either longitudinal direction relative to the housing **12** to develop a substantial hydraulic pressure sufficient for expanding the elastomeric packing elements **55** outwardly into sealing engagement with the casing **22** and firmly engaging the anchoring means **15**. This increased hydraulic pressure is, of course, readily transmitted through the check valve **110**.

Once, however, such an increased hydraulic pressure is applied in the enclosed spaces **51** and **67** between the setting sleeves **40** and **45** and under the elastomeric sleeve **56**, the check valve **110** will prevent loss of this pressure through the passage **111** regardless of any subsequent decrease in developed hydraulic pressure as will occur, for example, when the mandrel **11** approaches the center of its span of travel. It should also be noted that should the pressure-developing means **13** subsequently develop a higher hydraulic pressure than that already trapped within the enclosed spaces **51** and **67**, the check valve **110** will, of course, re-open to admit this higher pressure into these enclosed spaces.

It will be appreciated, however, that to retrieve the bridge plug **10**, the hydraulic pressure in the fluid-tight spaces **67** and **51** beneath the elastomeric sleeve **56** and between the setting sleeves **40** and **45** must be relieved to retract the pressure-responsive means **14** and **15**. Moreover, as the bridge plug **10** is being positioned in a well bore, it will be recalled that the casing-engaging members **57** and **58** will be maintained against the casing **22** by the operation of the compensating piston **96**.

Thus, should the bridge plug **10** move from one joint of casing **22** to another of slightly larger diameter, the spring **99** will shift the compensating piston **96** upwardly enough to keep the casing-engaging members **57** and **58** against the casing. If further movement of the bridge plug **10** carries it into yet another joint of casing **22** of a smaller diameter, the casing-engaging members **57** and **58** must retract slightly to accommodate the smaller diameter and this retraction will increase the pressure in the hydraulic system unless the fluid in the fluid-tight space **67** can return freely to the compensating chamber **95**. It will be recognized that the check valve **110** will not permit such return communication through the passage **111**.

Accordingly, the control means **16** of the present invention includes valve means **17** that are selectively operable between one condition of operation to permit substantially unrestricted return fluid communication from the pressure-responsive means **14** and **15** back to the compensating chamber **95** and another condition of operation where such return communication is regulated. To accomplish such selective operation, actuating means **112** are provided which respond to movement of the mandrel **11** as the lug **73** is shifted from the shorter slot portion **76** to the longer slot portion **75**.

As best seen in FIG. 5, the valve means **17** includes a slidable actuator **113** that is disposed in a longitudinal bore **114** through the valve body **105** and arranged to slide therein between spaced longitudinal positions as shown in FIGS. 2 and 4. An annular valve seat **115** is fluidly sealed in the longitudinal bore **114** and adapted to receive a movable valve member, such as a ball **116**, in the bore therebelow between the valve seat and actuator **113**. To maintain the ball **116** in operative relation to the valve seat **115**, a conventional cage **117** is disposed in the bore **114** to loosely retain the ball in alignment with the actuator **113**.

The upper portion of the actuator **113** is coaxially counterbored, as at **118**, to partially receive a compression spring **119** that projects upwardly a short distance thereabove. A retainer, such as a removable screw **120**, is coaxially mounted in the actuator bore **118** and extended through the spring **119**. To maintain the spring **119** in compression, a washer **121** is loosely fitted around the screw shank below the screw head and engaged on the top of the spring. Thus, by suitably selecting the various dimensions of the related elements, the spring **119** will normally be held in compression between the bottom of the bore **118** and the underside of the washer **121**. By threading or unthreading the screw **120**, the force applied against the washer **121** may be varied to suit a particular operating condition as will subsequently become apparent.

A slidable follower **122** having a coaxially aligned upright extension **123** and a hollowed, downwardly extending skirt **124** is slidably disposed in the longitudinal bore **114** below the ball **116**. The follower extension **123** is adapted to pass into the ball cage **117** and engage the ball **116**. The follower skirt **124** is suitably proportioned to rest on the exposed portion of the washer **121** extending beyond the head of the screw **120** so that the screw head can pass into the hollowed skirt without engaging the follower **122**.

A transverse passage **125** through the body **105** provides fluid communication between a longitudinal bore **126** above the seat **115** and the outer sealed space **108** around the valve body. Likewise, to facilitate fluid communication through the longitudinal bore **114** between the inner sealed space **109** and valve seat **115**, bypass means, such as longitudinal flutes **127** and **128** (FIGS. 6 and 7) formed around the actuator **113** and follower **124**, are provided.

To actuate the valve means **17**, a flat transverse cam surface **129** is formed along a chord across the mandrel **11** adjacent to the valve body **105** and a cam, such as a ball **130**, is loosely fitted in an opening **131** through the valve body adjacent to the flat surface. An annular member **132** below the valve body **105** retains the ball **130** in position. The lower end of the actuator **113** is skewed to provide a beveled transverse cam surface **133** that is tangentially engaged by the ball **130**. By aligning the cam surfaces **129** and **133** along intersecting transverse planes, when the ball **130** is shifted radially outwardly by rotation of the mandrel **11**, the actuator **113** is shifted longitudinally upwardly. To maintain the skewed surface **133** against the ball **130** and in proper orientation to the mandrel surface **129**, a radial pin **134** in the actuator **113** is loosely fitted within a longitudinal slot **135** along one surface of the longitudinal bore **114**.

By aligning the mandrel flat **129** and actuator skewed surface **133** in proper relation to the mandrel lug **73** and T-slot **74**, it will be appreciated that when the mandrel lug is in the shorter slot portion **76**, the ball **130** will be displaced inwardly and resting on the mandrel flat to allow the actuator **113** to assume its lowered position as shown in FIG. 2. Conversely, as the mandrel lug **73** is shifted into the longer slot portion **75**, the mandrel flat **129** will be rotated from under the ball **130** and the ball will be cammed radially outwardly as the full-diameter mandrel surface, as at **136** (FIGS. 5 and 7), is rotated under the ball. Thus, it will be recognized by comparison of FIGS. 2 and 4 that in this latter mandrel position, the outward camming of the ball **130** against the skewed cam surface **133** will in turn shift the actuator **113** longitudinally upwardly.

Accordingly, by appropriately arranging the pertinent dimensions of the various elements of the valve means **17**, the follower extension **123** will engage the check ball **116** and urge it against the valve seat **115**. As the ball **116** is urged against its seat **115**, the follower skirt **124** will shift the washer **121** downwardly against the force of the spring **119** and away from the underside of the head of the screw **120**. Thus, the full force of the spring **119** will be urging the check ball **116** into seating engagement with the valve seat **115**. It will be recognized, of course, that this will require a pressure differential tending to open the check ball **116** to reach a particular magnitude commensurate with the spring force before the check ball will be unseated.

It will be understood, however, that although the spring **119** need not be normally held in compression by the engagement of the washer **121** against the head of the screw **120**, it is preferred to "pre-load" the spring to insure that a spring force of at least a predetermined magnitude is imposed against the check ball **116** when it is seated. By compensating for manufacturing tolerance in this manner, the force required to unseat the check ball **116** will be whatever preloaded force is given to the spring **119** plus whatever slight additional spring force is developed whenever the spring is further compressed as the check ball is unseated.

Thus, it will be seen that the control means **16** serves to regulate the hydraulic pressure applied to the pressure-responsive means **14** and **15**. When the bridge plug **10** is in its retracted position (FIG. 2), the pressure-developing means **13** is deactivated and only whatever hydraulic pressure is developed by the compensating pressure-developing means **18** will be admitted through the reduced-diameter mandrel portion **102** and check valve **110** (and quite possibly the ball valve **116**) to the pressure-responsive means **14** and **15**. In this situation, as already discussed, the compensating spring **99** and piston **96** are capable of developing a hydraulic pressure sufficient only to urge the casing-engaging members **57** and **58** outwardly with a moderate holding force. This moderate holding force will suffice to secure the housing **12** to the casing **22** to permit the movement of the mandrel **11** relative thereto. Any increase of hydraulic pressure in the space **67** under the elastomeric sleeve **56** (as developed by inward movement of the casing-engaging members **57** and **58**) will be relieved through the valve seat **115** and around the ball valve **116** to the compensating chamber **95**.

Then, whenever the mandrel **11** is rotated to shift the mandrel lug **73** into the elongated slot portion **75**, the follower ball **130** will be cammed outwardly to urge the actuator **113** upwardly to urge the ball valve **116** against its seat **115**. With the fluid communication closed through the valve seat **115**, only the check valve **110** will open as the mandrel **11** shifts to actuate the pressure-developing means **13**. Since the check valve **110** will function only to admit a higher developed hydraulic pressure to the pressure-responsive means **14** and **15**, the packing elements **55** and casing-engaging members **57** and **58** will be extended against the casing **22** with a force proportional to the pressure developed by the pressure-developing means **13**. Accordingly, the pressure-responsive means **14** and **15** will be firmly engaged against the casing **22** as the bridge plug **10** is set.

After the bridge plug **10** is set, it will be recognized that the hydraulic pressure applied to the pressure-responsive means **14** and **15** will always be maintained at a high magnitude. Should the hydraulic pressure within the pressure-developing means **13** decrease sufficiently, the ball valve **116** will open to relieve the pressure applied to the pressure-responsive means **14** and **15** to some predetermined magnitude greater than that in the pressure-developing means as determined by the force applied by the spring **119**. Then, the ball valve **116** will again close. Any increase of developed pressure, however, will be admitted through the check valve **110** to the pressure-responsive means **14** and **15**.

When the bridge plug **10** is to be retrieved, it is necessary only to return the mandrel lug **73** to the shorter slot portion **76**. As the mandrel **11** is rotated, the follower ball **130** is again re-engaged on the mandrel flat **129** to allow the actuator **113** to return to its lower position. As the actuator **113** returns, the valve means **17** will open to again equalize the pressure in the hydraulic system. Thus, the pressure-responsive means **14** and **15** will retract and the bridge plug **10** can be retrieved.

It is also of special significance to the present invention that the packing means 14 are settable without further hydraulic pressure being developed by action of the pressure differential in the well bore on the packing elements 55 or setting sleeves 40 and 45 themselves. For example, assume that there was no outer setting sleeve 45 on the present bridge plug 10 and the lower packing elements 55 merely rested on top of the upper housing end 48. In such an instance, a well bore pressure differential acting upwardly across the bridge plug 10 would tend to build up hydraulic pressure within the enclosed space 51. Such a pressure would be trapped in this space 51 and, if it were not for the valve means 17, could quite possibly develop a hydraulic pressure sufficient to burst the housing 12 or cause failure of an O-ring, as at 43, for example. Other conventional setting sleeves are similarly susceptible to such hazards.

The present invention avoids such hazards, however, by arranging the setting sleeves 40 and 45 to telescope within one another and to be separated by a rigid stop as provided by the housing shoulder 44. It will be recognized that this unique arrangement prevents such a hazard from arising. Thus, should there be an increased pressure differential from above the set bridge plug 10, the inner setting sleeve 40 will be depressed and further foreshorten the packing elements 55. This downward shifting of the setting sleeve 40, however, will not cause an increase in the hydraulic pressure in the enclosed space 51 since movement of the lower piston end 42 of the setting sleeve will increase the volume of the enclosed space. The downward travel of the mandrel 11 in response to this increased pressure differential will shift the upper piston 84 sufficiently to develop an increased hydraulic pressure in the enclosed space 51 that is proportionately related to the differential. The outer setting sleeve 45 cannot shift downwardly since it will be stopped by the upper housing end 48. It will be noted that an increased pressure differential from below the set bridge plug 10 will have a similar action on the outer setting sleeve 45, with the housing shoulder 44 serving as a stop for the inner setting sleeve 40.

When the bridge plug 10 has been positioned at the depth at which it is to be set, it is halted and an upward strain is taken on the tubing string 20 as it is rotated to the right. This concerted application of tension with clockwise torque will bring the mandrel lug 73 into alignment with and then shift it through the transverse slot portion 77 into the elongated slot portion 75 of the T-slot 74.

Once the mandrel lug 73 is shifted into the elongated slot portion 75, the mandrel 11 is free to be shifted the full limit permitted by the slot portion 75. Accordingly, by shifting the tubing string 20 either upwardly or downwardly, the pressure-developing means 13 will be employed as already described to develop a sufficient hydraulic pressure for setting the bridge plug 10.

Then, as the hydraulic pressure is increased, the elastomeric packing elements 55 will be foreshortened by the setting sleeves 40 and 45 and thereby expanded into sealing engagement with the casing 22. Similarly, as the hydraulic pressure is developed, the casing-engaging members 57 and 58 will be urged against the casing 22 to anchor the bridge plug 10 securely. Once the packing means 14 and anchoring means 15 are engaged, the overshot 24 is removed from the fishing neck 23. As the overshot 24 is removed, the valve member 29 is pulled upwardly thereby to close the bypass ports 30 and the central bore 28 through the mandrel 11.

It will be recognized, of course, that after the overshot 24 has been disengaged from the fishing neck 23, the mandrel 11 is free to shift longitudinally within the limits determined by the length of the longitudinal housing slot 75. Any pressure differential across the packing elements 55 will also act on the mandrel 11. Should the pressure in the well bore 21 above the bridge plug 10 be greater than the pressure below, the pressure differential will act to shift the mandrel 11 downwardly. Downward shifting of the mandrel 11 will cause the shoulder 93 to drive the upper slidable piston member 84 downwardly, which action will result in increasing the hydraulic pressure within the system to press the casing-engaging members 57 and 58 of the anchor 15 against the well casing 22 with a force proportionately related to the pressure differential across the bridge plug 10.

Should, perchance, the pressure in the well bore 21 below the bridge plug 10 become greater than the pressure thereabove, the mandrel 11 will be shifted upwardly. As the mandrel 11 shifts upwardly, the hydraulic pressure will be momentarily reduced as the upper piston member 84 returns to its initial position against housing shoulder 86. Moreover, as the reduced-diameter mandrel portion 102 passes upwardly relative to O-ring 92 within the lower piston 85, there will be a momentary resumption of fluid communication between the hydraulic system and the compensating chamber 95. At this point, however, the check valve 110 and valve means 17 will maintain the pressure within that portion of the hydraulic system thereabove at a sufficient magnitude to keep the packing elements 55 and wall-engaging members 57 and 58 firmly secured against the casing 22. Then, as the mandrel 11 continues to travel upwardly, the reduced-diameter mandrel portion 102 will move upwardly relative to the lower piston 85 which will then itself be shifted upwardly by the lower mandrel shoulder 94. Should the mandrel 11 continue its upward movement a sufficient distance, hydraulic pressure will again be increased within the fluid-filled hydraulic system to again urge the packing elements 55 and casing-engaging members 57 and 58 against the casing 22 with a greater force that is proportionately related to the pressure differential across the bridge plug 10.

It must be emphasized, however, that regardless of the shifting of the mandrel 11, the ball valve 116 will remain in the position shown in FIG. 5 and the check valve 110 will function to trap whatever pressure is needed to maintain the casing-engaging members 57 and 58 and packing elements 55 firmly engaged with the casing 22. Thus, even as the mandrel 11 shifts to its central position, the packing means 14 will maintain sealing engagement with the casing 22. Moreover, should pressure differentials in the well require a greater sealing engagement with the casing 22, the check valve 110 will function to admit into the enclosed spaces 51 and 67 any higher hydraulic pressures developed as the mandrel 11 is shifted by such pressure differentials.

To release the bridge plug 10, it is necessary only to re-engage the overshot 24, the equalizing valve member 29 is again shifted downwardly to bring ports 33 therein into registry with mandrel ports 30. With the fluid pressure equalized across the retrievable bridge plug 10, the mandrel 11 is shifted to its intermediate position and torqued to the left to return the mandrel lug 73 through the transverse slot portion 77 into the shorter slot portion 76.

It will be appreciated that as the mandrel lug 73 is being rotated through the slot portion 77, the valve actuator 113 will be returned downwardly (by the spring 119) to re-establish direct communication between the enclosed and fluid-tight spaces 51 and 67 and the balance of the hydraulic system. Moreover, with the mandrel 11 again in its intermediate "neutral" position, the compensating chamber 95 will also again be in communication (by way of reduced mandrel portion 102) with the hydraulic system. Thus, the pressure in the system will now drop to what it was before the bridge plug 10 was set and the packing means 14 and anchoring means 15 will return to their retracted position.

It will be understood, of course, that once it is retracted and as the retrievable bridge plug 10 is being shifted, the compensating spring 99 will remain engaged with the compensating piston **96**. Thus, the wall-engaging members **57** and **58** will still be held against the casing **22** with the predetermined holding force as previously described. Thus, should it be desired to position the bridge plug **10** at a different depth without first removing it from the well bore, it is only necessary to halt the bridge plug at the desired position and repeat the above-described setting operation. Then, when it is desired to finally retrieve the bridge plug, it is necessary only to repeat the above-described retrieving operation and remove the bridge plug **10** from the well bore **21**.

Turning now to FIG. 8, an alternate embodiment is shown of a bridge plug **200** incorporating the features of the present invention. Comparison of the bridge plug **200** with the one already described will show that this alternate embodiment has pressure-responsive packing means **201** and anchoring means **202** as well as pressure developing means **203** arranged in the same manner. Moreover, since the equalizing valve (not shown) is identical to that one (at **29**) already described, it has been omitted.

The principal distinctions, therefore, between the bridge plugs **10** and **200** are that, in the latter, control means **204** are placed in the hydraulic system between the packing means **201** and anchoring means **202** and that the compensating piston **205** is releasably secured by latch means **206**. As will be subsequently described in greater detail, isolation of the packing means **201** from the anchoring means **202** by the control means **204** will allow the hydraulic pressure applied to the anchoring means to vary in relation to the shifting of the mandrel **207**. The control means **204** will, however, maintain the hydraulic pressure in the enclosed space **208** at a magnitude sufficient to hold the packing elements **209** sealingly engaged in the same manner as the previously described control means **17**.

With the separation of the pressure-responsive means **201** and **202**, it will be recognized that the casing-engaging members **210** and **211** must be urged against the casing with more residual holding force than in the bridge plug **10** of FIG. 2 since there will be situations of a slight pressure differential that could displace the bridge plug **200** without shifting the mandrel **207** sufficiently to develop a greater hydraulic pressure. Thus, in the bridge plug **200**, one or more compensating springs **212** are somewhat stouter than the spring **99** so as to urge the compensating piston **205** with more force and develop a greater initial or minimum holding force.

Although this approach shown in FIG. 8 is generally successful, it has been found difficult in some instances to shift a bridge plug **200** arranged in this manner downwardly in the well bore before it has reached a depth where the tubing string has sufficient weight to overcome the above-mentioned holding force. Inasmuch as the minimum required holding force may well be in the order of a few thousand pounds, it will be recognized that, in some instances, several hundreds of feet of tubing will be required before the weight of the assembled tubing string will freely shift the bridge plug **200** downwardly.

Accordingly, the bridge plug **200** includes means for initially removing the spring bias from the compensating piston **205** until such time that the bridge plug has reached a substantial depth in the well bore. To accomplish this, the upper end of the springs **212** are preferably confined within a follower sleeve **213** having an inwardly directed shoulder **214** and a depending skirt **215** to keep the individual springs concentrically positioned. A retainer sleeve **216** having an outwardly directed shoulder **217** is extended through the springs **212**, with the shoulder **217** being normally disposed a short distance below the compensating piston **205** and engaged on top of the follower sleeve shoulder **214**. Selectively operable latch means **206** are employed to releasably secure the retainer sleeve **216** to the housing **218** for temporarily depressing the springs **212** away from the compensating piston **205**.

In the arrangement of the latch means **206** depicted in FIG. 8C, the lower end of the retainer sleeve **216** is telescoped into the upper end of a slidable locking sleeve **219**. A plurality of detents, such as balls **220** loosely mounted in the locking sleeve **219** and partially extending into a complementary annular recess **221** in the retainer sleeve **216**, releasably connect the retainer sleeve to the locking sleeve. The lower end of the locking sleeve **219** is enlarged so as to define an enclosed space **222** between the sleeve end and the inwardly directed housing shoulder **223** thereabove. An O-ring **224** in the housing shoulder **223** fluidly seals the upper portion of the locking sleeve **219** to the housing **218**.

At the lower end **225** of the locking sleeve, a slight clearance is left to provide a predetermined annular space **226** between the sleeve **219** and housing **218** so that a viscous fluid **227**, such as grease or the like, may be confined within the enclosed space **222** therebetween. A screw **228** through the housing **218** secures the locking sleeve so that, as seen in FIG. 8, so long as the sleeve **219** is in its lowermost position, the locking balls **220** will be a short distance below an enlarged recess **229** in the inner wall of the housing shoulder **223**.

It will be appreciated, therefore, that so long as the locking balls **220** remain in the retainer sleeve recess **221**, the retainer sleeve **216** will remain connected to and be held down by the locking sleeve **219** and screw **228** to the housing **218** against the upwardly directed force of the springs **212**. Thus, so long as the springs **212** are prevented from shifting the follower sleeve **213** against the compensating piston **205**, no pressure will be developed thereby in the hydraulic system.

Accordingly, in the operation of the bridge plug **200**, the screw **228** is removed a short time before the bridge plug is introduced into the casing. Once the screw **228** is removed, the springs **212** will begin urging the follower and retainer sleeves **213** and **216** upwardly. However, by appropirately selecting the viscous fluid **227** and sizing the annular clearance **226** with respect to the spring rate of springs **212**, it will require a measureable time period for a sufficient volume of the fluid to be displaced through the clearance **226** and allow the locking sleeve **219** to shift upwardly where the balls **220** can enter the housing recess **229**. Then, when the balls **220** enter the housing recess **229**, the retainer sleeve **216** will be disconnected from the locking sleeve **219** and be free to move further upwardly with the follower sleeve **213** to engage the compensating piston **205**. Once the compensating piston **205** is biased by the springs **212**, the hydraulic pressure developed thereby will be effective to frictionally engage the casing-engaging members **210** and **211** with the casing as in the bridge plug **10** previously described with respect to FIG. 2.

The control means **204** in the bridge plug **200** is similar in many respects to the control means **16** already described. It differs primarily, however, in that in the control means **204**, there is free communication throughout the hydraulic system in either direction so long as the mandrel lug **230** is retained in the shorter portion **231** of the T-slot **232**. Then, once the mandrel **207** is rotated to shift the lug **230** into the longer slot portion **233**, the control means **204** will function to permit free communication from the pressure-developing means **203** to the packing means **201** but regulate communication in the reverse direction. With the control means **204** functioning in this latter manner, an equalizing or relief valve **234** (somewhat similar to that already described at **17**) will function to relieve any excessive pressure differential between the enclosed space **208** and the pressure-developing means **203**.

To accomplish this, an annular valve member **235** is slidably disposed within the housing **218** and co-rotatively secured to the mandrel **207** by a complementary longitudinal spline and groove, as at 236. Longitudinally spaced reduced-diameter portions 237 and 238 are formed around the valve member 235 to leave an intermediate full-diameter portion 239 and provide clearance between the valve member and inner wall of the housing 218. O-rings 240 and 241 above and below the reduced-diameter portions 237 and 238 fluidly seal the valve member 235 to the housing 218.

The adjacent ends of longitudinal housing passages 242 and 243 are terminated in longitudinally spaced, inwardly opening annular recesses 244 and 245 formed adjacent to one another in the internal wall of the housing 218. An O-ring 246 in the internal wall of the housing 218 between the recesses 244 and 245 is arranged to engage the intermediate full-diameter portion 239 of the valve member 235 whenever this portion is opposite the O-ring 246.

Thus, it will be appreciated that, when the valve member 235 is so positioned that the O-ring 246 is engaged with the intermediate full-diameter portion 239 of the valve member, the reduced-diameter portions 237 and 238 will be respectively opposite the housing recesses 244 and 245 and the O-ring 246 will block direct fluid communication therebetween. Conversely, by longitudinally shifting the valve member 235 slightly downwardly with respect to the housing 218 to the position shown, the intermediate full-diameter valve member portion 239 will be displaced from sealing engagement with the O-ring 246 and direct fluid communication will be established between the housing recesses 244 and 245 by way of, for example, the reduced-diameter valve member portion 237. In either position of the valve member 235, the O-rings 240 and 241 at its opposite ends will straddle the housing recesses 244 and 245 and remain in sealing engagement with the inner wall of the housing 218.

It will be appreciated, therefore, that the valve member 235 will selectively open and close fluid communication through the housing passages 242 and 243 depending upon its longitudinal position relative to the housing 218. Thus, with the valve member 235 displaced slightly downwardly (as seen in FIG. 8) and its intermediate full-diameter portion 239 out of sealing engagement with the O-ring 246, there will be fluid communication from the pressure-developing means 203 to the enclosed space 208 between the setting sleeves 247 and 248 of the packing means 201. On the other hand, when the valve member 235 is elevated therefrom, fluid communication exterior of the valve member is blocked by the sealing engagement of O-ring 246 with the intermediate valve member portion 239.

To control this longitudinal position of the valve member 235, an inclined slot 249 is formed in the exterior of the valve member and receives an inwardly projecting housing lug 250. Accordingly, as the mandrel 207 is rotated to shift the mandrel lug 230 from the shorter slot portion 231 into the longer slot portion 233, the splined connection at 236 will rotate the valve member 235 as well. By properly arranging the inclination of the slot 249, the camming action of the housing lug 250 will shift the valve member 235 upwardly along the mandrel 207 into its elevated position. It will be recognized, of course, that the slots 232 and 249 must be so arranged relative to one another that the rotation of the mandrel 207 necessary to shift the lug 230 from one slot portion 231 to the other portion 233 will be sufficient to simultaneously elevate the valve member 235 to the desired position.

Thus, it will be understood that with the mandrel 207 in its intermediate position, there is full communication between the pressure-responsive packing means 201 and the pressure-developing means 203. With the mandrel lug 230 in the longer slot portion 233, however, this fluid communication is blocked irrespective of the longitudinal position of the mandrel 207. To provide selective control of fluid communication to and from the packing means 201, bypass means, such as a conventional spring-biased unidirectional check valve 251 disposed in an interconnecting passage 252 through the valve member 235 between the reduced portions 237 and 238, are provided. Thus, with the check valve 251 correctly oriented, when the valve member 235 is cammed upwardly into its elevated position, hydraulic fluid can move from the passage 243 to the passage 242 by way of the check valve 251 and bypass passage 252 and to the packing means 201. Flow in the reverse direction is prevented, however, by the check valve 251 as well as by the sealing engagement of the O-ring 246 with the full-diameter valve member portion 239.

It will be recognized that means should be provided as in bridge plug 10 for limiting the magnitude of hydraulic pressure retained in the enclosed space 208 between the setting sleeves 247 and 248. To accomplish this, a check valve 253 is disposed in the valve member 235 and arranged with a sufficiently strong spring 254 to open under a predetermined hydraulic pressure differential between the enclosed space 208 and pressure-developing means 203. By providing a relief passage 255 between the reduced portions 237 and 238 of the valve member 235, the relief valve 253 and spring 254 will function to relieve any excessive hydraulic pressure differential between the packing means 201 and pressure-developing means 203. Here again, however, this relief valve 253 will not limit the application of even extreme hydraulic pressures to the packing means 201. It will function only to relieve such extreme pressures whenever the hydraulic pressure in the pressure-developing means 203 decreases to the predetermined difference in pressures.

Accordingly, it will be appreciated that the present invention provides unique controls for hydraulically actuated well tools as well as for setting an expansible packing element. By providing a well tool with selectively operable control means arranged in accordance with the present invention, the tool is given substantially more flexibility in that the mandrel is movable in one manner to operate valve means; but, in another position, the mandrel is free to move without also actuating the valve means. Thus, by employing the control means of the present invention with a hydraulically actuated well packing apparatus having separately movable anchoring and packing elements, selective actuation of these elements is now possible.

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.

I claim:

1. A well tool sized and adapted for reception in a well bore comprising: a tubular housing; a body movably disposed within said housing and arranged for movement therein between an inactive position and an active position; pressure-responsive means movably mounted on said housing and movable relative thereto in response to a hydraulic pressure; means responsive to movement of said body toward its said active position for developing a hydraulic pressure sufficient to move said pressure-responsive means; first control means including first passage means interconnecting said pressure-developing means and pressure-responsive means and first valve means in said first passage means for admitting hydraulic pressure into said pressure-responsive means but preventing release of hydraulic pressure therefrom; and second control means including second passage means interconnecting said pressure-developing means and pressure-responsive means, second valve means in said second passage means, and actuating means between said second valve means and body responsive to movement of said body out of said active position for closing said

second valve means and responsive to movement of said body into said inactive position for opening said second valve means to release hydraulic pressure from said pressure-responsive means.

2. A well tool sized and adapted for reception in a well bore comprising: a tubular housing; pressure-responsive packing means including a member having a piston portion telescoped within one end of said housing and fluidly sealed thereto and an exposed portion including abutment means spaced from said housing end, a sleeve telescoped around an intermediate portion of said member, annular expansible packing element around said member and between said abutment means and sleeve, and means fluidly sealing said sleeve to said housing and member for defining an enclosed space between said sealing means and piston portion; a mandrel movably disposed within said housing and arranged for movement therein between spaced positions; pressure-developing means including piston means fluidly sealed within said housing and slidable in response to movement of said mandrel toward one of its said positions for developing an increased hydraulic pressure; and passage means interconnecting said pressure-developing means and said enclosed space.

3. A well tool sized and adapted for reception in a well bore comprising: a tubular housing; a mandrel telescopically disposed within said housing and arranged for movement therein from an inactive position to longitudinally-spaced active positions; pressure-responsive packing means on said housing and movable relative thereto from a retracted position to an extended position upon application of hydraulic pressure thereto; means including piston means fluidly sealed within said housing and slidable in response to movement of said mandrel toward a first one of its said active positions for developing a hydraulic pressure sufficient to extend said packing means; first control means including first passage means interconnecting said pressure-developing means and packing means and first valve means in said first passage means for admitting hydraulic pressure to said packing means but preventing release of hydraulic pressure therefrom; and second control means including second passage means interconnecting said pressure-developing means and packing means, second valve means in said second passage means, and actuating means between said second valve means and mandrel responsive to movement of said mandrel toward said first active position for closing said second valve means and responsive to movement of said mandrel into said inactive position for opening said second valve means to release hydraulic pressure from said packing means.

4. The well tool of claim 3 further including second piston means fluidly sealed in said housing and slidable in response to movement of said mandrel toward a second one of its said active positions for developing a hydraulic pressure sufficient to extend said packing means, and wherein said actuating means are responsive to movement of said mandrel toward either of said first and second said active positions for closing said second valve means and responsive to movement of said mandrel into said active position for opening said second valve means to release hydraulic pressure from said packing means.

5. The well tool of claim 3 wherein said pressure-responsive packing means include a member having a piston portion telescoped within one end of said housing and fluidly sealed thereto and an exposed portion including abutment means spaced from said housing end, a sleeve telescoped around an intermediate portion of said member, an annular expansible packing element around said member and between said abutment means and sleeve, and means fluidly sealing said sleeve to said housing and member for defining an enclosed space between said sealing means and piston portion into which said passage means connect.

6. The well tool of claim 3 wherein said second valve means includes a valve seat, a valve member movable into and out of seating engagement with said valve seat; and said actuating means is aligned with said valve member and valve seat and adapted to engage and shift said valve member into seating engagement with said valve seat, cam means between said actuating means and mandrel for shifting said actuating means toward said valve member in response to movement of said mandrel toward said active positions and freeing said actuating means for movement away from said valve member; and biasing means normally urging said actuating means away from said valve member.

7. The well tool of claim 6 wherein said actuating means includes first and second members aligned with said valve member and valve seat, said first member having one portion adjacent to and adapted to engage and shift said valve member into seating engagement with said valve seat and another portion extending toward said second member, said second member having one portion with an enlarged portion extending toward said first member and a reduced portion between said enlarged portion and the remainder of said second member, and a retainer loosely disposed around said reduced portion adapted to engage said other portion of said first member; and wherein said biasing means includes a spring member between said retainer and said remainder of said second member.

8. The well tool of claim 3 further including pressure-responsive anchoring means on said housing and movable relative thereto from a retracted position to an extended position upon application of hydraulic pressure thereto; and third passage means interconnecting said anchoring means to said other passage means.

9. The well tool of claim 8 further including second piston means fluidly sealed in said housing and slidable in response to movement of said mandrel toward a second one of its said active positions for developing a hydraulic pressure sufficient to extend said packing means and anchoring means, and wherein said actuating means are responsive to movement of said mandrel toward either of said first and second active positions for closing said second valve means and responsive to movement of said mandrel into said active position for opening said second valve means to release hydraulic pressure from said packing means and anchoring means.

10. The well tool of claim 9 wherein said third passage means are connected to said other passage means between said valve means and said pressure-developing means.

11. The well tool of claim 9 wherein said third passage means are connected to said other passage means between said valve means and said packing means.

12. The well tool of claim 9 wherein said pressure-responsive packing means include a member having a piston portion telescoped within one end of said housing and fluidly sealed thereto and an exposed portion including abutment means spaced from said housing end, a sleeve telescoped around an intermediate portion of said member, annular expansible packing means around said member and between said abutment means and sleeve, and means fluidly sealing said sleeve to said housing and member for defining an enclosed space between said sealing means and piston portion into which said passage means connect.

13. The well tool of claim 9 wherein said inactive position is intermediate of said first and second active positions, said piston means are first and second annular piston members respectively slidably disposed around and fluidly sealed to said mandrel; and further including first and second spaced opposed means on said mandrel adapted to engage and shift their associated piston members as said mandrel respectively moves toward either of said first and second active positions.

14. The well tool of claim 13 further including means coupling said mandrel to said housing for securing said

mandrel in said second position in one angular position relative to said housing and for freeing said mandrel for longitudinal shifting between said first and third positions in other angular positions relative to said housing.

15. The well tool of claim **14** wherein said pressure-responsive packing means include a member having a piston portion telescoped within one end of said housing and fluidly sealed thereto and an exposed portion including abutment means spaced from said housing end, a sleeve telescoped around an intermediate portion of said member, annular expansible packing means around said member and between said abutment means and sleeve, and means fluidly sealing said sleeve to said housing and member for defining an enclosed space between said sealing means and piston portion into which said passage means connect.

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