

April 16, 1968

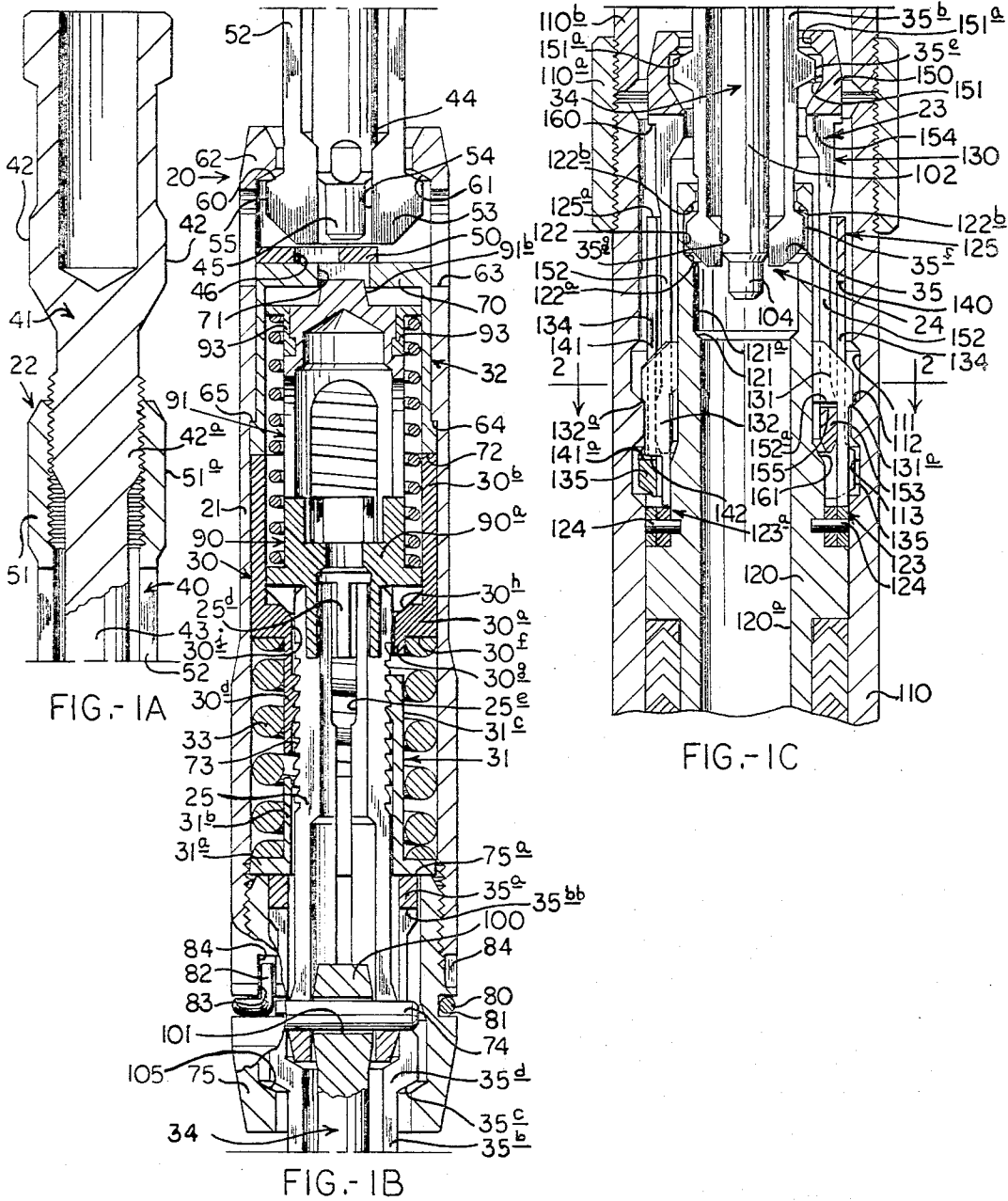
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3,378,080

FLUID PRESSURE OPERATED ACTUATED OPERATOR TOOL FOR WELL TOOLS

Filed Sept. 13, 1965

4 Sheets-Sheet 1



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4 Sheets-Sheet 2

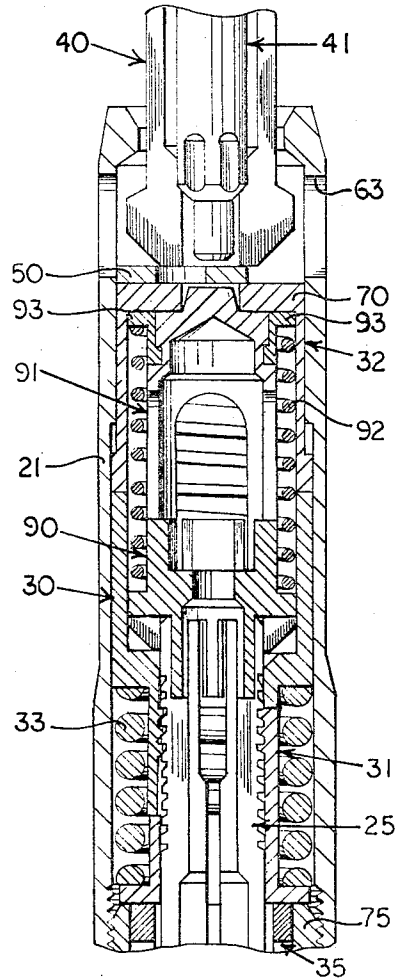


FIG.-4

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FLUID PRESSURE OPERATED ACTUATED OPERATOR TOOL FOR WELL TOOLS

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4 Sheets-Sheet 3

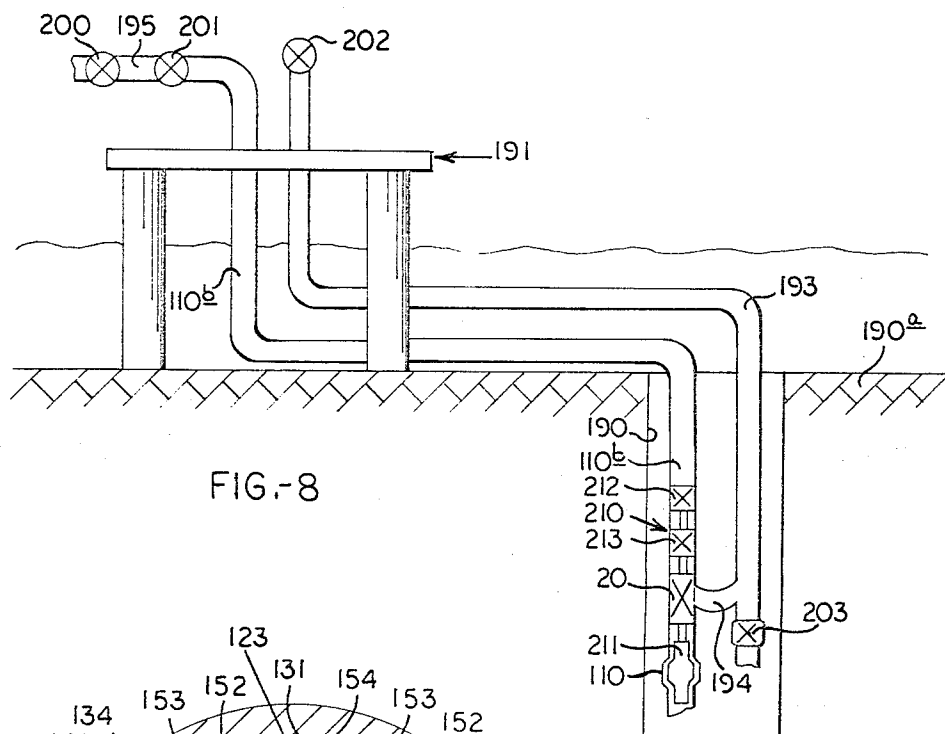


FIG.-8

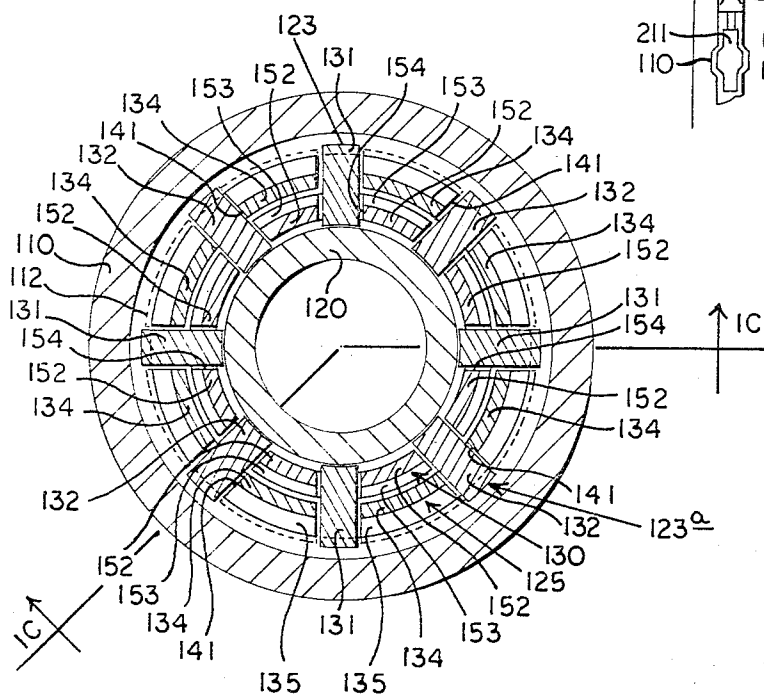


FIG.-2

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FLUID PRESSURE OPERATED ACTUATED OPERATOR TOOL FOR WELL TOOLS

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4 Sheets-Sheet 4

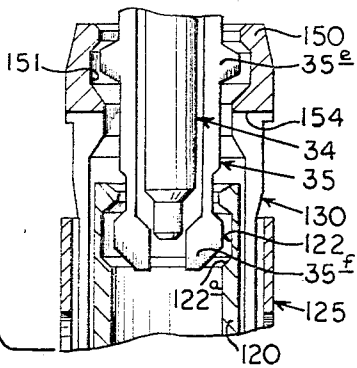
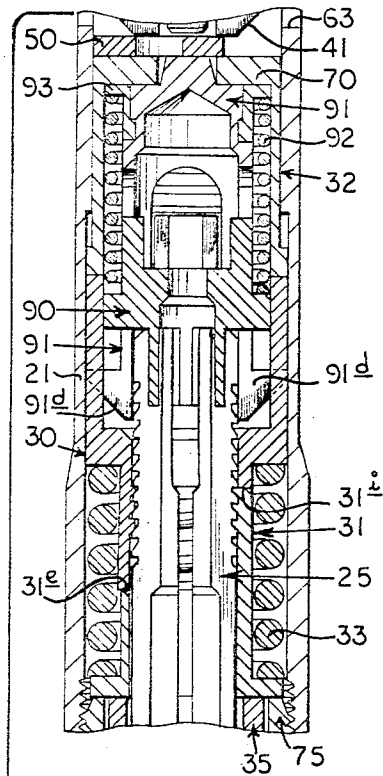


FIG.-5

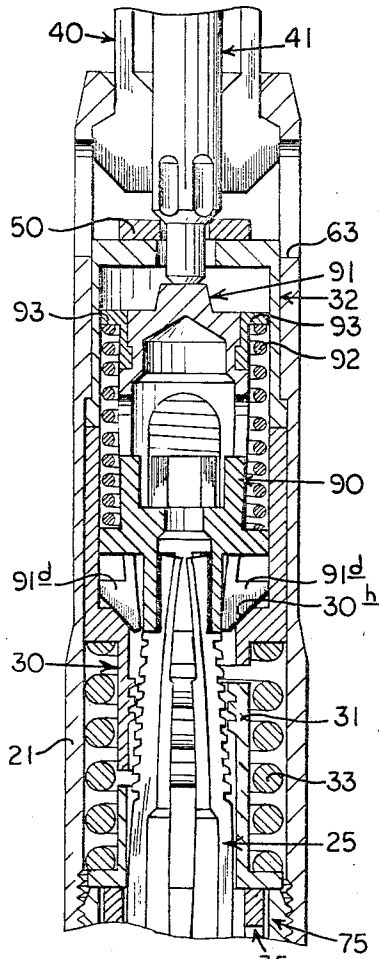


FIG.-6

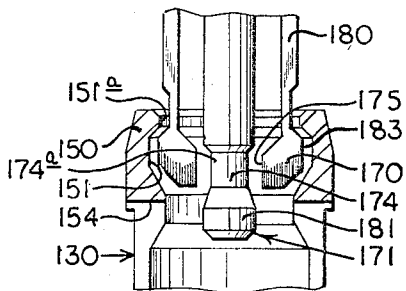


FIG.-7

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## FLUID PRESSURE OPERATED ACTUATED OPERATOR TOOL FOR WELL TOOLS

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Filed Sept. 13, 1965, Ser. No. 486,641

18 Claims. (Cl. 166—156)

### ABSTRACT OF THE DISCLOSURE

A fluid pressure actuated operator tool for use in wells for running, setting and pulling well tools in a well, and for actuating tools therein in response to fluid pressure pulses generated across the tool.

This invention relates to well tools and more particularly relates to an operator tool for installing and removing various well devices.

It is a principal object of this invention to provide a new and novel operator tool for installing well devices in and removing well devices from a landing nipple connected in a tubing string of a well.

It is another object of the invention to provide a running and pulling tool which is connected in a train of tools pumped by fluid pressure between a wellhead and a desired location within a well bore at which well devices are installable in and removable from a landing nipple connected in a tubing string in a well.

It is still another object of the invention to provide a running and pulling tool which is remotely actuatable by application of force pulses to the upper end of the tool from either a mechanically or hydraulically actuated unit engaged with the upper end of the tool.

It is a still further object of the invention to provide a running and pulling tool which is actuatable between a plurality of positions for connecting and disconnecting said tool and a well device supported from said tool on a ratchet mechanism.

It is a still further object of the invention to provide a running and pulling tool which is operable by a series of force pulses applied to the tool independent of the rate or smoothness with which the force pulses are developed and applied.

It is still another object of the invention to provide a force pulse actuated running and pulling tool which is not rendered inoperative by force pulses which exceed the force required to operate the tool.

It is a further object of the invention to provide a force pulse operated running and pulling tool which remains in each of its locked and unlocked positions during several cycles of operation to permit the tool to be forced past obstructions in the tubing string when moving the tool to the desired location in a well bore.

It is a still further object of the invention to provide a force pulse actuated operator tool which when serving a pulling function is releasable without shear pins from the well device to which it is secured when the well device is stuck in the well.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of a device constructed in accordance with

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the invention, and reference to the accompanying drawings thereof, wherein:

FIGURES 1A and 1B taken together constitute a longitudinal view in section of a major portion of an operator tool according to the invention, including the upper ends of the running collet and prong;

FIGURE 1C is a longitudinal view in section along the line 1C—1C of FIGURE 2 of the lower portions of the running collet and prong of the tool of FIGURES 1A and 1B when engaged with a well tool being set in a landing nipple of a tubing string;

FIGURE 2 is a view in section along the line 2—2 of FIGURE 1C;

FIGURE 3 is an exploded view in perspective of the principal components of the ratchet operating and reset assembly employed in the well tool of FIGURE 1;

FIGURE 4 is a fragmentary view in section of the ratchet operating and reset assembly during an intermediate stage of operation of the tool while connecting the tool with a well device to be installed by it;

FIGURE 5 is a fragmentary view in section showing the ratchet operating and reset assembly and the running collet and prong when the prong is lifted by the jack rod substantially to the unlocked position;

FIGURE 6 is a fragmentary view in section showing the ratchet and reset assembly during the initial step of the reset procedure;

FIGURE 7 is a fragmentary view in section of the lower end of the tool illustrating the pulling collet and prong used in removing a well device from a landing nipple; and

FIGURE 8 is a diagrammatic view in section and elevation illustrating a well system in which the running and pulling tool of the invention is used.

The invention has to do with well installations utilizing fluid pressure circulated through two flow courses to insert and remove tools therein, and is directed to an operator tool for supporting and manipulating well tools in the flow conductor which can be controlled from the surface by means of the force of fluid pressure pulses applied across the operator tool to cause the same to actuate through a predetermined series of cycles to effect the desired operation in the well. The operator tool is provided with a plurality of ratchet-like teeth on an actuator rod and a plurality of mating teeth on an actuating sleeve. A spring biases the sleeve longitudinally with respect to the rod, and upon movement of the sleeve compressing the spring, as a result of force applied by fluid pressure to a member connected with the sleeve, the sleeve is depressed one ratchet interval and will, upon release or reduction of pressure differential force, move the actuator rod a distance equal to the one ratchet interval of compression of the spring. In this manner, a predetermined number of cycles will cause a predetermined movement of the actuator rod to effect the desired operation of connecting means at one end of the tool, whereby the tool is actuated in response to fluid pressure force impulses applied thereto in the well conductor to cause the desired longitudinal movement of the actuator rod and the well tool connected to the operator tool.

Referring to FIGURES 1A—1C and 2, an operating tool 20 includes a tubular body 21 suspended from an operator rod and collet assembly 22 used in supporting and operating this tool. A well device 23, such as a safety valve which is installed and removed by the tool 20, is

connected to the tool by a running collet and prong assembly 24 supported from and operated by a jack rod 25 which is lifted between positions by a lift ring 30 and retained at each position by a hold ring 31. The lift ring is forced downwardly by the plunger cap 32 against a lift spring 33 and is returned upwardly by the spring to raise the jack rod to shift the running collet and prong assembly 24 between locking and unlocking positions by lifting a running prong 34 relative to a running collet 35.

Referring to FIGURE 1A, the assembly 22 includes a supporting and operating collet 40 threaded over an operator rod 41. A suitable coupling, not shown, is connected with or formed on the upper end of the operator rod for pivotally connecting the operator tool at the lower end of a series of other tools forming an articulated train of tools which can traverse a pipe string having sections curved on radii of as little as 60 inches or less. The operator rod has a plurality of longitudinal outside flat surfaces 42 circumferentially spaced around the rod for the engagement of a tool such as a wrench for manual rotation of the rod relative to the collet 40. The operator rod is rotatably secured through the collet by the externally threaded intermediate section 42a below which the rod is reduced in diameter along a section 43 which near its lower end is provided with a plurality of flat detent surfaces 44. A cylindrical lower end section 45 of the operator rod is extendable below the lower end of the collet 40 and through a central opening 46 in a floating washer 50 during the reset step of the operation of the tool as will be explained hereinafter.

The collet 40 includes an internally threaded head section 51 from which a plurality of collet fingers 52 extend. Each of the collet fingers has a head 53 with an internal boss 54 and an external boss 55. The inner bosses 54 interfere with the detent surfaces 44 when the operator rod is rotated to provide a detent holding the operator rod against rotation in the collet until the heads 53 are cammed outwardly enough to permit rotation of the operator rod. The external boss 55 on each collet finger has an upwardly and outwardly facing shoulder 60 to engage a downwardly facing internal annular shoulder 61 formed by an inwardly extending internal annular flange 62 within the upper end of the body 21. A plurality of flat longitudinal surfaces 51a are formed on and circumferentially spaced around the collet head 51 for engagement of a wrench or similar tool during the procedure of connecting the operating tool with the well device 23.

The upper end section of the body 21 has at least two lateral windows 63 circumferentially spaced 180 degrees apart for access to the floating washer 50 so that the washer may be manipulated into the desired positions when securing the well tool with the well device 23.

The plunger cap 32 slidably fits within the body 21 and is held against upward movement by an internal annular shoulder 64 within the body which engages an external annular shoulder 65 on the plunger cap. The top portion 70 of the plunger cap has a central opening 71 through which the lower end section 45 of the operator rod 41 is extendable when the floating washer 50 is properly aligned, as will be explained hereinafter.

The lower end surface 72 of the plunger cap is engaged with the upper end of the lift ring 30 which is biased upwardly against the plunger cap by the lift spring 33. The lift ring includes a base ring 30a and a plurality of upwardly extending cylindrical segments 30b which are uniformly spaced around the base ring and spaced apart from each other forming the upwardly opening longitudinal slots 30c. The outer surfaces of the cylindrical segments 30b fit in sliding relationship within the body 21 below the annular shoulder 64. The lift ring also includes a pair of oppositely positioned lift fingers 30d in the form of cylindrical segments extending downwardly from the base ring 30a so that a plurality of horizontal teeth 30e along the inside of each finger are engageable with a plurality of horizontal external teeth

73 on the jack rod finger 25b when the lift ring is raised. The lift ring fingers fit over the jack rod fingers within the lift spring. The combined flexibility of the lift ring fingers and the jack rod fingers allow the lift fingers to move downwardly over the jack rod fingers. The lift fingers are positioned inwardly on the base ring to provide a downwardly facing external annular shoulder 30f around the base ring to permit the upper end of the spring 33 to seat against the base ring, as best seen in FIGURE 1B. A short downwardly extending circumferential skirt 30g is formed on the bottom face of the base ring 30a extending circumferentially between the lift fingers to hold the lift spring away from the jack rod along the spaces between the lift fingers around the seat 30f so the spring will not tend to become entangled with the jack rod teeth. An inwardly and upwardly facing internal annular cam surface 30h is formed on the base ring around its bore 30j.

The jack rod 25 comprises a ring 25a supporting a plurality of upwardly extending fingers 25b each of which is in the shape of a segment of a cylinder and provided with a plurality of external horizontal teeth 73. A pair of oppositely positioned fingers 25d are engageable by the lift fingers 30d to raise the jack rod. A pair of oppositely positioned laterally opening holes 25c in the base ring 25a receive a pin 74 which engages the running collet and prong assembly 24 as will be discussed in more detail hereinafter. The fingers 25d are evenly spaced circumferentially around the ring 25a and are spaced apart from each other so that a longitudinal upwardly opening slot 25d is provided between each pair of adjacent fingers to permit the fingers to flex sufficiently for the proper engagement and disengagement of the teeth on the jack rod and the teeth of the lift and hold rings. Each slot 25d is slightly enlarged along its upper end section 25e by a reduction in size of each of the jack rod fingers along such section.

The hold ring 31 is held within the body around the jack rod by an annular retainer 75 which is threaded into the lower end section of the body and held against rotation relative to the body by a resilient wire clip 80 which fits around the retainer in an external annular locking recess 81. The clip 80 has one end 82 which is bent normal to the circular main body of the clip to fit through one of several slots 83 formed in the retainer above the recess 81 into one of a plurality of longitudinal downwardly opening slots 84 formed at the lower end of the body 21. A sufficient even number of slots is formed in one of the members and odd number in the other so that when the retainer is threaded into the body to the desired degree of tightness there will be at least one slot 83 opening into a slot 84 to receive the end 82 of the wire clip to hold the retainer against rotation in the body.

The hold ring 31 comprises a horizontal base ring 31a the lower face of which rests on the upper end 75a of the retainer 75 and the upper face of which supports the lower end of the lift spring 33. An upwardly extending cylindrical ring 31b is formed on the base ring and supports two hold ring fingers 31c each of which is in the shape of a cylindrical segment and has a plurality of internal horizontal teeth 31d. The hold fingers are evenly spaced apart from each other and each finger engages one of an oppositely positioned pair of the jack rod fingers 25b while the lift ring fingers 30d engage the other two oppositely positioned jack rod fingers. The hold ring fingers mesh between the lift ring fingers with the upper ends of the hold ring fingers being engageable with the lower edge 30i of the lift ring and the lower ends of the lift ring fingers being simultaneously engageable with the upper edge 31e of the ring 31b of the hold ring to limit the relative movement of the lift ring toward the hold ring. The lift and hold rings are spaced apart from each other within the body a sufficient distance to allow the lift ring to move downwardly the length of one and one-half teeth on the jack rod fingers before they engage

each other. By so dimensioning and positioning the lift and hold rings the lift ring will advance the length of one full tooth during each cycle of operation as will be discussed in more detail hereinafter.

A reset cap 90 is supported on the upper end of the jack rod to provide a means for engaging and pushing the jack rod downwardly during the reset procedure. The reset cap comprises a cylindrical core or ring 90a on which are formed a plurality of radially extending circumferentially spaced quadrantal flanges or brim 90b, upwardly extending cylindrical fingerlike segments 90c, and downwardly extending quarter-cylindrical shaped fingers 90d. The spaced apart relationship of the quadrantal flanges form circumferentially spaced outwardly opening slots 90e between the flanges. The reset cap is supported on the upper ends of the jack rod fingers 25b with the fingers 90d being received in the recesses 25d between the jack rod fingers to orient the reset cap and the jack rod relative to each other. The fingers 90d are smaller in cross section than the recesses 25d so that the jack rod fingers may be cammed radially inwardly during the lifting and resetting of the jack rod.

A reset collet 91 is disposed within the plunger 32 and the lift ring 30 over the reset cap and the upper end section of the jack rod. The reset collet has a head section 91a with a centrally located upwardly extending guide lug 91b which is tapered upwardly and inwardly so that the upper end section of the lug is receivable within the opening 71 through the cap member 32 when the reset collet is in the upper position illustrated in FIGURE 1. A plurality of downwardly extending circumferentially spaced collet fingers 91c extend from the head section. Each of the reset collet fingers has a radially outwardly extending head 91d with a lower cam surface 91e and an upper shoulder surface 91f. A reset spring 92 is disposed around the reset collet and confined between the upwardly facing shoulders 91f on the collet finger heads and two semicircular lock ring segments 93 which are disposed within the spring around the head of the reset collet. The upper end of the reset spring engages the lower face of an outwardly extending flange 93a on each lock ring segment. An internal flange 93b within each lock ring segment is received in an external annular locking recess 91g around the reset collet head 91a to hold the lock ring segments against longitudinal movement on the collet head while the reset spring fitting around the segments keeps the segments in place on the head.

The reset cap is raised and lowered by the jack rod within the reset collet during operation of the tool. The quadrantal flanges 90d on the reset cap fit between the reset collet fingers 91c to orient the reset collet with respect to the jack rod so that each reset collet finger is aligned with the outer toothed surface of a jack rod finger and thus inward movement of each reset collet finger will force the corresponding jack rod finger inwardly during the reset operation. When the jack rod is lifted farther into the reset collet to a position at which the upper face of each of the quadrantal flanges 90b is above the upper shoulders 91f on the heads of the reset collet fingers, the quadrantal flanges engage the lower end of the reset spring to compress the spring and lift the lower end of the spring above the shoulders on the reset collet finger heads. The lower cam surface 91e on each reset collet head is engageable with the upwardly facing cam surface 30h of the lift ring to cam the reset collet fingers inwardly when the reset collet is forced downwardly toward the lift ring during the reset procedure, as will be discussed hereinafter. Each reset collet head 91d extends radially outwardly through a recess 30c between the cylindrical segments 30d of the lift ring thereby orientating the lift ring relative to the jack rod since the reset collet is interlocked with the reset cap which meshes with the jack rod.

As illustrated in FIGURES 1B and 1C, the operator

tool is equipped with the running collet and prong assembly 24 which includes the running control prong 34 and the running locking collet 35. The running prong has a head section 100 provided with a lateral bore 101 to receive the pin 74 for holding the prong head within the lower end section of the jack rod. The running prong is substantially uniform in diameter along an intermediate section 102 comprising a major portion of its length which when disposed within the running collet finger heads holds them in a "fully locked" position. A reduced lower end section 104 on the running collet when disposed within the running collet finger heads allows them to be cammed inwardly to a "half-locked" position. The running collet 35 includes a head ring 35a from which a plurality of collet fingers 35b depend. The collet fingers are circumferentially spaced around the head ring providing downwardly opening slots 35bb between the fingers to permit the fingers to expand and contract between locked and unlocked positions. The outer end sections of the pin 74 are received in the slots 35bb between the collet fingers 35b while the collet is held against downward movement by engagement of an upwardly facing internal annular shoulder 105 within the retainer ring 75 with a downwardly facing surface 35c on a collet boss 35d on each collet finger. Each running collet finger has a central outwardly extending boss 35e and a lower external boss 35f. A lower internal boss 35g is formed along the lower end section of each of the running collet fingers to cooperate with the running prong for controlling the positioning of the running collet fingers between locked, half-locked and unlocked positions.

In FIGURE 1C the running collet and prong assembly 24 is illustrated engaged within the locking assembly 23 of a well device, not shown, being locked within a landing nipple 110 secured by a coupling 110a to a well tubing string 110b. The landing nipple is provided with an internal annular locating recess 111 having an upwardly facing internal annular shoulder 112. Below the locating means the landing nipple has an internal annular locking recess 113. The locking assembly 23 of the well device includes a mandrel 120 with a central bore 120a and provided with an upwardly facing internal annular shoulder 121 at the lower end of an enlarged bore section 121a. An upper internal annular locking recess 122 is formed in the mandrel around the bore above the section 121a. An annular outer retainer ring 123 and an annular inner retainer ring 123a are secured on the mandrel by a plurality of pins 124 to hold a locking collet assembly 125 and a locking finger assembly 130 on the mandrel. The outer retainer ring assembly 123 includes a plurality of circumferentially spaced fingers 131 for holding the locking finger assembly 130 on the mandrel. The inner retainer ring 123a has a plurality of circumferentially spaced fingers 132 between the fingers 131 for holding the locking collet assembly 125 on the mandrel. The fingers 131 and 132 are provided with downwardly and outwardly facing surfaces 131a and 132a, respectively, which are engageable with the locking shoulder 112 of the landing nipple to locate the well device in the landing nipple and hold the device against downward movement within the nipple.

The locking collet assembly 125 includes a plurality of collet fingers 134 with collet heads 135 which are circumferentially spaced to provide the downwardly opening longitudinal recesses 140 each of which receives one of the fingers 131 on the retainer ring assembly 123. Each of the collet fingers 134 is provided with an upwardly opening longitudinal recess 141 to receive the fingers 132 on the inner retainer ring 123a with the downwardly facing shoulder surface 142 on each of the fingers 132 being engageable with a surface 141a at the lower end of each slot 141 to hold the locking collet assembly 125 against upward movement on the mandrel while permitting the collet fingers to expand and contract around the mandrel. The locking finger assembly 130 is provided with

an annular head 150 having an internal annular locking recess 151 and a plurality of downwardly extending locking fingers 152 each of which is provided with a head section 153 and a longitudinally extending slot 154 to receive one of the fingers 131 on the outer hold ring 123 for holding the locking finger assembly on the mandrel while permitting the assembly to move longitudinally relative to the mandrel within the locking collet assembly. A downwardly facing shoulder 155 on each of the fingers 131 of the outer hold ring assembly is engageable with a surface 152a at the lower end of each recess 154 in the locking finger heads to hold the locking finger assembly on the mandrel. The locking fingers 152 are movable downwardly around the mandrel within the locking collet assembly 125 until a downwardly facing annular shoulder 160 around the head 150 engages the upper end 125a of the locking collet assembly to position the heads 153 of the locking fingers behind the collet heads 135 expanding the heads into the locking recess 113 to hold the well device within the landing nipple. The locking heads 153 are cammed outwardly by an external annular surface 161 formed on the mandrel 120.

When the operator tool 20 is used to remove a well device from a well bore it is fitted with a pulling collet 170 and a pulling prong 171 as shown in FIGURE 7. The head section of the pulling prong, not shown, and the manner of securing it to the jack rod are identical to the running prong so that the prong is raised and lowered by the jack rod for locking and unlocking the pulling collet. The pulling prong has a reduced "unlock" section 174 providing an external annular recess 174a to receive an inner boss 175 on each pulling collet finger 180 so that the collet fingers may be cammed inwardly around the prong for releasing the operator tool from a well device. A lower enlarged section 181 of the pulling prong coacts with the internal bosses of the pulling collet fingers to hold the fingers in a locked position within the well device. The pulling collet fingers 180 extend downwardly from and are circumferentially spaced apart around a head ring of the collet identical to the head ring 35a of the running collet with the pin 74 extending between the collet fingers. Each of the pulling collet fingers is provided with an external boss corresponding to the boss 35b and shoulder 35c of the running collet, and a downwardly facing external shoulder, engageable with the shoulder 105 within the retainer ring 75 to hold the collet against downward movement within the retainer ring. The pulling collet is loosely fitted within the retainer ring 75 so that the collet fingers are readily expanded and contracted during the locking and unlocking steps.

The operator tool 20 is used to remotely install and remove a down hole well device in a well system as shown in FIGURE 8. A well 190 is drilled into the ocean bottom 190a at a horizontally spaced position from platform 191 which supports the necessary wellhead and equipment for producing and servicing the well. Two tubing strings 110b and 193 extend from the platform along the ocean bottom into the well. Within the well the tubing strings are interconnected by a cross-over connection 194 so that a complete fluid circulation path may be established from the platform into the well and back to the platform. The platform end of the tubing 110b has a manifold 195 between two spaced apart valves 200 and 201 to provide means for introducing well tools into the tubing string while the well is under pressure. A pump, not shown, is suitably connected into the manifold to permit the fluid pressure to be applied to pump well tools from it through the tubing string 110b. The platform end of the tubing string 193 is provided with a valve 202 and may be provided with flow lines and other equipment, not shown, for producing and servicing the well. A plug 203 is releasably secured in the lower end of the tubing 193. The landing nipple 110 is connected into the tubing string 110b below the cross-over connection 194. Generally a well so equipped is produced through the tubing string

193 by closing the surface end of the tubing string 110b and allowing the well fluids flowing into the lower end of the string 110b to cross over through the connection 194 and flow to the surface through the string 193 to maintain the tubing string 110b in a substantially clean condition so that the well may be serviced without cleaning out the tubing string each time it is desired to perform a service operation through it.

An articulated train 210 of pump down type well tools is illustrated at a position for installing a well device, such as a safety valve 211, in the landing nipple 110. The tool train includes a pair of slidable seal units 212 and 213 which are flexibly coupled together so that the units may readily be pumped through curves and obstructions within the tubing string 110b. Suitable slidable seal units are illustrated and described in United States patent application, Ser. No. 402,707, filed by Norman F. Brown on Oct. 9, 1964. The seal units serve as propulsion units to move the tool train through the tubing string. Effecting a pressure differential across each seal unit causes them to move through the tubing in the direction of the low pressure. The operator tool 20 is flexibly coupled to the seal unit 213 for supporting the safety valve 211 during the installation and removal of the safety valve. The landing nipple 110 is connected in the tubing string at a location below the cross-over connection 194 which will permit the tool train to insert the safety valve to the landing nipple while the seal units 212 and 213 remain above the cross-over connection between the tubing strings.

The safety valve 211 is installed in the landing nipple 110 in accordance with the following procedure. The operator tool 20 is fitted with the running prong 34 and the running collet 35 which initially are in the relative position illustrated in FIGURE 1B. The running prong is retracted into the running collet until the section 104 of the running prong has been lifted above the inner running collet finger bosses 35g so that the running collet fingers may be cammed inwardly to the fully unlocked position. The retracting of the running prong is accomplished with two hand wrenches or similar tools, one of which is engaged with the flat surfaces 51a on the head section 51 of the collet 40 while the other is engaged with the flat surfaces 42 on the operator rod 41. The operator rod is rotated relative to the collet by holding the collet stationary and turning the operator rod to thread the operator rod through the collet so that the inward end of the operator rod bears against the upper surface of the floating washer 50. The floating washer is manually manipulated through the lateral windows 63 in the tool body to an off-center position at which the port 45 through the washer is misaligned from the operator rod and the opening 71 in the plunger cap 32 as shown in FIGURE 1B whereby force applied to the top surface of the washer causes the washer to bear against the top of the plunger cap. The operator rod is threaded through the collet against the eccentrically displaced washer forcing the plunger cap farther into the body 21 compressing the lift spring 33. The lower end of the plunger cap bears against the upper end of the lift ring which engages the upper end of the lift spring through the annular shoulder 30f. The reaction force between the operator rod and the collet 40 holds the shoulders 60 on the collet finger heads against the internal annular shoulder 61 within the head section of the body as the operator rod is threaded through the collet. The lift ring is forced into the body against the lift spring until the lower end 30i of the lift skirt 30g engages the upper ends of the upwardly extending hold ring fingers 31c. In the particular embodiment of the tool illustrated the distance provided between the lift and hold rings permits the lift ring to be forced toward the hold ring a distance of approximately one and one-half times the height of one intermeshing tooth on the hold and lift rings and the jack rod. As the lift ring is forced downwardly, the teeth 30e on the lift ring fingers 30d slide over the external teeth 73 on the

jack rod fingers since both the lift ring fingers and the jack rod fingers are flexible which permits the two lift ring fingers to move over the teeth on the jack rod fingers with which they are engaged. The distance of one and one-half times the height of a tooth is provided between the lift and hold rings as a factor of safety to insure that the hold ring will advance at least one tooth when the lift spring relaxes to reengage the hold ring fingers with the jack rod.

When the operator rod has been threaded through the collet 40 until the adjacent ends of the lift and hold rings are engaged with each other, it will be evident to the operator as his wrenches will no longer turn and the operator rod cannot be easily threaded farther into the collet. While the two lift ring fingers 30d are being forced downwardly along two of the jack rod fingers 25d, the two hold ring fingers 31c are engaging the other two jack rod fingers holding the jack rod against downward movement while the lift ring is being advanced. The operator rod 41 is now rotated in the opposite direction to retract the inward end of the rod from the floating washer and relieve the plunger cap 32 of the pressure imposed on it by the operator rod. When the operator rod is no longer engaged with and holding the plunger cap down, the lift spring 33 expands until the lift spring is relaxed and the shoulder 65 on the plunger cap engages the shoulder 64 in the body to raise the lift ring and the plunger cap back to the position shown in FIGURE 1B. As the lift ring is raised by the lift spring the teeth on the lift ring fingers engage the teeth on the corresponding meshing fingers of the jack rod to lift the jack rod to a new position which is one tooth higher than the previous position of the jack rod since the lift ring advanced effectively the distance of one tooth as it was moved downwardly while the jack rod was held against downward movement. During the upward movement of the lift ring, the teeth of the lift ring fingers mesh with the jack rod teeth, lift the jack rod, and the teeth of the hold ring fingers mesh with the jack rod to hold it at the lifted position. As the lift ring raises the jack rod the flexibility of the fingers of the jack rod engaged with the hold ring fingers allows the teeth of the jack rod to snap over the teeth of the hold ring fingers so that the hold ring fingers advance one tooth distance to hold the jack rod at its new, one-tooth-higher position.

During the downward movement of the lift ring as above described, the hold ring is held against downward movement by the engagement of its lower end surface with the upper end 75a of the retainer 75 which is threaded into the body 21. Upon relaxation of the force against the lift spring permitting it to expand; it can expand only upwardly away from the hold ring and thus the jack rod is lifted while the hold ring remains stationary.

As the jack rod is lifted it is moved the distance of one tooth farther into the lift ring and reset collet raising the reset cap 90 along with its quadrantal segments 90d to compress the reset spring 92 a distance equal to the length of one tooth.

The above described procedure of threading the operator rod through the collet 40 to compress the lift spring and unthreading the operator rod to permit the lift spring to relax and raise the jack rod is repeated until the running prong has been withdrawn into the running collet a sufficient distance to raise the half-lock section 104 of the prong above the inner bosses 35g of the collet heads. The embodiment of the tool illustrated requires six cycles of operation to fully unlock the running collet. FIGURE 4 illustrates the tool as it completes the first half of the fifth cycle at the end of which the running collet will be fully unlocked and the jack rod will have been raised five teeth in height. The reset spring has been lifted and compressed by the reset cap a distance equal to the height of six of the teeth on the jack rod and lift ring fingers.

The running collet and prong assembly of the operator tool is inserted into the locking assembly 23 of the safety

valve by inserting the running collet fingers into the upper end of the mandrel 120 until the collet finger heads snap into the locking recess 122. Since the interference of the running prong has been removed by lifting the prong from within the collet finger heads the heads are readily cammed inwardly as the operating tool is pushed downwardly with the collet finger heads being introduced into the upper end of the mandrel 120. The locking finger assembly 130 of the safety valve is lifted over the running collet fingers until the collet bosses 35e on the collet fingers snap into the locking recess 151 within the head of the locking finger assembly. The locking finger assembly is held in an upward position relative to the mandrel and the collet heads 135 on the locking collet assembly 125 of the safety valve are free to be cammed inwardly so that the safety valve may be inserted into the landing nipple 110 when the valve reaches the landing nipple.

After the running collet is engaged with the locking assembly of the safety valve, as above described, the running prong is reset or returned to the full locked position illustrated in FIGURE 1C so that the safety valve can be supported from the operator tool and run into the well. The operator rod 41 and the collet 40 are engaged with suitable wrenches at the flat surfaces 42 and 51a, respectively to thread the operator rod into the collet. The floating washer 50 is manipulated through the lateral windows 63 to align the hole 45 through the washer with the hole 71 through the plunger cap. With the floating washer so aligned the operator rod is threaded farther into the collet until the end section 45 of the operator rod passes through the holes in the washer and the plunger cap against the lug 91b on the top of the reset collet 91 to force the collet downwardly with the surfaces 91e on the collet heads engaging the cam surface 30h of the lift ring to cam the reset collet fingers radially inwardly around the jack rod fingers 25b. As the reset collet fingers move inwardly they engage all of the jack rod fingers forcing the jack rod fingers also radially inwardly. The operator rod is threaded through the collet 40 until the rod has forced the reset collet downwardly a sufficient distance to cam the collet fingers and jack rod fingers inwardly until the meshing teeth of the jack rod fingers and the lift and hold ring fingers are fully disengaged from each other. When the jack rod and lift and hold ring teeth are so released, the jack rod is no longer held against downward movement and the reset spring 92 expands until the lower end of the spring engages the upper surfaces 91f on the reset collet finger heads. As the reset spring expands the lower end of the spring acting on the quadrantal segments 90b of the reset cap forces the cap downwardly which forces the jack rod downwardly to insert the running prong 34 within the bosses 35g of the heads of the collet 35 until the section 102 of the running prong is within the collet head bosses so that the running collet is in the fully locked position. In carrying out the reset procedure it will generally be determinable by sound when the jack rod along with the running prong have been returned to the locked position. As soon as the operator rod depressed the reset collet sufficiently to disengage the jack rod fingers from the lift and hold ring fingers the reset spring will suddenly expand and in one continuous quick motion move the jack rod and running prong to the locked position illustrated in FIGURE 1B. As soon as the sound of the snap action of the jack rod subsides the operator tool should be locked with the safety valve. Force may be applied between the body of the operator tool and the locking assembly of the safety valve tending to pull the two devices away from each other to determine if the proper locked relationship has been established between the running prong and collet of the tool. If the running prong has not been returned to the locked position the tool may be readily withdrawn from the safety valve locking assembly.

After it has been determined that the running prong is in the full locked position, the operator rod 41 is rotated

relative to the collet 49 until the head lower end section 45 of the rod has been withdrawn to within the collet heads as illustrated in the FIGURE 1C. The reset collet fingers spring radially outwardly with the camming action between the surface 30h of the lift ring and the surfaces 91e on the reset collet finger heads causing the reset collet to move back to the position illustrated in FIGURE 1-A permitting the jack rod fingers to spring back outwardly to their normal positions with the teeth on the jack rod fingers again meshing with the teeth of the lift and hold ring fingers locking the jack rod in the position illustrated in FIGURE 1-B. The jack rod and running collet assembly remain locked until it is desired to release the tool from the locking assembly of the safety valve.

In the position of the operator rod 41 shown in FIGURE 1A the flat surfaces 44 engage inside surfaces of the collet fingers 52 serving a detent function to oppose the unscrewing of the operator rod from the collet 40 so the operator tool may be supported by the tool string through the operator rod.

When the operator tool is fully locked with the safety valve and the operator rod 41 has been retracted into the collet 40 as above described, the operator tool is coupled with the pump down tool train 210. With the valve 201 closed, the valve 200 in the tubing string 110b on the platform 191 is opened and the tool train is inserted into the manifold 195. The valve 200 is then closed and the valves 201 and 202 are opened while fluid is pumped into the manifold behind the tool train to displace the train through the tubing string 110b until the safety valve 211 is seated within the landing nipple. Fluid in the tubing strings 110b and 193 ahead of the tool train is displaced from the system through the valve 202. Pressure and flow rate readings at the surface end of the tubing string 110b provide an indication of when the tool train reaches the position that the safety valve is seated in the landing nipple. During the movement of the tool train between the platform and the landing nipple there is substantially no variation in the pressure and flow rate in the tubing string 110b as measured at the platform. When the tool train reaches the landing nipple and is stopped from further movements, the pressure in the tubing behind the tool train increases indicating the arrival of the safety valve at the landing nipple.

Preferably just prior to the arrival of the safety valve at the landing nipple the direction of circulation through the tubing strings 110b and 193 is briefly reversed to determine the pressure required to move the tool train upwardly in the tubing string 110b. Reverse circulation is maintained only long enough to provide pressure and flow rate readings for upward movement of the tool train. Such readings serve as a base or reference in subsequently determining if the safety valve is locked in the landing nipple as explained hereinafter. As soon as the desired reference readings are obtained, flow into the tubing 110b is reestablished to pump the safety valve into the landing nipple.

The tool train pushes the safety valve into the landing nipple until the shoulders 131a and 132a on the fingers 131 and 132 engage the seat surface 112 within the landing nipple to hold the safety valve and the tool train against further movement through the tubing string 110b. Generally, the safety valve will enter and seat in the landing nipple sufficiently abruptly to cause the operator tool 20 to function through one cycle lifting the jack rod one tooth. When the surfaces 131a and 132a on the fingers 131 and 132 engage the seat surface 112, the mandrel 120 is held against further downward movement by the connection through the pins 124 with the fingers 131 and 132. The section 102 of the running prong is within the bosses 35g of the heads of the running collet fingers so that the running collet fingers cannot be cammed inwardly. The outer bosses 35f on the running collet finger heads are in the locking recess 122 of the mandrel 120

holding the running collet against downward movement in the mandrel so that the hold ring 31 of the operator tool is also held against downward movement due to the engagement of the upper end of the running collet with the bottom surface of the base ring 31a of the hold ring. The hold ring fingers are engaged with the jack rod fingers holding the jack rod against downward movement due to the impact landing of the safety valve within the landing nipple.

While the body of the operator tool along with the jack rod and related connected structure are held against downward movement upon impact of the safety valve in the landing nipple, the collet 40 and the operator rod 41 together with the tools in the tool train above the operator rod are not so restrained against downward movement. The train of tools down through and including the operator rod and the collet 40 are carried by their momentum farther downwardly with the lower end of the collet 40 engaging the floating washer 50 to depress the plunger cap 32 until the lower end of the lift ring engages the upper end of the hold ring causing the teeth on the fingers of the lift ring to slide over the teeth on the fingers of the jack rod. When the force of the momentum of the tools above the tool 20 is expended, the compressed lift spring 33 expands to lift the jack rod one tooth in height with the teeth on the fingers of the hold ring sliding over the teeth on the fingers of the jack rod and remeshing with the jack rod teeth to hold the jack rod at its raised position.

The safety valve is seated but not yet locked in the landing nipple and the running tool has cycled once lifting the running prong the length of one tooth on the jack rod leaving the section 102 of the running prong within the running collet to hold the running collet in the full locked position. The next steps are to lock the safety valve in the landing nipple and then to release the operator tool from the safety valve so it and the tool train may be removed from the well. The flow rate into the tubing string 110b is increased to a level sufficient to effect a pressure drop across the seal assemblies 212 and 213 adequate to force the assemblies downwardly against the operator tool forcing the collet 40 downwardly against the floating washer to depress the plunger cap and lift ring compressing the lift spring until the lower end of the lift ring again engages the upper end of the hold ring. The flow rate into the tubing string is then reduced permitting the lift spring to expand to raise the jack rod a second tooth in height at which position the running prong remains with the section 102 within the running collet head continuing to hold the running collet at the full locked position. While a predetermined minimum pressure drop across the seal assemblies is required to compress the lift ring sufficiently to cycle the running tool, a pressure drop in excess of the required minimum does not result in any additional cycles since the lift spring can only be compressed the distance provided between the lift and hold ring responsive to each downward force on the lift ring. Therefore, a pressure substantially in excess of the required minimum may inadvertently be imposed on the train of tools without ill effect or interruption of the proper operation of the running tool. For the same reason, the duration of the period during which the pressure is applied to the train of tools is of no consequence since the cycle which lifts the jack rod occurs only during expansion of the lift spring upon relaxation of the force being applied to the tool.

The pressure in the tubing string is increased and decreased causing the collet 40 to again be forced against the upper end of the washer to operate the operator tool through a third cycle lifting the jack rod a third tooth in height to raise the running prong to the level at which the half-lock section 104 of the prong is within the inner bosses of the running collet finger heads so that the running collet finger heads may be cammed inwardly around the running prong sufficiently for the outer bosses

35f of the running collet finger head to move into the enlarged bore 121a in the safety valve mandrel so that the running collet may move downwardly in the mandrel. The pressure in the tubing string 192 is again increased at the surface to effect a fourth cycle of operation of the running tool. Since the running collet may now move downwardly in the bore 121a of the mandrel, the downward force resulting from the fourth increase in pressure pushes the entire tool train downwardly until the lower end of the retainer 75 engages the upper end of the annular head 150 on the locking finger assembly 130. The downward force causes the shoulder 122a in the mandrel 120 to cam the running collet finger heads inwardly to allow the downward movement into the bore section 121a. The locking finger assembly 130 is moved downwardly by the lower end of the retainer 75 on the tool body 21. The downward movement of the locking finger assembly 130 forces the locking fingers 153 against the cam surface 161 on the safety valve mandrel camming the locking fingers outwardly as the fingers move downwardly to force the locking collet heads 135 into the locking recess 113 of the landing nipple. The locking finger assembly is forced downwardly until the annular shoulder 160 on the locking assembly head engages the upper end 125a of the locking collet assembly 125 to wedge the heads 153 behind the heads 135 so that the safety valve is held against upward movement within the landing nipple. In applying the force of the pressure increase for the fourth cycle to the running tool the collet 40 depresses the plunger cap and lift ring against the hold ring with the hold ring in turn transferring the force to the upper end of the retainer 75 and the running collet forcing both the running collet and the locking finger assembly 130 downwardly to effect the above described locking of the safety valve in the landing nipple. The pressure is then again relieved in the tubing string permitting the lift spring to raise the jack rod and running prong to the fourth position at which the section 104 of the running prong still remains within the heads of the running collet at the half locked position.

The half locked position of the running collet permits a testing function to determine if the safety valve is firmly locked in its landing nipple prior to withdrawal of the tool train. The half locked position allows the running collet to move downwardly into the bore section 121a to lock the safety valve while upward movement of the collet is limited by engagement of the internal shoulder 122b with the bosses 35f to prevent removal of the running collet from the mandrel 120 so long as the collet is in the half locked condition. Reverse circulation is now established with fluid flowing downwardly in the tubing string 193 and upwardly in the tubing string 110b to lift the tool train to determine if it is locked in the landing nipple. The pressure and flow rate in the tubing string 193 is raised substantially above the reference readings determined as previously described when reverse flow was briefly established just before insertion of the safety valve into the landing nipple. Since the reference pressure and flow rate were determined as required to lift the tool train alone the additional pumping into the tubing string 193 effects an appreciable upward force in excess of that required to lift the train. If, with this additional force being applied on the tool train, the flow rate from the tubing string 110b indicates that the tool train is remaining stationary, the tool train is being held by the safety valve being firmly locked in the landing nipple and the reverse circulation testing step may be terminated.

At the completion of the test procedure as above described the pressure within the tubing string 192 is raised and lowered a fifth and a sixth time causing the running tool to cycle in the previously described manner to lift the jack rod and running prong until the lower end of the running prong is above the inner bosses 35g of the running collet finger heads so that the running collet

fingers may be cammed inwardly to the fully unlocked position. Actually, upon completion of the fifth cycle of operation the running prong is lifted to a sufficient height that the running collet is fully unlocked, though the tool is cycled the sixth time to insure that the safety valve has been fully locked in the landing nipple and the running collet may release from the safety valve.

The circulation pattern between the tubing strings 110b and 193 is now reversed with pressure being applied through the tubing string 193 and the cross-over connection 194 to the lower ends of the seal units 212 and 213 so that forces are applied to the tool train lifting the train upwardly in the tubing string 110b. With the operator tool having been cycled six times to lift the jack rod and fully retract the running prong into the running collet, the upward movement of the tool train causes the running collet fingers to be cammed inwardly by the engagement of the surface 122b within the safety valve mandrel with the surfaces 35f on the running collet finger heads. The upward movement of the running collet thus frees the running collet from the locking assembly of the safety valve. The wedging of the locking finger heads 153 behind the collet finger heads 135 prevents the locking assembly of the safety valve from being unlocked when the running collet is lifted from the upper end of the locking assembly. Upward movement of the running collet does not lift the locking finger assembly as the surface of the bore section 121a holds the running collet fingers inwardly sufficiently that the bosses 35e clear the flange 151a as the running collet is lifted. Also, the bosses 35f clear the flange 151a so that the lift finger assembly remains in its lower locked position.

The tool train including the released operator tool is pumped to the surface into the manifold 195 from which it is removed by closing the valve 201 and opening the valve 200.

Preferably, when the operator tool is returned to the surface the reset procedure is followed to decompress the lift spring and return the jack rod and running collet prong to the position shown in FIGURE 1. This procedure is preferred since it is not considered desirable to leave the lift spring in the compressed condition when the tool is at the surface not in use. Also, it is necessary that the lift spring be decompressed to lower the jack rod so that access may be obtained to the pin 74 for releasing the running collet and prong to replace them with the pulling collet and prong.

When desired, the pump down tool train including the operator tool 20 is used to remove the safety valve 211 from the well. The tool 20 is fitted as a pulling tool by removing the running collet and the running prong and replacing them with the pulling collet 170 and the pulling prong 171. To disconnect the running prong and the collet the wire clip 80 is first removed by prying the end 82 of the clip from the slot 84 in which it is engaged and springing the clip outwardly from the recess 81 to disengage the clip from the retainer ring 75. The retainer is then rotated to disengage its threads from the body 21 and the retainer is moved toward the heads of the running collet and the prong with the running collet fingers being manually depressed slightly inwardly to insure clearance of the retainer over the bosses of the collet fingers. With the retainer removed from over the running collet and prong the pin 74 is disengaged from the jack rod releasing the collet and prong from the jack rod. The head of the pulling prong is then placed within the lower end section of the jack rod and the pulling collet 170 is positioned over the jack rod and pulling prong with the pin 74 being inserted between the fingers of the pulling collet through the jack rod and the hole in the head of the pulling prong. The position of the jack rod with the lift spring relaxed positions the recess 174a on the pulling prong within the heads 183 on the fingers of the pulling collet, as illustrated in FIGURE 6. The retainer 75 is placed over the pulling collet and

prong with the collet heads being slightly manually depressed inwardly to permit the retainer to pass over the collet. The retainer is then threaded into the body 21 and the wire clip 80 replaced around the retainer with the end 82 of the clip being received in corresponding slots 83 and 84 of the retainer and body to lock the retainer against rotation on the body.

The operator tool, fitted for pulling, is connected in the tool train with the seal units 212 and 213 and placed in the manifold 195 from which it is pumped as described above through the tubing string 192 into the well bore until the pulling collet engages the locking assembly of the safety valve stopping further downward movement of the tool train. The arrival of the pulling tool at the safety valve is detectable at the surface by an increase in fluid pressure in the tubing string 192. The pulling collet enters the head section 150 of the locking finger assembly 130. Since the collet heads 183 are aligned with the recess 174a on the pulling prong, the internal flange 151a cams the collet fingers inwardly allowing the collet to move downwardly until the heads snap outwardly into the locking recess 151 and the lower end of the retainer 75 engages the upper end of the head 150 preventing further downward movement of the operator tool and collet. The impact of the arrival of the running tool at the safety valve will cause the running tool to operate through its first cycle in the same manner and for the same reasons that the tool initially cycled when installing the safety valve in the landing nipple. Subsequent to the initial operational cycle the recess 174 of the pulling prong remains aligned within the heads of the pulling collet fingers so that the pulling collet is still in the unlocked condition. The pressure within the tubing string 110b is increased and decreased to operate the operator tool through the second cycle lifting the pulling prong a second tooth in height within the pulling collet. After the second cycle of operation the pulling collet and prong remain in an unlocked relationship while the force which effected the cycle tends to firmly seat the operator tool with the safety valve in the event the initial impact failed to do so.

The pressure above the tool train is again raised and lowered causing the operator tool to cycle for the third time to lift the pulling prong to the first of two positions in which the head 181 of the pulling prong is within the pulling collet finger heads so that the pulling collet finger heads cannot be forced inwardly and thus the pulling collet is in the locked condition within the head 150 of the locking assembly 130 of the safety valve. The pressure is now raised within the tubing string 193 to initiate reverse circulation between the tubing strings 193 and 119b increasing the pressure below the tool train to pump the tool train back to the surface. As the tool train is lifted by the force of the pressure differentials applied across the seal units 212 and 213, the pulling collet heads 183 being locked in the locking recess 151 lift the locking finger assembly 130 withdrawing the locking finger heads 153 from behind the locking collet heads 135 so that the locking collet heads may be cammed inwardly around the mandrel 120 of the safety valve to release the safety valve from the landing nipple. The locking finger assembly is pulled upwardly until the surfaces 152a on the locking finger heads at the lower ends of the recesses 154 engage the surfaces 155 on the fingers 131 applying a force through the pins 124 to the safety valve mandrel to lift the safety valve from the landing nipple. With the locking finger heads raised above the cam surface 161, the locking collet heads are free to move inwardly as the safety valve is lifted so that the locking collet heads may freely move out of the locking recess 113 of the landing nipple to release the safety valve from the nipple. The tool train is pumped through the tubing string 110b to the surface into the manifold 195 from which it is removed as previously described.

In the embodiment of the operator tool illustrated the pulling collet fingers are locked by the pulling prong after both the third and fourth operational cycles. The pulling prong is moved to a position to release the collet fingers following the fifth and sixth cycles. It will, therefore, be clear that if the tool train is pumped to the surface following the third cycle it is removed from the manifold 195 in the locked condition to which it moved subsequent to the third cycle of operation. The safety valve is then disengaged from the operator tool by manually manipulating the operator rod 41 and the collet 40 with wrenches or similar suitable tools in the manner previously described to thread the operator rod through the collet against the floating washer to move the running tool through its fourth and fifth cycles. At the conclusion of the fourth cycle the head 181 of the pulling prong remains within the heads of the pulling collet fingers so that the collet is still locked. Upon completion of the fifth cycle the running prong head is retracted within the pulling collet sufficiently to permit the collet finger heads to be cammed inwardly as the operator tool is pulled away from the safety valve. The pulling tool is forced away from the safety valve by manual or other suitable means so that the engagement of the shoulder 151a at the upper end of the locking recess 151 with the surfaces 183a on the collet finger heads cams the heads inwardly around the pulling prong disengaging the pulling collet from the head of the locking finger assembly on the safety valve.

The operator tool is then manually reset to relax the lift spring and move the jack rod back to a position at which the pulling collet and prong may be removed and replaced by the running collet and prong in the previously described manner for subsequent installation of the safety valve or other well devices. The reset procedure is carried out by manipulating the floating washer so that the operator rod is inserted through the hole in the washer against the upper end of the reset collet to depress the collet camming the jack rod fingers inwardly to release the teeth on the fingers from the teeth on the lift and hold ring fingers so that the reset spring returns the jack rod downwardly.

During the procedure of using the operator tool to remove the safety valve from the landing nipple the pulling prong and collet are moved into locked relationship by the third operational cycle leaving available the fourth cycle after which the locked condition still exists if it should be necessary to apply an additional downward pressure pulse or force on the tool train in manipulating the train past an obstruction in the tubing string or in jarring the safety valve loose in the landing nipple. For example, if when reverse circulation is started following the third cycle the safety valve is not pulled from the landing nipple, a jarring force may be applied through the tubing string 192 by a pressure increase to push the safety valve in a downward direction which may loosen it from the landing nipple. Also, if an obstruction is encountered in the tubing between the landing nipple and the platform, the fourth cycle provides a safety factor if a downward force is helpful in freeing the tool from a stuck condition.

If, after the fourth cycle, it is found that the safety valve cannot be pulled from the landing nipple a pressure pulse applied through the tubing string 192 to the top of the tool train will force the tool train downwardly to cause the operator tool to cycle for the fifth time retracting the pulling prong into the pulling collet to permit the collet to release from the safety valve disengaging the operator tool from the safety valve. Reverse circulation is then established to lift the tool train including the operator tool leaving the safety valve in the landing nipple. Therefore, where malfunction prevents normal removal of the safety valve by the operator tool, the tool is releasable from the safety valve without the necessity of shearing one or more pins and thus leaving the debris of the shear

pins in the well bore, possibly in the machines of the safety valve and operator tool.

Upward forces applied to the operator tool through the operator rod 41 and the collet 40 when lifting the operator tool and safety valve from the landing nipple do not cause the tool to cycle. The upward forces in pulling the tool are applied to body 21 of the tool by engagement of the surfaces 60 on the collet heads with the internal annular downwardly facing surface 61 within the body head causing the body to be lifted upwardly so that the upper end of the retainer 75 applies force to the lower end of the hold ring 31. The engagement of the teeth on the hold ring fingers with the jack rod lifts the jack rod along with the particular prong connected with the jack rod. The upward force of the retainer also engages the internal upwardly facing annular surface 105 in the retainer with the running or pulling collet to lift the collet along with the jack rod and prong so that the relative positions of the collet and prong are not altered. Since no downward force is being applied to the plunger cap 32 through the floating washer the lift spring is not compressed to cause the required relative motion between the lift and hold rings for cycling of the tool.

It will now be seen that there has been described and illustrated a new and novel operator tool for installing and removing well devices.

It will be seen that the tool is readily fitted to perform either a running or pulling function in a well tubing string.

It will also be seen that the operator tool is connected in a train of tools which are pumped to and from a landing nipple through a tubing string extending between the nipple and a wellhead at the surface.

It will be further seen that the operator tool as an element of a train of pump down type tools will traverse turns of relative short radius formed in the tubing string through which the train of tools is pumped between the surface and the desired location within a well bore.

It will be further seen that the operator tool is remotely actuatable by application of force to the upper end of the tool.

It will be further seen that the operator tool is remotely actuatable between a plurality of positions for operating the tool through both locked and unlocked conditions.

It will be additionally seen that the operator tool is operable responsive to force pulses while not being sensitive to the rate or smoothness with which the force pulses are applied to the tool so long as such pulses exceed a predetermined minimum value.

It will be further seen that the running and pulling tool remains in each particular locked or unlocked condition through several cycles of operation to permit the tool to be forced past obstructions in a tubing string and jarred to release the well device connected to the tool from a stuck condition within the landing nipple.

It will additionally be seen that the tool when fitted to perform a pulling function may be cycled to an unlocked condition to free the tool from the device being pulled upon in the event that such device is lodged within a landing nipple or well bore and cannot be freed by the forces being applied through the operator tool.

It will be recognized that while the particular tool illustrated and described remains at each locked or unlocked stage during two operational cycles, an operator tool may be readily designed in accordance with the invention to remain in each position through more or less cycles. Changes in the jack rod and lift and hold ring teeth and in the length of the cooperating surfaces of the running and pulling prongs and collets are readily made to change the cycle relationship of the tool's operation. Also, the relative movements of the lift and hold rings may be varied by design to cause more teeth on the hold and lift rings and jack rod to be included during each operational cycle.

It will also be recognized that while the operator tool

has been described in terms of its function as a member of a train of hydraulically actuated pump down tools which are manipulated in the tubing string of a well by fluid pressure, the operator tool may be incorporated as an element in a tool string of the wireline type as illustrated and described at page 3742, Composite Catalog of Oil Field Equipment and Services, 1964-65 edition, published by World Oil Company, Houston, Tex. The operator tool when used with such a string of tools is connected at the lower end of the string with the force required for operating the operator tool being supplied through the jars in the tool string.

It will thus be seen that the operator tool functions responsive to force applied to the tool from either mechanically or fluid pressure actuated means.

The foregoing description of the invention is explanatory only, and changes in the details of the construction illustrated may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. An operator tool for supporting and manipulating an object comprising: locking means at one end of said tool for releasably connecting said tool with said object; operating means for moving said locking means between locked and unlocked relationship with said object; connecting means at the other end of said tool for supporting said tool within a well bore and actuating said operating means; and means operatively associated with said connecting means and said operating means and movable longitudinally through a predetermined plurality of reciprocating movements for actuating said operating means responsive to a plurality of cycles of longitudinal movement of said connecting means.

2. An operator tool for supporting and manipulating an object comprising: coupling means at one end of said tool for releasably connecting said tool with said object; ratchet means connected with said coupling means and operable through a predetermined plurality of reciprocating cycles for actuating said coupling means to move said coupling means between and holding said coupling means at locked and unlocked positions; and connecting means releasably secured at the other end of said tool for supporting said tool and applying force to said ratchet means to reciprocally actuate said ratchet means for moving said coupling means between locked and unlocked positions.

3. An operator tool for supporting and manipulating an object comprising: a hollow body; locking means supported at one end of said body for releasably locking said tool with said object; operator means disposed within said body for movement to actuate said locking means longitudinally from a first position to a plurality of other positions; actuating means for engaging and moving said operator means in one direction in a predetermined plurality of reciprocating cycles to actuate said locking means from said first position; holding means for releasably holding said operator means against movement in the other direction; release means for moving said actuating means to release said operator means to return said locking means to said first position; and means releasably connected with the other end of said body for supporting said body and for actuating said actuator means.

4. An operator tool for supporting and manipulating an object comprising: a body having a bore therethrough; a locking collet supported from one end of said body, said collet having radially flexible fingers for releasably connecting said tool with said object; a collet control member supported within for movement relative to said collet between a plurality of positions for releasing said collet fingers for inward movement and for holding said collet fingers against inward movement; a ratchet member disposed within said body and connected with said collet control member; and a connecting assembly releas-

ably secured to the other end of said body adapted to support said body and move longitudinally relative to said body to actuate said ratchet member.

5. An operator tool for supporting and manipulating an object comprising: a body having a bore therethrough; a collet secured at one end of said body and having radially flexible fingers extending from said body for releasably locking said tool with said object; a control prong supported within and movable relative to said collet to coact with said fingers for releasing said fingers for inward movement and holding said fingers against inward movement; a ratchet assembly supported within said body and connected with said control prong for moving said prong between a first position and a plurality of other positions relative to said collet; means supported within said body and operatively associated with said ratchet assembly for returning said control prong to said first position; and an assembly releasably connected with the other end of said body for supporting said tool and for actuating said ratchet assembly and said means for returning said control prong to said first position.

6. An operator tool for supporting and manipulating an object comprising: a body having a bore therethrough; a collet supported at one end of said body and having a plurality of radially flexible collet fingers extending from said body for releasably locking said tool with said object; a control prong supported within said collet for movement between a plurality of positions cooperating with said collet fingers for controlling the radial movement of said collet fingers between a plurality of radial positions around said prong; a ratchet assembly within said body connected with said prong for moving said prong within said collet fingers between a first position and a plurality of other positions for changing the relationship between said collet fingers and said prong; reset means operatively engaged with said ratchet assembly for releasing said ratchet assembly and returning said prong to said first position; and support and operator means releasably connected with the other end of said body for supporting said tool and actuating said ratchet assembly and said reset means.

7. An operator tool for supporting and manipulating an object comprising: a body having a bore therethrough; a collet supported at one end of said body and having a plurality of radially flexible collet fingers extending from said body for releasably connecting said tool with said object; a control prong movably supported within said collet fingers for movement between a first and a plurality of additional positions for controlling the radial position of said collet fingers around said prong; a longitudinal rod connected with said prong within said body for longitudinal movement relative thereto, said rod having teeth formed thereon; a first rod engaging means disposed within said body and adapted to be moved in a first direction over said teeth on said rod means and to be returned in a second direction to engage a portion of said teeth on said rod means to move said rod means and said prong within said collet fingers; resilient means for engaging and moving said first rod engaging means in said second direction; second rod engaging means for engaging said teeth on said rod to hold said rod while said first rod engaging means moves in said first direction; reset means for engaging said rod means to disengage said rod means from said first and said second rod engaging means and return said rod and said prong to said first position; and means releasably engaged with the other end of said rod supporting said body and for operatively engaging said first rod engaging means to move said means over said rod and for operatively engaging said reset means for returning said rod and said prong to said first position.

8. An operator tool for supporting and manipulating an object comprising: a body having a bore therethrough; a collet secured at one end of said body and provided with radially flexible fingers extending from said body for releasably locking said tool with said object; a con-

trol prong supported within and movable relative to said collet to control the radial position of said collet fingers; and operator rod connected with said control prong for moving said control prong relative to said collet; means for engaging said operator rod to move said rod in a first direction; means for engaging said operator rod to hold said rod against movement when said rod is not being engaged by said last mentioned means and moved in said first direction; means for releasing said operator rod and returning said rod in a second direction to an initial position; and supporting and actuating means releasably connected with the other end of said body and engageable with said means for moving said operator rod in said first direction to cause the movement of the control prong by said operator rod.

9. An operator tool for supporting and manipulating an object comprising: a body having a longitudinal bore extending therethrough; a collet supported within one first end section of said bore of said body and having a plurality of radially resilient collet fingers extending from said end of said body for releasably locking said tool with said object; a control prong supported within said collet for movement between a first and other positions for controlling the radial positioning of said collet fingers around said prong; a jack rod connected with said prong for moving said prong relative to said collet, said jack rod having resilient fingers each provided with a toothed outer surface; a first jack rod engaging assembly disposed around said jack rod adapted to move in one direction over said jack rod, to engage said jack rod, and to move said jack rod in the other direction; resilient means engaged with said first jack rod engaging assembly adapted to be stressed when said jack rod engaging means is moving over said jack rod and to relax to move said jack rod engaging assembly and said jack rod in said other direction; a second jack rod engaging assembly disposed around said jack rod within said body to hold said jack rod while said first jack rod engaging assembly is moving over said jack rod, to release said jack rod for movement by said first jack rod engaging assembly in said other direction and to reengage said jack rod when said resilient means is relaxed; a reset assembly engageable with said resilient fingers of said jack rod for camming said fingers out of engagement with said first and second jack rod engaging means to return said jack rod and said prong to said first position; supporting and operating means releasably connected with the other end of said body for operatively engaging said first jack rod engaging assembly and said reset assembly for advancing and resetting said jack rod responsive to longitudinal movement of said supporting and operating means.

10. An operator tool for supporting and manipulating a well device within a well bore comprising: a body having a longitudinal bore extending therethrough; a locking collet supported in one end section of said bore of said body and having circumferentially spaced, radially resilient, collet fingers extending from said end of said body for releasable engagement with said well device; a prong supported within said locking collet for movement relative thereto to control the radial positioning of said collet fingers; a jack rod movably positioned within said body connected with said prong for moving said prong from a first position to a plurality of additional positions, said jack rod having resilient longitudinally extending fingers with toothed outer surfaces; a lift ring assembly movably disposed over said jack rod and having fingers with toothed inner surfaces for releasably engaging a first set of said jack rod fingers to move said jack rod with said lift ring assembly in a first direction and adapted to be released from said jack rod and moved over said jack rod in a second direction; spring means disposed within said body around said jack rod and said lift ring assembly in said first direction, said spring means being adapted to be compressed responsive to movement of said lift ring assembly in said second

direction and to expand to return said lift ring assembly and said jack rod in said first direction; a hold ring assembly disposed within said body around said jack rod, said hold ring assembly having resilient fingers having toothed inner surfaces releasably engageable with a second set of said jack rod fingers for holding said jack rod against longitudinal movement while said lift ring assembly is moving in said second direction and for releasing said jack rod when said lift ring assembly is moving said jack rod in said first direction; a reset assembly disposed within said body and operatively engageable with said jack rod fingers to release said fingers from said jack rod lift ring assembly and said jack rod hold ring assembly and return said jack rod and said prong to said first position from said additional positions; a supporting collet releasably engaged with the other end of said body for supporting said operator tool and actuating said lift ring assembly; and an operating rod movably engaged through said supporting collet and adapted to support said collet and move through said collet to engage and actuate said reset assembly.

11. An operator tool for supporting and manipulating a well device in a well bore comprising: a body having a longitudinal bore extending therethrough; a collet supported at one end of said body and having a plurality of collet fingers extending from said end of said body and adapted for radial expansion and contraction to releasably secure said well device to said operator tool; a control prong disposed within said collet and adapted to move longitudinally relative to said collet to limit the extent to which said collet fingers may be moved inwardly around said prong; a jack rod movably disposed within said body along a longitudinal axis, said jack rod being connected at one end to said control prong and having a plurality of radially resilient longitudinally extending fingers, each of said fingers having a toothed outer surface; a lift ring assembly disposed within said body and movable telescopically over said jack rod and having lift fingers provided with internal toothed surfaces engageable with one set of said jack rod fingers for moving said jack rod in a first direction and disengageable from and slidable over said jack rod fingers when moving in a second direction relative to said jack rod; a hold ring assembly positioned around said jack rod and having hold fingers provided with internal toothed surfaces engageable with a second set of said jack rod fingers for holding said jack rod against movement when said lift ring fingers are disengaged from and moving over said jack rod fingers, said hold ring fingers being disengageable from said jack rod fingers when said lift ring fingers are moving said jack rod in said first direction; spring means confined between said lift ring assembly and said hold ring assembly for biasing said lift ring assembly in said first direction, said spring means being compressible while said lift ring assembly is moving in said second direction over said jack rod and being expandable to lift said lift ring assembly and said jack rod in said first direction; a reset collet having a plurality of radially flexible fingers disposed within said body in telescopic relationship over said jack rod, said reset collet fingers being adapted to be cammed inwardly to disengage said jack rod fingers from said hold ring and said lift ring fingers to return said jack rod to a first position subsequent to movement of said jack rod by said lift ring assembly away from said first position; a reset spring confined around said reset collet, said reset spring being operatively engageable with said jack rod to return said jack rod to said first position; a support and operating collet releasably engaged with the other end of said body for supporting said body and for operatively engaging said lift ring assembly to move said lift ring assembly in said second direction over said jack rod; an operator rod engaged through said support and operating collet and adapted to be moved relative thereto to operatively engage said lift ring assembly for moving said lift ring

assembly in said second direction over said jack bar and for operatively engaging said reset collet independent of said lift ring assembly for moving said reset collet toward and over said jack rod to return said jack rod to said first position.

12. An operator tool for supporting and manipulating a well device within a well bore comprising: a tubular body having a longitudinal bore extending therethrough; a locking collet secured at one end of said body and having collet fingers extending from said end of said body and adapted to be expanded and contracted for releasably connecting said well device to said operator tool; a retainer connected with said end of said body around said collet to hold said collet with said body; a control prong movably supported within said collet and longitudinally movable from a first position to a plurality of additional positions for controlling the radial positions of said collet fingers; a jack rod longitudinally positioned within said body connected with said control prong for moving said prong from said first position to said additional positions within said collet, said jack rod having a plurality of radially flexible longitudinal fingers, each of said jack rod fingers having a plurality of outer teeth; a lift ring assembly positioned within said body for telescopic movement over said jack rod fingers, said lift ring assembly having lift fingers, each of said fingers being provided with internal teeth engageable with said teeth on a first set of said jack rod fingers when said lift ring assembly is moved in a first direction relative to said jack rod to move said jack rod in said first direction to move said control prong from said first position to said additional positions, said lift ring fingers being disengageable from said jack rod fingers and movable over said jack rod fingers when said lift ring assembly is moved in a second direction relative to said jack rod; a hold ring assembly positioned within said body around said jack rod, said hold ring assembly having hold ring fingers each provided with internal teeth engageable with said teeth on a second set of said jack rod fingers to hold said jack rod against longitudinal movement when said lift ring assembly is moved over said jack rod in said second direction; a spring confined between said lift ring assembly for biasing said lift ring assembly away from said hold ring assembly, said spring being adapted to be compressed when said lift ring assembly is moved in said second direction and to expand to move said lift ring assembly in said first direction to move said jack rod and said control prong from said first position to said additional positions; a reset collet disposed within said body in telescopic relationship over said jack rod fingers, said reset collet having radially flexible fingers adapted to be cammed inwardly by said lift ring assembly when said reset collet is moved toward said jack rod to engage said jack rod fingers to disengage said jack rod fingers from said lift ring and said hold ring fingers for returning said jack rod and said control prong to said first position; a reset spring confined around said reset collet; a cap member on said jack rod operatively engageable with said reset spring to compress said spring when said jack rod is moved from said first position to said additional positions, said reset spring being adapted to expand to return said jack rod to said first position when said jack rod fingers are disengaged from said lift ring and hold ring fingers; a support and operating collet releasably connected with the other end of said body and operatively engageable with said lift ring assembly for moving said assembly in said second direction over said jack rod; and an operator rod movably engaged through said support and operator collet and adapted to be moved relative to said collet for engaging said reset collet independent of said hold ring assembly for returning said jack rod and said operator prong to said first position.

13. An operator tool for supporting and manipulating a well device within a well bore comprising: a hollow

tubular body; a locking collet disposed within a first end of said body, said locking collet having a plurality of radially flexible circumferentially spaced collet fingers extending from said first end of said body for releasably connecting said well device with said operator tool; an annular retainer secured to said first end of said body around said locking collet; said locking collet and said annular retainer having co-engaging shoulders for holding said locking collet within said retainer; a control prong disposed within said locking collet for movement between a first and a plurality of additional positions for controlling radial inward movement of said locking collet fingers around said control prong; a jack rod longitudinally disposed within said body and connected with said control prong for moving said prong between said first position and said additional positions, said jack rod having longitudinal radially flexible fingers each provided with a plurality of outer teeth; an annular hold ring assembly disposed within said body and held against movement toward said first end of said body by said annular retainer, said hold ring assembly having hold fingers provided with internal teeth engageable with said teeth on a first set of said jack rod fingers for holding said jack rod against movement toward said first end of said body, said first set of said jack rod fingers and said hold ring fingers being resilient to permit disengagement of said hold ring fingers from said jack rod fingers to allow said jack rod to be moved into said body away from said first end of said body; a lift ring assembly disposed within said body adapted to be telescoped over said jack rod toward said first end of said body, said lift ring assembly having lift fingers provided with internal teeth engageable with a second set of said jack rod fingers for moving said jack rod into said body away from said first end of said body, said lift ring fingers and said second set of said jack rod fingers being resilient to permit disengagement of said lift ring fingers when said lift ring assembly is moved over said jack rod toward said first end of said body; said hold ring assembly and said lift ring assembly each having external annular shoulders facing each other; a lift spring disposed around said hold ring assembly and said lift ring assembly confined between said annular shoulders on said assemblies to bias said lift ring assembly away from said hold ring assembly, said lift spring being compressible when said lift ring assembly is moved toward said first end of said body and being expandable to move said lift ring assembly away from said first end of said body to engage said lift ring fingers with said second set of said jack rod fingers to move said jack rod and said control prong from said first position to said additional position; a reset collet disposed within said body telescopically over said jack rod, said reset collet having radially flexible collet fingers provided with collet heads each having a downwardly facing cam surface; said lift ring assembly having an internal annular upwardly facing cam surface around said jack rod fingers engageable with said cam surfaces on said reset collet fingers to cam said collet fingers inwardly toward said jack rod fingers into engagement with said jack rod fingers for releasing said jack rod fingers from said lift ring and hold ring fingers; an annular retainer ring engaged around the head end of said reset collet and having an outwardly extending annular flange; a reset spring disposed around said reset collet confined between said annular retainer ring on said collet and said heads on said collet fingers; a jack rod cap member supported on said jack rod and having outwardly extending flanges circumferentially spaced to fit between said reset collet fingers to engage said reset spring above said collet finger heads for compressing said reset spring when said jack rod is moved by said lift ring assembly away from said first end of said body, said reset spring being adapted to expand when said jack rod fingers are disengaged from said lift and hold ring fingers to move said jack rod toward said first end of said body to return said jack rod and

said control prong to said first position; a plunger cap disposed within said body telescopically over said reset collet and engageable with said lift ring assembly, said plunger cap having a central opening through the head thereof; a loose washer having a central opening there-through disposed within said body on said plunger cap, said opening through said washer being alignable with said opening through said plunger cap by manipulation of said washer; a supporting and operating collet releasably engaged with the second end of said body adapted to support said body and move longitudinally into said body to depress said washer against said plunger cap for moving said lift ring assembly over said jack rod compressing said lift spring; an operator rod movably secured through said support collet for connecting said operator tool with supporting means and adapted to be moved into said collet against said washer when said opening through said washer is misaligned from said opening through said plunger cap to depress said plunger cap and said hold ring assembly and said operator rod being further movable through said opening through said washer and said opening through said plunger cap when said opening through said washer is aligned with said opening through said plunger cap to engage and move said reset collet toward said lift ring assembly for releasing said jack rod fingers from said lift and hold ring fingers to permit said reset spring to return said jack rod and said control prong to said first position.

14. A running and pulling tool comprising: a tubular mandrel; a locking collet supported at a first end of said mandrel and having radially flexible collet fingers extending from said first end of said mandrel for releasably engaging a well device; a control prong disposed within said mandrel for movement within said locking collet to control the radial positions of said collet fingers; an externally toothed jack rod connected with said control prong and adapted for longitudinal movement within said mandrel; a lift ring assembly having internally toothed fingers engageable with said jack rod for moving said jack rod from a first longitudinal position to each of a plurality of additional positions; a hold ring assembly having internally toothed fingers for releasably holding said jack rod in each of said positions while said lift ring assembly is moved over said jack rod for engaging and moving said jack rod; a reset assembly telescopically movable over said jack rod and engageable with said jack rod for releasing said jack rod from said lift and hold ring assemblies and returning said jack rod to said first position; a supporting and operating collet releasably secured with the other end of said mandrel for supporting said mandrel and actuating said lift ring assembly; and an operator rod movably engaged through said support collet for supporting said support collet and operatively engaging and actuating said reset assembly and said lift ring assembly.

15. An articulated pump-down tool train for supporting and manipulating a well device within a well bore comprising: at least one movable seal unit adapted to be pumped by fluid pressure through a conduit; and an operator tool pivotally secured with said seal unit adapted to be releasably locked with a well device, said operator tool being actuatable between a plurality of locked and unlocked positions by a predetermined number of reciprocating cycles impressed thereon by movement of said seal assembly within said conduit responsive to fluid pressure differentials effected across said seal assembly.

16. An operator tool according to claim 5, wherein said control prong is provided with a first locking surface for holding said flexible fingers at a fully locked outward position and a second locking surface for holding said flexible fingers at an intermediate locked position.

17. An operator tool in accordance with claim 13, wherein said control prong has a collet finger engaging

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surface for holding said locking collet fingers at a fully outward locked position and a lower end reduced collet finger engaging surface for holding said locking collet finger at an intermediate locked position.

18. An operator tool in accordance with claim 13, 5 wherein said control prong has central and lower end locking collet finger engaging surfaces for holding said collet fingers outwardly at a fully locked position and said prong has a reduced section between said central and lower surfaces for allowing said collet fingers to be 10 cammed inwardly to an unlocked position.

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**Disclaimer and Dedication**

3,378,080.—*John V. Fredd*, Dallas, Tex. FLUID PRESSURE OPERATED ACTUATED OPERATOR TOOL FOR WELL TOOLS. Patent dated Apr. 16, 1968. Disclaimer and Dedication filed Jan. 6, 1983, by the assignee, *Otis Engineering Corp.*

Hereby disclaims and dedicates to the Public the remaining term of said patent.

[*Official Gazette April 5, 1983.*]