THROUGH-THE-FLOWLINE TOOL INSTALLATION SYSTEM

FIG. 1

FIG. 5

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FIG. 2A

FIG. 2B

FIG. 2C

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The present invention relates to a system for running well tools into and out of well strings through curved conduits communicating therewith. More particularly, the invention is directed to a means for installing and retrieving well tools in well strings disposed in underwater wells through curved flowlines communicating with these wells. The invention has specific application to the running in and retrieving of well tools from well string mandrels disposed at locations inaccessible to conventional running and retrieving apparatuses.

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 between a surface location, such as an operating station, and a submerged well installation. With such techniques, a submersed 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 flow 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 at 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. Furthermore, the positioning of 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 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 has, however, presented new problems with regard to the carrying out of workover, maintenance, and 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 tool being worked on. The well tool is then going to and entering the wellhead assembly and any tubing, and/or casing strings connected thereto. During such major workover operations, situations may even arise where it is necessary to remove the entire wellhead assembly to the surface. However, in order to carry out some of the more simple production, workover and maintenance operations, such as the perforation of well casings, the opening of a packer, the removal or insertion of a valve, the cleaning of paraffin from a tubing string, etc., it has been found both convenient and necessary to develop an entirely new line of well tools adapted for through-the-flowline operations. Preferably, in these operations, tools can be pumped through a well string from some remote location, often hundreds of feet away from the well. Upon entering the well with such tools, the tool is positioned for carrying out the desired operation and then 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 retrieving 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 select 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 and check valves, have been run into preselected positions in well strings through means of wire line devices extended through the strings. Such devices were generally lowered into the well strings on a wire line and actuated by said line at a selected point to force the tool carried by the line into a selected pocket or mandrel. In this case, the length of the wire line run into the string indicated the depth of the tool and, forces imparted through the wire line at the selected depths were utilized to activate an installation mechanism secured to the wire line.

Wire line 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 wire line descend directly down the well string by virtue of their weight and the weight of the wire line. 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. Due to the relatively large depths encountered in offshore drilling operations, ranging in hundreds of feet, it is impossible to maintain the flowlines extending between surface stations and the wellhead assemblies in a straight condition. For this reason, the flowlines are flexible to some extent, and generally include curves of varying degrees. Because of these curves, the lowering of tools through the flowline and into the well string through means of land base type wire lines proves difficult, if not impossible. It is believed apparent that the reliance of tool weight to impart movement through a curved flowline will result in hanging up of the tool in the curved and horizontal sections of the flowline and also in fouling of the wire line.

It is noted that curved flowlines communicating with underwater well strings are not limited to lines extending above the given station located on the surface of the body of water above the wellhead. For example, it is anticipated that flowlines may run, together with the ocean to a station disposed thereon remote from the wellhead assembly. In the latter case, however, the problems encountered with the use of wire line lowering are still
resent, since such flowlines are likely to be curved and un along the relatively horizontal bottom of the ocean.

In addition to the aforesaid wire locating systems, "no-go" systems have been used to selectively locate tools within pockets or mandrels disposed along well strings. Such systems rely on the use of mandrels having different diameters and on the use of mating, eating or installation diameter carried by the tool de
dited to be located. In actual application, the mandrels or pockets are located at spaced locations along the length of the string or conduit in which they are formed and are spaced along the top and bottom or upstream location o the bottom or downstream location. With this ar
rangment, a tool having an installation diameter secured hereto will pass through mandrels having diameters ar
er than the installation diameter and will seat in the first mandrel encountered having a diameter smaller than that of the installation diameter. Movement beyond the desired mandrel is prevented by abutment with the installation diameter with the mandrel diameter. Thus, it can be seen that the "no-go" system provides a means whereby a tool may be positioned in one of a series of mandrels positioned in a conduit or well string. Furthermore, since the system is not dependent on wire
e actuating means, pumpable carrier tools may be utilized to propel the tool and the desired installation diameter secured thereto to the preselected position. Thus, such systems may be utilized in curved and hori
zontal flowlines.

The use of "no-go" systems has the disadvantage, however, that the number of positioning mandrels that may be located in the well string is severely limited due to the reduced area required at each of said mandrels. This limitation results from the fact that the mandrels may only be reduced in diameter to a size sufficient to
iset tools passing therethrough to successive mandrels. In addition to the limitation in number, the "no-go" sys
ystem is also often limited in the type of mandrel that can be used therewith, since certain mandrels and tools cooperating therewith will not accommodate the reduced diameters required by the system.

It is recognized that various systems have been develop
oped in the past which provide for indexing in conduits without the use of either the above wire line or "no-go" systems. Typically, these devices include magnetically, elect
ro-magnetically and mechanically actuated tools. The mechanisms used in such tools and the mandrels cooperating therewith have not, however, proved infallible. Furthermore, these mechanisms are generally expensive to fabricate and maintain.

Thus, the need for a tool carrier adapted to pass through curved tubing or flowlines extending into under
water well strings is still present. Furthermore, the necessity of the versatile and practical selecting mech
anism to be used in combination with such carriers to select preselected pockets or mandrels within the well string is believed obvious. It was with these considera
ctions in mind that the present invention was developed. 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 communi
cation therewith.

Another object of the invention is to provide a flexi
ble apparatus adapted to be pumped through curved tubing or 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 to pass through a well string and automatically install a tool secured thereto in one preselected mandrel of a plurality of substantially identical mandrels spaced along the well string. In this respect, it is another ob
ject of the invention to provide an installation mech
anism adapted to be selectively operated by said apparatu
us to lock the tool desired to be located in the pre
selected mandrel.

Yet another object of the invention is to provide a well tool carrier adapted to run tool installation and re
move means that pass to a preselected position therein. In relation to this object, it is another ob
ject to provide said carrier with means to selectively re
lease and remove the tool from the preselected position.

Broadly, the present invention provides a system for installing a tool in a preselected tool receiving position within a conduit having a series of such tool receiving positions formed therein at longitudinally spaced loca
ations. The system includes identical indexing areas loc
ated within the conduit at each of said positions. The latter areas are identical to each other in internal diam
eter, but have a diameter different from 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 mech
anism secured to the tool and adapted to be activated to install it in the preselected position. An indexing de
vice is operatively secured to the installation mechanism carrier a sensing means cooperable with the index
ing areas within the conduit to sense the number of such areas through which the indexing device has passed. The indexing device also carries an actuator cooperable with the sensing means to activate the installation mech
anism 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 there
with through the conduit and at least one dog carried by and adapted to pass through said tool and into locked engagement with the conduit. Biasing means are interposed between the dog and the housing to pro
vide for extension of the dog and retaining means car
ried by the housing to normally hold the dog in re
tracted position. The retaining means is operable to selectively activate the biasing means to extend the dog into engagement with the conduit.

The invention further includes a coupling for flexibly connecting a pair of elements, such as the aforementioned tool and the installation mechanism, together for movement through a curved conduit. The coupling com
prises a first flange fixed to and spaced from one of said elements and a second corresponding flange fixed to and spaced from the other of said elements. To incomplete the coupling, a sleeve extends over the flanges and has a mid-portion received loosely therearound. The ends of the sleeve have internal shoulders formed therein of a reduced diameter less than that of the flanges re
ceived therein. These shoulders are positioned between the flanges in the elements fixed thereto and are spaced apart sufficiently to allow the respective flanges to move towards and away from each other within the mid-port
ion of the sleeve. Through the latter arrangement, the elements fixed to the flanges may move relative to each other when they pass through curved sections of a con
duit. However, the shoulders positioned between the flanges and the elements fixed thereto prevent said elements from being completely separated from each other.

The invention, and the enumerated and other objects, will be more fully understood when viewed in light of the following detailed description and the accompanying ill
ustrations, wherein:

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

FIGURES 2A, 2B and 2C are partial sectional views of the through-the-flowline insertion assembly of the in
vention;
FIGURE 3 is an exploded view of the indexing device, illustrated in FIGURE 2B, with certain retaining elements omitted therefrom for the sake of clarity.

FIGURE 4 is a perspective view of the actuating rod of the FIGURE 3 device.

FIGURES 5 and 6 are longitudinal sectional views of the starting nipple and the locking indexing nipple, respectively, adapted to be assembled in a tubing string as indexing areas.

FIGURE 7 is a perspective view of the actuating probe to be used in the installation or lock-down mechanism of the assembly shown in FIGURE 2C, an exploded perspective view of the double knuckle joint illustrated in the assembly of FIGURE 2C; and,

FIGURES 9A and 9B are longitudinal views of a running assembly adapted to retrieve tools that have been positioned with the assembly of FIGURES 2A, 2B and 2C.

Referring now to FIGURE 1, a wellhead assembly is shown positioned below the surface of a body of water on the floor thereof. The wellhead assembly comprises a platform 13 secured to the top of a conductor pipe 14. A well casing is extended into the earth below the body of water and is preferably cemented in position. The wellhead assembly 10 is shown as being provided with two or more vertically positioned guide columns 15 and 16 which are fixedly secured at their lower ends through the platform 13. A well casing head 10 is mounted on the top of the conductor pipe 14 and has a control equipment housing 20 secured thereto. The equipment housing 20 closes the top of the casing head and/or any casing and tubing suspension equipment employed on the wellhead assembly, as well as various control valves in other control equipment used on the well.

A pair of flowlines 21 and 22 emerge from the housing in gently sweeping curves from a vertical position. These lines extend upwardly to an operating station 23 located at the surface of the body of water 11 at a location approximately above the assembly 10. In addition to the surface casing 14, a well or tubing string 24 extends down from the casinghead 17 in suspended relationship therewith. The string 24 is provided with a starting nipple 25 at the upper end thereof and a plurality of indexing and locking nipples 26 spaced longitudinally therealong below the starting nipple. Although only two locking nipples 26 are illustrated, it is to be understood this number may be increased without departing from the invention.

The detailed structure and operation of the starting nipple 25 and the locking nipples 26 will be developed subsequently with respect to FIGURES 5 and 6. The string 24 further includes a circulating nipple 27 located therein below the lowermost nipple 26 and a packer 30 positioned below the nipple 27 in sealing engagement with the casing 14. In order to isolate the interior of the casing 14 from the formation into which it extends, a drillable bridge plug 31 is positioned therein below the lowermost end of the tubing string 24.

In the illustration of FIGURE 1, the flowlines 21 and 22 are in communication with the tubing string 24 and the annular space between said string and the casing, respectively. It is to be understood, however, that in installations wherein double tubing strings are utilized, both flowlines would be in communication with a tubing string. Thus, with either a single or a double tubing string, circulation may be provided by means of the flowlines 21 and 22. At this point it is noted that the flowline 21 communicating with the tubing string having the nipples therein emerges from the equipment housing 20 in a gently sweeping curve, preferably having a radius of five feet or more. The use of such a radius insures that tools may be passed through the line without the danger of fouling or hanging up.

The operating station 23 illustrated in FIGURE 1 is typical of those used in offshore drilling and production operations and includes a derrick 32 extending upwardly therefrom and a traveling block 33 carried by the derrick. A well or opening 34 extends through the operating station directly below the derrick 32 and is open to the body of water in which the station floats. It is through this well that the flowlines 21 and 22 extend from the station into the body of water 11. Preferably, the flowlines 21 and 22 are secured to the station through winches 35 and 36, respectively. In order to maintain the station 23 at a location approximately above the well casing 10, anchor lines 37 and 40 extend downwardly therefrom to heavy anchors (not shown) positioned on the floor 12.

Referring now to FIGURES 2A, 2B and 2C, therein is illustrated a partial vertical section of the assembly adapted to run tools from the station 23 through the flowline 21 into selected nipples 26 in the tubing string 24. The assembly includes a pair of spaced motor swabs 41 and 42 joined together through a universal type ball joint 43. The motor swabs 41 and 42 are of relatively conventional structure and include resilient cups 44 and 45, respectively, adapted to sealingly engage the walls of the tubing string as the cups are run. Thus, fluid pressure imposed within such a conduit will function to force the motor swabs and any elements secured thereto through a conduit toward the direction of lowest pressure. A fishinghead 46 is secured to the upper motor swab 41 in order to facilitate removal of any tools or any elements secured thereto in case the swabs and or elements should become fouled within a conduit.

The motor swab 42 is joined to an indexing mechanism 47 through a double ball joint assembly 50. The sole purpose of the indexing mechanism, as will be described subsequently, is to selectively operate an installation mechanism 51 secured to the indexing mechanism 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 and the other end secured to a retaining probe 55 in the mechanism 51 through means of a stop 58. As is illustrated in detail in FIGURE 2C, the retaining probe 55 normally assumes a position entirely within the housing 56 of the mechanism 51. This position of the probe functions to partially inactivate the installation mechanism, as will be developed in detail substantially.

The lower end of the mechanism 51 is flexibly secured to the well tool 57, desired to be positioned by the installation assembly, through means of a double acting knuckle joint 60. Although the tool 57 illustrates the form of a storm choker, it is to be understood that the assembly is not limited to use in positioning any one particular tool. The storm choker illustrated is of conventional internal character and differs from commercially available units only in that it utilizes a compact packing arrangement in order to minimize its length. This packing arrangement comprises resilient packing elements 61 fixed to the tool 57 and adapted to sealingly engage a mandrel in which the tool may be received.

Referring now to the detailed structure of the indexing mechanism 47, illustrated in vertical section in FIGURE 2B 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 a portion of enlarged actuating diameter 63 and a grooved portion of reduced diameter 64 adapted to cooperate with the internal structure of the indexing mechanism, as will be developed subse-
The remaining portions of the rod 54 are of substantially equivalent diameters, including the upper and lower ends thereof fixedly secured to a cap member 65 and retention collar 66, respectively, as by screw threads. As housing section 62, the rod 54 is rigidly joined to the housing section 62 and is resiliently urged upwardly herein 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 retained by four retention dogs 70 pivotally secured to the housing section 62 at pivots 71 and having hinged ends 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 of the housing section 62. Through these rollers, the dogs 70 are pivoted about the pivot 71 when the mechanism passes through an area in the flowline of sufficiently reduced diameter, thus releasing the retention collar 66 and permitting the rod 54 to move under 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 raising of all of the rollers 74 through an area of reduced diameter.

Upward movement of the rod 54 is normally limited by a latching arm 75 having an arcuate end 76 secured in the grooved portion 64. The latch arms 75, as will be developed in detail subsequently, are 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 at the upper extremity of movement, as limited by the grooved portion 64, the cap 65 is forced into a position where it holds for restoring dogs 77 in a substantially horizontal position. In this position, the rearward ends of the dogs 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 side of the dogs. It is noted that the springs 80 merely function to bias the dogs 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 rod 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 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 2B 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 to 86 are rigidly joined by spacer bars 87 secured thereto within the 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. This ends acting as a receiver for the ratchet mechanism is secured by securing the lowermost edges of the spacer plates in recessed slots 90 formed in the external surface of an externally threaded nipple 91 threadably engaging 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 end of the threaded portion being formed into 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 2B, it is to be understood that the mechanism includes four of such bars, each of which is received in one of the rectangular-shaped peripheral recesses formed in the plates 82 to 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 through said plates. The arm 75 is urged in a clockwise direction through the engagement of the arm 75 with slot 93 fixed thereto and extending slidable through a slot 94 in the end 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 slidable 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 counterclockwise direction, thus removing it from the limiting diameter in the actuating rod 54.

Counter-clockwise movement is selectively imparted to 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 abut against the pin 96 and pivot the latching arm 75 out of engagement with the limiting diameter 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 slidable through the plate 85 for rotational movement with respect thereto. Through means of a shoulder 103 formed on the tip of a pin 93 fixed thereto and extending slidable through the plate 85, the plate 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 to 112 are of relatively conventional nature and form 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 to 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 ar-
arrangement, the drum 102 may always be manually turned counterclockwise with respect to the drum 107.

Referring now to the control means adapted to selective rotation of the drums, the rod 54 is pivotally secured to the drums 102 and 107 through the spring 104. It will be noted that 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 slidable through the cage 114 into the end faces of the drum with plate 86. The ratchet 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 enlarged 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 below the enlarged portion 63 is sufficiently reduced to freely slide through the cage 114. Thus, downward movement of the rod 54 forces the cage towards 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 slidable through slots 119 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 enlarged portion 63 of the rod 54. When the cage is moved downward, the ratchet teeth 123 are engaged by the long fingers 121 and 122 at the outset, but are released when slots 124 and 125 are engaged by the respective long fingers. These 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°, at which point the ratchet teeth 123 engage the ends of the short fingers 117 and 120. When the enlarged portion 63 moves upwardly, the spring 116 forces the cage 114 up, thus withdrawing the short fingers 117 and 120 from the ratchet teeth 123 in freeing the drum 107 for counterclockwise movement through 15°, at which point the long fingers 121 and 122 re-engage the ratchet 123. Hence, the drum 107 and 102 move 30° close to the rod 54 moves up and down, as when the previously described rods 70 and 77 contact an area of reduced diameter. It is noted, that although the described ratchet arrangement limits the indexing mechanism to 12 counts (i.e., twelve 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 on 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 to 112 on the ratchet teeth 113 and can be substantiated through means of indexing markings 116 on the indexing plate 100 and an 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 fingers 101 and 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 75, because the spring load on the rod 54 is carried by the aforesaid restoring dogs 77. With the latching arm 75 out of its restrictive position in the grooved portion 56, the rod 54 is free to rotate through the drum 102 and 107. The upper extremity of the indexing tool the next time the retaining 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 56. The probe 55, in turn, functions to activate the installation mechanism 51 and thus position the tool 57, as will be developed in detail subsequently.

Referring now to the internal structure of the installation mechanism 51 illustrated in FIGURE 2C, this structure comprises a tubular housing 56 having a probe 55 slidably received therein, as described previously. The upper end of the housing 56 has four slots 130 extending therethrough at intervals around its circumference spaced apart by 90°. Slots 131, corresponding in configuration to the four slots 130, extend through the lower end of the housing 56 at 90° intervals offset from the intervals of the slots 130 by 45°. As is clearly illustrated in the left-hand section of the upper slot 130, each of the slots 130 carries a dog 132 mounted therein for pivotal movement about a shaft 133 extending through the housing 56 transversely of the slot 130. The dogs 132 are permanently biased outwardly with respect to the housing 56 by a compression coil spring 134 interposed between one end of the dog and a web 135 formed in the housing 56 at the upper inner end of the slot 130. The degree to which the upper end of the dog 132 can be extended with respect to the housing 56 is limited by a stud 136 formed in the housing 56 at the lower end of the slot 130 in a position wherein it will abut with the lower end of the dog upon extension of the upper end thereof. Dogs 137, corresponding identically to the dogs 132, are received in each of the lower slots 131 for pivotal movement with respect to the housing 56 in a manner identical to that above-described with respect to the dogs 132. It is noted that the slots 131 and dogs 137 are inverted with respect to the slots 130 and dogs 132 so that the dogs 137 extend from the lower ends of the slots, rather than the upper end of the slots as do the dogs 132.

The operation of the installation mechanism 51 will now be described with reference to the structure thereof illustrated in FIGURE 2C and the perspective view of the probe 55 illustrated in FIGURE 7. The probe 55 is of fluted cross-sectional configuration and includes four laterally spaced longitudinally extending protrusions 140 spaced therearound at 90° intervals separately recessed flutes 141. The protrusions 140 extend over only the mid-portion of the probe body and have spaced therebelow a pair of inclined stop protrusions 142 located at diametrically opposed pair of the flutes 141. Through the particular fluted configuration of the probe 55, it is adapted to be seated in the housing 56 and selectively unseated, through means of the cable 53, to operate the installation mechanism 51.

Initially, when the mechanism 51 is prepared for insertion into a conduit in which it is to be positioned, the probe 55 is forced into the housing 56 to a position where the protrusions 142 seat on a shoulder 143 formed in the lower end of the housing. As the probe 55 is inserted into the housing 56, it is manually turned to a position where the flutes 141 are aligned with the inner diameters of the dogs 132 and, as a result, the protrusions 140 are aligned with the dogs 137. With the probe and housing so oriented, forcing the probe into seated engagement with the shoulder 143 functions to retract the dogs 137 into a flush position with respect to the outer surface of the housing 56, while the dogs 132 remain undisturbed in their extended position. Retraction of the dogs 137 by the probe 55 is facilitated by the inclined shoulders
3,308,880 144 formed on the lower ends of each of the protrusions 140. With the probe 55 received in the housing 56, the mechanism 51 is in condition to pass downwardly through a conduit without interruption. During such movement, the dogs 132 are free to contract upon encountering any areas of reduced diameter and the dogs 137 are retracted in a position where they will not hang up on such reduced diameter. In the forward position in the conduit, however, the indexing mechanism 47 pulls the probe 55 to a position where both the upper dogs 132 and the lower dogs 133 assume an extended position with respect to the housing 55. At this point, the extended dogs 137 will abut against the next area of reduced diameter encountered in the conduit through which the mechanism 51 is passing and, as a result the assembly of components illustrated in FIGURES 2A, 2B and 2C will be stopped within the conduit. Furthermore, if this stopped position is also provided with means to engage the dogs 132, the mechanism 51 will be locked within the conduit against movement in either direction.

FIGURE 8 illustrates an exploded perspective view of the double actuating knuckle joint 60 illustrated in partial section in FIGURE 2C. This joint is designed to facilitate ready separation of the elements joined thereby whereby providing a strong and flexible connection between these elements when they are joined. Although the joint is shown coupling the mechanism 51 and the well tool 57, it is to be understood that the joint is equally well adapted for use in flexibly joining other and varying elements. For example, it is anticipated that a joint constructed as the joint 60 could be used in place of the double ball joint connection 52 illustrated in FIGURE 2B.

As illustrated, the joint 60 includes a first annular flange 145 fixed to and spaced from the housing 56 through means of a tubular section 146. The joint further includes a second annular flange 147, corresponding to the flange 145, fixed to and spaced from the tool 57 by a tubular section 150. The flanges 145 and 147 are dimensioned so as to be loosely received within a pair of arcuate-shaped cylindrical sections 151 and 152. The latter sections are adapted to be assembled in juxtaposed relationship to form a closed cylinder around the flanges 145 and 147. Alignment of the sections 151 and 152 in the juxtaposed relationship is facilitated through means of dowels 153 fixed to and extending from the section 152 and mounting spacers 154 formed in the section 151. After the sections 151 and 152 are assembled in the juxtaposed relationship, they may be secured through means of a sleeve 155 adapted to be threaded over their outer surfaces, as illustrated clearly in FIGURE 2C. In order to limit the extent to which the flanges 145 and 147 may move longitudinally within the assembled sections 151 and 152, each of these sections are formed with internal shoulders at the ends thereof. These shoulders, designated as 156 and 157 in the section 151 and as 160 and 161 in the section 152, have a diameter less than the flanges 145 and 147, but greater than the sections 146 and 150. In addition, the shoulders are spaced apart sufficiently to allow the flanges 145 and 147 to move towards and away from each other when the sections 151 and 152 are assembled therearound.

From the foregoing description, it can be seen that the double joint 60 provides means whereby a pair of elements are flexibly connected. Furthermore, the joined elements are arranged for double knuckle, thus maximizing the flexibility of the elements joined thereby. The latter feature is of particular importance, since it is often the critical factor limiting the radius of curves in a conduit through which joined elements may be passed.

Referring now to FIGURE 5, therein is illustrated a vertical section of the starting nipple 25 illustrated diagrammatically in FIGURE 1. The nipple includes an internally stepped upper section 162 and an externally stepped lower section 163. The latter is received 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 and are equal in size to the internal diameter of the conduit into which the nipple is assembled. Intermediated between the steps 165 and 163, the section 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 79 and 77 carried by the indexing mechanism 47. Thus, upon pumping of the assembly illustrated in FIGURES 2A, 2B and 2C through the nipple 25 located in the tubing string 24, the indexing mechanism, 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 mechanism will be in condition to lock in the next encountered locking nipple 26. However, if the indexing mechanism 47 had 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.

FIGURE 6 illustrates a vertical section of one of the locking nipples 26 shown assembled into the tubing string 24 in FIGURE 1. It is noted that each of the nipples 26 used in a system, such as illustrated in FIGURE 1, is identical to the other. The nipple 26 includes internally stepped and externally stepped sections 171 and 172, respectively, at its upper and lower ends dimensioned to be secured to a conduit into which the nipple is assembled. The nipple further includes end diameter sections 173 and 174 and FIGURES 2A, 2B and 2C. The joint also includes having dimensions equal to the internal diameter of the conduit into which the nipple is assembled. A recessed locking bore 176 is positioned between the sections 173 and 175 and has a length equal to or slightly greater than the longitudinal distance between the end surfaces of the dogs 152 and 153 carried by the housing 56 of the installation mechanism 51. Through the inter-relationship between the dimensions of the installation mechanism 51 and the locking bore 176, the dogs 152 and 137 of the installation mechanism will function to lock the mechanism within the locking bore when the mechanism enters the bore with the tip of the index counting area 170 to a point where it releases the dogs 137. It is noted, however, that with only the dogs 132 extended, the installation mechanism 51 will be free to pass through the locking bore in a downward direction, since the dogs 132 will be compressed by any obstructions encountered during such movement.

A pack-off and counting area 177, having a diameter equal to the diameter of the counting area 170 of the nipple 25, is located within the nipple 26 between the sections 174 and 175. The area 177 leads smoothly into the sections 177 and 175 through tapered sections 180 and 181. The pack-off and counting area 177 is located in a position relative to the locking bore 176 wherein it will sealingly pack off the packing elements 61 of the tool 57 when the installation mechanism 51 is locked within the locking bore 176. In addition to performing the pack-off function, the indexing mechanism 47 is provided with a means of actuating a indexing mechanism passing therethrough in a manner corresponding to that described with reference to the counting area 170 of the nipple 24.

Thus, the nipple 26 functions as a counting area for the indexing mechanism 47, a locking recess for the installation mechanism 51 and a pack-off area for the locking mechanism 51.
Indexing mechanism have been expended prior to the time the installation mechanism enters the nipple. If the counts have not been so expended, the assembly shown in FIGURES 2A, 2B and 2C will pass completely through the nipple 25, removing a count from the indexing mechanism 47 when it passes through the area 177. Thus, it can be seen that one count is expended from the indexing mechanism 47 as it passes through the nipple 25 and each of the subsequent nipples 26. After all the counts have been expended, the indexing mechanism functions to reduce the size of the sleeves on the dogs on the installation mechanism 51 and preparing the installation mechanism for locking engagement with the next nipple 26 encountered. It can thus be seen that one count installed on the indexing mechanism will function to lock the installation mechanism 51 in the first nipple 26 encountered. Likewise, a greater number of counts on the indexing mechanism 47 will function to lock the installation mechanism 51 in the nipple 26 having a number equal to the number of said counts, when said nipples are numbered successively, beginning with the first nipple below the starting nipple 25.

After the installation mechanism 51 and the tool 57 have been locked in a preselected nipple 26, the insertion assembly, comprising the motor swabs 41 and 42, the double ball joint 50, the indexing mechanism 47 and the double ball joint connection 52 may be removed from the assembly illustrated in FIGURE 2A. This removal is facilitated by a break-away mechanism 182 pivotedly secured to the lower end of the double ball joint connection 52 and releasably engaged in the upper end of the installation mechanism 51. An external view of a break-away mechanism 182A, corresponding identically to the mechanism 182, is shown in full lines in FIGURE 9B. The detailed function of the mechanism 182A will be developed subsequently with respect to the description of FIGURES 9A and 9B.

The break-away mechanism 182 includes a unitary housing section 183 pivotally received on the lower ball of the connection 52 and adapted to pass into a cylindrical recess 184 in the upper end of the installation mechanism 51. The section 183 is slidably received in the recess 184 and is adapted to be retained within said recess through means of a retention arrangement adapted to engage with an annular groove 185 formed within the recess 184. The details of the retention arrangement will become apparent from the following description, when viewed in light of the structures illustrated in FIGURES 2B and 9B.

The retention structure includes a V-shaped groove 186 formed in the section 183 and having a split expansion ring 187 received loosely therein. The retention arrangement further includes a cylindrical surface 190 of reduced diameter formed in the section 193 at a location spaced slightly below the groove 186. A sleeve 191 is slidably received on the surface 190 and is normally retained in position thereon by a plurality of shear screws 192 threaded through the sleeve into engagement with the openings in the section 183. To conclude the retention arrangement, a second split expansion ring 193 is loosely received in a groove 194 formed in the section 183 directly below the surface 190. In order to secure various elements of the assembly 182, and to prevent the shear screws 192 from passing into the opening extending through the section, the lower end of the section is threaded to receive a mating threaded element, such as a sleeve 195 as illustrated in FIGURE 2B or a probe 196 as illustrated in FIGURE 9B.

To operate, the break-away mechanism is initially assembled as illustrated by the mechanism 182A in FIGURE 9B. When so assembled, the mechanism is in condition to be forced into the cylindrical recess 184, thus slightly compressing the expansion rings 187 and 193, as illustrated in FIGURE 2B. Upon entering the groove 185, the expansion ring 186 expands slightly and removal of the break-away mechanism from the recess 184 is prevented by abutment of the expansion ring with the upper shoulder of the groove 185 and the upper edge of the sleeve 191. Thus, once the mechanism 182 is forced into the recess 184, separation of these elements is prevented. However, upon imparting a force on the mechanism 182 with respect to the installation mechanism 51, the expansion ring 187 will be forced against the sleeve 191 to an extent sufficient to shear off the screws 192. At this point, the expansion ring 187 will ride out of the groove 185 and fall onto the cylindrical surface 190. The latter surface is of a smaller diameter to permit the walls of the recess 184 to compress the expansion ring to a point where it may be pulled through the groove 184, thus permitting the mechanism 182 to be removed from engagement with the installation mechanism 51. As the mechanism 182 is so removed, the expansion ring 193 will expand to a diameter where it abuts against the lower end of the sleeve 191, thus retaining this sleeve on the section 183 for removal therewith.

Referring now to FIGURES 9A and 9B, therein is illustrated a running assembly adapted to be pumped through a conduit to retrieve an installation mechanism and tool positioned therein through means of the assembly illustrated in FIGURES 2A, 2B and 2C. The running assembly of FIGURES 9A and 9B is identical to the running assembly illustrated in FIGURE 2A in that it includes pivotally joined motor swabs 200 and 201 corresponding to the swabs 41 and 42, respectively, and a double ball joint assembly 202 corresponding to the assembly 50 secured to the lower end of the swab 201. The lower end of the ball joint assembly 202 is pivotally secured to the break-away mechanism 182A in the manner corresponding to that illustrated between the ball joint connection 52 and the housing section 153 shown in FIGURE 2B.

In application of the assembly 197 in retrieving an installed tool within a nipple 26, the assembly would be pumped to the nipple through means of conduits and flowlines communicating therewith, such as the flowline 21 and tubing string 24 illustrated in FIGURE 1. It is noted that at the time the assembly 197 is pumped to the nipple, the running assembly used to initially install the tool in the nipple 26 has been broken away at the break-away mechanism 182 and removed from the system. As the assembly 197 is pumped through the tubing string 24, it passes the nipple 25 and the nipples 26 until it reaches the nipple 26 having the installation mechanism 51 engaged therein. At this point, the probe 196 of the assembly is forced into the cylindrical opening extending into the mechanism 51, thus pivoting the dogs 133 to a position where their outer surfaces are flush with the outer surface of the housing 56. The latter function is accomplished since the probe 196 has a diameter substantially equal to the diameter defined by the outside surfaces of the protrusions 140 on the probe 55 (i.e., a diameter only slightly less than the internal diameter of the opening extending through the housing 56). The probe 196 is also dimensioned so as to permit the break-away mechanism 182A to engage the recess 184 in a manner corresponding to that described with reference to the break-away mechanism 182. Thus, when the assembly 197 is pumped into engagement with the mechanism 51, the assembly is locked to the mechanism while it retracts the upper dogs 132. At this point, further downward movement of the assembly is restrained by the dogs 137 and a pressure buildup will be sensed in the tubing string 24 and the flowline 21 communicating therewith. Upon sensing such a pressure build-up, flow within the tubing string and flowline should be reversed to thus pump the assembly 197 and the mechanism 51 and tool 57 secured thereto to the operating station 23.

To summarize, the system of the present invention provides means whereby tools may be installed and retriever
from preselected locations in a conduit, such as a tubing string. The apparatus of this system is adapted to pass through curved flowlines into well strings disposed at inaccessible and remote locations. Although the system has been described with reference to the installation of a storm choke, it is to be understood that the invention may equally well be used for inserting and retrieving other tools.

The foregoing description of the invention is, therefore, merely intended to be explanatory thereof. Various changes in the details of the described system may be made, within the scope of the appended claims, without departing from the spirit of the invention.

I claim as my invention:

1. A system for installing a tool in a preselected tool receiving positions formed therein at longitudinally spaced locations, comprising:
   (a) identical short indexing areas located within the conduit adjacent said positions, said areas having an internal diameter less than the internal diameter of the conduit;
   (b) a carrier operatively engaging the tool and adapted to propel said tool through the conduit;
   (c) a selectively operable installation mechanism secured to the tool and adapted to be activated to install said tool in said preselected position;
   (d) an indexing device operatively secured to said installation mechanism;
   (e) sensing means carried by said indexing device and cooperating with said indexing areas to sense the number of said areas through which the device has passed; and,
   (f) actuating means carried by said indexing device and cooperating with said sensing means to activate said installation mechanism to install the tool in said preselected tool receiving position.

2. A selectively operable installation mechanism for securing a tool within a conduit, comprising:
   (a) a housing member having a central bore and adapted to be operably secured to the tool and propelled therewith through the conduit;
   (b) at least one dog carried by said housing and being adapted to be extended therefrom into locked engagement with the conduit;
   (c) biasing means to extend said dog from the housing; and
   (d) a probe reciprocably mounted with said bore,
   (e) at least one shoulder formed on said probe to engage and hold said dog in retracted position,
   (f) actuating means operatively connected to said probe to selectively reciprocate said probe to release said dog; whereby said biasing means extend said dog into locked engagement with said conduit.

3. An installation mechanism as defined in claim 2 wherein:
   (a) said probe is formed with a central passage there-through; and,
   (b) said actuating means extends said passage and engages one end of said probe.

4. An installation mechanism as defined in claim 2 wherein said mechanism further includes at least one additional dog carried by said housing and longitudinally spaced from said first dog, said additional dog being biased into continual sliding engagement with said conduit and adapted to positively engage said conduit when said mechanism is moved in a direction opposite to the direction said mechanism is being propelled to said conduit.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,308,880

March 14, 1967

Edward D. Yetman

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 15, line 16, after "receiving" insert -- position within a conduit having a series of such tool receiving --.

Signed and sealed this 7th day of November 1967.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents