United States Patent

[11] 3,602,300

[72] Inventor **Albert P. Jaffe**
Ellicott City, Md.

[21] Appl. No. **837,658**
[22] Filed **June 30, 1969**
[45] Patented **Aug. 31, 1971**

[73] Assignee **Westinghouse Electric Corporation**
Pittsburgh, Pa.

---

[54] **DOWN-HOLE INSTALLATION, RECOVERY, AND MAINTENANCE TOOL FOR WELLS**
14 Claims, 5 Drawing Figs.

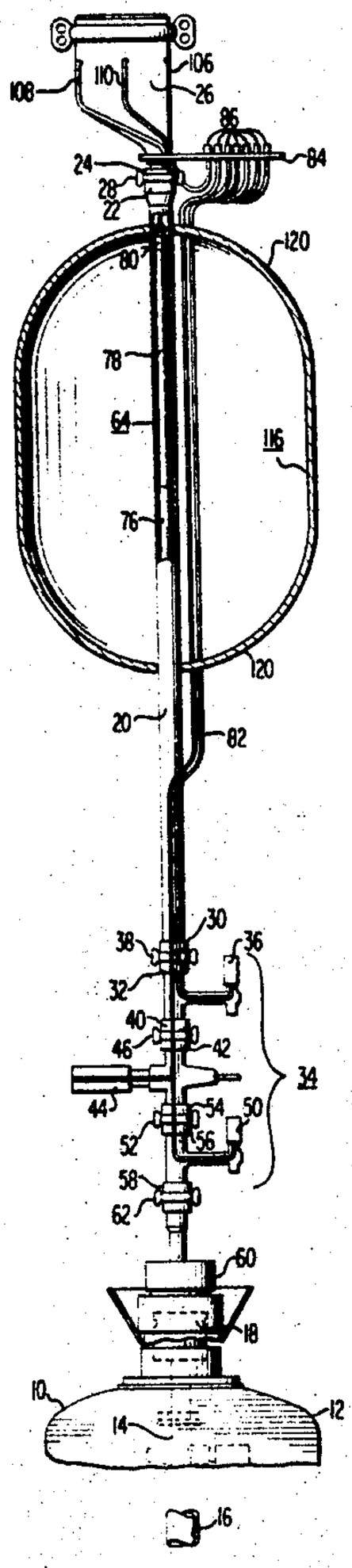
[52] **U.S. Cl.** **166/.5,** 166/70, 166/75, 254/150
[51] **Int. Cl.** **B66d 3/20,** E21b 23/00, E21b 33/035
[50] **Field of Search** ..... 166/.5, .6, 75, 77, 84, 70; 254/150 FH; 60/53 W, 53 R; 92/58

[56] **References Cited**
UNITED STATES PATENTS

3,511,312	5/1970	Laffont et al.	166/.5
3,517,736	6/1970	Waldron	166/.5
Re.24,086	11/1955	Summers	166/77
1,110,313	9/1914	Davenport	254/150 (FH)
1,817,201	8/1931	Minor	166/84 X
1,875,600	9/1932	Hele-Shaw et al.	254/150 (FH)
2,810,439	10/1957	McCullough et al.	166/77
3,408,822	11/1968	Chate et al.	166/.5 UX
3,415,317	12/1968	Drivet	166/.6
3,500,907	3/1970	Gentry	166/.6 X
3,504,740	4/1970	Manning	166/.5

Primary Examiner—Ian A. Calvert
Attorney—Brady, O'Boyle & Gates

ABSTRACT: A down-hole maintenance tool incorporating a wire line and lubricator as well as a complete hydraulic wire line drive motor unit enclosed within a single composite pressure vessel coupled to the wellhead. The entire pressure vessel is internally exposed to the pressure of the well at the wellhead thereby eliminating all seals such as the stuffing box normally required for the passage of the wire line cable to the lubricator.



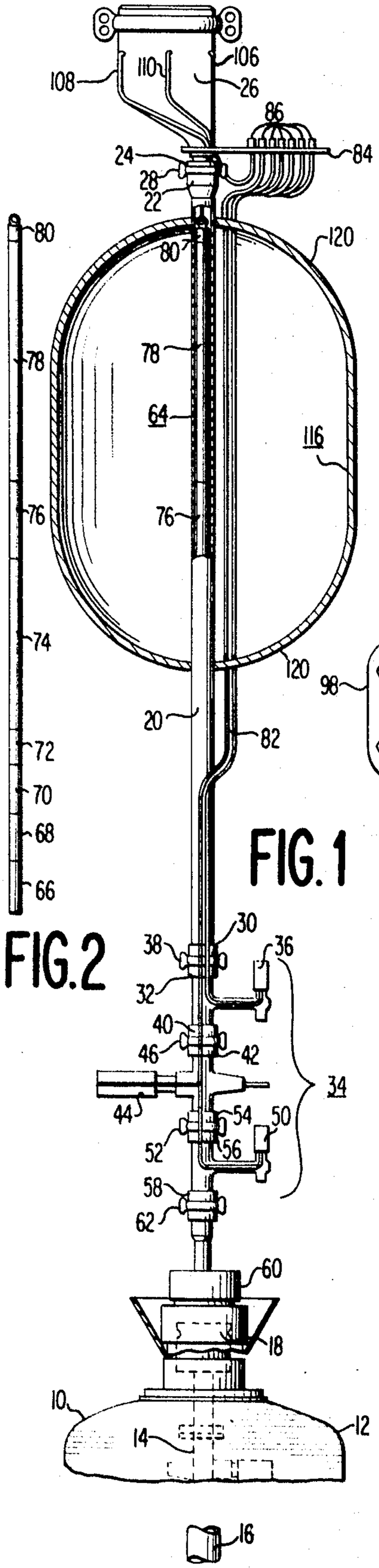


FIG. 1

FIG. 2

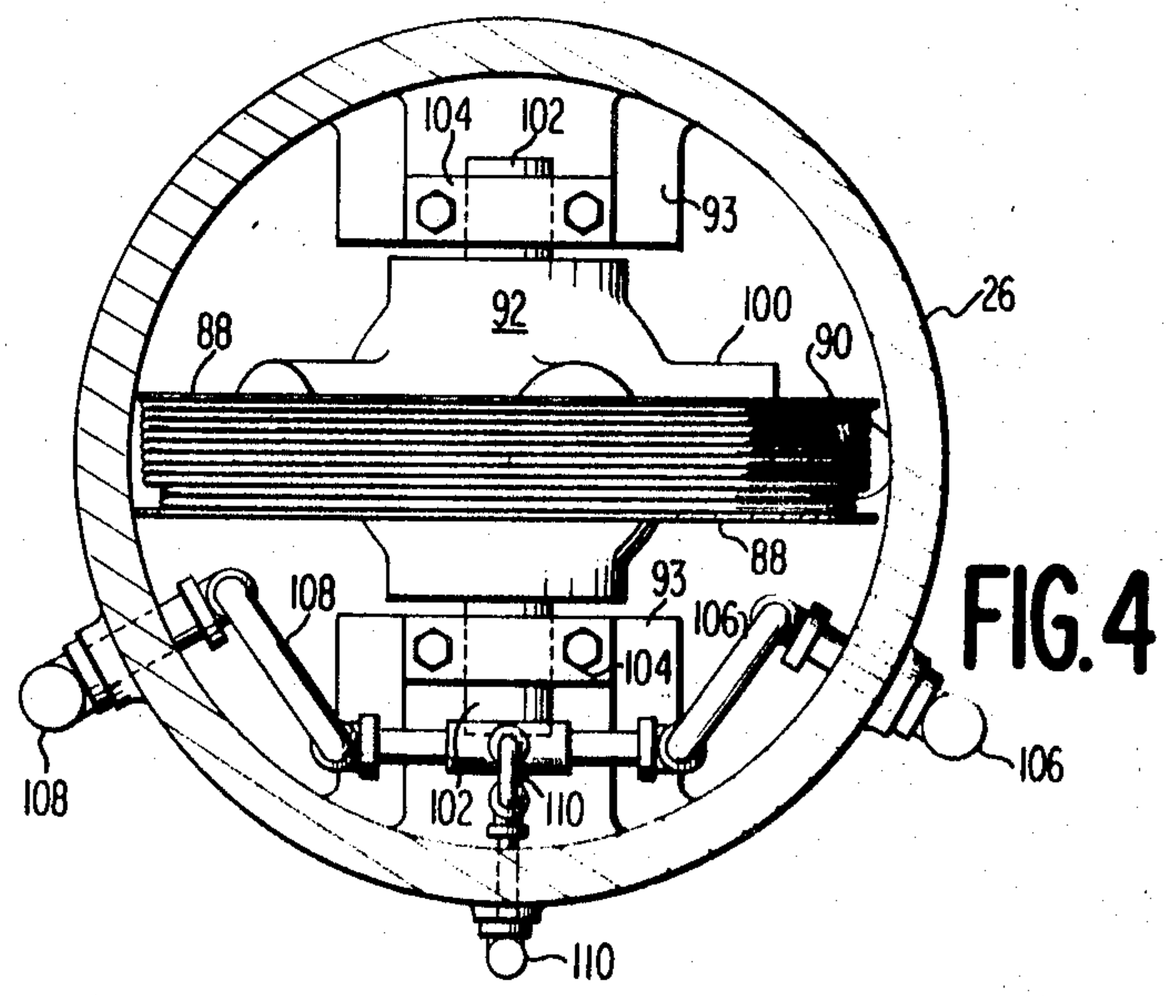


FIG. 4

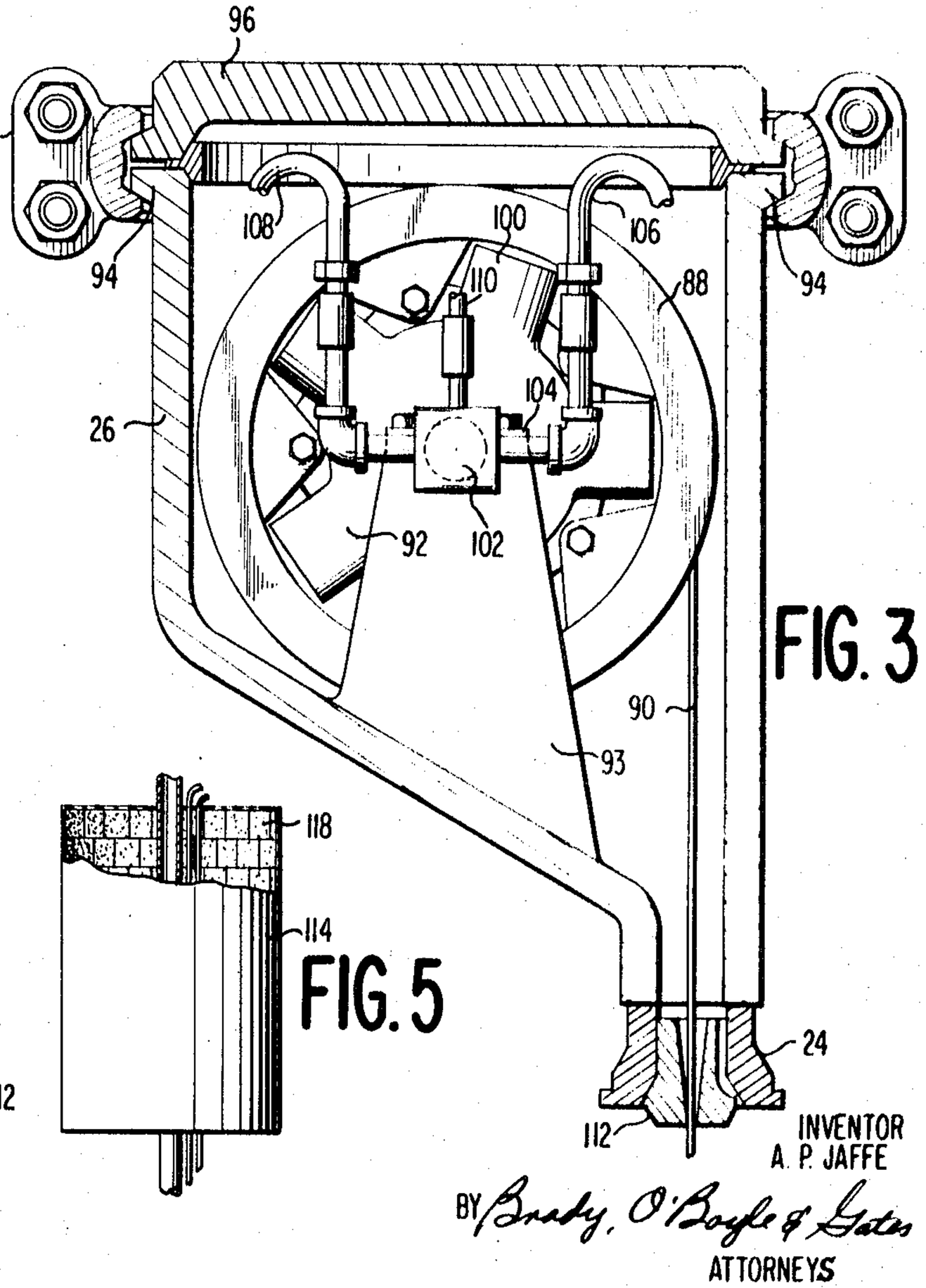


FIG. 3

FIG. 5

INVENTOR
A. P. JAFFE

BY Brady, O'Boyle & Gates
ATTORNEYS

DOWN-HOLE INSTALLATION, RECOVERY, AND MAINTENANCE TOOL FOR WELLS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is directed to means for performing remedial action down-hole in an oil well such as paraffin cleaning, sand bailing, setting down-hole pressure recorders, setting and removing storm chokes or down-hole well safety valves, etc. One of the present methods of performing these operations is by the use of a wire line and lubricator unit which comprises a permanent or temporary insertion in the tubing contained in the well of apparatus which is lowered at the end of a steel wire line through a housing called the lubricator. A conventional lubricator unit is coupled to an external motor driven drum and cable unit contained in a separate housing and is coupled by means of a combination of stuffing boxes and pulleys so that the lubricating unit is exposed to wellhead pressure while the housing containing the motor unit is sealed only from the outside ambient environment or, in some cases, open to the atmosphere.

2. Description of the Prior Art

To provide for safety shut-in of a subsea well under certain emergency circumstances, a preferred method is to use a remotely controlled subsurface safety valve, which is installed in the production tubing string, within a few hundred feet of the sea bottom mud line. For increased reliability such valves are available in types which can be removed through the tubing string for periodic preventive maintenance. The shallow location of the valve permits easier access and less costly maintenance. The valve is controlled by hydraulic pressure via the subsea wellhead, and it is designed to automatically close in the event of failure above the valve at the wellhead equipment or subsea flow line, thereby protecting against uncontrolled spillage.

Reliable operation of the subsurface safety valve can be obtained by the intentional closing and reopening at regular intervals and by periodic removal and reinstallation of the valve. Control of this valve is effected remotely by means of a hydraulic system incorporated in a removable wellhead module. Removal and reinstallation of this valve is accomplished by a down-hole maintenance tool temporarily installed on the top of the wellhead module. The ball-type safety valve is arranged within a circular sleeve assembly which is locked into a special tubing nipple by a locking mandrel. At the top of the sleeve assembly is a fishing neck to adapt to running tools for storing the valve sleeve assembly and pulling tools for removal of the valve sleeve assembly. These installation and removal tools are arranged to provide the relatively large axial forces required to set the valve in place and to remove it after an extended period in service. To provide these large forces, a system of cable-operated down-hole tools is used, including an adapter to mate with the running or pulling tool, a hydraulic jar, a weighted spool, an accelerator, a hydraulic piston and an adapter to attach the cable tool.

One example of a down-hole maintenance tool for a subsea well is disclosed in U.S. Pat. No. 3,415,317 issued to J. A. P. Drivet. The apparatus disclosed comprises a housing enclosing a winch drum and wire line cable through which a lubricator unit passes axially therethrough for coupling to the wellhead. The wire line cable is fed from the housing, which protects the winch drum from the surrounding water and subsea pressure, by means of a first stuffing box over a pulley arrangement into the lubricator unit through a second stuffing box. The wire line cable is connected to the well tool inside of the lubricator which is exposed to the wellhead pressure. The first stuffing box protects the winch drum housing from the surrounding environment while the second stuffing box provides a pressure seal for the lubricator unit between the wellhead pressure and the surrounding environment.

SUMMARY

Briefly, the subject invention is directed to a down-hole maintenance tool for operations on surface and subsea wells which eliminates the need for stuffing boxes or pressure seals of the wire line between the lubricator unit and the motor driven drum and cable unit housing and comprises an elongated tubular tool housing adapted to contain a well tool assembly therein and a winch housing directly connected to the upper terminal end of the tool housing. The winch housing includes a hydraulic motor, winch drum and wire line coupled to the tool assembly. A valve assembly is connected to the other terminal end of the tubular housing for isolating the tubular housing from the well bore and for venting and bleeding the apparatus during installation and removal. Additionally, a wellhead connector is coupled to the valve assembly for attachment to a wellhead assembly. A socket base for a control pod is attached to the apparatus for coupling hydraulic power and control signals to the hydraulic motor and operating the valve assembly respectively. For subsea operations, a buoyancy chamber or housing is mated to the tool housing at a selected point along its length to provide neutral buoyancy in sea water of the entire apparatus. By the direct connection between the tool housing and the winch housing, the internal pressure of both housings is exposed to wellhead pressure when the valve assembly is selectively actuated. By this arrangement the need for stuffing boxes and pressure seals required by conventional apparatus is eliminated.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side elevational view partially in section of the preferred embodiment of the subject invention;

FIG. 2 is a schematic illustration of a typical well tool assembly used in conjunction with the subject invention;

FIG. 3 is an enlarged vertical sectional view of the upper portion of the embodiment shown in FIG. 1;

FIG. 4 is a horizontal cross-sectional view of the upper portion shown in FIG. 3 taken below top housing cover; and

FIG. 5 is a fragmentary view of buoyancy housing utilized with the embodiment shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the present invention and more particularly to FIG. 1, there is disclosed a composite pressurized vessel adapted to be subjected internally to the pressure of a well drilled deep into the earth from land or through the sea. Although not restrictive thereto, the preferred embodiment will be described with reference to a wire line pressure vessel for coupling to a subsea well. Reference numeral **10** refers to a subsea wellhead module including a wellhead housing **12** and a "Christmas tree" assembly **14** connected to the production tubing string **16**. A reentry connection unit including a hub **18** is located at the top of the wellhead module **10** for obtaining down-hole access to the well. An elongated tubular housing **20** for a well tool comprises a heavy wall steel pipe with an inside diameter commensurate with the production string diameter and a length which depends on the desired functions. It is terminated at its upper end with a hub **22** for direct coupling to a mating hub **24** on the lower extremity of a motor and winch housing **26** by means of a split clamp **28**. The lower end of the housing **20** is provided with a hub **30** similar to the upper hub **22** which is provided for connection to a mating hub **32** of a valve assembly **34** including, inter alia, a drain valve **36**. A split clamp **38** is utilized for connecting the hubs **30** and **32**. The lower portion of the drain valve **36** terminates in a hub **40** which mates with a hub **42** of an isolation valve **44**. This connection is made by means of the split clamp **46**. A relief valve **50** is coupled to the isolation valve **44** by means of the split clamp **52** connecting the hubs **54** and **56**. The lower portion of the relief valve **50** terminates in a hub **58** which couples to a hydraulically actuated wellhead connector assembly **60** by means of the split clamp **62**. The wellhead connector assembly

60 provides a means for attachment to the reentry hub 18 on top of the "Christmas tree" assembly 14 and is provided with hydraulic lines, not shown, to lock and unlock the connector and permit testing of the connector joint seals.

The housing 20 is adapted to contain a well maintenance tool assembly 64. A typical tool assembly is shown schematically in FIG. 2 and comprises, for example, a ball-type tubing safety valve 66, a locking mandrel 68, a running or pulling tool 70, a tool joint adapter 72, a hydraulic jar assembly 74, a weight bar 76, a nitrogen-actuated jar accelerator 78 and a cable connector 80. A11 of these elements are well known to those skilled in the art and have specified dimensions for being lowered through the tool housing 20 and the valve assembly 34 into the tubing string 16 via the "Christmas tree" 14.

Additionally, the tubular well tool housing 20 is adapted to couple a plurality of hydraulic lines 82 necessary to operate the valves 36, 44 and 50 from a controlled pod, not shown. The hydraulic lines are coupled to a socket base 84 attached to the motor and winch housing 26 and includes a plurality of female hydraulic coupling members 86. The "Christmas tree" valves may be independently operating or when desirable, may be operated by additional hydraulic lines connected to the socket base 86.

When the tool assembly 64 is positioned inside of the housing 20 above the drain valve 36, the isolation valve 44 is maintained in a closed position. The portion of the housing 20 above the isolation valve 44 is filled with a hydraulic fluid after the tool assembly 64 has been placed in the housing prior to being brought into the vicinity of the wellhead module 10. The isolation valve 44 prevents this fluid from being lost prior to placement of the embodiment shown in FIG. 1 on the wellhead module 10 including the "Christmas tree" 14. When the configuration shown in FIG. 1 is mated to the wellhead module 10, the vent valve 50 is opened to prevent a hydraulic lock from forming in the tubing bore. It is also opened after completion of a tool string operation when the valving of the "Christmas tree" 14 and the isolation valve 44 are closed so as to release the pressure of the fluid trapped in the tubing section between these two valves. Opening of the isolator valve 44 exposes the well pressure not only to the tool housing 20, but also to the motor and winch housing 26. When the tool assembly 64 is removed from the tubing 16, the isolator valve 44 is closed and the drain valve 36 is opened to release the pressure within the tool housing 20 and the winch housing 26 as well as draining off the mixture of hydraulic fluid, production fluid, and sea water. This configuration is shown by way of example only for depending upon the specific application and permissible drainage of the fluid in the tool housing 20, the number of necessary valves can be reduced.

Since one of the functional objectives of the subject invention is to provide means to position a down-hole ball safety valve in the well rather than using a storm choke, the tool assembly 64 must be able to be lowered approximately 200 feet below the wellhead module 10. In order to accomplish this operation, a motor driven drum winch and wire line unit located in the winch housing 26 is coupled to the connector 80.

Referring now to FIGS. 3 and 4 which disclose sectional views of the last mentioned assembly, a winch drum 88, a wire line 90 spooled thereon as well as a hydraulic drive motor 92 are located on the frame 93 inside of the winch housing 26 which communicates directly with the tool housing 20. Thus instead of exposing the winch 88, the motor 92 and the cable 90 to the sea water or including a separate pressure vessel, they are exposed instead directly to the pressure and fluid environment of the well tubing string 16.

Since the winch housing 26 is subjected to well pressures in the region of 5000 p.s.i., it is designed to withstand these pressures by the use of cylindrical surfaces such as shown with respect to FIG. 4. The housing comprises an alloy steel casting in the shape of an eccentric reducer pipe fitting the small end of which is provided with the hub 24 for connection to the hub 22 at the top of the tool housing 20. The upper end of the winch housing 26 is formed as an integral hub 94 which is adapted to seat a housing cover 96. The split clamp 98 and the sealing ring 99 provide the means for securing the cover 96 to the hub 94.

A winch drum 88 is mounted on and secured to the radial piston motor housing 100. The shaft 102 is anchored against rotation by means of the bolted clamp assembly 104 attached to the frame 93. By anchoring the shaft against the rotation, the motor housing will rotate about the fixed shaft. A hydraulic supply line 106 is adapted to supply hydraulic fluid to the motor pistons not shown in the housing 100 by means of conduits, not shown, in the shaft 102 while a return line 108 couples hydraulic fluid out of the motor. A third hydraulic line 110 is utilized as a motor casing drain. By mounting the motor housing 100 to the interior perimeter of the winch drum 88, the hydraulic motor 92 can be made to drive the winch drum directly without the use of a coupling. The bearings within the motor housing itself thus serve to support the winch drum. A port adapter not shown, at one end of the stationary shaft 102 can be utilized for rotation reversal by reversing the direction of flow of the hydraulic fluid in the inlet and exhaust lines 106 and 108. The hydraulic motor 92 is of a conventional design, an example of which is a "Rotapowr" motor made by Houdaille Industries, Inc., Buffalo, New York.

The wire line 90 is coupled to the connector 80 of the tool assembly 64 through a guide 112. Since the interior of the winch housing 26 and the tool housing 20 are at the pressure of the well and since the need for stuffing boxes is removed, the configuration of the wire line 90 can be either a solid wire, a stranded cable, or a flat steel ribbon or tape depending upon the application. A flat ribbon can be employed since there is no seal through which the steel ribbon must pass. One advantage of the flat steel tape is in its self alignment feature with the cable guide 112 which also obviates the need for a "level-wind" mechanism necessary to wind a wire cable or rope uniformly upon the winch drum 88.

The embodiment of the subject invention is installed and removed from the top of the wellhead module 10 by a maintenance unit such as a tethered vehicle, submersible or telechiric device, not shown, designed to handle well maintenance tasks. Hydraulic control of the connection, operation and removal of the apparatus is accomplished from a control point located at the maintenance unit which will also contain the hydraulic power source and control valves required for remote operation of the valve assembly 34 and the hydraulic drive motor 92. The hydraulic power will be transferred from the maintenance unit to the socket base 84 by means of suitable hydraulic tubing and a multiline male connector adapted to make connection with the female coupling members 86. The socket base 84 includes a structural steel bracket welded to the body of the winch housing 26 near the upper end of the tool housing 20.

The weight in air of the subject embodiment of the invention is substantial. In order to facilitate installation and removal of the embodiment shown in FIG. 1 from the wellhead module 10 by means of a maintenance unit, it may be necessary to make the entire configuration substantially neutrally buoyant when immersed in sea water. This can be accomplished by means of either a buoyancy housing 114 as shown in FIG. 5 or a buoyancy chamber 116 as shown in FIG. 1. The buoyancy housing 114 is filled with moulded blocks 118 of syntactic foam material having a specific gravity less than water. The center of buoyancy of the flotation material must be located above the center of gravity of the immersed steel mass of the entire configuration. Therefore, the syntactic foam blocks 118 must be symmetrically arranged around the upper portion of the tool housing 20. The buoyancy housing 114 is particularly adaptable for deep water applications where depths of 1000 feet or more are encountered.

For depths of less than 1000 feet, the buoyancy chamber configuration 116 may be preferable. It is designed as an airtight vessel capable of withstanding external pressure equal to the head of the sea which could effect a differential pressure

as much as 445 pounds per square inch. Accordingly, a cylindrical shell can be utilized with hemispherical heads **120** on each end of the chamber. Also the axis of the chamber is concentric with the tool housing **20** near the upper portion of the assembly. In order to lighten the weight and to reduce the cost of the buoyancy chamber, precharging of the chamber with compressed gas is also contemplated. For example, if the chamber is precharged to about 225 p.s.i. before immersion, in water depths of about 500 feet, the external sea pressure would be about the same as the internal pressure, so that there would be no pressure differential across the shell. In 1000 feet of water, the external pressure would exceed the internal pressure by about 220 p.s.i. so that the design of the buoyancy chamber **116** could be based on the net differential pressure at a savings in weight and cost.

The versatility of the embodiment of the subject invention is immediately evident inasmuch as the same configuration can be utilized either on land or under the sea with the mere deletion of the buoyancy housing or chamber. It is recognized, however, that this configuration will not have the same advantage on land due to the weight of the additional high-pressure section, and the increased danger due to the larger encased volumes at high pressure. The unit can be varied in accordance with the functions which are desired to be performed with it, merely by changing design details. For example, depending upon forces required at a depth which must be reached for a desired operation, cable size, drum size, motor power and pressure housing size will necessarily be selectively altered. Also, depending upon the length of the tools required and the diameter of the well tubing to be entered, the vertical or tool housing will be sized accordingly.

What has been shown and described, therefore, is an improved down-hole maintenance tool for either surface or subsea wells which employs a composite wire line vessel operable at well pressure and enclosing not only the wire line tool assembly, but also the winch and drive motor, thereby eliminating all wire line seals.

I claim as my invention:

1. A down-hole maintenance tool, including a tool assembly, adapted to be coupled to a tubing string of either a surface or a subsea well for performing wire line operations, comprising in combination:

a pressure vessel including means coupling said vessel in fluid communication with said tubing string, said first recited means exposing the interior of said vessel directly to the pressure in the tubing string and allowing the interior of said vessel to be filled with the well fluid whereby the normally required stuffing box is eliminated so that any type or shape of wire for lowering the tool assembly into said tubing string can be utilized;

a winch drum drive motor and winch drum coupled thereto mounted inside of said pressure vessel;

a wire line wound on the winch drum and directly connected to said tool assembly; and

means coupled to said pressure vessel and said drive motor for operating said drive motor from a remote control station.

2. The invention as defined by claim **1** wherein said drive motor comprises a hydraulic motor and said second recited means comprises a hydraulic motor and said second recited means comprises hydraulic valving and connector means coupled to said remote control station.

3. The invention as defined by claim **1** wherein said winch drum drive motor includes a motor includes a motor housing and a shaft; and additionally including:

means for mounting said which drum around said motor housing; and

means for locking said shaft against rotation thereby causing said housing to rotate upon operation of said drive motor.

4. The invention as defined by claim **1** wherein said winch drum drive motor comprises a radial piston hydraulic motor.

5. The invention as defined by claim **1** wherein said pressure vessel additionally includes means for containing said tool assembly.

6. The invention as defined by claim **1** wherein said wire line comprises a flat metallic ribbon of a predetermined length wound onto said winch drum.

7. The invention as defined by claim **1** wherein said wire line comprises a stranded cable wound onto said winch drum.

8. The invention as defined by claim **1** and additionally including buoyancy means attached to said pressure vessel to provide substantially neutral buoyancy of the maintenance tool in water.

9. The invention as defined by claim **8** wherein said buoyancy means comprises a substantially hollow chamber axially disposed around the pressure vessel.

10. The invention as defined by claim **8** wherein said buoyancy means comprises a housing axially disposed around the pressure vessel and including buoyancy material contained therein.

11. The invention as defined in claim **1** wherein said first recited means includes a valve assembly.

12. The invention as defined by claim **1** wherein said pressure vessel additionally comprises a relatively long hollow member containing said tool assembly.

13 The invention as defined by claim **1** wherein said pressure vessel comprises a hollow chamber housing said winch drum drive motor and winch drum and additionally including an access cover removably secured to said chamber at one end thereof, pressure sealing means located intermediate said access cover and said chamber for providing a pressure seal when said access cover is secured to said chamber and clamping means for securing said access cover to said hollow chamber.

14. The invention as defined by claim **13** wherein said pressure vessel additionally comprises an elongated tubular member terminated at one end in said hollow chamber for housing said tool assembly.