

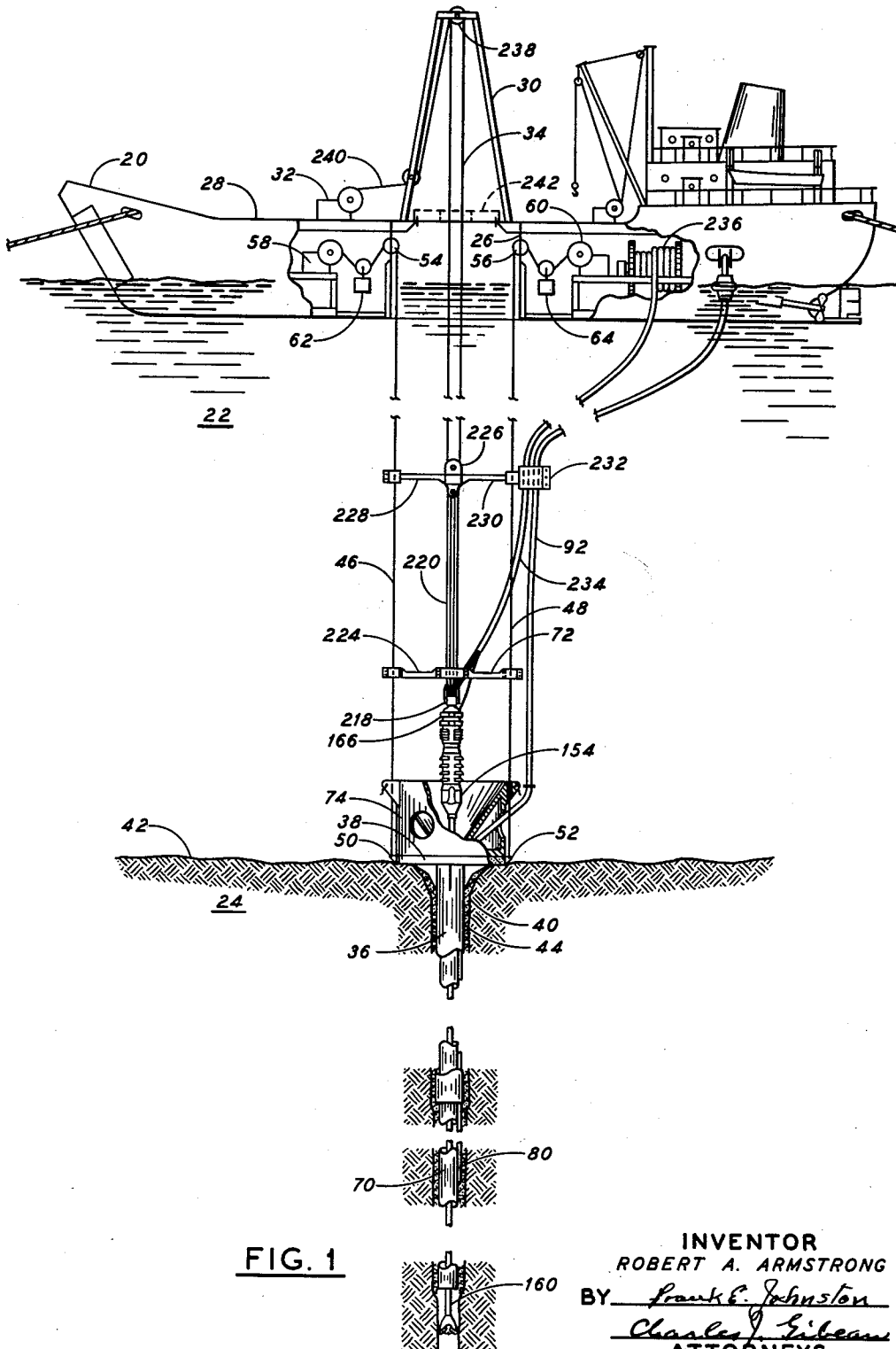
April 21, 1964

R. A. ARMSTRONG
METHOD AND APPARATUS FOR DRILLING AND
WORKING IN OFFSHORE WELLS

3,129,774

Filed Sept. 9, 1960

7 Sheets-Sheet 1



INVENTOR
ROBERT A. ARMSTRONG
BY Frank E. Johnston
Charles E. Gibbons
ATTORNEYS

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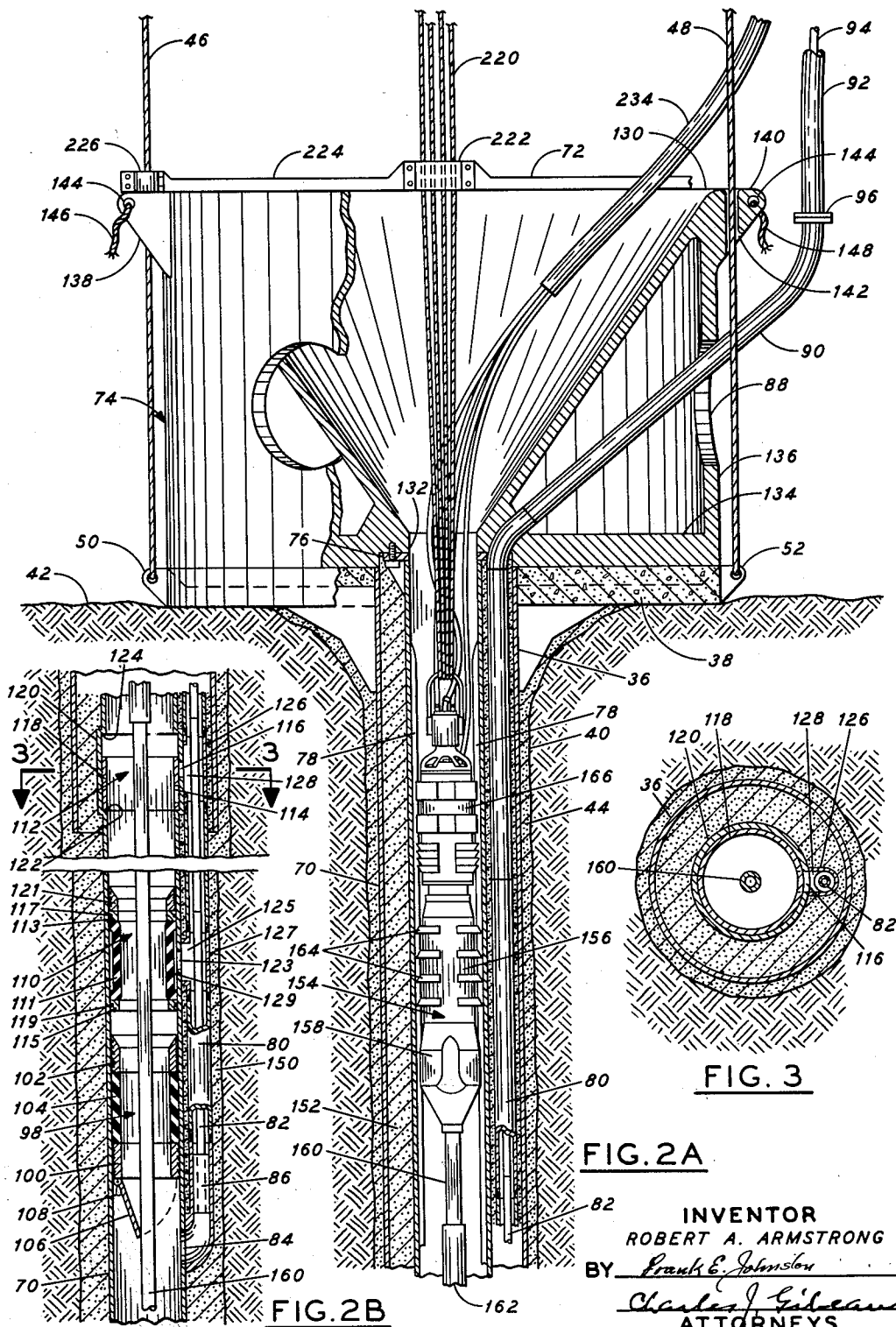


FIG. 2A

FIG. 3

FIG. 2B

INVENTOR
ROBERT A. ARMSTRONG
BY *Frank E. Johnson*
Charles J. Gibbons
ATTORNEYS

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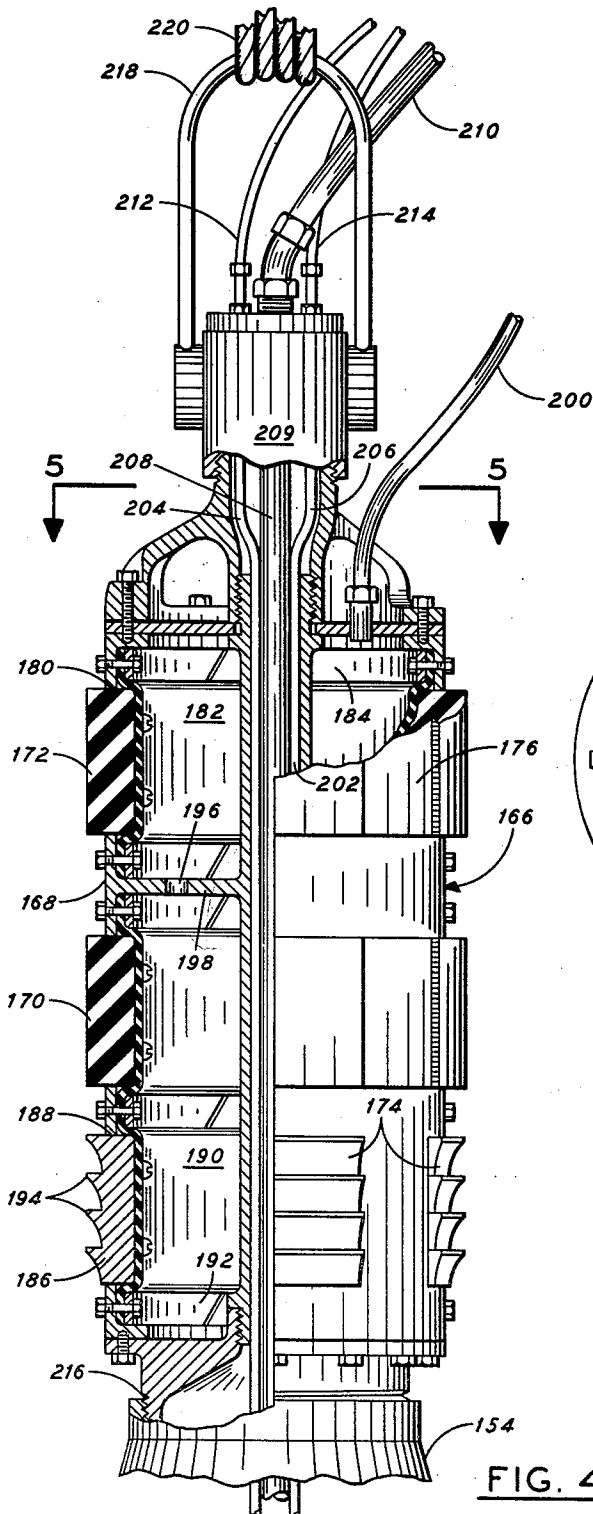
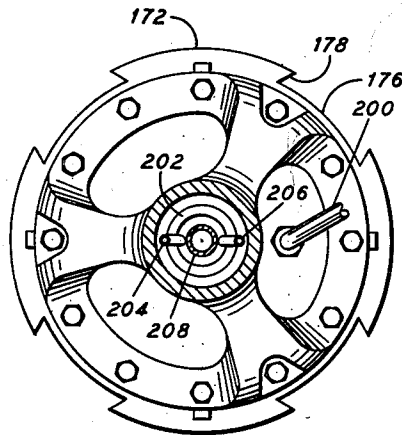


FIG. 5

FIG. 4

INVENTOR
ROBERT A. ARMSTRONG
BY Frank E. Johnston
Charles J. Gibbons
ATTORNEYS

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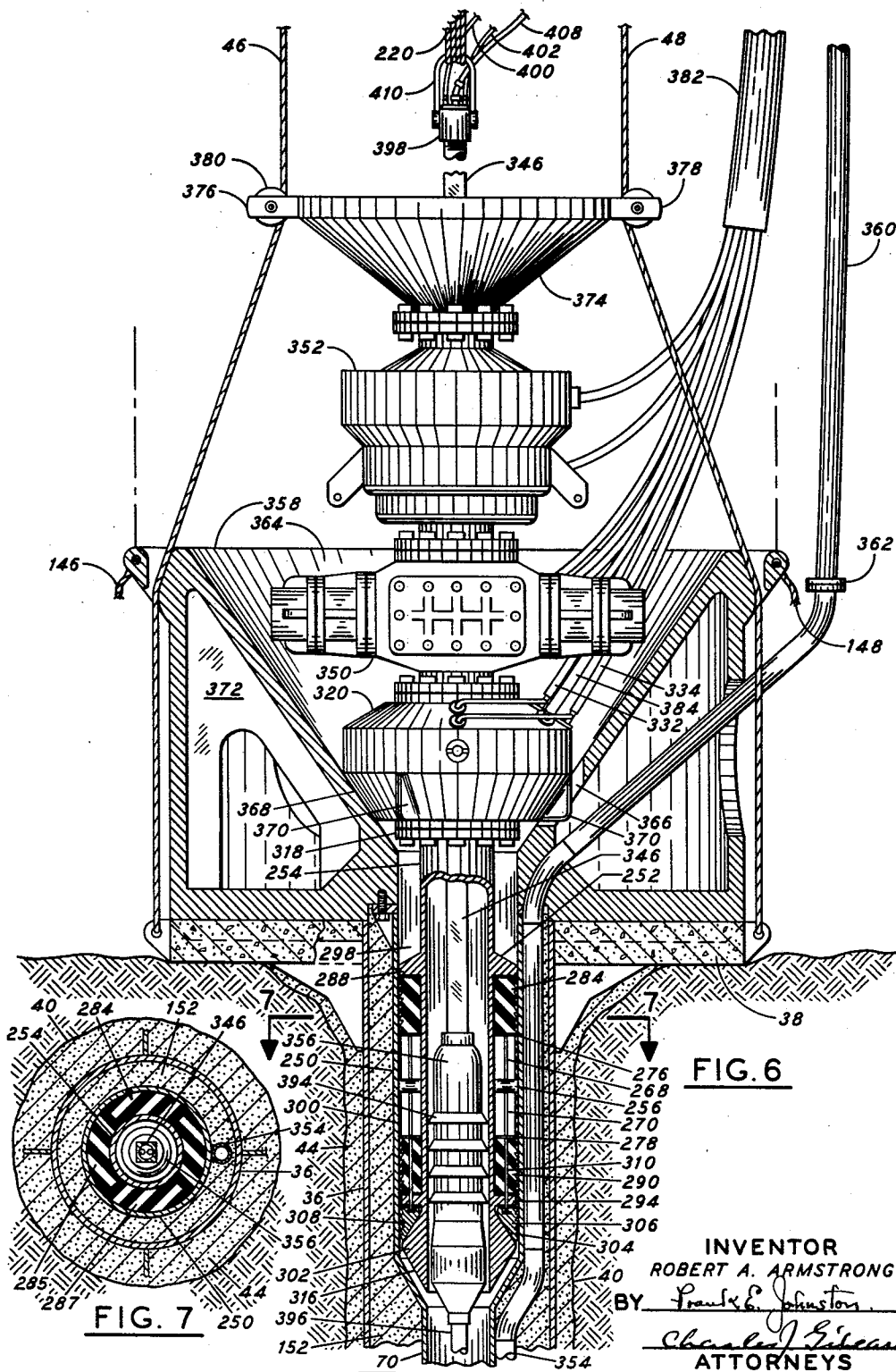


FIG. 6

FIG. 7

INVENTOR
ROBERT A. ARMSTRONG
BY Frank E. Johnston
Charles E. Gibson
ATTORNEYS

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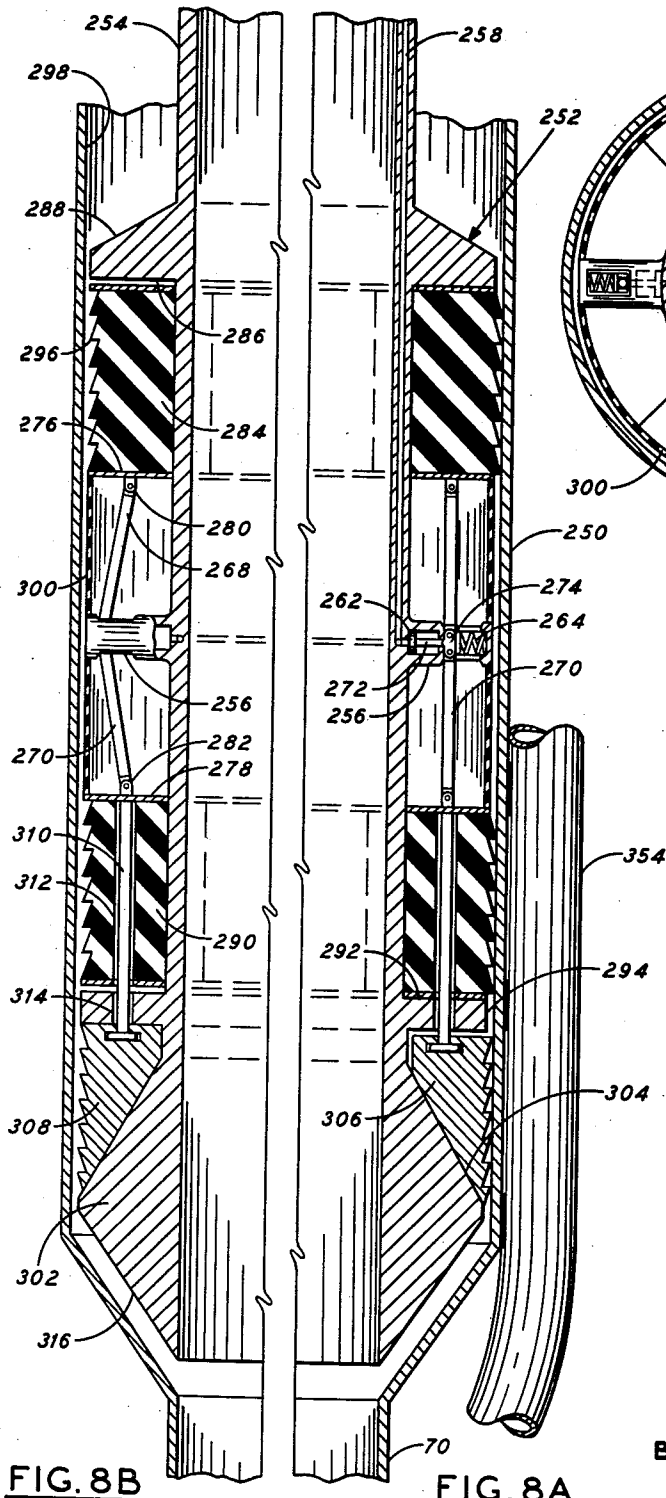
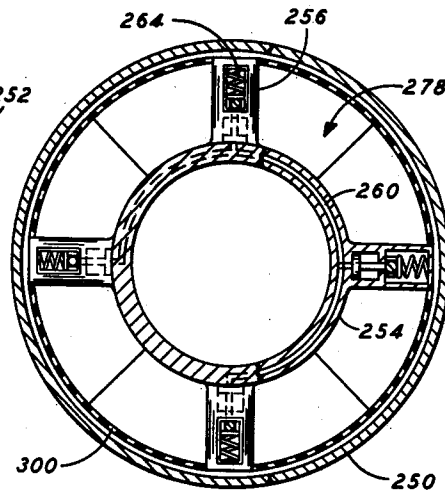


FIG. 9

INVENTOR
ROBERT A. ARMSTRONG
BY Frank E. Johnston
Charles E. Gibson
ATTORNEYS

April 21, 1964

R. A. ARMSTRONG
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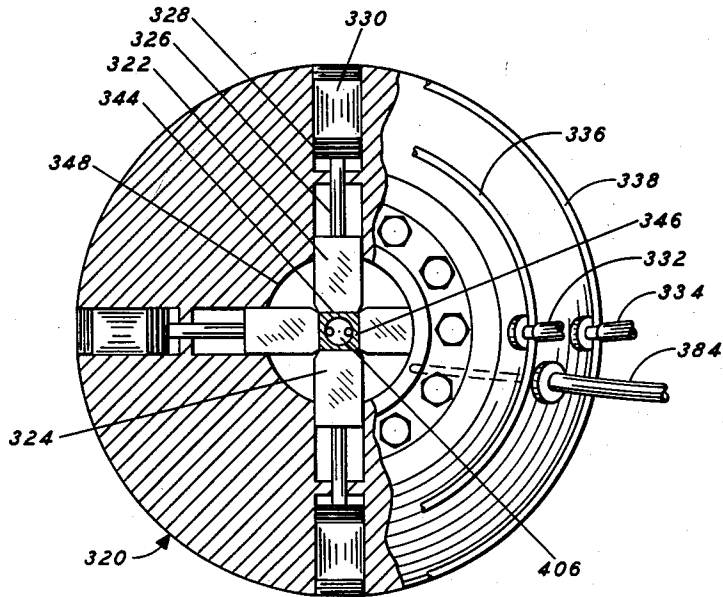


FIG. 10

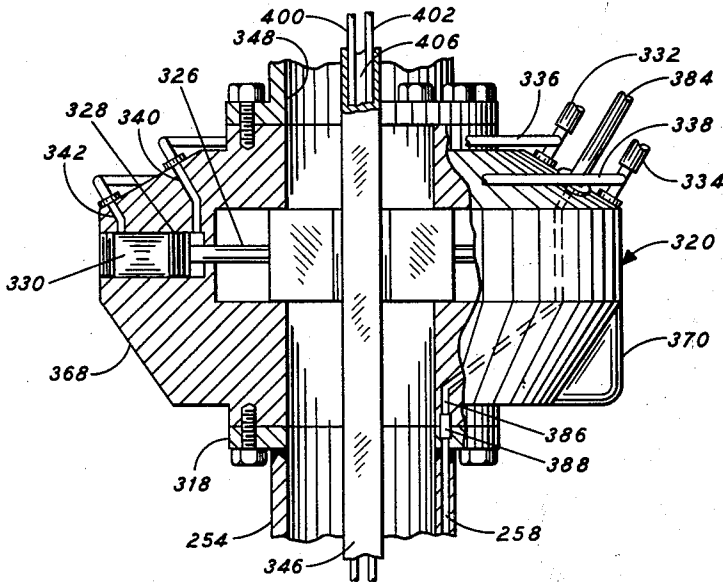


FIG. 11

INVENTOR
ROBERT A. ARMSTRONG
BY Frank E. Johnston
Charles J. Gibbons
ATTORNEYS

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R. A. ARMSTRONG
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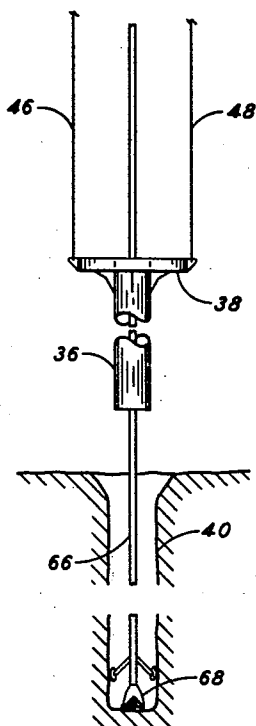


FIG. 13

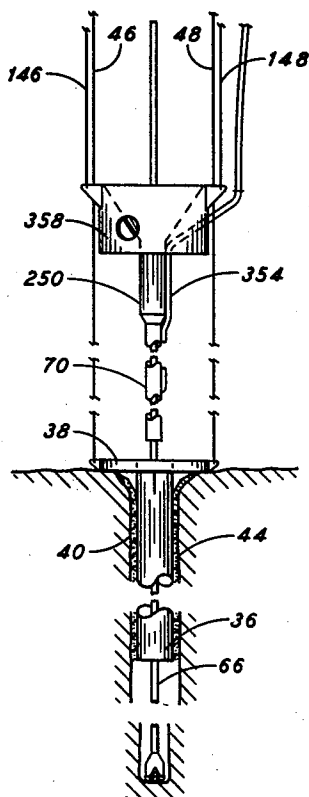


FIG. 14

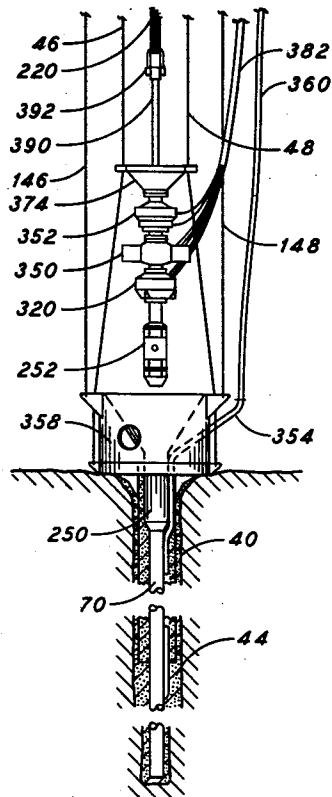


FIG. 15

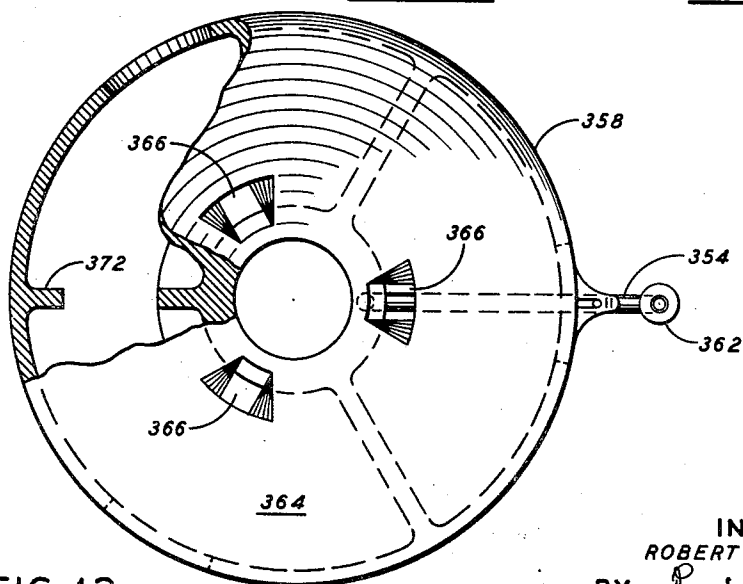


FIG. 12

INVENTOR
ROBERT A. ARMSTRONG
BY Frank E. Salton
Charles J. Gibbons
ATTORNEYS

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METHOD AND APPARATUS FOR DRILLING AND WORKING IN OFFSHORE WELLS

Robert A. Armstrong, Laguna Beach, Calif., assignor to California Research Corporation, San Francisco, Calif., a corporation of Delaware

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11 Claims. (Cl. 175—7)

This invention relates to a method and apparatus for drilling and working in an offshore well from a drilling platform at the surface of the water, and more particularly to means for drilling from a fully floating platform by apparatus which is not susceptible to being damaged because of stresses induced in it through the displacement in position of the drilling vessel by the variable wind and water forces acting on the latter.

It has been proposed heretofore that well bores be drilled in submerged locations by extending a drill string downwardly from a floating drilling platform and into the submerged earth and drilling a well bore by rotating the drill string through a rotary table aboard the drilling platform. Guidelines are employed to guide the lower end of the drill string into alignment with the submerged well bore into which it is inserted through rigidly fixed, submerged wellhead control apparatus. The drill string is restrained from flexing laterally at the portion of it confined within the rigidly fixed wellhead control equipment, while immediately above this equipment the drill string rises unsupported through the water and is displaced from a truly vertical position either by the water forces acting on it or by the displacement of the drilling vessel from a position directly above the submerged well site.

The major portion of the stress caused by the displacement of the drill string from a vertical position will occur at the point where it enters the rigidly fixed wellhead control apparatus, since this will be the point where the drill string bends most abruptly. During the drilling operation the stress concentration at this point in the drill string, particularly if the drilling vessel has moved in its anchored position from a point approximately directly above the submerged well, may exceed the strength limits of the drill pipe and cause it to rupture.

The possibility of damaging the drill string or the submerged wellhead control apparatus increases when the forces at the surface of the water which affect the position of the drilling vessel become more severe. When storm conditions are approached, it is necessary from the standpoint of safety of the operation to stop drilling and withdraw the drill string from the submerged well bore until conditions become more favorable for the drilling to proceed. If the drilling vessel does not obtain warning of an approaching storm in sufficient time to withdraw the drill string, or in some manner detach it from the drilling vessel, the danger of parting the drill string and losing a portion of it in the well bore, or of damaging the wellhead control apparatus in such a manner that a blowout of the well cannot be prevented, are readily apparent hazards.

In the above-described method for offshore drilling, a second point of high stress concentration occurs in the drill string at the position where it is supported in the rotary table on the drilling vessel. Gimbal-mounted

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rotary tables have been used on floating drilling vessels to support the drill string without transmitting the rolling motion of the drilling vessel to it and have operated adequately under normal water conditions. However, in rough water the limits of permissible motion of the gimbal-mounted rotary table may be exceeded, or the physical clearance between the drill string and adjacent portions of the drilling vessel may not be sufficient to accommodate the relative motion between the drill string and the drilling vessel when the latter is rolling or pitching excessively. In these circumstances the upper portion of the drill string has a bending load placed on it which either in itself may exceed the allowable tensile stress of the metal or may be transmitted to the lower portion of the drill string to increase the stress at the location where it enters the submerged wellhead apparatus. Thus, the possibility of failure of the drill string is increased.

It is an object of this invention to provide a novel method and apparatus for offshore drilling from a floating surface platform in which the drill string connection between the platform and the submerged well bore is eliminated and the possibility of damaging the drilling equipment or losing the well when the drilling platform is inadvertently displaced from a position directly above the well bore is obviated.

Another object of this invention is to provide a novel arrangement of apparatus which will permit an offshore drilling operation from a floating drilling vessel to be continued while the drilling vessel is exposed to rough water conditions without danger of damaging either the drilling apparatus or the well.

A further object of this invention is to provide means for drilling and working in a submerged well bore from a floating drilling vessel while maintaining a fully flexible connection between the drilling vessel and the submerged well which will permit the drilling vessel to move from a position approximately vertically above the well bore without damaging the drilling or well working equipment extending from the vessel into the submerged well bore or causing the drilling operation to be halted.

Other objects of this invention will become apparent as the description of it proceeds hereinafter and with reference to the accompanying drawings, which form a part of this specification.

In accordance with this invention, a fully floating drilling platform is anchored at the surface of a body of water above a submerged well site. A length of casing is lowered from the platform and into an appropriate bore in the submerged earth, to which it is cemented to fix it rigidly in place. The top end of the casing is positioned at the underwater bottom, and to it is attached a guide funnel which rests on the submerged land surface with the open end of the funnel directed upwardly. The guide funnel is connected to the drilling platform by fully flexible guidelines which permit displacement of the drilling platform relative to the submerged well site while maintaining a communication between the platform and the submerged well.

The drilling apparatus comprises a hydraulic motor assembly which is constructed to be received and operated within the upper portion of the casing in longitudinally sliding relationship with means provided to prevent relative motion between the motor assembly and the casing. The motor is energized through fully flexi-

ble power lines connecting it with the drilling platform to rotate a drill string and drill bit operatively connected to and extending downwardly from the motor assembly into the well bore to place the drill bit at the bottom of the borehole.

A conduit for drilling fluid is formed through the assembly and communicates with the interior of the tubular drill string. This conduit is connected by a fully flexible conduit to the drilling platform to permit a drilling fluid to be pumped from the platform to the drill bit. A return conduit for drilling fluid communicates with the casing below the lowest point of travel of the motor assembly and is also connected with the drilling platform through a fully flexible return conduit.

The motor assembly includes flexible packing means which closes the annulus between the assembly and the inner wall of the casing in a fluid-tight manner, both to exclude the sea water from flowing into the open upper end of the casing and to divert the return drilling fluid flowing upwardly in the annulus between the drill string and the wall of the borehole or the inner wall of the casing into the return drilling fluid conduit.

The motor assembly is connected by supporting lines to a traveling block which in turn is connected to a crown block of a derrick mounted on the drilling platform above a trunk in the central portion of the platform, which trunk is constructed to provide an opening through the platform from the working deck to the water beneath it. The lines between the crown and traveling blocks are operated by a drawworks to lower and raise the traveling block and the motor assembly connected to it through the water toward and away from the submerged well bore. While drilling is progressing, the motor assembly is supported by the derrick, and the drawworks is operated to lower the motor assembly downwardly in the casing to follow the drill bit as the hole is deepened. The assembly is supported with sufficient restraint to maintain a predetermined weight on the drill bit in contact with the bottom of the well bore.

The motor assembly is guided by the guidelines and guide funnel into the upper portion of the submerged casing where the motor is set in operation through the flexible power lines connecting it with the drilling platform. The motor assembly has a range of permissible travel of up to 90 feet in the upper portion of the casing, a distance equal to three times the length of a standard section of drill pipe. When the motor assembly reaches the lower limit of permissible travel, it, together with the drill string connected to it, is raised through the water until the motor assembly and top portion of the drill string are on the deck of the drilling platform. Additional sections are then placed in the drill string, and the assembly is again lowered through the water and into the submerged casing to drill additional hole.

Blowout preventer means are provided to enable the opening of the well bore to be closed if conditions requiring this are encountered during the drilling operation. In one embodiment of the invention, the blowout preventer means is incorporated with the motor assembly in a unitary manner and is operated to pack off the well bore immediately above the motor assembly at any point of travel of the latter within the upper portion of the submerged casing. In another embodiment of the invention, the blowout preventer equipment is rigidly affixed to the top portion of the submerged casing, and the motor assembly travels through it as it is lowered or raised into and out of its operating position.

All of the lines connecting the submerged apparatus with the floating drilling platform, including the mud lines, the power lines, and the lifting and lowering lines, are fully flexible and permit the drilling platform to move with the surface of the water or be displaced from a position directly above the submerged well bore without disturbing or interrupting the drilling operation. The equipment of this invention permits the drilling platform

to be exposed to sudden storms or other rough-water conditions without danger of damaging the drilling equipment or losing control of the submerged well.

The following specification, together with the accompanying drawings which form part of it, describes several modifications of apparatus for accomplishing the objects of this invention.

With reference to the drawings:

FIG. 1 illustrates in side elevation and partly in section an offshore drilling operation in which apparatus made in accordance with this invention is being used.

FIG. 2A illustrates in side elevation and partly in section an arrangement of the apparatus within the region of the opening of a submerged well, and illustrates the position of the motive power and blowout preventer equipment within the upper portion of the well casing while a drilling operation is being performed.

FIG. 2B illustrates a lower extension of the arrangement illustrated in FIG. 2A and indicates the relative positions of various valves and conduits within this portion of the well casing.

FIG. 3 is a plan view taken along the line 3—3 of FIG. 2B.

FIG. 4 illustrates in side elevation and partly in section details of the blowout preventer and interconnected portions of the equipment of this modification of the invention.

FIG. 5 is a plan view taken along the line 5—5 of FIG. 4.

FIG. 6 illustrates in side elevation and partly in section apparatus of another embodiment of this invention in the region of the opening of a submerged well.

FIG. 7 is a plan view taken along the line 7—7 of FIG. 6.

FIG. 8A is a detail in sectional elevation of apparatus employed for securing portions of the equipment illustrated in FIG. 6 to the submerged well casing and showing this apparatus in one position of operation.

FIG. 8B is a detail similar to FIG. 8A and showing the apparatus in another position of operation.

FIG. 9 is a sectional plan view of the apparatus in the operating position of FIG. 8A taken through a mid-section thereof with portions broken away to show further details of the construction.

FIG. 10 illustrates in plan view and partly in section apparatus employed in the embodiment of FIG. 6 for preventing relative reverse rotation of the power unit actuating the drill string.

FIG. 11 is a view in side elevation and partly in section of the apparatus of FIG. 10.

FIG. 12 is a plan view partly in section of a guide funnel employed in the embodiment of the invention illustrated in FIG. 6.

FIGS. 13, 14 and 15 are schematic illustrations of procedures employed while establishing equipment of this invention at a submerged well site.

Referring to FIG. 1 of the drawings, there is illustrated an offshore drilling vessel 20 anchored at the surface of a body of water 22 at a site where a well is to be drilled in the submerged earth 24. The drilling vessel is made with a trunk 26 amidships through which drilling and well-working equipment can be lowered and raised from the deck 28 of the vessel through the body of water beneath the vessel and into and out of a submerged well bore. A derrick 30 is mounted on the vessel to extend above the trunk 26, and a drawworks 32 associated with the derrick provides the power for operating the lifting and lowering lines 34.

In the initial stages of establishing the submerged well, a length of conductor casing 36, to the top of which is affixed a base plate 38, is set in a hole 40 formed directly beneath the drilling vessel with the base plate in contact with the submerged land surface 42, and the conductor casing is cemented throughout its length to the earth, as indicated by the cement 44. The base plate is connected

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to the drilling vessel by a pair of fully flexible guidelines 46 and 48 which are attached to the base plate at diametrically opposite sides of it at the projections 50 and 52, respectively. The guidelines extend upwardly through the water and are mounted over respective pulleys 54 and 56 on the drilling vessel and thence are connected to respective winch mechanisms 58 and 60. In their operating condition, respective counterweights 62 and 64 interpose a load on each guideline which holds the guidelines at a substantially constant tension as the vessel moves with the surface of the water and changes elevation relative to the underwater bottom.

A preferred method for setting the conductor casing and base plate secured at the underwater bottom is schematically indicated in FIG. 13. A length of conductor casing 36 to the top of which the base plate 38 is affixed is suspended within the water through the trunk 26 of the vessel by the guidelines 46 and 48 which at this time are not loaded with their corresponding counterweight masses. A drill string 66 with an expandable and retractable drill bit 68 attached to the lower end thereof is passed downwardly from the drilling vessel longitudinally through the suspended conductor casing to place the drill bit in contact with the submerged earth. A drill string is rotated by a rotary table aboard the drilling vessel to drill a hole 40 into the submerged earth of sufficient diameter and depth to receive the length of conductor casing.

With the drill string remaining in the borehole, the conductor casing and attached base plate are lowered along the drill string by paying off the guidelines from their respective winches. The drill string acts as a guiding means to guide the conductor casing into the borehole. The conductor casing and attached base plate are lowered until the conductor casing is fully inserted into the borehole and the base plate is resting on the submerged land surface. The conductor casing is then cemented throughout its length to the walls of the borehole by cement forced downwardly from the drilling vessel through the drill string or, alternatively, through a string of tubing in a manner familiar to the art.

The guidelines 46 and 48, which were employed as lowering lines during the foregoing procedure, are slacked off while the cement is setting, so that the motion of the drilling vessel will not move the conductor casing and base plate from its desired position relative to the submerged land surface. After the cement is set, the counterweight masses 62 and 64 are applied to the guidelines to hold them taut while they are used to guide other apparatus downwardly from the drilling vessel to the submerged well opening.

The drill string and drill bit used to drill the hole for the conductor casing are withdrawn from the hole and elevated to the drilling vessel. The drill bit is replaced by one of smaller diameter to drill a hole of the proper size to accept a string of surface casing 70. The drill string and attached drill bit are lowered from the drilling vessel and guided into the open upper end of the conductor casing. The taut guidelines and a pair of guide arms (not shown), similar to the guide arms 72 of FIG. 1, but constructed to fit the drill string 66, assist this operation. The drill bit is lowered through the conductor casing 36 until it comes into contact with the subterranean formations below it, and the drill string is rotated by means aboard the drilling vessel to deepen the borehole the amount necessary to accept a predetermined length of surface casing.

The desired length of surface casing will depend upon the character of the earth formations into which the well bore is drilled, and this string of casing is long enough both to achieve the shutoff of the surface water when the casing is cemented in the borehole and to form a secure anchor against blowout of the casing under the effect of high-pressure well fluids.

A guide funnel structure 74 is rigidly affixed to the top-

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most end of the string of surface casing, as by bolting a flange 76 of the surface casing to the guide funnel structure, as shown in FIG. 2A.

A plurality of torque rails 78 are rigidly affixed to the inner wall of the upper portion of the string of surface casing in circumferentially uniformly spaced-apart relationship. The torque rails extend from approximately the upper end of the string of surface casing downwardly into it a distance of from one to several times the length of a standard section of drill pipe, that is, from approximately 30 to approximately 90 feet. The torque rails are designed to receive in longitudinally sliding contact complementary notches or keyways formed in a motor assembly proportioned to be received within the upper end portion of the string of surface casing, as will be described in more detail hereinafter.

Extending along the exterior surface of the upper portion of the string of surface casing is a conduit 80 within which is a second concentric conduit 82. These conduits extend longitudinally along the upper portion of the string of surface casing downwardly to a position below the lowermost ends of the torque rails 78 where the inner conduit 82 communicates with the interior of the surface casing through a port 84. The lower end of the inner conduit 82 is secured in a tubing anchor 86 which is inserted into the outer conduit 80 and closes the annulus between the two conduits. The port 84 is formed through the wall of the surface casing at a position far enough below the lower ends of the torque rails to permit valves and packers to be positioned at predetermined locations along the surface casing in positions between the port and the lower ends of the torque rails.

The conduits 80 and 82 preferably are metal conduits made in sections which can be assembled together as the string of surface casing is made up to the desired length. Preferably these conduits extend diagonally through the interior of the guide funnel structure 74, as indicated by the numeral 90, and through an opening 88 in the outer wall thereof to dispose their ends exteriorly of the guide funnel structure. A fully flexible corresponding conduit, 92 and 94, respectively, is connected to the rigid conduits 80 and 82 by appropriate connectors, as indicated by the flange 96 in FIG. 2A, and the flexible conduits extend upwardly through the water to the drilling vessel. The inner conduit 82 is used as a drilling fluid return line during the drilling operation, and as a production line when the well is completed. The outer conduit 80 may be used initially to pressurize a packer against the drill string, and subsequently as an entry into the casing string to facilitate working on or treating the well when it is put on production.

A valve 98 is set within the surface casing above the opening of the port 84. This valve, which is schematically illustrated in FIG. 2B, may be similar to a known type of production packer, an example of which is illustrated in the Composite Catalog of Oil Field Equipment and Services, published by World Oil, Houston, Texas, 22nd Edition, 1957, Vol. 1, page 590. The valve is constructed to be set in the casing string after the latter is made up, and employs sets of slips 100 and 102 with a flexible packing element 104 between them, by which combination the valve is held in place within the string of casing with a fluid-tight seal formed between the valve and the inner wall of the casing. A flapper valve 106 is pivotally mounted on the lower end of the valve body and biased by a spring 108 to swing to a closed position to completely block the passage through the string of casing. The flapper valve may be pivotally displaced by an object, such as a drill bit, which is pushed downwardly on it and will then open to permit passage of the object downwardly through the string of casing. When this object is withdrawn from the well bore, the flapper valve will swing closed and prevent the passage of well fluids upwardly through the casing.

Set above the valve 98 is a flexible packer 110 which

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can be operated by hydraulic pressure to constrict around a drill string, or similar object, or pack off against it with a fluid-tight seal. The packer 110 is set a sufficient distance above the valve 98 to permit a drill bit to clear the flapper valve 106 and the latter to close prior to the time the drill bit reaches the packer.

As illustrated in FIG. 2B the packer 110 comprises a flexible rubber sleeve 111 which is secured at its top and bottom edges, respectively, to rings 113 and 115. The rings fit within the casing string in sliding relationship and engage the inner wall of the casing with a fluid-tight seal, as by means of O-rings 117 and 119 which are mounted in the periphery of the ring. The packer is held in position against the pressure of well fluids by slips 121 which may be constructed to set the packer assembly in the casing string, after the latter is made up, in a manner analogous to that described heretofore for the valve 98.

The packer 110 is set in the casing string at the location of a port 123 formed through the wall of the casing and communicating with the interior chamber 125 of a fitting 127, which latter is affixed to the exterior surface of the casing in a fluid-tight manner. The fitting 127 is interposed in the conduit 80, and the chamber 125 forms a continuation of this conduit while providing communication between it and the annular chamber 129, of which the rubber sleeve 111 forms one wall. When a hydraulic fluid under pressure is introduced into the chamber 129 through the conduit 80, the rubber sleeve constricts around the drill string and prevents well fluids from blowing by the packer. When the pressure is released from the conduit 80, the rubber sleeve relaxes and retracts from the drill string, permitting a drill bit to be pulled through it.

A sleeve valve, such as represented schematically by the valve 112, may be placed in the string of surface casing above the position of the packer 110 to provide a communication with the upper portion of the casing string through the conduit 80. This sleeve valve may be made an integral part of the surface casing and constructed to permit passage of the valve 98 and packer 110 through it when the latter are being set in the casing, or may be a valve formed with slips in the manner of valve 98 to be inserted into the casing string after it is made up. The sleeve valve is made with a port 114 which can be brought into alignment with a complementary port 116 formed through the wall of the surface casing and communicating with the interior of the conduit 80. Valves of the type known as "full bore circulating valves," an example of which may be found at pages 1974 and 1976 of the above-noted Composite Catalog, may be used for this purpose.

In the embodiment of the invention illustrated in FIG. 2B the sleeve 118 is placed within a diametrically enlarged portion 120 of the casing to dispose the inner wall of the sleeve in alignment with the inner wall of the casing. Thus, the full bore of the casing is maintained in the region of the valve. The valve sleeve may be engaged by an appropriate tool inserted into the casing and moved in an axial direction between the shoulders 122 and 124 to bring the port 114 into alignment with the port 116 or to cause the sleeve to close the port 116. A fitting 126 similar to the fitting 127 and containing a chamber 128 is affixed to the exterior surface of the casing 70 in a fluid-tight manner at the location of the sleeve valve, and the port 116 through the wall of the casing communicates with this chamber, as indicated in FIG. 3. Sections of the conduit 80 are secured to the fitting in a fluid-tight manner, and the chamber 128 forms a continuation of this conduit while providing communication between it and the interior of the surface casing when the valve 112 is open. The conduit 82 is separately continuous through the chambers 127 and 128.

The string of surface casing and the conduits 80 and 82 associated with it are made up to the desired length from sections assembled aboard the drilling platform, and the lower portion of the assemblage is lowered away from the platform as it is made up. The drill string 66 which

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was used to drill the hole to receive the surface casing remains in the borehole during this operation, and the string of surface casing is threaded over the drill string, which serves to guide it into the borehole.

When the string of surface casing is made up to its desired length, the guide funnel structure 74 is secured to the top end of it. The flared end 130 of the funnel is directed upwardly toward the drilling platform, and the apex of the funnel has an opening 132 through it in alignment with and of the same diameter as the internal diameter of the surface casing. The funnel structure has an extended bottom 134 which meets with and rests securely on the base plate 38 to support the string of surface casing prior to the time the latter is cemented in the well bore. A circumferential skirt 136 is provided to give rigidity to the structure, and a plurality of openings similar to the opening 88 may be formed through it.

Radially outwardly extending projections 138 and 140 are formed in a unitary manner on each side of the guide funnel structure at the upper portion thereof and are positioned on diametrically opposite sides of it in alignment with the projections 50 and 52 of the base plate. A respective axially directed hole 142 is formed in each projection to receive the corresponding guideline 46 and 48 in sliding relationship. Each projection has a second hole 144 formed in its outer end portion to receive a corresponding line 146 and 148, respectively, by means of which it and the string of surface casing attached to it can be lowered from the drilling vessel through the water to the submerged well opening. Prior to lowering the guide funnel structure through the water, the flexible conduits 92 and 94 are connected to the corresponding conduits 80 and 82. The upper ends of these flexible conduits are retained aboard the drilling platform as the surface casing and guide funnel structure assemblage is lowered through the water.

The lines 146 and 148 are operatively attached to appropriate winches, not shown, aboard the drilling platform, and the surface casing and guide funnel structure assemblage thus can be lowered from the drilling platform and guided by the taut guidelines and the drill string, as explained heretofore, into registry with the submerged well bore, as indicated schematically in FIG. 14. The assemblage is lowered until the bottom of the guide funnel structure rests securely on the base plate 38.

The surface casing is then cemented in the well bore, as indicated by the cement 150, either by a cementing material forced down through the drill string or by other procedures familiar to the art. The cement is forced upwardly in the annulus between the surface casing and the wall of the borehole and also upwardly into the annulus between the string of surface casing and the conductor casing, as indicated at 152, until the cement reaches the base plate. Thus, the two strings of casing are cemented securely to each other and to the wall of the borehole throughout their length from the surface of the submerged land to the bottom end of the string of surface casing.

The lines 146 and 148 may now, if desired, be severed close to the guide funnel structure and cleared from possible entanglement with other parts of the submerged apparatus. In some installations, it may be desirable to leave these lines attached to the submerged guide funnel structure to assist in the recovery of the latter when a drilling operation is completed, as indicated in FIG. 15.

With the guide funnel firmly established around the submerged well opening and with the string of surface casing, including the torque rails in the upper portion thereof, firmly secured to the earth, the submerged apparatus is ready to receive the drilling equipment by which the well bore can be deepened into an oil formation.

In the embodiment of the invention illustrated in FIG. 2A, the drilling equipment comprises a motor assembly 154 in which a hydraulically operated motor, preferably of the type known to the art as a power swivel, is encased in a housing 156 proportioned in transverse dimension to

be received in sliding relationship within the upper portion of the string of surface casing. The motor assembly housing has keyways or notches 158 formed in its exterior surface complementary with and made to receive the torque rails 78 in sliding relationship. The hydraulic motor within the housing is operatively connected to a string of drill pipe 160, the latter of which is assembled from sections in the usual manner. The drill string may, if desired, contain telescoping splined sections 162 which will transmit the rotary motion of the drill string to the bit connected to the lower end of it while permitting some vertical motion of the motor assembly without affecting the pressure of the drill bit on the bottom of the hole.

A series of flexible packing elements 164 are affixed to the exterior wall of the housing 156 and project radially toward and into contact with the inner wall of the surface casing. These packing elements are notched to receive the torque rails in a fluid-tight sliding contact and engage the inner wall of the surface casing in a like manner. The packing elements 164 pack off the annulus between the housing 156 and the surface casing to prevent the encroachment of sea water into the borehole and to prevent the drilling mud in the borehole from flowing upwardly in the casing past the motor assembly.

A blowout preventer assembly is rigidly affixed to the top end of the motor assembly and is proportioned in lateral dimension to be received within the upper portion of the string of surface casing and to move longitudinally of it as the motor assembly moves. As illustrated in FIGS. 2A and 4, the blowout preventer assembly 166 comprises a housing 168 which has mounted in its circumferential wall packing elements 170 and 172 and gripping elements 174, the latter in the form of slips. Each packing element, as represented by the packing element 172, is made of a rubberlike material in the form of a ring, the outer circumferential surface of which has formed in it axially disposed notches 176 to receive a corresponding torque rail in sliding relationship. Preferably these notches are made with radial surfaces which converge toward the mating torque rails, as indicated at 178, to assure a fluid-tight seal between the packing material and the sides of the torque rail when the packing material is pressed against the latter. The ring of packing material passes through a circumferential opening 180 in the wall of the housing 168 and into contact with a flexible diaphragm 182 which is secured in a fluid-tight manner at both its axially upper and lower marginal edges to the inner wall of the chamber 184 within the housing 168. Pressure placed against the inner surface of the diaphragm 182 forces the ring of packing material to expand radially outwardly and into fluid-tight contact with the inner wall of the surface casing and with the torque rails and prevents the blowout of well fluids past the blowout preventer assembly.

The gripping elements, as represented by the gripping element 186, are segments of a hard steel ring. Each segment is mounted in a corresponding opening 188 through the circumferential wall of the housing 168, and they are displaced circumferentially apart from each other to engage the inner wall of the surface casing in the space between the torque rails. The gripping elements are backed by a flexible diaphragm 190 secured to the inner wall of the chamber 192 of the blowout preventer assembly in a fluid-tight manner, and the gripping elements are mounted to move radially inwardly and outwardly with respect to the housing as pressure is applied to and released from the chamber. The outer circumferential surfaces of the gripping elements are formed with a series of laterally disposed, sharp edges 194 which will engage the inner wall of the surface casing when the gripping elements are forced into engagement with it and thus prevent the blowout preventer assembly from being forced upwardly in the surface casing under the pressure of well fluids.

The chamber 192 is in communication with the chamber 184 through openings 196 formed through the diametrically disposed strengthening member 198. The packing and gripping elements are extended and retracted by the pressure changes in a hydraulic fluid which is introduced into and withdrawn from the chamber through a flexible conduit 200 which extends to the drilling platform and is connected to a suitable source of motive fluid.

A centrally disposed passageway 202 extends axially through the blowout preventer assembly to receive a group of conduits which are operatively connected to other elements of the drilling apparatus. These conduits include the hydraulic lines 204 and 206, which are connected to the motor assembly, and the drilling fluid conduit 208, which communicates with the interior of the string of drill pipe. Each conduit is connected at the top member 209 of the assembly with a corresponding fully flexible conduit which communicates with the appropriate auxiliary equipment on the drilling platform. Thus, the conduit 208 is connected to the flexible conduit 210 which extends to the drilling platform and is operatively connected to mud pumps which can be employed to force the drilling fluid downwardly into the string of drill pipe and thence to the drill bit to perform its usual function. The conduits 204 and 206 are connected, respectively, to the flexible lines 212 and 214. These lines are connected on the drilling platform to a source of hydraulic fluid which can be forced down one line and returned through the other to circulate through the motor unit of the motor assembly and provide the power for rotating the drill string. The closed system for circulating the hydraulic fluid to the motor assembly prevents the contamination of this fluid by extraneous material, such as drilling mud or cuttings from the well, and prolongs the life of the motor unit by preventing abrasive substances from being introduced into its mechanism.

As mentioned heretofore, the blowout preventer assembly is connected to the motor assembly in a rigid manner, such as by the mating screw threads 216, and both assemblies move as a unit. If a high-pressure formation is entered while the well is being drilled, the blowout preventer can be operated from the drilling vessel to close the well immediately at the elevation of the blowout preventer equipment within the surface casing. The well may then be brought under control by forcing a weighted drilling mud into it through the drilling fluid return conduit 82, in a manner familiar to the art.

A pivoted bail 218 is mounted on the top member 209 of the assembly and serves as a means for connecting the supporting lines 220 to the submergible drilling equipment. These lines run upwardly through corresponding guide holes in a central hub 222 of a pair of guide arms 72 which stretch rigidly between and are designed to run along the guide cables 46 and 48. A guide collar 226 is securely but detachably affixed to the end of each guide arm, as shown on the guide arm 224, and surrounding the complementary guide cable. Preferably the guide collars and the central hub 222 are made in half-sections which can be assembled together surrounding their corresponding lines or separated apart to enable the guide arms to be cleared from the apparatus. The guide arm serves to keep the supporting lines separated to prevent them from becoming entangled with each other as the equipment is raised and lowered through the water, and assist in orienting the motor assembly and blowout preventer assembly with the opening of the surface casing as these assemblies are lowered into it.

The supporting lines 220 continue upwardly to a traveling block 226 which has demountable guide arms 228 and 230 extending transversely from it to the guide cables to which they are connected in sliding relationship, as indicated in FIG. 1. The traveling block is designed to move upwardly and downwardly through the body of water as the drilling equipment is raised and lowered in the well bore. The guide arms 228 and 230 restrain the

traveling block to the plane of the guide cables 46 and 48 and assist in preventing the supporting lines 220 from becoming entangled through the action of water forces on the parts of the equipment exposed thereto.

Secured to the outer end of guide arm 230 are guide sleeves 232 through which the flexible conduits from the submerged equipment pass in sliding relationship. These guide sleeves preferably are made in half-sections which can be separated to release the conduits from their confinement. Desirably, the flexible conduits connected to the blowout preventer assembly, including the drilling fluid line and the hydraulic lines to the motor assembly, are gathered together in a bundle and placed within a single, flexible covering 234 to prevent these lines from becoming entangled or exposed to damage through water forces or water-borne debris. The bundle of lines 234 may be wound as a unit on a winch drum 236, as indicated in FIG. 1, and the separate lines connected to the appropriate auxiliary equipment on the drilling vessel through rotary connections associated with the winch drum, in a manner familiar to the art.

The length of the drilling fluid return conduit 94 and the conduit 92 remains substantially constant once the guide funnel structure has been established at the ocean bottom and hence will not be reeled and unreeled in the manner of the other flexible conduits. These lines, therefore, may be brought up to the drilling platform separately from the other lines, as FIG. 1 illustrates. The guide sleeves 232 serve to keep the flexible conduits oriented with the submerged well bore as the associated apparatus is run in and out of it and prevents the conduits from kinking and becoming overstressed and damaged.

The traveling block 226 is connected by lines 34 through the crown block 238 of the derrick 30 with a drawworks 32. Preferably, this drawworks is of the type which is actuated by changing loads on the live line 240 to let off or take up line in a manner to maintain a predetermined constant load on the line and thus hold the bit on the bottom of the hole with a constant pressure.

In preparation for a drilling operation, a drill string 160 is made up of sufficient length to reach from the bottom of the well bore to the upper portion of the surface casing to place the motor assembly and the blowout preventer assembly in engagement with the upper end portions of the torque rails 78 when the drilling assemblage is lowered into the well bore. The connections are made aboard the drilling platform, and for this purpose a removable cover 242 is placed over the trunk 26, as indicated by the dotted lines in FIG. 1. The cover has a central opening through which the drill string extends, and is employed in the same manner as the floor of an onshore drilling rig to enable removable slips to be used to hold the depending portion of the drill string as sections are added to it.

When the drill string is made to the desired length, the drill bit of course being attached to the lower end of it, the motor assembly and related blowout preventer assembly are secured to the top of the string with the drill string in operative connection with the hydraulic motor unit. The flexible conduits are attached between the submergible units and the auxiliary equipment aboard the drilling vessel. The drilling apparatus is then lowered from the drilling vessel and into the submerged well opening, the taut guidelines, the guide funnel, and, if necessary, auxiliary guide arms placed along the length of the drill string cooperating to center the submergible apparatus within the open end of the surface casing.

The hydraulic motor of the motor assembly is placed in operation by remote control from abroad the drilling platform, and drilling fluid circulation is established downwardly through the drill string by means of the conduit 210, the return flow being received abroad the drilling platform through the flexible conduit 82. As the borehole is deepened, the motor assembly and blowout preventer assembly which are supported from the derrick 30 move longitudinally relative to the surface casing through

the operation of the drawworks 32 and downwardly into the well until they approach the lower ends of the torque rails. The hydraulic motor is then stopped, and the drawworks 32 is placed in operation to retract the submerged assemblage up to the drilling vessel until the motor assembly is at the working deck. The motor assembly is detached from the top of the drill string, and new sections are added to the latter to increase its length an amount equal to the travel permitted by the length of the torque rails. The drilling apparatus is then again lowered into the well bore, and drilling resumed.

When the well is completed and the drill string removed from it, the flapper valve 106 closes the opening of the well at the position of the valve 98. The flow of fluids from the well is diverted through the port 84 into the conduit 82, which now becomes a production line for the well fluids. The valve 112 provides access to the casing string 70 above the closed valve 98 through the conduit 80. Thus, this valve may be opened before the top end of the casing string is packed off, or capped, and may be employed to take fluids from the well or introduce fluids into it through the conduit 80. In this circumstance, preferably the packer 110 will be removed from the casing, and either the port 123 will be used as an additional opening into the casing string or a plug will be set in the fitting 127 to close this port and the well-working apparatus removed from it.

When the well is completed, the conduits 92 and 94 are cast off from the drilling platform with their upper ends buoyed at the surface of the water. Preferably, the guide cables 46 and 48 also are cast off from the drilling vessel with marker buoys attached to their upper ends so that they may be retrieved and placed in operation if it is necessary to re-enter the well bore. The drilling vessel is then free to leave the well site and proceed to a new station.

It will be apparent from the above description of the invention that, while the drilling vessel is in operation drilling the submerged well, all of the connections between it and the stationary apparatus secured to the submerged land are fully flexible, and a drilling vessel may move freely with the surface of the water or be displaced by wind or water forces from its position vertically above the well bore without causing the drilling operation to be halted or overstraining, damaging or breaking the drilling and associated equipment.

FIG. 6 illustrates another embodiment of this invention. In this embodiment, the principal well control equipment is placed at the bottom of the water exteriorly of the surface casing but secured to it by an internal clamping arrangement which can be actuated by remote operation from the drilling vessel to secure the control equipment to the well opening, or release it therefrom.

In this modification of the invention, the upper end portion of the string of surface casing 70 is radially extended to form a section 250 of increased internal diameter to receive a packing and clamping assembly 252. This assembly is formed around a conduit 254 which has the same internal diameter as a standard section of surface casing 70.

A plurality of hydraulic cylinders 256 are fixedly mounted on the conduit at approximately the mid-section of the assembly and extend radially outwardly therefrom. The external diameter of the assembly is slightly less than the internal diameter of the section 250 of the casing string to provide sufficient clearance for the assembly to be telescoped into and withdrawn from the latter.

A conduit 258 for hydraulic fluid is formed through the wall of the conduit 254 and extends in an axial direction from the location of the hydraulic cylinders 256 to the upper end of the conduit, as indicated in FIG. 8A. The hydraulic cylinders are manifolded together by a circumferential conduit 260 which may be formed in the wall of the conduit 254, as indicated in FIG. 9, or may take the form of an auxiliary circumferential conduit which communicates with each cylinder 256. A hydraulic fluid

introduced under pressure into the conduit 258 will force the pistons 262 within the cylinders 256 in a radially outwardly direction against the pressure of a respective spring 264. When the hydraulic pressure is released from the conduit 258, the spring forces the piston in a radially inwardly direction.

One end of the linkage rods 268 and 270 is pivotally connected to the piston rod 272, as by the double clevis 274, and the rods extend respectively upwardly and downwardly longitudinally of the conduit 254 to transmit motion from the piston rod to movable plates 276 and 278. The respective free ends of the linkage rods are pivoted to their complementary movable plates, as at 280 and 282. Thus, when the pistons 262 move radially outwardly, the clevises 274 and the adjacent pivoted ends of the linkage rods also are forced radially outwardly while the pivoted ends 280 and 282 of these rods remain unchanged in their relative radial position. Such a movement of the piston, therefore, draws each plate 276 and 278 toward the cylinders 256, as indicated in FIG. 8B. In the reverse operation, when hydraulic pressure is released from the conduit 258 and the springs 264 force the pistons radially inwardly, the motion transmitted to the plates 276 and 278 through the linkage rods 268 and 270 forces these plates away from the cylinder 256, as indicated in FIG. 8A.

A resilient, rubberlike ring of packing material 284 is placed between the plate 276 and a radially extending shoulder 286 of an annular projection 288 formed in a unitary manner on the outer wall of the conduit 254 at the upper portion thereof. A similar ring of packing material 290 is placed between the movable plate 278 and the radially extending shoulder 292 of the annular projection 294 formed in a unitary manner on the lower portion of the conduit 254. Each ring of packing material has radially extending, circumferential lips 296 formed on its radially outer surface. When the movable plates 276 and 278 are forced away from the position of the cylinders 256, each ring of packing material is compressed and expands radially outwardly into fluid-tight engagement with the inner surface 298 of the casing section 250. When the movable plates are retracted toward the position of the cylinders 256, the pressure is relieved from the resilient packing elements, and they retract away from the inner surface 298.

The movable plates 276 and 278 and the associated packing rings 284 and 290 may be and preferably are made of circumferentially adjoining segments, two such segments being indicated by the segments 285 and 287 of FIG. 7, with each corresponding set of segments of the assemblage connected to a respective piston rod through respective linkage rods.

The portion of the assemblage between the movable plates is enclosed in a fluid-tight manner within a skirt 300 of rubber or rubberized fabric to exclude water and well fluids from the cylinders 256 and the interconnected mechanism.

A unitary projection 302 is formed on the lower end of the conduit 254 with an upper surface 304 which converges in an upwardly direction in the form of a section of a cone. This tapered surface forms the seat for a segmented wedge-shaped slip, two of which segments are shown at 306 and 308. Each slip segment is connected by a respective rod 310 to the movable plate 278, the rod passing slidably through a corresponding passage 312 in the packing ring 290 and an aligned hole 314 in the projection 294. Thus, motion of this movable plate is transmitted to the slip segments to cause them to move radially outwardly into a wedging relationship with the inner surface 298 of the section 250 when the movable plates are forced away from the position of the cylinders 256 and to be retracted from the inner surface when the movable plates are drawn toward the position of the cylinders. When the pistons 262 are actuated by the springs 264, the slip segments are moved radially outwardly to clamp

the assembly 252 within the upper portion 250 of the surface casing, and the packing rings 284 and 290 are compressed against the inner surface 298 of the casing in a fluid-tight manner which prevents well fluids from escaping around the exterior of the clamping assembly.

The lower surface 316 of the projection 302 converges downwardly in a conical configuration to provide a surface which assists in centering the clamping assembly within the upper portion of the surface casing as it is lowered into it.

The top end of the conduit 254 terminates in a flange 318 which is bolted to a hydraulically operated kelly bushing assembly 320, as shown in FIGS. 6 and 11. The kelly bushing assembly comprises pairs of opposed rams which are operated by respective hydraulically actuated pistons to force the rams to approach each other and clamp a kelly bar between them, and in reverse operation to be retracted from engagement with the kelly bar and clear the axial passageway through the bushing assembly.

In a preferred embodiment of the invention, as shown in FIGS. 10 and 11, the bushing assembly has two pairs of diametrically opposed rams, as represented by the rams 322 and 324, to engage a square kelly bar. Each ram is slidably mounted in the body of the bushing assembly for movement radially toward and away from the center of it. Each ram is connected by a corresponding rod 326 to a respective piston 328 within a corresponding hydraulic cylinder 330. Hydraulic lines 332 and 334 are connected to respective manifold conduits 336 and 338 which in turn are connected to opposite ends of each cylinder 330 through respective passages 340 and 342, as indicated in FIG. 11. Thus the pistons 328 are powered to move simultaneously and synchronously toward or away from each other.

The radially inwardly surface 344 of each ram is made to engage a flat side of a square kelly bar 346. The rams prevent the kelly bar from rotating when the bushing assembly is actuated to the clamping position. When the rams are fully retracted from the clamping position, they clear the axial passage 348 through the bushing assembly so that its full opening is effective for the passage of equipment therethrough.

Referring again to FIG. 6, a blowout preventer 350 is bolted to the top of the kelly bushing assembly. This blowout preventer preferably is of the conventional ram type which includes rams which pack off on the kelly bar in a fluid-tight manner. Connected in sequence above the blowout preventer 350 is a second blowout preventer 352 which preferably is of the conventional type containing a resilient, annular element which can be forced into engagement with, and pack off against, apparatus of irregular shape extending through the axial opening of the blowout preventer.

In this embodiment of the invention, a single conduit 354 extends longitudinally of the upper portion of the string of surface casing and communicates with the interior of the surface casing through a port below the limits of travel of the motor assembly 356 in a manner similar to that explained heretofore with respect to conduit 82 in the previously described embodiment of the invention.

The conductor casing 36 and string of surface casing 70 are set into and cemented within the submerged well bore 40 in the manner described heretofore, and as exemplified schematically in FIGS. 13 and 14, with the guide funnel structure 358 fixedly connected to the top end of the string of surface casing and connected to the drilling vessel by the guidelines 46 and 48. The fully flexible conduit 360 is connected to the conduit 354 at the connection 362 prior to the time the string of surface casing and the attached guide funnel structure are lowered through the water.

In this modification of the invention, the inner conical surface 364 of the guide funnel structure has a plurality of slots 366 formed through it in uniformly spaced-apart positions on a circumference upon which the lower cir-

cumferential conical surface 368 of the kelly bushing assembly will rest when the latter is lowered into full engagement with the inner surface of the guide funnel. These slots are made to receive unitary projections 370 extending from the surface 368 of the kelly bushing assembly to prevent rotation of this assembly relative to the guide funnel structure when the drilling apparatus is placed in operation. The guide funnel structure is strengthened by radial webs 372 to enable it to support without damage the weight of the drilling equipment.

After the guide funnel has been secured to the submerged well opening, the clamping assembly 252, the kelly bushing 320, and the blowout preventers 350 and 352 are assembled together aboard the drilling vessel, and a second guide funnel 374 is secured to the top end of the blowout preventer 352. This second guide funnel has radial arms 376 and 378 extending from its upper edge in alignment with the guide cables 46 and 48, and respective pulleys 380 mounted on the ends of the arms engage the guide cables to guide the assembled apparatus to the submerged well opening as it is lowered through the water.

Prior to lowering the assembled well control apparatus, the hydraulically operated units have appropriately connected to them the ends of fully flexible conduits for hydraulic fluid, and these conduits are gathered together in a bundle within a single flexible cover 382, as indicated in FIGS. 6 and 15. The upper ends of these conduits are retained aboard the drilling vessel as the apparatus is lowered through the water and are connected to appropriate sources of hydraulic fluid aboard the vessel by which the submerged units of apparatus may be operated by remote control. One of these hydraulic lines 384 is connected to conduit 386 formed in the body of the kelly bushing 320, as shown in FIG. 11, and thence conduit 384 is joined by the connector 388 to the conduit 258 of the clamp assembly 252. Thus there is provided a means for controlling the action of the pistons 262 of the clamp assembly from the drilling vessel.

The interconnected, submersible apparatus described immediately above is lowered from the drilling vessel by clamping an appropriate tool 390, such as a section of kelly bar, between the rams of the blowout preventer 350 or the kelly bushing 320, or both, and connecting the supporting lines 220 to a pivoted bail 392 affixed to the top of the tool, as indicated at FIG. 15. The assemblage is lowered through the water and the clamping assembly 252 operated to telescope within the expanded upper portion 250 of the string of surface casing until the kelly bushing 320 rests in the guide funnel with the projections 370 engaging the notches 366. The clamp mechanism is then activated to clamp against the internal surface 298 of the portion 250 of the casing string and pack off the annulus between the conduit 254 and this inner surface. The tool 390 is released from the submerged apparatus and withdrawn aboard the drilling vessel.

In this modification of the invention, a motor assembly 356 is employed which has resilient packing rings 394 affixed to its outer surface in a manner similar to that described heretofore. The present motor assembly is designed to work within a smooth-walled cylindrical conduit, and hence neither the body of the motor assembly nor the packing rings incorporated with it are notched to receive the guide rails which were formerly employed.

A square kelly bar 346 is secured to the top end of the motor assembly in a manner to prevent relative rotation between the two. The kelly bar preferably has a length equal to that of several sections of standard drill pipe and may, for example, be from 30 to 90 feet long. A string of drill pipe 396 similar to the drill string 160 described heretofore is operatively connected to the motor unit within the motor assembly 356 to be rotated by the hydraulic motor to turn the drill bit attached to the lower end of the string. The length of the string of drill pipe

is selected to place the motor assembly in the region of the clamp assembly 252 when drilling is started with the drill bit resting at the bottom of the well bore. The uppermost end of the kelly bar has a top member 398 mounted on its supporting conduit connectors and a pivoted bail in the manner of the member 209.

The top member 398 has connections for two fully flexible hydraulic lines 400 and 402 which pass through it and through the longitudinal channel 406, FIG. 10, and are operatively connected to the motor assembly 356 to power the hydraulic motor therein. A third fully flexible conduit 408 connects to the top member and communicates with the channel 406 in the kelly bar to carry drilling fluid into the latter, from whence it flows through a conduit in the motor assembly and through the interconnected drill string 396 to the drill bit.

The pivoted bail 410 is mounted on the top member 398 and is connected by the supporting lines 220 to a traveling block 226 in a manner similar to that illustrated in FIG. 1. The traveling block is in turn connected to the derrick 30 and the drawworks 32 as explained heretofore.

With the wellhead control equipment submerged in the water and connected to the well opening, as illustrated in FIG. 6, and with the blowout preventers and the kelly bushing rams fully open, the motor assembly with the interconnected drill string and kelly bar is lowered from the drilling vessel and guided by the taut guide cables and interconnecting guide arms to the submerged wellhead. The drill bit is guided by the guide funnel 374 into alignment with the well bore, and the assemblage is lowered until the drill bit contacts the bottom of the well bore. The length of drill string 396 has been selected to place the motor assembly 356 below the kelly bushing 320 at the beginning of the drilling operation. The rams of the kelly bushing are closed on the kelly bar with sufficient pressure to prevent the kelly bar from rotating, while permitting it to slide downwardly into the surface casing as the drill bit deepens the well. Telescoping splined sections may be used in the drill string, similar to the sections 162 of the first-described embodiment of the invention, to permit some variation in elevation of the motor assembly while maintaining constant bit pressure in the bottom of the well bore. The drilling fluid is forced downwardly from the drilling vessel through the fully flexible conduit 408 and ultimately to the drill bit. Drilling fluid return is through the conduit 354 and the fully flexible conduit 360 back to the drilling vessel.

The drilling operation is continued until the kelly bar reaches the downward limit of its permissible travel. The drilling apparatus is then withdrawn from the well bore and elevated to the drilling vessel, where additional sections are added to the drill string below the motor assembly 356. Again the drilling apparatus is lowered into the well bore, and drilling is continued.

When the drilling operation is completed, the motor assembly and drill string are withdrawn from the well bore, and the well is packed off by a retrievable packer in the surface casing below the position of the expanded portion 250. The clamp mechanism 252 is then released from engagement with the surface casing and, together with the well control equipment connected to it, is recovered aboard the drilling vessel. Well completion and control equipment is then installed, and the well production taken off through flexible conduits, either to surface or submerged storage tanks or to an onshore installation. As explained heretofore, the drilling fluid return conduit also may be used as a production line.

In the embodiment of the invention described immediately heretofore, it will be noted that all connections between the floating drilling vessel and the fixed, submerged equipment are fully flexible and permit the vessel to move with the surface of the water or be displaced from a position directly above the submerged well bore without disturbing the drilling operation.

It is apparent that the method of operation and the apparatus of this invention fulfill the objects for which it was designed. Other modifications than those described herein may be made to the apparatus of this invention, or equivalent apparatus employed, without departing from the inventive concept. Therefore, it is intended that the invention embrace all equivalents within the scope of the appended claims.

I claim:

1. The method of drilling an off-shore well comprising anchoring a drilling vessel on the surface of a body of water above a submerged well site, cementing a length of casing vertically in the submerged earth at said well site with the top end of said casing positioned adjacent the surface of said submerged earth, attaching a flexible guiding means between the said top end of said casing and the said drilling vessel, operatively connecting a sectional drill string including a drill bit attached to the lower end thereof to a rotary motor unit which is within a motor assembly proportioned to fit within the upper end portion of said casing in sliding relationship, suspending said motor assembly from said drilling vessel by lifting and lowering lines which enable said motor assembly with the said drill string extending downwardly therefrom to be lowered from said drilling vessel and into the said top end of said casing and to be raised from said casing to said drilling platform, connecting said rotary motor unit to a source of motive power therefor on said drilling vessel by power-transmitting flexible lines, lowering said motor assembly and said drill string from said drilling vessel and guiding said drill bit and said drill string into said top end of said casing, continuing lowering said motor assembly and said drill string from said drilling vessel until said drill bit is in contact with the subterranean formations below said casing and said motor assembly is positioned within the upper end portion of said casing and supported therein by said lifting and lowering lines, providing means to prevent a relative rotation between said motor assembly and said casing, actuating said rotary motor unit by remote control from said source of motive power on said drilling vessel to rotate said drill string and said drill bit, drilling a well bore by lowering said motor assembly within the said upper portion of said casing by manipulation of said lifting and lowering lines from said drilling vessel to maintain contact between said drill bit and said subterranean formations while rotating said drill string by said rotary motor unit, lifting said motor assembly and the attached said drill string from said casing and through said body of water to place said motor assembly and the upper portion of said drill string at said drilling vessel, connecting an additional section to said drill string below said motor assembly to increase the length of said drill string, again lowering and guiding said motor assembly and the attached said drill string into said casing to dispose said motor assembly within the said upper portion of said casing and with said drill bit in contact with the bottom of said well bore, actuating said rotary motor unit to rotate said drill string and said drill bit while further lowering said motor assembly by said lifting and lowering lines to deepen said well bore, and positioning a blowout preventer assembly at the open upper end of said casing connecting said blowout preventer assembly to said drilling vessel by power transmitting flexible lines and operating said blowout preventer assembly from said drilling vessel by remote control to prevent the blowout through said casing of well fluids from said subterranean formations.

2. The method in accordance with claim 1 including connecting said blowout preventer assembly to said drilling vessel by flexible operating lines therefor, lowering said blowout preventer assembly from said vessel through said body of water and guiding said blowout preventer assembly to and inserting said blowout preventer assembly within the said upper portion of said casing, re-

motely operating said blowout preventer assembly from said drilling vessel to detachably clamp said blowout preventer assembly to the interior surface of the said upper portion of said casing and to close the opening through said casing against the flow of well fluids therefrom.

3. A method for drilling an offshore well comprising anchoring a drilling vessel on the surface of a body of water above a submerged well site, cementing a length of casing vertically in the submerged earth at said well site with the top end of said casing submerged in said water and terminating adjacent the underwater bottom, suspending a hydraulic rotary motor unit from said vessel by flexible lifting and lowering lines and connecting said motor unit to a source of hydraulic power on said vessel by first and second flexible conduits for remote operation of said motor unit from said vessel, connecting a drill string with a drill bit affixed to the lower end thereof to said motor unit for rotary operation thereby with said drill string extending downwardly from said motor unit a distance sufficient to place said drill bit in contact with the earth in a well bore below said casing while said motor unit is maintained within the upper portion of said casing, lowering and guiding said drill bit said drill string and said motor unit from said vessel and into said casing, operating said motor unit from said vessel to rotate said drill string and said drill bit while forcing a drilling fluid downwardly from said vessel to said drill bit through a third flexible conduit which is connected to said drill string and returning said drilling fluid and drill cuttings entrained thereby to said vessel through a fourth flexible conduit which is in communication with the interior of said casing at a location below the position of said motor unit in said casing, lowering said motor unit within the said upper portion of said casing by manipulation of said lifting and lowering lines on said vessel while maintaining a substantially constant pressure on said drill bit to cause said motor unit to follow said drill bit downwardly as said drill bit deepens said well bore while maintaining said motor unit within the said upper portion of said casing and above the location at which said fourth conduit communicates with the interior of said casing, and placing blowout preventer means within the said upper portion of said casing connecting said blowout preventer means to said drilling vessel by flexible control lines and remotely operating said blowout preventer means from said vessel through said flexible control lines to close the opening through said casing against the flow of well fluids therefrom at the elevation of said motor unit in the said upper portion of said casing.

4. A method in accordance with claim 2 including connecting flexible guide means between the submerged said top end of said casing and said vessel, periodically lifting said motor unit and said drill string through said body of water to said vessel by said lifting and lowering lines, adding additional sections of drill pipe to said drill string to lengthen said drill string to a length substantially equal to that to which said well bore has been deepened, again lowering said drill string and said motor unit from said vessel through said body of water and guiding said drill string and said motor unit into the submerged said casing by said flexible guide means until the drill bit is in contact with the bottom of said well bore and said motor unit is inserted within the said upper portion of said casing, and operating said motor unit within the said upper portion of said casing to deepen said well bore an additional amount.

5. A method in accordance with claim 3 including the step of automatically closing the opening through said casing to the flow of well fluids through the said upper portion thereof when said drill string and drill bit are withdrawn from said casing.

6. Apparatus for drilling and working in an offshore well comprising a casing affixed in fluid-tight relationship in a well bore submerged under a body of water and with the top end of said casing located adjacent the underwater bottom, a hydraulic motor assembly adapted to be in-

serted within and withdrawn from the top portion of said casing in longitudinally slidable relationship therewith, means connected to said top portion of said casing and engageable with complementary means connected to said assembly to prevent a relative rotation between said assembly and said casing while permitting sliding in a longitudinal direction of said assembly relative to said casing, a hydraulic motor within said assembly and operatively connected to a string of drill pipe extending below said assembly to rotate said drill pipe, a drill bit affixed to the lower end of said string of drill pipe, flexible conduits for hydraulic fluid operatively connected to said hydraulic motor and to a source of hydraulic motive fluid on a platform located at the surface of said body of water above said well bore, means for circulating said hydraulic motive fluid under pressure through said flexible conduits to pass through said hydraulic motor and return to said source, flexible packing means affixed to said assembly to engage the inner wall of the upper portion of said casing in fluid-tight sliding relationship, a first conduit for drilling fluid formed axially through said assembly and communicating with the interior of said string of drill pipe, a flexible second conduit connecting said first conduit with a source of drilling fluid on said platform, a drilling fluid return conduit communicating with the interior of said casing at a location below the top end thereof, a flexible third conduit connecting said drilling fluid return conduit with said platform, lifting and lowering lines operatively connected to said assembly and to said platform, means for actuating said lifting and lowering lines to raise and lower said assembly and said string of drill pipe and said drill bit out of and into said upper portion of said casing and through said body of water, means for guiding said assembly and said string of drill pipe and said drill bit into the upper portion of said casing, blowout preventer means actuated by remote control, flexible operating lines connecting said blowout preventer means with said platform and operated at said platform to detachably clamp said blowout preventer means to the interior surface of said upper portion of said casing and to close the opening of said casing against the flow of well fluids therefrom.

7. Apparatus for drilling and working in an offshore well comprising a casing affixed in fluid-tight relationship in a well bore submerged under a body of water and with the top end of said casing located adjacent the underwater bottom, a hydraulic motor assembly adapted to be inserted within and withdrawn from the top portion of said casing in longitudinally slidable relationship therewith, means connected to said top portion of said casing and engageable with complementary means connected to said assembly to prevent a relative rotation between said assembly and said casing while permitting sliding in a longitudinal direction of said assembly relative to said casing, a hydraulic motor within said assembly and operatively connected to a string of drill pipe extending below said assembly to rotate said drill pipe, a drill bit affixed to the lower end of said string of drill pipe, flexible conduits for hydraulic fluid connected to said hydraulic motor and to a source of hydraulic motive fluid on a platform located at the surface of said body of water above said well bore, means on said platform for circulating said hydraulic motive fluid under pressure through said flexible conduits to pass through and actuate said hydraulic motor and return to said platform, flexible packing means affixed to said assembly to engage the inner wall of the upper portion of said casing in fluid-tight sliding relationship, a first conduit for drilling fluid formed axially through said assembly and communicating with the interior of said string of drill pipe, a flexible second conduit connecting said first conduit with a source of drilling fluid on said platform, a drilling fluid return conduit communicating with the interior of said casing at a location below the position of said assembly therein, a flexible third conduit connecting said drilling fluid return conduit with said platform, lifting and lowering lines operatively connected

to said assembly and to said platform, flexible guide means for said assembly and connected between the said top end of said casing and said platform, means for actuating said lifting and lowering lines for raising and lowering said assembly and said string of drill pipe and said drill bit out of and into said upper portion of said casing along said guide means and through said body of water, a blowout preventer assembly detachably connected to the said upper end portion of said casing, and flexible operating lines connecting said blowout preventer assembly with said platform for operating said blowout preventer assembly remotely from said platform to be detachably clamped to the interior surface of said top portion of said casing and to selectively close and open a passageway through the said top end of said casing.

8. Apparatus for drilling and working in an offshore well comprising a casing affixed in fluid-tight relationship in a well bore submerged under a body of water with the top end of said casing located adjacent the underwater bottom, a hydraulic motor assembly adapted to be inserted within and withdrawn from the top portion of said casing in longitudinally sliding relationship therewith, a rigid elongated element affixed to the top end of said assembly and projected upwardly therefrom, adjustable bushing means connected to said top portion of said casing and operable by remote operation to engage said elongated element to prevent a relative rotation between said assembly and said casing while permitting said assembly to slide longitudinally relative to said casing and to disengage said elongated element to permit said assembly to be withdrawn from said casing through said bushing means, a hydraulic motor within said assembly and operatively connected to a string of drill pipe extending below said assembly to rotate said drill pipe, a drill bit affixed to the lower end of said string of drill pipe, flexible conduits for hydraulic fluid passing longitudinally through an axial passage through said elongated element and connected to said hydraulic motor and to a source of hydraulic motive fluid on a platform located at the surface of said body of water, means on said platform for circulating said hydraulic motive fluid under pressure through said flexible conduits to pass through and actuate said hydraulic motor and return to said platform, a first conduit for drilling fluid formed axially through said assembly and communicating at one end with the interior of said string of drill pipe and at the other end with said passage through said elongated element, a flexible second conduit connecting said passage through said elongated element with a source of drilling fluid on said platform, a drilling fluid return conduit communicating with the interior of said casing at a location below the position of said assembly therein, a flexible third conduit connecting said drilling fluid return conduit with said platform, lifting and lowering lines operatively connected to the top end of said elongated element and to said platform, means on said platform for actuating said lifting and lowering lines to raise and lower said elongated element and the attached said assembly and said string of drill pipe and said drill bit through said body of water to and from said platform and out of and into said upper portion of said casing, means for guiding said assembly and said string of drill pipe and said drill bit into the said upper portion of said casing, a blowout preventer assembly detachably connected to the said upper end portion of said casing, flexible operating lines connecting said blowout preventer assembly with said platform for operating said blowout preventer assembly remotely from said platform to be detachably clamped to the interior surface of said top portion of said casing and to selectively close and open a passageway through said top end of said casing and an additional flexible operating line connecting said bushing means with said platform for remote operation of said bushing means from said platform.

9. Apparatus for drilling and working in an offshore well comprising a surface casing affixed in fluid-tight re-

lationship in a well bore submerged under a body of water with the top end of said surface casing located adjacent the submerged land surface, an assembly comprising a hydraulic motor and a blowout preventer adapted to be inserted into the top end of said surface casing in slidable engagement therewith, complementary engaging surfaces formed between said assembly and the top portion of said surface casing to prevent said assembly from rotating relative to said surface casing while permitting said assembly to slide longitudinally within and relative to said surface casing, flexible hydraulic lines connecting said hydraulic motor and a source of hydraulic motive fluid on a drilling platform at the surface of said body of water to circulate said hydraulic motive fluid through said hydraulic motor and return said hydraulic motive fluid to said source, flexible operating lines connecting said blowout preventer and said drilling platform to energize said blowout preventer remotely from said drilling platform to close the opening at said top end of said surface casing, a string of drill pipe operatively connected to said hydraulic motor for rotation thereby and extending downwardly therefrom substantially the length of said well bore, a drill bit connected to the lower end of said string of drill pipe, a conduit for drilling fluid formed through said assembly and connected to one end with said string of drill pipe and at the other end with said drilling platform through a first flexible conduit, a second flexible conduit connecting said drilling platform and a drilling fluid return conduit opening into the said upper portion of said surface casing at a location below said assembly, hoist lines connecting said drilling platform and said assembly for controllably supporting said assembly within the said top portion of said surface casing to maintain a substantially constant pressure of said drill bit on the bottom of said well bore and for selectively raising and lowering said assembly and said string of drill pipe and said drill bit through said body of water out of and into said surface casing and said well bore to and from said drilling platform, and means for guiding said assembly and said string of drill pipe and said drill bit into said surface casing.

10. Apparatus for offshore drilling and well working comprising a floating drilling vessel on the surface of a body of water above a submerged well site, a surface casing secured in fluid-tight relationship in a submerged well bore at said well site and with the top end of said casing located adjacent the submerged land surface, torque rails within the upper interior portion of said surface casing and affixed to the inner surface thereof in circumferentially spaced-apart relationship to each other and parallel to the axis of said surface casing, a hydraulic motor contained in a housing adapted to be received within the said upper portion of said surface casing, axially disposed grooves in the outer surface of said housing to engage said torque rails in complementary sliding relationship, packing means affixed to the said outer surface of said housing and extending radially therefrom to engage the inner circumferential wall of said upper portion of said surface casing and said torque rails in a fluid-tight slidable relationship, a remotely operated blowout preventer assembly affixed to the upper end of said housing in a unitary manner and adapted to be received within the said upper portion of said surface casing, a plurality of selectively expandable and retractable packer means on said blowout preventer which are expandable by remote operation from said drilling vessel to close the opening between the said housing and the said inner circumferential wall of said upper portion of the said surface casing and which are retractable to permit said housing and said assembly to slide longitudinally relative to said surface casing, a string of drill pipe operatively connected to said hydraulic motor and extending downwardly with respect to said housing substantially the length of said well bore, a drill bit affixed to the lower end of said string of drill pipe, a valve-controlled flexi-

ble conduit for hydraulic fluid connected to said hydraulic motor and to a source of hydraulic motive fluid aboard said drilling vessel to permit operation of said hydraulic motor from said drilling vessel, a second flexible conduit for said hydraulic fluid connected to said hydraulic motor and to said source of hydraulic motive fluid for the return flow of said hydraulic motive fluid from said hydraulic motor to said drilling vessel, a first conduit for drilling mud constructed axially through said housing and said blowout preventer assembly and communicating at its lower end with the interior of said string of drill pipe and terminating at its upper end in a connector for a flexible conduit, a flexible second conduit operatively connected to said connector and to a source of drilling mud aboard said drilling vessel and adapted to direct drilling mud under pressure from said drilling vessel into said first conduit and thence into said string of drill pipe and to said drill bit, a drilling mud return flexible conduit communicating with the interior of said upper portion of said surface casing through an opening formed in the wall of said upper portion of said surface casing at a position below said torque rails and extending upwardly through said body of water to said drilling vessel, raising and lowering lines connected to said blowout preventer assembly and to operating means on said drilling vessel for selectively raising said assembly and said housing and said drill pipe and said drill bit out of said surface casing and upwardly through said body of water to said drilling vessel and for selectively lowering said drill bit and said drill pipe and said housing and said blowout preventer assembly from said drilling vessel into said surface casing, a guide funnel affixed to the top end portion of said surface casing in coaxial alignment therewith, flexible guidelines connecting said guide funnel with said drilling vessel, and guide arms connected between said guidelines and the apparatus being raised out of and lowered into said surface casing and constraining said equipment to move longitudinally along said guidelines and into engagement with said guide funnel as said apparatus is lowered from said drilling vessel.

11. Apparatus for drilling and working in an offshore well comprising a surface casing affixed in fluid-tight relationship in a well bore submerged under a body of water with the top end of said surface casing located adjacent the surface of the submerged land, a plurality of rails affixed to the inner surface of the top portion of said surface casing and disposed with each rail parallel to the longitudinal axis of said casing and in circumferentially spaced relationship to each other, an assembly comprising a hydraulic motor and a blowout preventer adapted to be inserted into and operated within said top portion of said surface casing in slidable engagement with said rails, complementary engaging surfaces formed between said assembly and said rails to prevent said assembly from rotating relative to said surface casing while permitting said assembly to slide longitudinally within and relative to said surface casing, flexible hydraulic lines connected to said hydraulic motor and to a source of hydraulic fluid on a drilling platform at the surface of said body of water, means for circulating said hydraulic fluid from said drilling platform through said hydraulic lines and said hydraulic motor to energize said hydraulic motor, flexible operating lines connected between said blowout preventer and said drilling platform to operate said blowout preventer remotely from said drilling platform to selectively close and open the space between said assembly and the inner wall of said surface casing, a string of drill pipe operatively connected to said hydraulic motor for rotation thereby and extending downwardly from said assembly, a drill bit affixed to the lower end of said string of drill pipe, a first conduit for drilling mud formed through said assembly and communicating with the interior of said drill pipe, a flexible second conduit connected to the said first conduit and to a source of drilling fluid on said drilling platform, a flexible drilling fluid re-

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turn conduit connected between said drilling platform and said surface casing and communicating with the interior of said surface casing through an opening formed through the wall thereof at a position below the lower ends of said rails, lifting and lowering lines connected between said assembly and said drilling platform for supporting said assembly within the said top portion of said surface casing to control the pressure of said drill bit against the bottom of said well bore and for selectively raising and lowering said assembly and said string of drill pipe and drill bit out of and into said surface casing and said well bore to and from said drilling platform, and means for

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guiding said assembly and said string of drill pipe and said drill bit into said surface casing.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,129,774

April 21, 1964

Robert A. Armstrong

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 1, line 45, for "possibilty" read -- possibility --; column 2, line 59, for "drililng" read -- drilling --; column 5, line 45, for "more" read -- move --; column 6, line 34, for "asesmbled" read -- assembled --; line 69, for "puhsed" read -- pushed --; column 11, line 71, for "abroad" read -- aboard --; column 16, line 49, for "continuel" read -- continued --; column 17, line 63, after "casing" insert a comma; column 21, line 25, for "to" read -- at --.

Signed and sealed this 22nd day of September 1964.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents