Oct. 9, 1962 P. PATTERSON ETAL 3,057,406

CONTROL APPARATUS FOR USE IN WELLS

Filed March 28, 1958 2 Sheets-Sheet 1

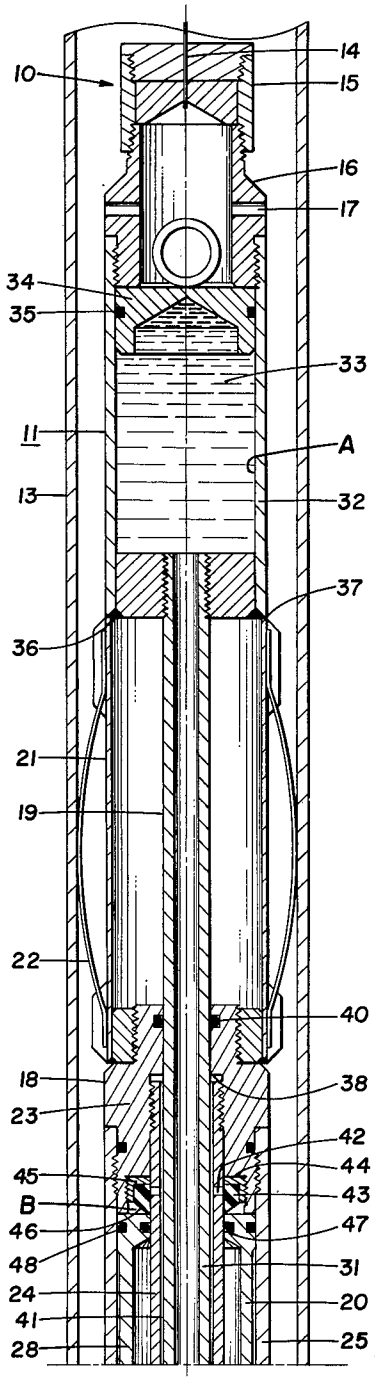


FIG. 1.

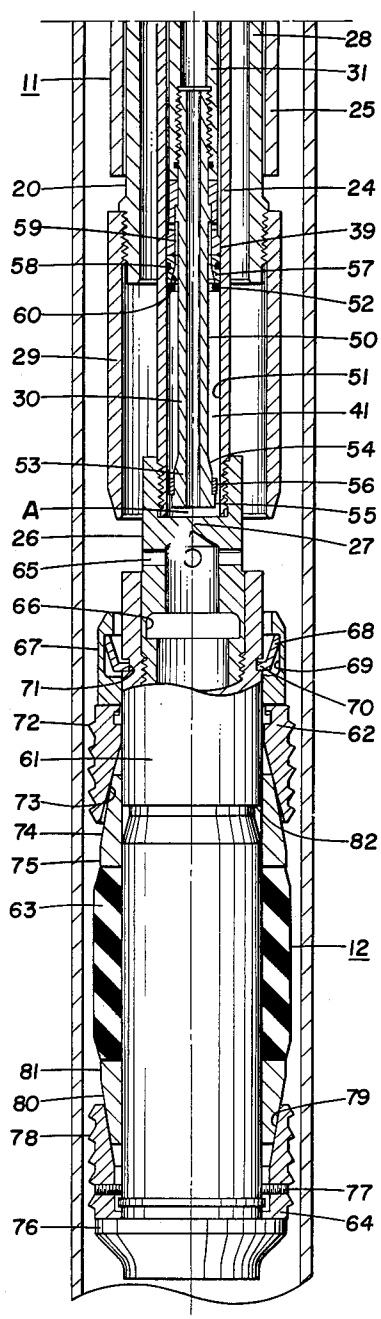


FIG. 1a.

INVENTORS
Pat Patterson
Alonzo E. Cummins
BY William L. Jones
ATTORNEY

Oct. 9, 1962 P. PATTERSON ETAL 3,057,406

CONTROL APPARATUS FOR USE IN WELLS

Filed March 28, 1958 2 Sheets-Sheet 2

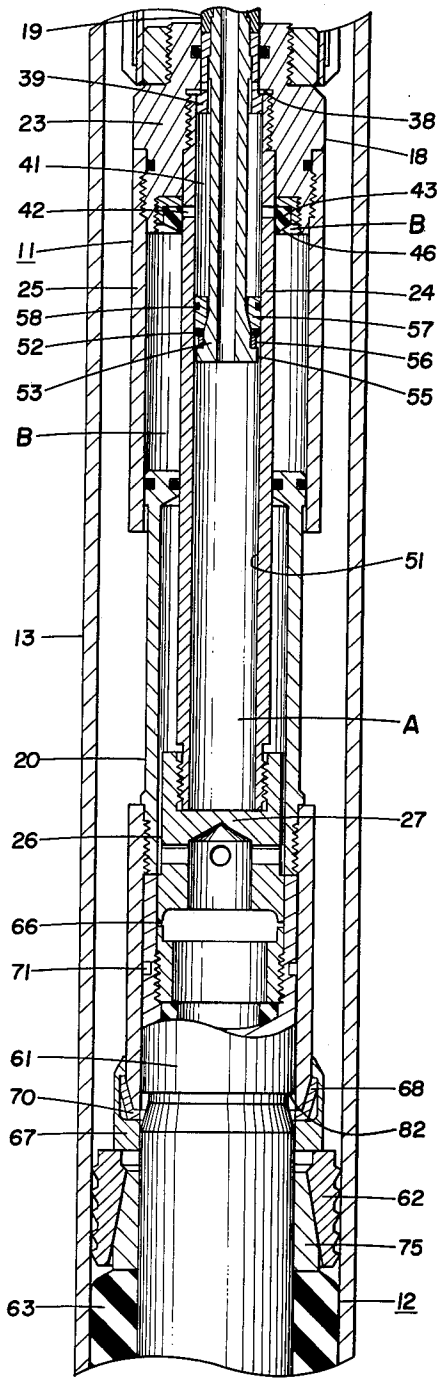


FIG. 3

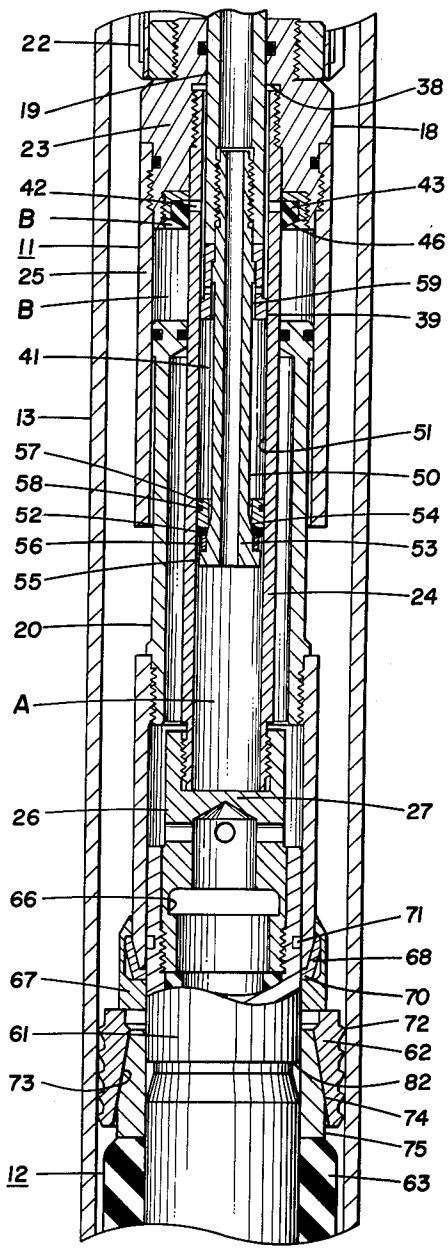


FIG. 2

INVENTORS
Pat Patterson
Alonzo E. Cummins
BY William L. Jones
ATTORNEY

United States Patent Office

3,057,406
Patented Oct. 9, 1962

3,057,406

CONTROL APPARATUS FOR USE IN WELLS

Pat Patterson, Oklahoma City, and Alonzo E. Cummins, Duncan, Okla., assignors to Halliburton Company, a corporation of Delaware

Filed Mar. 28, 1958, Ser. No. 724,676
16 Claims. (Cl. 166—123)

This invention relates to apparatus for use in oil and gas wells or the like to control fluid and equipment therein, such as to control or pump fluid and thereby apply force to control a well device or tool at a desired location in a well.

One application wherein the invention provides particular advantages is in connection with the setting or expanding of a well packer to effect a seal at a desired location in a well. Thus, the invention may be incorporated in a packer setting or control device which may be lowered into a well as part of an assembly including a well packer, whereupon the control device may then be operated from the surface of the ground to actuate or apply controlling forces resulting in the setting or expansion of the packer.

The setting or expanding of one of the modern well packers now in general use commonly involves the necessity of developing or producing relatively large forces in the well, often at a considerable depth below the surface of the ground. Where a packer is lowered into the well on a rigid conduit, such as below a string of tubing or drill pipe, this conduit is commonly employed as the medium through which controlling forces are applied to the packer from the surface of the ground, either mechanically by manipulating the conduit or hydraulically by pumping fluid downwardly through the conduit. At times a packer assembly is lowered into the well on a flexible line or cable containing one or more electrical conductors or wires which are used to supply electrical energy to actuate a suitable setting or control device included in the packer assembly. For example, the setting or control device may be of the powder-type, containing an explosive charge which is electrically controlled and which, upon being detonated, develops or produces the forces required to set or expand the packer.

While generally successful results have been obtained using the various prior art arrangements, difficulties have at times been encountered. In particular, there is need for a packer setting or control device which upon being lowered into a well on a flexible line or cable, or any other suitably strong means, may then be operated from the surface of the ground by relatively simple manipulations of the line or cable, but which nonetheless is capable of developing or producing relatively large forces at the desired location in the well.

One object of the present invention is to provide an improved fluid moving device and an improved valve therefor.

Another object of the invention is to provide an improved fluid moving device or pump for use in wells, the pump being operable from above by manipulating the means suspending it in the well.

A further object of the invention is to provide an improved valve for controlling fluid movement between concentric, relatively movable surfaces.

In one aspect thereof, the invention involves the concept of a control device which includes fluid moving or pumping means responsive to relative movement of a plunger member within a housing for exerting fluid pressure so as to move a piston member which is adapted to apply force at a desired location, such as in a well to control or operate other materials or equipment. If desired, the plunger member may be repeatedly moved within the housing to cause the exertion of increasing or repeated pressure tending to move the piston member.

In an arrangement for use in wells, the plunger member is adapted to be secured or connected to upwardly extending support means, such as a flexible line or cable, on which the control device and perhaps other apparatus, such as a well packer or other tool releasably connected below the housing, may be lowered and suspended at the desired location in the well. The housing and any apparatus therebelow is then supported in the well to some extent, such as by its own weight or by drag springs or the like mounted thereon, whereupon the upwardly extending supporting means secured to the plunger member may be manipulated from the surface of the ground to operate the control device in the well.

In accordance with a related aspect of the invention, a preferred fluid moving or pumping means is provided. To this end, it is preferred that the plunger member and a surrounding wall of the housing together form relatively movable inner and outer members having elongated, concentric surfaces defining an annular space or passageway along which fluid may be moved or pumped toward an outlet opening. In the control device, this annular space or passageway may communicate at one end thereof directly with a relatively large chamber or reservoir adapted to hold a hydraulic fluid. The outlet opening may be located near the other end of the annular space or passageway and is preferably controlled by normally closed, pressure-responsive one-way valve means which, in the control device, may open into a second fluid chamber located adjacent the piston member on which fluid pressure is to be exerted.

In order that successive quantities of fluid may be moved or pumped along the annular space or passageway between the aforesaid concentric surfaces and thence through the outlet opening, valve means is provided for automatically placing and removing a fluid restriction or seal across such annular space in response to relative longitudinal movement occurring between the inner and outer members. The arrangement is such that upon the inner or plunger member being moved in one direction (for example, upwardly due to raising of the flexible line or cable secured thereto), the valve means closes but nonetheless permits further movement of such member in said one direction, whereupon fluid is moved or forced along such annular space or passageway toward the outlet opening. Upon the inner or plunger member thereafter being moved in the opposite direction (for example, downwardly due to the flexible line or cable being released or lowered at the surface, permitting the plunger member to fall or be pulled down by weight), the valve means opens to permit additional fluid to enter such annular space or passageway and be in position to be moved or pumped therealong upon the plunger member being again moved in said one direction.

The foregoing and additional features, objects and advantages of the invention will be more apparent from the following description when read in connection with the

accompanying drawing of an illustrative embodiment thereof. Similar reference characters are used to designate similar parts in the drawing, wherein:

FIGURE 1 and FIGURE 1*a*, its lower continuation, together provide an elevational, mainly cross-sectional view of an assembly of apparatus shown positioned in a well casing, such as immediately after being lowered thereinto, the assembly including control apparatus in accordance with the invention and, therebelow, also including a conventional well packer of a type suited for use with the invention;

FIGURE 2 is a longitudinal, cross-sectional view of a portion of the control apparatus and well packer of FIGURES 1 and 1*a*, showing the parts in the respective positions occupied by them at a later stage of operation; and

FIGURE 3 is a view similar to that of FIGURE 2, but showing the parts in the respective positions occupied by them at an even later stage of operation, such as just prior to the control apparatus being removed from the well.

Referring to the drawing in detail, the invention is there illustrated and is hereinafter described, by way of example, with particular reference to its application in connection with apparatus for use in applying force to set or expand a well packer. It is understood, however, that the invention may be applied elsewhere, such as in connection with the controlling or operating of other materials or equipment in oil and gas wells or the like.

Referring first to the arrangement of FIGURE 1 and the lower continuation thereof in FIGURE 1*a*, there is shown a packer assembly **10** which generally includes, in the upper portion thereof, a packer setting or control device **11** having the invention incorporated therein and, in the lower portion thereof, a well packer **12** of conventional design.

The assembly **10** is shown positioned in a well casing **13** after having been lowered to a desired depth therein on flexible supporting means in the form of a wire line **14** (see FIGURE 1). At its lower end, the wire line **14** is suitably fastened or secured within a weighted member **15**. The weighted member **15** in turn is shown screwed onto an upper coupling member **16** which is hollow and is provided with lateral passageways **17** communicating with the space outside the assembly **10**.

The wire line **14** extends upwardly through the well casing **13** to the surface of the ground (not shown) where it may be manipulated, as will appear more fully hereinafter, to control the assembly **10** in the well.

The packer setting or control device **11** is shown as generally including a housing **18** having an upwardly extending plunger member **19** and a downwardly extending piston member **20** slidably mounted each in a separate hollow portion thereof. For convenience of assembly, or for other reasons, the housing **18** and elongated members **19** and **20** may each be made of several parts threadedly or otherwise connected together.

As illustrated, the housing **18** includes an upper portion **21** carrying a set of conventional drag springs **22** which are suitably mounted thereon in angularly spaced relation to each other. The springs **22** are each bowed outwardly so as to slidably engage the well casing **13**, thereby resisting to some extent relative longitudinal movement of the housing **18** therein. Also, the springs **22** function to centralize the entire assembly **10** within the casing **13**.

The housing **18** has its upper portion **21** shown threadedly connected to an intermediate portion **23** thereof. This portion **23** in turn is shown threadedly connected to downwardly extending, spaced-apart walls **24** and **25** in the lower portion of the housing **18**.

As illustrated, the housing inner wall **24** encircles the plunger member **19** and is threadedly connected to a lower coupling member **26** having a transverse wall **27** which closes off the lower end of the space within which the plunger member **19** is mounted. The housing outer wall **25** is shown encircling an upper portion **28** of the piston member **20** which in turn encircles the housing inner wall **24** and is movable, as will appear more fully hereinafter, within the space provided between the housing walls **24** and **25**.

It will be noted that the piston member **20** has its upper portion **28** shown threadedly connected to a lower portion **29** thereof. Upon the member **20** being moved downwardly a suitable distance, its lower portion **29** engages and applies force to a surface on the well packer **12** therebelow, as will appear more fully hereinafter.

As illustrated, the plunger member **19** includes a lower portion **30** and an intermediate portion **31** which are threadedly interconnected and extend upwardly out of the housing **18**. Also, the plunger member **19** is shown as including an enlarged upper portion **32** which is screwed onto the intermediate portion **31** thereof and is disposed entirely above the housing **18**.

The plunger member **19** may be hollow throughout its length, as shown, with the interior thereof forming part of a relatively large reservoir or chamber A adapted to hold a supply of hydraulic fluid **33**. The chamber A also includes the hollow portion of the housing **18** disposed between the lower end of the plunger member **19** and the aforesaid transverse wall **27** of the lower coupling member **26**.

The enlarged upper portion **32** of the plunger member **19** is threadedly or otherwise connected to the upper coupling member **16** which is shown extending downwardly into such portion **32**. Therebelow, a "floating" separator or plug **34** is shown mounted within the plunger member **19**. The plug **34** carries a sealing ring wiper **35** which preferably slidably engages the wall of the enlarged upper portion **32** immediately above the hydraulic fluid **33** therein.

The plunger member **19** is mounted for limited relative longitudinal movement with respect to the housing **18**. To limit relative downward movement thereof, the member **19** is shown provided with a downwardly facing abutment **36** which is disposed on its enlarged upper portion **32** and is adapted to engage an upwardly facing abutment **37** provided by the upper end surface of the housing **18**. To limit relative upward movement of the plunger member **19**, a downwardly facing abutment **38** is shown provided interiorly of the housing **18** on the intermediate portion **23** thereof. This abutment **38** is adapted to be engaged (see FIGURE 3) by abutment means in the form of an annular ridge **39** shown provided on the plunger member **19** near the lower end of its intermediate portion **31**.

The plunger member **19** is shown disposed in close but slidable relation to such of the intermediate portion **23** of the housing **18** as is above the abutment **38** thereon. Therebelow the plunger member **19** is disposed in spaced relation to the housing **18** and to the aforesaid transverse wall **27** of the lower coupling member **26**, which wall **27** may be considered as part of the housing **18**. Sealing means is preferably provided between the closely but slidably related portions of the plunger member **19** and the housing **18**, such as by the O-type sealing ring **40** which is shown carried by the intermediate portion **23** of the housing **18**.

It will be noted that the plunger member **19** and the surrounding housing wall **24** together define a somewhat elongated annular space or passageway **41**. At its lower end, the passageway **41** normally communicates past the lower end of the plunger member **19** with the portion of the chamber A therebelow. Thus, the passageway **41** is normally substantially filled with the hydraulic fluid **33**.

Near the upper end thereof, the passageway **41** communicates with one or more outlet openings **42** which are shown provided in the housing inner wall **24**. The outlet openings **42** are preferably controlled by normally closed, pressure-responsive one-way valve means. To this end, a

valve member including a sealing ring 43 is shown mounted opposite the openings 42 in a downwardly facing recess 44 which is provided in the intermediate portion 23 of the housing 18 between the walls 24 and 25.

The sealing ring 43 is made of a resilient and expansible material, such as rubber or the like, and is shown as having a rectilinear cross-section (when viewed from a broken end thereof, as shown). The ring 43 encircles the housing inner wall 24 and is of sufficient length to cover all of the openings 42 therein. An annular body 45, which may be made of metal or the like, surrounds and is bonded or otherwise secured to the outer and upper sides of the ring 43. The annular body 45 in turn is threadedly or otherwise connected to the recessed portion of the housing 18.

It will be noted that the sealing ring 43 has a downwardly and inwardly tapered lower surface 46. This surface 46 is exposed to a chamber B which is provided between the housing walls 24 and 25 above the slidably mounted piston member 20. Fluid-tight sealing means is preferably provided between the piston member 20 and each of the adjacent walls 24 and 25, such as by O-type sealing rings 47 and 48 which are shown carried, respectively, on the inner and outer sides of the upper portion 28 of the member 20.

In accordance with one aspect of the invention, a preferred fluid moving or pumping arrangement is provided whereby successive quantities of the hydraulic fluid 33 entering from chamber A into the aforesaid passageway 41 may be moved past the one-way valve means controlling the outlet openings 42 and into the chamber B to exert pressure tending to move the piston member 20 downwardly therein.

In the arrangement shown, the passageway 41 is formed between spaced-apart, relatively movable inner and outer surfaces 50 and 51 which are provided, respectively, on the plunger member 19 and the surrounding housing wall 24. One-way valve means including an annular sealing member 52 responsive to relative longitudinal movement between the surfaces 50 and 51 is provided for controlling the fluid 33 in the passageway 41.

The sealing member 52, which may be made of rubber or the like, is shown as being a resilient and expansible O-type sealing ring having an annular cross-section (when viewed from a broken end thereof, as shown). The sealing member or ring 52 encircles the surface 50 on the plunger member 19 and is adapted to slidably engage the surrounding surface 51 on the housing wall 24.

It is preferred that the outside diameter of the ring 52 be slightly larger than the inside diameter of the housing wall 24. Also, it is preferred that the inside diameter of the ring 52 be slightly smaller than the diameter of a lateral protuberance 53 which is provided on the plunger member 19 near the lower end thereof.

It will be noted that the protuberance 53 is somewhat elongated and provides on the surface 50 a vertically extending portion which is disposed in somewhat closer-spaced relation to the surrounding surface 51 than is the portion of the surface 50 thereabove. At its upper end, the vertically extending portion of the protuberance 53 joins an inwardly extending portion 54 thereof which is preferably tapered upwardly to facilitate entry thereof into the sealing ring 52. At its lower end, the protuberance 53 joins an outwardly extending flanged portion 55 of the plunger member 19.

It has been found desirable, and it is herein proposed, to include within the passageway 41 below the sealing ring 52 a lower collar-like member 56 which encircles the plunger member 19 and is engageable from below by the flanged portion 55 thereof. The collar-like member 56 may be loosely slidable with respect to both the vertically extending portion of the surface 50 on the protuberance 53 and the surrounding surface 51 on the housing wall 24. The length of the collar-like member 56 is preferably such that, when it is in engagement with the flanged portion 55 of the plunger member 19, its upper end is disposed somewhat below the inwardly extending portion 54 of the protuberance 53 (see FIGURES 1*a* and 2).

It has also been found desirable, and it is herein proposed, to include within the passageway 41 above the sealing ring 52 an upper collar-like member 57 which encircles the plunger member 19 and is engageable from above by the annular ridge 39 thereon. The collar-like member 57 may be loosely slidable with respect to the portion of the surface 50 which extends along the plunger member 19 between the ridge 39 and protuberance 53. However, collar-like member 57 preferably carries on the outer surface thereof a sealing ring wiper 58 or the like which closely but slidably engages the surrounding surface 51 on the housing wall 24.

In order to provide pressure equalization between the portions of the passageway 41 above and below the annular ridge 39, such as when the collar-like member 57 is in engagement therewith, an interior passageway 59 is shown extending in the plunger member 19 between a point on the surface 50 above and a point thereon below the ridge 39.

As will appear more fully hereinafter, the collar-like members 56 and 57 are each adapted to engage the sealing ring 52. At times both of the members 56 and 57 are in engagement with the ring 52, the member 56 from below and the member 57 from above (see FIGURE 2). To this end, the upper collar-like member 57 preferably has the lower portion of its inner surface 60 tapered outwardly and downwardly so as to receive the inwardly and upwardly extending portion 54 of the protuberance 53 provided, as aforesaid, on the plunger member 19.

The well packer 12 may be of conventional design and, accordingly, it is believed unnecessary to describe its construction and operation in detail. As shown best in FIGURE 1*a*, the packer 12 generally includes an elongated inner body or mandrel 61 having radially outwardly movable or expansible top slips 62, packing sleeve 63 and bottom slips 64 mounted thereon.

The mandrel 61, which is hollow, encircles and extends downwardly from the aforesaid coupling member 26 which, below its transverse wall 27, is also hollow and is provided with lateral passageways 65 communicating with the space outside the assembly 10.

The mandrel 61 is threadedly or otherwise connected to the lower end portion of the coupling member 26. At an intermediate portion 66 thereof, the coupling member 26 is suitably weakened to provide a yieldable connection between its upper and lower portions and, thus, between the housing 18 connected thereabove and the mandrel 61 connected therebelow.

An upper or top shoe 67 is slidably mounted on the upper portion of the mandrel 61 above the top slips 62 thereon. The shoe 67 is shown suitably counterbored from the upper end thereof to receive the lower portion of the piston member 20, as will appear more fully hereinafter. The shoe 67 is normally supported in an upward position on the mandrel 61 by a radially expansible split-type latching rings 68. The ring 68 is mounted in an inner annular recess 69 provided on the counterbored portion of the shoe 67 and has a lower, inwardly extending flange 70 which normally extends into an annular groove 71 on the mandrel 61.

The top slips 62 are slidably mounted on the mandrel 61 immediately below the top shoe 67. On the outer surface thereof, the slips 62 are provided with upwardly facing teeth 72 which, upon the slips 62 being set, are adapted to bitingly engage the well casing 13. A downwardly and outwardly tapered inner surface 73 of the slips 62 encircles the upper end of a companion outer surface 74 suitably provided on an upper expander member 75. The expander member 75 is slidably mounted on the mandrel 61 adjacent the upper end of the packing sleeve 63, which thus normally holds both the member 75 and

the top slips 62 in upward positions on the mandrel 61.

A lower or bottom shoe 76 is fixedly mounted on the lower portion of the mandrel 61 below the bottom slips 64 thereon. The slips 64 are slidably mounted on the mandrel 61 but are normally yieldably secured thereto, such as by frangible pins 77 which are shown extending through the slips 64 and into the mandrel 61.

On the outer surface thereof, the slips 64 are provided with downwardly facing teeth 78 which, upon the slips 64 being set, are adapted to bitingly engage the well casing 13. An upwardly and outwardly tapered inner surface 79 of the slips 64 encircles the upper end of a companion outer surface 80 suitably provided on a lower expander member 81. The expander member 81 is slidably mounted on the mandrel 61 adjacent the lower end of the packing sleeve 63, which is thus adapted to be expanded by longitudinal compression thereof between the expander members 75 and 81.

In operation, the weight of the assembly 10 will ordinarily be sufficient to permit it to move downwardly into the well upon the wire line 14 being slacked-off or lowered at the surface. If necessary or desired, the weighted member 15 secured to the lower end of the wire line 14 may be made sufficiently heavy, or other suitable additional weight may be included, to insure that the assembly 10 moves downwardly through the casing 13.

It is understood that the wire line 14 may be replaced, if desired, by other flexible or even rigid supporting means of suitable strength. For example, the assembly 10 may be suspended from and lowered into the well on a string of rigid pipe or rod sections or on a suitably strong electrical cable of the tape commonly employed in connection with certain well logging and other operations. However, one important advantage of the invention arises from the construction and arrangement which permits use of simple flexible supporting means, such as the wire line 14, which need not contain electrical conductors or the like for transmitting energy into the well.

During and immediately after the lowering thereof, the parts of the assembly 10 are ordinarily in the respective positions shown in FIGURES 1 and 1*a*. Thus, the slips 62 and 64 and the sleeve 63 of the packer 12 are then in their unexpanded positions. The piston member 20 is then in an upward position with respect to the housing 18 and with respect to the packer 12 therebelow. The plunger member 19 is ordinarily then in a downward position within the housing 18, since the weight of such member 19 and apparatus connected thereabove will ordinarily be sufficient to offset any excess in weight of the housing 18 and apparatus connected thereto over the resistance offered to downward movement of the housing 18 as a result of the engagement of the drag springs 22 with the casing 13.

It will be noted that, in the arrangement shown, the drag springs 22 support the assembly 10 to some extent, both during and after the lowering thereof into the well. However, insofar as the operation of the present invention is concerned, the drag springs 22 function primarily as casing-engaging means for resisting further relative downward movement of the housing 18 after the assembly 10 has reached the desired depth in the well.

Thus, when the control device 11 is to be operated, the weight itself of the housing 18 and apparatus connected thereto, such as the packer 12, will ordinarily offer sufficient resistance to relative upward movement of the housing 18 to permit the plunger member 19 to be moved upwardly therein by simply taking-in or raising the wire line 14 at the surface. Thereafter, due partly to the functioning of the drag springs 22, the plunger member 19 may be returned to a downward position within the housing 18 by simply slacking-off or lowering the wire line 14 at the surface.

For certain applications it may be necessary or desirable to employ means other than casing-engaging means for resisting relative downward movement of the housing 18 within the well. For example, a downwardly extending anchor pipe or the like (not shown) of suitable length may be connected below the packer 12 so as to engage the bottom of the well and thereby support the housing 18 against further downward movement therein. Also, for applications where sufficient liquid is present in the well, satisfactory results may be obtained using one or more downwardly-facing, liquid-engaging members (not shown), which may be mounted on the housing 18 or on apparatus connected thereto. These liquid-engaging members may or may not also engage the well casing 13.

In the control device 11, it will be noted that since the slidably mounted sealing ring 52 and upper collar-like member 57 are each adapted to closely engage the surface 51 on the surrounding housing wall 24, these parts tend to support themselves within the passageway 41. Accordingly, upon the assembly 10 reaching the desired depth in the well, the exact positions of the ring 52 and member 57 may depend largely on the procedure followed in assembling and handling the control device 11 prior to lowering it into the casing 13. On the other hand, since the lower collar-like member 56 is freely slidable with respect to both of the concentric surfaces 50 and 51, it will during the lowering operation ordinarily drop within the passageway 41 to a downward position wherein it encircles the lateral protuberance 53 and is engaged from below by the flanged portion 55 of the plunger member 19.

As shown best in FIGURE 2, the lower collar-like member 56 is carried in its downward position on the plunger member 19 as such member 19 is moved upwardly within the housing 18 by raising the wire line 14 after the assembly 10 has reached the desired location in the well. As the upward stroke or movement of the plunger member 19 continues, its lateral protuberance 53 engages an inner portion of the sealing ring 52, which becomes seated thereon above the lower collar-like member 56. This has the effect of closing the one-way valve means controlling the fluid 33 in the passageway 41. That is, the sealing ring 52 upon being engaged by the protuberance 53 places a fluid restriction or seal across the concentric surfaces 50 and 51 at a location near the lower end of the passageway 41, whereupon the fluid 33 thereabove is prevented from passing downwardly past the lower collar-like member 56 as the upward stroke or movement of the plunger member 19 continues.

After the sealing ring 52 has been engaged by the protuberance 53, as aforesaid, further upward movement of the plunger member 19 moves or forces the fluid 33 along the passageway 41 toward the outlet openings 42 near the upper end thereof. It will be noted that, as the upward stroke or movement of the plunger member 19 continues, the sealing ring 52 may move downwardly into very tight engagement with the lower collar-like member 56. However, the seal across the passageway 41 is effected due to the engagement of the sealing ring 52 with each of the surfaces 50 and 51.

During the upward stroke or movement of the plunger member 19, the lower collar-like member 56 functions somewhat as a positioning means which assists in maintaining the ring 52 efficiently disposed in transverse relation to the passageway 41. Also, the member 56 by limiting downward movement of the sealing ring 52 along the protuberance 53 reduces the likelihood of the ring 52 becoming undesirably caught or stuck between the moving parts, such as between the housing wall 24 and the lower flanged portion 55 of the plunger member 19.

As the upward stroke or movement of the plunger member 19 continues, sufficient fluid pressure builds up in the passageway 41 to open the normally closed one-way valve means controlling the outlet openings 42. That is, sufficient fluid pressure is exerted against the inner surface of the sealing ring 43 which surrounds the openings 42 to move the lower portion of the ring 43 outwardly. Thus, a portion of the fluid 33 in the pas-

sageway 41 passes along the inner surface of the ring 43 into the chamber B, whereupon pressure is exerted tending to move the piston member 20 downwardly with respect to the housing 18.

It will be noted that the fluid 33 thus supplied to the chamber B is prevented from returning through the openings 42 into the passageway 41. This is because the fluid 33 in chamber B exerts pressure against the tapered lower surface 46 of the sealing ring 43 in a direction such as to move the ring 43 radially inward into closer engagement with the surfaces around the openings 42 in housing wall 24.

Prior to the plunger member 19 reaching its uppermost position within the housing 18, the upper collar-like member 57 engages the sealing ring 52 from above, whereupon further upward movement of the plunger member 19 results in each of the collar-like members 56 and 57 and the interposed ring 52 being in effect carried upwardly therewith (see FIGURE 3). It will be noted that during this latter portion of the upward stroke or movement of the plunger member 19, both of the collar-like members 56 and 57 function as positioning means to maintain the sealing ring 52 efficiently disposed between the relatively moving, concentric surfaces 50 and 51.

Upon the plunger member 19 reaching its uppermost position within the housing 18, as shown in FIGURE 3, the upper collar-like member 57 is disposed a suitable distance below the annular ridge 39 which is then engaging the abutment 38 on the housing 18. Upon the plunger member 19 being thereafter moved downwardly within the housing 18, the upper collar-like member 57, due to the wiper 58 thereon being in close engagement with the surrounding surface 51, tends to support itself in an upward position until engaged from above by the ridge 39. On the other hand, the sealing ring 52, which is in close engagement with each of the surfaces 50 and 51 as the downward stroke or movement of the plunger member 19 commences, tends initially to move downwardly with the plunger member 19. However, at this time the fluid 33 in the chamber A is attempting to move upwardly into the passageway 41, such as because of the low pressure zone established therein above the sealing ring 52 as the plunger member 19 moves downwardly. Thus, an upwardly acting force is applied to the sealing ring 52 and the freely slidable collar-like member 56 therebelow, with the result that the protuberance 53 becomes disengaged from the ring 52 during the downward stroke or movement of the plunger member 19. This has the effect of opening the one-way valve means in the passageway 41, whereupon additional fluid 33 from the chamber A is permitted to move into position to be pumped or moved into the chamber B during the next or subsequent upward strokes of the plunger member 19. At the same time, the "floating" separator or plug 34 (see FIGURE 1), due to the weight thereof, moves downwardly within the upper portion 32 of the plunger member 19 and thereby reduces the effective size of the chamber A, with the result that there is less likelihood of a low pressure or vacuum-like condition being established in the chamber A above the fluid 33 therein. Also, the plug 34 reduces the likelihood of the hydraulic fluid 33 being contaminated by well or other fluids which may be present in the hollow coupling member 16 thereabove.

It will be noted that the upper collar-like member 57, upon being engaged by the ridge 39 on the plunger member 19 during the downward stroke or movement thereof, is returned to a downward position within the passageway 41 (see FIGURE 1*a*). Also, the sealing ring 52, which is engageable from above by the collar-like member 57, is returned to a downward position within the passageway 41 (see FIGURE 1*a*). In this connection, the collar-like member 57 functions primarily as a positioning means to assist in maintaining the ring 52 efficiently disposed in transverse relation to the passageway 41.

Upon the plunger member 19 being repeatedly moved upwardly and downwardly within the housing 18, as aforesaid, successive quantities of the fluid 33 are moved or pumped through the outlet openings 42 into the chamber B. In this way, repeated pressure may be exerted on the piston member 20. Since the outlet openings 42 are controlled by one-way valve means opening into the chamber B, the repeated pressure exertions are cumulative and each results in the application of additional force tending to move the piston member 20 farther downwardly with respect to the housing 18.

It will be noted in FIGURE 2 that upon the piston member 20 being moved increasingly farther downwardly, as aforesaid, its lower end is received within the counterbored portion of the top shoe 67 and engages an inner portion of the expansible latching ring 68, moving it radially outward sufficiently to withdraw the flange 70 thereon from the groove 71 provided on the mandrel 61. This releases the top shoe 67 for downward movement along the mandrel 61. As downward movement of the piston member 20 continues, it applies force through the ring 68 and top shoe 67 to move the top slips 62 downwardly and radially outward along the tapered surface 74 of the upper expander member 75, whereupon the teeth 72 on the slips 62 bitingly engage the casing 13.

Thereafter, the slips 62 in engagement with the casing 13 resist further downward movement of the piston member 20, with the result that the pressure exerted due to additional fluid 33 being thereafter supplied to the chamber B tends to move the housing 18 and apparatus connected thereto in an upwardly direction with respect to the piston member 20. This results in the application of force tending to move the parts mounted on the mandrel 61 below the top slips 62 in an upwardly direction. For one thing, the upper expander member 75 is caused to move upwardly into tighter engagement with the tapered inner surface 73 of the top slips 62, which are thereby moved into even tighter engagement with the surrounding casing 13.

Also, relative upward movement of the mandrel 61 results in the application of compressive force lengthwise between the fixed bottom shoe 76 thereon and the upper expander member 75. This force tends to compress the packing sleeve 63 between the expander members 75 and 81, thereby expanding the sleeve 63 radially outward into sealing engagement with the casing 13. Also, upon a predetermined force being developed or applied, the frangible pins 77 are sheared, whereupon the bottom slips 64 are then moved upwardly and radially outwardly along the tapered outer surface 80 of the lower expander member 81 and into engagement with the casing 13.

After the packer 12 has been fully set or expanded, as aforesaid, further relative upward movement of the housing 18 overcomes the yieldable connection normally coupling the control device 11 and packer 12 together. That is, the lower coupling member 26 is stretched or elongated sufficiently to separate or pull it apart at the intermediate weakened portion 66 thereof (see FIGURE 3).

It will be noted in FIGURE 1*a* that a circumferentially extending notch 82 is shown provided on the mandrel 61 a suitable distance below the annular groove 71 thereon. Upon the packer 12 becoming fully set or expanded, as shown in FIGURE 3, the mandrel 61 is then in a relative upward position wherein the surface defining the upper limit of the notch 82 is above the flange 70 on the latching ring 68. This notch 82 receives the flange 70 and thus permits the ring 68 to contract or move radially inward upon the piston member 20 being raised upwardly out of the counterbored portion of the top shoe 67 as the control device 11 is withdrawn from the well. Thus, the packer 12 remains "locked" in its fully set or expanded position after the control device 11 has been removed from operative engagement therewith.

It will be appreciated by those skilled in the art that the arrangement herein described permits the development of relatively large forces which may be applied to control or operate materials or equipment located at a considerable depth in a well. Also, it will be appreciated that the arrangement permits the use of relatively simple flexible supporting means, such as the wire line **14**, which during the manipulation thereof is only required to withstand relatively small forces, as compared to the total forces applied to control or operate the equipment in the well.

In this connection it is pointed out that the control device **11** may be constructed and arranged so that a relatively large number of upward strokes of the plunger member **19** is required to fully set or expand the packer **12** and subsequently release the device **11** therefrom. During each upward stroke, the wire line **14** may be subjected to relatively small forces tending to stretch or elongate it, yet for each stroke the piston member **20** is moved farther downwardly. The arrangement is such that the successive forces applied to the piston member **20** and through it to the equipment in the well therebelow are cumulative while the successive forces required to be withstood by the wire line **14** are not.

While the invention has been described herein with particular reference to one embodiment and use thereof, various modifications will now present themselves to those skilled in the art. Accordingly, the invention should not be considered limited to the particulars hereof.

What is claimed is:

1. In a force-applying control device, the combination of means including a housing forming first and second fluid chambers, a plunger member mounted for movement within said first chamber and forming with said housing relatively movable elongated surfaces defining a passageway having an inlet communicating with said first chamber and an outlet communicating with said second chamber, one-way valve means including a slidable sealing member in said passageway responsive to relative movement between said surfaces in one direction to close and in the opposite direction to open said passageway near the inlet thereof, said valve means upon closing permitting further relative movement between said surfaces in said one direction to move fluid along said passageway toward the outlet thereof, and a force-applying piston member mounted for movement within said second chamber and actuatable by the pressure of fluid entering said second chamber through the outlet of said passageway.

2. The invention as claimed in claim 1 including pressure-responsive normally closed one-way valve means for controlling the entry of fluid from the outlet of said passageway into said second chamber.

3. The invention as claimed in claim 1 wherein the one-way valve means includes a protuberance and a ridge longitudinally spaced on said plunger member and wherein the slidable sealing member in said passageway is disposed loosely with respect to the portion of said plunger member between the protuberance and ridge thereon, the sealing member being engageable by the protuberance to close and disengageable therefrom to open the valve means.

4. In a fluid moving or pumping device, the combination of relatively movable inner and outer members having elongated surfaces defining an annular fluid passageway, the elongated surface of said inner member having a lateral protuberance and an annular ridge longitudinally spaced thereon, an annular sealing member adapted to loosely encircle the portion of said inner member between said protuberance and ridge and to cosely but slidably engage the elongated surface of said outer member, said sealing member being engageable by said protuberance to place and disengageable therefrom to remove a fluid restriction across said passageway, and positioning means including a collar-like member in said passageway disposed between and in engageable relation to said sealing member and ridge and in close but slidable relation to the elongated surface of said outer member.

5. The invention as claimed in claim 4 wherein said positioning means also includes a freely slidable collar-like member adapted to encircle and be carried on said protuberance to limit movement of said sealing member in one direction with respect to said inner member.

6. A valve comprising two members having relatively movable elongated surfaces defining a fluid passageway, one of said surfaces having a protuberance and a ridge longitudinally spaced thereon, a sealing member in said passageway disposed loosely with respect to the portion of said one surface between the protuberance and ridge thereon, the sealing member being engageable by the protuberance to close and disengageable therefrom to open the valve, and positioning means including a freely slidable member in the passageway adapted to be carried on the protuberance of the said one surface to limit movement of the sealing member in one direction with respect to said one surface.

7. A valve as claimed in claim 6 herein said positioning means includes a member in the passageway disposed between and in engageable relation to the sealing mem-member and the ridge of the said one surface and in close but slidable relation to the other of said surfaces.

8. In a fluid moving device, the combination of relatively movable inner and outer members having elongated surfaces defining an annular passageway, said passageway having an inlet and an outlet for fluid, one of said surfaces having a protuberance disposed thereon near the inlet of said passageway, an annular sealing element encircling said inner member and disposed in said passageway in loosely slidable relation to the one of said elongated surfaces having the protuberance thereon and in closely slidable relation to the other of said elongated surfaces, said protuberance being engageable with and disengageable from said sealing element, whereby relative movement between said members in one direction places and in the opposite direction removes a fluid restriction across said passageway near the inlet thereof, positioning means including a collar-like member disposed between said elongated surfaces in engageable relation to said sealing element, and pressure-responsive normally closed one-way valve means controlling the outlet of said passageway.

9. In a control device, the combination of means including a housing forming first and second fluid chambers, a plunger member movably mounted in said first chamber, a piston member movably mounted in said second chamber, said plunger member and housing forming a fluid passageway having an inlet communicating with said first chamber and an outlet communicating with said second chamber, and one-way valve means including a slidable sealing member in said passageway, said valve means being responsive to relative movement between said plunger member and housing in one direction to place and in the opposite direction to remove a fluid restriction across said passageway near the inlet thereof, said piston member being actuatable by the pressure of fluid entering said second chamber through the outlet of said passageway.

10. The invention as claimed in claim 9 including pressure-responsive, normally closed one-way valve means for controlling the passage of fluid from the outlet of said passageway into said second chamber.

11. In combination with a well packer adapted to be set or expanded in a well by the application of force longitudinally thereof, a packer setting or control device comprising a housing yieldably connected to and above said packer, friction drag means on said housing for resisting longitudinal movement thereof within the well, means including a first hollow portion of said housing for holding a supply of hydraulic fluid within said control device, fluid pumping means including a plunger member mounted for repeated relative upward and downward movement within said first hollow portion of said housing

to pump successive quantities of said hydraulic fluid in said housing, upwardly extending flexible support means operatively connected to said plunger member and adapted to be manipulated from the surface of the well to operate said pumping means, said housing having a second hollow portion for receiving the fluid pumped by said pumping means, means including a passage in said plunger member connecting said hollow portions of said housing, pressure-responsive one-way valve means in said housing for permitting the entry of fluid from said first hollow portion into said second hollow portion of said housing, and a force-applying piston member movably mounted in said second hollow portion of said housing, said piston member being actuatable by the pressure of hydraulic fluid pumped by said pumping means and being mounted for movement in response to said fluid pressure downwardly into operative engagement with the packer therebelow.

12. In combination with a well packer adapted to be controlled or operated by the application of force thereto after being lowered into a well to a desired location where the packer is to remain set or expanded for a period of time, a packer setting or control device comprising means including a housing disposed above said packer, yieldable coupling means interconnectiing said housing and the packer therebelow, friction drag means on said housing for resisting movement thereof in at least a downwardly direction within the well, means including a first hollow portion of said housing for holding a supply of hydraulic fluid, fluid pumping means including an upwardly extending plunger member mounted for repeated upward and downward movement within said first hollow portion of said housing to pump successive quantities of said hydraulic fluid, flexible support means operatively connected to said upwardly extending member and adapted to be manipulated from the surface of the well to operate said pumping means, said housing having a second hollow portion for receiving the fluid pumped by said pumping means, means including a passage in said plunger member connecting said hollow portions of said housing, a force-applying piston member movably mounted in said second hollow portion of said housing, said piston member being actuatable by fluid pressure exerted thereon due to the pumping of hydraulic fluid by said pumping means, said force-applying member being mounted for movement in response to said fluid pressure in a downwardly direction toward operative engagement with the packer therebelow, and a pressure-responsive one-way valve within said housing for permitting the entry of fluid from said first hollow portion into said second hollow portion of said housing and thereby accumulating successive quantities of hydraulic fluid pumped by said pumping means in said second hollow portion in actuating relation to said force-applying member whereby the repeated exertions of fluid pressure thereon are cumulative.

13. In a force-applying device for use with a tool within a well casing, the combination of means including a tubular housing forming a first fluid chamber for holding a supply of hydraulic fluid, fluid pumping means including a plunger member mounted for reciprocating movement within said first chamber to pump successive quantities of the hydraulic fluid therein, means whereby said plunger member may be reciprocated by means of a wire line extending into the well casing, friction drag means in said housing adapted to engage the casing, said housing having a second fluid chamber for receiving the fluid pumped by said pumping means, pressure-responsive one-way valve means between said first and second fluid chambers, said valve means being normally closed and adapted when open to permit fluid flow into said second chamber, and a force-applying piston member concentric with said plunger member and movably mounted in said second chamber, said piston member being actuatable by the pressure of fluid pumped by said pumping means and being mounted for movement in response to said fluid pressure in a direction to apply force to said tool.

14. In a force-applying device for use with a tool within a well casing, the combination of means including a tubular housing forming a first fluid chamber for holding a supply of hydraulic fluid, fluid pumping means including an elongated member mounted for longitudinal reciprocating movement within said first chamber to pump successive quantities of the hydraulic fluid therein, said elongated member and housing forming a fluid passageway having an inlet communicating with the supply of hydraulic fluid and having an outlet for fluid pumped by said pumping means, means whereby said elongated member may be reciprocated by means of a wire line extending into the well casing, friction drag means on said housing adapted to engage the casing, said housing having a second fluid chamber communicating with the outlet of said passageway, pressure-responsive one-way valve means normally closing the outlet of said passageway and adapted when open to permit fluid flow from said passageway into said second fluid chamber, and a force-applying annular piston member encircling a portion of said elongated member and movably mounted in said second chamber, said piston member being actuatable by the pressure of fluid pumped by said pumping means and being mounted for movement in response to said fluid pressure in a direction to apply force to said tool.

15. In a force-applying device for use with a tool within a well casing, the combination of means including a tubular housing forming a first fluid chamber for holding a supply of hydraulic fluid, an upwardly extending elongated member mounted for repeated upward and downward movement within said first chamber and forming with said housing an elongated fluid passageway, said passageway having an outlet near its upper end and communicating near its lower end with the supply of hydraulic fluid, means whereby said elongated member may be reciprocated by means of a wire line extending into the well casing, friction drag means on said housing adapted to engage the casing, said housing having a second fluid chamber communicating with the outlet of said passageway, a first one-way valve means including a sealing element disposed in said passageway in slidable relation to said housing and in engageable relation to a lower portion of said elongated member, a second one-way valve means including a pressure-responsive element normally closing the outlet of said passageway and adapted when open to permit fluid flow from said passageway into said second chamber, and a force-applying piston member concentric with said elongated member and movably mounted in said second chamber, said piston member being actuatable by the pressure of fluid entering said second chamber through the outlet of said passageway and being mounted for movement in response to said fluid pressure in a direction to apply force to said tool.

16. In a force-applying device for use with a tool within a well casing, the combination of means including a tubular housing forming a first fluid chamber for holding a supply of hydraulic fluid, fluid pumping means including an elongated member mounted for repeated upward and downward movement within said first chamber, said elongated member forming with said housing an elongated fluid passageway having an inlet at its lower end communicating with the supply of hydraulic fluid and having an outlet near its upper end for fluid pumped by said pumping means, said pumping means also including a sealing element disposed in said passageway in slidable relation to said housing and in engageable relation to a lower portion of said elongated member, means whereby said elongated member may be reciprocated by means of a wire line extending into the well casing, friction drag means on said housing adapted to engage the casing, said housing having a second fluid chamber communicating with the outlet of said passageway for receiving fluid pumped by said pumping means,

pressure-responsive one-way valve means normally closing the outlet of said passageway and adapted when open to permit fluid flow from said passageway into said second chamber, and a force-applying piston member concentric with said elongated member and movably mounted in said second chamber, said piston member being actuatable by the pressure of fluid pumped by said pumping means through the outlet of said passageway into said second chamber and being mounted for movement in response to said fluid pressure in a direction to apply force to said tool.

References Cited in the file of this patent

UNITED STATES PATENTS

2,377,916	Anderson	June 12, 1945
2,396,878	Plumb	Mar. 19,1946
2,589,506	Morrisett	Mar. 18, 1952
2,691,503	Bigelow	Oct. 12, 1954
2,692,023	Conrad	Oct. 19, 1954
2,747,673	Lawrence	May 29, 1956