Jan. 19, 1965 B. J. WATKINS 3,166,123

METHOD AND APPARATUS FOR UNDERWATER WELLS

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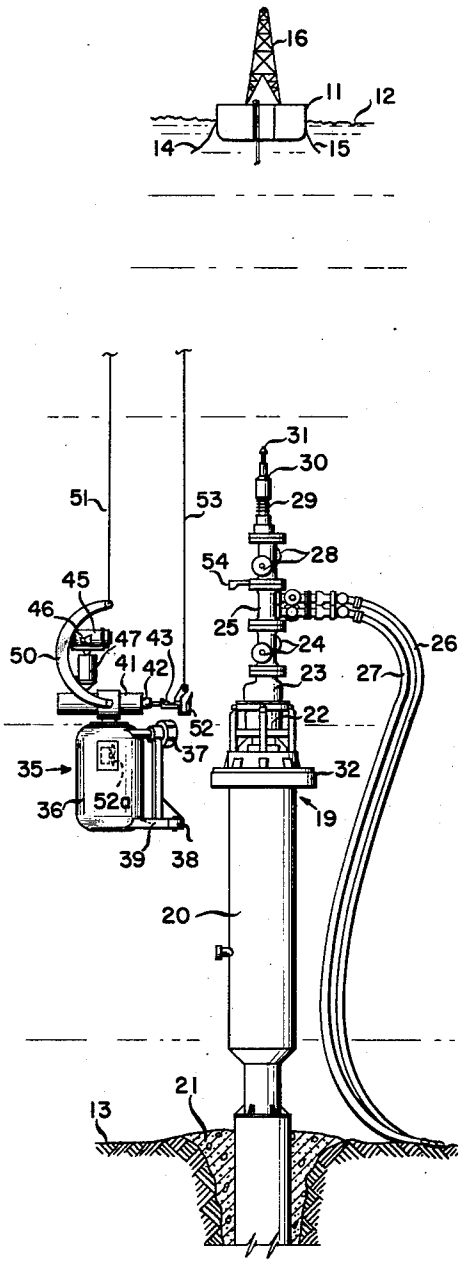

FIG. 1

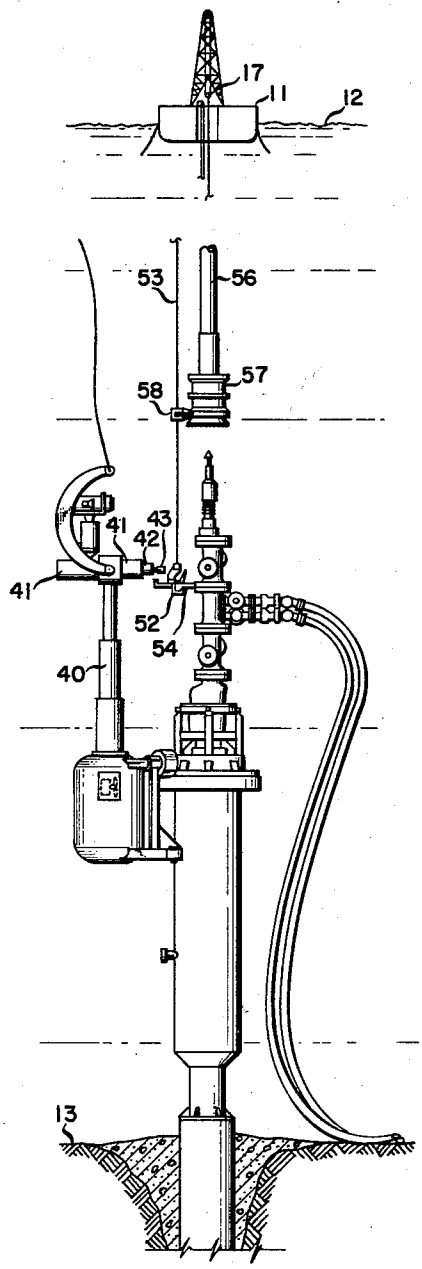

FIG. 2

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METHOD AND APPARATUS FOR UNDERWATER WELLS

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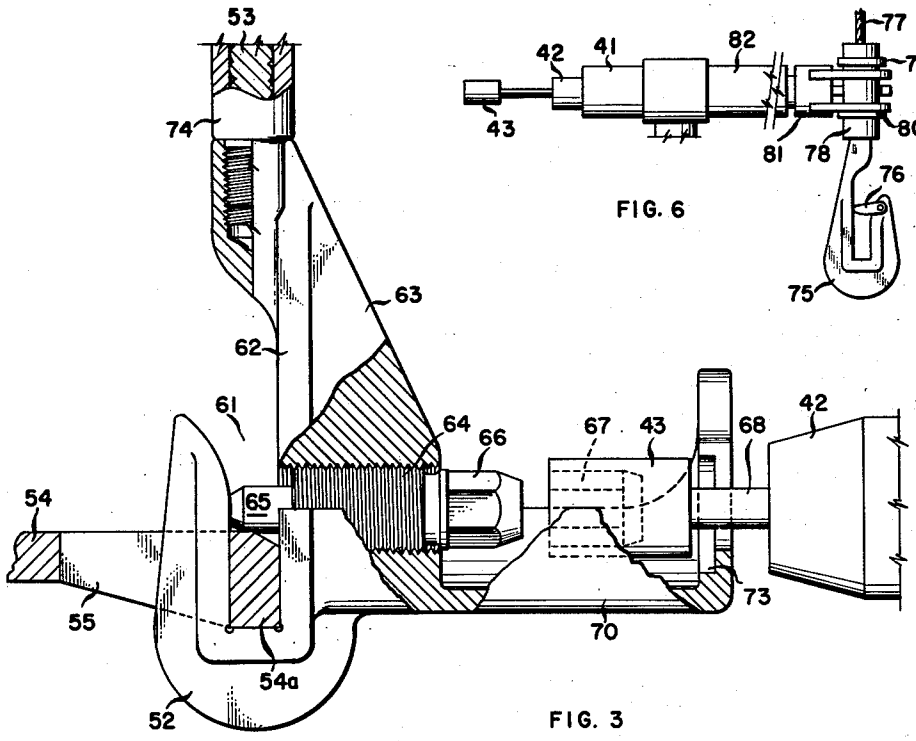

FIG. 3

FIG. 6

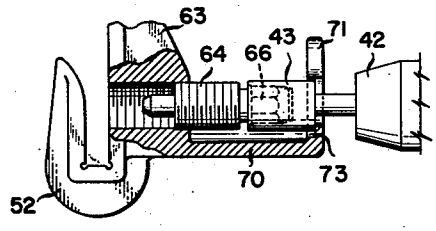

FIG. 4

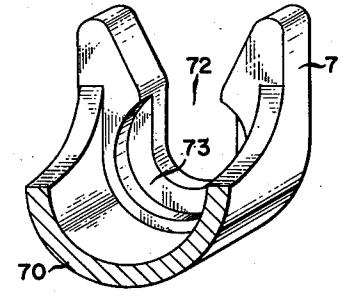

FIG. 5

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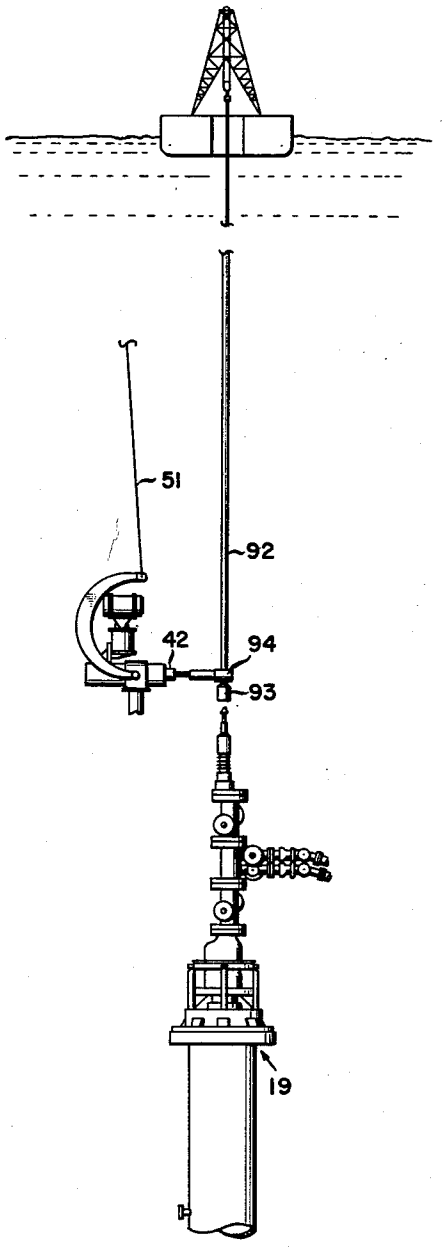

FIG. 7

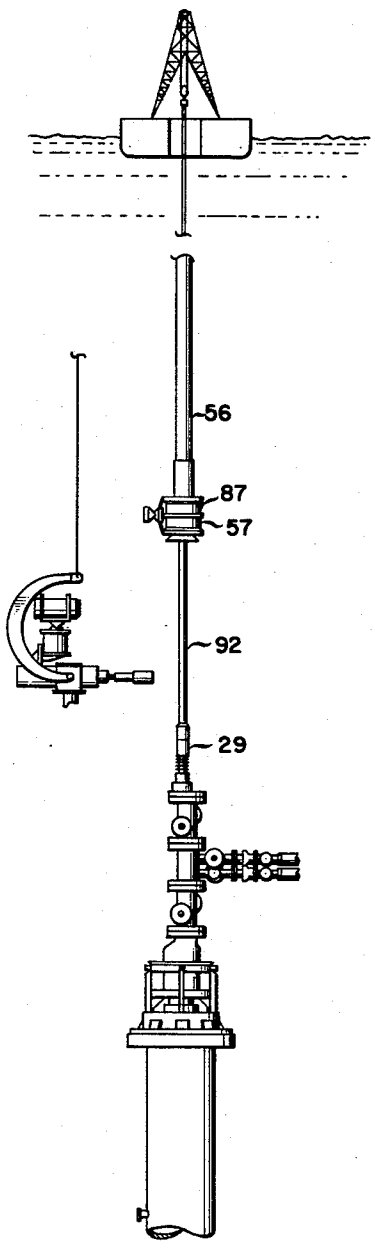

FIG. 8

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METHOD AND APPARATUS FOR UNDERWATER WELLS

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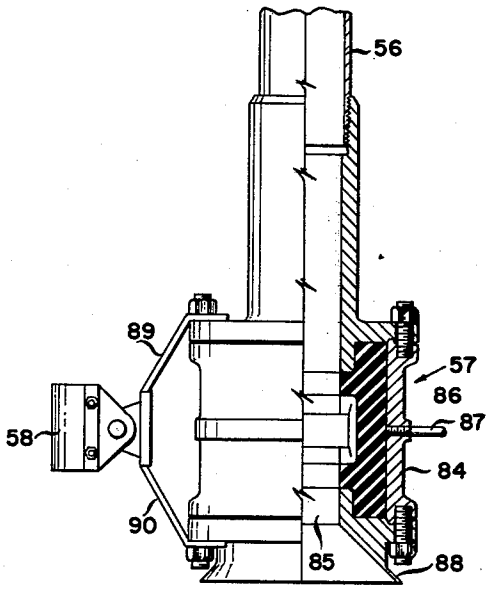

FIG. 9

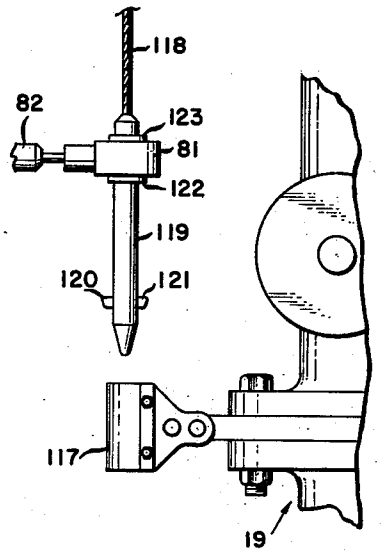

FIG. 10

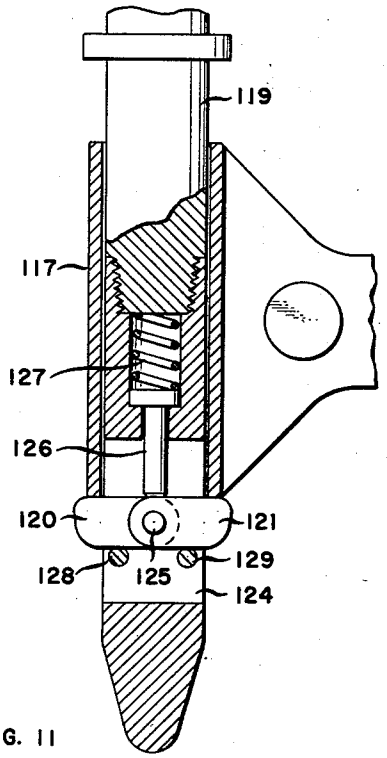

FIG. 11

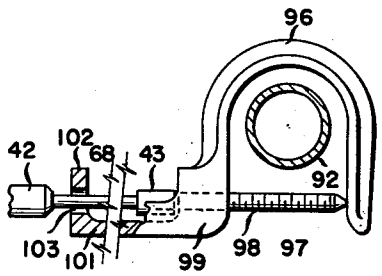

FIG. 12

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METHOD AND APPARATUS FOR UNDERWATER WELLS

Filed May 23, 1962 5 Sheets-Sheet 5

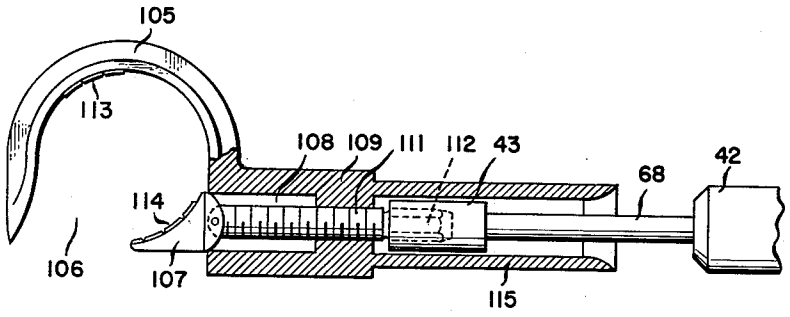

FIG. 13

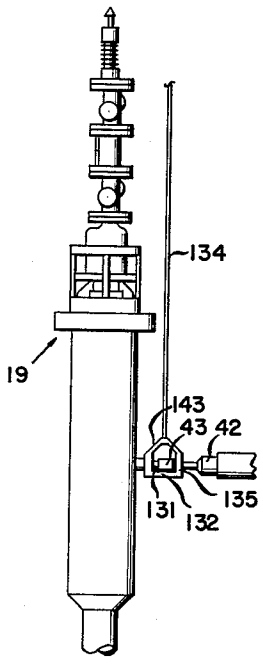

FIG. 14

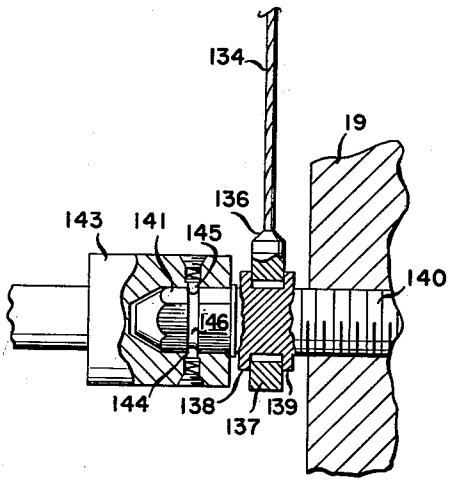

FIG. 15

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United States Patent Office 3,166,123
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3,166,123

METHOD AND APPARATUS FOR UNDERWATER WELLS

Bruce J. Watkins, West Covina, Calif., assignor to Shell Oil Company, New York, N.Y., a corporation of Delaware

Filed May 23, 1962, Ser. No. 197,093
10 Claims. (Cl. 166—46)

This invention relates to operations to be carried out on underwater wells, and pertains more particularly to a method and apparatus for connecting a vessel floating on the surface of the water to an underwater wellhead assembly of an oil or gas well.

A relatively recent development is the drilling of oil and gas wells at offshore locations wherein the wellhead assembly is positioned at a substantial distance below the surface of the water or on the ocean floor. During the drilling and completion of a well of this type suitable provisions are made for maintaining contact between the vessel on the surface of the water and the underwater wellhead, as by means of a plurality of guide lines or one or more elongated pipe strings. Using guide lines or a pipe string between the vessel and the ocean floor, the well may be drilled and all the necessary equipment lowered into place on top of the wellhead. When the well has been completed the guide lines extending to the vessel are disconnected from the vessel and either dropped to the ocean floor or secured to a buoy which marks the location of the well.

The use of buoys to mark a well or to support guide lines is not desirable since they constitute a navigation hazard and may break free from the cables. Additionally, the dropping of guide lines to the ocean floor is not too satisfactory since the lines often become entangled and are subject to corrosion. However, it is necessary to mark the well in some manner or be able to locate it so as to go back over the well with the vessel for the necessary work-over operations that must be carried out on all wells from time to time.

It is therefore a primary object of the present invention to provide a method and apparatus for establishing a connection between a vessel on the surface of a body of water and a wellhead assembly positioned at a distance below the surface of the water.

Another object of the present invention is to provide a method and apparatus whereby a cable or wire line may be run from the vessel down through the body of water to the underwater assembly where it is securely fastened thereto.

A further object of the present invention is to provide a method and apparatus for lowering an elongated tubular member from a vessel on the surface of the water to a point adjacent an underwater wellhead structure and for guiding and aligning the lower end of the elongated tubular member into its seating position on the wellhead assembly.

A further object of the present invention is to provide a method of establishing connection between a vessel and underwater wellhead by means of an elongated element whereby equipment used in work-over operations on the well may slide down the elongated guide element into position on the wellhead assembly.

A still further object of the present invention is to provide apparatus for securing the lower end of a cable or wire line to a wellhead assembly.

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 illustrating the operation of lowering a cable from a vessel at the surface of the water to a wellhead positioned near the ocean floor;

FIGURE 2 is a diagrammatic view of the vessel and wellhead assembly of FIGURE 1 after a guide cable has been attached to the wellhead and a string of pipe is being lowered down along the guide cable;

FIGURE 3 is a longitudinal view taken partially in cross-section of a hook-type cable connector secured to an element of an underwater wellhead assembly;

FIGURE 4 is a longitudinal view taken in partial cross section of the hook-type cable connector of FIGURE 3 secured to a power wrench adapted to be lowered to an underwater wellhead assembly;

FIGURE 5 is an isometric view of one portion of the hook-type cable connector of FIGURE 3;

FIGURE 6 is a diagrammatic view illustrating a claw-arm of an underwater manipulator secured to a cable hook;

FIGURE 7 is a diagrammatic view illustrating a tubular pipe element being lowered from a vessel at the surface of a body of water with an underwater manipulator guiding the lower end of the tubular element onto the top of an underwater wellhead assembly;

FIGURE 8 is a diagrammatic view illustrating a marine conductor pipe being lowered from a vessel at the surface of a body of water over a small-diameter pipe string having its lower end connected to a wellhead at the ocean floor;

FIGURE 9 is a longitudinal view taken in partial cross-section of a landing head of a marine conductor string;

FIGURE 10 is a longitudinal view illustrating a portion of the landing head assembly of FIGURE 9 together with another form of a cable connector being guided by an arm of an underwater manipulator into position to connect to a wellhead assembly;

FIGURE 11 is a longitudinal view taken partially in cross section and in enlarged detail of the cable connector of FIGURE 10 when locked to a receiving sleeve on the wellhead assembly;

FIGURES 12 and 13 are plan views of two types of connectors for securing an underwater manipulator to a small-diameter pipe string;

FIGURE 14 is a diagrammatic view of an underwater wellhead assembly showing the lower end of a guide element being secured thereto; and

FIGURE 15 is a longitudinal view taken in partial cross section of the cable connector of FIGURE 14 and the manner in which it is secured to the power wrench of the underwater manipulator.

Referring to FIGURES 1 and 2 of the drawing, a drilling barge 11, of any suitable floating or floatable type is illustrated as floating on the surface of the water 12 while being substantially fixedly positioned over a preselected well location by being anchored to the ocean floor 13 by anchor lines 14 and 15 running to anchors (not shown). Equipment of this type may be used when carrying on well drilling operations or well work-over operations in water varying from about 100 feet to 1500 feet or more. The barge or vessel 11 is equipped with a suitable derrick 16 containing a fall line system 17 (FIGURE 2). The vessel 11 is also provided with other auxiliary equipment needed during well operations, such for example as a rotary table positioned on the operating deck, a hinged slip and spider assembly, etc.

The exact position of an underwater well is known on a map and a vessel 11 may be positioned over the wellhead assembly in any suitable manner, as by the use of SHORAN or other similar position-finding systems well known to the art.

The underwater wellhead structure illustrated in FIG-

URES 1 and 2 is similar to that which is assembled during the drilling and completion of an underwater well in accordance with the method described in copending application, Serial No. 118,849, filed June 22, 1961. The wellhead assembly includes a large-diameter conductor or foundation pile **20** which is secured in the well by means of cement **21**. The upper end of the wellhead assembly has a casinghead **22** closed by a production bonnet **23** on which the mounted maste valves **24**. A production T **25** above the master valves **24** is adapted to receive a pair of flow lines **26** and **27**. A pair of swabbing valves **28** are mounted above the production T **25** and the top of the well is closed by means of a lubricator barrel **29** and a plug **30**. The top of the plug **30** is provided with a fishing head **31** by which it may be readily removed.

Fixedly secured to the foundation pile **20** near the top thereof is a track **32** which extends around the foundation pile while being positioned outwardly thereof. As shown in FIGURE 2, the track **32** is adapted to receive and hang therefrom an underwater manipulator device which is self-propelled at least in a horizontal direction and is preferably selectively buoyant.

The manipulator device, generally represented by numeral **35**, may be of any suitable type, two of which are shown in copending patent applications, Serial No. 24,558, filed April 25, 1960, now Patent No. 3,099,316, and Serial No. 80,275, filed January 3, 1961. The manipulator device comprises a body member **36** having means such as wheels **37** for securing it to the wellhead assembly, that is, to the track **32** in this particular illustration. The wheels **37** are preferably actuated by motor means operatively connected to the wheels and positioned either inside or outside the body member **36**. Additionally, the body member **36** is preferably provided with a pair of idler rollers **38** mounted on an outwardly-extending frame **39** so as to contact the outer surface of the foundation pile **20**, as shown in FIGURE 2, when the drive wheels **37** are hung on the track **32**. Alternatively, the rollers **38** could be powered to make friction contact with the outer surface of the foundation pile to drive the manipulator device **36** around the wellhead assembly.

A portion of the body member is arranged for upward extension from the body member, preferably in the form of a telescoping arm **40**, as shown in FIGURE 2. Mounted on the top of the telescoping arm or body portion **40** is a laterally-extending cylinder **41** having a telescoping arm **42** extendible outwardly therefrom. The arm **42** is provided with a rotatable wrench head **43** that is power operated by suitable motor means mounted in the arm **42** or in the cylinder **41**, preferably in the rear portion **44** thereof. A television camera **45** and suitable lights **46** are mounted at the top of the manipulator device on a power-actuated light swivel and tilting mechanism **47**, while the television viewing screen is positioned on the vessel **11** at the surface.

The manipulator device **35** may be suspended on a hook **50** having a weight-supporting and current-transmitting cable **51** attached to its upper end. Thus, power for operating the manipulator device and its associated equipment is sent down the cable **51** from the vessel **11** while television signals are returned up the cable to the vessel.

At the same time the manipulator device may be lowered from the vessel **11** by means of the cable **51** and its hoist to any selected level in the water. For moving the manipulator device **35** laterally at the end of the cable **51**, the manipulator device **35** is provided with suitable propulsion means such, for example, as motor-driven propellers **52***a* which are mounted outboard of the body member **36** on at least two sides thereof. At least a portion of the body member **36** may form a void chamber which may be selectively flooded by controls at the vessel **11** for adjusting the buoyancy of the manipulator device **35**. If additional buoyancy is desired, suitable buoyancy tanks may be secured to the weight supporting cable **51**.

In FIGURE 1 the vessel **11** is shown as having been positioned over the wellhead assembly, generally represented by numeral **19**, and the manipulator device **35** has been lowered to a level to one side of the wellhead assembly and just above the point where the wheels **37** would sit on the track **32** of the wellhead assembly. Prior to lowering the manipulator device **35** from the vessel **11**, a hook or other suitable connector device **52** was secured to the wrench head **43** of the manipulator device **35**. Attached to the upper end of the hook **52** is a wire line or cable **53** which is to serve as the guide line connecting the vessel **11** to the wellhead assembly **19** during at least a portion of the work-over operations on the well. Fixedly secured to some portion of the wellhead assembly **19** is a bracket ring or other cooperating connector device **54** to which the hook **52** may be connected.

In FIGURE 2, the hook **52** is illustrated as having been connected to the bracket **54** while the wrench head **43** of the manipulator device **35** has been disconnected from the hook **52** so that the manipulator device could be moved away from the wellhead assembly at any time. However, the manipulator device is left in place so that a television camera **45** can observe the top of the wellhead assembly as a marine conductor pipe string **56** and its landing head **57** are guided down along the guide line **53** onto the lubricator **29** of the wellhead assembly. The landing head or mandrel **57** is slidably mounted on the guide line **53** by means of a sleeve **58**.

The bracket **54** which is shown as fixedly mounted to the wellhead assembly in FIGURES 1 and 2 is shown in FIGURE 3 as having an opening **55** therein so that a portion **54***a* of the bracket can fit within a hook or other connector element.

A preferred form of cable hook **52** (FIGURE 1) is shown in FIGURE 3 as having a throat opening **61** of a size to receive a portion **54***a* of the bracket **54**. The shank **62** of the hook **52** has a boss **63** extending away from the throat opening **61**. A laterally-extending locking screw **64** is mounted in the boss **63** with a forward end **65** of the screw **64** adapted to close the throat opening **61** of the hook **52**. The head **66** of the screw **64** is adapted to be received in the recess **67** of the socket wrench **43**. The socket wrench **43** is mounted at the end of a power-driven shaft **68** which is extendible out the end of the arm **42**.

Integrally formed on the back end of the boss **63** is a suitable locking bracket **70** which supports an end plate **71** having a vertical opening **72** therein (FIGURE 5) of a size at least slightly wider than the diameter of the stem or shaft of the wrench head **43**. Formed on the inner face of the end plate **71** is a recess **73** which surrounds the lower end of the vertical opening or slot **72**. The recess **73** is of a size slightly larger than the rear end of the wrench head **43** so that it can be received therein as shown in FIGURE 4. In FIGURE 4 the hook **52** is shown in its open position with the locking screw **64** retracted a distance so that the screw head **66** is firmly seated in the socket wrench **43** while the socket wrench in turn is securely seated in the recess **73** of the bracket **70**. In this position the hook **52** is securely carried in a removable manner at the end of the arm **42** when it is desired to move the cable down through the water.

The cable **53** (FIGURE 3) is secured to the shank **62** of the hook **52** by any suitable type of cable socket **74**, preferably one which fails under a predetermined tension, say 8,000 pounds, so that the cable **53** may be pulled away from the hook **52** in an emergency. In FIGURE 6 another type of hook is shown which is provided with a retractable spring-loaded catch **76** which would prevent the hook **75** from falling off a bracket to which it was attached. The cable **77** to the hook **75** would be secured to the hook by means of a cable **78** which would fail under a predetermined tension. Fixedly secured to the outside of the cable socket **78** are one or more rings **79** and **80** which form movement-limiting stop means so that the hook and its socket **78** could be held by the claw arm of

the manipulator device 35 of FIGURE 1. The claw arm 81 would be mounted at the end of a cylinder 82 opposite to the cylinder 41 which held arm 42 and wrench socket 43 in the manner described in copending application, Serial No. 24,558, filed April 25, 1960. Thus, it may be seen that a cable hook may be run down through the water either by being attached to the manipulator 52 by the wrench socket 43 or by claw arm 81.

In practicing the method of the present invention for connecting a guide line cable between the vessel on the surface of the body of water and a wellhead assembly positioned at a distance below the surface of the water, the vessel 11 (FIGURE 1) would first be positioned substantially over the underwater wellhead assembly 19. The hook 52 at the lower end of the guide line 53 would then be secured to the manipulator device 35, as in a manner illustrated in FIGURE 4 wherein the socket wrench is seated in the recess 73 of the bracket 20 so that the hook 52 is fixedly secured to the arm 42. The manipulator device 35 is then lowered on its support cable 51 from the barge where the cable 51 is secured to a suitable hoist drum or other cable-storing device (not shown). With the weight of the manipulator device being supported by the cable 51, the manipulator device 35 together with the hook 52 and its guide line 53 are lowered through the water to a position adjacent the wellhead assembly 19 (FIGURE 1). While observing the wellhead assembly by means of the television camera 45, the propellers 52*a* of the manipulator device 35 are driven to propel the manipulator device against the wellhead assembly with sufficient cable 51 being let out at the vessel so as to lower the wheels 37 of the manipulator device 35 on the track 32.

With the manipulator device 35 seated on the track 32 (FIGURE 2), the telescoping vertical arm or body portion 40 of the manipulator device is raised and the laterally-extending arm 42 at the end thereof is moved to engage the hook 52 in the bracket 54 secured to the wellhead assembly 19. The power wrench and the arm 42 are then actuated so that the socket wrench moves the locking screw 64 (FIGURE 3) forward to close the throat 61 of the hook 52. As shown in FIGURE 3, as the wrench head 43 moves forward with the screw head 63, it comes out at the recess 73 in the end plate 71 so that the entire wrench head 43 is forward of the end plate 71. After retracting the wrench head 43 to the position shown in FIGURE 3, the shaft 68 of the power wrench may be lifted vertically out of the opening 72 (FIGURE 5) by extending the telescoping arm 40, as shown in FIGURE 2. With the guide cable 53 securely locked to the wellhead assembly 19, as shown in FIGURE 2, a conductor pipe 56 and its landing head 57 may be guided from the vessel into alignment and down on the top of the wellhead assembly 19 by slidably mounting the landing head 57 to the guide line 53 by means of a sleeve 58. Seating of the landing head 57 on top of the wellhead is either aided by the television camera 45 or may be carried out by a blind stab, that is by stabbing on top of the wellhead and if necessary rotating the marine conductor around the guide line 53 until the landing head 57 has been successfully stabbed over the top of the wellhead assembly 19. As an alternative, two guide lines 53 can be attached to better align to landing head 57.

One form of a marine conductor pipe 56 on the landing head 57 of FIGURE 2 is shown in FIGURE 9 wherein the landing head comprises a body member 84 having a vertical bore therein of a size to receive the top of a tubular well member. Carried within the body member 84 and surrounding its bore 85 is a bag-type sealing element 86 which may be compressed to seal around an object in the bore 85 by applying pressure fluid through a conduit 87 extending through the wall of the body member 84. The lower end of the landing head is preferably provided with a skirt 88 which aids in guiding the landing head on a wellhead projection. The guide sleeve 58 through which the guide line 53 (FIGURE 2) passes may be secured to the body member 84 in any suitable manner, as by means of brackets 89 and 90.

In another form of establishing a connection between a vessel on the surface of a body of water and a wellhead assembly positioned at a distance below the surface thereof, the present method described hereinabove is modified so that an elongated tubular element in the form of a pipe string 92 (FIGURE 7) may be lowered from a vessel to a position above an underwater wellhead assembly, at which point the arm 42 of a manipulator device aligns the lower end or seating socket 93 of the pipe string on the top of the wellhead 19. The pipe string 92 may be any suitable type of pipe, preferably in the form of 30-foot sections that are connected together at the vessel before they are lowered into the water. The connecting element 94 carried at the end of the arm 42 of the manipulator device may be in the form of grab arms 81 (FIGURE 6) or any other suitable hook or connector device. Additionally, when it is desired to align the lower end of a pipe string 92 for stabbing it on the top of a tubular element of a wellhead, the connector device 94 of the manipulator device may be loosely secured to the pipe string 92 so that it can slide vertically down over the pipe as the manipulator device is lowered through the water. Thus, substantially the entire pipe string would first be made up section by section and lowered into the water prior to lowering the manipulator device on its support cable 51 down to the lower end of the pipe string 92. As in the case of securing a cable to the underwater wellhead, it is preferred that the manipulator device 35 be seated on its track 32 as shown in FIGURE 2, at the time the pipe line 92 is lowered onto a tubular element of the wellhead assembly. However, it is to be understood that the manipulator device 35 may be propelled by its propellers 52*a* through the water to a position adjacent the wellhead assembly and to align the lower end of the pipe string 92 or to connect the hook 52 on bracket 54 (FIGURE 2) without seating the manipulator device 35 on its track 32.

In FIGURE 8 the pipe string 92 is shown as having been seated on the top of the lubricator 29 at the top of the well assembly with a marine conductor pipe 56 and its landing head 57 being lowered into place on top of the wellhead assembly using the small-diameter pipe string 92 as a guide. After seating the landing head 57 on the lubricator 29, pressure fluid will be applied through conduit 87 which extends downwardly from the vessel 11 to actuate the seal 86 (FIGURE 9) of the landing head against the lubricator 29.

One suitable type of pipe connector for securing the pipe to the arm 42 of the manipulator device is shown in FIGURE 12. The pipe connector is essentially a hook 96 having a throat opening 97 of a size greater than the diameter of the pipe string 92 to be received therein. The throat 97 of the hook 96 is closed in any suitable manner, as by a screw 98 which is threaded in a boss 99. A bracket 101 attached to the boss 99 has an end piece 102 with an opening 103 therein for receiving the shaft 68 to the socket wrench 43. The pipe connector, when used, is secured to the pipe string 92 and to the wrench socket 43 prior to lowering the pipe string in the water. After the lower end of the pipe string has been seated on the wellhead assembly, the wrench socket 43 of the power wrench is actuated to retract the screw 98 and open the throat 97 of the hook 96 so that the arm 42 of the manipulator device could be rotated laterally so that the hook 96 comes off the pipe 92. Thus, on retracting the manipulator device and its arm 42, the hook 96 would come with it.

Another form of a pipe hook is shown in FIGURE 13 as comprising a hook 105 having an open throat 106 that may be partially closed by means of a pipe-engaging element 107 which is slidably mounted in a recess 108 in

the boss **109** formed on one side of the hook. Movement of the pipe-engaging element **107** is provided by a screw **111** which is threaded to the boss **109**. The head **112** of the screw **111** is adapted to be engaged by the wrench socket **43** of the power wrench shaft **68** which extends from the arm **42**. If desired, to prevent longitudinal slipping of the hook **105** on a pipe string positioned therein, the inner surface of the hook **105** and the pipe contacting face of the pipe engaging element **107** may be provided with teeth or serrated elements **113** and **114** which would frictionally engage the outer surface of a pipe positioned in the hook **105** when the pipe-engaging element **107** was closed against it. When a pipe element having pipe hook **105** attached thereto has been seated at the wellhead, the socket wrench **43** may be withdrawn from the extending sleeve **115** of boss **109** with the hook **105** being left on the pipe at the wellhead while the manipulator device is taken away. Alternatively, the socket wrench **43** may be actuated to retract the screw **111** and pull the pipe-engaging element **107** back into the recess **108** at which time the hook **105** could be removed from the pipe by rotation of the arm **42** in a plane normal to the axis of the pipe. If desired, the socket wrench **43** may be secured to the head **112** of the screw **111** in a manner described with regard to FIGURE 15 hereinbelow.

In another form of the present invention, a connection may be made between a vessel at the surface of the water and an underwater assembly when using a stab-type connector adapted to pass at least partially through an element of the underwater wellhead assembly having an opening therein. While the bracket **54** (FIGURE 3) having a hole **55** therein may be employed, a sleeve **117** (FIGURE 10) which is connected to the wellhead structure **19** may be employed. In this case the lower end of a guide cable **118** is provided with a connector having a body element **119** of a size sufficient to pass through the sleeve **117**. A pair of radially-extendible latching dogs **120** and **121** are provided with a pair of ring elements **122** and **123** which would prevent a claw arm **81** of the manipulator device or any other suitable connector means from slipping off the body member **119** when the body member and its cable **118** were lowered through the water to the wellhead assembly.

As shown in FIGURE 11, the latching dogs **120** and **121** are pivotally secured in a slot **124** in the body member by means of a pin **125**. The latching dogs **120** and **121** are readily retracted to their inoperative position within the body member **119** when the body member is lowered through the sleeve **117** and the latching dogs contact the upper edge of the sleeve. However, the latching dogs **120** and **121** are normally urged upwardly by means of a piston member being urged downwardly by a compression spring **127**. The latching dogs **120** and **121** are normally maintained in a horizontal position by shear pins **128** and **129** which may be selected to shear at any desired tension on the cable **118** (FIGURE 10). Thus, when the guide line **118** is no longer to be used, an excessive upward pull on the guide line would cause shear pins **128** and **129** (FIGURE 11) to shear and the latching dogs **120** and **121** would pivot downwardly into the slot **124** so that the body member **119** could be pulled out of the sleeve **117**.

Instead of employing connectors at the lower end of a guide cable of the type described hereinabove, the connector may include a screw element **131** which may be directly connected to the wellhead assembly **19**. Thus, in FIGURE 14 an arm **42** and its socket wrench **43** are shown as being connected to a screw member **131** which is attached to the lower end of a cable or guide line **133** by means of any suitable cage member **134**. The end plate **135** of the cage **134** is preferably in the form of the end plate **71** shown in FIGURE 5 so that the socket wrench **43** can be lifted out of the cage **134** after the screw has been run into the wellhead assembly **19**. In FIGURE 15 the cable **134** is secured by means of a cable socket **136** to a ring **137** which is rotatably mounted between shoulders **138** and **139** on a screw **140**. The head **141** of the screw **140** is carried within a socket wrench **143** which is provided with one or more spring-loaded plugs or detent members **144** and **145** which are adapted to seat in a circumferential groove **146** in the head of the screw **140**. Thus, in running a cable **134** down to an underwater wellhead assembly, the screw head **141** would be seated in the wrench socket **143** so that the detents **144** and **145** would hold it there during the time that the screw was being run down to the wellhead and secured to the wall thereof. With the cable secured to the wellhead the socket wrench would then be pulled axially away from the screw head **141** and the manipulator device could be returned to the surface.

While the present invention has been described with regard to running an elongated tubular member, rod or cable between a vessel and a wellhead assembly positioned beneath the surface of the water, it is to be understood that the apparatus and method of the present invention could also be employed to run or lower and subsequently connect any elongated element from any operating platform or vessel above the surface of the water down to any underwater installation such for example underwater storage tanks, pipe lines, oil production handling facilities, waste disposal wells, etc. In some instances, such for example as underwater oil storage facilities and production handling stations, the station or assembly to which the cable rod or tubular member is to be attached may not be fixedly secured to the ocean floor but may be movably positioned below the surface of the water within a certain area. Also, the guide cable installed by the method of the present invention may be employed to lower equipment to carry out certain functions at the wellhead, as for example, adjusting the setting of wellhead components, opening or closing valves, connecting a flowline to the wellhead, etc.

In carrying out the method of the present invention it is to be understood that the vessel at the surface of the water need not be anchored by anchor lines but may alternatively be positioned by a series of two or more opposing outboard motors. Also, it may be desirable in some circumstances to equip the manipulator device **35** with some energy transmitting apparatus for finding an underwater wellhead at considerable distances, such for example as a SONAR system which is well known to the art, which system may be used as a substitute for or in addition to the television camera. Since the manipulator device **35** may be equipped with buoyancy tanks which may be selectively flooded by controls on the vessel **11**, it is understood that the manipulator device may be lowered through the water by selectively flooding the buoyancy tanks to cause the manipulator device to sink slowly to a selective position adjacent an underwater installation.

The method of the present invention may also be carried out by lowering the manipulator device and the flexible connector element, that is, either a cable or pipe string, independently through the water into the vicinity of the wellhead structure. The manipulator device by means of its television apparatus would then locate the flexible connector element and secure its arm to the lower end thereof, after which the manipulator device would propel both itself and the flexible connector unit into position for attaching the lower end of the flexible connector element to the underwater installation. In some cases, the seating and latching socket **93** (FIGURE 7) can be employed to connect a guide cable to the top of the wellhead either before or after the plug **30** has been removed. Alternatively, with plug **30** removed the connector **119** could be lowered into the top of the wellhead to engage a latch surface and secure cable **118**

to the wellhead so that equipment could be stripped over or guided along the cable.

I claim as my invention:

1. A method of establishing a connection between a vessel on the surface of a body of water and an assembly positioned at a distance below the surface of water, said method comprising

(*a*) positioning said vessel substantially over said underwater assembly,

(*b*) removably mechanically attaching one end of an elongated connector element to a self-propelled submersible manipulator,

(*c*) lowering said manipulator and said attached elongated connector element in said body of water,

(*d*) simultaneously increasing the length of said elongated connector element as it is lowered through the water with the manipulator so that the upper end of said elongated connector element is above the surface of the water,

(*e*) locating the underwater assembly with a television camera carried by the manipulator and observing on the vessel at the surface the position of the underwater assembly relative to the manipulator,

(*f*) remotely moving and guiding from the vessel the manipulator and the attached elongated connector element through the water to a position adjacent said assembly,

(*g*) positioning the manipulator in movably supported contact on said assembly,

(*h*) positioning the lower end of the elongated connector element in contact with said assembly,

(*i*) remotely actuating the manipulator from the vessel to attach the lower end of the elongated connector element to said assembly, and

(*j*) mechanically remotely actuating the manipulator from the vessel to disconnect the manipulator from the elongated connector element attached to the assembly.

2. The method of claim 1 including the steps of

(*k*) guiding the lower end of a large-diameter pipe string along the elongated connector element while lowering it from the vessel,

(*l*) telescopically connecting the lower end of the large-diameter pipe string to a mating portion of the assembly, and

(*m*) subsequently raising the manipulator to the vessel at the surface.

3. A method of establishing a connection between a vessel on the surface of a body of water and an underwater wellhead assembly positioned at a distance below the surface of water, said method comprising

(*a*) positioning said vessel substantially over said underwater assembly,

(*b*) lowering an elongated connector element from the vessel down through the water until the lower end of the connector element is in the vicinity of the wellhead assembly,

(*c*) removably and slidably attaching near the upper end of said elongated connector element a self-propelled submersible manipulator at a point above the surface of the water,

(*d*) lowering said manipulator through the water while sliding along said elongated connector element to a point near the lower end thereof,

(*e*) locating the underwater wellhead assembly with a television camera carried by the manipulator and observing on the vessel at the surface the position of the underwater assembly relative to the manipulator,

(*f*) remotely moving and guiding from the vessel the manipulator and the attached elongated connector element through the water to a position adjacent said wellhead assembly,

(*g*) positioning the lower end of the elongated connector element in contact with said wellhead assembly, and

(*h*) remotely actuating the manipulator from the vessel to attach the lower end of the elongated connector element to said wellhead assembly.

4. The method of claim 3 including

(*i*) disconnecting the manipulator from elongated connector element attached to the wellhead assembly, and

(*j*) subsequently raising the manipulator to the vessel at the surface.

5. The method of claim 3 including the steps of

(*i*) subsequently sliding the manipulator device up the elongated connector element to the surface of the water and

(j) disconnecting the manipulator from said elongated connector element.

6. A method of establishing a connection between a vessel on the surface of a body of water and an underwater wellhead assembly positioned at a distance below the surface of water, said method comprising

(*a*) positioning said vessel substantially over said underwater assembly,

(*b*) removably attaching one end of an elongated flexible cable to a self-propelled submersible manipulator at a point above the surface of the water,

(*c*) lowering said manipulator and said attached flexible cable in said body of water at the end of a weight-supporting cable element,

(*d*) simultaneously increasing the length of said cable and cable element as they are lowered through the water with the manipulator,

(*e*) locating the underwater wellhead assembly with a television camera carried by the manipulator and observing on the vessel at the surface the position of the underwater assembly relative to the manipulator,

(*f*) remotely moving and guiding from the vessel the manipulator and the attached end of said flexible cable through the water to a position adjacent said wellhead assembly,

(*g*) positioning the manipulator in weight-supporting engagement on said wellhead assembly,

(*h*) remotely actuating the manipulator from the vessel to attach the lower end of the flexible cable to said wellhead assembly,

(*i*) remotely actuating the manipulator from the vessel to disconnect the manipulator from flexible cable attached to the wellhead assembly, and

(*j*) subsequently raising the manipulator by its cable element to the vessel at the surface.

7. The method of claim 6 wherein the lowering of the manipulator takes place by selectively adjusting the buoyancy of the manipulator to cause it to sink to the vicinity of the wellhead assembly.

8. A method of establishing a connection between a vessel on the surface of a body of water and an underwater wellhead assembly positioned at a distance below the surface of water, said method comprising

(*a*) positioning said vessel substantially over said underwater assembly,

(*b*) removably attaching one end of an elongated flexible pipe string to a self-propelled submersible manipulator at a point above the surface of the water,

(*c*) lowering said manipulator and said attached flexible pipe string in said body of water at the end of a weight-supporting cable element,

(*d*) simultaneously adding sections of pipe to the upper end of said flexible pipe string as it is lowered through the water by the manipulator so that the upper end of said pipe string is above the surface of the water,

(*e*) locating the underwater wellhead assembly with a television camera carried by the manipulator and observing on the vessel at the surface the position of the underwater assembly relative to the manipulator,

(*f*) remotely moving and guiding from the vessel guiding from the vessel the manipulator and the attached pipe string through the water to a position adjacent said wellhead assembly,

(g) positioning the manipulator in movably supported contact on said wellhead assembly,

(h) remotely actuating the manipulator from the vessel to attach lower end of the flexible pipe string to said wellhead by lowering the connector element from the surface to engage telescopically a portion of said wellhead assembly, and

(i) remotely actuating the manipulator from the vessel to disconnect the manipulator from flexible pipe string attached to the wellhead assembly.

9. A method of establishing a connection between a vessel on the surface of a body of water and an underwater wellhead assembly positioned at a distance below the surface of water, said method comprising

(a) positioning said vessel substantially over said underwater assembly,

(b) lowering a self-propelled submersible manipulator and a flexible connector element independently through said body of water to the vicinity of the wellhead assembly,

(c) locating the lower end of said connector element with said manipulator,

(d) moving the manipulator to said connector element and mechanically connecting it to the lower end thereof,

(e) locating the underwater wellhead assembly with the manipulator,

(f) moving and guiding the manipulator and the attached flexible connector element through the water to said wellhead assembly, and

(g) attaching the lower end of the flexible connector element to said wellhead assembly.

10. Apparatus for establishing a connection between a vessel on the surface of a body of water and an underwater assembly positioned at a distance below the surface of water, comprising

(a) self-propelled submersible manipulator,

(b) weight-supporting and signal-transmitting cable means having one end secured to said manipulator and the other end adapted to be secured to a vessel on the surface of the water,

(c) elongated guide pipe means of a length to extend from said underwater assembly to a point above the surface of the water,

(d) pipe connector means affixed to one end of said elongated guide pipe and adapted to be carried by said manipulator and lowered through the water therewith,

(e) cooperating means on said manipulator for removably securing said connector means thereto, and

(f) remotely-controlled actuator means operatively connected through said cable means to said vessel and carried by said manipulator and engageable with connector means for removably attaching said connector means to said underwater assembly.

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