March 29, 1966 G. D. JOHNSON ETAL 3,242,991

UNDERWATER WELLHEAD WITH RE-ENTRY LUBRICATOR

Filed Aug. 7, 1962 2 Sheets-Sheet 1

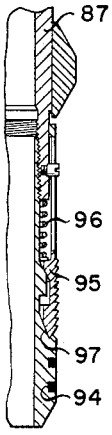

FIG. 5

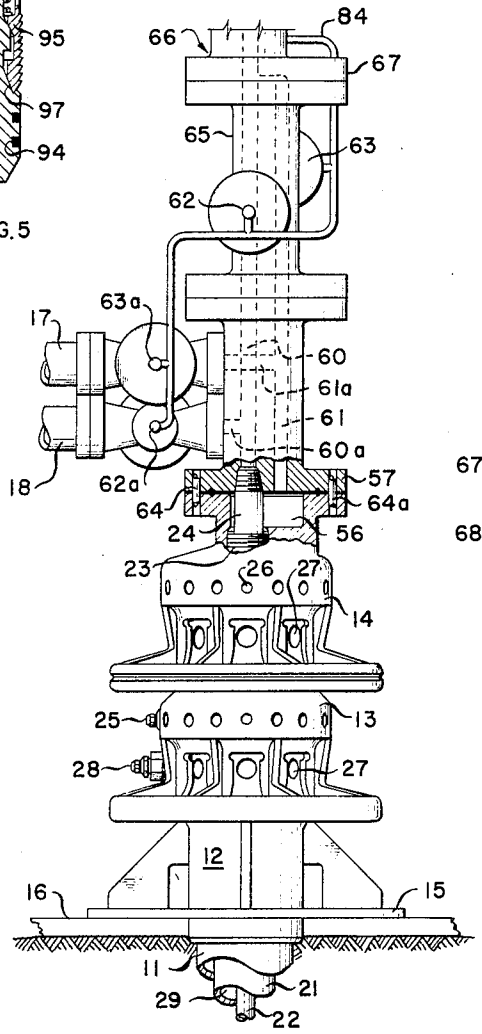

FIG. 1

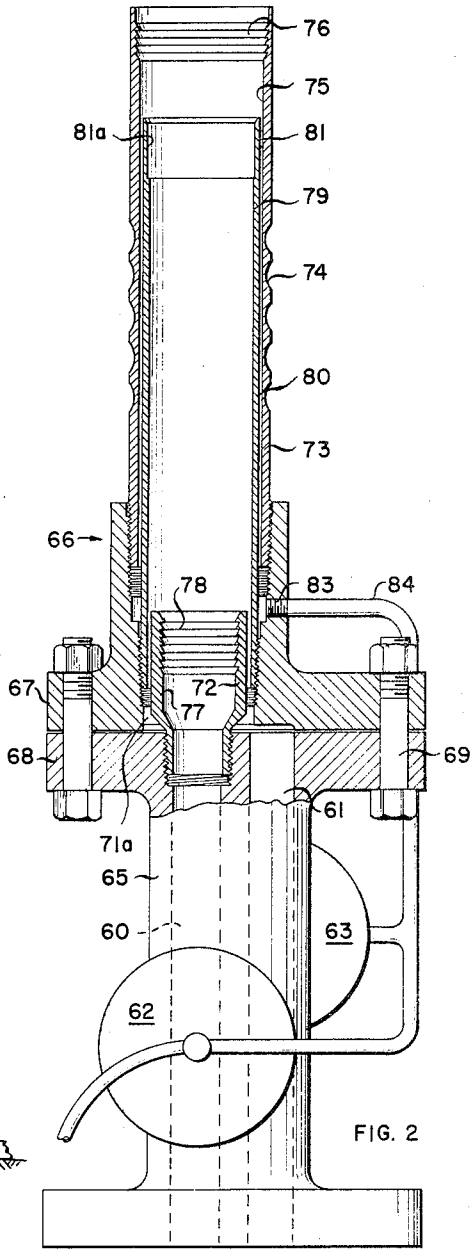

FIG. 2

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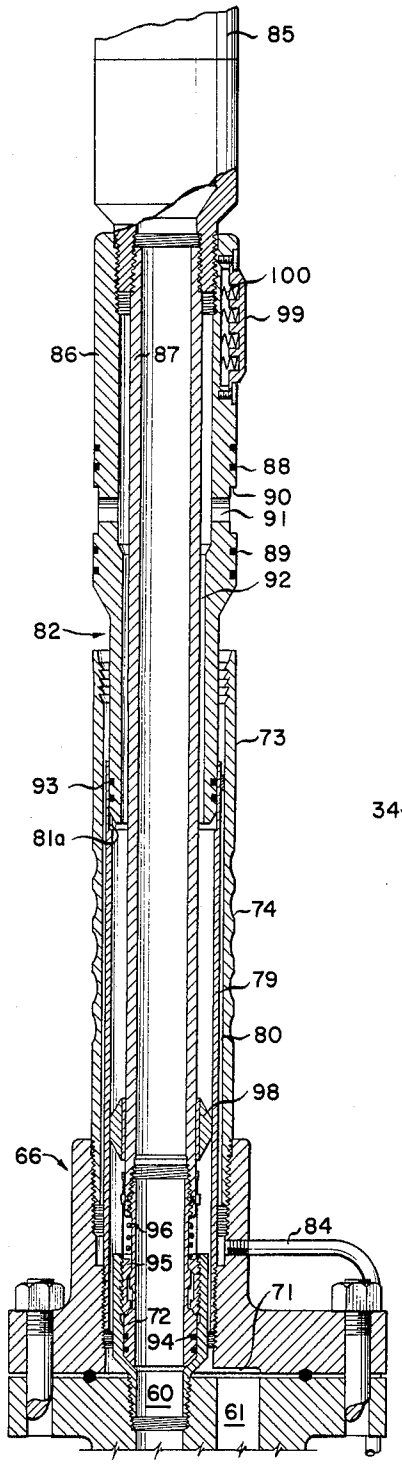

FIG. 3

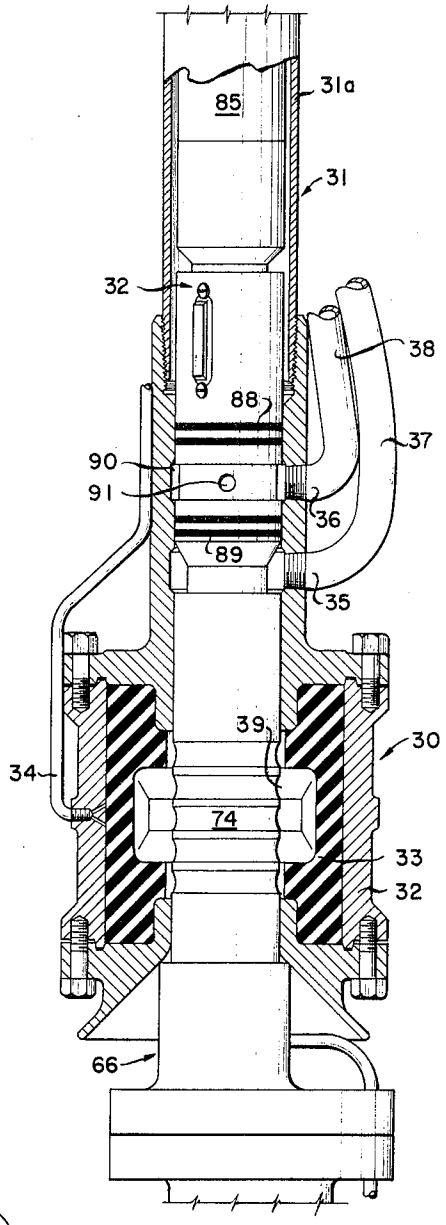

FIG. 4

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3,242,991

UNDERWATER WELLHEAD WITH RE-ENTRY LUBRICATOR

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9 Claims. (Cl. 166—75)

This invention relates to an underwater wellhead for closing the top of oil and gas wells and pertains more particularly to a wellhead assembly provided with a re-entry lubricator at the top thereof which, when coupled to other apparatus, forms a workover lubricator assembly through which communication with the interior of the well may be obtained from a remote location, such for example as from a vessel, barge or platform at the surface of a body of water.

A recent development in the oil industry is the drilling and producing of offshore wells wherein the wellhead assembly and the production flowline are positioned below the surface of the water, preferably on or near the ocean floor so as not to be subjected to the major wind and wave forces and to be out of the way of boats that may navigate in the area. Most offshore well drilling operations of this type are conducted from a platform or anchored barge or vessel from which the various pieces of equipment, used in or on the well during drilling, production or workover operations, are lowered through the water from the vessel to their position near the ocean floor. When operating at water depths or at locations where a diver cannot be employed to assemble the equipment on the ocean floor, it is necessary to provide apparatus that may be lowered through the water from a remote station, and then aligned and connected to other pieces of equipment at the ocean floor.

One method of drilling and completing an underwater well is described in copending application, Serial No. 24,558, filed April 25, 1960, and one form of a suitable wellhead for closing an underwater oil or gas well is described in U.S. Patent No. 3,186,488. Wellheads have to be opened or removed at certain times in order to carry out workover operations within the well, or in order to replace a tubing or casing string therein.

It is therefore a primary object of the present invention to provide a wellhead lubricator connected to the top of an underwater wellhead through which communication with the well may be obtained in order to carry out certain well operations.

A further object of the present invention is to provide a workover lubricator assembly for an underwater well which, in addition to the lubricator at the top of the well, includes a marine conductor pipe assembly and the fluid flow-controlling lubricator mandrel positionable therein after the well has been opened so as to provide fluid communication with the interior of the well.

Another object of the present invention is to provide a workover lubricator assembly for underwater wells which is adapted to be connected to an open lubricator at the top of a well and provide at least two conduit means between the well and the surface of the ocean or a vessel thereon whereby fluid, tools, or instruments may be pumped down one conduit while fluid is returned up the other conduit.

A further object of the present invention is to provide a workover lubricator assembly for a wellhead whereby a pair of parallel conduits above the production tree of the wellhead assembly may be brought into communication with a pair of concentrically-arranged conduits in the lubricator of the wellhead.

Another object of the present invention is to provide a

workover lubricator assembly for an underwater wellhead wherein conduit means are provided independent of the bore of the assembly for supplying a pressure fluid to the control valves of the wellhead assembly to open and close the necessary valves thereof so that workover operations may be carried on in the well.

Still another object of the present invention is to provide a wellhead lubricator including means by which a wellhead assembly may be raised or lowered into position.

A further object of the present invention is to provide a well workover method by which communication may be established between a vessel on the surface of the ocean with an underwater wellhead positioned at a substantial depth therebelow in order to carry out various well operations.

These and other objects of this invention will be understood from the following description taken with reference to the drawing, wherein:

FIGURE 1 is a diagrammatic view of one form of an underwater wellhead adapted for use with the workover lubricator assembly of the present invention;

FIGURE 2 is a longitudinal view taken in partial cross section illustrating the lubricator of the present invention secured to the top of the wellhead assembly of FIGURE 1;

FIGURE 3 is a longitudinal view taken in partial cross section illustrating a fluid flow controlling lubricating mandrel in accordance with the present invention, inserted in the wellhead lubricator of FIGURE 2;

FIGURE 4 is a diagrammatic view taken in partial longitudinal section showing a marine conductor pipe assembly which extends from the surface of the ocean and connects to the lubricator of FIGURE 3 while the lubricator mandrel is positioned therein; and,

FIGURE 5 is a fragmental view, taken in longitudinal cross section of one suitable form of latch means provided at the lower end of the lubricator mandrel of FIGURE 3.

In FIGURE 1 of the drawing, numeral **11** represents a surface casing or conductor pipe which has been installed in a well in the ground and preferably cemented therein in a conventional manner. At the time the surface casing is positioned in the well, a wellhead or casing-head **12**, in accordance with the present invention, has been fixedly secured to the top of the surface casing in any suitable manner such as by welding or threading. In the particular arrangement of the wellhead shown in the drawing, which is described in more detail in U.S. Patent No. 3,186,488, the wellhead comprises lower, intermediate and top sections **12**, **13** and **14**, respectively, of a housing which forms the wellhead at the underwater location. The lower section **12** of the housing is preferably provided with a support base **15** which is fixedly secured to the lower section, as by welding. The support base **15** in turn may rest on a cement foundation (not shown) or any other suitable foundation **16** or base placed around the well.

The lower section **12** of the housing of the wellhead is provided with a suitable casing hanger (not shown) within its bore which is employed to support a string of well casing **21** within the surface casing **11**. The intermediate section **13** of the housing is also provided with hanger means (not shown) therein for hanging a tubing string **22** therefrom. The top section **14** of the housing, known as a production bonnet, is provided with conduits **23** and **24** concentrically arranged and in communication at their lower ends with well casing **21** and tubing string **22**, respectively.

A plurality of locking screws **25** are horizontally positioned in a threaded manner within the lower end of the intermediate section of the housing **13** and arranged to extend through the wall thereof and into cooperating recesses (not shown) formed in the wall of the lower

housing section 12 near the top thereof. In a like manner, the top section 14 of the housing would be provided with similar lock screws adapted to extend through the holes 26 in the walls thereof and extend therethrough into recesses formed in the outer wall of the intermediate section 13 near the top thereof. Additionally, the intermediate and upper sections 13 and 14, respectively, of the housing are provided with a series of radially-directed holes through the wall thereof through which extend hold-down screws 28, only one of which has been shown for ease of illustration. These hold-down screws engage the casing and tubing hangers within the wellhead in a conventional manner.

Formed in the top of the upper bonnet section 14, which forms the closure section of the housing, is a chamber 56, which is in communication with the open top of conduit 23 and thence through the wellhead with the space 29 between the casing string 21 and the tubing string 22. This annular space 29 is normally known as the casing-tubing annulus. The top section 14 of the housing and the fluid cross-over chamber 56 are closed in any suitable manner as by a suitable cover plate 57 which may form the lower flange of a production tree which is secured to the top of the well. The production tree may include a pair of flow conduits 60 and 61 having valves 62 and 63 located therein, respectively. The flow conduits 60 and 61 are in communication with a pair of side-branching conduits 60*a* and 61*a* having flow-control valves 62*a* and 63*a* positioned therein, respectively. The cover plate 57 is connected in any suitable manner to the top section 14 of the housing, as by bolts 64 and 64*a*.

The flow passageway 61 is in communication through chamber 56 with the open top of conduit 23 and thence through the wellhead with the annular space 29 between the tubing string 22 and the casing string 21. Thus, means are provided for measuring the casing pressure within the well or for extracting or injecting fluid into the annulus 29 between the tubing string 22 and the casing string 21. By providing concentric tubing and casing strings 22 and 21, respectively, below the wellhead, smaller diameter pipe may be employed than would be needed if two parallel tubing strings were run down the well. Additionally, the casing string 21 has considerably more strength than a tubing string 22. The inner conduit 24 which is in communication with the top of the tubing string 22, is preferably screw-threaded at its upper end or otherwise suitably secured to the cover plate means or flange 57.

Fixedly attached to the top of the wellhead assembly of the present invention, as to the valve spool member 65 at the top thereof, is a re-entry housing or lubricator housing 66 whose lower flange or plate member 67 may be bolted to the valve spool 65, by bolts 68 and 69 (FIGURE 2). The lower end of the lubricator housing 66 or the upper end of the valve spool 65 is provided with a cross-over chamber 71 in communication between the top of the conduit 61 through the valve spool 65 and a space 71*a* at least partially surrounding a bushing member 72 which is screw-threaded into and in communication with the flow conduit 60 in the valve spool 65.

The lubricator 66 may take a variety of forms but in general the lubricator is provided with at least one upwardly extending tubular member 73 having a sealing surface, preferably grooved, as at 74, on the outer wall thereof, against which a surrounding piece of equipment, such as a landing head or wellhead connector 30 (FIGURE 4), may be sealed in a fluidtight manner.

In the most simple form, the re-entry housing or lubricator 66 is provided with the upwardly-extending tubular member 73 which has a sealing surface 75 on the inner wall thereof against which seals carried by a closure plug (not shown) may be sealed in a fluidtight manner. Additionally, the inner wall of the tubular member 73 is provided with grooves or latching recesses 76 near the upper end thereof for latching a wellhead closure plug in place. The bushing member 72 is also provided with a sealing surface 77 and may, as desired, be provided with grooves or latching recesses 78 which are preferably employed for latching a running tool thereto in order to lower the production head of the wellhead into place at the ocean floor.

In order to provide a bypass conduit in the lubricator past the grooved outer sealing surface 74 thereof, a second tubular member 79 is fixedly secured within the lubricator housing 66 concentric with and within the tubular member 73, thus forming a bypass conduit in the form of an annular space 80 between the tubular members 73 and 79. If desired, a series of small spacer elements 81 may be positioned between the two tubular members 73 and 79 near the top thereof in order to center the inner tubular member 79. The inner tubular member 79 is also provided with a sealing surface 81*a* for receiving the seals of a closure plug (not shown) or for receiving the seals of a workover lubricator mandrel 82 (FIGURE 3) of a size adapted to be received within the lubricator housing 66.

As shown in FIGURES 1 and 2, the lower end of the bypass conduit or annular space 80 is in communication through a port 83 through the wall of the lubricator housing 66 with a conduit 84 which is in communication with the control valves 62, 62*a*, 63, 63*a* of the production wellhead, or the valve operators, so that the valves may be selectively opened or closed by applying a pressure fluid through conduit 84 and thence to the control valves. Preferably, the valves are of a design or the operators thereof are so arranged so that when a pressure fluid is applied through conduit 84, the swab valves 62 and 63 and any master valves (not shown) which may be employed are pressured open while the flow control valves 62*a* and 63*a* in the side conduits are pressured closed, thus enabling workover operations to be carried out without discharging any fluid through the normal well flowlines 17 and 18 (FIGURE 1).

When it is desired to communicate with two pipe strings, for example with the tubing in the well and with the tubing-casing annulus, a workover lubricator assembly is employed, one form of which is shown in FIGURE 4. The workover lubricator assembly comprises three main parts: the lubricator 66 at the top of the wellhead, a marine conductor pipe assembly 31 extending from a vessel on the surface of the ocean and being provided with a landing head 30 at its lower end for sealing around the lubricator housing 66, and a fluid flow-controlling lubricator mandrel 82 insertable through the marine conductor pipe assembly 31 with a portion thereof insertable into the lubricator housing 66. As shown in FIGURE 4 of the drawing, the landing head or wellhead connector 30 may be of any suitable design adapted to seal the lower end of the conductor pipe assembly 31 of the lubricator housing 66. For this purpose the landing head 30 is provided with a bore 39 extending upwardly from the bottom therof and adapted to receive therein the lubricator housing 66. Contained within the housing 32 of the landing head 30 is an annular resilient sealing member 33, preferably in the form of a rubber packer, which is adapted to be contracted radially about the grooved surface 74 on the lubricator housing 66 upon application of a pressure fluid through conduit 34 from a pressure source on the vessel at the surface of the water.

The landing head housing 32 is provided with one or more ports 35 and 36 through the wall thereof and in communication with the bore thereof. Conduits 37 and 38 are connected to the ports 35 and 36, respectively, and extend upwardly through the water, preferably being strapped to the marine conductor pipe 31*a*, to the vessel at the surface where they may be coupled to a pressure source or a discharge tank.

As shown in FIGURES 3 and 4, the fluid flow-controlling lubricating mandrel **82** is secured, as by threading, to the lower end of a small-diameter pipe string **85** which is insertable through the marine conductor pipe **31***a*. In order to establish communication with two pipe strings within the well, the lubricator mandrel **82** comprises a pair of concentric downwardly-extending tubular members **86** and **87**, the diameter of the outer tubular member **86** being substantially equal to that of the bore through the landing head housing **32** at a point adjacent the upper port **36** through the wall thereof. The lubricator mandrel **82** is provided with sealing means, such for example as O-rings **88** and **89** positioned above and below a recessed annular flow passageway **90** which is in communication through ports **91** with an annular flow passageway **92** between the outer and inner tubular members **86** and **87**, respectively. The length of the inner tubular member **87** is such that, when the lubricator mandrel **82** is positioned in the lubricator **66** and the landing head housing **32**, the annular flow passageway **90** is adjacent the port **36** through the wellhead closure housing wall and the seals **88** and **89** carried by the lubricator mandrel sealed against the inner wall of the housing **32** above and below the ports **36**.

Below the seals **89**, the outer tubular member **86** of the lubricator mandrel **82** is reduced in diameter so as to fit in the open top of the lubricator **66** or the tubular member **73** thereof. The lower end of the outer tubular member **86** of the lubricator mandrel **82** is provided with seals **93** for sealing against the sealing surface **81***a* at the top of the tubular member **79** of the lubricator housing. The lower end of the inner tubular member **87** of the lubricator mandrel **82** is provided with sealing means **94** carried outwardly thereon for sealing against the inner sealing surface **77** (FIGURE 2) of the bushing **72**.

If it is desired to employ the lubricator mandrel **82** in order to lower the production wellhead of the present invention to the ocean floor, the lower end of the inner tubular member **87** of the lubricator mandrel **82** may be provided with suitable latches **95** normally urged outwardly and downwardly by means of a compression spring **96** (FIGURE 5) which forces the latches **95** downwardly along the face of the slip bowl **97** and in turn forces the serrated latches outwardly into the latching grooves **78** (FIGURE 2) when the lower end of the tubular member **87** is stabbed into the bushing **72**. The latching recesses **78** are preferably in the form of a thread whereby the lubricator mandrel may be unlatched from the bushing **72** by unscrewing the apparatus. Preferably, the grooves **78** are in the form of a left-hand thread. If desired, the lower end of the inner tubular member **87** of the landing mandrel **82** may be provided with one or more spacing lugs **98** which are fixedly secured to the outer surface of the tubular member **87** and slidably engage the inner surface of the tubular member **79** of the lubricator. Additionally, the outer tubular member **86** of the lubricator mandrel **82** may be provided with one or more spacer lugs **99** which are spring-loaded by springs **100**. Upon lowering the lubricator mandrel **82** at the lower end of the pipe string **85** through hundreds of feet of the marine conductor pipe **31***a*, the spacer lugs **99** on the outer tubular member **86** (FIGURE 3) tend to centralize the lubricator mandrel **82** so that the O-ring seals **88** and **89** are not worn by rubbing against the walls of the marine conductor pipe **31***a*.

In operation, with the workover lubricator assembly arranged as shown in FIGURE 4, communication is obtained with the tubing string of the well from the vessel through the pipe string **85**, through its depending tubular member **87**, and through the bushing **72** which is in communication with the flow conduit **60** and hence with the tubing string **22** (FIGURE 1) of the well. In carrying out workover operations with the workover lubricator assembly of the present invention, the marine conductor pipe assembly would be first run from the vessel down to the wellhead and seated over the lubricator housing **66** at the top of the wellhead. Fluid pressure would be applied through conduit **34** to compress the landing head sealing element **33** against the grooved outer sealing surface **74** of the lubricator housing **66**. A fishing tool would then be run in either on a wire line or a pipe string down through the marine conductor pipe **31***a* to remove the closure plug (not shown) from the top of the well so that the lubricator housing **66** was open in a manner shown in FIGURE 2 but with the marine conductor pipe and its landing head **30** in place as shown in FIGURE 4.

The lubricator mandrel **82** of FIGURE 3 would then be run at the lower end of a pipe string **85** down through the marine conductor pipe **31***a* (FIGURE 4) to seat it in the position shown in FIGURES 3 and 4. In this position, with the seals **88** and **89** being positioned above and below port **36** in the wall of the landing head, conduit **38** which extends downwardly from the vessel would be in communication through port **36** and annular flow passageway **90** through port **91** in the wall of the outer tubular member **86** (FIGURE 3) and the downwardly-extending annular space **92** between outer and inner tubular members **86** and **87**, respectively, and through the crossover chamber **71** in communication with the other parallel conduit **61** through the production wellhead. Thus, by means of conduit **61**, communication would be established with the tubing casing annulus **29** of the well so that fluid could be injected thereto or obtained therefrom. Communication is thereby established through pipe string **85** and conduit **38** with two of the pipe strings within the well.

If other means are not provided for selectively opening and closing the various valves on the wellhead during workover operations, the conduit **37** in communication with port **35** and the bypass conduit in the form of annular space **80** in the lubricator housing **66**, provides communication around or vertically past the sealing element **33** of the landing head **30** whereby a pressure fluid can be supplied from the vessel through conduit **37**, in port **35**, down through bypass conduit **80** and out the valve control conduit **84** so that pressure may be applied to the various valves of the production wellhead. It is apparent that other means for controlling the flow control valves of the wellhead may be provided, but the apparatus of the present invention provides as assembly of simplified design whereby three lines of communication may be provided between a vessel at the surface of the water and a wellhead at the ocean floor by the simple means of stabbing a single mandrel into the lubricator housing of the wellhead without need for rotation of one element relative to the other in order to assure alignment of the mating conduits. The workover lubricator assembly of the present invention also provides means for running parallel strings of conduits down to an underwater wellhead for workover purposes and changing over to concentric flow conduits as the lubricator mandrel of the assembly enters the single opening of the lubricator housing at the top of the wellhead.

In the event that the equipment of the present invention was employed to lower a wellhead assembly into place on the ocean floor, the pipe string **85** and its lubricator mandrel **82** would be stabbed into the lubricator housing **66** so that the latches **95** carried at the lower end of the inner tubular member **87** of the lubricator mandrel **82** engage the groove **78** of the bushing **72**. The connected structure would then be lowered into place at the top of the wellhead and connected in any suitable manner well known to the art. Subsequently, the marine conductor pipe assembly **31** would be stripped down over the smaller pipe stripe **85** and the wellhead connector **30** would be secured to the lubricator housing **66**. The smaller pipe string **85** and its lubricator mandrel **82** would be retrieved by unscrewing the latches **95** and pulling the spring **85**

back to the well. A closure plug (not shown) would then be lowered through the marine condutor pipe **31***a* and seated and latched in the top of the lubricator.

We claim as our invention:

1. A lubricator for a wellhead structure through which communication with a well may be obtained in order to carry out certain well operations, said lubricator comprising

(a) a tubular lubricator housing secured to the top of a production wellhead assembly which is positioned at and normally closes to top of a well having at least two strings of pipe suspended therein, said tubular housing having a vertical bore therethrough in communication at its lower end with at least one pipe string of said well and being open at its upper end,

(b) an outer sealing surface formed as part of the outer surface of said tubular lubricator housing, said sealing surface being adapted to receive thereon annular sealing means,

(c) vertical by-pass conduit means in said lubricator housing in communication through said housing with the space outside thereof above and below the outer sealing surface thereof, and

(d) inner sealing surface means formed on the inner wall of said tubular lubricator housing for receiving seal means carried by a lubricator mandrel.

2. The apparatus of claim **1** wherein said tubular lubricator comprises first and second concentric tubular portions secured to said production wellhead assembly and in communication through said wellhead assembly with two pipe strings within a well.

3. The apparatus of claim **2** wherein said inner sealing surface means comprises first and second axially displaced sealing surface means formed on said first and second concentric tubular portions of said lubricator housing.

4. The apparatus of claim **1** wherein said tubular lubricator housing is provided with latching recess means formed in the wall near the upper end thereof for receiving latching elements therein.

5. The apparatus of claim **2** wherein said first and second concentric tubular portions of said lubricator housing are provided with latching recess means formed in the wall near the upper end thereof for receiving latching elements therein.

6. The apparatus of claim **1** including conduit means carried outside said lubricator housing, the upper end of said conduit means being secured to said housing and in communication at one end with the lower end of said by-pass conduit means, and at the other end with pressure responsive elements of said wellhead assembly.

7. A marine conductor pipe assembly adapted to provide fluid communication between a vessel on the surface of a body of water and an underwater wellhead, said conductor pipe assembly comprising,

(a) a string of pipe of a length sufficient to extend from an underwater wellhead to the surface of the water,

(b) wellhead connector means carried by the lower end of said pipe string, said wellhead connector having an upwardly extending bore therein of a size to receive therein a tubular well member of said underwater wellhead, said wellhead connector including inwardly-expansible annular seal means for sealing on the outer surface of said well member, and

(c) conduit means extending down along the outside of said pipe string and through the wall of said wellhead connector in communication with the bore thereof above the annular seal means thereof.

8. The apparatus of claim **7** wherein said conduit means include first and second conduits in communication with the bore of said wellhead connector through the wall thereof at axially displaced points.

9. A workover lubricator assembly for a well positioned under the surface of a body of water, said assembly comprising

a tubular lubricator secured to the top of an underwater production wellhead assembly, said lubricator having

a vertical bore therethrough,

outer sealing surface means on the outer wall thereof,

inner sealing surface means on the inner wall thereof,

by-pass conduit means in said lubricator in communication with the space outside thereof around said outer sealing surface means,

a marine conductor pipe assembly extending from said lubricator to the surface of the water, said pipe assembly comprising

a string of pipe

a wellhead connector carried by the lower end of said pipe string and having a vertical bore therein surrounding said lubricator and including annular seal means positioned for sealing engagement adjacent the outer sealing surface of said lubricator,

first conduit means through the wall of said connector above said seal means and in communication with the upper end of said by-pass conduit in said lubricator,

second conduit means through the wall of said connector in communication with the bore thereof above said seal means,

a fluid flow-controlling lubricator mandrel insertable at the end of a small-diameter pipe string down through said marine conductor pipe string and being positionable in said lubricator and said wellhead connector, said lubricator mandrel having a bore therethrough adapted to register with the bore of said lubricator and port means through the wall of said mandrel which includes

first and second seal means carried outwardly above and below said port means and adapted to seal against the inner wall of said wellhead connector above and below the second conduit means through the wall thereof, and

third seal means carried outwardly on said mandrel at a level to seal against the inner wall of said tubular lubricator.

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