June 1, 1965 B. J. BULLARD ETAL 3,186,499

WELL DRILLING METHOD

Filed Sept. 28, 1962 4 Sheets-Sheet 1

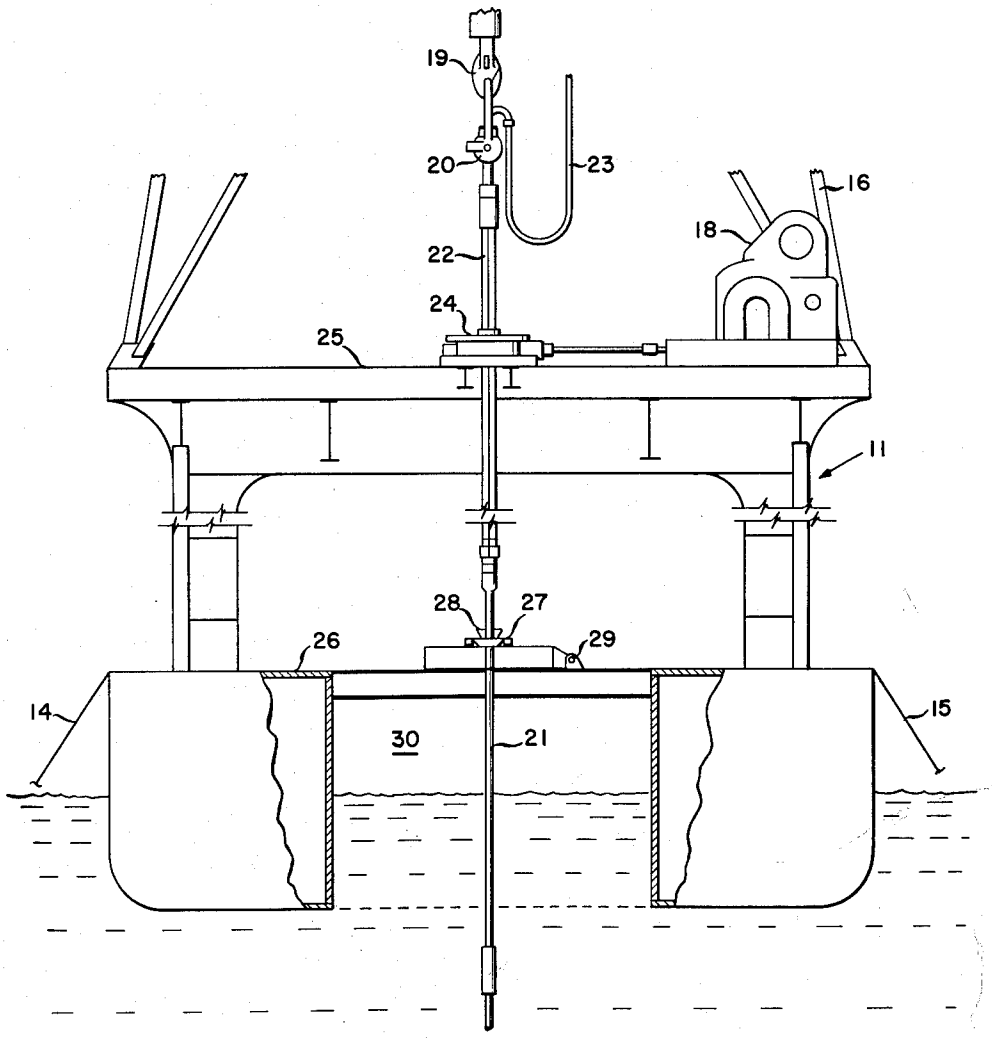


FIG. 1

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WELL DRILLING METHOD

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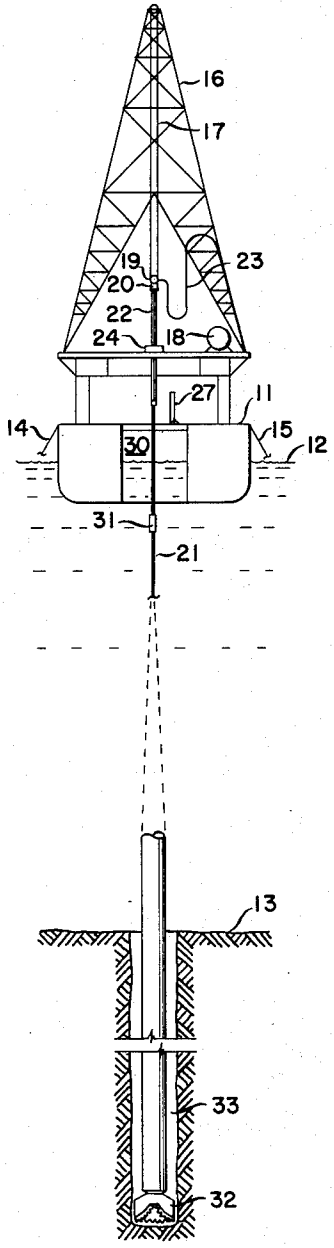


FIG. 2

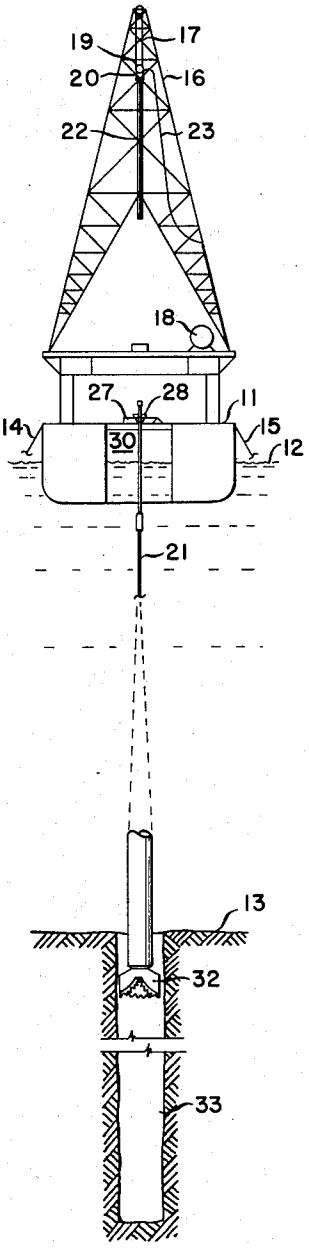


FIG. 3

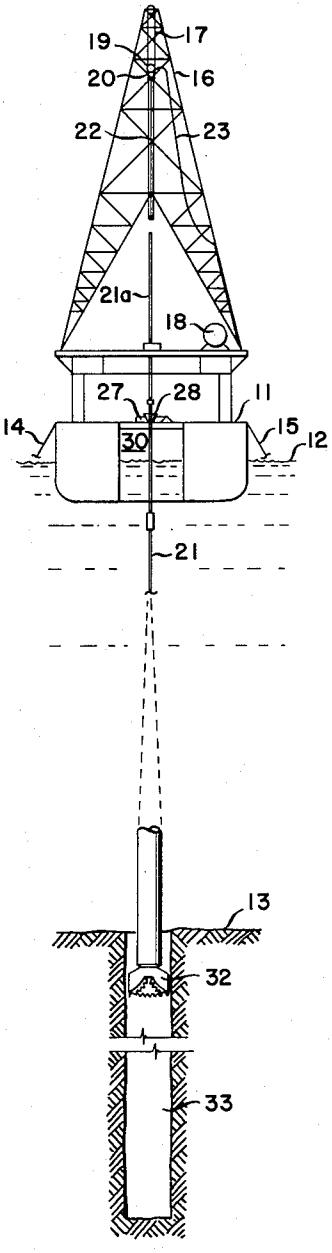


FIG. 4

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WELL DRILLING METHOD

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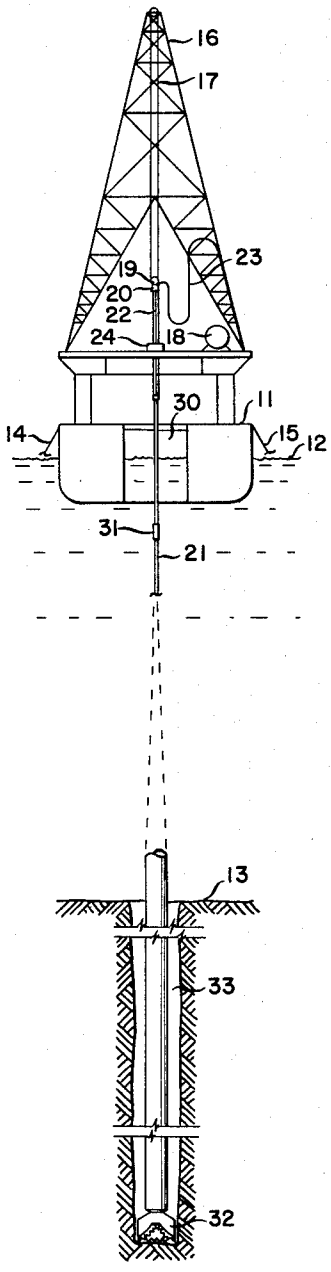


FIG. 5

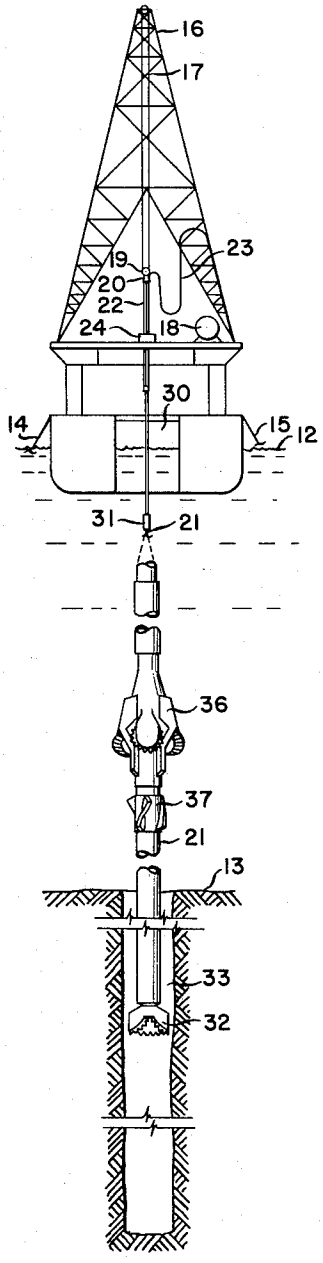


FIG. 6

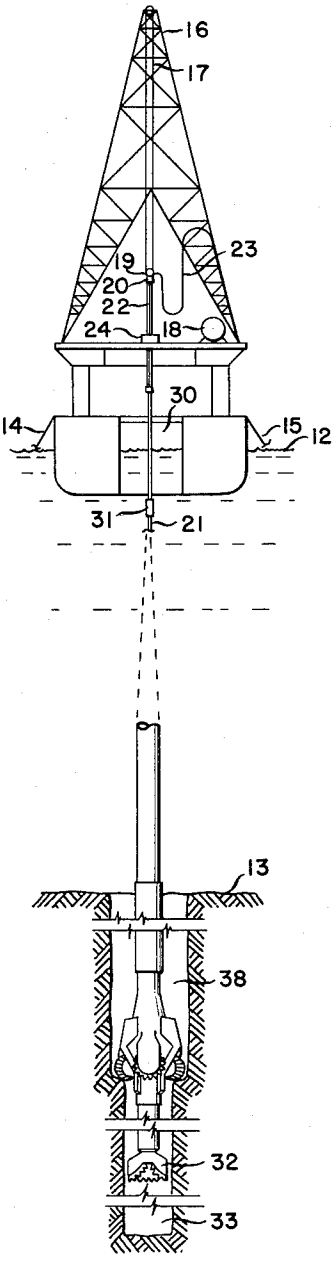


FIG. 7

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WELL DRILLING METHOD

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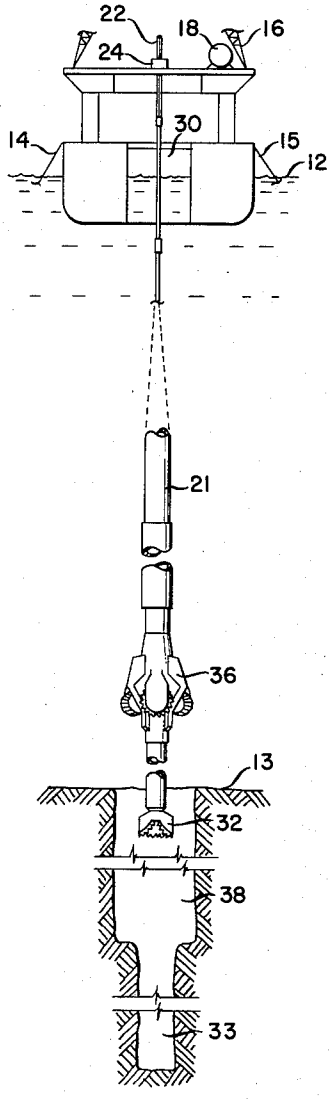


FIG. 8

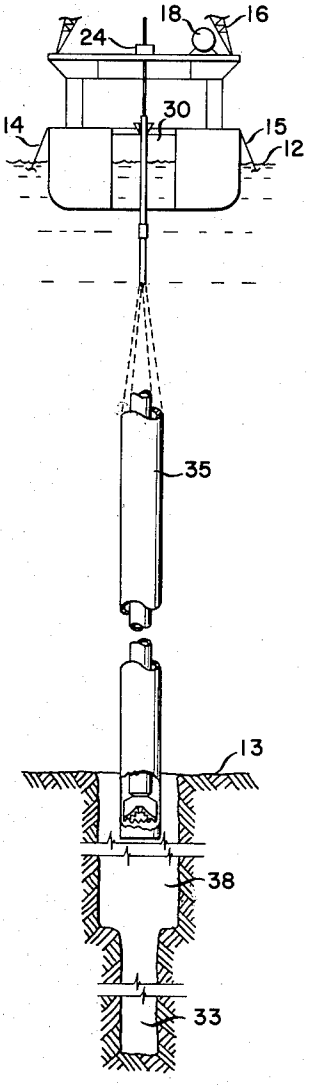


FIG. 9

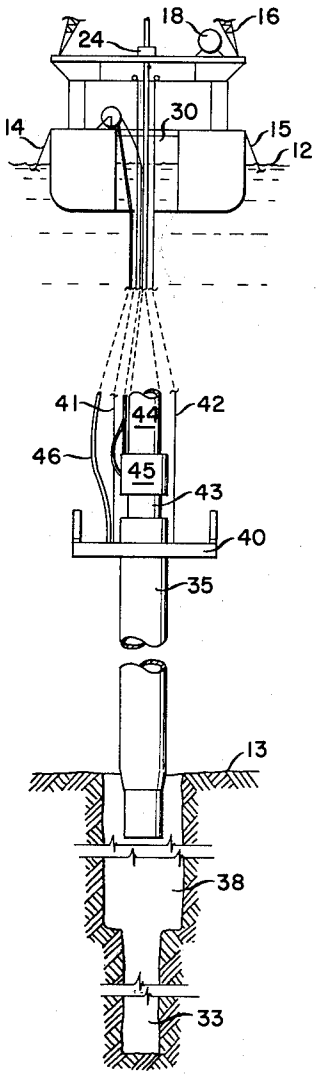


FIG. 10

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WELL DRILLING METHOD

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Filed Sept. 28, 1962, Ser. No. 226,877
9 Claims. (Cl. 175—5)

This invention is related to the underwater drilling of oil and gas wells and pertains more particularly to methods and apparatus for maintaining contact with a hole drilled in the ocean floor during drilling operations and subsequently when installing a foundation pipe string in the hole.

During recent years, the continued search for oil has resulted in developing methods and apparatus for drilling underwater wells at locations where the water may range from 100 to 1500 feet or more in depth. In these locations it is customary to position the wellhead at a considerable distance below the surface of the water, preferably on the ocean floor, so that it is not a hazard to the navigation of ships in the area. One method of drilling and completing wells in this manner is described in copending patent application, Serial No. 830,538, filed July 30, 1959, and entitled "Underwater Well Completion Method."

One of the most important operations in the drilling of an underwater well is that of starting the well and installing the conductor or foundation pipe in the ocean floor. This operation may be carried out in any one of several ways, one of which is described in U.S. Patent 2,929,610 which issued March 20, 1960, to H. Stratton. In the described method of the patent, a drill bit drills a hole in the ocean floor slightly larger in diameter than the diameter of the well conductor or foundation pipe which is subsequently slipped down along the drill pipe and into the hole during which time drilling fluid is pumped down the drill pipe and up the outside of the foundation pipe. This method is limited somewhat in its application in that in order to slip a foundation pipe down over a drill string and bit into a hole drilled in the ocean floor, the drill bit must be smaller than the internal diameter of the foundation pipe so that the pipe can be slipped over it. However, the drill bit must be capable of drilling a hole larger than the outside diameter of the foundation pipe in order for the foundation pipe to enter the hole in the ocean floor. Thus it is essential that the drill bit be of the collapsible or retractable type or that a second drill bit be mounted on the drill string of this type. The second bit in its expanded position would be wide enough to drill a hole in the ocean floor large enough to insert the foundation pipe therein. Prior to inserting the foundation pipe, the second bit would be collapsed or the extended cutting arms retracted so that the foundation pipe could be slipped over it.

Collapsible drill bits or drill bits having retractable cutting elements are inherently weaker and less rigid than ordinary drag or rock bits due to their complicated design. Hence, upon being subjected to abnormal drilling forces while drilling into some formations, a greater amount of bit failure has been experienced.

It is therefore a primary object of the present invention to provide a method for drilling an underwater well in the ocean floor and subsequently installing a foundation pipe therein without being limited in any way to the type or size of bit used.

A further object of the present invention is to provide a method for drilling a hole in the ocean floor, reaming the hole and subsequently installing a well conductor or foundation pipe without losing contact with the hole.

A further object of the present invention is to provide a method whereby an elongated pipe string may be suspended from a vessel floating on the surface of the ocean and be manipulated so that its lower end is adapted to be freely rotated in a well without danger of the pipe section becoming uncoupled.

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

FIGURE 1 is a diagrammatic view, taken in partial longitudinal cross section, of a drilling vessel during the drilling of an underwater well.

FIGURES 2 through 10 are diagrammatic views taken in longitudinal projection illustrating a floating vessel positioned over a drilling location during the sequential steps of starting to drill a well, adding a pipe section to the drill string, drilling more hole, adding a reaming bit to the drill string, reaming the hole, removing the reamer, and installing a foundation pipe in the hole.

Referring to FIGURES 1 and 2 of the drawing, a drilling vessel, barge or platform **11**, of any suitable floating or floatable type is illustrated as floating on the surface of a body of water **12** while being substantially fixedly positioned over a preselected well location by suitable vessel-positioning means well known to the art, or by being anchored to the ocean floor **13** by anchor lines **14** and **15** running to the anchors (not shown). Equipment of this type may be used when carrying on well drilling operations or well work-over operations in water varying from about 150 feet to 1500 feet or more in depth. The drilling vessel **11** is equipped with a suitable derrick **16** containing a fall line system **17** which includes a suitable hoist **18**, traveling block **19** and suitable hook and swivel or other connector means **20** adapted to be connected to the top of a drill pipe **21** during well drilling operations and being adapted to circulate a drilling fluid therethrough in a manner well known to the art. A kelly **22**, which is a section of pipe having a square or non-round outer surface, is interposed between the top pipe section of the drill string **21** and the swivel **20**. A hose **23** for circulating mud into the top of the drill string is connected to the swivel **20**.

The vessel **11** is also provided with other auxiliary equipment needed during well drilling operations, such for example as a rotary table **24** positioned on the operating deck **25** of the vessel. A lower auxiliary deck **26** is provided with a removable spider **27** and slip assembly **28** hinged at **29** to be tilted out of the way when not in use. The derrick **16** is positioned over a drilling slot or well **30** which extends vertically through the vessel in a conventional manner. When using equipment of the present invention, a slot **30** in the vessel **11** may be either centrally located or extend in from one edge. Alternatively, drilling operations may be carried out over the side of the vessel without the use of a slot. For example, the drilling vessel may be provided with a deck portion which overhangs the hull of the vessel.

The drill string **21** (FIGURE 2) preferably includes a telescoping joint **31** in its length to compensate for the rise and fall of the vessel **11** relative to the drill string **21**. The length of the telescoping joint **31** is selected to be slightly greater than the expected rise and fall of the vessel so that the drill bit **32** will remain in drilling contact with the bottom of the well or hole **33** regardless of the weather conditions at the surface. Although for ease of illustration the drill string **21** is shown as a unitary length of pipe, it is well known that a pipe string or drill string used in well drilling operations is made up by threadedly connecting together several short (say 30 feet) sections of pipe to make up a pipe string of a desired length.

FIGURES 1 and 2 illustrate the start of the method of the present invention in which an underwater well is drilled from a drilling vessel **11** positioned at the surface of the water **12**, the vessel **11** being provided with

a rotary table 24 and means, such for example a spider assembly 27 and slips 28, for supporting the drill string 21 below the rotary table. In starting a well the drilling vessel 11 is first positioned at a selected drilling location. The drill string 21 having a bit 32 at the lower end thereof is lowered from the vessel into contact with the ocean floor. Several of the bottom sections of pipe forming the lower end of the drill string 21 may be thick-walled pipe in the form of drill collars, if desired. The drill string 21 includes a kelly 22 at the upper end thereof which is slidably positioned in the bushing of the rotary table 24 in a manner well known to the art. Drilling is commenced by the rotary table 24 being driven by suitable motor means to rotate the kelly 22 and the drill string 21 connected to its lower end. As the drill bit 32 is drilled into the ocean floor, the kelly 22 slides down through the rotary table 24 until the upper end thereof reaches the rotary table 24.

At this time, in conventional land operations, the kelly is pulled upwardly together with the drill string and the top pipe section of the drill string just below the kelly 22 is wedged in the rotary table and supported therefrom by means of slips positioned around the drill pipe in a manner well known to the art. The kelly 22 is disconnected from the suspended drill string 21, a new section of pipe is connected in its place, the kelly is then connected to the new section of pipe, and the drill string and kelly are lowered so that the kelly is in the rotary table again. Drilling of the well is then continued. It is apparent from the above description that if the drill string is pulled up and suspended from the rotary table of a drilling vessel in the above-described manner, the lower end of the drill string will be pulled out of the hole 33 in the ocean floor and it cannot readily be blindly inserted back in the hole by conventional drilling practices. It is therefore important that at least the lower end of the drill string 21 remain in the hole 33 in the ocean floor at all times during drilling operations.

In the drilling method of the present invention, instead of pulling the drill string 21 back to the rotary table 24 in order to support it while adding an additional length of pipe to the upper end thereof, the upper end of the drill string 21 is supported at a level substantially below the rotary table, as shown in FIGURE 3. One form of apparatus for supporting the drill pipe in this manner is provided by the spider assembly 27 mounted on the auxiliary deck 26 below the main operating deck 25. The distance below the supported upper end of the drill pipe, shown in FIGURE 3, and the bottom of the rotary table 24 is preferably at least as long as the section of pipe to be added to the drill string. Although drill pipe sections are normally 30 feet long, during this portion of the operation short sections, say 10 feet in length, may be employed. With the upper end of the drill string 21 supported at this lower level, the drill bit 32 at the lower end of the drill string 21 remains in the hole 32 at all times.

In FIGURE 4 a new section of drill pipe 21*a* is shown as having been connected to the top of the drill string 21. Thereafter, the kelly is connected to the top of the drill string section 21*a* and lowered so that the kelly 22 is positioned in the rotary table 24 as previously shown with the bit on the bottom of the hole 33, as shown in FIGURE 5. As additional hole is drilled, the upper end of the drill string 21 may be suspended from the rotary table when additional sections of drill pipe are to be added to the top thereof without fear of pulling the drill bit 32 from the hole 33.

If a well foundation pipe or well conductor 35 (FIGURE 10) is to be installed in the well 33 and has a diameter greater than the drill bit 32, a rigid hole opener or reaming bit 36 (FIGURE 6) is connected into the drill string 21. Preferably, a centralizer 37 is connected

in the drill string 21 just below the reaming bit 36 to aid in centering the drill string 21 and bit 36 in the hole. The diameter of the reaming bit 36 is greater than the outside diameter of the foundation pipe 35 (FIGURE 10). In installing the reaming bit 36 in the drill string 31, the drill string is withdrawn to the vessel until only the lower end thereof remains in the well 33 so as not to lose contact between the vessel and the hole. The drill string 21 is uncoupled at the vessel 11 so that the reaming bit 36 can be coupled thereto at a distance above the bit 32 which is greater than the depth of the water at the drilling location. The rest of the drill string is connected to the top of the reaming bit 36 and the entire assembly is lowered to the ocean floor 13 where the drill string 21 is rotated so that the reaming bit 36 cuts a hole 38 in the ocean floor 13 greater than the diameter of the foundation pipe 35. Alternatively, as the drill string is originally lowered through the water to contact the ocean floor, a rigid-type reaming bit of larger diameter may be connected into the drill string as long as the distance between the two bits is greater than the depth of the water at the drilling location. Simultaneous reaming and drilling operations may be carried out with this arrangement of apparatus.

During the reaming operation illustrated in FIGURE 7 it will be noted that the drill bit 32 and the length of the drill string 21 between the bit 32 and the bit 36 is substantially freely suspended in the hole with the bit not bearing against the formation. In drilling or reaming certain formations, such for example as those off the coast of Alaska, it may happen that the reaming bit 36 encounters a boulder in the formation which would at least momentarily halt the rotation of the drill string 21. In such a case the rotational inertia in the drill string 21 would act on the freely suspended lower end of the drill string and bit 32, possibly causing the threaded section of the pipe or drill bit to unscrew one from the other possibly an amount sufficient to uncouple two sections of drill pipe or at least weaken the drill pipe at that point. To obviate such a difficulty, in making up the drill string 21 between the bits 32 and 36, that is, in connecting the sections of pipe together, it is preferred that the pipe couplings be fixedly anchored together in any suitable manner, as by welding vertical steel straps on the outside thereof. Preferably, a cement is applied to the threads of each pipe section before the pipe couplings are screwed together so that they cannot be unscrewed under forces described above. Preferably, the cementing material is a thermoplastic material which, upon heating, say to 400° F., will lose its bonding strength so that the coupling can be broken or unscrewed.

Prior to reaming the hole 38 as shown in FIGURE 7, the smaller borehole 33 was drilled to a depth greater than the depth of the water plus the length of the foundation pipe (FIGURE 10) to be inserted in the hole. The hole 38 is reamed to a depth greater than the length of the foundation pipe 35. After the hole 38 has been reamed, the drill string 21 is raised to the vessel so that the reaming bit 36 is at the vessel where it is uncoupled while the smaller drill bit 32 still remains in the top of the hole as shown in FIGURE 8. In order to install a foundation pipe 35, lengths of large-diameter pipe are coupled together at the vessel 11 and inserted over the drill string 21 and slipped down over the drill string and bit into the hole 38 as shown in FIGURE 9. The foundation pipe 35 may have a base member 40 secured to the upper end thereof with guide lines 41 and 42 extending between the base member 40 and the vessel 11. In running the foundation pipe 35, base member 40 and its upwardly extending tubular member 43 into position within the hole 38, a running pipe string having a remotely controlled connector unit 45 at the lower end thereof is secured to the foundation pipe and lowered from the ves-

sel **11**. Alternatively, the base member **40** and foundation pipe **35** may be lowered at the end of a line **46** until the base member **40** was positioned on or near the ocean floor. The cementing of the foundation pipe in the hole could be carried out by pumping cement down the running string **44** and through the foundation pipe **35** to come up and fill the annular space between the outer wall of the foundation pipe **35** and the wall of the hole **38**.

In certain areas it is possible to utilize the tides in starting to drill an underwater well, for example in Alaskan waters. Thus, in starting to drill an underwater well the vessel would be first positioned at the selected drilling location after which a drill string having a bit at the lower end thereof and a kelly at the upper end thereof would be lowered from the vessel into contact with the formation beneath the body of water. A hole would be drilled in the ocean floor by rotating the drill string and bit. This drilling operation would be carried out preferably during a falling tide or at least over a period where a drop in the tide takes place which is substantially greater than any rise in tide which may occur. A net drop in tide results in a decrease in the distance between the formation and the vessel and a corresponding increase in the depth of the hole drilled in the formation without stopping drilling operations to add new sections of pipe to the top of the drill string, thus it is possible to add a new section of drill pipe to the top of the drill string at a low tide since the amount of hole drilled in the formation would be greater than the distance necessary to raise the drill string to support it at the rotary table during the operation of adding a new section of pipe between the top of the drill string and the kelly. In raising the drill string the lower end thereof would maintain contact with the hole at all times. After adding a new section of drill string to the top thereof it would be lowered into the hole and drilling operations continued.

We claim as our invention:

1. A method of drilling an underwater well from a floating drilling vessel at the surface of a body of water, said vessel having a rotary table above an unobstructed passage to the surface of the water and means for supporting a drill string below said rotary table, said method comprising the sequential steps of

(a) positioning said vessel at a selected drilling location,

(b) lowering from the vessel into contact with the formation beneath the body of water a drill string having a kelly at the upper end thereof,

(c) inserting the kelly in the rotary table,

(d) drilling a hole in the formation by applying a rotating force to the kelly to rotate the drill string,

(e) supporting on said floating drilling vessel at a level below the rotary table the upper end of the drill string at a point below the kelly, with the lower end of the drill string being freely suspended for vertical up and down movement in the drilled hole,

(f) disconnecting the kelly from the top of the drill string,

(g) coupling a section of drill pipe to the top of the drill string and connecting the kelly to said pipe section, and

(h) rotating the drill string to drill more hole.

2. The method of claim **1** wherein the drill string is supported in a manner such that the upper end of the drill string is spaced below the lower end of the kelly in raised position of the kelly in the rotary table at least a distance equal to the length of the section of drill pipe to be added.

3. A method of initially starting the drilling of an underwater well from a floating drilling vessel at the surface of a body of water, said vessel having a rotary table above an unobstructed passage to the surface of the water, said method comprising the sequential steps of

(a) positioning the vessel at a selected drilling location,

(b) lowering from the vessel into contact with the formation beneath the body of water a drill string having a bit at the lower end thereof and having a kelly at the upper end thereof positioned in a rotary table during drilling operations,

(c) drilling a hole in the formation by rotating the drill string,

(d) carrying out said drilling operation over a period where a drop in tide takes place which is substantially greater than any rise in tide which may occur resulting in a decrease in the distance between the formation and the vessel and a corresponding increase in the depth of the hole drilled in the formation,

(e) raising the drill string an amount sufficient to suspend it from the vessel without the lower end of the drill string losing contact with the hole,

(f) adding a first new section of drill pipe between the kelly and the top of the drill string,

(g) inserting the drill string back to the bottom of the hole, and

(h) continuing drilling operations.

4. The method of claim **3** wherein drilling of the hole in the formation beneath the body of water is started at substantially high tide and the first added section of drill pipe to the drill string is connected thereto at a substantially lower tide.

5. A method of drilling an underwater well from a floating drilling vessel at the surface of a body of water, said vessel having a rotary table above an unobstructed passage to the surface of the water, said method comprising the sequential steps of

(a) positioning the vessel at a selected drilling location,

(b) lowering from the vessel into contact with the formation beneath the body of water a drill string having a bit at the lower end thereof and having a kelly at the upper end thereof positioned in a rotary table during drilling operations,

(c) attaching into the drill string a rigid reaming bit larger in diameter than the bit at the lower end of the drill string and the diameter of a foundation pipe to be inserted in the hole, the distance between the two bits being greater than the depth of the water at the drilling location,

(d) drilling a hole in the formation until the reaming bit has penetrated a distance greater than a foundation pipe to be inserted in the hole,

(e) withdrawing the upper portion of the drill string including the reaming bit to the vessel while leaving at least a portion of the drill string depending within the hole,

(f) removing the reaming bit from the drill string,

(g) stripping a foundation pipe over the drill string,

(h) lowering the foundation pipe over the drill pipe and bit and into the hole.

6. The method of claim **5** including the step of cementing the foundation pipe in the hole after lowering it therein.

7. A method of drilling an underwater well from a floating drilling vessel at the surface of a body of water, said vessel having a rotary table above an unobstructed passage to the surface of the water, said method comprising the sequential steps of

(a) positioning the vessel at a selected drilling location,

(b) lowering from the vessel with the formation beneath the body of water a drill string having a bit at the lower end thereof and having a kelly at the upper end thereof positioned in a rotary table during drilling operations,

(c) drilling a hole in the formation a depth greater than the length of a foundation pipe to be positioned in the hole plus the depth of water at the drilling location,

(d) withdrawing the upper portion of drill string to the vessel while leaving at least a portion of the drill string depending in the hole,

(e) connecting into the drill string at the vessel a rigid reaming bit larger in diameter than the bit at the lower end of the drill string and larger than the diameter of a foundation pipe to be inserted in the hole,

(f) adding drill pipe to the drill string above the reaming bit and lowering the drill string until the reaming bit engages the formation,

(g) reaming out the upper section of the hole a depth sufficient to receive a foundation pipe,

(h) withdrawing the upper portion of the drill string including the reaming bit to the vessel while leaving at least a portion of the drill string depending within the hole,

(i) removing the reaming bit from the drill string

(j) stripping a foundation pipe over the drill string,

(k) lowering the foundation pipe over the drill pipe and bit and into the hole.

8. The method of claim 7 including the step of anchoring together all connections in the drill string between the lower end thereof and the reaming bit.

9. The method of claim 8 wherein the step of anchoring comprises cementing.

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