

June 10, 1958

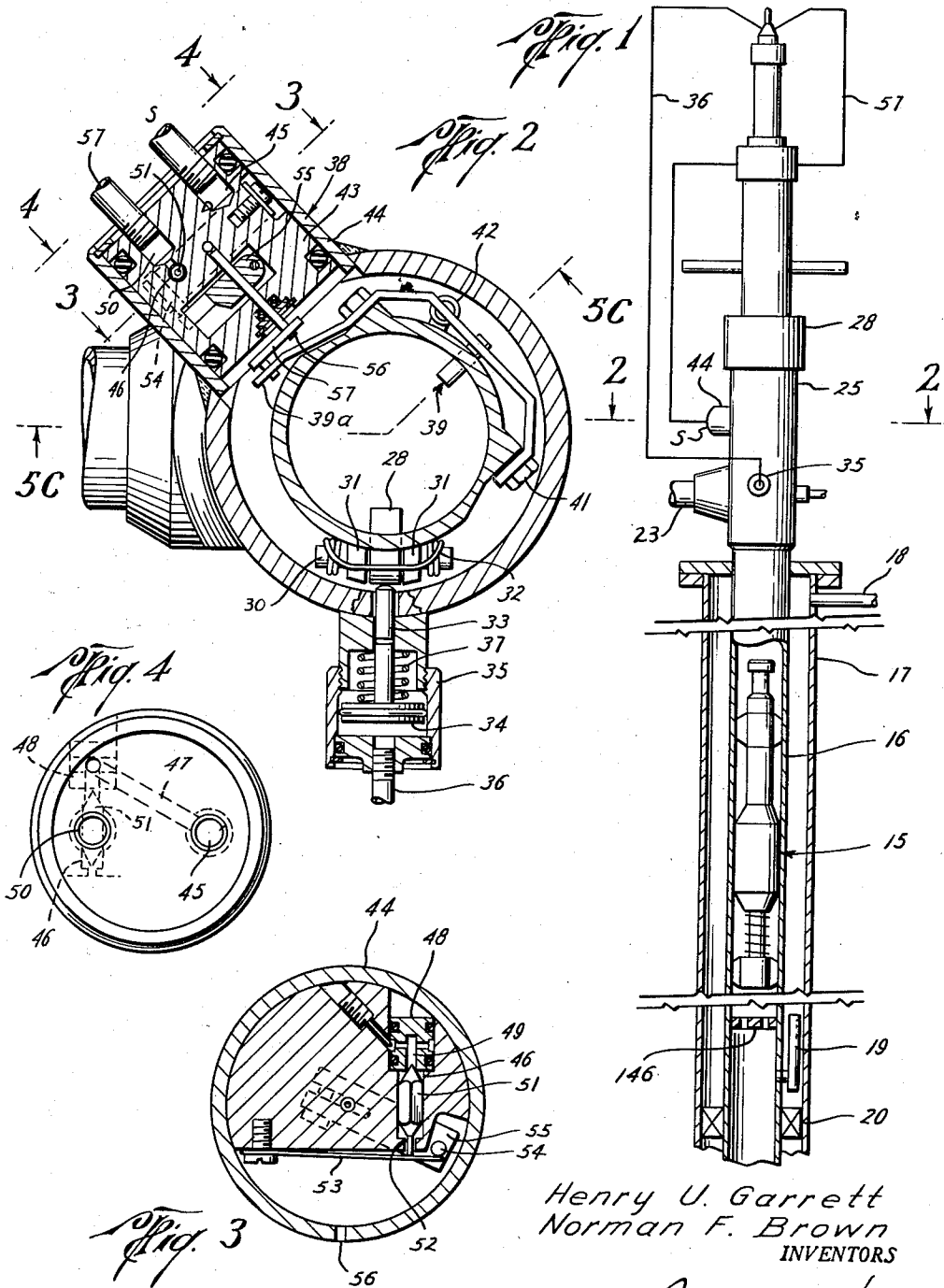
H. U. GARRETT ET AL

2,838,006

WELL APPARATUS

Filed Sept. 16, 1955

7 Sheets-Sheet 1



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June 10, 1958

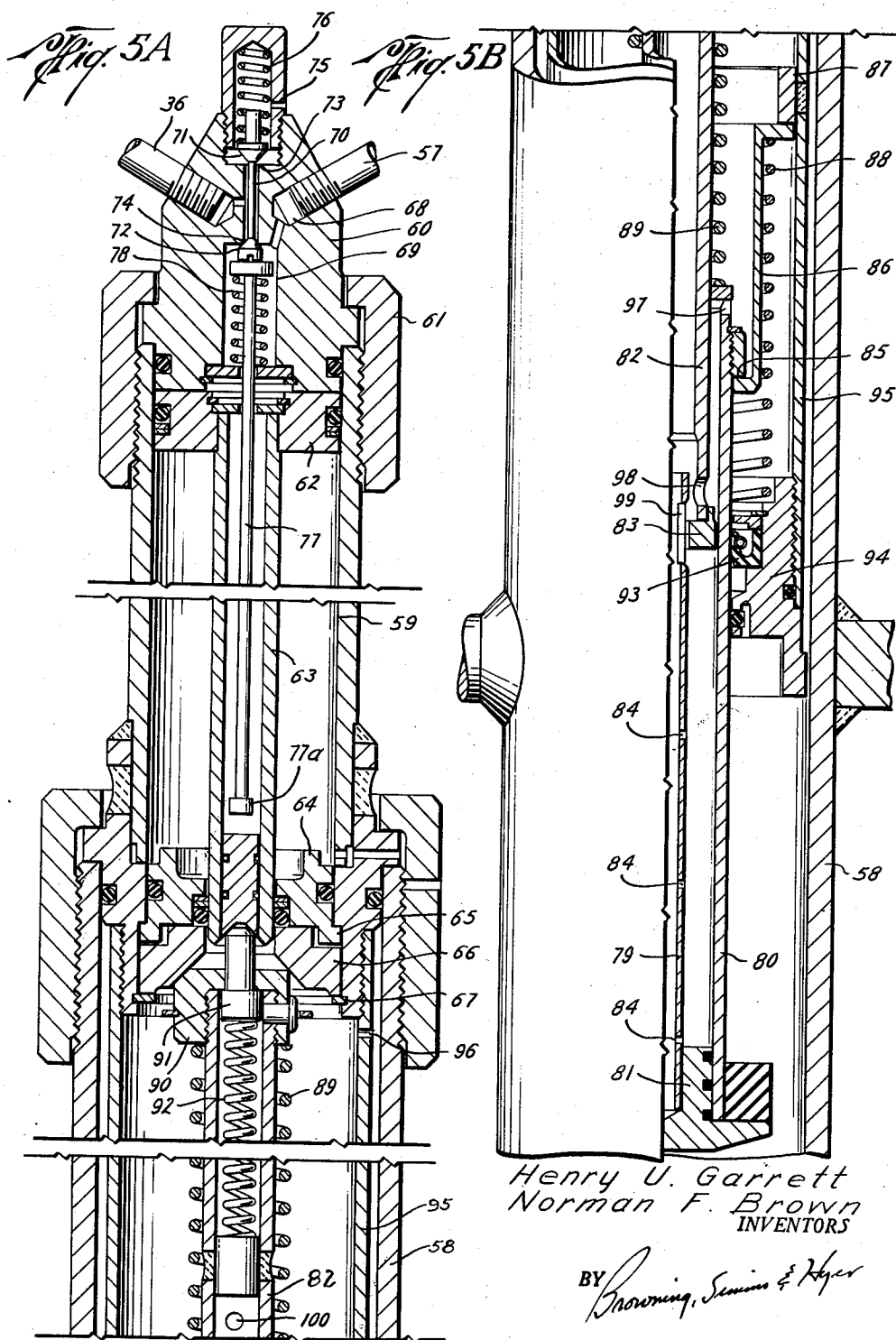
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WELL APPARATUS

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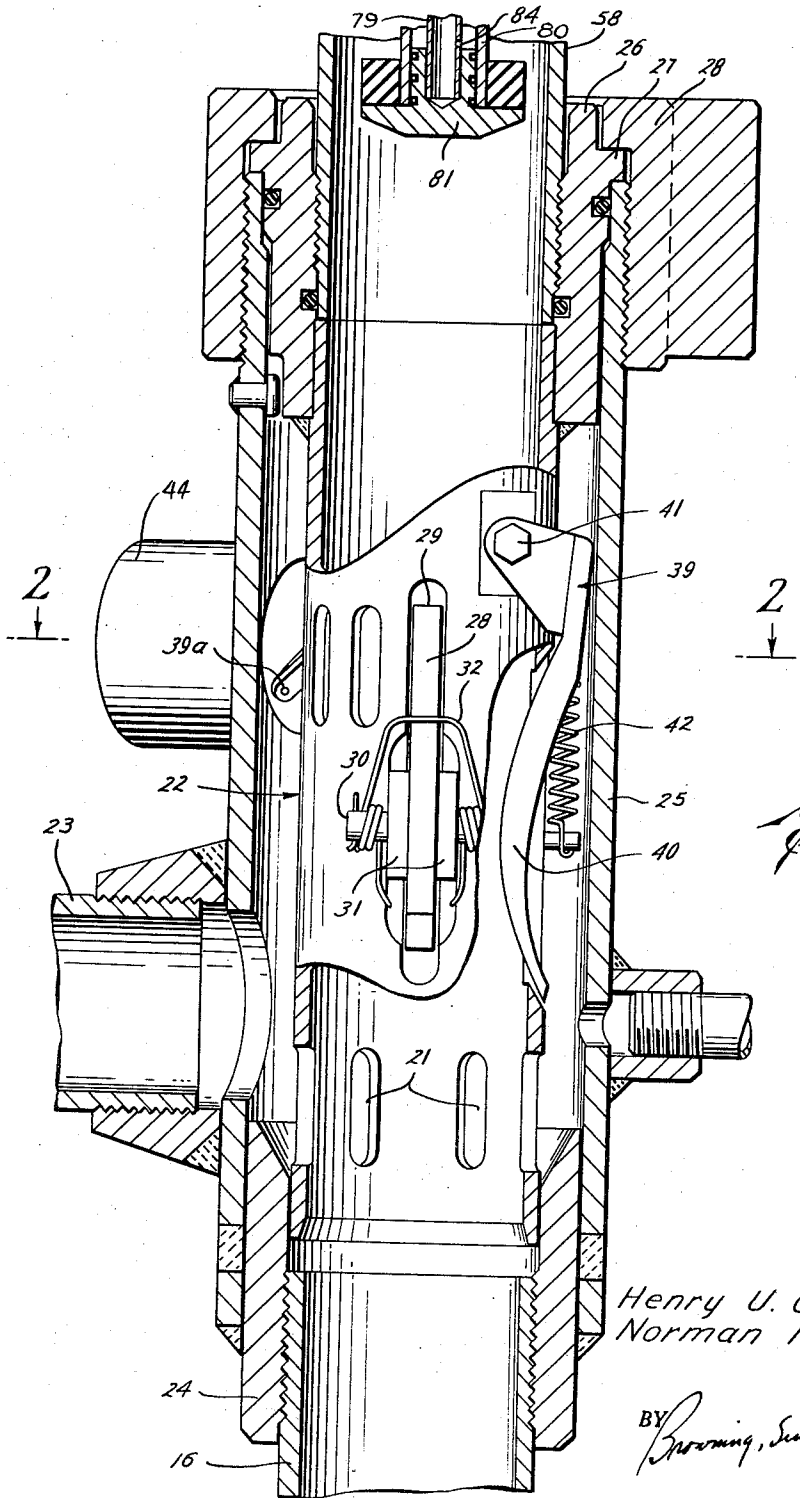
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WELL APPARATUS

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7 Sheets-Sheet 3



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WELL APPARATUS

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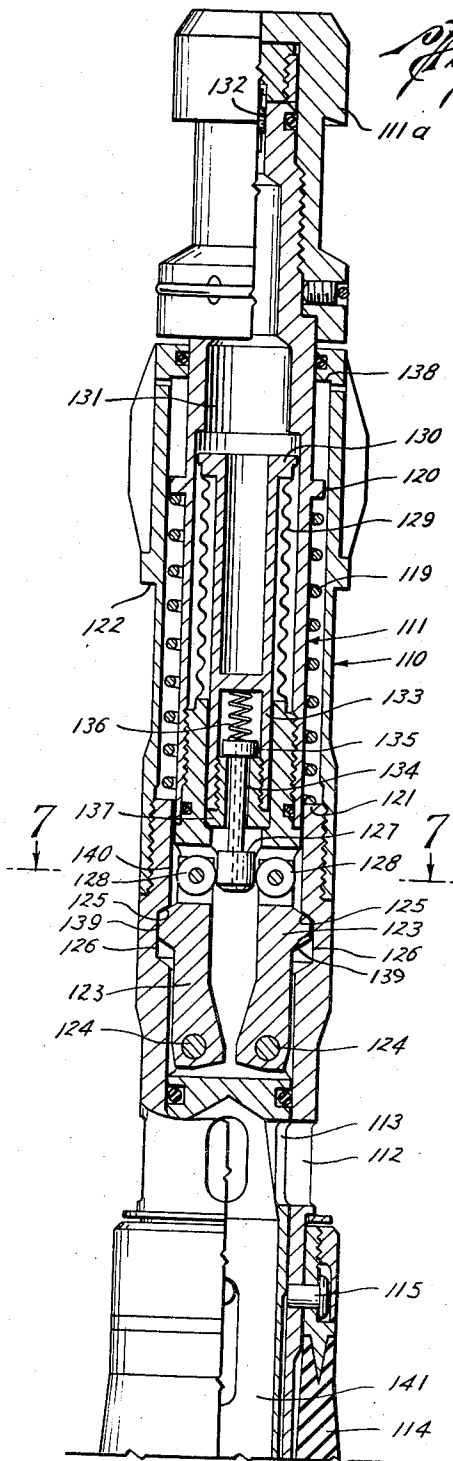


Fig. 6A

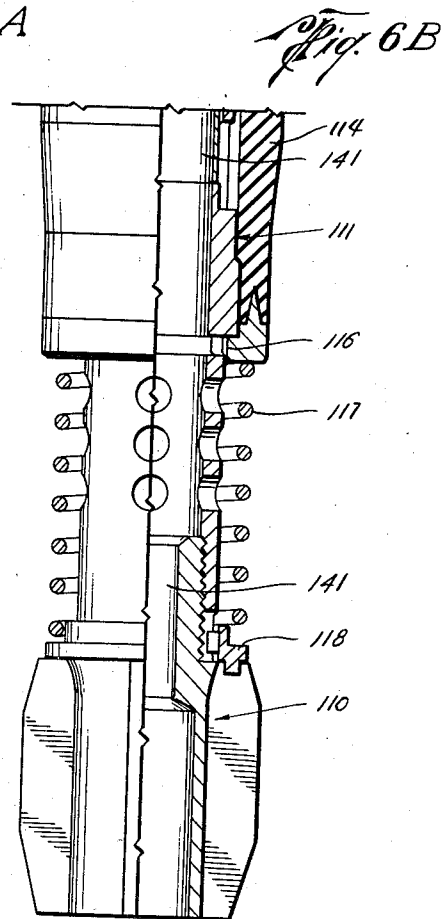


Fig. 6B

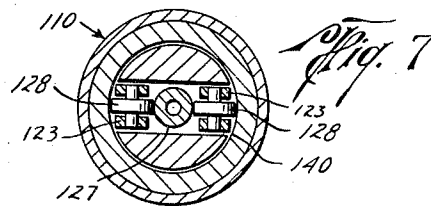


Fig. 7

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Fig. 8A

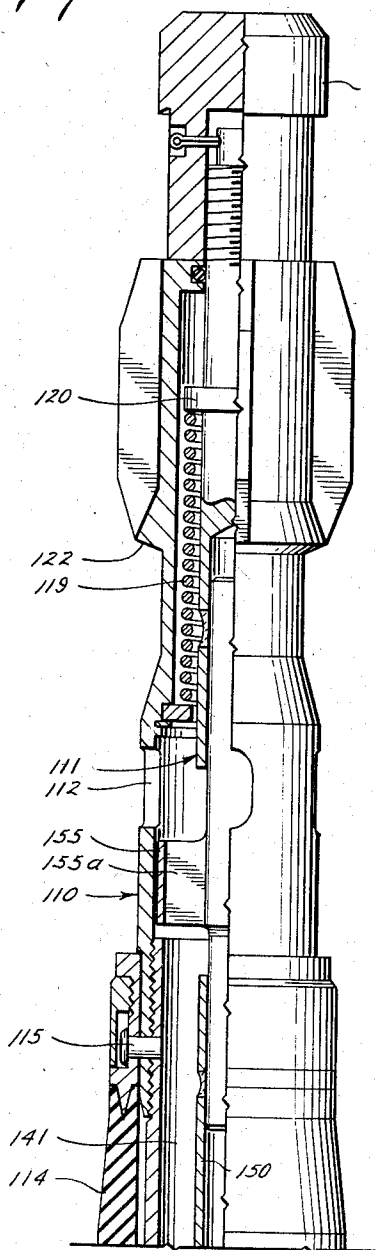
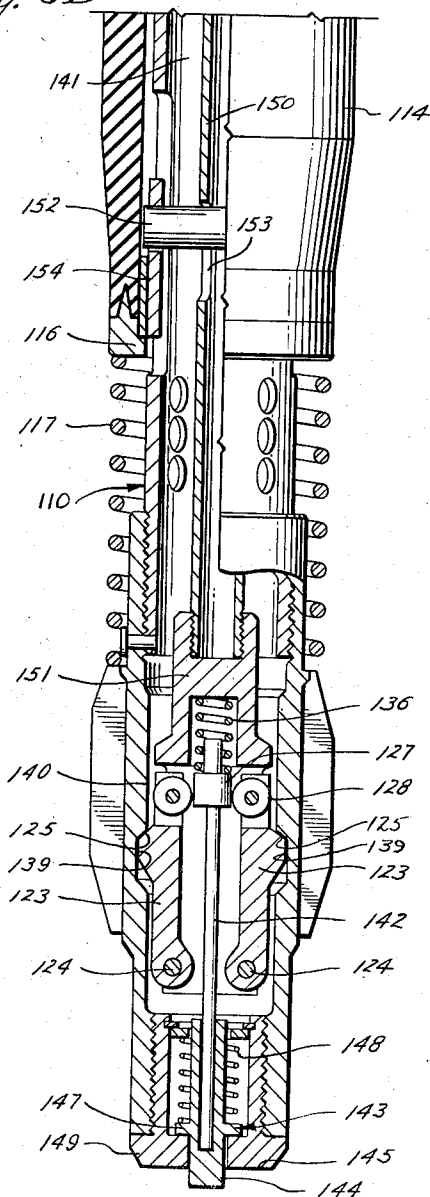


Fig. 8B



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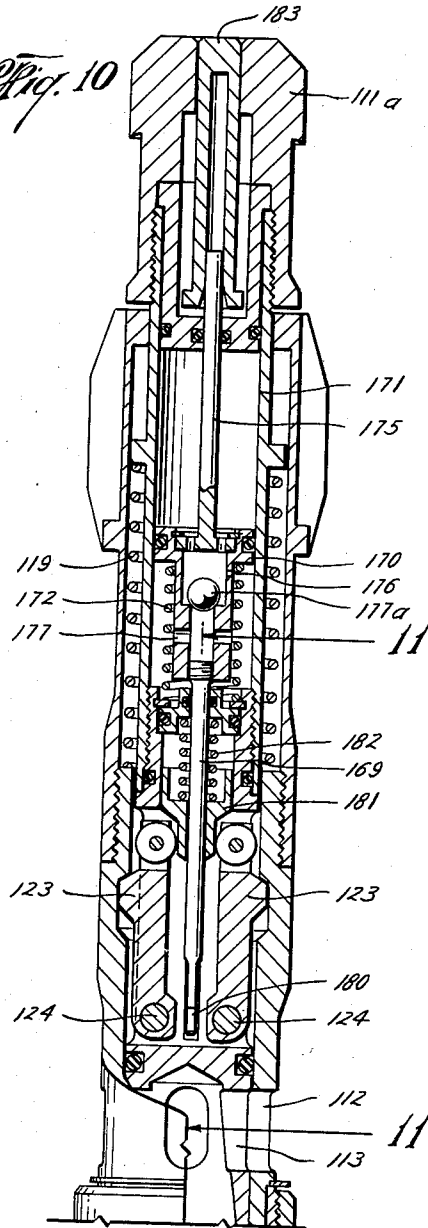
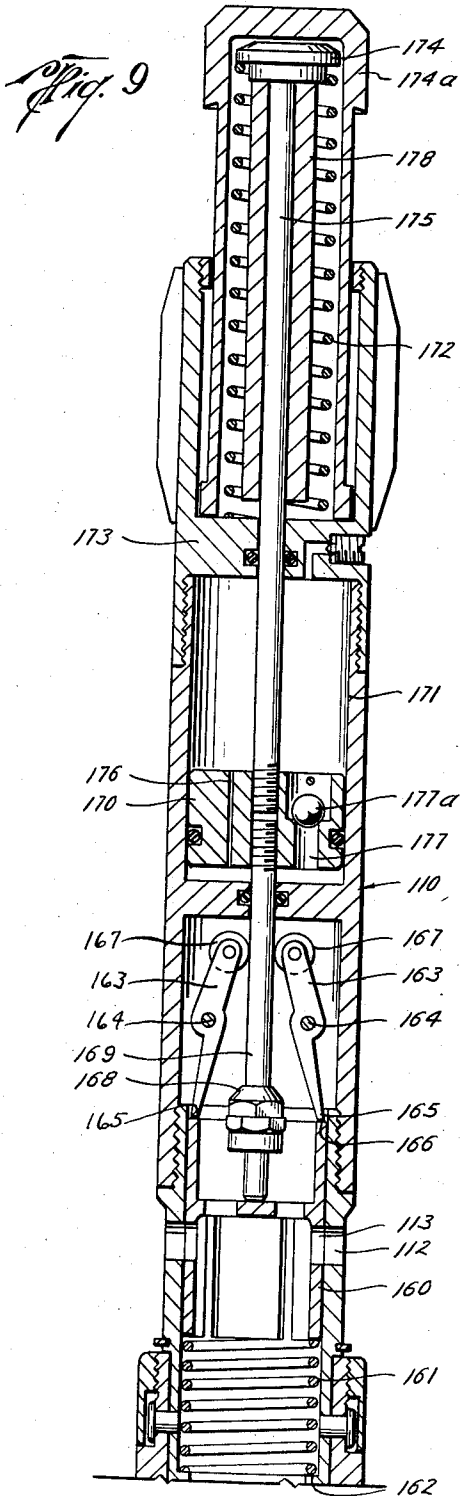
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7 Sheets-Sheet 6



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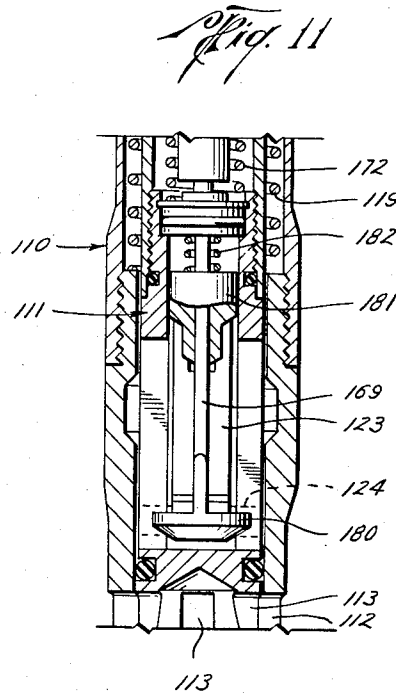
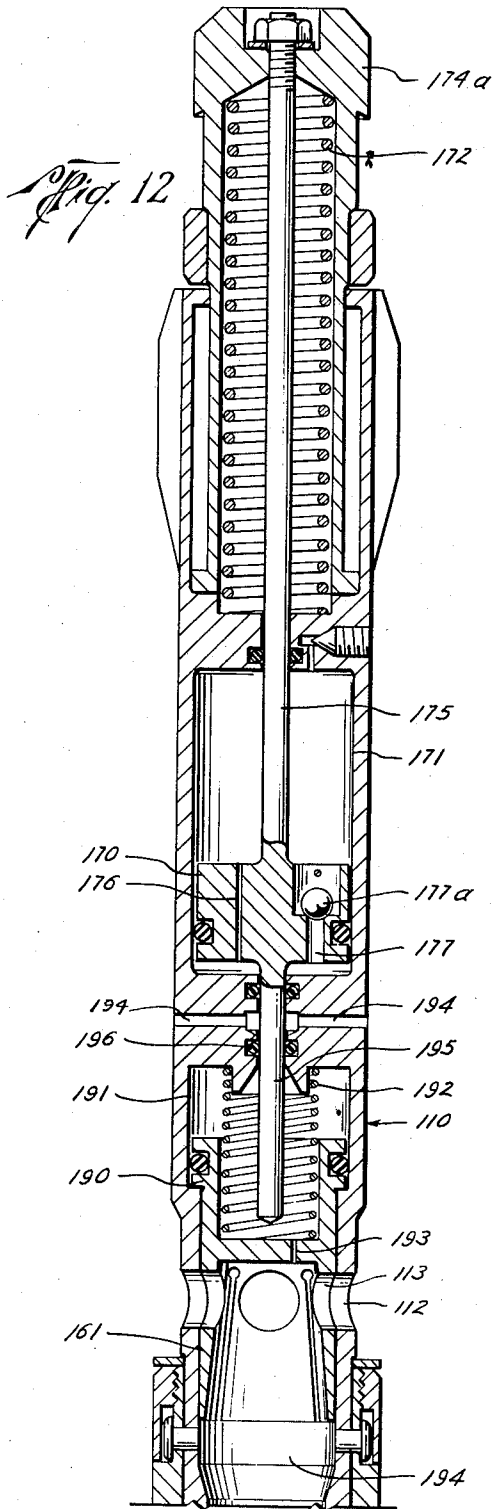
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7 Sheets-Sheet 7



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2,838,006

WELL APPARATUS

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Application September 16, 1955, Serial No. 534,728

32 Claims. (Cl. 103—52)

This invention relates to improved free pistons of the type which are moved upwardly through a well conduit by fluid flow and then drop downwardly through the conduit to perform various functions. In one of its aspects, the invention relates to free pistons and to well systems employing the same wherein improved surface mechanisms are provided for reloading the free pistons and wherein improved arrangements are provided in the free pistons to determine or aid in the determination of the lower level reached by the free pistons before they start their upward journey. In a broader aspect, the invention relates to improved latching mechanisms for determining the point or time at which a free piston is actuated before beginning its movement through the conduit.

In our copending application "Well Apparatus," Serial No. 534,727, filed September 16, 1955, there is described as one embodiment a free piston which is essentially self-contained in that power for its actuation is derived from a change in a well condition, such as temperature or pressure. In the instant application, the free pistons described as illustrative embodiments are essentially of the type which cooperate with a surface mechanism which applies force to reload the free pistons or, in other forms, which relies upon the momentum of the free piston to develop force for the reloading function. In both applications, however, various mechanisms have been provided for preventing actuation of the free piston until a certain event has occurred whereupon the free piston is actuated to enable it to reverse its direction of travel. The various types of such mechanisms described in both applications are useful with either type of free piston mentioned above, as well as with other types.

Thus, in the use of any type of free piston, it is necessary to determine the point in the operating cycle of the free piston at which it is placed in condition to reverse its direction of travel. In some instances it has been found that the free piston should be actuated to reverse its travel responsive to the free piston reaching a point in the well where the static pressure is at a predetermined value. Then, knowing the pressure gradient of the well, it is possible to set the free piston to be actuated at a particular pressure and hence at a particular depth in the well, all without necessarily providing any mechanism in the well to cooperate with the free piston for that purpose. In other instances it has been found desirable to actuate the free piston to reverse its direction of travel after the lapse of a predetermined time interval. In still other instances, it has been found desirable to reverse the direction of travel responsive to the free piston arriving at a position in the well having a predetermined temperature or upon the free piston encountering a stop in the well.

It is therefore a general object of this invention to provide a well system and a free piston for use therein wherein actuation of the free piston to reverse its direction of travel is governed by a timing mechanism so that upon the occurrence of an event, the free piston will be actuated at a predetermined time after such event.

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Another object of this invention is to provide a well system and a free piston for use in such a system wherein the free piston is actuated to reverse its direction of travel upon the lapse of a predetermined time interval which interval, in some cases, is started upon the free piston leaving its upper or its lower level or, in other cases, upon the free piston arriving at one of such levels.

Another general object is to provide a well system and free piston for use therein wherein the free piston is triggered for actuation to reverse its direction of travel responsive to arrival of the free piston at a point in the well where the static pressure is of predetermined magnitude.

Another general object of the invention is to provide timing, pressure responsive, and position responsive mechanisms in a free piston of the surface loading type for triggering the same upon lapse of predetermined time, exposure of the free piston to a predetermined static pressure, or its arrival at a stop in a well, respectively.

Another object of the invention is to provide a free piston which is reloaded at an upper or lower level by utilizing the momentum of the free piston to accomplish such function and wherein a mechanism is employed to trigger the actuation of the free piston to reverse its direction of travel upon lapse of a predetermined time after reloading.

Another object of the invention is to provide a free piston in which a timing mechanism is primed at the surface of the well to start the running of a time interval at the end of which the free piston will be actuated to permit reversal of its direction of movement but, should the free piston arrive at a stop in the well before the end of such interval, it will be reprimed to start the interval running again.

Another object of the invention is to provide a free piston in which movement of a valve member controlling flow from one end of the piston to the other is accomplished by controlling a pressure differential applied to a pressure responsive means connected to the valve member, the application of such differential in turn being controlled by a suitable means such as a timing mechanism.

Another object is to provide a well system and a free piston for use therein in which energy is stored in the free piston by a reloading mechanism at the surface of the well and in which a latch mechanism is employed to prevent such energy from being utilized to actuate the free piston while it is moved downwardly through the well but is adapted to be released responsive to the arrival of the free piston at its lower level and independently of rate of flow of fluid in the well or, stated in another manner, the latch mechanism is released by means settable to accomplish such function within a predetermined time of the free piston arriving at its lower level.

Another object of the invention is to provide improved surface equipment for applying energy to a free piston to reload the same wherein a shock absorber is arranged so that it not only absorbs the shock of the free piston's arrival but also acts to transmit force from a force applying mechanism to the free piston to reload the latter.

Other objects, advantages and features of this invention will be apparent to one skilled in the art upon the consideration of the written specification, the appended claims and the attached drawings wherein:

Fig. 1 is a schematic illustration of a well system embodying this invention and showing a free piston in a well conduit and also the preferred form of surface loading equipment attached to the well head;

Fig. 2 is a cross-sectional view taken on the line 2—2 of Figs. 1 and 5C and illustrates one form of a catching mechanism for the free piston and a pilot valve means

actuatable responsive to arrival of the free piston at the well head to start the reloading operation;

Fig. 3 is a section taken on the line 3—3 of Fig. 2 to illustrate some of the details of the pilot valve;

Fig. 4 is an elevational view taken on line 4—4 of Fig. 2 to further illustrate the pilot valve;

Figs. 5A, 5B and 5C are views, partially in section and partially in elevation, illustrating a preferred embodiment of the surface loading mechanism of this invention, it being understood that the views are continuations one of the other from top to bottom in the order above named;

Figs. 6A and 6B show an embodiment of a surface loaded free piston wherein a latch mechanism for holding the free piston in one of its operative positions is released responsive to the free piston being exposed to a static well pressure of a certain magnitude;

Fig. 7 is a section on the line 7—7 of Fig. 6A;

Figs. 8A and 8B show another arrangement of a surface loaded free piston wherein there is provided a latch mechanism releasable by the free piston striking a stop situated in a well conduit;

Fig. 9 illustrates one embodiment of a free piston employing a timing mechanism, the particular timing mechanism illustrated being adapted to be reset at the well surface or, if desired, at a stop in the well and arranged to permit actuation of the free piston to reverse its direction of travel after the lapse of a predetermined time;

Fig. 10 illustrates an alternative embodiment of a timing mechanism arranged in a somewhat different type of surface loaded free piston;

Fig. 11 is a longitudinal sectional view along the line 11—11 of Fig. 10 to illustrate further details of the latch and release mechanisms; and

Fig. 12 is a view illustrating a time responsive type of free piston in which a valve member's movement is controlled by pressure differential applied thereto under the control of a timing mechanism.

Like characters of reference are used throughout the several views to designate like parts.

General well system

In Fig. 1, there is shown a typical well system of this invention in which a free piston 15 is reciprocated in a tubing 16 disposed in the well which can have a casing 17 if desired. In the various embodiments of the free piston to be described hereinafter, the free piston is actuated at a lower level in the tubing to cause it to form a substantially impermeable plug in the tubing. The flow of fluid up the tubing will then cause the piston to rise therein. Such flow can either be natural or induced as by injection of lifting gas into the tubing via a pipe 18, casing 17 and a gas lift valve 19. The tubing casing annulus can be packed off as at 20 if it is desired to prevent the application of lifting gas pressure to the formation. At any rate, as the piston rises up the tubing, it forces any fluid thereabove upwardly along the tubing to be discharged through ports 21 in catcher sleeve 22 (Fig. 5C) and finally out through a flow line 23. Upon arrival of the piston at the upper end of its stroke, a mechanism is operated responsive to such arrival to catch and hold the piston and to apply force from an exterior source to prime or reload the piston. In some instances, the priming or reloading can be accomplished by taking advantage of the momentum of the piston as will be described in more detail below. At any rate, after the free piston is primed or reloaded, it is free to fall by gravity down the tubing until it arrives at the level where it is to form a substantially impermeable plug in the tubing. In this manner, the free piston can act as an aid in improving the gas lifting efficiency of a well, as a paraffin scraper, or for other purposes.

Surface reloading mechanism

Referring now to Figs. 2 through 5C for a more detailed description of a preferred embodiment of the

reloading mechanism of this invention, catcher sleeve 22 can have one end disposed within a collar 24 on the upper end of tubing 16 or other well apparatus as desired. The catcher sleeve is supported by a fluid-tight housing 25 by means of a support nipple 26, the latter having a shoulder 27 overlying the upper end of housing 25 and maintained in place by wing nut 28. The support nipple also serves to close off the upper end of the housing and to support the elements of Figs. 5A and 5B. At this point, it is well to note that Fig. 5C is drawn to larger scale than are Figs. 5A and 5B for the sake of clarity.

As indicated above, means are provided to catch and hold the free piston while it is being reloaded at the well head. Such means is illustrated in Figs. 2 and 5C as including a releasable holding latch 28 having an upper end 29 engageable with a shoulder on the free piston. The holding latch is carried on a pivot pin 30 extending through ears 31 on catcher sleeve 22 and has its upper end biased inwardly to piston catching position by a spring 32. Thus, with the holding latch in catching position, the free piston can move upwardly into the reloading mechanism by momentarily pushing the upper end of the holding latch outwardly until a suitable shoulder on the free piston passes above end 29 of the holding latch. Thereafter, the holding latch engages such shoulder to prevent downward movement of the free piston.

While there are a number of manners of releasing the holding latch, it is desired to have such release to be automatic and responsive to completing the reloading of the free piston. An automatic means for accomplishing this function can include a pressure-actuated trip as illustrated in Fig. 2. Such trip includes a pin 33 engageable with the holding latch to swing upper end 29 outwardly and out of engagement with the free piston. Pin 33 is illustrated as being actuated by a pressure-responsive piston 34 slidably received in a housing 35. Pressure is applied against an outer end of the piston via conduit 36 to move pin 33 inwardly against the force of spring 37. Then upon application of pressure through conduit 36, the holding latch is moved to the released position to permit the free piston to drop down the well.

In a preferred embodiment, a reloading means is provided which is actuated responsive to arrival of the free piston at the well head. As a part of such means, a pilot valve 38 is arranged to transmit fluid from a source S to the reloading mechanism to power the same upon the free piston arriving at the well head. The pilot valve is actuated by a trip lever 39 which has a portion 40 engageable by the free piston to be moved outwardly about pivot 41 against the force of spring 42. Such movement causes arm 39a to swing and actuate pilot valve 38.

Turning to the details of the pilot valve, it comprises a valve body 43 housed in a coupling 44 welded to housing 25. The valve body has an inlet port 45 communicating with valve chamber 46 via passage 47 and an insert seat 48 having a passage 49 therein. The valve body is also provided with another port 50 which communicates with valve chamber 46 at a point midway the latter's length. Disposed in the valve chamber is a valve member 51 adapted to seat in one position against insert 48 to prevent flow through passage 49 and in another position to seat against shoulder 52.

The valve member is urged to seated position against insert 48 by a spring 53. The spring is movable by pin 54 carried on arm 55 to permit the valve member to seat against shoulder 52. Arm 55 is connected by a shaft 56 to an arm 57 which in turn is connected to arm 39a for movement thereby. It will be noted that a vent 56 is provided in the coupling 44.

With the above arrangement, arrival of the free piston at the well head moves trip lever 39 outwardly which movement causes spring 53 to be depressed so that valve member 51 seats on 52 to prevent venting and at the same

time to open supply S for flow of pressure fluid through port 50 and conduit 57.

Referring now to Figs. 5A and 5B, there is illustrated a reloading mechanism and shock absorber carried in a housing 58, a portion of which comprises a cylinder 59. The upper end of the cylinder is closed by plug 60 maintained in place by a ring nut 61. Disposed within cylinder 59 is a piston 62 having a piston rod 63 extending through a seal in partitioning member 64. The latter is maintained in place by a shoulder 65 and a stop part 66 which in turn is secured in cylinder housing 59 by a snapping ring 67.

Means are provided for applying pressure to piston 62 to move it to cause reloading of the free piston and for automatically releasing the piston-catching mechanism shown in Fig. 2 upon the reloading being completed. Such means can include an inlet port 68 communicating with conduit 57 from pilot valve 38 and also with the upper end of piston 62 via chamber 69. Then upon the pilot valve being moved to permit pressure to flow from source S, such pressure will be applied to piston 62 to move it downwardly in cylinder 59. There is also provided a pilot valve for applying and venting pressure from piston 34 to actuate the holding latch. Such pilot valve includes a valve member 70 formed with heads 71 and 72 alternately seatable against shoulders 73 and 74, respectively, to control venting of the holding latch tripping mechanism and the application of pressure thereto. Valve member 70 is urged to one of its seated positions by spring 76 and to its other by valve rod 77 and spring 78. Spring 78 is made stronger than spring 76 so that with the parts positioned as shown in Fig. 5A, the tripping mechanism is vented. The valve rod has a head 77a engageable by piston 62 to move the valve rod downwardly after the piston has moved through a substantial portion of its reloading stroke. Thus, upon the application of pressure to piston 62 from conduit 57, the piston moves downwardly while valve member 70 is maintained in venting position. However, as soon as the piston has moved a sufficient distance, it will engage head 77a and pull rod 77 down whereby spring 76 moves valve member 70 downwardly to close off communication between vent 75 and conduit 36 and at the same time open conduit 36 to conduit 57 whereby pressure fluid flows to the latch tripping mechanism to trip the latch and release the free piston.

An hydraulic shock absorber is illustrated in Figs. 5A and 5B in an arrangement where it engages the free piston to dissipate the impact energy thereof and thereafter transmits the reloading force thereacross to reload the free piston. The details of construction of this shock absorber are described and claimed in co-pending application Serial No. 391,030, filed November 9, 1953, now Patent No. 2,812,717, and only sufficient description will be given here to illustrate the fundamentals of its operation.

Thus the shock absorber comprises inner and outer tubes 79 and 80 supported concentrically of each other by impact head 81. A reservoir tube 82 carries a piston 83 adapted to move into the annular space between inner and outer tubes 79 and 80. The shock absorber is filled with oil or other suitable liquid so that movement of piston 83 through the annulus forces the oil through restrictions 84 in the inner tube thereby controlling the rate of upward movement of impact head 81 and causing the dissipation of impact energy.

Outer tube 80 is provided with a shoulder 85 engageable by a support member 86 which in turn is urged upwardly against a stop 87 by a spring 88. In this manner, inner and outer tubes 79 and 80 are maintained in impact receiving position and in turn, support reservoir tube 82 by means of spring 89 which urges the reservoir tube upwardly so that its head 90 abuts stop part 66.

A pin 91 is carried by head 90 and it is urged thereagainst by spring 92 to abut the lower end of piston

rod 63. The function of this arrangement will be described later.

As mentioned above, the annular space between inner and outer tubes 79 and 80 is filled with oil. It will be noted that outer tube 80 has a sliding seal 93 with an annular plug 94 which is supported by a sleeve 95 suspended from a lower end of cylinder portion 59 of the housing. The space above plug 94 and within sleeve 95 can be substantially filled with oil to assure that an adequate supply of oil is always available to fill inner and outer tubes 79 and 80. In this connection, it will be noted that a vent 96 is provided in the upper end of sleeve 95 so that oil in the shock absorber is always exposed to well head pressure. Also, the upper end of outer tube 80 and the lower end of tube 82 are provided with ports 97 and 98, respectively, whereby oil from the reservoir in sleeve 95 can flow freely into the shock absorber to assure the annulus between the inner and outer tubes is always filled. To aid in this and to allow any gas to escape, the upper end of the inner tube can be slotted as at 99 so that fluid and gas can flow freely around piston 83 into the annulus while the shock absorber is in the extended position shown in the drawings.

In describing the operation of the well head apparatus, let it be assumed the apparatus is in the position shown in the drawings. Upon arrival of free piston, its momentum moves the impact head 81 and tubes 79 and 80 upwardly. This movement forces oil through restrictions 84 for flow upwardly through reservoir tube 82 from which it can flow through port 100. During such movement, head 90 is held in fixed position by stop 66 and spring 89. As soon as the free piston has been stopped, spring 89 moves tubes 79 and 80 downwardly until shoulder 85 comes to rest on support member 86. By such time, holding latch 28 has engaged the free piston to prevent it from moving downwardly and the latter has moved trip lever 39 so that the valve member of the pilot valve is moved to block the vent therein and to place the supply S in communication with conduit 57. The resulting pressure on piston 62 moves it downwardly and the first portion of its movement collapses the shock absorber to abut piston 83 with impact head 81. Further movement of the piston applies the reloading force to the free piston to reload the same. During such further movement, spring 88 will be compressed and support member 86 moved away from stop 87 due to the downward movement of outer tube 80. This sequence of movement is due to spring 88 being made stronger than spring 89. Just before piston 62 abuts partitioning member 64 (e. g., when the spacing therebetween is $\frac{1}{8}$ inch and the reloading of the free piston has been completed), piston 62 engages rod head 77a and moves rod 77 downwardly so that valve member 70 is moved by spring 76 to place conduit 36 in communication with conduit 57 and out of communication with vent 73. The resulting application of pressure through conduit 36 causes the holding latch to be tripped whereby the free piston is dropped down the well conduit. Also during the final movement of piston 62, pin 91 has been moved downwardly relative to head 90 to compress spring 92 so that when the free piston is released, spring 92 gives the free piston a downward kick.

After the free piston has been released, trip lever 39 is moved inwardly by spring 42 and such movement rotates arm 55 of the pilot valve in a direction to release spring 53. The spring then urges valve member 51 to seat against insert seat 48 thereby cutting off the supply pressure. At the same time, it is unseated from 52 which opens conduit 57 to vent 56. The resulting reduction in pressure above piston 62 permits spring 88 to move the entire assembly upwardly until stop 87 is reached and also spring 89 to move reservoir tube 82 until head 90 abuts stop 66. During the initial upward movement of piston 62, valve rod 77 is also moved up-

wardly by spring 78 thereby causing valve member 70 to vent conduit 36.

Free piston

In Figs. 6A and 6B, there is shown an embodiment of a free piston adapted to be reloaded by a loading mechanism such as that just described and to be actuated to form a substantially impermeable plug in a tubing responsive to the free piston arriving at a depth in the well having a predetermined static pressure. Thus, the free piston can comprise relatively movable body parts 110 and 111 which are movable to limit and permit flow from one end of the free piston to the other. Such control of flow is here illustrated as being effected by a valve formed by ports 112 and 113 which can be brought into and out of register upon relative movement of the parts. Also, an expansible packer 114 is arranged so that it can form a sliding seal with the tubing when the body parts are in one position and then stretched to disrupt such seal when the body parts are in another position. While the packer is shown here to comprise a rubber element, it is contemplated that suitable expansible metal packers can be employed. At any rate, one end of the packer is connected to outer body part 110 as by means of pin 115 while the other end has an inturned shoulder 116 engageable with a corresponding shoulder on the lower end of inner body part 111. These shoulders are urged into constant abutment by a packer expansion spring 117 which engages the lower end of the packer and an opposing spring retainer ring 118 carried by the outer body part. With this arrangement, movement of the inner body part upwardly moves ports 112 and 113 out of register and at the same time applies force through spring 117 to the lower end of the packer to expand the same. Conversely, downward movement of the inner body part moves the ports in register and also contracts the packer.

Energy storage means in the form of a resilient spring 119 is provided to urge the inner and outer body parts to flow restricting position. Thus, spring 119 abuts one of its ends against a shoulder 120 carried by the inner body part and its other end against shoulder 121 on the outer body part. The inner part has a head 111a which is engageable with the lower end of the shock absorber mechanism described above. The outer part has a shoulder 122 engageable with the holding latch of the surface reloading mechanism so that the outer body part is prevented from moving downwardly as the reloading mechanism applies force to the head 111a and the inner body part to reload the free piston. During such reloading movement, the inner body part moves downwardly and compresses spring 119 to store energy therein.

Means are provided for latching the inner body part in one of its positions relative to the outer body part after the free piston has been reloaded. Here such means is illustrated as including a pair of latch levers 123, each pivoted on a pin 124 carried by the outer body part. The levers are formed with latch portions 125 engageable within a groove 126 in the outer body part. Thus when the latch fingers are in a position shown in Fig. 6A, they prevent actuating spring 119 from causing relative movement between the inner and outer body parts of the free piston.

Means are provided for releasing the latch levers responsive to the free piston being exposed to a predetermined static pressure. Such means can include a latch holding head 127 adapted to be disposed between rollers 128 carried by latch levers 123 to hold the latter in latched position. Also, pressure responsive means are provided for moving the latch holding head to releasing position and can comprise a bellows 129 having one end fixed to inner part 111 and the other end to a movable bellows head 130. The inner body part is formed to provide a pressure charge chamber or dome 131 into which a resilient pressure fluid can be introduced through a charging valve 132. The bellows head carries a guide 133 which

supports the latch release head by means of stem 134. The stem terminates in a head 135 against which a spring 136 acts to urge the latch head 127 to latch holding position.

In operation, let it be assumed that the free piston has its parts disposed in the position shown in Figs. 6A and 6B so that it is just beginning its downward stroke in the well conduit. As the free piston drops, the charge in dome 131 maintains the pressure responsive means and the latch holding head 127 in their downmost position. As the free piston falls through the conduit, the pressure exerted on the interior of the bellows by the well fluid increases. When such pressure increases sufficiently to overcome the force exerted by the dome pressure, bellows head 130 moves upwardly which withdraws latch holding head 127 from between latch levers 123. This will occur at some depth in the well depending upon the well pressure and the amount of charge in dome 131.

Upon withdrawal of the latch holding head, the latch levers swing inwardly by virtue of the force exerted by spring 119 acting across sloping shoulders 125. Spring 119 then moves the inner body part upwardly relative to the outer body part until shoulder 120 strikes stop 138 in the outer body part. Such movement results in port 113 being moved out of register with port 112 and packer 114 expanding. As a result of these movements, the free piston forms a substantially impermeable plug in the well conduit and any flow of fluid through such conduit will cause the piston to move upwardly.

As the free piston moves upwardly, it may be that the well pressure exerted on the interior of bellows 129 will decrease to such an extent that the dome pressure will move the bellows head downwardly. Since the latch fingers are held in their inward position by portion 139 thereof bearing against bore 140, latch holding head 127 cannot move downwardly but instead it remains in abutment with the upper end of the latch levers. Therefore, downward movement of the bellows head compresses spring 136.

Upon the free piston reaching the surface reloading mechanism, holding latch 28 moves in under shoulder 122 and trip lever 39 is moved outwardly to begin the operation of the reloading mechanism as above described. During the reloading, impact head 81 pushes downwardly on head 111a to move the inner body part downwardly. Upon sufficient of such movement occurring, latch levers 123 are positioned so that they can swing outwardly to latching position whereupon spring 136 not only causes them to do so but also moves latch head 127 therebetween to hold them in latched position. Then upon release of the free piston by the reloading mechanism, it drops down the well conduit to begin a new cycle of operation.

It will be noted that while the free piston is dropping, fluid can flow upwardly through bore 141 in the lower portion of the free piston and thence out through ports 112 and 113 to flow to the other end of the piston.

It will also be noted that the magnitude of the charge in dome 131, relative to the static pressure in the well existing at any particular depth, will determine the lower level reached by the free piston before reversing its direction of movement. In this manner, the extent of the free piston's movement can be made to be dependent upon the static pressure existing at some depth in the well.

Referring now to Figs. 8A and 8B, there is shown a free piston similar in many respects to that of Figs. 6A and 6B, the principal difference being that the triggering is by bottom contact instead of increase in static well pressure. Thus, for convenience the latch levers 123 had been moved to a lower position in the free piston and latch holding head 127, instead of being movable by a pressure responsive means, is provided with an extension 142 which is slidably received within a contact pin 143. The latter has a portion 144 extending below the lower end 145 of the outer body part so that such por-

tion can strike a stop in a well such as is schematically illustrated at 146 in Fig. 1. Portion 144 has an annular shoulder 147 against which a spring 148 acts to urge contact pin 143 downwardly in cap 149. Also, the inner body part here is formed as a central spindle 150 which extends downwardly to support a latch lever head 151. The latch levers, of course, are pivoted to this head by means of pins 124 to prevent upward movement of the spindle when the levers are in latching position. A cross pin 152 extends through longitudinal slots 153 in spindle 150 to carry a member 154 having a shoulder abutable with shoulder 116 of the packer. In this instance, the by-pass valve is shown as including an annular sleeve 155 fixed on spindle 150 by webs 155a to be moved upwardly and downwardly by the spindle to permit and restrict flow through ports 112.

In operation, and assuming the free piston has been reloaded and is on its downward journey, fluid can flow up through the annular bore 141 and out through ports 112 to the upper end of the free piston. When the free piston reaches stop 146, portion 144 is moved upwardly to in turn move latch holding head 127 upwardly. This permits latch levers 123 to pivot inwardly thereby releasing the energy stored in spring 119. As a result, the inner body part moves upwardly so that sleeve 155 closes ports 112 and packer spring 117 expands packer 114. The free piston thus forms a substantially impermeate plug in the well tubing and moves upwardly therethrough under the impetus of fluid flowing through the tubing. Upon arrival of the free piston at the surface reloading mechanism, holding latch 28 again moves out under shoulder 122 and the reloading mechanism exerts force downwardly on head 111a to compress spring 119. Such movement also opens port 112 and stretches packer 114. During the initial portion of the reloading movement, latch portions 139 slide along bore 140 so that the latch holding head 127 is held in an upper position with spring 136 compressed. However, when the latch levers have been moved downwardly sufficiently to be able to move outwardly into latching position, spring 136 moves latch holding head 127 between rollers 128 to maintain the latching levers in latched position. Then upon release of the free piston at the well head, it is free to drop down the well to again repeat the cycle.

Another form of free piston constructed in accordance with this invention is one which employs a timing mechanism for determining actuation of the free piston. There are a number of forms such timing mechanism can take and several will be described here to illustrate the principles involved. Thus referring to Fig. 9, the upper portion of the free piston is illustrated while the lower portion including the packer has not been shown. The packer can be constructed of resilient material similar to packer 114 and shaped so that when in an unstressed condition, it is of a diameter to form a suitable sliding seal with the tubing. In the form of the free piston shown in Fig. 9, the packer is not intended to be contracted and expanded mechanically as shown in the previous figures but remains in substantially the same shape throughout the operation of the free piston. In this form, ports 112 and 113 are again disposed in inner and outer body parts but the inner body part is shortened considerably so that it comprises essentially a valve member 160 for port 112. It is urged to one position by spring 161 which bears against the lower end of the valve member and also abuts shoulder 162 on the outer body portion. In this manner, spring 160 has a similar function to spring 119 in Figs. 6A and 6B, for example.

Valve member 160 is held in port opening position by a pair of latch levers 163 which are pivoted on pins 164 carried by the outer body part so that the lower ends 165 thereof can swing into and out of engagement with the upper end 166 of the valve member. The upper end of the latch levers are formed with rollers 167 which, with the latch levers in latching position, overhang a

latch releasing knob 168 carried by rod 169. With this arrangement, upward movement of rod 169 pulls knob 168 between rollers 167 and causes the latch levers to release the valve member. Upon downward movement of rod 169, its lower end abuts the valve member to move it downward against the force of spring 160 and permit the latch levers 163 to move to latching position as shown in Fig. 9.

Connected to the latch release mechanism comprising knob 168 is a timing mechanism which preferably is in a form as to be resettable so that an element thereof moves through a predetermined distance within a predetermined time. Such timing movement is employed to move knob 168 from its Fig. 9 position to its latch releasing position so that after the timing element starts moving, a predetermined time will elapse before the valve member 161 is released to move to port closing position. In the illustrated structure, the timing mechanism takes the form of a timing piston 170 slidably disposed in a cylinder 171 in the outer body member. The timing piston is urged to move through the cylinder in a timing stroke by spring 172 which acts between a partition 173 and a rod head 174 connected to piston 170 by rod 175. The timing piston is also provided with a restricted flow passageway or orifice 176 providing communication from one side of the timing piston to the other. Then upon filling cylinder 171 with an hydraulic fluid, the piston is urged upwardly therethrough by spring 172 at a rate dependent upon the strength of the spring and the size of restricted passageway 176. As a result, the time interval required for knob 168 to move from its Fig. 9 position to its latch lever releasing position can be determined and therefore the time for the free piston to fall to its lower level.

Timing piston 170 is also provided with means for permitting it to move in a retraction stroke (downwardly) at a rapid rate. Such means can take the form of a one-way by-pass 177 controlled by a ball check 177a. With such arrangement, the application of force to the timing piston to move it downwardly permits oil to flow rapidly upwardly through passage 177 and hence the piston to move rapidly downwardly.

The upper end of the free piston comprises a cover head 174a which is adapted to strike a stop, such as a shock absorber, at the well head so that the momentum of the free piston causes timing rod 175 to move downwardly.

In operation, assume the parts of the piston are disposed as shown in Fig. 9 and that the piston is moving downwardly in the conduit. As it so moves, timing spring 172 will move timing piston 170 upwardly in cylinder 171. When timing piston 170 has moved a sufficient distance, knob 168 will cause latch levers 163 to disengage from valve member 160. This results in spring 161 moving the valve member to port closing position. Thereupon, flow of fluid through the well conduit causes the free piston to move upwardly. As the free piston rises, it will eventually strike a stop at the well head and since outer body part 110 and the mechanisms carried thereby may be made to be of considerable mass, they tend to continue upwardly upon head 174a striking the stop. As a result, head 174a and piston 170 move downwardly relative to the outer body part with fluid by-passing the timing piston rapidly through passage 177 and check 177a. During such downward movement, the lower end of rod 169 abuts valve member 160 and moves it downwardly against spring 161. Latch levers 163 then pivot to engage the valve member and hold it in port opening position. At such interval, the free piston is ready to begin its downward movement to start another cycle of operation.

If desired, the momentum operation of the free piston just described can be supplemented by a loading mechanism, such as the one described above, at the surface which will engage the free piston to move the timing

piston downwardly by the application of an external force. Of course, it is desirable to dispense with the loading mechanism where possible since it is much more expensive than a simple stop at the well head.

In some instances, it may be desirable to start the time interval running after the free piston abuts a stop at a lower level in the well. To permit this, a weight 178 can be connected to rod 175 with the weight being of a mass such that upon the free piston striking the lower stop, the momentum of the weight will cause timing piston 170 to move downwardly to its lowermost position but once such momentum is spent, spring 172 can lift the weight to start a new timing stroke of the timing piston. With such construction, it is possible for the free piston to fall for at least a predetermined time through the tubing and then to start its upward journey only after it has rested for such time interval on a bottom stop in the well tubing. If the free piston should not reach the stop within the time interval for which the timing mechanism is set, it will immediately have its latch mechanism tripped and begin its upward stroke.

Referring now to Figs. 10 and 11, there is shown a timing mechanism suitable for use in a free piston of the type shown in Figs. 6A and 6B. Thus, in effect, a timing mechanism is substituted for the pressure responsive tripping mechanism of Fig. 6A and otherwise the parts of the free piston may be substantially the same. Here again, a timing piston 170 is reciprocally disposed in cylinder 171 and is provided with a restricted passageway 176 for timing its movement under force exerted by spring 172. It also has the one-way by-pass permitting rapid movement of the timing piston in a downward direction. However, here piston rod 169 terminates in a T-head 180. Also, latch holding head 181 is slidable upon rod 169 until engaged by the T-head for movement from between latch levers 123. The latch holding head is urged to holding position by spring 182.

The upwardly extending piston rod 175 extends into a cap 183, which is slidably disposed in head 111a, to move the cap to an extended position above head 111a as the timing piston moves through its timing stroke. Then upon the free piston arriving at the surface reloading mechanism, cap 183 strikes the impact head of the shock absorber to move the timing piston downwardly in cylinder 171. During such movement latch holding head 181 remains on top of latch levers 123 and does not move down between them until the reloading mechanism has moved the inner body part downwardly and compressed spring 119. Then the latch levers 123 are free to move outwardly and spring 182 moves the latch holding head 181 between these latch levers to maintain them in latched position. It will be noted that the timing piston cannot begin its upward or timing stroke until the free piston has left the surface of the well but immediately upon so doing, the timing piston begins its timing stroke. Upon lapse of predetermined time, the T-head 180 abuts latch holding head 181 and moves it upwardly out from between the rollers on the latch levers. The latter accordingly can then move inwardly to unlatched position and spring 119 acts to move the two body parts of the free piston to form a substantial imperforate plug in the well tubing.

Referring now to Fig. 12, there is shown a free piston of a construction quite similar to that of Fig. 9 in that the free piston can be loaded by self-impact alone at the well head and the packer is not mechanically stretched or expanded. However, in this instance, valve member 161 is formed with a pressure responsive means, such as piston 190 reciprocally disposed in a cylinder 191 in the free piston. The valve member and piston 190 are urged downwardly to port closing position by spring 192. Restricted passageway or orifice 193 provides communication between cylinder 191 and a point upstream of ports 112 and 113, such point preferably being in a fluid passageway 194 extending in the body of the free piston to its lower end. Ports 194, of considerably

larger flow capacity than that of restricted passageway 193, are provided to communicate between cylinder 191 and a point exteriorly of the piston and preferably downstream of ports 112—113. Flow through ports 194 is controlled by a rod-like valve member 195 which extends from the timing mechanism and has a sliding seal with O-rings 196.

With the parts disposed as shown in Fig. 12 and as the free piston falls through the tubing or well fluid is otherwise caused to flow upwardly past the free piston, a pressure differential exists between the interior of the free piston and the inlets to ports 194. However, with ports 194 closed and the timing mechanism moving through its timing stroke, the pressure in cylinder 191 is equalized with that below piston 190 by flow through restricted passageway 193. Upon the timing mechanism withdrawing valve rod 195 from seal 196, ports 194 will be open and since their capacity is much greater than that of restricted passageway 193, the pressure in cylinder 191 will fall to the lower pressure existing at ports 194. As the result, the higher pressure interiorly of the free piston moves the valve member and piston 190 upwardly against spring 192 to close ports 112—113. The valve member remains in this closed position until the free piston arrives at the well head to reset the timing mechanism. Upon such resetting, valve rod 195 again seals off ports 194 so that the pressure within cylinder 191 is equalized with that in the interior of the free piston thereby permitting spring 192 to move and hold valve member 161 to port opening position. Thereupon, the free piston is free to fall down the tubing to begin another operating cycle.

While the timing mechanisms and pressure responsive tripping mechanisms have been herein illustrated as useful with pistons which are reloaded by an external loading mechanism at the surface of the well or by momentum of the free piston, they can also be employed with the self-contained pistons shown in our co-pending application identified above. Also, the temperature actuated tripping mechanism shown in such co-pending application can be substituted for the tripping mechanisms shown in this application to provide an externally reloaded temperature tripped free piston.

From the foregoing it will be seen that this invention is one well adapted to attain all of the ends and objects hereinabove set forth, together with other advantages which are obvious and which are inherent to the apparatus and system.

It will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and is within the scope of the claims.

As many possible embodiments may be made of the invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

The invention having been described, what is claimed is:

1. A free piston adapted to reciprocate between upper and lower levels in a well conduit which comprises, in combination, piston body means including flow control means movable between two positions to limit and permit flow from one end of the free piston to the other, energy storage means urging the flow control means to one of its positions, said piston body means including means engageable with an instrumentality exteriorly of the free piston for moving the flow control means to its other position upon arrival of the free piston at one of said levels and by such movement causing energy to be stored in said storage means, a disengageable latch mechanism holding the flow control means in said other position when moved thereto, and means for disengaging

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said latch mechanism including trigger means movable to cause disengagement of the latch mechanism, said trigger means having means to contact with a trigger trip means carried by the well conduit at the other of said levels so that upon arrival of the free piston at said other level, the trigger means is caused to move by the trigger trip means to cause disengagement of the latch mechanism.

2. A free piston adapted to reciprocate between upper and lower levels in a well conduit which comprises, in combination, piston body means including parts movable relative to each other to control flow from one end of the free piston to the other, energy storage means connected between the parts to urge them in relative movement in one direction, said parts also being relatively movable in an opposite direction responsive to arrival of the free piston at one of said levels so as to store energy in the energy storage means by reason of such relative movement, a latch mechanism engageable between the parts upon predetermined relative movement thereof in said opposite direction to limit their movement in said one direction but being disengageable to permit the parts to move in said one direction, and means responsive to the arrival of the free piston at its other level for disengaging the latch mechanism independently of rate of flow of fluid in the well conduit past the free piston.

3. A free piston adapted to reciprocate between upper and lower levels in a well conduit which comprises, in combination, piston body means including parts movable relative to each other between first and second positions to limit and permit flow from one end of the free piston to the other, energy storage means connected between the parts to urge them toward said first position, means for causing movement between the parts to said second position responsive to arrival of the free piston at one of said levels and connected to the energy storage means to cause energy to be stored therein by means of such relative movement, a releasable latch mechanism engageable with the parts upon their movement to said second position and preventing their movement to said first position, and means movable to release said latch mechanism including a timing mechanism having an element movable through a predetermined distance during a predetermined time interval and connected to said releasing means to cause movement of the same to release the latch mechanism upon lapse of said predetermined time interval.

4. The free piston of claim 3 wherein said timing mechanism includes a fluid chamber, and element movable relative to the chamber to vary the volume thereof, one of said chambers and element being connected to said latch mechanism releasing means to move the same to releasing position upon movement of the element in one direction to cause a predetermined change in volume of said chamber, and a restricted flow passageway communicating with said chamber and limiting flow so that said predetermined volume change occurs during said predetermined time interval.

5. The free piston of claim 4 wherein said element comprises a piston in said chamber and wherein means are provided for rapidly transferring fluid from one side of the piston to the other upon movement of the piston in an opposite direction.

6. In a free piston adapted to reciprocate between upper and lower levels in a well conduit and having parts movable relative to each other between two positions to limit and permit flow from one end of the free piston to the other and wherein means are provided to urge relative movement of the parts toward one position, a releasable latch normally preventing such movement of the parts toward said one position, a mechanism for releasing the latch including means movable to release the latch, timing means having an element movable through

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a predetermined distance during a predetermined time interval, and a connection between said element and said movable means causing the latter to move to latch releasing position upon movement of said element through said predetermined distance.

7. In a free piston adapted to reciprocate between the upper and lower levels in a well conduit and having the parts which are relatively movable between two positions to limit and permit flow from one end of the free piston to the other and wherein means are provided to urge the parts in movement toward one position, a releasable latch normally preventing such movement of the parts toward said one position, a mechanism for releasing the latch including means movable to release the latch, timing means having an element movable through a predetermined distance in one direction during a predetermined time interval and through such distance in another direction during a shorter time interval, means for moving said element in said another direction responsive to the arrival of the free piston at one of said levels, and a connection between said element and said movable means causing the latter to move to latch releasing position upon movement of said element in said one direction through said predetermined distance.

8. The free piston of claim 7 wherein said element is a piston reciprocal in a fluid cylinder, resilient means urging the piston in said one direction, a restricted fluid passageway communicating between opposite ends of said cylinder for timing the piston's movement in said one direction, and a one-way fluid bypass means around the piston permitting its rapid movement in said other direction.

9. In a free piston adapted to reciprocate between upper and lower levels in a well and having parts movable relative to each other to a first position to permit flow past the free piston as it moves downwardly and also movable to a second position to restrict flow past the free piston so it can be moved upwardly, motor means for moving the parts to their second position upon the free piston reaching its lower level, latch means carried by one of the parts and engageable with the other part when in said first position to prevent movement to said second position and including a detent holding the latch means in latched position and actuatable to release the latch means, a cylinder in the body means, a timing piston reciprocal in said cylinder, means urging the timing piston in one direction, means for moving the timing piston in the other direction responsive to the free piston arriving at one of said levels, a restricted fluid passageway communicating between opposite ends of the cylinder to time the timing piston's movement in said one direction, one-way fluid bypass means around the timing piston permitting rapid movement thereof in the other direction, and a lost motion connection between said detent and said timing piston permitting the latter to move a predetermined distance in said one direction whereupon it actuates the detent to release the latch means and also permitting the timing piston to move in said other direction without moving the detent so that said timing piston can be moved in said other direction prior to the latch means moving to latching position.

10. The free piston of claim 9 wherein said motor means comprises resilient means connected between the parts to urge them to said second position and wherein the parts are provided with means engageable by an instrumentality at the upper level to move them to said first position.

11. The free piston of claim 10 in combination with means situated adjacent the upper end of said conduit and operable responsive to the arrival of the free piston at such end to engage said engageable means on said parts and apply force thereto to move the parts to said first position, said means for moving the piston in said

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other direction also being moved responsive to the arrival of the free piston at said upper end.

12. In a free piston adapted to reciprocate between upper and lower levels in a well conduit and having parts movable relative to each other between two positions to limit and permit flow from one end of the free piston to the other and wherein means are provided to urge the parts in movement toward one position, a releasable latch normally preventing movement of the parts toward said one position when the parts are in said other position, a mechanism for releasing the latch mechanism including timing means having an element moved through a predetermined distance during a predetermined time interval and upon movement through such distance causing release of the latch mechanism, said timing means being resettable to again start said element moving through said predetermined distance, and means for resetting the timing mechanism responsive to arrival of the free piston at one of said levels.

13. The free piston of claim 12 wherein said resetting means includes a weight movable to reset the timing means, said weight being movable relative to one of the body parts which is adapted to strike a stop in the well conduit so that upon such part striking the stop, the momentum of the weight causes the weight to move relative to such part and apply force to the timing means to reset the same.

14. In a free piston adapted to reciprocate between upper and lower levels in a well conduit, body means having a fluid passageway through at least a portion thereof to permit flow from one end of the free piston to the other, a valve member movable between open and closed positions to control flow through the passageway, resilient means urging the valve member to one of its positions, a latch carried by one of the body means and valve member and engageable with the other to hold the valve member in its other position, and means for releasing the latch part after a predetermined time interval including a cylinder, a timing piston movable in the cylinder, means urging the piston to move in one direction, a restricted fluid passageway communicating between opposite ends of said cylinder to time movement of the timing piston in one direction, one-way flow means communicating between opposite ends of the timing piston and permitting rapid movement of the timing piston in its other direction, means connected to the timing piston for moving the latch to released position upon movement of the timing piston through a predetermined distance in said one direction, and a member connected to the timing piston and movable relative to the body means for moving the timing piston in said other direction responsive to arrival of the free piston at one of said levels.

15. The free piston of claim 14 wherein said means for moving the latch to released position includes a rod connected to the timing piston, an abutment carried by the rod to engage the latch and move it to released position upon movement of said timing piston through said predetermined distance, said rod extending for abutment with the valve member to move it to its other position responsive to movement of the timing piston in said other direction and at the same time moving the abutment out of engagement with the latch whereby the latter can engage the valve member to hold it in its other position.

16. In a free piston adapted to reciprocate between upper and lower levels in a well conduit and having parts movable relative to each other between two positions to limit and permit flow from one end of the free piston to the other and wherein means are provided to urge the parts toward one of such positions, a releasable latch normally preventing movement of the parts toward said one position, a mechanism for releasing the latch including an element for holding the latch in latching

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position and movable to release the same, and pressure responsive means for moving the element to latch releasing position responsive to a predetermined change in static pressure exteriorly of the free piston.

17. The free piston of claim 16 wherein said pressure responsive means includes a charge chamber defined in part by a pressure responsive member, said pressure responsive member being exposed on one side to the interior of the charge chamber and on the other side to pressure fluid exteriorly of the free piston.

18. The free piston of claim 17 wherein said pressure responsive member has a lost motion connection with the element holding the latch in latching position and means urging the element towards latch holding position.

19. A free piston adapted for reciprocal movement between upper and lower levels in a well conduit which comprises, in combination, piston body means including two parts movable relative to each other to permit and limit flow between opposite ends of the free piston, resilient means connected between the parts urging them toward flow limiting position, said parts having portions engageable by an instrumentality at the upper level to apply force thereto to move the parts to flow permitting position, such movement also causing energy to be stored in said resilient means, a latch mechanism engageable between the parts to hold them in flow permitting position in opposition to force applied thereto by said resilient means, means for releasing the latch mechanism including a pressure responsive means exposed on one side to static pressure exteriorly of the free piston and movable responsive to an increase in said static pressure to release the latch mechanism, and means isolating the other side of the pressure responsive means from said static pressure so that said increase in static pressure will be effective to release the latch mechanism independently of the rate of fluid flow in said conduit past the free piston.

20. A free piston adapted for reciprocal movement between upper and lower levels in a well conduit which comprises, in combination, piston body means including two parts movable relative to each other to permit and limit flow between opposite ends of the free piston, resilient means connected between the parts urging them toward flow limiting position, said parts having portions engageable by an instrumentality at the upper level to apply force thereto to move the parts to flow permitting position, such movement also causing energy to be stored in said resilient means, a latch mechanism including a pair of dogs movable toward and away from each other between latching and unlatching positions, the dogs in latching position engaging between the parts to hold them in flow permitting position in opposition to force applied thereto by said resilient means and in unlatching position permitting movement of the parts to flow limiting position, a detent holding the dogs in one of their positions and movable to permit the dogs to move to their other position, the dogs when in said other position preventing the detent from moving to holding position, a pressure responsive means exposed to static pressure exteriorly of the free piston and movable responsive to an increase in said static pressure, a limited sliding connection between said pressure responsive means and said detent causing the latter to be moved from holding position upon predetermined movement of said pressure responsive means in one direction and permitting movement of the pressure responsive means in an opposite direction without movement of the detent, and resilient means urging the detent toward holding position.

21. A free piston adapted to reciprocate between upper and lower levels in a well conduit which comprises, in combination, body means having a fluid passage therein through which fluid passes in flowing from one end of the free piston to the other, valve means controlling flow through said passage including a valve member movable

to open and close the passage, a piston connected to the valve member and reciprocal in a cylinder in the body means, a restricted fluid passageway communicating between said cylinder and said fluid passage, port means communicating between said cylinder and the exterior of the free piston at a point above the valve member, said port means having a substantially greater flow capacity than said restricted passageway, a valve element controlling through said port means, and timing means connected to said valve element to move it to port opening position after a predetermined lapse of time.

22. A free piston adapted to reciprocate between upper and lower levels in a well conduit which comprises, in combination, body means having a fluid passage therein communicating between one end of the free piston and a point intermediate the ends thereof, a port in the body means communicating between the exterior thereof and said fluid passage, a valve member movable to open and close said port, a piston reciprocal in a cylinder in said body means and connected to said valve member to move the same to port opening and closing positions, resilient means urging the valve member to one of its positions, a restricted fluid passageway communicating between said cylinder and said fluid passage, port means communicating between said cylinder and the exterior of the free piston, a valve element for opening and closing said port means, and timing means connected to said valve element to move it from one of its port opening and port closing positions to the other of such positions upon the lapse of a predetermined time interval.

23. A free piston adapted to reciprocate between upper and lower levels in a well conduit which comprises, in combination, body means providing a fluid passage from one end to the other thereof, a valve member controlling flow through said passage, pressure responsive means for moving said valve member between open and closed positions, and means for varying the pressure differential applied to said pressure responsive means to cause movement of the valve member including a first passageway communicating between opposite sides of said pressure responsive means to tend to reduce the pressure differential applied thereto, a second passageway of larger flow capacity than the first passageway communicating with one side of the pressure responsive means and a point remote from the other side thereof and at which pressure in operation is different from that at said other side, and means for opening and closing said second passageway upon the free piston arriving at one of said levels.

24. The free piston of claim 23 wherein the last-mentioned means includes a timing mechanism operable and effective to open said second passageway upon the lapse of a predetermined time.

25. The free piston of claim 23 wherein the last-mentioned means includes a timing mechanism operable and effective to close said second passageway upon the lapse of a predetermined time.

26. In an apparatus for reloading a free piston at the surface of a well, a housing, a shock absorbing mechanism including first and second parts the first of which in a first position is exposed for impact by the free piston to be moved thereby upwardly to a second position in stopping the free piston, first resilient means connected to the housing and the first part to support the latter in impact receiving position, second resilient means between the parts urging the second part upwardly and the first downwardly, power means for moving the second part downwardly to collapse the shock absorber and then to move both parts downwardly together to reload the free piston, and means responsive to the arrival of the free piston at the housing for actuating said power means and for holding the free piston while it is reloaded.

27. The apparatus of claim 26 wherein said first resilient means connection includes a support urged upwardly by the first resilient means against a stop carried by the housing, said support engaging a stop on the first

part so as to limit downward movement thereof without moving the first resilient means but to permit it to move upwardly relative to the support.

28. Apparatus for pumping liquid from a well by gaseous pressure comprising, in combination: a free piston reciprocable between upper and lower levels in a well conduit and having parts movable relative to each other between two positions to permit and restrict flow from one end of the free piston to the other, energy storage means urging the parts toward one of such positions, latch means engageable between the parts to hold them in the other of their positions against force exerted by said energy storage means, means including a timing mechanism operable to release the latch means upon the lapse of a predetermined time after the free piston leaves the upper level or arrives at the lower level and independently of rate of fluid flow in said conduit past the free piston; and means at the surface of the well engageable with said parts to move them to said other position responsive to the arrival of the free piston at said upper level.

29. Apparatus for pumping liquid from a well by gaseous pressure comprising, in combination: a free piston reciprocable between upper and lower levels in a well conduit and having parts movable relative to each other between two positions to permit and restrict flow from one end of the free piston to the other, energy storage means urging the parts toward one of such positions, latch means engageable between the parts to hold them in the other of their positions against force exerted by said energy storage means, means including pressure responsive means operable to release the latch means upon the free piston being exposed to a predetermined pressure in said conduit at said lower level and independently of rate of fluid flow in said conduit past the free piston; and means at the surface of the well engageable with said parts to move them to said other position responsive to the arrival of the free piston at said upper level.

30. Apparatus for pumping liquid from a well by gaseous pressure comprising, in combination: a free piston reciprocable between upper and lower levels in a well conduit and having parts movable relative to each other between two positions to permit and restrict flow from one end of the free piston to the other, energy storage means urging the parts toward one of such positions, latch means engageable between the parts to hold them in the other of their positions against force exerted by said energy storage means, means including a part engageable with a stop in said conduit at said lower level and movable thereby to cause release of said latch means independently of rate of fluid flow in said conduit past the free piston; and means at the surface of the well engageable with said parts to move them to said other position responsive to the arrival of the free piston at said upper level.

31. In a free piston adapted to reciprocate between upper and lower levels in a well conduit and having parts movable relative to each other between two positions to limit and permit flow from one end of the free piston to the other and wherein means are provided to urge the parts in relative movement toward one position, a releasable latch preventing such movement of the parts toward said one position, timing means having said element movable through a predetermined distance during a predetermined time interval, said element being connected to said latch to move the latch to latching position upon movement of said element through said predetermined distance.

32. In a free piston adapted to reciprocate between upper and lower levels in a well conduit and having parts movable relative to each other between two positions to limit and permit flow from one end of the free piston to the other and wherein means are provided to urge the parts in relative movement toward one of said positions, a

releasable latch preventing such movement of the parts toward said one position, a trigger carried by the free piston and engaging the latch and having means to hold the latch in latching position, said trigger being movable to release said latch and permit it to move to unlatched position and having a part exposed for impact with a means carried by the well conduit to move the trigger to latch releasing position.

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