United States Patent

Pearce, Jr.

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[54] WELL TOOLS

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[73] Assignee: **Otis Engineering Corporation**, Dallas, Tex.

[22] Filed: **Apr. 24, 1970**

[21] Appl. No.: **31,533**

[52] **U.S. Cl.** **166/212**, 166/125, 166/217

[51] **Int. Cl.** **E21b 23/00**

[58] **Field of Search** 166/212, 214, 217, 215, 216, 166/123, 125, 136, 137

[56] **References Cited**

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Primary Examiner—James A. Leppink
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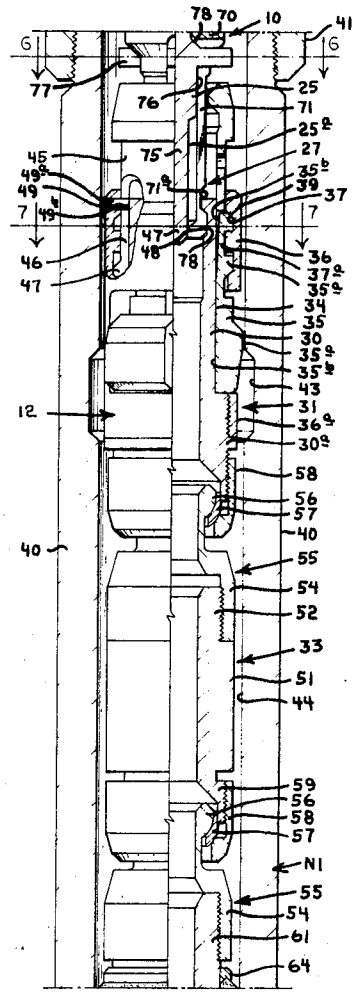
[57] **ABSTRACT**

A locking device and a setting tool for setting said locking device in any selected one of a plurality of identical landing nipples having a locking recess and sealing surface therein installed at spaced intervals in a well tubing string to form a part thereof. The setting tool and locking device are attached to a string of operating tools and moved through the well tubing by fluid pressure or by conventional wire line. Locating means on the setting tool is initially held by retaining means in retracted position but is released for movement to expanded position enabling the setting tool to be stopped at an upwardly facing shoulder spaced in said tubing from the lock recess in the selected landing nipple. Longitudinal movement of the operating tools then expands the locking dogs of the locking device into locking engagement with said lock recess of said nipple, and reverse movement of said operating tool string releases said setting tool from said locking device for removal of the setting tool from the tubing string leaving the locking device locked in said landing nipple. Means for releasing the retaining means which is mechanically operated and means which is responsive to hydrostatic pressure are disclosed.

16 Claims, 21 Drawing Figures



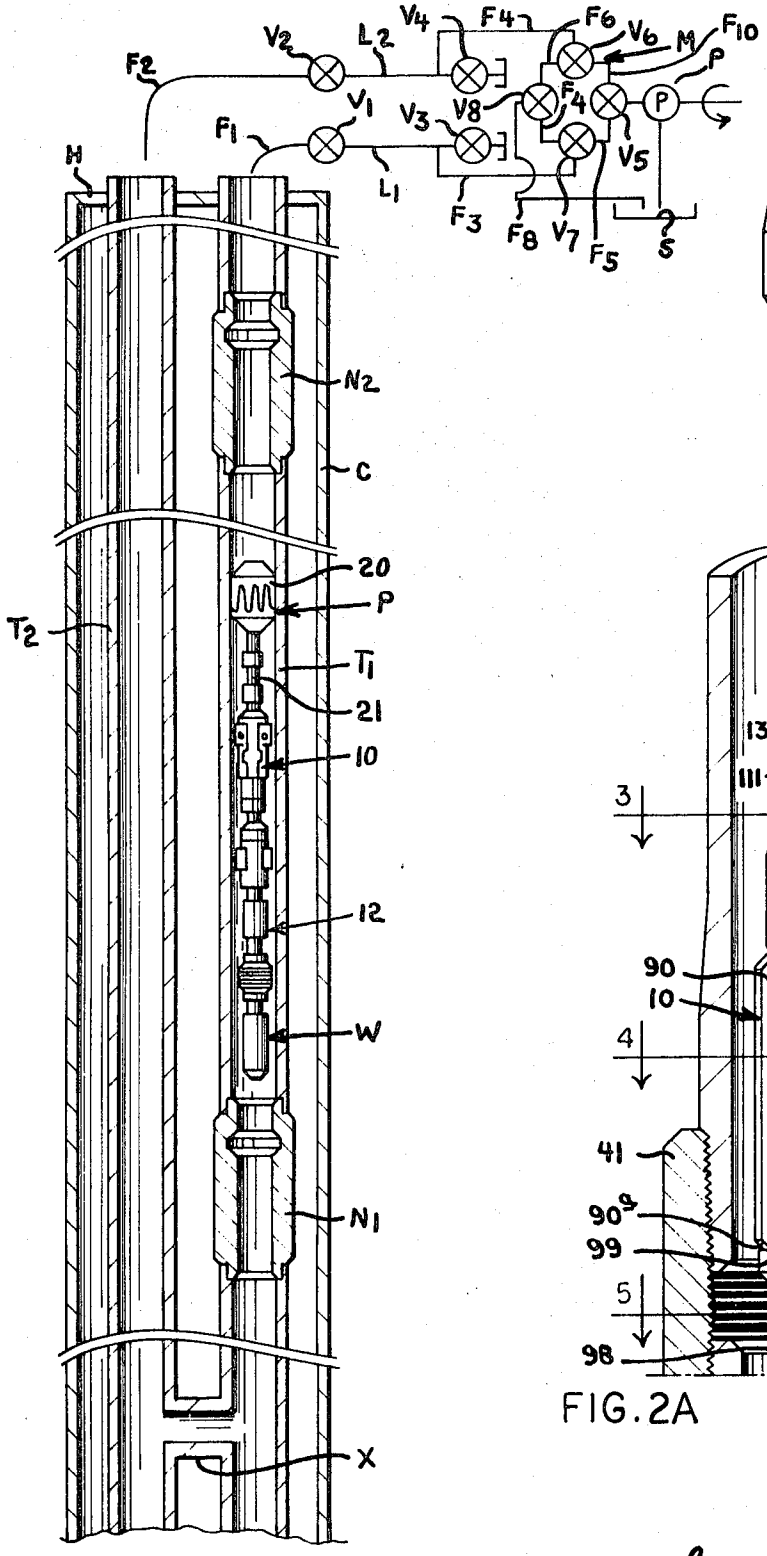


FIG. 1

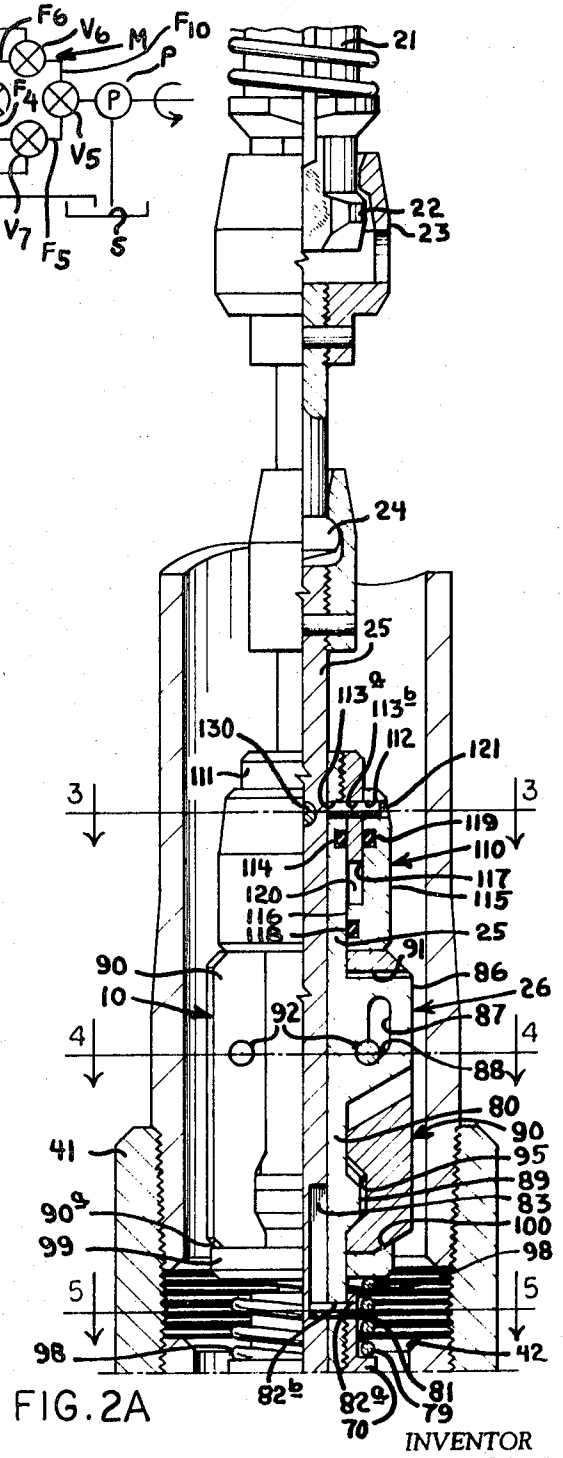


FIG. 2A

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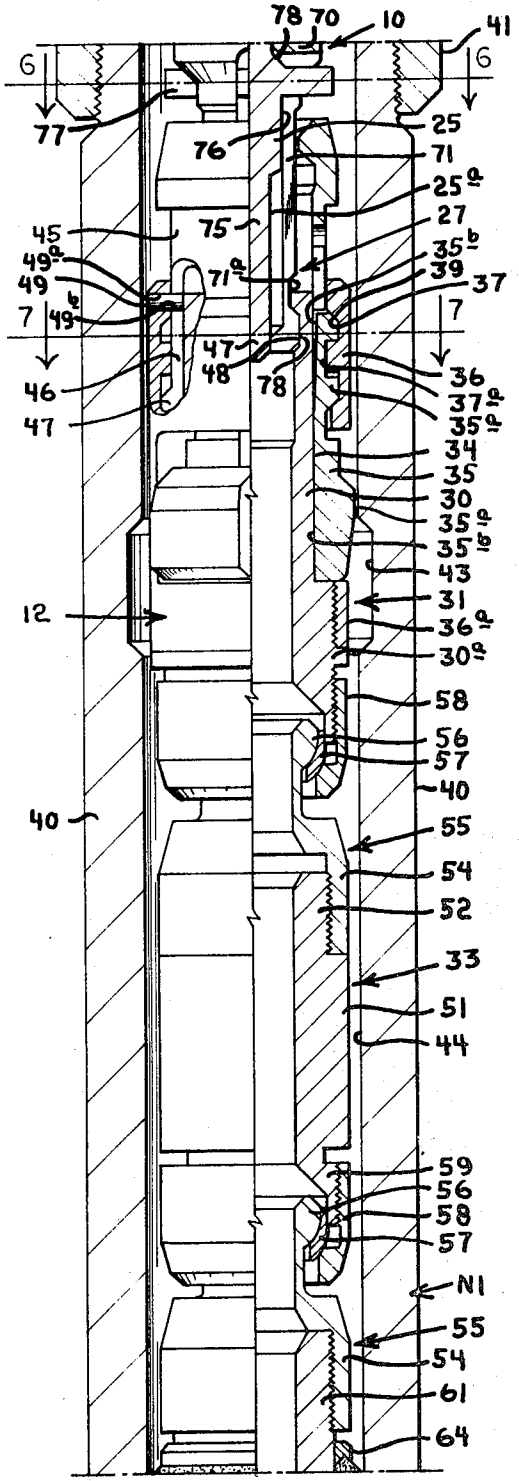

FIG. 2B

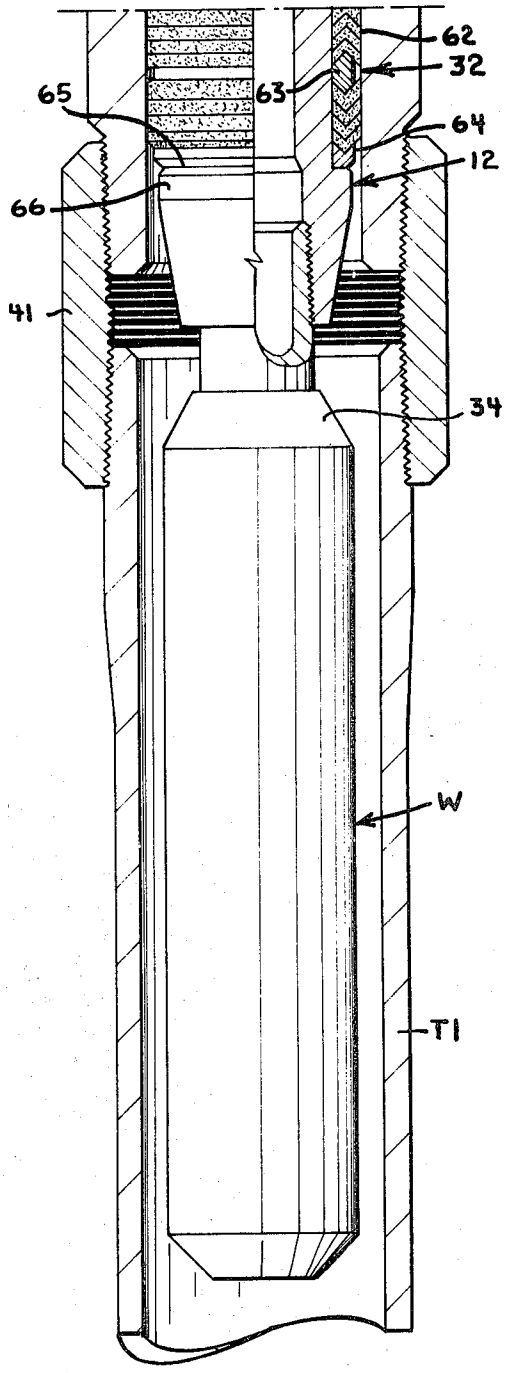

FIG. 2C

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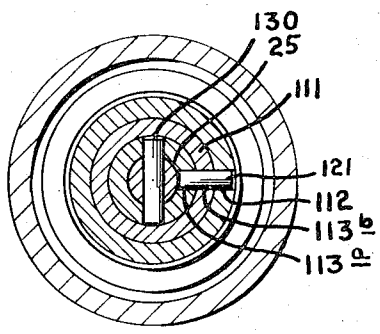

FIG. 3

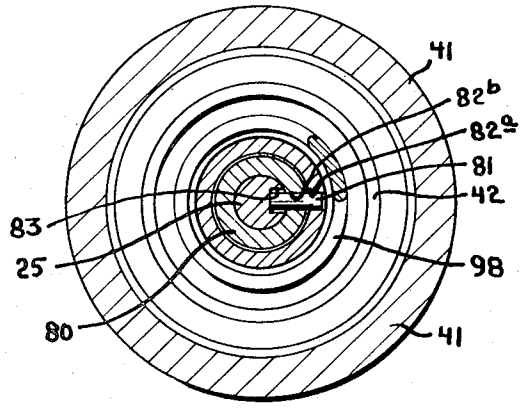

FIG. 5

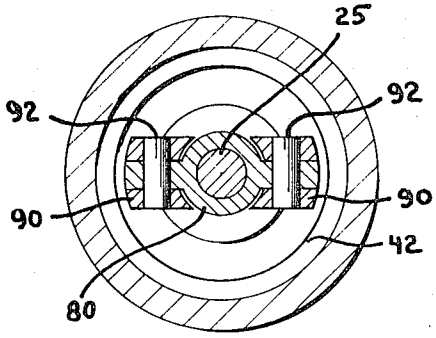

FIG. 4

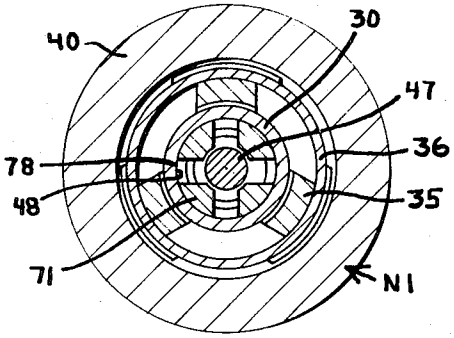

FIG. 7

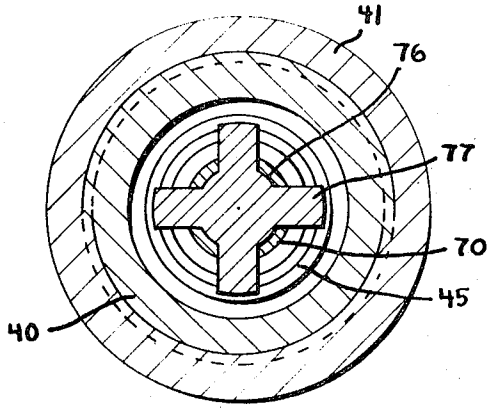

FIG. 6

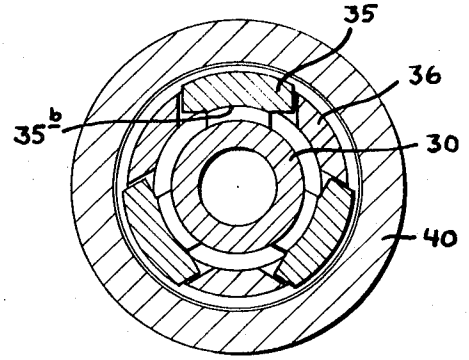

FIG. 11

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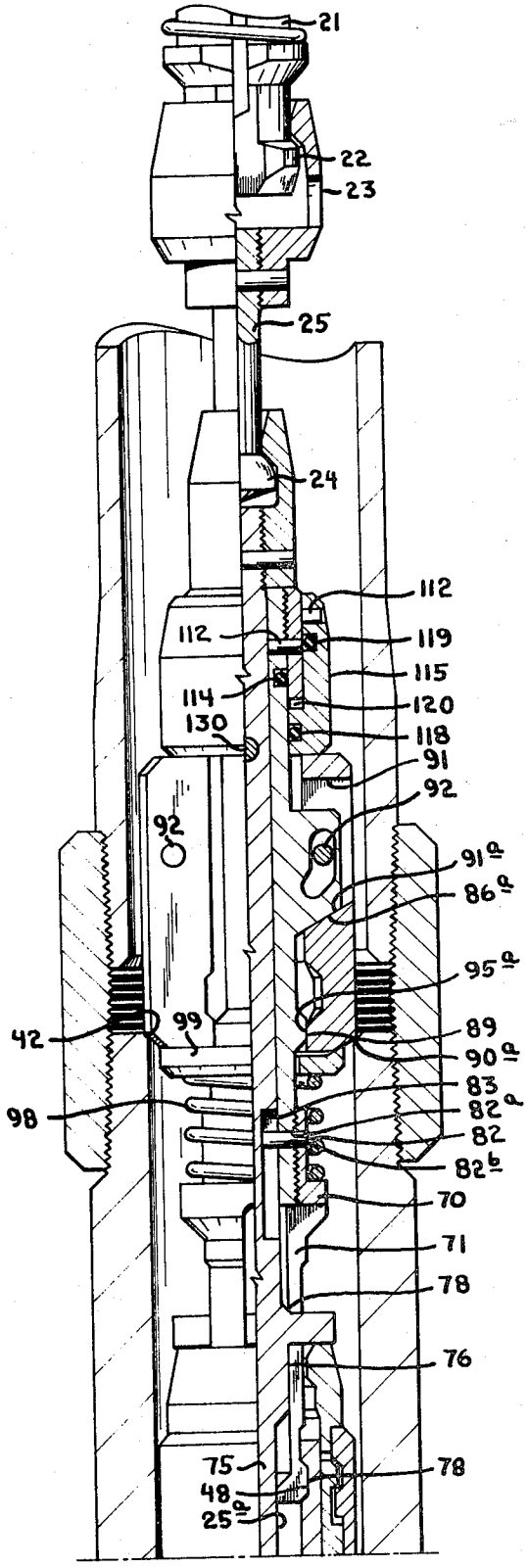

FIG. 8A

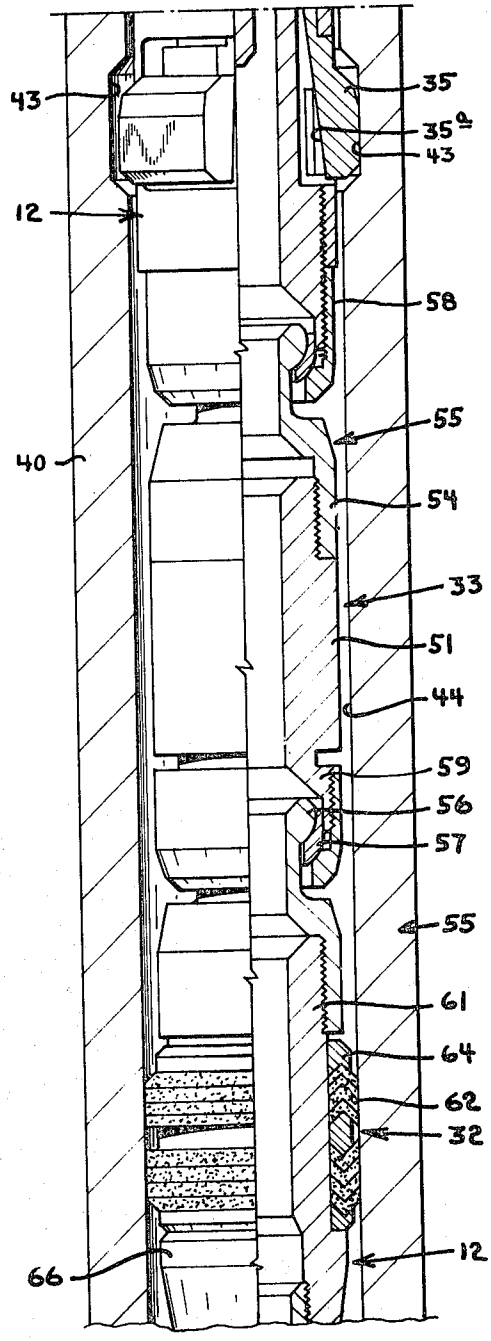

FIG. 8B

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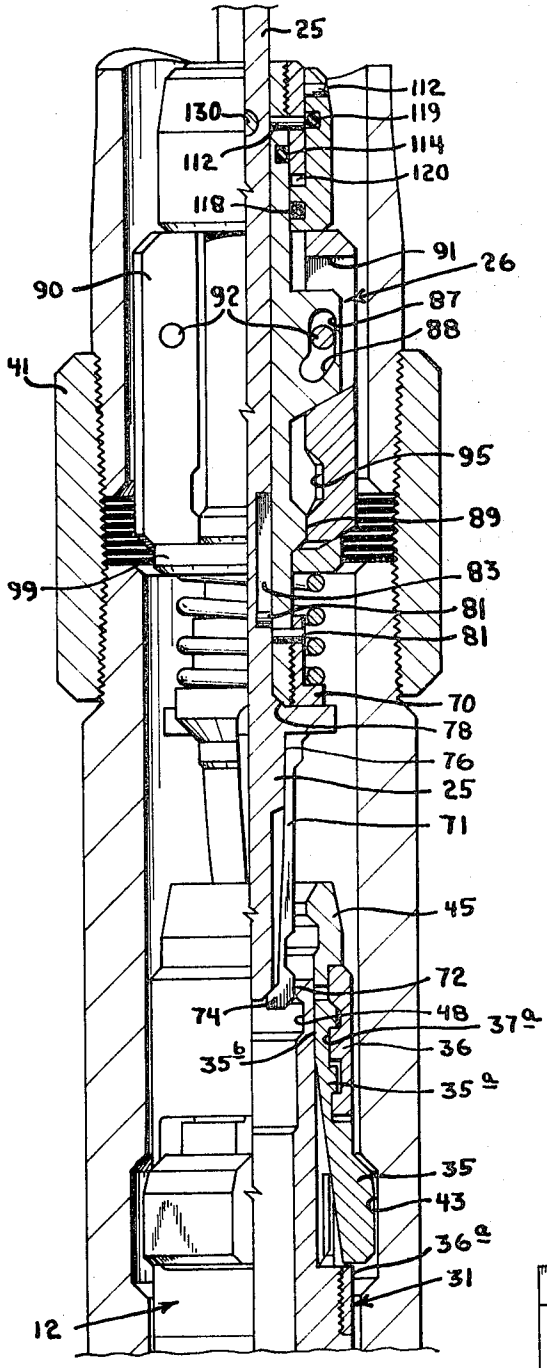

FIG. 9

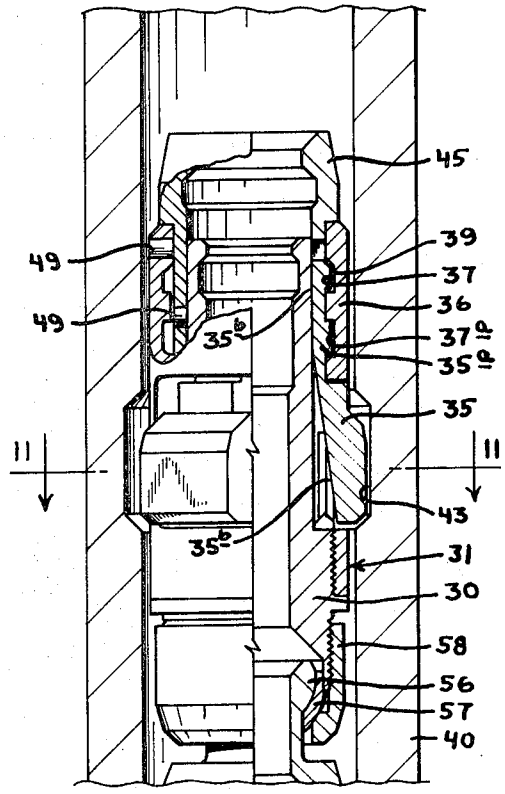

FIG. 10

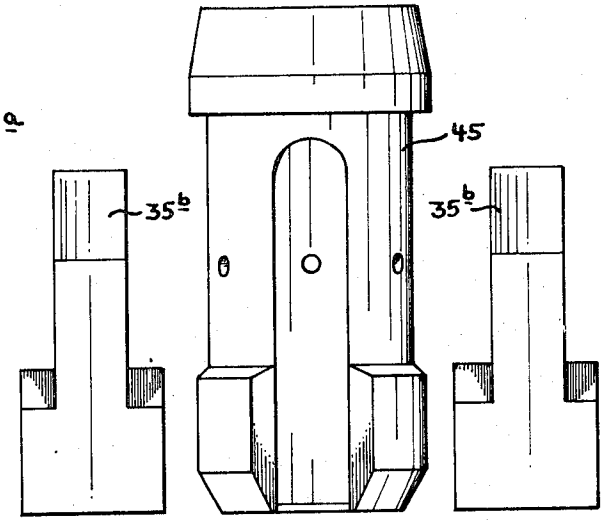

FIG. 16

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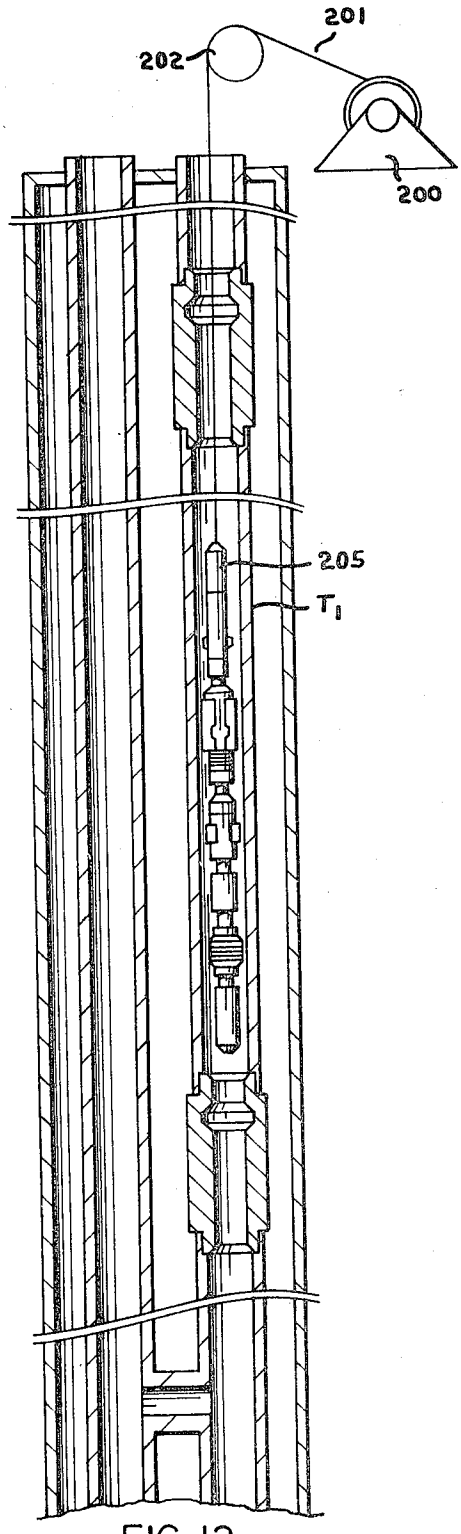

FIG. 12

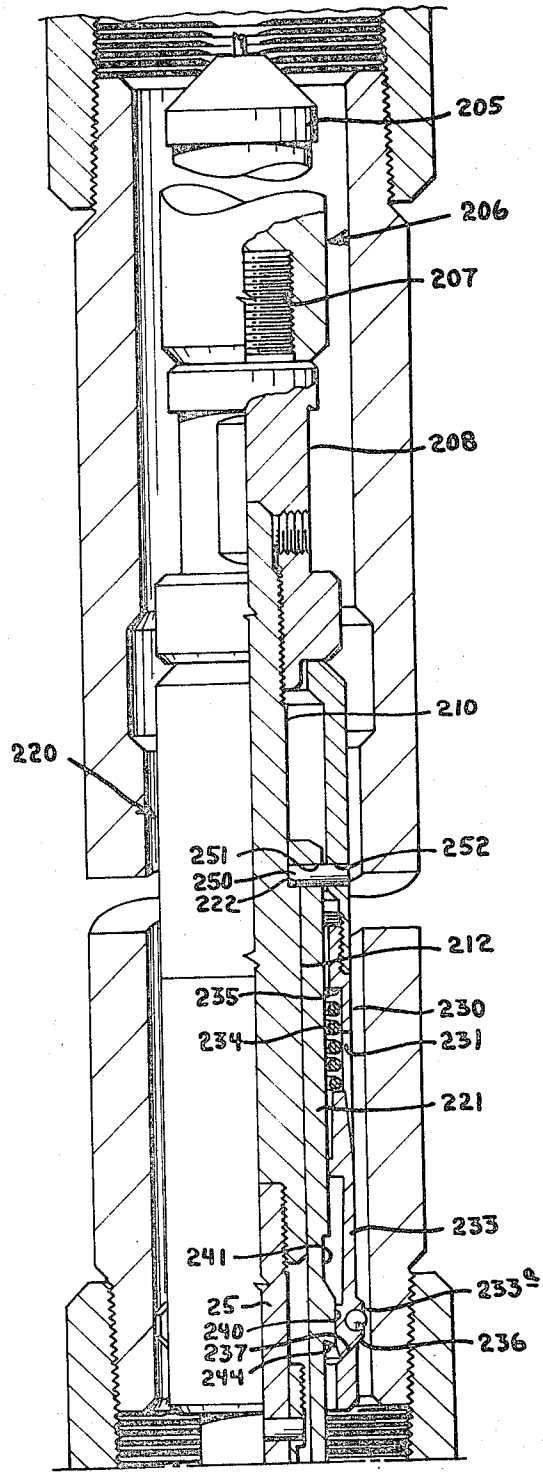

FIG. 13A

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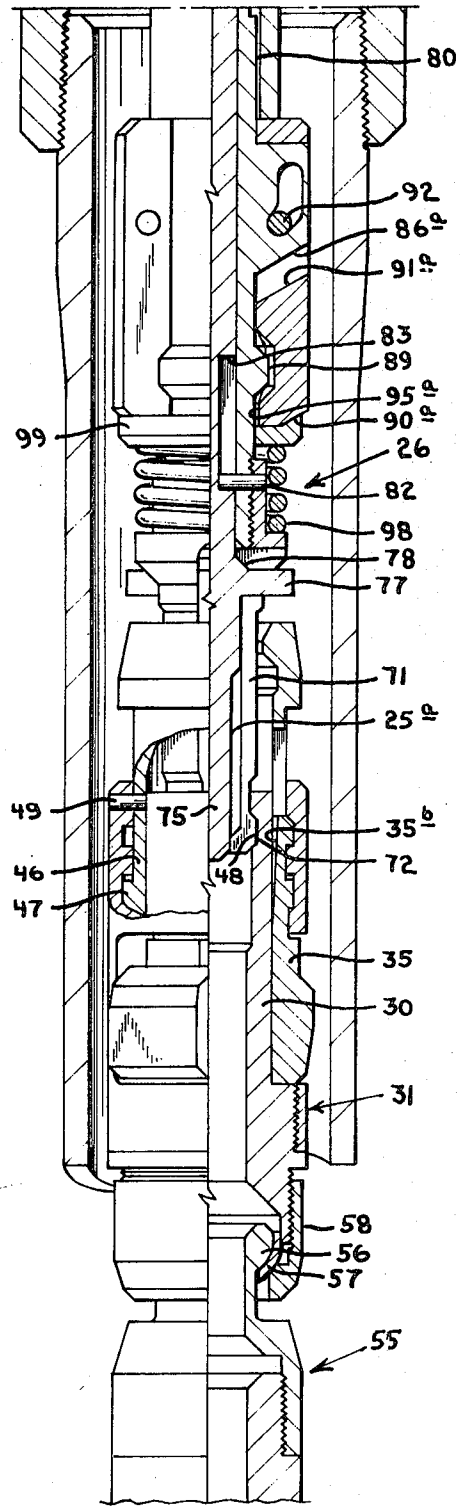

FIG. 13B

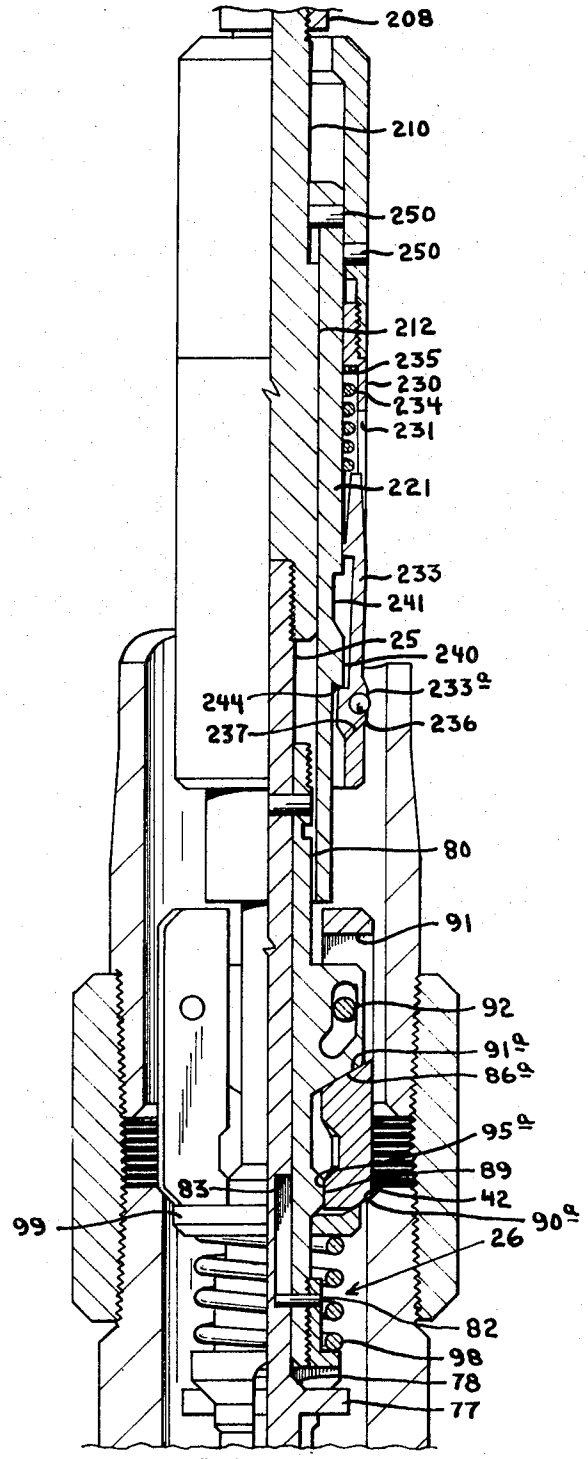

FIG. 14

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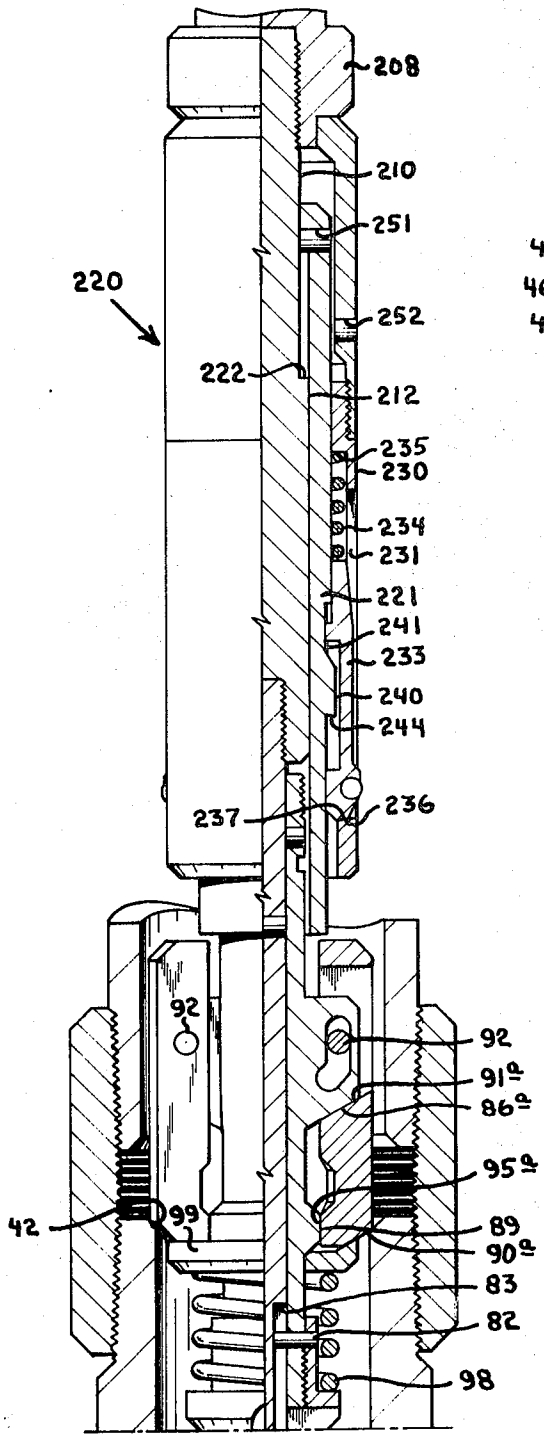

FIG. 15A

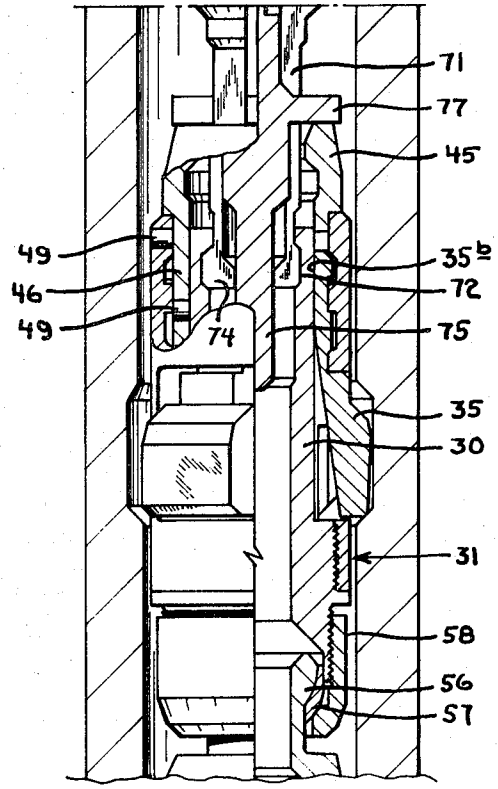

FIG. 15B

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WELL TOOLS

One object of this invention is to provide an improved setting tool for locking devices used to secure well tools such as flow control devices in well flow conduits.

Another object of this invention is to provide a running tool for installing a locking device in any selected one of a plurality of identical landing nipples or receptacles in a flow conduit.

An important object is to provide such a running tool which is movable through the flow conduit by fluid pressure as by circulating control liquid through a well in a pumpdown tool installation, and which is convertible for movement through the flow conduit on a conventional wire line. Another object of this invention is to provide such a running tool having initially retracted locating means mechanically releasable in the flow conduit for movement to expanded position for locating said running tool and said well lock relative to said selected one of said plurality of identical landing receptables.

Another important object of this invention is to provide a locking device for anchoring a well tool in a well flow conductor against displacement therein in either longitudinal direction to anchor a well tool therein against longitudinal displacement from said landing nipple.

Still another object of the invention is to provide a locking device for anchoring a well tool in any selected one of a plurality of identical landing nipples connected in a well flow conductor.

A further object is to provide a locking device for landing a well tool in a receptacle forming a part of a well flow conductor and anchoring said well tool in said receptacle against longitudinal displacement therefrom, said receptacle having an internal annular lock recess formed in its bore and said locking device being provided with locking dogs expandable into locking engagement within said nipple recess, and means for expanding said locking dogs and locking them in such expanded position to prevent longitudinal displacement of said locking mandrel from said receptacle.

Still another object of the invention is to provide a locking device and a running tool therefor having means for selectively locating said locking device in any selected one of a plurality of separate longitudinally spaced landing nipples in a flow conductor designed to receive said locking device for locking said locking device in place in said selected landing nipple, and wherein said locking device has locking members thereon engageable with said selected landing nipple and constituting the sole means of anchoring said locking device in said landing nipple against forces tending to displace it therefrom in either longitudinal direction; said running tool being releasable from said locking device and removable from said flow conductor independently of said locking device; and wherein said locking device after having been locked in place in said landing nipple is releasable from such locking position, when desired, for removal from the flow conductor; and, wherein said running tool is actuatable by fluid pressure operating means or by mechanical means to effect installation of said locking device in said landing nipple.

A still further object of the invention is to provide a landing nipple adapted to be connected in a tubing string alone or in combination with other like landing nipples and which is designed for use in conjunction with a running tool for locating and locking a well tool locking device in said single nipple or in any one of the several longitudinally spaced like nipples in said tubing string.

A still further object of this invention is to provide a plurality of landing nipples longitudinally spaced in the tubing and each including an internal annular recess for receiving the locking dogs of the locking device and an annular projecting stop shoulder spaced from the recess for engagement by the locating keys of the running tool, said recess and shoulder being spaced a predetermined distance apart so that when the locating keys engage the stop shoulder the locking dogs are aligned with the recess.

The invention is directed to an improved locking device and running tool therefor; said running tool having means for selectively locating said locking device in any one of a plurality of separate longitudinally spaced landing nipples in a flow conductor designed to receive said locking device and for locking said locking device in place in said landing nipple, and wherein said locking device has locking members thereon engageable with said landing nipple designed for and constituting the sole means of locking said device in said landing nipple against forces tending to displace the locking device from said landing nipple in either longitudinal direction, and wherein said running tool is releasable from the locking device and removable from the flow conductor independently of said locking device; and wherein said locking device, after having been locked in place in said landing nipple, is releasable from such locked position, when desired, for removal from the well; and wherein said running tool is actuatable by fluid pressure or by mechanical means for locating and locking said locking device in said landing nipple.

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

FIG. 1 is a schematic view of a well installation showing the well tool of the invention being installed in the well by the fluid operated pumpdown method;

FIGS. 2A, 2B, and 2C are enlarged views, partly in elevation and partly in section, of a well tool constructed in accordance with the invention and showing the same being installed in a well flow conductor;

FIGS. 3 through 7 are horizontal cross-sectional views taken on the lines 3—3, 4—4, 5—5, 6—6, and 7—7 of FIGS. 2A and 2B;

FIGS. 8A and 8B are vertical views, partly in elevation and partly in section, similar to FIGS. 2A, 2B, and 2C showing the well tool being located in a landing nipple and locked in position therein;

FIG. 9 is a fragmentary view, partly in elevation and partly in section, of a portion of the well tool, showing the locking mandrel anchored in place in the landing nipple and the setting tool being disconnected from the locking mandrel for removal from the landing nipple;

FIG. 10 is a view, partly in elevation and partly in section, of the locking mandrel of the well tool located and locked in place in the landing nipple of the well flow conductor and the setting tool completely removed therefrom;

FIG. 11 is a horizontal cross-sectional view taken on the line 11—11 of FIG. 10;

FIG. 12 is a schematic view, partly in elevation and partly in section, of a well installation showing a modified form of well tool constructed in accordance with the invention being lowered into place in the well flow conductor by a flexible line running and pulling mechanism;

FIGS. 13A and 13B are enlarged views, partly in elevation and partly in section, of the setting tool of the modified form of the invention shown in FIG. 12, showing the same connected to a well tool and being lowered into a well flow conductor;

FIG. 14 is a view, partly in elevation and partly in section, of the upper portion of the setting tool of FIGS. 13A and 13B showing the release dogs released and the locator keys expanded into locating position and in engagement with the locating shoulder and the landing nipple preparatory to setting the locking mandrel of the well tool;

FIGS. 15A and 15B are views similar to FIG. 14 showing the setting tool moved downwardly to move the expander sleeve downwardly to lock the locking dogs of the locking mandrel of the well tool while the locator keys are in engagement with the locating shoulder of the landing nipple; and,

FIG. 16 is an exploded view in elevation of the dog expander sleeve and of the inner surfaces of two of the locking dogs of the locking mandrel.

DESCRIPTION OF PREFERRED EMBODIMENT

In the drawings, FIG. 1, the number 10 designates a well locking and setting apparatus constructed in accordance with the invention and showing the same being moved into a well flow conductor or tubing string T1 forming a part of the U-tube type pumpdown installation in which a second tubing string T2 is suspended alongside and parallel to the tubing string T1 in a well casing C having a closure H at its upper end and traversing the usual well producing formation. Near the lower end of the tubing strings T1 and T2 is a crossover fitting or crossflow device X conducting fluids between the two tubing strings T1 and T2 in the usual manner. A plurality of vertically spaced landing nipples N1 and N2 which may be identical in internal configuration are connected in the tubing string T1 for receiving a well locking and sealing assembly 12 moved through the tubing string by means of the running tool assembly or operating tool string 10. The term running tool assembly has been applied to the assembly 10, but the assembly may be used to run the well tool 12 into or out of the tubing string T1 as desired, as will be hereinafter more fully explained.

A pumpdown locomotive string P is connected to the upper end of the running tool assembly 10 and is moved into and out of the tubing string T1 by means of fluid pressure circulated through the two tubing strings and the crossover fitting X. Connected with the upper end of the tubing strings is a first lubricator L1 connected to the tubing string T1 and a second lubricator L2 connected to the tubing string T2, valves V1 and V2 being connected in the flow lines F1 and F2 between the tubing strings and the lubricators. The lubricator L1 is closed at its outer end by a valve V3 to provide a lubricator tubing chamber into which the string of well tools may be inserted when the valve is opened for movement into or out of the tubing string T1. Similarly, a valve V4 closes the outer end of the lubricator L2 and with the valve V2 provides a lubricator tubing chamber into which valves or other flow control devices may be inserted for movement into and out of the tubing string T2. The lubricators L1 and L2 are connected by means of flow lines F3 and F4, respectively, with a manifold M for controlling the flow of operating fluid into and out of the tubing strings T1 and T2 in the well known manner. Fluid is supplied from a sump or source S by means of a pump P to the manifold M and will be directed through a valve V5 and flow lines F5 through a valve V7 communicating with the flow line F3 and the lubricator L1, whereby fluids supplied by the pump will be directed into the tubing string T1. A valve V6 is connected by means of a flow line F6 with a valve V8 and a flow line F8 leads from the valve V8 to the supply or sump S, whereby fluids pumped downwardly through the tubing strings T1 and through the crossover fitting X and upwardly through the tubing string T1 to the flow line F2 will pass through the lubricator L2, the flow line F4, the valve V6, the flow line F6, the valve V8, and the flow line F8 to the sump. To reverse flow, fluids are directed from the pump through the valve V5 and a flow line F10 to the valve V6 and the flow line F4 thence through the lubricator L2, the valve V2 and the flow line F2 into the tubing string T2 and downwardly into the well to the crossover fitting X. The fluids then flow upwardly through the tubing string T1 to the flow line F1 and valve V1 and into the lubricator F1, and through the flow line F3, the valve V7 and a flow line F9 to the valve V8 and thence through the flow line F8 into the supply or sump S. In this manner fluids may flow downwardly into the well through the tubing string T2 and upwardly out of the well through the tubing string T1. The manifold M may be arranged in any other suitable manner than that just described, so long as the fluids may be directed into and out of the well through the tubing strings in the manner just described to provide flow into and out of the well through the U-tube formed by the two tubing strings and the crossover fitting. In this manner the well pumpdown tool assembly P may be moved into and out of the tubing string T1 as desired.

The foregoing constitutes the usual pumpdown tool installation in a well, and may be used in either offshore submarine wells or in other wells.

The pumpdown tool string P may be of any desired type and include a power piston 20 which may be of the type shown in the patent to N. F. Brown, U.S. Pat. No. 3,419,074, dated Dec. 31, 1968. The piston 20 will be connected by means of a suitable knuckle joint coupler 21 also of the type shown in the patent to Brown, U.S. Pat. No, 3,419,074, having a pair of resiliently coupled members provided with external bosses 22 at their opposite ends for engaging in a coupling socket 23 connected by means of a knuckle joint 24 to the upper end of the well tool setting or retrieving device. The setting device 10 includes an elongate stem 25 on which a locator assembly 26 is mounted, and having at its lower end a connector setting tool 27 which is releasably connected to the upper end of the tubular mandrel 30 of the locking assembly 31 of the locking and sealing assembly 12. The seal assembly 32 of the locking and sealing assembly 12 is connected by means of a knuckle joint connector member 33 to the lower end of the locking assembly 31 and a well flow control device W is connected by means of a fluidtight knuckle joint 34 to the lower end of the seal mandrel assembly 32. The knuckle joints provide articulation permitting movement of the well tools around short radius bends in the flow conductor, which is particularly desirable in submarine type installations in which the radius of curvature may be of the order of 5 feet or less.

In FIGS. 2A, 2B and 2C, the landing nipple N1 is shown to comprise an elongate tubular body 40 having external threads at its opposite ends by means of which the nipple may be connected by couplings 41 in the tubing string T1. As shown in FIG. 2A, a stop shoulder 42 is provided at the upper end of the bore of the landing nipple for engagement by the locator device 26 to position the locking device 31 in proper position in the landing nipple. Spaced a predetermined distance in the bore 44 of the mandrel from the stop shoulder 42 is an internal annular locking recess 43 into which the locking dogs of the locking device 31 are adapted to be expanded to hold the device securely positioned in the landing nipple. Below the internal annular locking recess 43, the bore 44 of the landing nipple provides an elongate cylindrical sealing surface which is adapted to be engaged by the sealing assembly 32 of the locking and sealing assembly 12, to direct fluids flowing from the well upwardly through the tubing string T1 through the well flow control device W in the usual manner.

The position of the annular locking recess 43 below the upwardly facing stop shoulder 42 is such that when the locator device is engaged with the stop or locator shoulder 42 the dogs of the locking device 31 are disposed to be expanded into the locking recess 43 in the nipple, as shown in FIGS. 8A and 8B.

The locking device 31 includes the elongate tubular mandrel 30 having its upper cylindrical portion reduced in external diameter to provide a neck 34 on which a plurality of locking dogs 35 are supported by means of a cylindrical supporting dog carrying sleeve 36 threaded at its lower end 36a onto the enlarged lower portion 30a of the elongate mandrel 30 below the neck 34. The upper portion of the bore of the dog supporting sleeve is enlarged to provide an internal annular recess 37 having an inwardly projecting annular stop flange 37*a* formed in the medial portion of said recess. The locking dogs 35 have handles 35*a* which extend upwardly in the bore of the dog carrying sleeve 36 and have a pair of longitudinally spaced outwardly projecting lugs or bosses 39 formed on their upper ends and engaging in the recess 37 on opposite sides of the flange 37*a* for retaining and supporting the dogs pivotally at their upper ends by means of said internal projecting flange and the externally projecting bosses on the handles of the dogs. The inner surfaces 35*b* of the dogs are inclined outwardly from adjacent the lower boss upwardly to the upper ends thereof to permit the dog handles to pivot in the annular space between the neck 34 of the mandrel and the bore of the slip carrying sleeve 36 at the recess 37.

An expander sleeve 45 is slidable on the neck 34 of the mandrel and has its lower portion longitudinally slotted to straddle and slide longitudinally along the dog handles 35*a* and provide a pair of expander legs 46 having expander bosses or locking surfaces 47 at their lower ends adapted to engage the inwardly facing portions of the bosses 35*b* of the lock dogs 35 to hold the lock dogs in the expanded position shown in FIG. 10 when the sleeve is moved downwardly relative to the dog carrier 36 to move the expander bosses into engagement with the inner faces of the dogs on either side of the handles of the dogs. The structure of the expander sleeve and the locking dogs is clearly illustrated in the patent to Marshall et al., U.S. Pat. No. 2,698,056. The locking dogs are thus held positively, by the locking surfaces of the legs of the expander sleeve, in the expanded locking position shown in FIGS. 10 and 11 to prevent displacement of the mandrel in either direction from the bore of the landing nipple N1. The expander sleeve 45 is held in the upper position shown in FIG. 2B by means of a shear pin 49 extending through a suitable aperture in the upper end of the dog carrying sleeve 49*a* above the recess 37 and engaging within registering aperture 49*b* formed in one of the legs of the expander sleeve 45, whereby the expander sleeve is positively held against downward movement with respect to the locking dogs 35 until the pin 49 has been sheared, as will be hereinafter explained.

The knuckle joint member 33 includes a mandrel 51 which has its upper reduced end 52 threaded to receive the skirt 54 of a tubular ball knuckle member 55 having a spherical ball segment 56 at its upper end. The ball segment 56 is seated upon a plurality of circumferentially spaced pads or bushings 57 which are confined within a thimble member 58 threaded onto the lower end of the mandrel 30 of the lock assembly 31 below the slip carrier sleeve 36. .The thimble 58 is locked in place on the threaded lower end of the mandrel to prevent displacement of the thimble from the mandrel and to provide a positive connection between the knuckle joint assembly 33 and the mandrel 30. A similarly reduced lower end portion 59 of the knuckle joint mandrel 51 has a substantially identical thimble 58 threaded onto such reduced lower end portion and supporting a plurality of circumferentially extending knuckle ball pads or bushings 57. This thimble 58 is also locked in place on the mandrel 51 to prevent displacement of the thimble from its mandrel. Thus, the thimble 58 threaded onto the reduced lower portion 59 of the mandrel 51 of the knuckle joint assembly and supports the bushings or pads 57 which likewise engage and support the spherical segment 56 at the upper end of a tubular knuckle joint member 55 having its depending skirt 54 threaded onto the upper end of a packing assembly mandrel 61 on which are mounted a set of a plurality of sealing rings 62, shown to be of opposed V-type rings disposed on opposite sides of a central spacer 63 and supported between back up rings 64 on the upper and lower ends of the set of sealing rings, confined between the lower end of the skirt 54 of the tubular knuckle joint member at the upper end of the packing mandrel and the upwardly facing shoulder 65 at the upper end of an external annular flange 66 formed at the lower end of the packing mandrel. The tubular packing mandrel receives in the threaded lower end of its bore the threaded reduced upper end of a knuckle joint 34 having a fluid tight sealing engagement with the upper end of a well flow control device W, which may be a safety valve, a flow regulator or any other suitable flow controlling device for use in the well flow conductor.

The locking mandrel 31 and sealing mandrel sealing assembly 32 with the flow control device W attached thereto are run into the well flow conductor or tubing string T1 by means of the running tool string 10. An elongate tubular sleeve 70 is slidable longitudinally of the mandrel 25 of the running tool assembly 10, and the lower end of said sleeve is slotted to provide a plurality of resilient collet fingers 71 having external bosses 72 formed on their lower ends below an external annular groove 71*a* formed in the lower end portions of the collet fingers of the setting tool 27. The bosses 72 on the collet fingers are engageable within an internal annular groove 48 formed in the upper end of the bore of the neck 34 of the mandrel 30 of the locking device, as shown in FIG. 2B. The lower reduced end of the elongate mandrel 25 of the setting tool is engaged between internal annular bosses 74 formed on the lower ends of the collet fingers, whereby the external bosses on the fingers are held firmly engaged in the recess 48 in the bore of the mandrel neck.

The mandrel 25 is provided with an external annular flange 76 having a plurality of radially extending integral arms 77 which extend outwardly through the slots between pairs of collet fingers 71 on the lower end of the setting tool sleeve 70 and with the upwardly facing inclined shoulder 78 at the upper end of the flange provide means for lifting the sleeve 70 by means of the mandrel and preventing rotative movement of the sleeve on the mandrel.

The laterally projecting arms 77 are disposed to engage the upper end of the expander sleeve 45 to force the expander sleeve downwardly to shear the pin 49, and then drive the sleeve downwardly with respect to the locking dogs 35 to move the expander surfaces of the locking sleeve into engagement with the inner locking surfaces of the dogs to hold the dogs in an expanded position.

The upper end of the bore of the collet sleeve 70 is internally threaded onto the externally threaded lower end of the locator carrier sleeve 80, as clearly shown in FIGS. 2A and 8A, the collet sleeve being secured against rotation with respect to the locator carrier sleeve 80 by means of a shear pin 81 extending through aligned openings 82*a* and 82*b* formed in the upper end of the collet sleeve and in the lower end of the locator carrier sleeve. The inner end of the pin 81 extends inwardly radially into an elongate longitudinal slot 83 formed in the exterior of the mandrel 45 and limits movement of the collet sleeve and locator carrier sleeve longitudinally of the mandrel and prevents rotative movement of the sleeves with respect to the mandrel. The locator carrier sleeve 80 is provided intermediate its ends with a pair of radially projecting ears or lugs 86 having longitudinally extending transverse slots 87, the lower portion of each of said slots being inclined inwardly and downwardly at 88. A pair of elongate locator keys 90 are movably mounted on the carrier sleeve 80. Each key has an elongate longitudinal slot or aperture 91 which receives one of the radially projecting ears 86 of the locator carrier sleeve, and a retainer pin 92 extends transversely of each key and the longitudinal slot in the key and through the elongate slot 87 formed in the projecting ear, whereby the pins 92 retain the locator keys in place on the locator carrier sleeve. The slots 87 permit longitudinal movement of the keys relative to the ears 86, and when the pins 92 engage the downwardly and inwardly inclined lower portion 88 of the slots 87 the pins and slots cam or urge the keys inwardly of the ears into close retracted engagement with the exterior cylindrical surface of the locator carrier sleeve, as clearly shown in FIG. 2A. In this retracted position, an internal recess 95 formed in the lower inner portion of each of the locator keys engages over an external annular beveled expander flange 89 on the expander carrier sleeve 80 whereby the keys may retract uniformly throughout their length. A helical coil spring is confined between an upwardly facing shoulder 79 on the upper portion of the collet sleeve 98 and the underside of an upwardly facing retainer washer 99, which is slidable on the lower portion of the locator carrier sleeve and has an upwardly and outwardly inclined upper annular flange surface 100 disposed to engage the beveled lower ends 90*a* of the locator keys, whereby the spring biases the retainer washer and the keys longitudinally upwardly of the locator carrier sleeve 80. When the keys are held in the lower position shown in FIG. 2A the beveled inclined surface 100 on the upper face of the retainer washer 99 cams the lower ends of the locator keys inwardly and resiliently retains them in such inward position, whereby the lower ends of both locator keys are held inwardly when the pins 92 are in the lower inwardly and downwardly inclined portion 88 of the slots 87 in the ears of the locator carrier sleeve 80.

For positively holding the locator keys downwardly in the position shown in FIG. 2A, a hydrostatically controlled retaining assembly **110** is mounted on the upper end of the locator carrier sleeve **80** and comprises a stationary or fixed piston member **111** threaded onto the upper end of said carrier sleeve and held in place thereon by means of a transverse shear pin extending through aligned apertures **111** and **112** formed in the upper end of the carrier sleeve and in the stationary piston member and terminating short of the exterior surface of the mandrel **25**. An O-ring seal **113** is disposed in an external annular groove in the locator carrier sleeve and seals between such sleeve and the bore of the stationary piston. A movable cylinder **115**, having an internal annular flange or head **116** at its lower end, is slidable on the upper reduced end of the locator carrier sleeve and has an enlarged bore **117** in its upper portion which telescopes over and slides longitudinally on the exterior surface of the stationary piston **111**. An O-ring seal **118** is disposed in suitable internal annular groove in the internal flange **116** of the movable cylinder, and an O-ring seal **119** is disposed in a suitable annular recess formed in the upper portion of the enlarged bore **117** of the cylinder and seals between the cylinder and the exterior surface of the stationary piston **111**. The chamber **120** formed in the enlarged bore of the movable cylinder between the flange **116** and the stationary piston **111** is therefore sealed off by the O-ring seal members, and atmospheric pressure is maintained in such chamber, since the device is assembled at the well surface under atmospheric conditions. The shear pin **112** has its outer end engaged in a radial opening **121** formed in the upper end portion of the movably cylinder **115** above the O-ring **119**, whereby the integrity of the sealed chamber is not affected by the shear pin and the apertures in which it is disposed.

The lower end of the movably cylinder **115** abuts the upper ends of the locator keys **90** and holds the keys downwardly on the locator carrier sleeve in the position shown in FIG. 2A. When the location in the well at which the landing nipple N1 is disposed is reached as the tools are moved downwardly through the tubing string T1 by means of the fluid pressure locomotive assembly P, with the string of tools located just above the landing nipple N1, the pressure within the tubing string is elevated to a sufficient degree or value to shear the pin **112**, by the force of the fluid pressure applied to the movable cylinder **115** across the differential area between the O-ring **118** and the O-ring **119**. The elevated pressure will shear the pin **112** and move the movable cylinder upwardly on the locator key carrier sleeve to the position shown in FIG. 8A, whereupon the helical coil spring **98** acting upon the washer **99** biases the locator keys upwardly of the carrier sleeve and the pins **92** carried by the keys are moved upwardly and outwardly in the lower portions **88** of the slots **87** into the longitudinal vertical portions of the slots, until the downwardly and inwardly inclined surface **91***a* at the lower end of the longitudinal slots **91** in the locator keys engages the downwardly and inwardly inclined expander surface **86***a* on the lower ends of the ears **86**. Also, the lower end portions of the inner surfaces **95***a* of the locator keys **90** engage the external annular beveled expander flange **89** on the locator carrier sleeve to bias the lower end portions of said keys outwardly and lock the same in the outer expanded position. The keys are thus positively held in aligned expanded position of the engagement of the pins **92** in the vertical portion **87** of the slots in the ears of the carrier sleeve and by the engagement of the locking surfaces **95***a* with the locking flange **89** on the sleeve, as shown in FIG. 8A.

In this position, the keys have an external diameter greater than the bore of the upwardly facing stop shoulder **42** at the upper end of the landing nipple, so that downward movement of the operating tool string and the setting tool with the locator assembly connected thereto is positively arrested by the engagement of the beveled lower ends **90***a* of the locator keys with such upwardly facing stop shoulder. With the downward movement of the string of tools so arrested, the locking dogs **35** of the locking mandrel are positioned in registry with the internal annular locking recess **43** in the bore of the landing nipple. Downward pressure applied to the mandrel **25** by the fluid pressure operated pump down locomotive piston P shares the transverse shear pin **130** (FIGS. 2A and 3) which extends through a transverse opening **131** in the setting tool mandrel **25** and into a pair of diametrically opposed registering openings **132** in the upper end of the locator carrier sleeve **80**. When the pin **130** is sheared, the mandrel **25** may move downwardly with respect to the locator carrier sleeve **80**, and the reduced lower portion **25***a* at the lower end of the mandrel slides longitudinally between the inwardly extending bosses **74** on the inner lower ends of the collet fingers **71** of the collet sleeve **70**. Such downward movement of the mandrel **25** then moves the radially projecting arms **77** into engagement with the upper end of the expander sleeve **45** for moving the expander sleeve downwardly.

Further downward force applied by means of the fluid pump down piston P then moves the mandrel **25** of the setting tool downwardly, shearing the pin **49** in the dog carrier sleeve and the expander sleeve **45**, whereupon the radially projecting arms **77** on the mandrel **25** are moved downwardly. The radially projecting arms **77** which are in engagement with the upper end of the expander sleeve **45** then moved the expander sleeve downwardly to move the locking surfaces at the lower ends of the legs of the expander sleeve into engagement with the inner surfaces of the locking dogs to move the dogs into and hold them positively in expanded locking position with the bosses **35***a* engaged in the locking recess **43**, as shown in FIGS. **8B** and **10**.

When the setting tool assembly has been operated in the manner just described, the locking device **31** is positively locked in place in the landing nipple N1 with the projecting bosses **35***a* of the locking dogs positively disposed in the internal annular locking recess **43** of the landing nipple to prevent longitudinal movement of the locking mandrel, the sealing mandrel and the well flow control device in either direction with respect to the landing nipple.

At this time, the direction of flow of operating fluids in the U-tube structure provided by the tubing T2, the crossover fitting X and the tubing string T1 is reversed. Fluid pressure then moves the locomotive piston P upwardly in the tubing string T1, and such upward movement of the locomotive piston moves the setting tool mandrel **25** upwardly with respect to the locator carrier sleeve and the collet sleeve until the lower end of the slot **83** in the mandrel engages the transverse pin **81** to lift the locator carrier sleeve and the collet sleeve with the mandrel. Upward movement of the collet sleeve is precluded by the engagement of the external bosses **72** at the lower end of the collet fingers in the internal annular recess **48** in the mandrel neck **34**, the bosses being positively held in such engagement by the reduced lower end portion **25***a* of the mandrel until the inner end portion of the transverse shear pin **81** is sheared off by the lower end wall of the slot **83**. After the pin **81** has been so sheared, the mandrel **25** may continue to move upwardly with respect to the collect sleeve and the locator carrier sleeve until the upwardly facing beveled shoulder **78** at the upper end of the external annular flange **76** on the mandrel engages the lower end of the locator carrier sleeve, and the arms **77** engage the upper ends of the slots between the collet fingers to lift the carrier sleeve and collet sleeve with the mandrel. At this time, the lower end of the reduced lower portion **25***a* of the mandrel has been moved upwardly above the inwardly facing internal bosses **74** on the lower ends of the collet fingers, and the fingers may cam inwardly as shown in FIG. **9**, the bosses swinging inwardly below the lower end of the mandrel to permit the external bosses **74** to be cammed inwardly by the beveled shoulder at the upper end of the internal annular recess **48** in the upper end of the bore of the neck **34** of the mandrel. The setting tool may thus be moved upwardly away from the locking mandrel and out of the tubing string by means of the locomotive piston P.

To remove the locking device, sealing mandrel and well flow control device from the landing nipple, a retrieving tool similar to the setting tool is lowered into the tubing string T1 by means of the locomotive operating tool string. The retriev-

ing tool is provided with a plurality of collet bosses which engage in an internal annular recess **140** formed in the upper end of the bore **141** of the expander sleeve **45** of the locking device, whereupon an upward pull applied to the expander sleeve **45** will move the same longitudinally upwardly with respect to the mandrel neck **34** and the locking dogs **35** to withdraw the expander locking surfaces on the lower ends of the slotted legs of the expander member out of engagement with the inner surfaces of the locking dogs **35** and permit the locking dogs to be cammed to swing inwardly out of the locking recess **43** in the landing nipple, and the locking device, sealing mandrel and well flow control device to be removed from the landing nipple and upwardly out of the tubing string T1.

The setting tool and locator device are also adapted to be operated by means of a flexible line operating mechanism, as shown shematically in FIG. **12**. As shown, a winch **200** is provided at the surface of the well and the flexible line **201** is reeled on the winch and extends over a pulley or sheave **202** and downwardly in the usual manner into the bore of the tubing string T1. The lower end of the line is connected to a flexible line connector socket **205** at the upper end of the usual flexible line operating tool string **206**, including a weight member, jars, etc. A pin at the upper end of a connector pin sub **208** threaded onto the upper end of a mandrel extension **210** is connected to the threaded box **207** at the lower end of the wire line operating tool string **206**. The mandrel extension **210** has a threaded counterbore at its lower end which is threaded on the upper end of the mandrel **25** of the setting tool assembly **26**. The mandrel **25** and the locator carrier sleeve **80**, as well as the locator assembly and setting tool assembly, of this form of the device are identical in structure to that of the form already described. However, in order to trip or release the locator keys **90** for movement to expanded position for location the locking assembly in position in the landing nipple, a releasing mechanism **220** is provided at the upper end of the mandrel **25** and on the mandrel extension **210**. The releasing mechanism consists of an elongate operator sleeve **221** which is slidable on the enlarged lower cylindrical portion **212** of the mandrel extension **210**, the downward movement of said operator sleeve being limited by the downwardly facing shoulder of an internal annular flange **222** formed at the upper end of the bore of the sleeve. The operator sleeve is slidable on the enlarged portion of the mandrel extension from the position shown in FIG. **13A** to a position in which the upper end of the sleeve engages the downwardly facing shoulder **209***a* on the under side of an external flange **209** on the lower portion of the connector sub **208**. A dog carrier sleeve **230** is slidable on the exterior of the operator sleeve **221** and is provided with a plurality of circumferentially spaced longitudinal slots **231** in which elongate tripping dogs **233** are movable, the dogs being biased downwardly by a helical coil spring **234** engaging the upper ends of the dogs and abutting a downwardly facing shoulder **235** formed in the lower portion of the carrier sleeve, the springs **234** being confined in the carrier sleeve between the upper ends of the dogs and the downwardly facing shoulder **235**. The lower ends of the dogs have inwardly and downwardly inclined camming surfaces **236** which engage inwardly and downwardly inclined complementary camming surfaces **237** at the lower ends of the slots in which the dogs are movably disposed. An expander flange **240** is formed on the external surface of the inner operator sleeve **221** and is adapted to engage the inner surfaces of the lower ends of the dogs to hold the same outwardly, as shown in FIG. **13A**. When the dogs move upwardly on the inner operator sleeve, the bosses on the inner surfaces of the dogs may enter an external annular recess **241** formed in the external periphery of the operator sleeve **220** to permit the lower ends of the dogs to cam inwardly. With the dogs held in the position shown in FIG. **13A**, the lower ends of the dogs may move upwardly with respect to the operator sleeve **221** upon encountering inwardly projecting shoulders in the tubing string or the reduced bores of landing nipples above the landing nipples at which the device is to be operated. When, however, the desired landing nipple N1 has been reached, the string of tools is moved below the landing nipple and the flexible line **201** is pulled upwardly to move the string of tools **206** upwardly in the tubing string to engage the external bosses **233***a* of the dogs with the downwardly facing shoulder at the lower end of the bore of the landing nipple, and such downward movement of the dogs will shear the pin, the transverse shear pin **250** extending through aligned radial openings **251** in the upper section of the carrier sleeve and **252** in the upper end of the inner operator sleeve **221** to permit the tripping dogs to be moved downwardly until the internal bosses on the dogs are moved below the retaining shoulder **244** at the lower end of the external flange **240** on the inner sleeve, at which point the lower ends of the dogs will cam inwardly and permit the running tool string **206** to move the setting tool assembly upwardly. The inner operator sleeve **221** is then permitted to move upwardly with respect to the outer dog carrier sleeve **230**, as shown in FIG. **14**, whereupon the locator keys **90** are biased outwardly in the manner already described, to the expanded position shown in FIG. **14**.

The inner operator sleeve **220** is biased upwardly by the helical coil spring **98**, which, acting through the washer **99**, moves the locator keys **90** upwardly and at the same time moves the inner operator sleeve **220** upwardly to permit the locator keys to be cammed outwardly to expanded position by the pins **92** engaging the inclined lower portions **88** of the slots **87** in the ears of the carrier sleeve, and the lower ends of the locator keys to engage the annular expander flange **89** on the expander carrier sleeve to bias the keys outwardly into expanded position. The expanded locator keys may then be moved downwardly into engagement with the upwardly facing shoulder **42** at the upper end of the bore of the landing nipple N1 to position the locking dogs **35** of the locking device in position to be expanded into locking engagement with the internal annular locking recess **43** in the nipple in the manner already described.

It will therefore be seen that a setting tool, locking device, and landing nipple has been described wherein the locking device is movable into, and positively lockable in place in, the landing nipple against movement in either direction longitudinally, by means of a setting tool and locator tool assembly which engages a locator shoulder on the landing nipple and disposes the locking dogs of the locking device into position to be expanded into such locking engagement. The tool is also clearly operable by the pump down tool method or by the wire line operating tool method of installation and operation. Any one of a plurality of longitudinally spaced, like landing nipples may be utilized to receive the locking device, the sealing mandrel and the well flow control device, by utilization of the locator device and setting tool of the invention just described.

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. A locating device and setting tool combination for setting a well tool having expansible locking means thereon in a landing nipple having an annular locking recess therein spaced a predetermined distance from a stop and locating shoulder thereon, including: an elongate mandrel; setting tool means connected with said mandrel and having means for releasably connecting it to said well tool; a plurality of locating keys mounted on said mandrel for movement longitudinally and laterally between expanded and retracted positions on said mandrel, said keys in expanded position being disposed to engage said stop and locating shoulder to position said locking means of said well tool to be expanded into said locking recess of said landing nipple; means biasing said locating keys to expanded position; holding means on said mandrel engageable with said keys for initially holding said keys in retracted posi-

tion; and release means for releasing said holding means to free said locating keys for movement to expanded position to engage said stop and locating shoulder to position said locking means of said well tool in said landing nipple for expansion into said locking recess for locking said well tool in said landing nipple.

2. A locating device and setting tool for setting a well tool having expansible locking means thereon in a landing nipple having an annular locking recess therein and longitudinally spaced first and second opposed stop and locating shoulders thereon, said second stop and locating shoulder being spaced a predetermined longitudinal distance from said locking recess, including: an elongate mandrel; setting tool means connected with said mandrel and having means for releasably connecting it to said well tool; a plurality of locating keys mounted on said mandrel and movably longitudinally and laterally between expanded and retracted positions thereon; means biasing said locating keys toward expanded position; holding means on said mandrel releasably holding said locating keys in retracted position; and release means on said mandrel operable to release said holding means to free said locating keys for movement on said mandrel between expanded and retracted positions; said locating keys being movable from expanded to retracted position against the biasing force exerted on said keys by said biasing means upon engagement of said keys with said first stop and locating shoulder of said landing nipple upon movement of said mandrel and said locating keys in a first direction longitudinally toward said first shoulder whereby said mandrel and said locating keys are movable past said first shoulder of said landing nipple; said mandrel and said locating keys having coengageable means operable to hold said locating keys in expanded position to engage said second stop and locating shoulder of said landing nipple to limit movement of said mandrel in a second direction longitudinally toward said second shoulder to position said locking means of said well tool in said landing nipple to be expanded into said locking recess for locking said well tool in said landing nipple, said setting tool means being releasable from said locked well tool.

3. A locating device and setting tool of the character set forth in claim 2 wherein said release means comprises: means connected with said holding means engageable with said first stop and locating shoulder of said landing nipple upon movement of said locating device and setting tool in said first direction longitudinally toward said first stop and locating shoulder to release said holding means to free said locating keys for movement between expanded and retracted positions on said mandrel.

4. A well tool including: a tubular landing nipple having an annular locking recess in its bore and a stop shoulder spaced longitudinally therefrom a predetermined distance; a locking device for locking well tools in said landing nipple and including: an elongate tubular mandrel having means at one end for connecting a well flow control device thereto, a dog-carrying sleeve on said mandrel and having a portion surrounding the same in spaced concentric relation to provide an annular dog-carrying recess therebetween; locking dog means swingably mounted at one end in said annular recess and having locking boss means at the opposite end projecting through an opening in said dog-carrying sleeve; an elongate expander member having expander wedge surface means at one end and having its other end extending upwardly above the dog carrying sleeve and above the upper end of the mandrel and slidably movable longitudinally on the mandrel within the annular space between the dog carrying sleeve and the mandrel and having said expander wedge surface means engageable with the boss means of said locking dog means to move the boss means to locking engagement in the recess in the landing nipple and to hold the same in such locking position; means in the bore of said mandrel for connecting the same to a running tool; means in the bore of said expander member spaced above the upper end of said mandrel for connecting the same to a retrieving tool; means for releasably securing said expander member in an inactive nonexpanding position on said mandrel and releasable to permit said expander member to move longitudinally of said mandrel to expand said locking dog means upon the application of a downward force to said expander member while said mandrel is held by such setting tool, said shoulder in said landing nipple providing means for engagement by said setting tool to position said locking boss means in alignment with the locking recess in said locking mandrel for expansion into said locking recess by downward movement of the expander member after said releasable means has been released.

5. A device of the character set forth in claim 4 wherein said means for holding said expander member in inoperative position comprises a releasable connection between said expander member and said dog-carrying sleeve releasable to permit said expander member to move longitudinally on the mandrel in the annular dog carrying recess to move the expander wedge means at the lower end of the expander member into engagement with the boss means portion of the locking dog means to move said locking boss means to and hold the same in locking engagement in the recess in the landing nipple.

6. A device of the character set forth in claim 3 wherein said releasable means comprises a shear pin disposed in openings in said dog carrying sleeve and in said expander member in a position when aligned to hold the said expander member in said inoperative position.

7. A setting tool for setting a subsurface well tool locking device in a landing nipple having a locating shoulder thereon and having a locking recess therein and connected in a well flow conductor having a plurality of such landing nipples spaced longitudinally of said flow conductor, said setting tool comprising: a mandrel; means on one end of said mandrel for attachment thereof to an operating means; means on the other end of said mandrel for connecting the same to said well tool locking device for releasably supporting said well tool locking device; locating keys expansibly and retractably mounted on said mandrel and adapted to engage said locating shoulders in said landing nipples; holding means releasably holding said locating keys in retracted position on said mandrel; release means on said mandrel operable to release said holding means to free said locating keys for movement to expanded locating position; means on said mandrel and said locating keys coengageable for positively moving said locating keys laterally with the exterior surfaces thereof maintained in a position parallel to the axis of said mandrel to provide substantially uniform parallel surfaces having downwardly facing shoulders at their lower ends for engaging the stop shoulder of a selected one of said landing nipples to stop the movement of said locating keys with respect to said landing nipple; means on said mandrel and said locating keys coengageable to limit downward movement of said mandrel with respect to said locating keys and with respect to said mandrel when said locating keys are in such expanded position in engagement with said shoulder, whereby said well tool locking device is located in position to engage said locking recess in said selected landing nipple; and means for actuating said well tool locking device to locking engagement with said landing nipple and releasing said means connecting said locking device to said mandrel from connection with said locking device, whereby said setting tool may be removed from the well flow conductor leaving the well tool locking device locked in place in said selected one of said landing nipples.

8. A well device setting tool set forth in claim 7 wherein said release means comprises: fluid pressure responsive means operable by a predetermined fluid pressure differential applied thereto for releasing said locator keys from retracted position for movement to expanded locating position.

9. A well setting tool of the type set forth in claim 7 wherein said release means comprises: trip means on said mandrel biased to a position for engaging the bore wall of said flow conductor upon downward movement of said setting tool in said flow conductor and engageable with a downwardly facing shoulder on said landing nipple for movement to releasing

position upon upward movement of said setting tool in said flow conductor to release said locating keys for movement to expanded locating position.

10. A well tool including: a tubular landing nipple having an annular locking recess in its bore and a locating and stop shoulder means spaced longitudinally from said recess a predetermined distance; a locking device for locking well tools in said landing nipple and having locking dog means thereon movable to engage said locking recess; a setting tool releasably connected to said locking device and operable to actuate said locking dog means to locking position in said recess of said nipple; and a location device including an elongate mandrel; a plurality of locating keys movably mounted on said mandrel for movement between retracted and expanded positions on said mandrel; means biasing said locating keys to expanded position; holding means on said mandrel engageable with said keys for holding said keys in retracted position; and release means for releasing said holding means to free said locating keys for movement between retracted and expanded positions on said mandrel; said locating keys, when expanded, preventing movement of said setting tool and said locking device longitudinally with respect to said landing nipple in one direction when in engagement with said locating and stop shoulder means of said landing nipple; said keys being movable to retracted position to permit movement of said setting tool and locking device and said locating device in the opposite longitudinal direction with respect to said landing nipple; said locating keys when holding said setting tool against movement providing means for operating said setting tool to actuate said locking dog means of said locking device into locking engagement in said locking recess of said nipple; said setting tool being releasable from said locking device after said locking dog means of said locking device has been actuated to engage the same in the locking recess in the landing nipple.

11. A device of the character set forth in claim 10, wherein: said locating device, said setting tool and said locking device are movable in said landing nipple by flexible line-operating means connected thereto.

12. A well tool of the character set forth in claim 10, wherein: the landing nipple is connected in a well flow conductor and said locating device, said setting tool and said locking device are connected with a pumpdown locomotive piston for actuation in said well flow conductor by fluid pressure circulated in the well flow conductor.

13. A well tool of the character set forth in claim 12, wherein said releasable means comprises fluid pressure-responsive means operable at a predetermined elevated fluid pressure within said well flow conductor for releasing said holding means to free said locating keys for movement between retracted and expanded position.

14. A device of the character set forth in claim 10, wherein said holding means for holding said locating keys in inoperative retracted position comprises a releasable connection between said mandrel and said holding means releasable to permit said locating keys to be moved between the expanded and retracted positions.

15. A well tool of the character set forth in claim 10, wherein said releasable means comprises means engageable with the landing nipple for movement of said holding means out of holding engagement with the locating keys to free said keys for movement between retracted and expanded positions.

16. A well tool of the character set forth in claim 10 wherein a plurality of landing nipples are connected at longitudinally spaced positions in a well flow conductor, said landing nipples each having a locking recess therein and a stop and locating shoulder means spaced a predetermined longitudinal distance from said locking recess, and wherein said locating device is operable to engage the stop and locating shoulder means of a selected one of said plurality of longitudinally spaced landing nipples to locate said locking device for actuation into locking engagement with the locking recess in said selected landing nipple, and wherein said locating device, said setting tool and said locking device are movable through each of the other landing nipples than the selected landing nipple prior to releasing the locating keys for movement to expanded locating position, said locating device and said setting tool being movable through all said landing nipples disposed between said selected landing nipple and the well surface after the locking device has been actuated to locking position.

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