April 25, 1967 W. C. TRIPLETT 3,315,741

METHOD AND APPARATUS FOR DRILLING OFFSHORE WELLS

Original Filed April 15, 1957 6 Sheets-Sheet 1

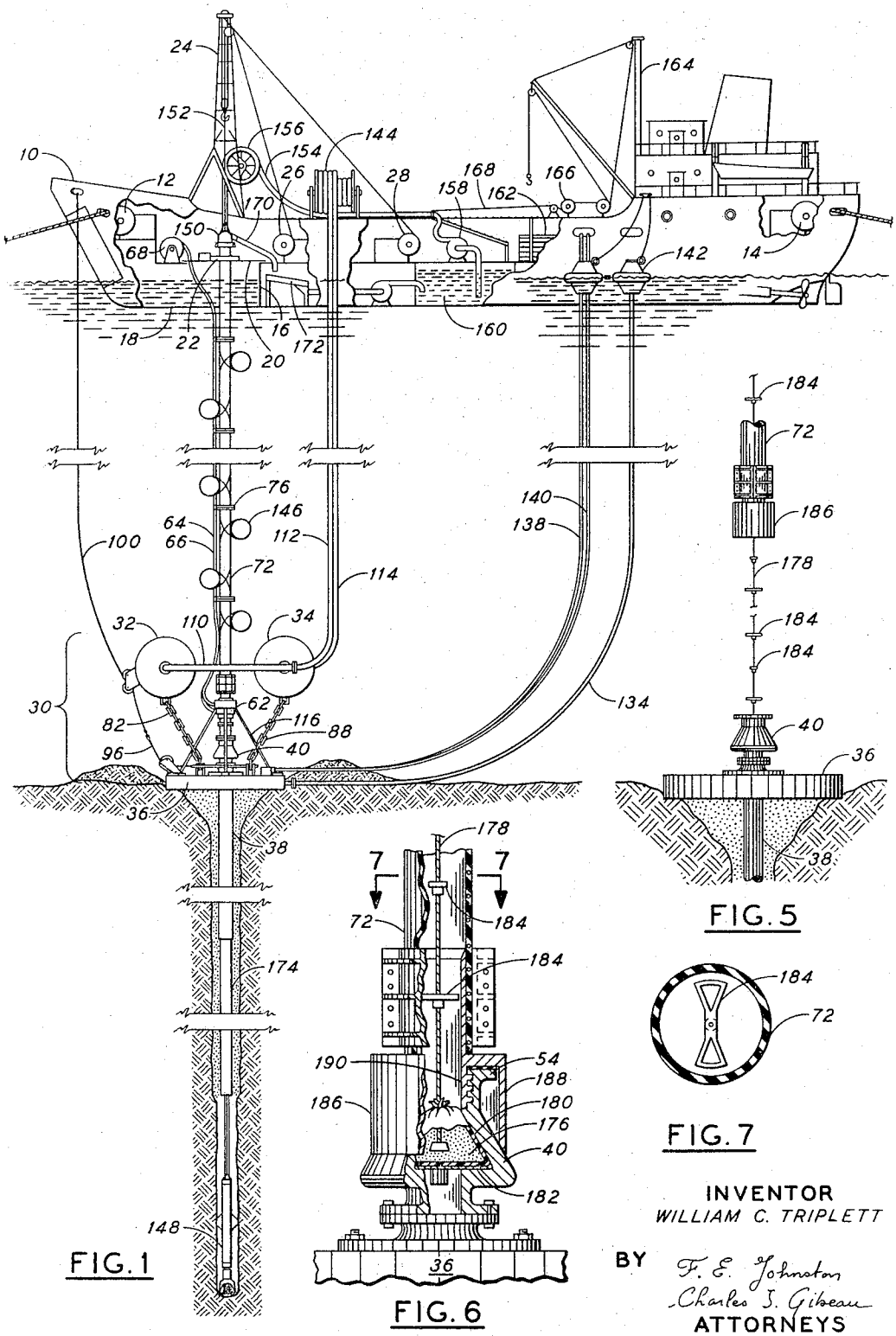


FIG. 1

FIG. 6

FIG. 5

FIG. 7

INVENTOR
WILLIAM C. TRIPLETT

BY F. E. Johnston
Charles J. Gibeau
ATTORNEYS

April 25, 1967 W. C. TRIPLETT 3,315,741

METHOD AND APPARATUS FOR DRILLING OFFSHORE WELLS

Original Filed April 15, 1957 6 Sheets-Sheet 2

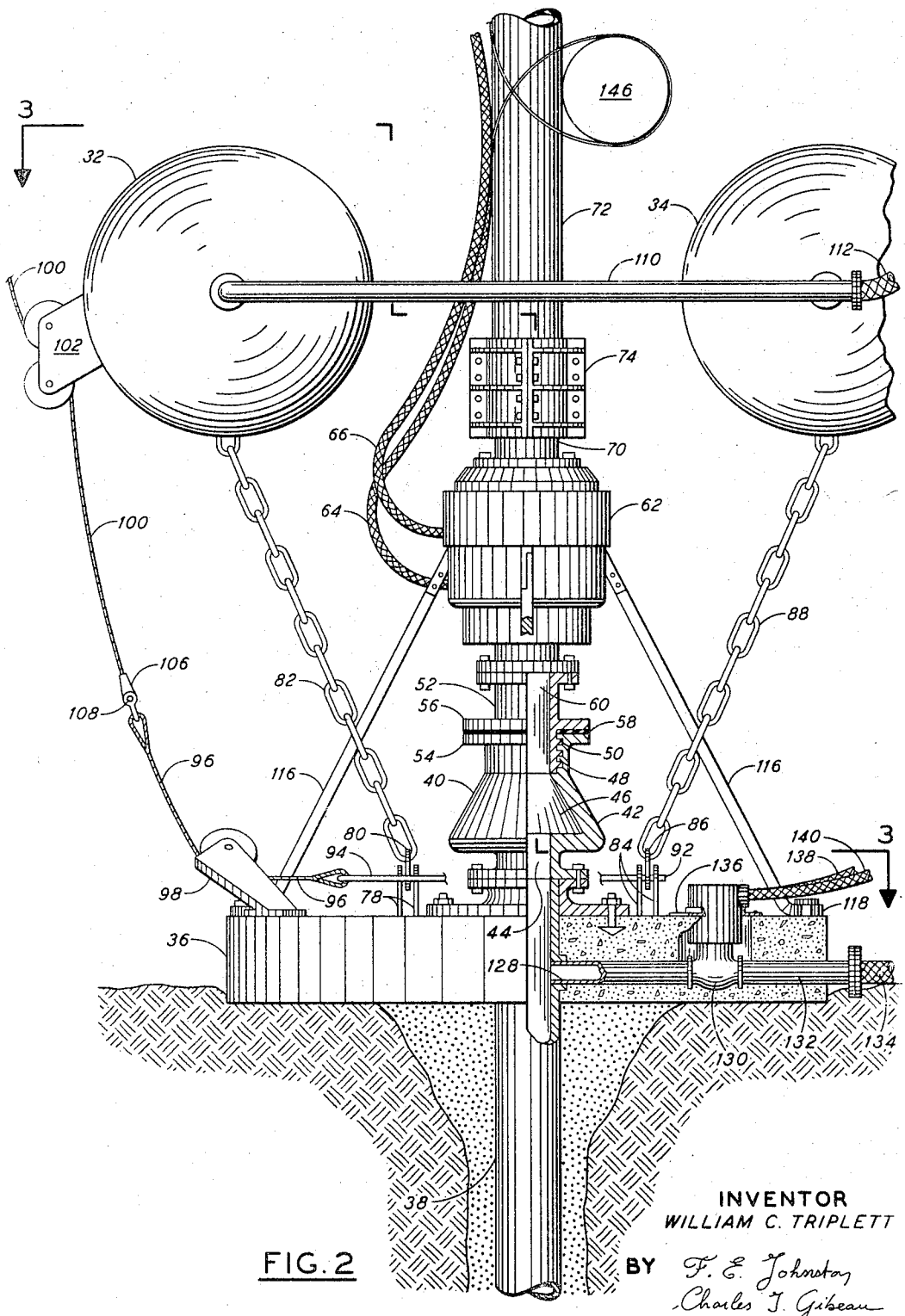


FIG. 2

INVENTOR
WILLIAM C. TRIPLETT

BY F. E. Johnston
Charles J. Gibeau
ATTORNEYS

April 25, 1967 W. C. TRIPLETT 3,315,741

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Original Filed April 15, 1957 6 Sheets-Sheet 3

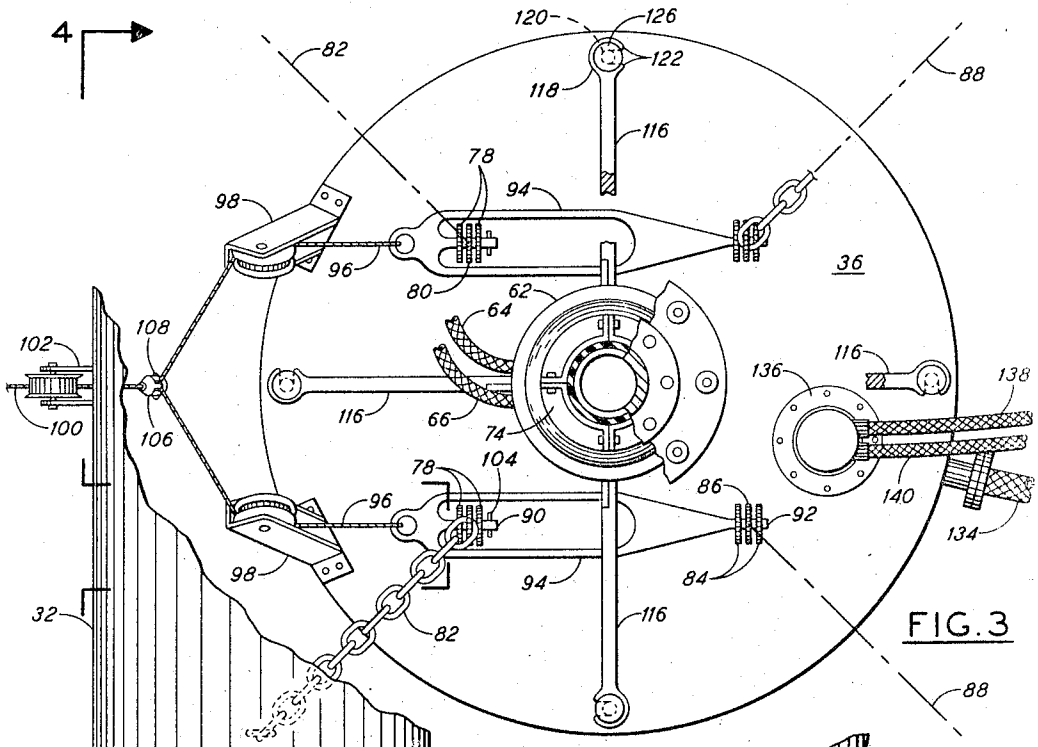


FIG. 3

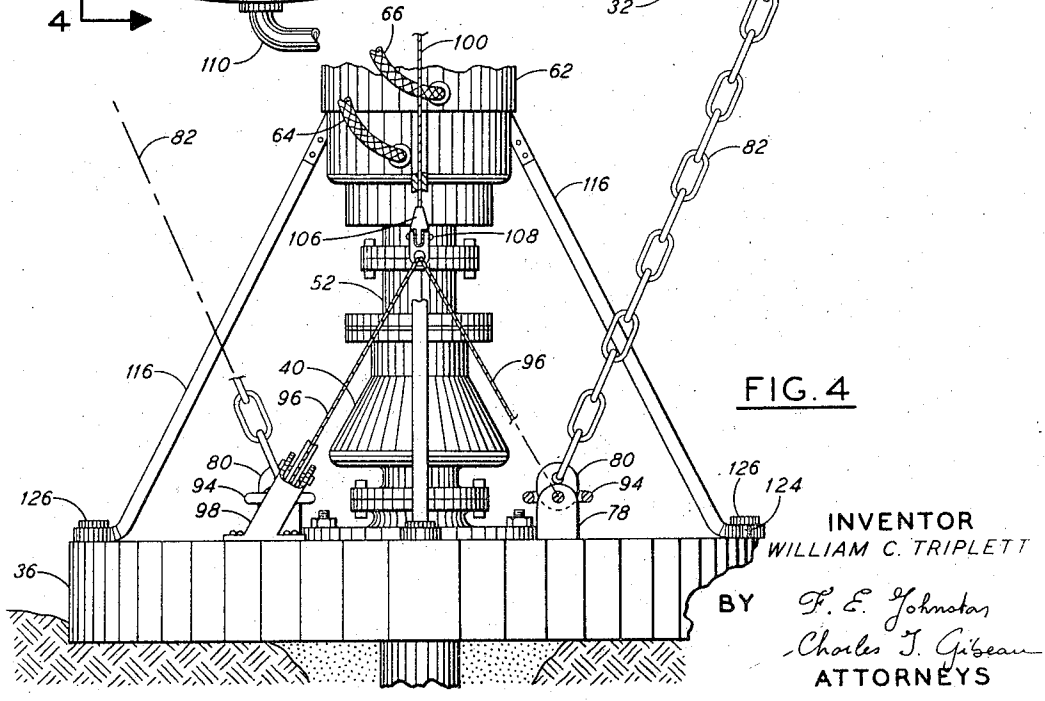


FIG. 4

INVENTOR
WILLIAM C. TRIPLETT
BY F. E. Johnston
Charles J. Gibeau
ATTORNEYS

April 25, 1967 W. C. TRIPLETT 3,315,741

METHOD AND APPARATUS FOR DRILLING OFFSHORE WELLS

Original Filed April 15, 1957 6 Sheets-Sheet 4

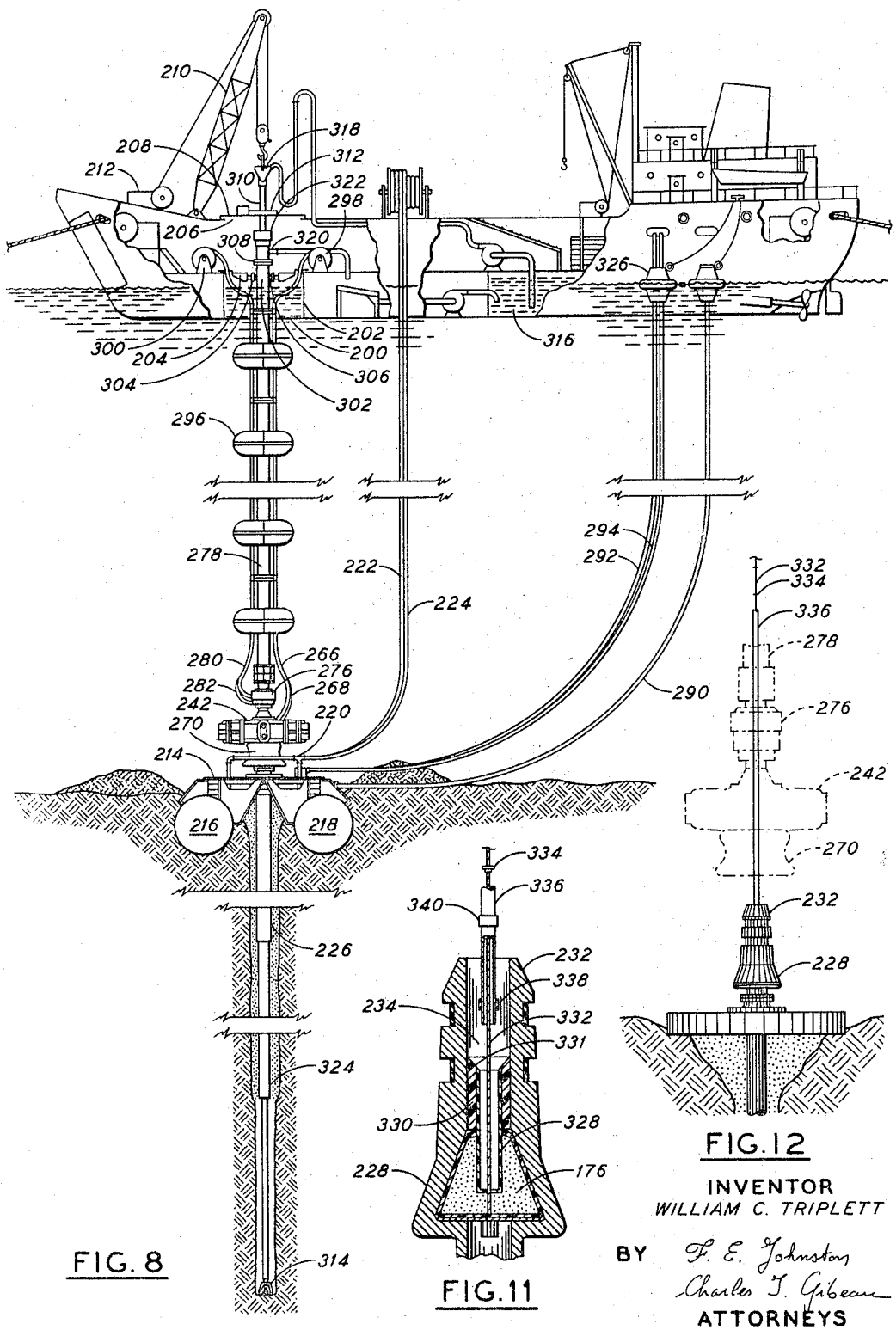


FIG. 8

FIG. 11

FIG. 12

INVENTOR
WILLIAM C. TRIPLETT

BY F. E. Johnston
Charles J. Gibeau
ATTORNEYS

April 25, 1967 W. C. TRIPLETT 3,315,741

METHOD AND APPARATUS FOR DRILLING OFFSHORE WELLS

Original Filed April 15, 1957 6 Sheets-Sheet 5

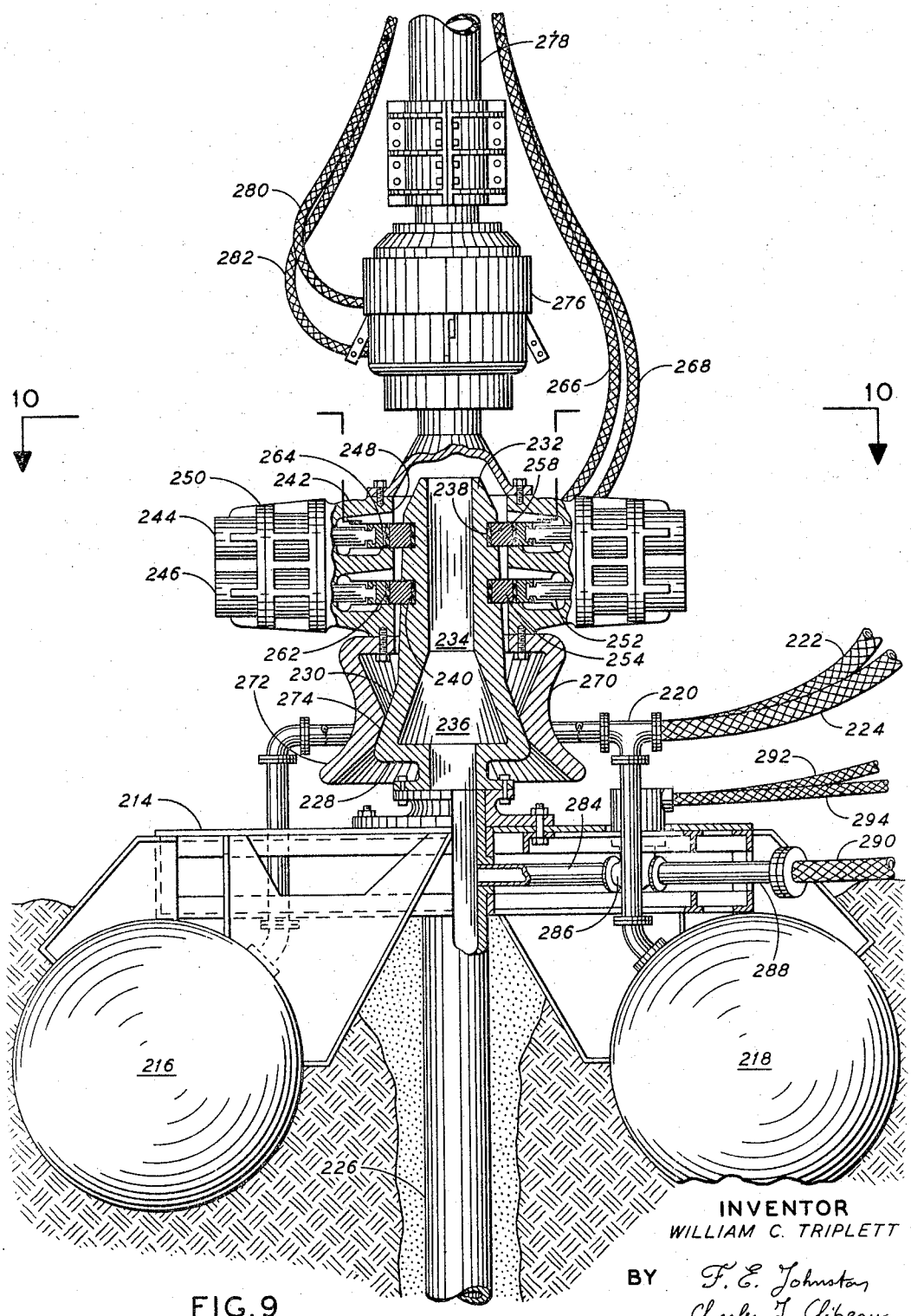


FIG. 9

INVENTOR
WILLIAM C. TRIPLETT

BY F. E. Johnston
Charles T. Gibeau
ATTORNEYS

METHOD AND APPARATUS FOR DRILLING OFFSHORE WELLS

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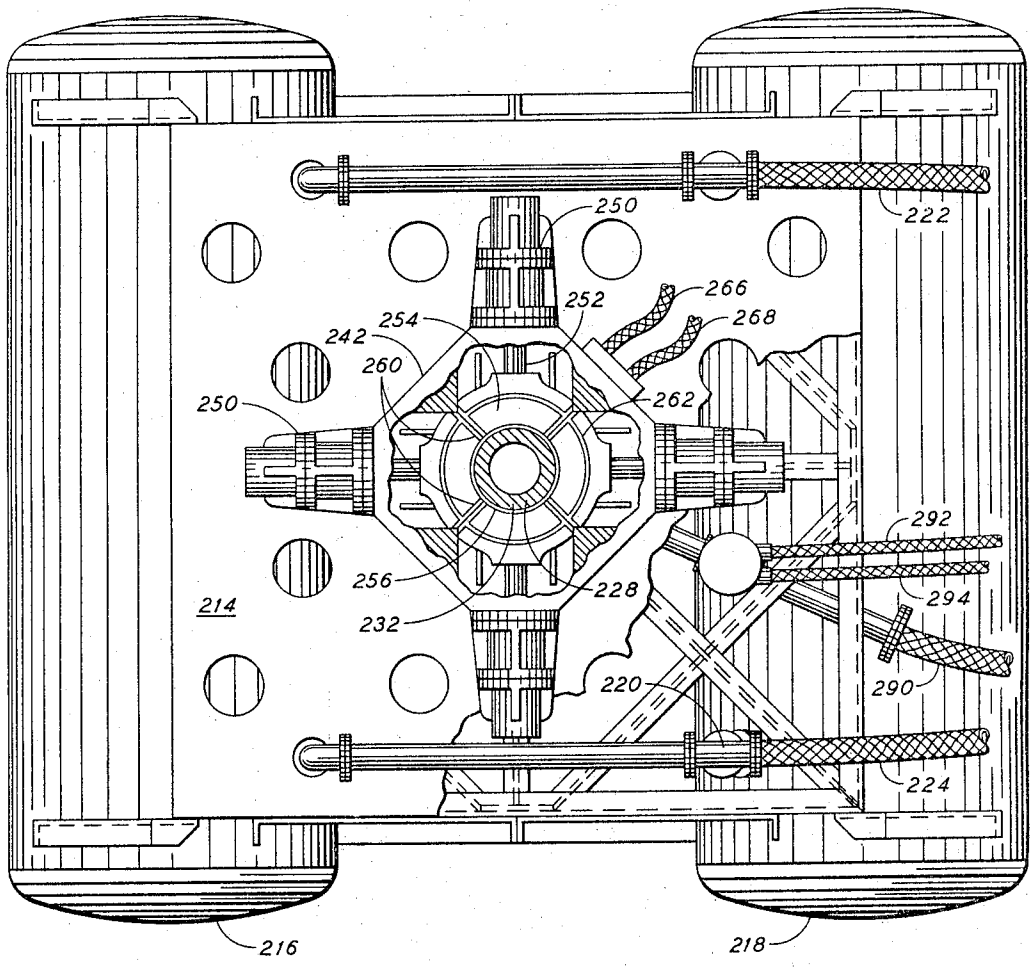


FIG. 10

INVENTOR
WILLIAM C. TRIPLETT

BY F. E. Johnston
Charles T. Gibeau
ATTORNEYS

United States Patent Office 3,315,741 Patented Apr. 25, 1967

3,315,741

METHOD AND APPARATUS FOR DRILLING OFFSHORE WELLS

William C. Triplett, Ingleside, Tex., assignor to Chevron Research Company, San Francisco, Calif., a corporation of Delaware

Original application Apr. 15, 1957, Ser. No. 652,756. Divided and this application June 14, 1966, Ser. No. 557,347

2 Claims. (Cl. 166—.5)

This application is a division of application Ser. No. 652,756, filed Apr. 15, 1957.

This invention relates to a method and apparatus for drilling wells in earth formations located under a body of water and more particularly for drilling offshore wells from a floating drilling platform.

As the search for offshore petroleum deposits moves progressively into deeper water, the limitations of fixed offshore drilling platforms become more apparent. Fixed platforms not only are very costly to build, but the engineering difficulties inherent in these structures increase exponentially as the water depth increases. A practical limitation is reached in waters well above the depth of those covering some potentially available petroleum deposits. Then, too, the susceptibility to storm damage of fixed drilling platforms located in open waters has been amply demonstrated by the destruction of such rigs by storms in the Gulf of Mexico and elsewhere.

It is desirable that some means be provided for drilling offshore wells which will not be limited in its application by the depth of the water; that relatively very maneuverable drilling apparatus be provided that can be moved from one well site to another with a minimum of delay and expense; that equipment be provided to control the opening of the well bore where it emerges from the submarine earth formations so that control of the well will not be subject to the hazard of damage through natural or other forces occurring in the water at the well site; that the well control equipment be operated by remote control from the surface of the water to obviate the necessity of using divers to manipulate the equipment; that provision be made for detaching the drilling apparatus from the well control equipment to permit it to proceed to a new location while leaving the well controlled by the submerged equipment; that provision be made for relocating a submerged drilled well from which the drilling apparatus previously has been disconnected and for reconnecting the drilling apparatus to the well by manipulation from the surface of the water; that provision be made to enable the drilling apparatus to avoid damage from heavy seas and storms; and that provision be made for controlling at the surface of the water the production from a completed well by remote operation of the submerged wellhead equipment.

It is among the objects of this invention to provide a novel method and means for satisfying the abovementioned desirable conditions. Other objects will become apparent as the description of the invention proceeds in conjunction with the accompanying drawings which form part of this specification.

In pursuance of this invention a floating drilling vessel is anchored over a submerged well site, and wellhead control equipment separate from the vessel is submerged in and at the bottom of the water and affixed to the bottom at the well site. The fixed wellhead equipment is connected to the floating drilling vessel by a string of flexible conductor casing which serves as a communicating conduit between the drilling vessel and the well. The flexible conductor casing string is arranged to permit the drilling vessel to move with the surface forces on the water without placing undue strain on or causing damage to the fixed wellhead control equipment. The wellhead control is operated from the floating drilling vessel remotely and independently of the vessel's connection through the flexible conductor casing string, and is not exposed to the hazard of malfunctioning which could follow from damage to the flexible conductor casing. Means are provided for remotely detaching and reattaching the flexible conductor casing string to the submerged wellhead, so that the vessel may leave the drilling site or return to it and be reconnected with the well through the operation of the apparatus aboard the vessel.

In the drawings:

FIGURE 1 illustrates diagrammatically in elevation and partly in section an example of apparatus employed in the method of this invention.

FIGURE 2 illustrates in sectional elevation details of parts of the apparatus illustrated in FIGURE 1.

FIGURE 3 is a plan view of a portion of the apparatus taken along the line 3—3 of FIGURE 2.

FIGURE 4 is an elevational view of a portion of the apparatus taken along the line 4—4 of FIGURE 3.

FIGURE 5 illustrates diagrammatically the arrangement of portions of the apparatus when the drilling vessel is being reconnected to a well.

FIGURE 6 illustrates in sectional elevation details of the apparatus shown in FIGURE 5.

FIGURE 7 is a plan view of a detail of the apparatus taken along the line 7—7 of FIGURE 6.

FIGURE 8 illustrates diagrammatically in elevation and partly in section a modification of apparatus employed in the method of this invention.

FIGURE 9 illustrates in elevation and partly in section details of a portion of the apparatus illustrated in FIGURE 8.

FIGURE 10 is a plan view partly in section of the apparatus taken along the line 10—10 of FIGURE 9.

FIGURE 11 is a diagrammatic illustration in elevation and partly in section of details of a modification of a portion of the apparatus.

FIGURE 12 is a schematic illustration of an alternate method for reconnecting the drilling vessel to the submerged wellhead.

Referring to the embodiment of the invention illustrated in FIGURE 1, there is shown a drilling vessel **10** which has been anchored on the surface of the water over the well site. This vessel may be a floating platform such as a barge which is towed to the well site, but preferably as illustrated it is a self-propelled ship which has been constructed or altered for well drilling purposes. The vessel is anchored by four anchors, two at the bow and two at the stern, and each pair of anchors is displaced at an angle of 45° to the longitudinal axis of the ship and hence at 90° to each other to increase the stability of the vessel in its anchored position. The winches **12** of the bow anchors are manually controlled in the usual manner. However, the stern anchor cables are wound on a winch **14** to be effective as a continuous line so that as the winch rotates one cable will be taken up as the other is payed out. The operation of the winch is governed automatically by a gyroscopically controlled selsyn arrangement which is designed to hold the vessel within ⅛° of arc of rotation in a horizontal plane to the position where it originally has been anchored.

The vessel has a bulkhead **16** built transversely across the forward portion of its hull and extending upwardly from the keel a distance appreciably above the water line. The bottom portion of the hull forwardly of the bulkhead has an opening **18** formed in it to provide access to the subjacent body of water from the interior of the vessel. A platform **20** is erected above the opening

and above the surface of the water within the hull, and on this platform is positioned a rotary table **22**. The platform **20** together with the rotary table and any other equipment which may be on the platform is removable so that access may be had to the opening in the bottom of the hull and equipment and apparatus may be passed through this opening and into the water for a purpose to be described hereinafter.

There is erected on the deck of the vessel for operation in vertical alignment with the opening in the hull a derrick **24** by which equipment can be raised and lowered through the opening and through the water. The derrick is fitted with gear and tackle connected to suitable power-driven drums **26** and **28** through which the hoisting operations can be accomplished. The vessel also is equipped with the power sources, pumps, tanks and other equipment normally used in a well drilling operation, as well as special equipment used in this invention, and to be described hereinafter.

When the vessel is anchored in position, wellhead control apparatus, designated generally by the number **30**, is assembled and supported in the water by cylindrical pontoons **32** and **34**. This apparatus comprises a base **36** which may be, by way of example, made of concrete. The base is illustrated as circular in shape, although it will be apparent that this particular shape is not necessary for its function. One end of a length of rigid conductor casing **38** is secured integrally in the base so that the casing extends axially from the bottom of it. The conductor casing extends also above the base a distance sufficient to permit the secure connection of equipment to it.

Attached to the top of the conductor casing is an element **40** which has a portion **42** of its exterior surface formed with a conical configuration. An axial conduit **44** is formed through the central portion of the element, in alignment and communicating with the interior of the conductor casing. Included in the conduit is a conically shaped chamber **46**, the smallest diameter of which is comparable to the internal diameter of the conductor casing. Coarse screw threads **48** are formed in the upper cylindrical surface of the conduit **44** to receive complementary screw threads **50** formed on an exterior surface of a nipple **52**. The upper end of element **40** terminates in a flange **54**, and the nipple **52** has a complementary flange **56** which mates with it. A gasket **58** may be placed between the flanges to form a fluid-tight connection. The nipple has an axial opening **60** through it of the same internal dimension as and in alignment with the interior of the conductor casing. Affixed to the top of and in axial alignment with the nipple is a hydraulically actuated blowout preventer **62** to which flexible hydraulic lines **64** and **66** are attached. The hydraulic lines are wound on a drum **68** mounted on the vessel, and suitable valves are placed in the lines so that the blowout preventer my be remotely operated from aboard the vessel.

A second nipple **70** is affixed to the top portion of the blowout preventer and projects in axial alignment upwardly therefrom. This nipple is designed to receive an end of a string of flexible conductor casing **72** which has an internal diameter comparable to that of the rigid conductor casing **38**. The flexible conductor casing is preferably made of a rubber-like material reenforced with steel wires so that it will have high tensile strength, and it may be fastened to the nipple **70** in any manner which will make a secure connection. As illustrated in FIGURE 2, a split clamp **74** is used for this purpose. The flexible conductor casing may be made in sections for convenience in handling and the sections joined together by flanges **76** as illustrated in FIGURE 1.

As illustrated in FIGURES 2, 3 and 4, the cylindrical pontoons **32** and **34** are connected to the base **36** by means of four chains, two from each pontoon. The chains have a fixed attachment to the pontoons but are detachably connected to the base by a remotely controlled connection, so that the pontoons may be recovered at the surface of the water when the base is landed on the well site. As shown in FIGURE 3, the free end of each chain terminates in an eye which is received within a clevis which is rigidly attached to the base; the clevis **78** receives the eye **80** of the respective chain **82**, and the clevis **84** receives the eye **86** of the chain **88**. A pin **90** is inserted through the clevis and eye combination **78–80**, and a pin **92** through the clevis and eye combination **84–86**. Each pin is attached to a frame **94** in a unitary manner so that when the frame is displaced longitudinally each pin also will be displaced the same distance simultaneously. A line **96** is attached to each frame and runs through a corresponding sheave **98** mounted on the base **36**. The lines from each of the two frames are run through their respective sheaves and thence are joined together and connected to a single line **100**. The sheaves are mounted at an angle on the base to accommodate the angle made by the line **96** and are positioned so that the stress in the line will be in axial alignment with the frame **94**.

Line **100** is run through a set of sheaves **102** affixed to the side of pontoon **32** so that the line will clear the pontoon and not become entangled in the wellhead apparatus. The line continues upwardly through the water to aboard the drilling vessel from which it can be manipulated to draw the pins **90** and **92** from the eye and clevis attachments on the base to thereby release the pontoons so that they may be buoyed to the surface and recovered.

The frame **94** and its attached pins are held in place in the eye and clevis connections by a shear pin **104** which is passed transversely through the pin **90** as shown in FIGURE 3. The shear pins are proportioned to shear under a predetermined stress placed on the lines **96** and prevent the pins **90** and **92** from being accidentally withdrawn from the eye and clevis connections prior to the time it is desired to release the pontoons from the base.

The line **100** is connected to the lines **96** by a shear pin connection **106** incorporating a shear pin **108**. This latter shear pin is, of course, proportioned to shear under a greater stress than is required to shear the pins **104** together. Hence, after the pontoons are released from the base additional stress may be placed on the line **100** to release the connection **106**, permitting the line to be cleared from the wellhead assembly and recovered aboard the drilling vessel.

The cylindrical pontoons are connected together by rigid members **110** placed between the corresponding axial ends thereof. These rigid members hold the pontoons in spaced relationship so that they will not impinge upon and damage the flexible conductor casing **72** or other apparatus associated with the wellhead. The members may be and preferably are manifold conduits by which the pontoons are joined to receive simultaneously air or water introduced into them through the flexible hoses **112** and **114** which are connected to appropriate sources of air and water aboard the drilling vessel. Obviously the buoyancy of the pontoons may be controlled from aboard the drilling vessel by manipulating appropriate valves to inject the proper amount of air or water into the pontoon structures.

The well head equipment extending above the base **36** is braced by diagonal bracing members **116**. These members are attached to the blowout preventer by a relatively rigid connection and extend thence diagonally outwardly to contact the base near its periphery. The ends of the diagonal members adjacent the base terminate in a foot **118** which is bent into a plane parallel with the top surface of the base. The foot has a circular opening **120** in it which is slotted **122** at one side so that the opening may receive the shank **124** of a headed pin **126** in a sliding connection. The head of the pin engages the topmost surface of the foot to prevent an axial displacement of the foot from the pin connection. However, the

foot may be slid out of connection with the pin when the blowout preventer is rotated about its longitudinal axis, carrying the diagonal braces **116** with it.

A valve controlled side take off conduit is provided in the wellhead equipment so that the flow of fluids from a completed well may be controlled and taken from the well directly at the wellhead where it emerges from the submarine earth formations. As illustrated, a conduit **128** is inserted through a side wall of the rigid conductor casing **38** in a fluid-tight fitting and extends radially therefrom. A remotely operable valve **130** is connected to the conduit in line with a second conduit **132** to which a pipe line **134** is connected. The conduits **128** and **132** may be cast into the concrete base **36** and the valve inserted in a recess formed in the base and covered with a water-tight cover **136**. Control lines **138** and **140** for the valve are passed through the cover through water-tight connections so that the valve and conduits will be protected from damage and from corrosion.

The pipe line **134** preferably is a flexible line such as a steel-reinforced rubber hose which can be brought to the surface so that its upper end may be secured to a buoy **142** until such time as the well is to be placed in production. At this time the pipe line will be connected to suitable separators and tanks on a floating vessel or will be extended by flexible or rigid line to reach along the bottom of the water to shore installations.

As stated previously, after the well site has been selected and the drilling vesesl anchored in place the wellhead control apparatus is assembled on its base and supported by pontoons at the surface of the water. The ends of the control lines are attached to their respective apparatus in the wellhead assembly, and the end of the flexible conductor casing **72** is secured to the top of the blowout preventer. The control lines are reeled on appropriate drums aboard the vessel so that they can be payed out as the wellhead assembly is submerged. For example, the air and water lines from the pontoons are reeled around the drum **144** which has incorporated with it rotary connections which permit the lines to be continuously connected to appropriate sources of pressurized air and water aboard the vessel.

The surface end of the flexible conductor casing is passed upwardly through the opening **18** in the bottom of the hull of the vessel and through an opening in the platform **20** so that it may be supported by the derrick.

The wellhead assembly is now ready to be lowered to the bottom of the water and fixed there at the drilling site. This is accomplished by injecting water into the pontoons until their buoyancy decreases sufficiently to permit the wellhead assembly to sink slowly through the water. As the submerged depth of the wellhead assembly increases, sections of flexible conductor casing are added to the conductor casing string so that the upper end of it remains above the water. The upper end of the flexible conductor casing string may be held on the platform **20** by slips while a section is being added to it.

Buoyant elements **146** are affixed to the flexible conductor casing string at spaced-apart intervals as it is being lowered into the water. These buoyant elements are proportioned to give the flexible conductor casing string substantially neutral buoyancy in the water. Preferably, the buoyant elements are made of a water-impervious, relatively rigid cellular material such as a plastic foam. The presently available commercial material called "Styrofoam" is suitable for this purpose. The buoyant elements may be attached to the flexible conductor casing string within the hull of the vessel as the sections are made up, and of course if they are attached to the string above the platform **20** the platform will subsequently be removed to permit the flexible conductor casing string together with the attached buoyant element to pass downwardly through the opening **18** in the bottom of the hull.

The hydraulic control lines for the blowout preventer **62** are payed out from reel **68** and secured along the side of the flexible conductor casing string as it is made up and lowered into the water. The release line **100** for the pontoons is also brought aboard the vessel and reeled on an appropriate drum, not shown.

As the wellhead assembly approaches the bottom of the water, the length of rigid conductor casing **38** projecting from the bottom of it comes in contact with the submerged earth formations. In muddy and silty bottoms the weight of the apparatus can be used to cause the rigid conductor casing to penetrate some distance into the bottom. However, in order to insure a firm connection with the earth formations it is preferable to make the rigid conductor casing string of such length that it will penetrate through the silt and into contact with the firmer subterranean formations. When downward progress of the wellhead assembly is stopped by the contact of the lower end of the rigid conductor casing string with the firmer earth formations, a string of tubing to the lower end of which jetting nozzles are attached is inserted into the upper end of the flexible conductor casing string and projected downwardly through the wellhead control equipment and the rigid conductor casing string until the nozzles are proximate the earth formations. A jetting fluid under pressure is forced down the tubing to jet the rigid conductor casing string into the earth formations. Jetting will continue until the base **36** is seated on the earth formations at the bottom of the water. Where the bottom is relatively firm, the engagement of the base with the bottom will stop the further downward travel of the wellhead assembly. However, if the bottom is mushy, the wellhead assembly is held in this desired position by the action of the pontoons with the assistance of the derrick supporting the upper end of the flexible conductor casing string. It is desired to keep the wellhead assembly directly on the bottom and positioned so that the upper end of the rigid conductor casing string will not extend above the earth formations and be exposed in the water, nor will the wellhead assembly be sunk into and be covered by silt or mud.

When the base has been landed, the jetting tubing is removed from the casing string and cement tubing and packers inserted therein. Cement is forced down the cement tubing in a manner analogous to the usual practice to cement the rigid conductor casing string to the submerged earth formations. This will assist in holding the wellhead assembly in position, as well as prevent the topmost layers of earth from caving into the hole.

When the rigid conductor casing string has been cemented and the cement tubing withdrawn from the casing, a self-contained drilling mechanism **148**, such as a mud-driven turbo drill or an electric drill, is inserted into the flexible conductor casing string, through the wellhead equipment and the rigid conductor casing string and into contact with the subterranean formations. The upper open end of the flexible conductor casing is closed by a head member **150**, which is securely attached to the casing, through which the operating lines to the drilling mechanism will pass slidably in a fluid-tight connection. The drilling mechanism is supported in the derrick by a wire line **152** which is connected to the drum **26**. This drum is automatically controlled to take up or let off line to hold constant weight on the bit while compensating for vertical motion of the drilling vessel and for the increasing depth of the bit as it drills into the subterranean formations.

When a mud-driven turbo drill is used, mud under pressure is fed to the drilling mechanism through a flexible hose **154** which also passes through the head member **150** in a slidable fluid-tight connection. In the modification of the invention shown in FIGURE 1 the hose **154** is run over a pulley **156** attached to the derrick structure in a position above the end of the flexible conductor casing string. The free end of the hose is connected to a mud pump **158** which will draw drilling mud from the

mud tank **160** and force it down the hose to drive the drill turbine.

The mud hose may be made in sections which are added to the string as the drill progresses deeper into the earth. As illustrated, the sections **162** may be stored aboard in a hold of the vessel from which they are lifted out by a crane **164** to be added to the mud hose string as needed. A power-driven winch **166** mounted on the deck is detachably secured by cables **168** to the mud hose before it passes over the pulley **156** so that the free end of the mud hose may be drawn up slack and disconnected from the mud pump when a section is to be added to the string. The winch **166** may also be used to place enough tension on the mud hose string to prevent an excess amount of it from following the drilling mechanism into the hole.

The head member **150** has a connection for a mud line **170** through which the mud circulated upwardly from the drilling mechanism will pass from the flexible conductor casing to a shale shaker and screen **172** and thence into the mud tank. The return mud may, of course, be treated, inspected and analyzed in conformance with the usual field practice. It will be appreciated that if an electric drill is used the drilling mechanism will be supported in the derrick by a constant feed apparatus in a manner analagous to that explained above, and the electrical conductors will be passed through the head members **150** through slidable fluid-tight connections. Mud will be circulated down to the drill and back through the flexible conductor casing and thence to the mud treating apparatus.

The upper end of the flexible conductor casing string may be supported on the platform **20**. The flexibility and buoyancy of the string will permit some motion of the vessel relative to the fixed wellhead equipment without placing undue strain on the parts. Alternatively the casing may be supported in the derrick by lines attached to the drum **28** which is automatically controlled to let off and take up line in accordance with the vertical motion of the vessel to prevent it from being placed under stress due to the latter cause.

With the drilling apparatus thus in place and connected to the sources of power aboard the vessel, a hole is drilled into the subterranean formations below the end of the rigid conductor casing string **38** of a diameter large enough to receive a string of surface casing **174**. The length of the surface casing string will depend on the nature of the earth formations to which it is to be secured, on the depth of the well it is desired to drill, and on the pressures like to be encountered as drilling progresses. This string will, for example, extend 500 feet into the earth. When the hole has reached the desired depth, the drilling mechanism is withdrawn and a string of surface casing is made up aboard the drilling vessel and lowered through the flexible conductor casing string which will guide it through the wellhead control equipment and thence into the rigid conductor casing string **38**. It will be appreciated that the surface casing string will be made up from sections in the usual manner and will be progressively lowered through the conductor casing. The upper end of the surface casing string is hung by casing hangers in the rigid conductor casing string so that the upper end of it is adjacent the bottom portion of the wellhead control assembly. Cementing tubing is then run to the bottom of the surface casing string, which is cemented to the earth formations in a manner well known to the art. The cement slurry is placed under enough pressure so that it will be forced into the annular space between the surface casing string and the rigid conductor casing string to a point adjacent the bottom of the base **36**. The wellhead assembly will thus be rigidly secured to the surface casing string and thus held in place in its position at the bottom of the water.

The pontoons **32** and **34** may now be detached from the base **36** and recovered. This is accomplished by decreasing the buoyancy of the pontoons to place slack in the chains **82** and **88**. The pins **90** and **92** are then withdrawn from the clevis and eye combinations so that the pontoons will be released from their attachment. Water may now be displaced from the pontoons by compressed air and the pontoons floated to the surface where they may be recovered and cleared from the apparatus. It will be appreciated that under some conditions the pontoons may be released from the base prior to the time the surface casing is set and cemented in place.

The drilling mechanism is now again lowered through the flexible conductor casing string and guided through the wellhead control equipment and the string of surface casing and into contact with the subterranean formations. It is then placed into operation to drill the well. The blowout preventer **62** will assist in maintaining control of the well should conditions require it. As noted previously, the blowout preventer is connected by lines **64** and **66** to appropriate valves aboard the vessel by which its action may be controlled. The blowout preventer is preferably of the well-known type which will close around the drill tubing and seal the opening of the well. When a flexible steel-reenforced rubber hose is used for drill tubing, it may be desirable to embed spaced-apart sections of a rigid conduit in the inner wall of the flexible tubing so that the blowout preventer may close on the tubing without crushing it. Additionally, a complete shutoff blowout preventer may be connected in axial alignment with the blowout preventer **62** to completely close the opening of the well when the drill tubing is withdrawn from the apparatus.

The well is drilled to the desired depth and completed in accordance with the usual practice. The opening of the well may now be closed by lowering a mass of cement slurry **176** on a wire line **178** to rest in the conical chamber **46** of element **40**. The cement slurry may be contained in a plastic sack **180**, FIGURE 6, inside of a flexible metal petal basket **182** formed of interleaved spring metal segments, a device known to the art. The basket will be collapsed about the sack of cement slurry as it is lowered through the flexible conductor casing string and the blowout preventer, and the petals will be expanded when the basket is located in the conical chamber **46** to confine the mass of slurry in this position. The cement slurry will be placed under sufficient pressure to cause it to conform to the shape of the chamber so that when it is set a fluid-tight seal is made.

With the well thus sealed the flexible conductor casing string and the attached blowout preventer may be disconnected from the wellhead control assembly. This is accomplished by placing the upper end of the flexible conductor casing string in the rotary table **22** and rotating it to unscrew the connection **48–50** at the top of the element **40**. All of the principal equipment except the element **40** and the base **36** and the connections between them may now be recovered. The control lines **138** and **140** remain attached to the side take off valve **130** so that this valve can be actuated to control the flow of well fluids through the pipe line **134**. Hence the well is completely sealed at the bottom of the water and, except for the control lines, and in some instances the pipe line, no apparatus extends substantially above the bottom to be damaged by water forces or solid objects impinging against them.

When the cement plug was set in the element **40** the wire line **178** on which it was lowered had attached to it at spaced intervals along its length guide members **184**. These guide members are proportioned with a circumferential portion of slightly less diameter than the internal diameter of the flexible conductor casing and are secured to the wire line so that they will extend radially from it. When the flexible conductor casing string is detached from the wellhead assembly, the wire line **178** with the attached guides remains secured to the cement plug **176**, and the casing is slipped upwardly over the guides. With

the casing removed, the upper end of the wire line is buoyed at the surface of the water so that it may be recovered.

Should it become necessary to gain entrance to the well for cleaning or other purposes, the wire line **178** and the attached guide members **184** serves as a means for guiding the flexible conductor casing string back to the wellhead. For reconnecting purposes a special guide fitting **186** is clamped to the lower end of the flexible conductor casing string. This guide fitting has a circumferential skirt portion **188** extending downwardly from it and proportioned to slip over the flange **54** and seat upon the conically shaped outer surface **42** of the element **40**. The fitting has an inner cylindrical extension **190** upon the outer surface of which screw threads are formed to mate with and be received by the screw threads **48** of the element **40**. The wire line and guide members will thus guide the lower end of the flexible conductor casing string to the submerged fixed wellhead and with the assistance of the depending skirt portion **188** it will be brought into axial alignment with the element **40**. The upper end of the flexible conductor casing string is then rotated to engage the screw threads to connect the lower end of it to the wellhead assembly. When the connection has been made the wire line **178** is severed where it enters the cement plug and the plug is drilled out to open the well so that the appropriate reworking equipment can be guided down through the reattached flexible conductor casing string and into the well. When the reworking of the well has been completed, the cement plug **176** again is established in the chamber **46** and the flexible conductor casing string is removed in the manner explained hereinbefore.

FIGURE 8 illustrates another embodiment of this invention. In this modification, the drilling vessel has an opening **200** placed through the bottom portion of the hull, and affixed to its periphery in a water-tight manner is the end of a vertical open cylinder **202**. The cylinder is open to the water at the bottom and extends upwardly into the hull above the water line. A removable platform **204** is placed across the top of the cylinder and above the surface of the water in it. An opening **206** is formed through the deck of the ship in alignment with the cylinder **202**, and this opening also is covered with a removable platform **208**.

A crane or derrick **210** is mounted on the deck of the vessel in a position to hoist equipment into and out of the water through the aligned openings in the deck and hull of the vessel and is connected to an automatically controlled hoisting apparatus **212** constructed to let off or take up the lifting cables to compensate for the vertical movement of the ship and the increasing depth of the drill bit when a drilling operation is in progress. This vessel contains the usual apparatus normally used in a rotary drilling operation.

The wellhead equipment in this modification of the invention is more clearly depicted in FIGURES 9 and 10. A base **214** is fabricated of metal members and is permanently secured upon cylindrical pontoons **216** and **218**. The pontoons are connected together by conduits **220** and are attached to sources of pressurized air and water aboard the drilling vessel by flexible hoses **222** and **224** so that their buoyancy may be controlled from the vessel. A string of rigid conductor casing **226** is secured to the center of the base in a unitary manner so that its lower end extends below it.

Wellhead control equipment is secured to the top surface of the base and to the upper end of the string of rigid conductor casing. This equipment comprises an element **228** which has a portion **230** of its lower outer surface of conical configuration with the smaller diameter disposed upwardly. A projection **232** extends upwardly from the lower portion, and this also has a generally conical outer configuration with the smaller diameter disposed upwardly. There is an axially disposed opening **234** through the element, in alignment with and having an internal diameter comparable to the conductor casing. A portion of the opening is expanded into a conical chamber **236** which also has its smaller diameter disposed upwardly. Axially spaced circumferential grooves **238** and **240** are formed in the exterior surface of the projection. These grooves are proportioned to engage parts of a clamping device **242** which is used to detachably secure other portions of the apparatus to the wellhead.

The clamp is made with two stages **244** and **246**, one superimposed axially on the other. The clamp body has an axial opening **248** through it of sufficient internal diameter to receive within it the projection **232**. Each stage has four similar power cylinders **250** disposed in a plane and operatively mounted within the body of the clamp to each slidably move a corresponding connecting rod **252** in a direction radial to the longitudinal axis of the opening **248**. Each connecting rod is attached to a ram **254**, and hence the rams will be moved radially inwardly and outwardly toward and away from the projection **232**. The rams are formed as quadrants of a disc in which the radially inwardly portion has been removed to form a circular edge **256** of approximately the same diameter as the base of the grooves **238** and **240**. When the rams are brought together their complementary edges will approach each other closely, and their radially inwardly portions will seat within the grooves and closely approach the base. A ring of packing material **258** of a resilient substance such as rubber is placed on the bottom of the grooves so that the rams will seat in the groove with a fluid-tight connection. Resilient packing material **260** is placed also on the radial edges of the rams and within the body of the rams as at **262**, so that when the rams are forced together the packing material will form a fluid-tight seal both between the ram quadrants and between the rams and the adjacent interior surfaces **264** of the body of the clamp. Thus, when the rams are forced inwardly to engage the grooves a fluid-tight seal is formed which will prevent fluids from escaping between the projection **232** and the clamp mechanism. The power cylinders of the clamp are manifolded together and connected by lines **266** and **268** to the drilling vessel so that they may be operated simultaneously to attach or detach the clamp and the element **228**.

Extending from the bottom of the clamp housing is a depending skirt portion **270** which terminates in a flared portion **272** in the form of an inverted funnel. The skirt has a lower interior circumferential surface **274** of a conical configuration complementary to the conical surface **230** of the element **228**. The skirt is constructed to engage with and seat on the conical surface **230** to assist in bracing the clamp structure on the wellhead and in centralizing the clamp in axial alignment with the projection **232**. It also positions the clamp so that the appropriate rams **254** are in alignment with the corresponding grooves **238** and **240** to enable the clamp to be engaged with and disengaged from the element **228**.

A blowout preventer **276** is secured to the top portion of the clamp body and in axial alignment with it, and to the top of the blowout preventer is secured the end of a flexible conductor casing string **278**. The blowout preventer is connected by lines **280** and **282** to the drilling vessel for operation therefrom.

A valve-controlled side take off conduit **284** is provided in the wellhead control equipment in communication with the upper portion of the rigid conductor casing string **226**. It is connected to a remotely controllable valve **286** which in turn is connected to a conduit **288** to which the pipe line **290** is attached. The flexible control lines **292** and **294** for operating the valve are reeled around an appropriate drum aboard the drilling vessel, and the end of the flexible pipe line is buoyed to the surface so that subsequently it may be retrieved and

connected to separating equipment and tanks aboard a vessel or to a land installation.

The wellhead control equipment is assembled at the surface of the water and floated on its two pontoons to a position above the well site. The various control lines are fastened to the appropriate units of the wellhead equipment, and they are arranged aboard the vessel so that they may be payed out as the wellhead assembly is lowered through the water. Prior to lowering, the blowout preventer together with the lower end of the flexible conductor casing string is attached to the element **228** through the action of clamp **242**. The upper end of the flexible conductor casing string is passed upwardly through the opening **200** in the hull of the vessel and extends upwardly through an opening in the platform **204**.

The wellhead control assembly is now lowered through the water by controlling the buoyancy of the pontoons from aboard the vessel through the lines **222** and **224**. As the wellhead assembly sinks, additional sections are added to the flexible conductor casing string **278** so that the upper end of it remains within the hull of the vessel. Buoyant elements **296** are positioned along the length of the flexible conductor casing string as it is made up. These buoyant elements may, as mentioned heretofore, be made of a relatively rigid cellular material, such as plastic foam. The buoyant elements may be substantially toroidal in form and be made in sections to be put together circumferentially around the flexible conductor casing string. They are then secured together and to the casing so that they will remain in place as they become submerged in the water and distribute their buoyant effect along the length of the casing string. In the instant modification of the invention it is preferable that the conductor casing string be given a positive buoyance for a purpose to be described hereinafter.

The control lines to the clamping device **242**, and the lines to the blowout preventer, may be secured to the side of the flexible conductor casing string as it is made up, and are wound on appropriate drums **298** and **300** respectively aboard the vessel. Appropriate valves are placed in the control lines so that the submerged apparatus can be operated from aboard the vessel.

The wellhead control assembly is lowered until the bottom of the rigid conductor casing string contacts firm submarine earth formations, after which the rigid conductor casing string is jetted in until the pontoons **216** and **218** rest on the earth formations at the bottom of the water. In silty or muddy bottoms the pontoons may be permitted to sink into the bototm until the base **214** is substantially even with the surface of the earth formations at the bottom of the water. The penetration of the pontoons into the bottom may, of course, be controlled by regulating their buoyancy.

As the wellhead control assembly is landed, a length of rigid casing **302** is added to the topmost portion of the flexible conductor casing string in a position to extend through the opening in the platform **204** and for some distance above and below the platform as illustrated in FIGURE 8. A gimbal mounting **304** is positioned on the platform and circumferentially surrounding the section of rigid conductor casing. This section of casing fits slidably within the gimbal mounting so that it may move longitudinally relative thereto as the ship is displaced vertically by the action of the water. Roller bearings **306** may be placed in the radially inwardly face of the gimbal mount so that the casing section may slide through it with minimum friction. The positive buoyancy of the flexible conductor casing will assist in retaining the rigid section **302** within the gimbal mounting, and the top of the flexible conductor casing string may be additionally supported from the derrick by an automatically operated device to compensate for vertical movement of the vessel, analagous to that discussed with reference to FIGURE 1. A flange **308** is placed on the topmost portion of the rigid section to assist in preventing it from disengaging with the gimbal mount. This arrangement permits the drilling vessel to move with the water with the minimum displacement of the upper end of the flexible conductor casing string. With the apparatus thus assembled, the rigid conductor casing string is cemented to the earth formations it penetrates.

In this modification of the invention, drilling is accomplished by rotating a string of drill tubing **310** by a rotary table **312** mounted on the platform **208**. The string is made up in the derrick from the deck of the vessel in a manner analagous to that commonly used in oil field practice and inserted into the upper end of the flexible conductor casing string, which guides it down to the submerged wellhead control equipment. The drill string is extended downwardly until the bit **314** is in contact with the submerged earth formations. Drilling mud is pumped down the drill tubing from the mud tank **316** through a swivel **318** and returns through the flexible conductor casing string, from which it flows through a connection **320** in the drilling head assembly **322**. The mud is reconditioned and returned to the mud tank for recirculation.

A bore hole is drilled below the end of the conductor casing string to accept a predetermined length of surface casing **324** which is inserted into the bore hole and cemented in place and to the conductor casing string, in a manner described heretofore, to anchor the wellhead control equipment to the well.

When the well has been drilled to the desired depth, a cement plug is set in the conical chamber **236** of the element **228**. The cement plug is let down into the chamber on a wire line which has guide elements for the flexible conductor casing string attached to it in the manner described heretofore.

When the cement plug is set, the clamp **242** is released from its engagement with the element **228** by remote operation from the floating drilling vessel. The flexible conductor casing string, together with the blowout preventer and clamp attached to the end of it, is withdrawn from the water and onto the drilling vessel. The air and water lines to the pontoons may now be severed at the wellhead and reeled aboard the vessel.

As described heretofore the side take off valve **286** is operated through the lines **292** and **294** to control the flow of fluids from the producing well. It will be appreciated that when the vessel leaves the drilling site these control lines will be disconnected from the vessel and supported at the surface of the water by a buoy **326** so that they may subsequently be retrieved and connected to a suitable power source to again control the valve.

When it is desired to reopen the well for reworking or other purposes, the clamp **242** is attached to the lower end of the flexible conductor casing string which is guided down to the wellhead on the wire line attached to the element **228** in the manner described heretofore with relation to FIGURES 5 and 6. As has been noted previously, projection **232** is of a generally conical configuration with the smaller diameter positioned uppermost. Thus as the depending skirt **270** of the clamp body approaches the fixed wellhead equipment it will be guided over the upper end of the projection, assisted by the flared portion **272**, and thence proceed downwardly along its conical outer surface, guiding the clamp body into a position surrounding and in axial alignment with the projection. When the interior conical surface **274** of the depending skirt portion seats on the complementary conical surface **230** of the element **228**, the clamp will be positioned so that the rams **254** are in radial alignment with the grooves **238** and **240**. The clamp is then actuated to close the rams onto the projection **232** to secure the lower end of the flexible conductor casing string to the fixed wellhead equipment.

An alternative means for reconnecting the flexible con-

ductor casing to the submerged wellhead apparatus is illustrated in FIGURES 11 and 12. In this modification the mass of cement slurry **176** which is used to occlude the opening of the well at the element **228** has embedded in it a socket **328** of drillable tubular material such as an appropriate synthetic resin, or soft metal. A centralizer **330** of drillable material is attached to the upper portion of the socket in a position to extend above the mass of cement slurry. The socket and centralizer are incorporated in the assemblage prior to the time the basket of slurry is lowered to the wellhead apparatus. The centralizer element is made with an outside diameter which will permit it to slide through the flexible conductor casing string and associated equipment and fit snugly within the opening **234** of the element **228**. It is designed to hold the open end of the socket **328** centralized within and in axial alignment with the opening **234**. The upper surfaces of the centralizer element and socket are formed with a conical configuration **331** to assist in guiding apparatus into the socket. When the cement is positioned in the conical chamber **236** and is set, the socket will be fixed rigidly in its axially aligned position.

The wire line **332** by which the basket of cement slurry was lowered into the chamber **236** has guide members **334** secured along its length in a manner similar to that of the guide members **184** described heretofore. However, the guide members **334** have an external diameter which will permit a string of pipe or tubing **336** to be slid over them. The wire line and guides are employed to guide the lower end of the string to the submerged wellhead and into the socket **328**. The inside diameter of the socket is large enough to receive freely the end of the string **336**. Flexible packing elements **338** and **340** are affixed to and positioned circumferentially around the end of the string where it engages the inner wall of the socket to act as centralizers to hold the lower end of the string in axial alignment with the opening **234** and thus with the element **228**.

The string **336** now forms a means connecting the submerged wellhead equipment and the floating drilling platform and can be used as a guide while lowering the end of the flexible conductor casing and its attached clamp to the submerged wellhead equipment for reattachment thereto. The string of pipe or tubing provides a more rigid guide means than the wire line **332** and hence will assist in guiding the lower end of the flexible conductor casing and its attached equipment more positively into axial alignment with the submerged element **228**, especially when rough water or strong ocean currents are present at the drill site. Obviously guide elements similar to the elements **184** described heretofore may be attached to the string **336** at intervals along its length, in a manner similar to that described in relation to FIGURES 5 and 6, for guiding the flexible conductor casing string to the submerged wellhead. However, if the apparatus of the present modification is employed, these guide means may be dispensed with by using a blowout preventer, such as the blowout preventer **276** described hereinbefore, as part of the assembly attached to the lower end of the flexible conductor casing string when it is lowered for reattachment to the submerged wellhead.

In accordance with this latter procedure the blowout preventer **276** is closed lightly upon the string **336** when the flexible conductor casing is to be lowered for reattachment to the submerged wellhead, in a manner to permit the blowout preventer and the equipment connected to it to slide downwardly along the string without permitting appreciable lateral motion of the parts. Thus the string will guide the clamp **242** to the submerged element **228** and substantially in axial alignment with the latter. The depending skirt portion **270** will perform the function as explained hereinbefore of centering the clamp over the projection **232** and in radial alignment with the circumferential grooves **238** and **240**, so that the clamp rams can be closed to attach the flexible conductor casing string to the submerged wellhead.

The modification of apparatus exemplified in FIGURES 11 and 12 lends itself to a further alternative means for reattaching the flexible conductor casing string to the submerged wellhead equipment. In this alternative, the blowout preventer **276** is again included in the apparatus attached to the lower end of the flexible conductor casing string. The blowout preventer is closed tightly upon the string **336** and adjacent its lower end prior to the time the string is lowered along the wire line guide. Enough of the lower end of the string **336** is left projecting below and beyond the clamp body so that the lower end of the string may be received within a socket **328** without interference from the equipment attached above it. The lower end of the flexible conductor casing string together with its associated equipment, is lowered together with the string **336**, and the wire line guide means will direct the end of the string into engagement with the socket. When this engagement has been accomplished, the blowout preventer **276** is opened by remote control from the floating drilling platform a sufficient amount to permit the lower end of the flexible conductor casing string and its associated equipment to slide down the remaining length of the string until the clamp device **248** is positioned to engage and be affixed to the submerged element **228**.

As has been explained hereinbefore, after the lower end of the flexible conductor casing string has been reattached to the submerged wellhead equipment the wire line, which was used to lower the basket assembly of cement slurry into place to occlude the opening of the well and which subsequently functioned as a guide means for reattaching the flexible conductor casing string to the submerged wellhead equipment, is severed and the cement plug is drilled out to reopen the well.

It is apparent from the above description of the several exemplary embodiments of the apparatus employed in the method of this invention that it achieves the objects set forth at the beginning of the specification. It is obvious that other modifications than those illustrated may be made employing the inventive concept without departing from it; therefore it is desired that this invention not be limited by the specific exemplary embodiments illustrated herein, but that it include all equivlaents within the scope of the appended claims.

I claim:

1. An offshore structure for carrying out well operations generally above submerged wellhead means, said structure adapted to be positioned at a selected offshore location in a manner sufficiently stationary to carry out operations wherein pipe means projecting generally upwardly from submerged wellhead means may be engaged generally above said submerged wellhead means at two vertically displaced levels, said structure comprising:

an operating deck having a vertical first opening therethrough of a size sufficient to pass well tools and equipment therethrough,

an auxiliary lower deck positioned below said operating deck, having a vertical second opening therethrough of a size sufficient to pass well tools and equipment therethrough, and in general vertical alignment with at least a portion of said first opening,

first pipe-engaging means supported by said operating deck and arranged in general alignment with at least a portion of said first opening in said operating deck,

second pipe-engaging means, independent of submerged wellhead means over which said structure is adapted to be positioned, carried by said auxiliary deck, and adapted to be positioned in general alignment with at least a portion of said second opening in said auxiliary deck,

said second pipe-engaging means being movably positioned relative to said auxiliary deck for movement

into and out of general alignment with at least a portion of said second opening in said auxiliary deck, and

platform means, interposed between said second pipe-engaging means and said auxiliary deck for supporting said second pipe-engaging means, said platform means being removable from placement extending at least partially across said opening.

2. The offshore structure of claim 1 wherein said offshore structure comprises a vessel continuously floating while carrying out said well operations, said vessel buoyantly supporting both said operating deck and said auxiliary deck.

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CHARLES E. O'CONNELL, *Primary Examiner.*

R. E. FAVREAU, *Assistant Examiner.*