April 4, 1967 E. D. YETMAN 3,312,283

SYSTEM FOR INSTALLING AND RETRIEVING WELL TOOLS IN WELL STRINGS

Filed June 30, 1964 5 Sheets-Sheet 1

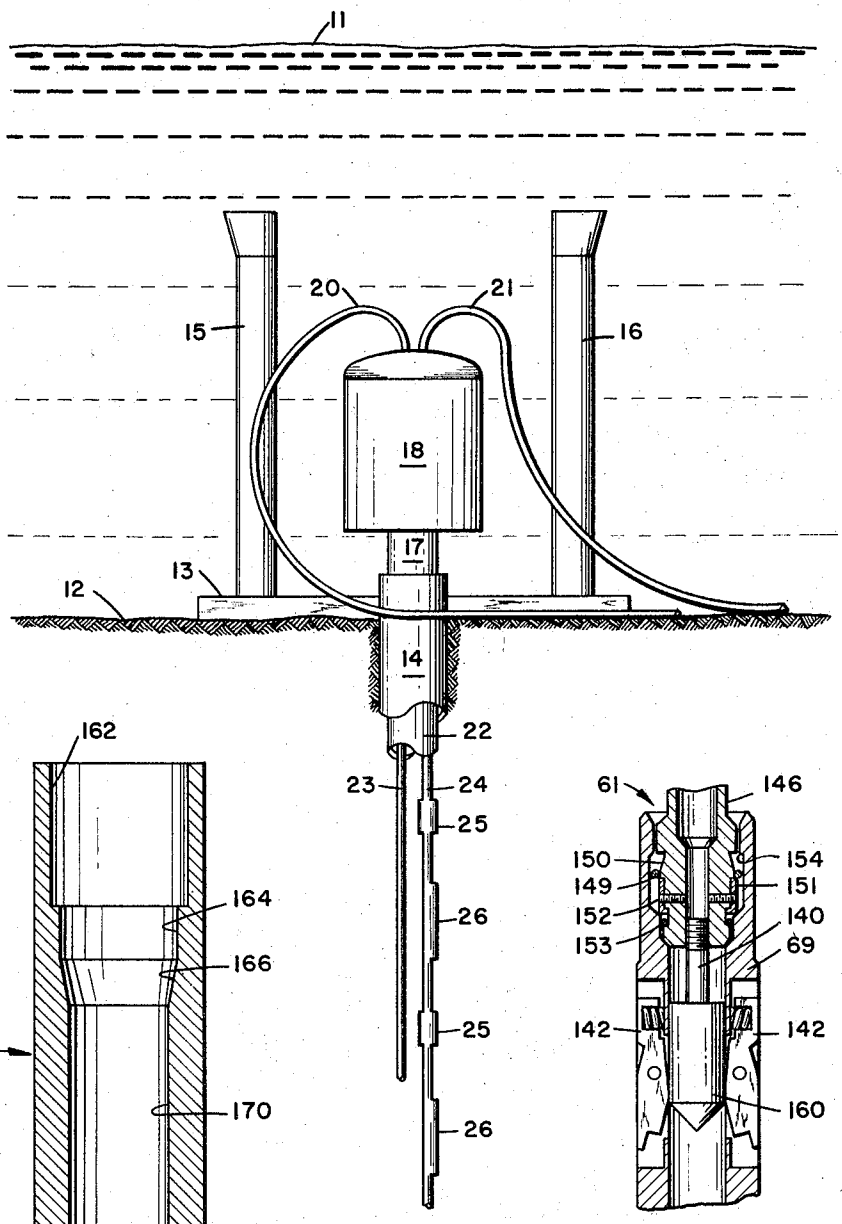


FIG. 1

FIG. 8

FIG. 9

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SYSTEM FOR INSTALLING AND RETRIEVING WELL TOOLS IN WELL STRINGS

Filed June 30, 1964 5 Sheets-Sheet 2

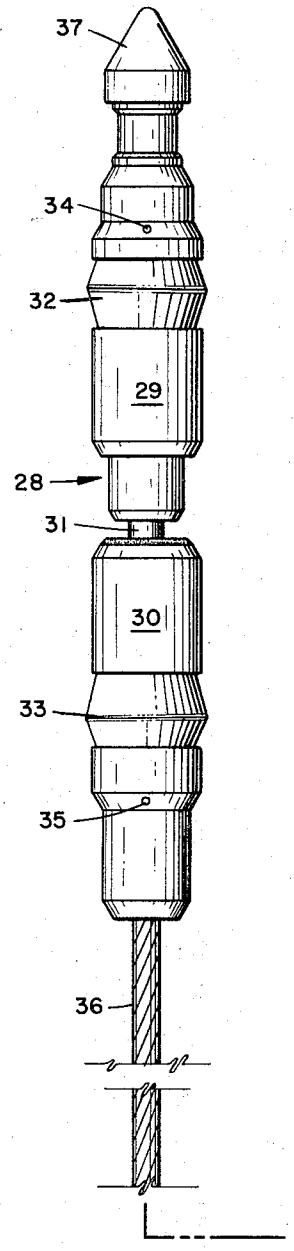


FIG. 2A

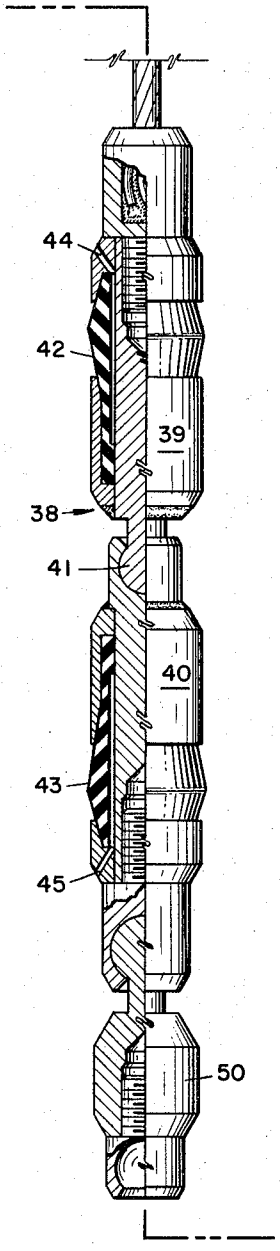


FIG. 2B

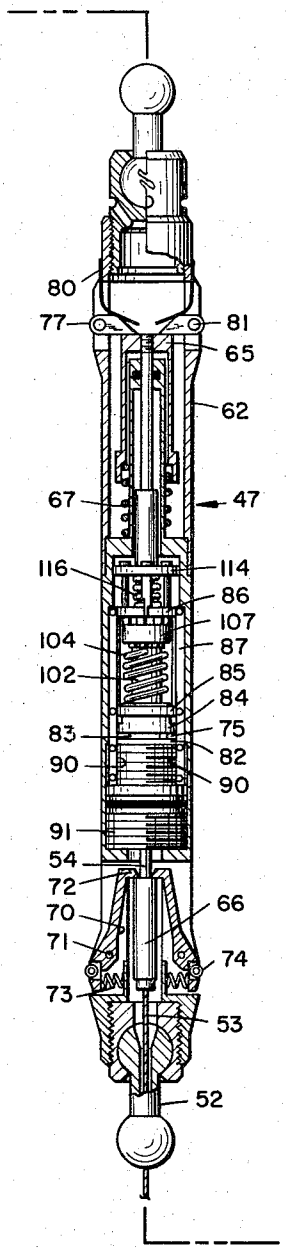


FIG. 2C

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SYSTEM FOR INSTALLING AND RETRIEVING WELL TOOLS IN WELL STRINGS

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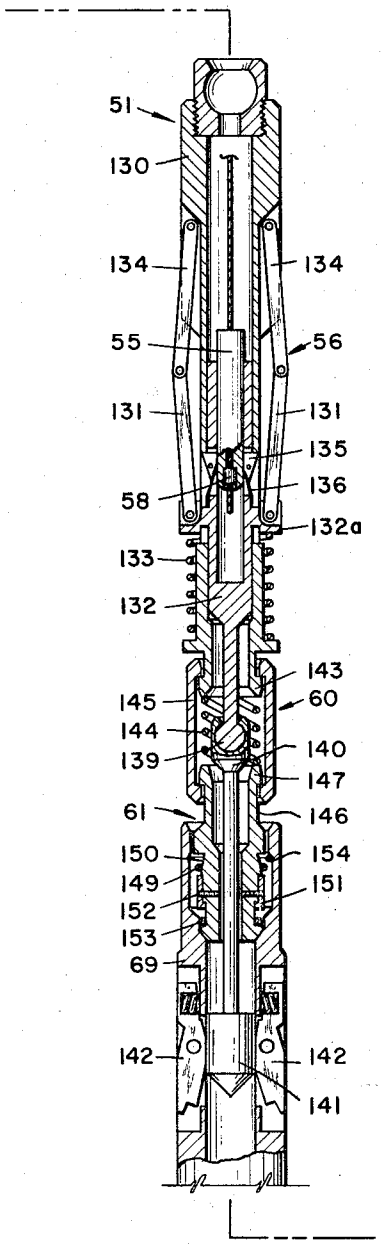


FIG. 2D

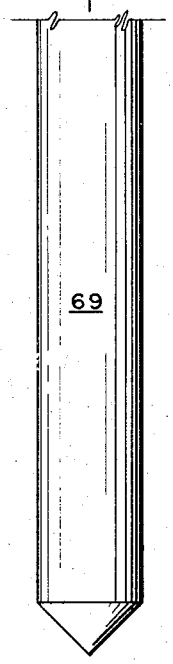


FIG. 2E

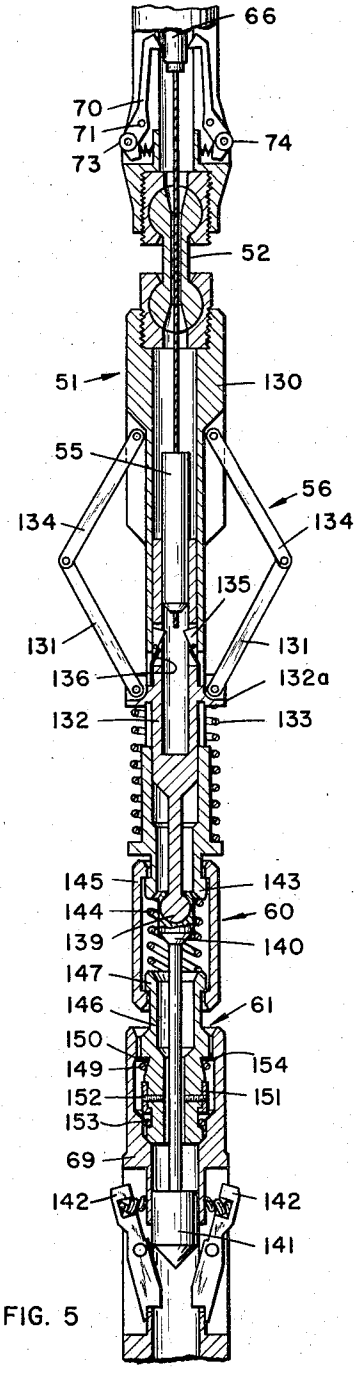


FIG. 5

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SYSTEM FOR INSTALLING AND RETRIEVING WELL TOOLS IN WELL STRINGS

Filed June 30, 1964 5 Sheets-Sheet 4

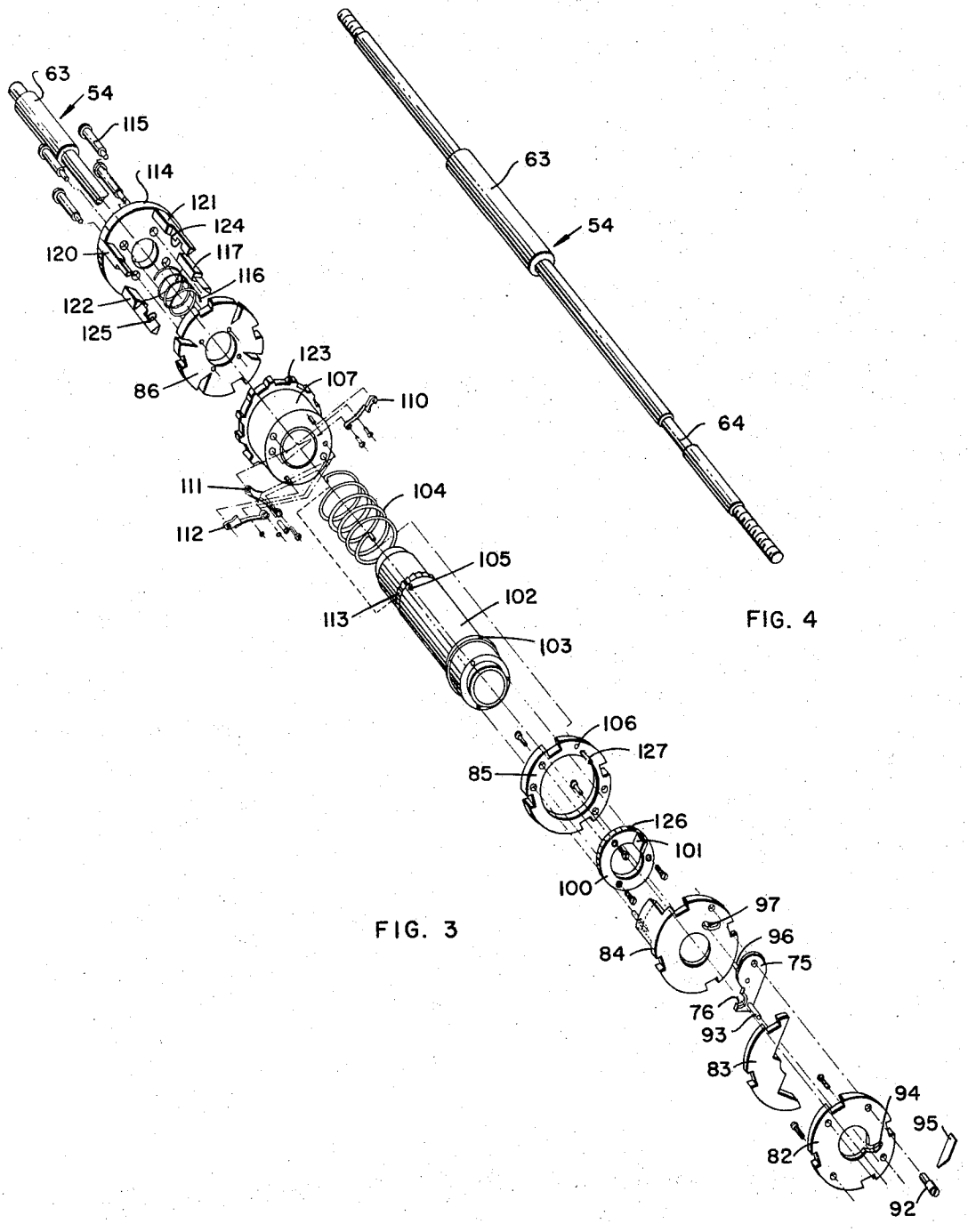


FIG. 3

FIG. 4

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SYSTEM FOR INSTALLING AND RETRIEVING WELL TOOLS IN WELL STRINGS

Filed June 30, 1964 5 Sheets-Sheet 5

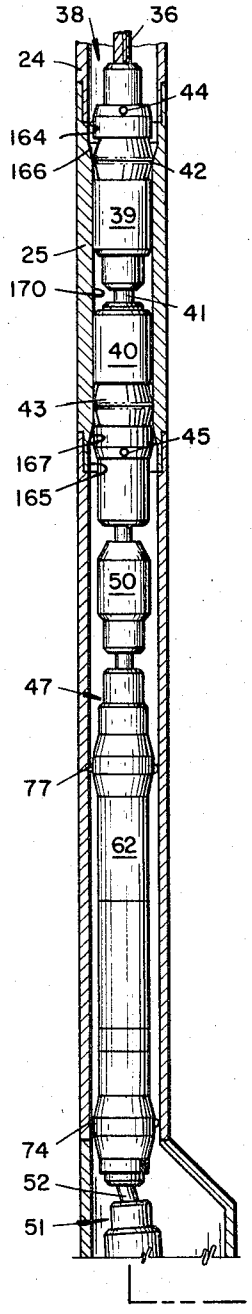


FIG. 6A

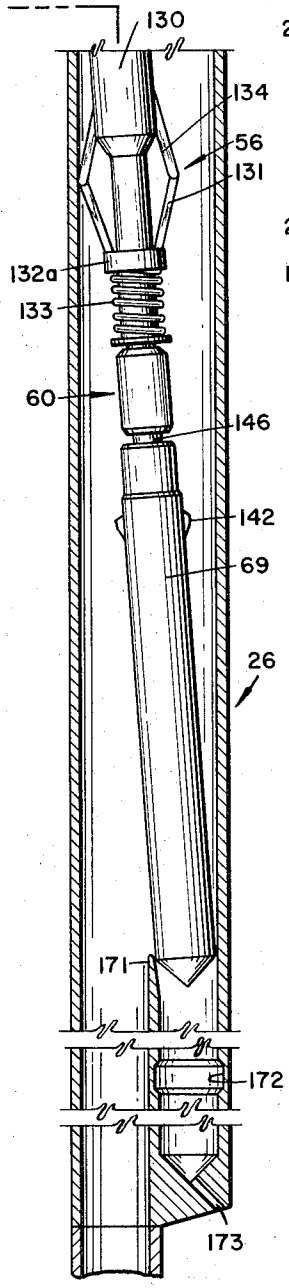


FIG. 6B

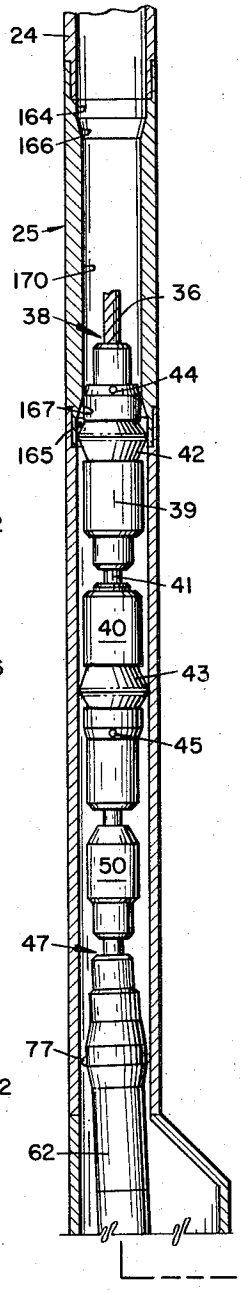


FIG. 7A

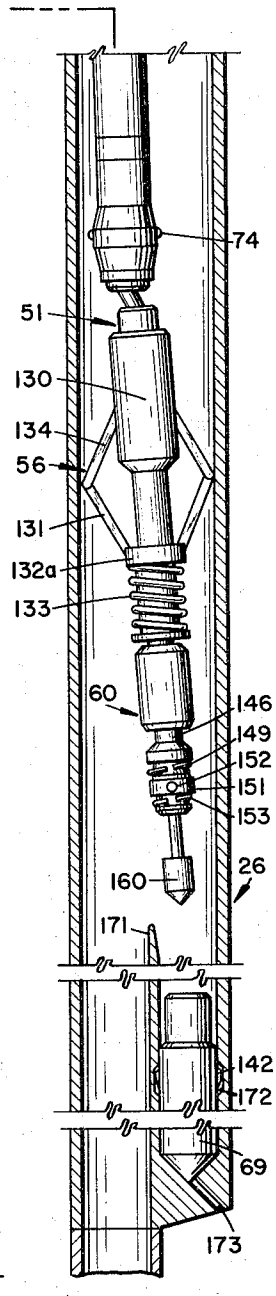


FIG. 7B

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United States Patent Office

3,312,283

Patented Apr. 4, 1967

3,312,283
SYSTEM FOR INSTALLING AND RETRIEVING WELL TOOLS IN WELL STRINGS

Edward D. Yetman, Bakersfield, Calif., assignor to Shell Oil Company, New York, N.Y., a corporation of Delaware

Filed June 30, 1964, Ser. No. 379,301
7 Claims. (Cl. 166—46)

This invention relates to a method and apparatus for running well tools into and out of well strings. More particularly, the invention is directed to a means for installing and retrieving well tools in well strings disposed in underwater wells. The invention has specific application to the running in and retrieving of well tools from side pockets disposed at locations within well strings that are inaccessible to conventional running in and retrieving apparatus.

The invention is particularly directed to the insertion of a tool, such as a gas-lift valve, in a preselected pocket of a series of substantially identical laterally disposed pockets extending from the sides of a well production string at axially spaced intervals therealong. The invention provides means whereby an insertion or retrieving mechanism may be pumped through a production string to a preselected pocket and there be activated to insert a tool into said pocket, or retrieve a tool from said pocket. The insertion or retrieving mechanisms are carried by a carrier of sufficient flexibility to pass through curved flow lines and/or wellhead conduits leading to the production or tubing string.

The invention is especially suited for the through-the-flowline operation of underwater wells. Through-the-flowline operations refer to techniques wherein well completion and operation procedures are conducted through a flowline communicating with a surface location, such as an operating station, and a submerged well installation. With such techniques, a submerged well can be equipped initially with facilities that will allow maintenance of production via the existing closed system for the life of the well without the use of wire line tools or workover rigs. A prime requirement of such techniques is the ability to select and land tools at will in any of several locations within a tubing string. The present invention was developed with this object in mind and has proved particularly suitable for inserting tools, such as gas-lift valves, in one of a preselected series of substantially identical tool-receiving positions within a well string. The invention provides means whereby an installation mechanism may be pumped into and through a well string to a preselected position where it can be activated to install a tool secured thereto in place. The invention also provides means whereby a tool so installed can be similarly retrieved.

The invention promises to be particularly valuable in the recent underwater completion procedures being used by the oil industry in offshore locations. In these procedures, both the wellhead assemblies and production control units are positioned beneath the surface of the water and preferably close to the bottom of the water. Positioning wellhead assemblies and control units in this manner has the advantage that it does not present navigation hazards, nor is it subject to the corrosive action of salt water spray and air, as are assemblies extending above the water. In addition, positioning wellhead assemblies and production control units at the bottom of the ocean results in considerable savings, since it is not necessary to erect protective stationary platforms around the wellheads in the manner employed to protect well casings and wellhead assemblies extending above the surface of the water. Furthermore, the positioning of wellhead assemblies on the ocean floor often becomes absolutely necessary where

depths are encountered which make it infeasible to extend structures from the floor of the ocean to the surface.

The placement of wellhead assemblies on the ocean floor raises new problems with regard to carrying out workover, maintenance, or other operations in completed wells. Major workover operations call for the use of an operating station in the form of a barge, platform or vessel positioned on the surface of the water above the well, together with equipment for going down and entering the wellhead assembly and the tubing and/or casing string connected thereto, and in some instances may require the entire removal of the wellhead assembly to the surface. In order to carry out some of the more simple workover or maintenance operations, such as the perforation of well casings, the removal or insertion of a valve, the cleaning of paraffin from a tubing string, etc., it has been necessary to develop an entirely new line of well tools which can be pumped through a well string from some remote location often a mile or more from the well. Upon entering the well with such tools, the tool passing through the well string is positioned therein for carrying out some preselected operation. After completing the operation, the tool in the well string is removed, generally by reverse circulation.

While the problems encountered in pumping a tool to the bottom of the well tubing string, or to a single stop shoulder, are fairly readily solved, the problems encountered in pumping a tool to a preselected position intermediate a series of similar positions is far more difficult. This is especially true where it is necessary to position a tool in a selected one of a series of identical locations located longitudinally along the well string. Such positioning, of necessity, requires an accurate locating or indexing system adapted for through-the-flowline use in the curved flowlines generally used to communicate with underwater installations.

In the past, well tools, such as gas-lift valves, have been run into selected positions in well strings through means of wireline devices extending to the top of the well. Such devices were generally lowered into the well string on a wireline and activated by said wireline at a selected depth to force the tool carried by the line into a selected pocket or mandrel. In this case, the length of the wireline run into the well string indicated the depth of the tool within the well string and forces imparted through the wireline at selected depths were utilized to activate a seating mechanism secured to the wireline and operatively engaging a tool carried thereby.

Wireline systems have proved effective when used in land-based wells having relatively straight strings extending into the earth. In such wells, tools secured to the wireline descend directly down the well string by virtue of their weight and the weight of the wireline. The environment surrounding offshore wells is, however, critically different from that of land-based wells. In offshore wells, wherein the wellhead assemblies are disposed on the bottom of the ocean, the line of communication between the well and the cooperating surface or possibly underwater operating or workover station includes lengths of flowline extending between the station and the wellhead assembly. For example, the flowlines may run along the bottom of the ocean to a station disposed thereon, remote from the wellhead assembly. These flowlines are flexible to some extent, and generally include curves of varying degrees to compensate for irregularities on the ocean floor. It is believed apparent that the reliance of tool weight to impart movement through a curved flowline will result in the hanging up of the tool in the curved and horizontal sections of the flowline and in fouling of the wireline secured to the tool.

Previous systems used to place gas-lift valves in side

pockets or mandrels relied upon different shaped or sized pockets or mandrels to interact with the indexing mechanism in order to insure that the valve was placed in the proper pocket or mandrel. Such systems severely limit the number of positioning mandrels that may be located in a well string, and are expensive to fabricate and maintain since they prevent the use of a uniform side pocket or mandrel. Furthermore, the kickover or expansion mechanism used in previous systems to place the gas-lift valve in the side pocket or mandrel was free to actuate at all side pocket locations prior to coming into contact with the preselected location at which it was to be permanently positioned. As a result, the gas-lift valves were often damaged before reaching the preselected pocket or mandrel within the well string.

Thus, the need for a tool carrier adapted to pass through curved flowlines extending into underwater well strings and position a tool within a preselected side pocket of a series of identical pockets located in the well strings is apparent.

It is therefore an object of the present invention to provide a system to pass well tools through a well string into preselected pockets or mandrels disposed in communication therewith.

Another object of the invention is to provide a flexible apparatus adapted to be pumped through curved and horizontal sections of flowlines communicating with a well string. In this respect, it is a more specific object of the invention to provide flexible coupling means to secure such an apparatus together for movement through curved sections of a flowline.

A further object of the invention is to provide an apparatus adapted to pass through a well string and automatically install a tool secured thereto in one preselected pocket of a plurality of identical pockets disposed laterally along the well string. In this respect, it is another object of the invention to provide an installation mechanism adapted to be selectively operated by said apparatus to lock the tool desired to be located in the preselected mandrel.

Yet another object of the invention is to provide a well tool carrier adapted to run tool installation and removal means through a well string to a preselected position therein. In relation to this object, it is another object to provide said carrier with means to selectively release and remove the tool from the preselected position.

These and other objects of this invention will become apparent from the following description and accompanying illustrations of the invention.

Broadly, the present invention provides a system for installing and removing well tools in preselected identical pockets disposed laterally of and in communication with the interior of a well string. The system includes identical indexing areas located within the conduit at each of the pockets. The latter areas are identical to each other in internal diameter, but have a diameter different from the internal diameter of the conduit. The system further includes a carrier operatively engaging the tool to propel it through the conduit and a selectively operable installation mechanism secured to the tool and adapted to be activated to install it in the preselected pocket. An indexing device is operatively secured to the installation mechanism and carries a sensing means cooperable with the indexing areas within the conduit to sense the number of such areas through which the indexing device is passed. The indexing device also carries an actuator cooperable with the sensing means to activate the installation mechanism and thus install the tool in the desired preselected tool receiving position.

More specifically, the installation mechanism of the above described system comprises a housing member adapted to be secured to the tool and propelled therewith through the conduit. Selectively operable throw-over means are operatively associated with the installation mechanism to automatically bias a tool connected thereto into alignment with the preselected tool pocket. In addition to being used as an installation means, the apparatus of the present invention may be used to retrieve tools from pockets disposed in well strings.

The invention will now be described with reference to the accompanying drawings wherein:

FIGURE 1 is a schematic view diagrammatically illustrating an underwater wellhead assembly having a pair of tubing strings extending downwardly therefrom;

FIGURES 2A, 2B, 2C, 2D and 2E are partial sectional or elevation views of the through-the-flowline insertion assembly of the invention;

FIGURE 3 is an exploded view of the indexing device, illustrated in FIGURE 2C, with certain retaining elements omitted therefrom for the sake of clarity;

FIGURE 4 is a respective view of the actuating rod of the FIGURE 3 device;

FIGURE 5 is a sectional view showing the throw-over means of the installation mechanism of FIGURE 2D in an expanded position;

FIGURES 6A and 6B are diagrammatic sectional views of a well string illustrating the application of the invention in the insertion of a gas-lift valve into a mandrel disposed in a side pocket of a well string;

FIGURES 7A and 7B are diagrammatic sectional views corresponding to FIGURES 6A and 6B, illustrating the application of the invention in the removal of a gas-lift valve from a mandrel disposed in a side pocket of a well string;

FIGURE 8 is a longitudinal sectional view of an indexing nipple adapted to be assembled in the well string as an indexing area; and

FIGURE 9 is a longitudinal sectional view illustrating a plunger head adapted to be used in a retrieving operation.

Referring to FIGURE 1 of the drawings, a wellhead assembly is shown as being positioned below the surface **11** of a body of water and preferably on the ocean floor **12**. The wellhead apparatus comprises a platform **13** secured to the top of a conductor pipe or surface casing **14** which in turn extends into the earth below the body of water and is preferably cemented therein in a conventional manner. The wellhead assembly may also be provided with two or more vertically positioned guide columns **15** and **16** which are fixedly secured at their lower ends to the platform **13**. A well casinghead **17** is mounted on the top of the conductor pipe **14** and a control equipment housing **18** closes the top of the casinghead and/or any casing and tubing suspension equipment employed on the wellhead assembly, as well as the various control valves and other control equipment normally used on the top of a well of this type.

Emerging from the housing **18** is a pair of flowlines **20** and **21** which preferably bend in long sweeping curves from a vertical position down to a substantially horizontal position so that they can run along the ocean floor to a remote location where fluid from the well, and normally from other wells, is collected and metered and treated. Such a collection station may be several miles away. During the production of the well, normally only one of the flowlines **20** or **21** is employed in transporting fluid away from the well. The well may be provided with one or more strings of well casing **22** suspended within the conductor pipe **14**. The flowlines **20** and **21** in the particular installation illustrated are in communication with and form continuations of a pair of tubing strings **23** and **24** depending within the well. However, in other installations utilizing a single tubing string, the second flowline may be in communication with the annular space between the tubing strings and the adjacent wellhead. Further, more than two flowlines may be used. The tubing string **24** is provided with a plurality of indexing nipples **25** spaced longitudinally along the string. Although

only two indexing nipples 25 are illustrated, it is to be understood that this number may be increased without departing from the invention. The tubing string 24 further includes a series of valve housings or side pockets 26 spaced therealong wherein gas-lift valves may be positioned. The detailed structure and operation of the indexing nipples 25 and side pockets 26 will be developed subsequently.

Referring now to FIGURES 2A, 2B, 2C, 2D and 2E, there is illustratetd the assembly adapted to run tools, such as a gas-lift valve, from a collection station through the flowline 21 into selected side pockets 26 in the tubing string 24. The assembly includes a pair of spaced tool carriers 28 and 38 joined together through a flexible member shown as cable 36. The tool carrier 28 (FIGURE 2A) comprises a central mandrel having sections 29 and 30 with axially spaced sealing elements or packers 32 and 33 mounted thereon. Packers 32 and 33 may be made of rubber or certain plastic materials. Preferably a ball-in-socket joint 31 joins sections 29 and 30 together so as to facilitate movement of the tool carrier 28 in curved sections of the flowline. Fliud ports 34 and 35 are provided through the walls of sections 29 and 30 so that fluid may enter the inside of the packers 32 and 33 to inflate and sealingly expand them against the inner walls of tubing string 24. The tool carrier 38 is in all respects identical with tool carrier 28 and elements 39–45 of carrier 38 correspond to the elements 29–35 of the previously described carrier 28. The exact internal details of the tool carriers 28 and 38 are not the subject of this invention and may take any suitable form such as that shown in U.S. Patent No. 3,052,302 to Lagucki or U.S. Patent No. 3,050,130 to Culver et al.

During use of the tool carrier 28, a pressure fluid enters port 34 so that packer element 32 is forced against the inner wall of tubing spring 24, thus causing the packer element to act as a piston, whereby the tool carrier 28 is forced downwardly through the tubing string 27. Thus, it may be seen that, on the downward travel of the present tool carrier 28 the upper sealing cement 32 maintains a tight fit against the tubing string 24 at all times, while the lower sealing element 33 is idle and merely acts as an inoperative piston which would not contact the tubing wall 24 with any force to form a seal thereagainst. The tool carrier 38 is necessary because the tool carrier 28 loses its sealing contact with the wall of tubing string 24 in areas of enlarged diameter, such as the side pocket locations 26, and the carrier 28 can no longer be forced downward by the driving fluid. The stiff, lightweight cable 36 provided between the tool carriers 28 and 38 is of sufficient length to span the enlarged-diameter portions of the tubing string 24 such as are encountered at side pockets 26 and, as a result, one of the tool carriers 28 or 38 is always in sealing engagement with a normal-diameter portion of the tubing string 24. A fishinghead 37 is secured to the upper end of tool carrier 28 in order to facilitate removal of the carriers and any elements secured thereto should they become fouled within the tubing string 24.

The mandrel section 40 of tool carrier 38 is joined to an indexing mechanism 47 through a double ball-joint assembly 50. The sole purpose of the indexing mechanism, as will be developed subsequently, is to selectively operate an installation mechanism 51 (FIGURE 2D) secured to the indexing mechanism 47 through a double ball-joint connection 52. The double ball-joint connection 52 has a flexible cable 53 extending therethrough and into the installation mechanism 51. This cable, as will be developed in detail subsequently, has one end secured to the actuating rod 54 of the indexing mechanism 47 and the other end secured to a retaining probe 55 (FIGURE 2D) in the installation mechanism 51 through means of a stop 58.

Reference is now made to the detailed structure of the indexing mechanism 47, illustrated in vertical section in FIGURE 2C and in perspective in FIGURES 3 and 4. The mechanism comprises a housing section 62 fabricated of several joined tubular sections and having housed therein the elements of the mechanism, including the previously mentioned actuating rod 54. The rod 54, as illustrated in full in FIGURE 4, is a unitary structure and extends through substantially the entire length of the housing section 62. At this point, it is noted that the rod 54 is of stepped configuration and includes an enlarged actuating portion 63 and a grooved portion 64 adapted to cooperate with the internal structure of the indexing mechanism, as will be developed subsequently The remaining portions of the rod 54 are substantially equivalent, including the upper and lower ends thereof fixedly secured to a cap member 65 and a retention collar 66, respectively, as by screw threads. As shown in FIGURE 2C, the rod 54 is slidably received in the housing section 62 and is resiliently urged upwardly therein by a compression coil spring 67 interposed between the cap member 65 and the housing section. In the illustrated position, upward movement of the rod is restrained by four retention dogs 70 pivotally secured to the housing section 62 at pivots 71 and having hooked ends 72 urged into locked engagement with the retention collar 66 by compression coil springs 73. It is noted that the exterior sides of the dogs 70 include rollers or followers 74 extending laterally out of the housing section 62. Through these rollers the dogs 70 are pivoted about the pivots 71 when the mechanism passes through an area of sufficiently reduced diameter, thus releasing the retention collar 66 and permitting the rod 54 to move under the action of the spring 67. It is noted that the dogs 70 are designed so that they must all be released simultaneously in order to release the retention collar 66. Thus, the collar can only be released upon simultaneous passing of all of the rollers 74 through an area of reduced diameter.

Upward movement of the rod 54 is normally limited by latching arm 75 (FIGURE 3) having an arcuate end 76 received in the grooved portion 64. The latching arm 75, as will be developed in detail subsequently, is resiliently urged into engagement with the rod 54 and is adapted to be selectively swung out of this engaged position to release the rod. When the latching arm 75 is engaged in the grooved portion 64 and the dogs 70 are released, the rod 54 moves upwardly by a distance approximately equal to the length of the grooved portion 64. Abutment of the arcuate end 76 with the lower shoulder of the grooved portion 64 thus restricts upward movement of the rod. When the rod 54 is at the upper extremity of movement, as limited by the grooved portion 64, the cap 65 is forced into a position where it holds four restoring dogs 77 in a substantially horizontal position. In this position, the rearward ends of the dogs 77 extend laterally from the housing section 62 to a slight extent At the same time, the inner ends of the dogs are continuously biased downwardly by leaf springs 80 interposed between the housing section and the upper sides of the dogs. It is noted that the springs 80 merely function to bias the dogs 77 inwardly about the pivots 81 on which they are mounted and that this biasing force is insufficient to compress the spring 67. With the dogs 77 in the substantially horizontal position, movement of the dogs through an area of reduced diameter will function to pivot the dogs inwardly, thus forcing the inner ends of the dogs against the cap 65. As the dogs are forced against the cap 65, the shaft 54 is forced downwardly to a position wherein the dogs 70 may re-engage the retention collar 66, thus restoring the shaft to its initial position At this point it is noted that the laterally extended ends of the dogs 77 and the extended rollers 74 of the dogs 70 are designed so as to be compressed by like areas of reduced diameter. Thus, a reduced diameter which functions to compress the rollers 74 will also function to pivot the dogs 77 about the pivots 81. Through this arrangement,

the shaft 54 moves both upwardly and downwardly within the housing section 62 when the section passes through an area of sufficiently reduced diameter. This arrangement, as will be developed subsequently, functions to activate sensing or counting means within the indexing mechanism.

The internal structure of the indexing mechanism will now be described with reference to FIGURES 2C and 3. This structure includes fixed or stationary elements comprising a latching arm bearing plate 82, a latching arm spacer plate 83, a latching arm backing plate 84, a spacer plate 85, and a ratchet backup plate 86. The plates 82–86 are rigidly joined by spacer bars 87 secured thereto within rectangular-shaped peripheral slots illustrated in FIGURE 3. In addition to securing the plates together, the spacer bars 87 secure the assembled plates within the housing section 62. The latter function is accomplished by securing the lowermost ends of the spacer bars in recessed slots 90 formed in the external surface of an externally threaded nipple 91 threadably engaging an extension of the housing section 62. It is noted that the nipple 91 is formed as a unitary member having threads on both ends thereof, with the upper of said ends acting as a receiver for the extension of the housing section 62 and the lower of said ends acting as a receiver for the section of the indexing mechanism carrying the retention dogs 70. Although only two of the spacer bars 87 are illustrated in FIGURE 2C, it is to be understood that the mechanism includes four such bars, each of which is received in one of the rectangular-shaped peripheral recesses formed in the plates 82–86 illustrated in FIGURE 3.

The latching arm 75, referred to previously, is pivotally secured between the plates 82 and 84 by a dowel 92 extending between said plates. The arm 75 is urged in a clockwise direction through means of a pin 93 fixed thereto and extending slidably through a slot 94 in the end of a plate 82, which pin is resiliently contacted by a leaf spring 95 carried by the dowel 92. A second releasing or disengaging pin 96 is fixed to the upper side of the arm 75 and extends slidably through a slot 97 in the latching arm backing plate 84. The latter pin, as will be developed in detail subsequently, is disposed so as to be selectively contacted to urge the arm 75 in a counter-clockwise direction, thus removing it from the grooved portion 64 in the actuating rod 54.

Counter-clockwise movement is selectively imparted to the pin 96 and the attached latching arm 75 through an index plate 100 mounted for concentric movement about the rod 54. A finger 101 is fixed to the plate 100 and positioned so as to move in a path wherein it will abut against the pin 96 upon rotation of the plate 100. Thus, upon clockwise movement of the plate 100 the finger 101 will butt against the pin 96 and pivot the latching arm 75 out of engagement with the grooved portion 64 of the actuating rod. The plate 100 is mounted for pivotal movement with respect to the plate 85 through means of a drum 102 extending slidably through the plate 85 for rotational movement with respect thereto. Through means of a shoulder 103 formed thereon and dimensioned to slidably engage the plate 85, the drum 102 also functions to position the index plate 100 between the plates 84 and 85. The drum 102 and the indexing plate 100 secured thereto are resiliently urged in a clockwise direction by a coil spring 104 having one end received in an opening 105 in the drum and the other end received in an opening 106 in the fixed spacer plate 85.

Rotational movement imparted to the drum 102 through the spring 104 is controlled through means of a ratchet drum 107 received on the upper end of the drum 102 for concentric movement with respect thereto in one direction. Movement of the drum 107 with respect to the drum 102 is limited to one direction through means of resiliently biased pawls 110, 111 and 112 mounted on the lower surface of the drum 107 for engagement with ratchet teeth 113 formed on the outer surface of the drum 102. The pawls 110–112 are of relatively conventional nature and comprise a tooth section secured to a resilient leaf section. The pawls are mounted so that the leaf sections thereof are backed up, thus resiliently urging the tooth sections into contact with the cooperating ratchet teeth 113. It is noted, that in the assembled position, the teeth on the pawls 110–112 assume an aligned relationship with the ratchet teeth 113. Through the ratchet and pawl arrangement on the drums 102 and 107, the spring 104 functions to turn the drums 102 and 107 clockwise as a unit. However, through the ratchet arrangement, the drum 102 may always be manually turned counter-clockwise with respect to the drum 107.

Referring now to the control means adapted to selectively limit the clockwise rotation that may be imparted to the drums 102 and 107 through the spring 104. This means comprises a ratchet cage 114 mounted on the ratchet backup plate 86 for slidable movement with respect thereto through means of guide bolts or dowels 115 extending slidably through the cage 114 into threaded engagement with the plate 86. The cage 114 is resiliently urged away from the plate 86 by a compression coil spring 116 interposed therebetween in concentric relationship with respect to the rod 54. The actuating portion 63 on the rod 54 is dimensioned so as to abut against the cage 114 on downward movement of the rod with respect to the cage. However, the diameter of the rod 54 below the actuating portion 63 is sufficiently reduced to freely slide through the cage 114. Thus, downward movement of the rod 54 forces the cage 114 toward the plate 86 and upward movement of the rod permits the spring 116 to force the cage away from the plate 86. The cage 114 further includes short ratchet fingers 117 and 120 and long ratchet fingers 121 and 122 fixedly secured thereto and extending slidably through peripheral slots in the plate 86. These fingers are positioned so as to selectively engage the ratchet teeth 123 on the drum 107, as will be developed in the subsequent description of the ratchet operation.

In operation, the spring-loaded ratchet cage 114 moves up or down on the guide bolts 115 during travel of the actuating portion 63 of the rod 54. When the cage is moved downwardly, the ratchet teeth 123 are engaged by the long fingers 121 and 122 at the outset, but are released by these fingers when slots 124 and 125 formed in the respective long fingers assume an aligned relationship with the ratchet teeth 123. At this point, the ratchet teeth 123 are released and the drums 107 and 102 move clockwise through 15 degrees, at which point the ratchet teeth 123 engage the ends of the short fingers 117 and 120. When the actuating portion 63 moves upwardly, the spring 116 forces the cage 114 up, thus withdrawing the short fingers 117 and 120 from the ratchet 123 in freeing the drum 107 for clockwise movement through 15 degrees, at which point the long fingers 121 and 122 re-engage the ratchet 123. Hence, the drums 107 and 102 move 30 degrees clockwise each time the rod 54 moves up and down, as when the previously described dogs 70 and 77 encounter an area of reduced diameter. It is noted that, although the described ratchet arrangement limits the indexing mechanism to twelve counts (i.e., 12 up and down movements of the rod 54), the ratchet arrangement could be modified within the scope of the invention to vary the number of such counts which the mechanism is capable of handling.

From the above description, it can be seen that as the ratchet drum 107 moves, so does the finger 101 on the index plate 100. The position of the drum 107 with respect to the index plate 100 can be adjusted by rotating the drum 102 with respect to the drum 107. Through this adjustment, the number of counts (i.e., up and down movements of the rod 54) required to turn the indexing

plate 100 to a position where it will release the latching arm 75 can be adjusted. The number of counts installed by rotating the drum 102 with respect to the drum 107 can be sensed by listening to the click of the pawls 110–112 on the ratchet teeth 113 and can be substantiated through means of indexing markings 126 on the indexing plate 100 and the indexing pointer 127 on the plate 85. Thus, in operation, after the installed counts have been expended, the finger 101 engages the releasing pin 96 on the latching arm 75. Preferably, the counting arrangement is designed so that the latching arm is moved by the finger 101 when the rod moves downwardly. This reduces the force required to move the arm 75 to the small value of the spring force imparted by the spring 95, because the spring load on the rod 54 is carried by the aforedescribed restoring dogs 77. With the latching arm 75 out of its restrictive position in the grooved portion 64, the rod 54 is free to travel to the upper extremity of the indexing tool the next time the retention dogs 70 are released. When this rod movement occurs, the cable 53 is pulled upwardly along with the probe 55 and the cap 65 rotates the restoring dogs 77 to a position where their activating surfaces are below the outside diameter of the housing section 62. The pulling of the probe 55, in turn, functions to activate the installation mechanism 51 and thus position the gas-lift valve 69, as will be developed in detail subsequently.

Reference is now made to the detailed structure of the installation mechanism 51 illustrated in FIGURES 2D and 5. This structure comprises a tubular housing 130 having throw-over means 56 mounted thereon with the lower end of the housing 130 connected to the tool, in this instance a gas-lift valve 69, through means of a flexible joint 60 and a break-away mechanism 61 mounted in the top of the gas-lift valve 69. The throw-over mechanism 56 comprises toggle links 131 pivotally secured to a sleeve 132 which is slidable within the tubular housing 130 and is biased upwardly by contact of the coil spring 133 with the outwardly flanged portion 132*a* of the sleeve 132. The toggle links 134 are pivotally secured to the free ends of the links 131 and extend into pivotal engagement with the housing 130. The throw-over mechanism 56 further includes a plurality of small dogs 135 which are pivotally mounted on the sleeve 132 and are biased by leaf springs 136 to swing radially inward out of engagement with housing 130. As shown in FIGURE 2D, the probe 55 prevents the dogs 135 from swinging inwardly out of engagement with the housing 130 and thus prevents the sleeve 132 from sliding upwardly into the housing 130 under the action of coil spring 133. However, when the probe 55 is pulled upwardly, as shown in FIGURE 5, the dogs 135 swing inwardly out of engagement with housing 130 and the sleeve 132 begins to move upwardly under the pressure of coil spring 133. As the spring-biased sleeve 132 moves upwardly, it forces the pivotally connected ends of the toggle links into engagement with the walls of the conduit, such as the tubing string 24, through which the throw-over mechanism 56 is passing and functions to force the throw-over mechanism and any structure secured thereto toward and into recesses encountered in the conduit. Thus, as shown in FIGURE 6B, the throw-over mechanism 56 has expanded to force the gas-lift valve 69 into a side-pocket 26.

The slidable sleeve 132, as illustrated in FIGURES 2D and 5 terminates in a ball 139 which has a plunger 140 pivotally mounted thereon. The plunger 140 extends downwardly into the interior of the gas-lift valve 69 and has an enlarged head portion 141 threadably secured on its lowermost end. The enlarged head 141 prevents the upper ends of a plurality of spring-biased dogs 142, pivotally mounted on the valve 69, from swinging radially outwardly. However, when the sleeve 132 moves upwardly after the probe 55 has been pulled, the plunger head 141 also moves upwardly out of engagement with dogs 142 and the tops of the dogs are free to swing outwardly (see FIGURE 5).

As illustrated in FIGURES 2D and 5, the joint 60 includes a first annular flange 143 fixed to the lower end of the tubular housing 130 and a second annular flange 147 fixed to the upper end of body member 146 of the break-away mechanism 61. The coil spring 144, while not an essential element, tends to increase the rigidity of the joint by urging the annular flanges 143 and 147 away from each other. The flanges 143 and 147 are dimensioned so as to be loosely received within a cylindrical section 145, thus maximizing the flexibility of the elements joined thereby. The flexible joint 60 facilitates passage of the apparatus through curved sections of the flow line.

Attached to the upper end of the gas-lift valve 69 there is shown (FIGURES 2D and 5) a break-away mechanism, generally indicated at 61, adapted to be disconnected from the gas-lift valve 69 after the latter has been run into one of the side pockets 26. A preferred form of break-away mechanism comprises a body member 146 having a split spring locking ring 149 carried on a downwardly and outwardly tapered shoulder 150 formed on the outward side of the body 146. The normal diameter of the split spring locking ring 149 is of a size to contact a shoulder 154 (at the top of gas-lift valve 69) when moved against it in an upward direction. At the same time the split spring locking ring 149 may be contracted sufficiently to pass the shoulder 154 when moving downwardly therethrough. Just below the tapered shoulder 150 is a downwardly slidable ring 151 pinned in place by shear pins 152 to the body 146 of the break-away mechanism 61. A retaining ring 153 is provided within an annular recess below the shear pin ring 151 for holding the latter on the body 146 after the shear pins 152 have been sheared. The external diameter of the shear pin ring 151 is slightly greater than that of the widest part of the tapered shoulder 150, so that on being forced downwardly the locking spring ring 149 will contact the top of the shear pin ring 151.

Referring now to FIGURES 6A and 6B, a section of the tubing string 24 is shown having an indexing nipple 25 positioned above a side pocket 26 disposed in the wall of the tubing string. Although the well casing 22 is not illustrated throughout these figures of the drawings, it is to be understood that it would generally assume a position corresponding to that shown in FIGURE 1. Furthermore, although the following description is directed to the illustrated section of the tubing string 24, an indexing nipple 25, and a side pocket 26 thereof, the description is equally applicable to any section of the string 24 having an indexing nipple and a side pocket disposed therein.

As best shown in FIGURE 8, the indexing nipple 25 includes an internally stepped upper section 162 and an externally stepped lower section 163 dimensioned to be secured to a conduit, such as the tubing string 24, into which the nipple is assembled. Sections 164 and 165 are formed in the upper and lower portions, respectively, of the nipple 25 and are equal in size to the internal diameter of the conduit 24 into which the nipple is assembled. Intermediate of the sections 164 and 165 the internal surface of the nipple converges through smoothly tapered sections 166 and 167 to a reduced diameter counting area 170. The counting area 170 is of a diameter sufficiently small to actuate both the dogs 70 and 77 carried by the indexing mechanism 47. Thus, on pumping of the assembly illustrated in FIGURES 2A, 2B, 2C, 2D and 2E through the nipple 25 located in the tubing string 24, the indexing mechanism 47, as described previously, advances by one count. At this point, should the indexing mechanism have had only one count installed thereon initially, the probe 55 will be pulled from the installation mechanism 51 and the throw-over mechanism 56 will be in condition to position the gas-lift valve 69 in the next encountered side pocket 26. However, if the indexing mechanism 47 has more than one count installed therein, the

probe 55 will not be pulled after the assembly passes through the nipple 25, but rather will be pulled at some subsequent location in the tubing string where the indexing mechanism has counted a number of counts equal to the counts initially installed therein.

The side pocket 26 includes a gas-lift valve mandrel 171 disposed at one end thereof. The mandrel 171 is provided with a latching bore 172 adapted to facilitate the locking of a gas-lift valve within the mandrel, as will be developed subsequently. The exterior end of the mandrel 171 is provided with openings 173 extending therethrough to facilitate fluid flow through a valve disposed within the mandrel.

The operation of inserting a gas-lift valve 69 into a preselected side pocket 26 will now be described with respect to FIGURES 6A and 6B. Although these figures show only one indexing nipple 25 and side pocket 26 in the tubing string 24, the string actually includes a series of such nipples and pockets in spaced longitudinal relationship. The entire apparatus comprising the spaced tool carriers 28 and 38, having the indexing device 47, installation mechanism 51, throw-over mechanism 56, breakaway mechanism 61 and gas-lift valve 69 are connected together and inserted into the flowline 21 (FIGURE 1) at a distant point, such for example, as a production platform or an installation on shore. A source of pressure fluid (not shown) is connected to the flowline 21 in back of the apparatus which has been inserted in the line, and the fluid is pumped through the line 21 in back of the tool carrier 28 until it has passed over the curved section of the flowline 21 and enters the wellhead assembly where it passes down the tubing string 24. As the apparatus moves downwardly through the tubing string 24, one count is expended or removed from the indexing mechanism 47 each time it passes through an indexing nipple 25. After all the counts have been expended, the indexing mechanism functions to pull the probe 55, thus allowing the dogs 135 (FIGURE 5) on the installation mechanism 51 to move radially inwardly under the action of leaf springs 136 so that the throw-over mechanism 56 is prepared to expand within the next side pocket 26 encountered. As shown in FIGURE 6B, the throw-over mechanism 56 has expanded under the action of coil spring 133 to move the gas-lift valve 69 into alignment with the preselected mandrel 171. As best shown in FIGURE 5, expansion of the throw-over mechanism 56 causes the plunger head 141 to move upwardly within the valve housing 69, thus allowing the upper ends of dogs 142 to move radially outwardly. The apparatus continues to move downwardly until the gas-lift valve 69 seats within the mandrel 171 and the dogs 142 engage the locking bore 172 to firmly secure the gas-lift valve 69 against upward movement out of the mandrel 171.

Circulation is now reversed so that the pressure fluid flows down the tubing string 23 and up through the tubing string 24. The apparatus is extracted from the body of gas-lift valve 69 in the following manner as the valve 69 is held in position within the locking bore 172 of mandrel 171 by the dogs 142. Upward pressure of fluid forces the body member 146 of the breakaway mechanism 61 (see FIGURE 2D) upwardly until the locking spring ring 149 contacts the shoulder 154 at the top of the gas-lift valve 69. As the body 146 of the breakaway mechanism continues to move upwardly, the split ring 149 is forced down the tapered shoulder 150 until it contacts the top of the shear-pin ring 151. An increase in the fluid pressure causes the shear pins 152, which are preferably bronze or some other soft metal in this operation, to shear and the shear pin ring 151 is initially prevented by the ring 149 from traveling upward, allowing the split ring 149 to move downwardly relative to the tapered shoulder 150 and contract to a smaller diameter below the shoulder. The ring 151 is then free to move upward out of the top of the valve member 69 engaged by the ring 153. With the breakaway mechanism 61 and plunger 140 free of the valve housing 69, the apparatus moves upwardly through the tubing string 24 with the tool carriers 28 and 38 where this portion of the apparatus can be retrieved at, for example, a well platform manifold.

It should be understood that the apparatus could be used to insert a gas-lift valve 69 as described above, without using an enlarged head plunger 140. This is due to the fact that dogs 142 carried by the gas-lift valve 69 only lock in the upward direction, and since the valve 69 is moving downwardly during the inserting operation there would normally be no chance of the dogs hanging up until the desired side pocket 26 is reached. However, it might sometimes be necessary to reverse the direction of the apparatus even in the inserting operation, for instance, if a miscount occurred in the indexing mechanism or if one of the side pockets were fouled, etc. When moving the valve 69 upwardly through the tubing string with the dogs 142 expanded, the valve could easily hang up such as at a nipple 25 and thus be sheared free from the rest of the apparatus and fall to the bottom of the well. Therefore, I prefer to use the plunger arrangement at 140, 141 as a safety measure to keep the dogs 142 retracted until the desired side-pocket has been reached.

Should it be desired to remove a gas-lift valve 69 from one of the mandrels 171, the operation would be substantially identical to the one described above. FIGURES 7A and 7B show the apparatus of the invention moving toward a gas-lift valve 69 which is to be retrieved from a preselected mandrel 171. The only difference between a retrieving mechanism and that employed to place the valve member 69 in place originally is that a slightly longer plunger head 160 (FIGURE 9) is attached to the end of the plunger 140, which in this instance may be threadably secured to member 146, so that the locking dogs 142 of the valve member 69 are retracted out of the locking bore 172 even though the throw-over mechanism 56 is in its expanded condition. Also, in the case of retrieving the valve 69, the shear pins 152 of the breakaway mechanism 61 are made of steel instead of a soft metal so that they will not shear. Thus, when circulation is reversed so that the locking spring ring 149 is forced upwardly into contact with the shoulder 154, a continued application of fluid pressure raises the entire gas-lift valve 69 with its retracted dogs 142 out of the mandrel 171 and the entire apparatus is circulated up the tubing string 24 where it may be recovered.

I claim as my invention:

1. An apparatus for installing well tools in one of a series of identical pockets disposed laterally of and in communication with the interior of a well string, said apparatus comprising:

(a) tool carrier means adapted to be pumped through the well string in sliding contact with the wall thereof;

(b) a selectively operable installation mechanism operatively associated with said carrier means and adapted to be activated to install a tool in a preselected pocket of the well string, said pocket being laterally offset from the well string axis in one direction;

(c) an indexing mechanism operatively secured to said installation mechanism and having means for determining the number of pockets by which the apparatus has passed; and

(d) actuating means carried by said indexing device and cooperable with said installation mechanism to install the tool in said preselected pocket of the well string when activated by said indexing mechanism.

2. Apparatus as set forth in claim 1 wherein said installation mechanism includes a selectively operable throw-over mechanism having means for biasing said tool

into alignment with a preselected pocket of the well string.

3. A system for installing a tool in one of a series of identical laterally disposed pockets formed within a well string at longitudinally spaced locations, comprising:

(a) identical indexing areas located within the well string at each of said pockets, said indexing areas having an internal diameter different from the internal diameter of the well string;

(b) carrier means operatively engaging the tool and adapted to propel said tool through the well string;

(c) an indexing mechanism secured to said carrier means and having sensing means cooperable with said indexing areas to sense the number of said indexing areas through which the indexing mechanism has passed;

(d) a selectively operable installation mechanism operatively associated with said indexing mechanism and adapted to be activated to install a tool in a preselected pocket of said series of pockets within the well string;

(e) said installation mechanism including a normally inactive throw-over device having means for biasing the tool into alignment with a preselected pocket in the well string; and

(f) actuating means carried by said indexing mechanism and extending into said installation mechanism is operable engagement with said throw-over device, said actuating means cooperating with the sensing means of said indexing device to actuate the throw-over device to bias the tool into alignment with a preselected pocket;

(g) said throw-over device further including means extending into operative engagement with said tool and adapted to release a latching mechanism carried by said tool upon actuation of said throw-over device.

4. An installation device for positioning a tool in a pocket disposed laterally of and in communication with the interior of a well string, said device comprising:

(a) a tubular housing;

(b) a slidable sleeve concentrically arranged within the housing and having an outwardly flanged portion extending outside the housing;

(c) resilient means mounted on the exterior of the housing at one end thereof, said resilient means contacting said outwardly flanged portion of the slidable sleeve to urge said sleeve away from said one end of the housing;

(d) releasable dog means mounted on said sleeve for preventing said resilient means from urging said sleeve away from said one end of the housing;

(e) a first plurality of toggle links pivotally mounted on said sleeve; and

(f) a second plurality of toggle links pivotally mounted on the other end of said housing; said toggle links having their free ends pivotally connected to each other.

5. A device as set forth in claim 4 wherein said sleeve is provided with an elongated plunger which extends beyond said one end of the tubular housing for operative engagement with a latching mechanism carried by said tool.

6. A method for installing well tools in one of a series of identical laterally disposed pockets formed within a well string at longitudinally spaced locations, comprising:

(a) securing a well tool to a tool carrier adapted to be pumped through the well string;

(b) pumping said carrier and tool through the well string;

(c) sensing the number of said identical pockets through which the tool carrier has passed;

(d) biasing the tool into alignment with a preselected one of said series of identical pockets;

(e) securing the tool within the preselected pocket;

(f) removing the tool carrier from the tool secured thereto and pumping said carrier to an accessible location remote from said pocket.

7. A method for installing and removing well tools from one of a series of identical laterally disposed pockets formed within a well string at longitudinally spaced locations, comprising:

(a) securing a well tool to a tool carrier adapted to be pumped through the well string;

(b) pumping said carrier and tool through the well string;

(c) sensing the number of said identical pockets through which the tool carrier has passed;

(d) biasing the tool into alignment with a preselected one of said series of identical pockets;

(e) securing the tool within the preselected pocket;

(f) removing the tool carrier from the tool secured thereto and pumping said carrier to an accessible location remote from said pocket;

(g) securing a tool retriever to said tool carrier and pumping the carrier and tool retriever to a location adjacent the pocket;

(h) biasing the retriever into the pocket;

(i) further pumping the carrier through the well string to force the retriever into engagement with the tool disposed within the pocket;

(j) pumping said carrier with the retriever having the tool engaged thereto in a direction to remove said tool from the pocket; and

(k) pumping said carrier and retriever with the tool engaged thereto through the well string to an accessible location remote from the pocket.

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