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3,312,282

PUMPING WELL TOOLS THROUGH FLOWLINES OF IRREGULAR DIAMETER

Filed Jan. 30, 1964

2 Sheets-Sheet 1

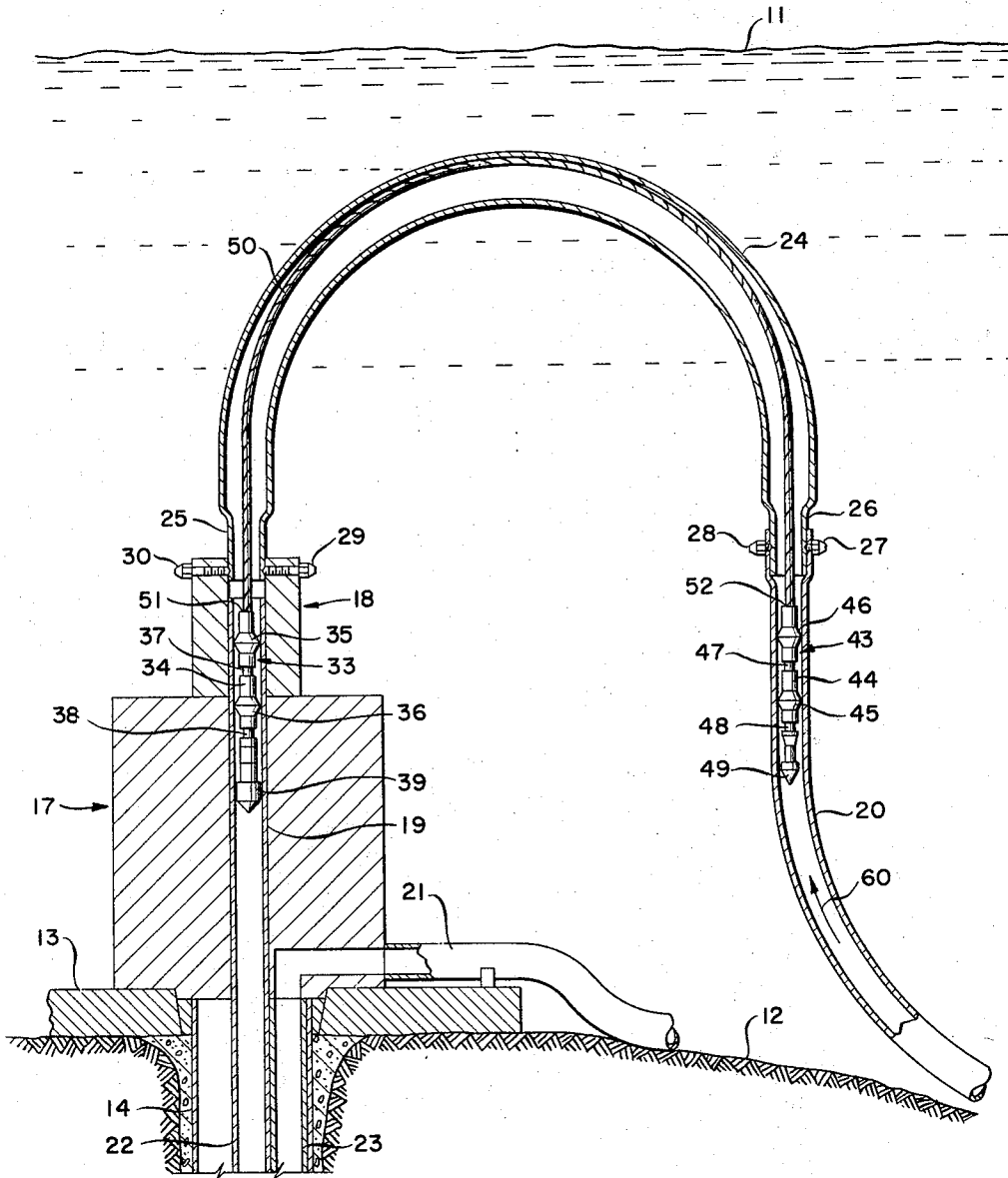


FIG. 1

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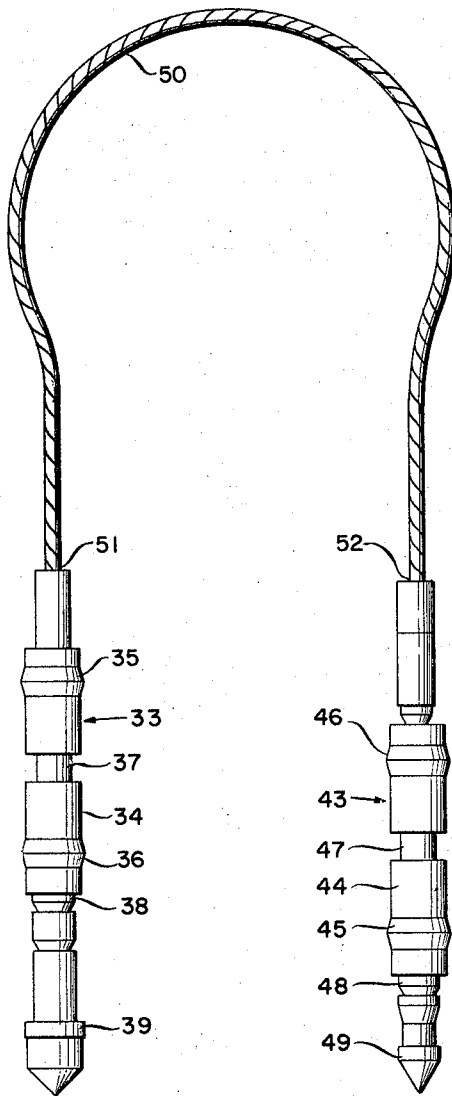


FIG. 2

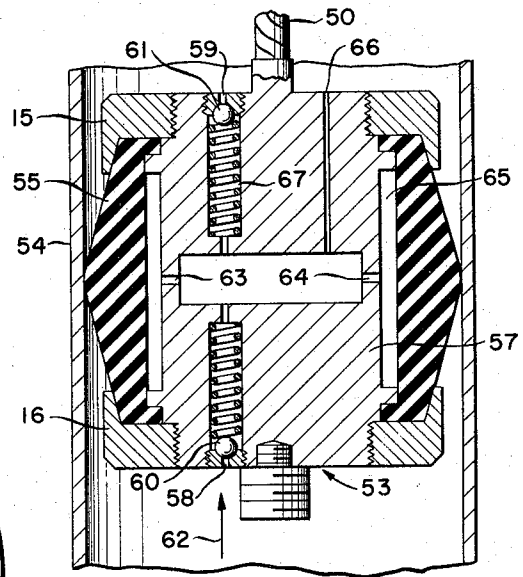


FIG. 3

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1

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4 Claims. (Cl. 166—46)

This invention relates to well tools adapted to be pumped through flowlines leading to underwater wellhead assemblies located on the ocean floor. More particularly, the invention is directed to a means for installing well tools and retrieving them from well strings disposed in underwater wells through irregular-diameter flowlines communicating with the wells.

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 by tools which pass through a flowline communicating between a surface location, such as an operating station, and a submerged well installation, movement of the tool being caused by pumping a driving fluid through the flowline. In order to carry out some of the more simple work-over or maintenance operations, such as the removal of a valve, the cleaning of paraffin from a tubing string, etc., there were developed an entirely new line of well tools which can be pumped through a production flowline from some remote location, oftentimes a mile or more from the well, and enter the well, passing down the tubing string therein to be subsequently positioned therein for carrying out some preselected operation. After completing the operation, the tool in the tubing string within the well is subsequently removed, generally by reverse circulation of the driving fluid. Examples of such operations and tools are shown in U.S. Patents Nos. 3,050,130 to Culver et al. and 3,090,440 to Lagucki.

Portions of the flowlines leading to underwater wells are curved, as where it is desired to pass around irregularities on the ocean floor and where the flowline rises off of the ocean floor to connect with the wellhead.

At present, the curved portions of flowlines communicating with underwater well installations are limited to a minimum radius of bend, typically five feet. The term "minimum bend radius" is used herein to denote the smallest bend radius which permits a tool to pass through a flowline of uniform diameter in sealed relation thereto. It presents a cumbersome limitation which has brought about serious problems in transporting flowlines to their underwater destination, particularly where the flowlines are attached to some large object such as the housing located at the top of a wellhead. Frequently, the curved sections of present-day flowlines are accidentally bent in handling and installation because of their awkward sizes. The five-foot bend system has the further disadvantage of making it difficult to circumvent irregularities on the ocean floor without using many extra feet of flowline, which would not be required if a smaller bend radius could be utilized. Prior attempts to eliminate the problems created by the five-foot bend system have met with little success since the known tools passed through flowlines are too long to pass around a bend having a radius of less than five feet.

By enlarging the internal diameter of a curved section, the tools can pass through the curve even though the bend radius is considerably reduced. However, the tools currently used depend upon a sealing engagement with the inside walls of the flowline in order that they may be pumped by the driving fluid to a desired location in the flowline. When such tools enter a flowline section of

2

enlarged diameter this sealing contact with the flowline wall is lost and the tool can no longer be forced forward by the driving fluid. Attempts have been made to couple several short tools together as by ball joints and the like, so that the composite tool will flex around the curved flowline of enlarged diameter and have at least one part thereof remain in sealing contact with those sections of the flowline of normal diameter. This is not a satisfactory solution because it requires the use of many expensive and otherwise unnecessary tool elements. Furthermore, if the section of enlarged diameter is of appreciable length, the train of coupled tools becomes so heavy that the sealing elements break down and allow the driving fluid to flow past the tools. Even in existing flowline systems, considerable economic saving could be realized if the internal diameter of the line did not have to stay within the exact tolerances now required.

Broadly, this invention presents a solution to the aforementioned problems by providing between the tool elements a lightweight unitary flexible connection of sufficient length to span the section of enlarged diameter. Preferably, the flexible connection consists of a metallic single- or multiple-strand cable which has sufficient stiffness to transmit longitudinal compressive force from one tool element to another. With such an arrangement, an enlarged-diameter portion of flowline can be spanned by the metallic cable in such a manner that at least one of the tool elements is always in sealing engagement with the inside wall of a section of the flowline having normal diameter.

In this manner it becomes possible to pass flowline tools through flowlines of irregular diameter without major redesign of the tool elements currently in use. The invention further provides an inexpensive and lightweight tool of simple design that can be pumped through a bore of enlarged diameter. These and other inventive features of my new device may be further understood by the following detailed description and drawings in which:

FIGURE 1 is a diagrammatic elevation, partially in longitudinal section, illustrating a wellhead assembly positioned on the ocean floor together with one arrangement of the apparatus of the present invention;

FIGURE 2 is a pictorial view of one form of the two-tool combination; and

FIGURE 3 is a diagrammatic view, partially in section, of another form of the tool.

Referring to FIGURE 1, a wellhead assembly is shown as 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 water and is preferably cemented therein in a conventional manner. A conventional or suitable well casinghead, outlined at 17, is mounted on the top of the conductor pipe 14 and carries a control-equipment housing 18 closing 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 equipment normally used on the top of a well of this type. The casinghead and housing provide a bore 19, which is in communication with casing 14.

Emerging from housing 18 is a flowline 20 which is sharply curved from a vertical upward direction to a downward direction and thence to a substantially horizontal direction running along the ocean floor 12. Similarly, a flowline 21 extends from the side of casinghead 17 and assumes a position along the ocean floor 12. Flowlines 20 and 21 lead to a remote location where fluid from the well, and normally from other wells, is collected, metered and treated. Such a collection station may be several miles away. Flowlines 20 and 21, in the particular installation

3

illustrated, are in communication with a pair of tubing strings 22 and 23, respectively, depending within the well. 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 underwater wellhead may take various other conventional forms such as the type employing Y-branched tubing as shown and described in U.S. Patent 3,101,118.

As shown, flowline 20 has an enlarged-diameter portion 24 which has a bend radius of less than the minimum bend radius, e.g., as small as two and one-half feet when the minimum bend radius is five feet. The ends 25 and 26 of the enlarged-diameter portion 24 are swaged down to the normal diameter of the flowline 20 and connected in fluidtight relation to the housing 18 and line 20. Set screws 27 and 28 can be used to facilitate keeping the swaged end 26 in tight engagement with the flowline 20. In like manner, set screws 29 and 30 keep the swaged end 25 in tight engagement with housing 18. It is to be understood that other conventional coupling means, such as hydraulic and pneumatic clamps and threaded or welded connections, can be used in place of the set screws.

As illustrated, a first tool carrier 33 is inside of the tubing string 22. Tool carrier 33 has a central mandrel 34 with axially spaced sealing elements or packers 35 and 36 mounted thereon. Packers 35 and 36 may be made of rubber or certain plastic materials. Preferably the mandrel 34 has a ball-in-socket joint 37 at a point between sealing elements 35 and 36 so as to facilitate movement of the tool carrier in curved sections of a flowline or pipe. Other ball-in-socket joints may be similarly used, as at 38, to connect one or more tools to the tool carrier 33. Only one such tool, a paraffin cutter 39, has been shown. A second tool carrier 43 with central mandrel 44, axially spaced sealing elements 45 and 46, and ball-in-socket joints 47 and 48 is shown inside flowline 20. Should the tool carrier become stuck in a well, tool carrier 43 is provided with a fishinghead 49 whereby a retrieving tool (not shown) attached to a wire line may be passed through the flowline 20 to latch onto fishinghead 49, thereby allowing removal of the tool carrier by pulling on the wire line. The internal details of tool carriers 33 and 43 are not the subject of my invention and may take any suitable form, such as that shown in U.S. Patent 3,052,302 to Lagucki or U.S. Patent 3,050,130 to Culver et al.

A flexible cable member 50 is suitably connected at 51 and 52 to each of the tool carriers 33 and 43. The cable member 50 is preferably either a single- or multiple-strand metallic member of sufficient length to span any enlarged-diameter portion of the flowline. I prefer to use an aluminum cable because of its light weight. The cable must be flexible enough to pass around curves having a small bend radius, say two and one-half feet, without exhibiting a binding effect on the internal walls of curved portions of the flowline, although contact with the internal walls is permissible. At the same time, the cable must possess sufficient stiffness to prevent any tendency to double back upon itself or otherwise buckle. This stiffness characteristic is especially important when the leading tool carrier is in an enlarged portion of the flowline and out of lateral sealing engagement with the internal walls of the flowline. When such a situation occurs, the cable must transmit to the leading tool carrier the pushing force exerted by the driving fluid against the trailing tool carrier. Should the cable buckle or double upon itself, then the trailing tool carrier might also move into the enlarged-diameter portion of the flowline and thereby lose its sealing engagement with the internal walls of the flowline. Due to its stiffness the cable will normally assume a near straight-line position between tool carriers 33 and 43. For purposes of illustration, it has been shown in a curved position in FIGURE 2. The cable 50 may be constructed of metal, rubber, synthetic rubber, rubberized fabric, nylon, certain plastic materials, or any other material suitable for the purpose, so long as it exhibits the required relationship between stiffness and flexibility referred to above.

4

In running one or more tools, such as paraffin cutter 39 through a flowline and down a well tubing, the tool 39 is first inserted at the origin (not shown) of flowline 20 with first tool carrier 33, flexible cable 50, and the second tool carrier 43 forced in behind it. Fluid under pressure is then pumped through the flowline 20 to drive the tool and its tool carriers down to the bottom of the well. Normally with the driving fluid flowing in the direction of arrow 60, the pressure of the driving fluid would, due to the construction of the carriers, act only against one of the sealing elements 45 or 46 of tool carrier 43 causing carrier 43 to slide through the flowline. At this time, the sealing elements 35 and 36 of carrier 33 are being similarly acted upon by the fluid and the entire assembly moves through the flowline. When tool carrier 33 enters an enlarged diameter portion of the flowline, the sealing contact is lost and the driving fluid passes around carrier 33. The pushing force exerted by carrier 43 as it slides, is then transmitted through cable member 50 to tool carrier 33, thereby moving the entire system of elements through the flowline. Since cable member 50 is of a greater length than any enlarged diameter portion of the flowline, the carrier 33 is pushed beyond the enlarged diameter portion and the flow of driving fluid causes one of the sealing elements of this carrier 33 to expand sufficiently into sealing engagement with a portion of the flowline having normal diameter. In this instance, tool carrier 33 would now be in sealing engagement with a portion of the flowline having normal diameter, and the driving fluid would push upon carrier 33 and thereby transmit a pulling force in the cable 50 to pull carrier 43 through the enlarged-diameter portion.

To return the tool carriers 33 and 43, with or without its accompanying tool(s) 39, circulation of the driving fluid in the well is reversed. In this manner, the carriers 33 and 43 alternately push and pull each other through the irregular diameter portions back to the origin of line 20.

The arrangement shown in FIGURE 3 of the drawings is a modified form of tool carrier. In this arrangement, tool carrier 53 is shown inside flowline 54. A packer or sealing element 55 of flexible material such as rubber, is mounted on mandrel 57 and held firmly in place by flanged retaining rings 15 and 16. The mandrel has an axial passage 67. Flow passages 58 and 59 at the ends of this passage 67 are normally closed by spring-loaded check valves 60 and 61, respectively, or any other suitable pressure-responsive valves which are set to open at a pressure lower than that needed to propel tool carrier 53 through a flowline. Ports 63 and 64 communicate with the annular space 65. The flexible cable 50 is shown attached to one end of tool carrier 53, and the other end of cable 50 is attached to another tool carrier (not shown) of the type shown at 53 in FIGURE 3. A small bleed port is shown at 66 to allow fluid to slowly escape when the carrier 53 is in an enlarged-diameter portion of the flowline; this allows radial contraction of the sealing element 55 and easy re-entry into a normal diameter portion of the flowline.

When pressure fluid is passed in the direction indicated by arrow 62, the pressure fluid flows past check valve 60 and enters fluid ports 63 and 64 leading to sealing element 55. Pressure fluid entering ports 63 and 64 passes into annular space 65 and forces the sealing element 55 against the inner wall of flowline 54 so that the sealing element 55 acts as a piston which slides through the flowline by the application of further pressure behind it. Similarly, carrier 53 will move in the opposite direction when fluid is passed into it through valve 61. By using one tool carrier 53 on each end of flexible cable 50, the entire system may be passed either forward or backward through a flowline having portions of irregular diameter since, due to the length of cable 50, one carrier 53 would always be in engagement with a portion of the flowline having normal diameter.

Various changes in the details of the described system may be made, within the scope of the appended claims,

5

without departing from the spirit and scope of the invention.

I claim as my invention:

1. For use in servicing underwater oil and gas wells an apparatus adapted to be pumped through a flowline having a major portion thereof of a given diameter and having at least one portion of enlarged diameter, said apparatus comprising:

- (a) a first tool carrier;
- (b) a second tool carrier axially spaced from said first tool carrier;
- (c) sealing means circumferentially mounted on each of said tool carriers for sliding engagement with the internal walls of the major portion of the flowline; and,
- (d) an elongated flexible unitary cable member axially joining said first and second tool carriers, the length of the cable member being at least as great as the length of said enlarged diameter portion, said cable member having sufficient stiffness to transmit forces of compression between the tool carriers without buckling.

2. In combination with the apparatus set forth in claim 1, a tool connected to at least one of said tool carriers by articulated coupling means.

3. Apparatus as set forth in claim 1 wherein said flexible cable member is a metallic cable.

6

4. In the method of pumping a series of tool carriers through a flowline having a major portion of given diameter and at least one portion of enlarged diameter, wherein the carriers have peripheral sealing means of given diameter for sliding engagement with the major portion of the flowline wall, the improvement of pumping the carriers through an enlarged diameter portion of flowline which comprises:

- (a) placing said carriers in the flowline in axially spaced relation at an interval greater than the length of said enlarged-diameter portion; and,
- (b) maintaining the interval between the tool carriers by flexible, unitary cable means of reduced diameter whereby at least one of said sealing means is at all times in sealing engagement with a given diameter portion of the flowline.

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