

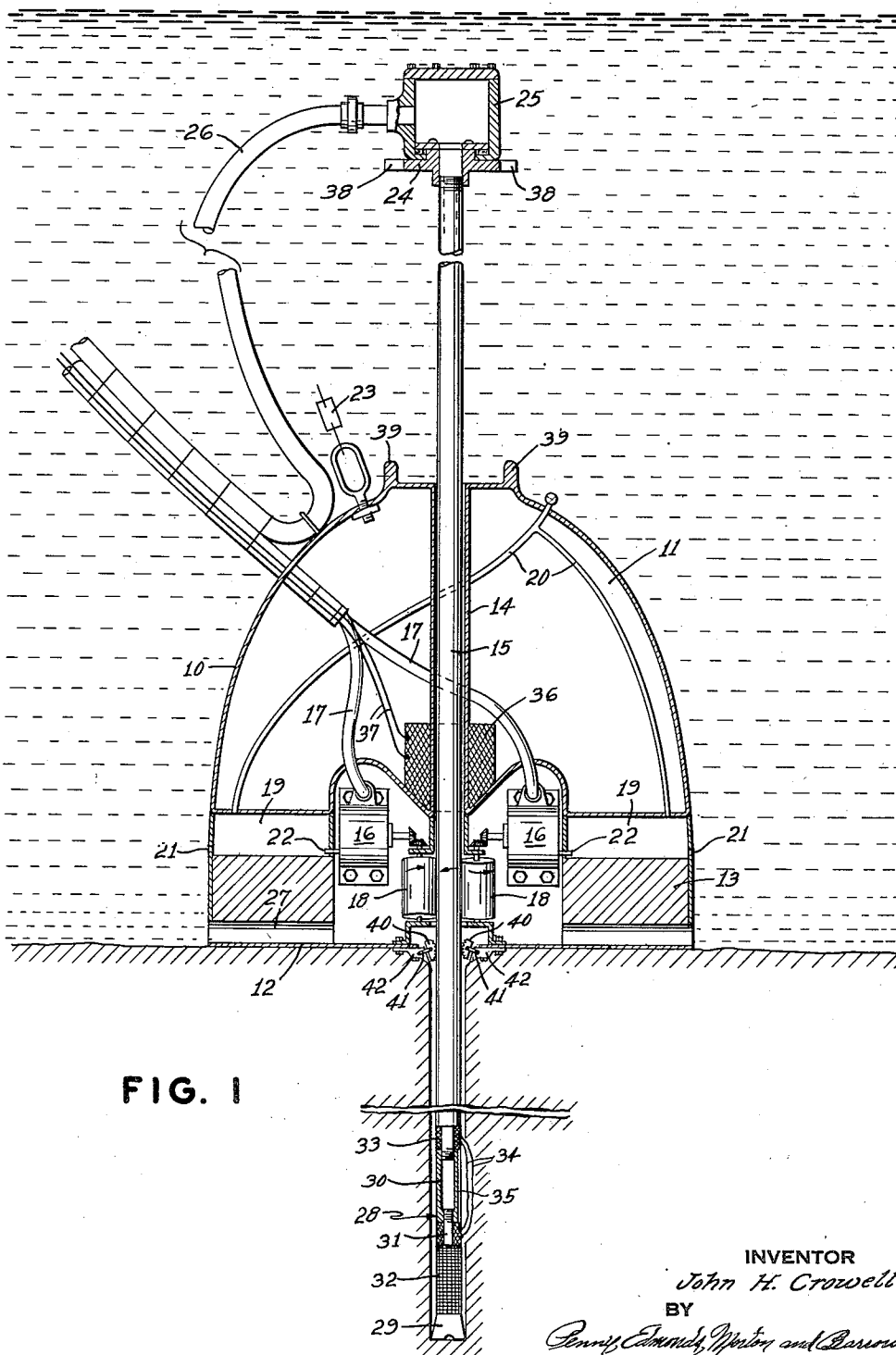
Feb. 16, 1954

J. H. CROWELL
EARTH DRILLING APPARATUS

2,669,431

Filed April 24, 1948

5 Sheets-Sheet 1



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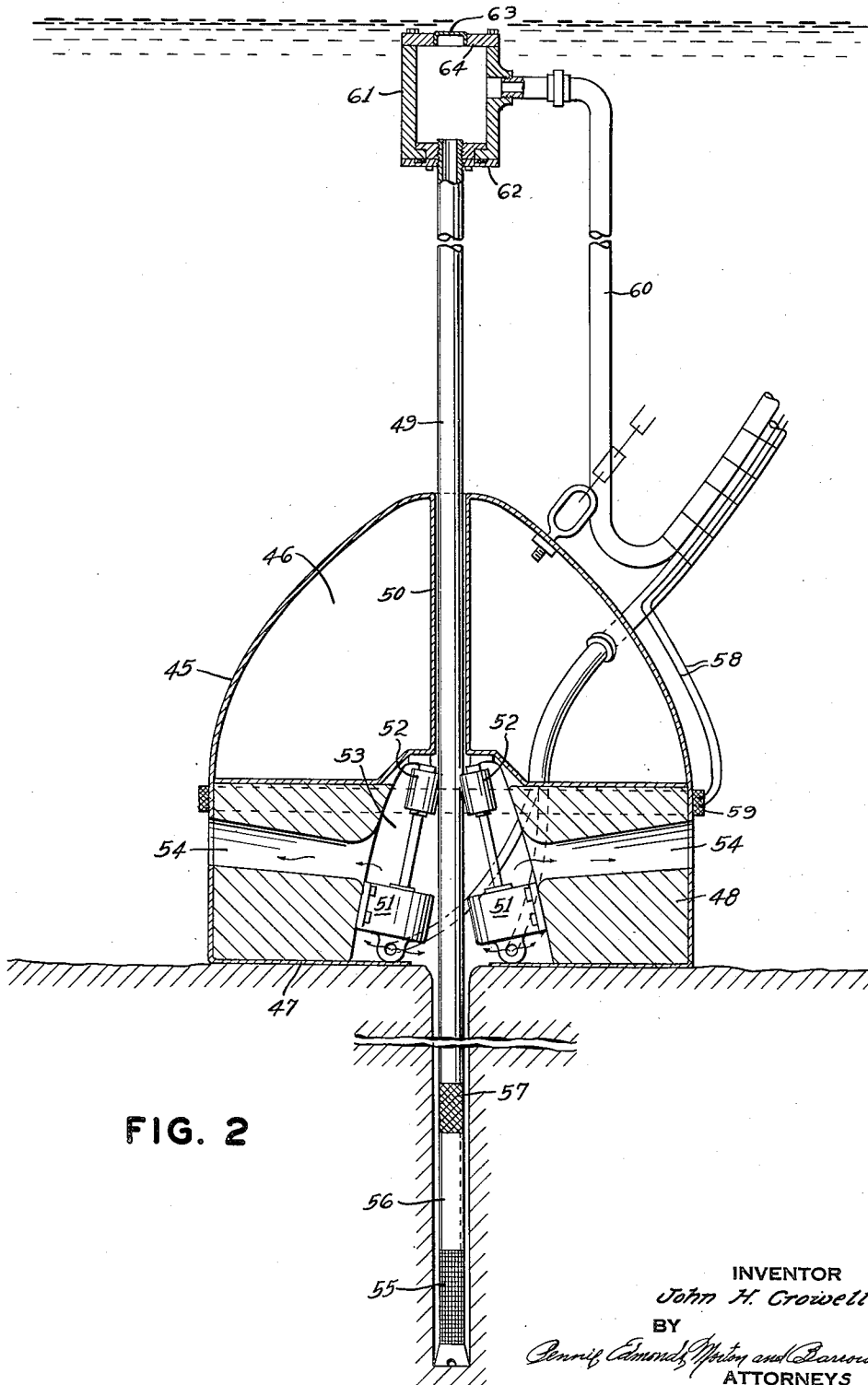
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EARTH DRILLING APPARATUS

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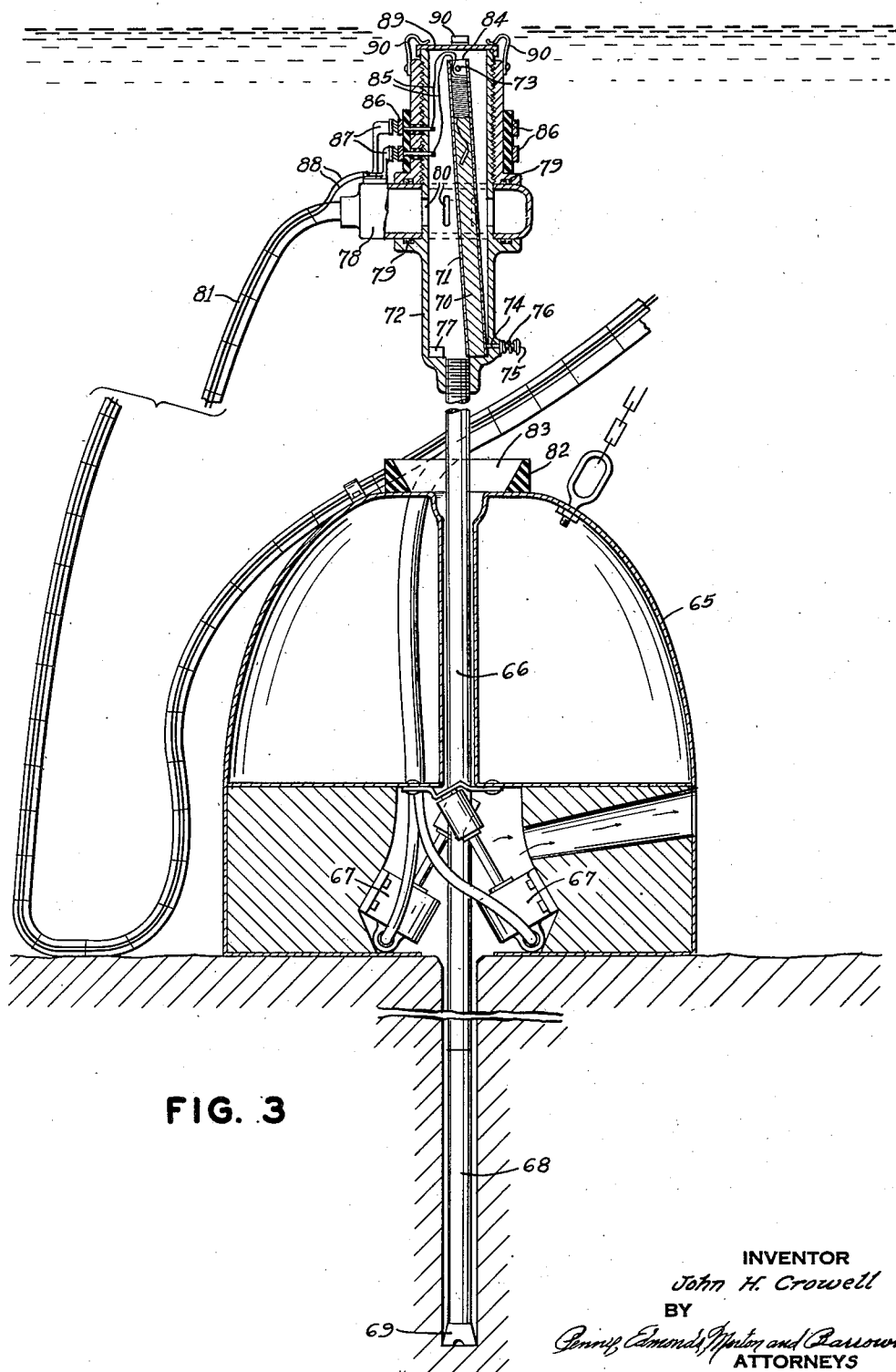
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EARTH DRILLING APPARATUS

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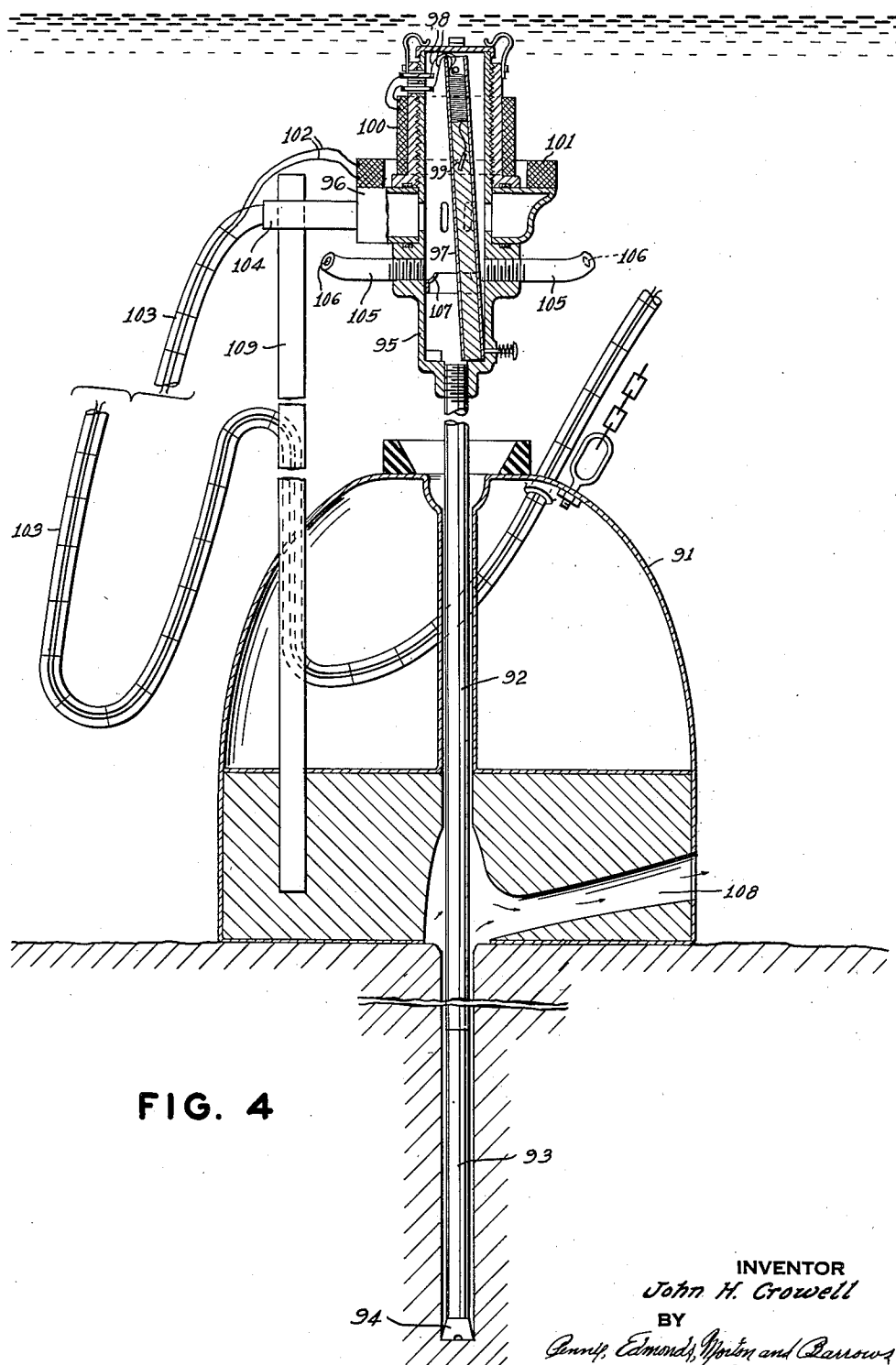
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FIG. 5

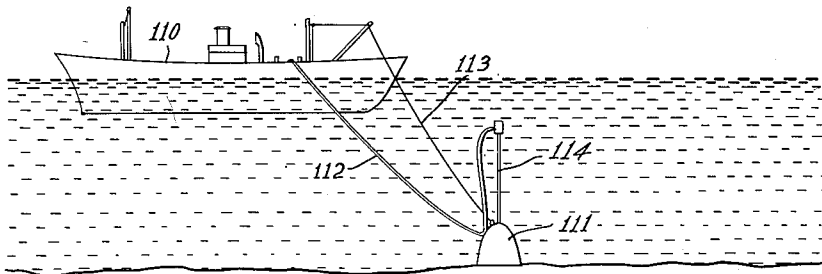


FIG. 6

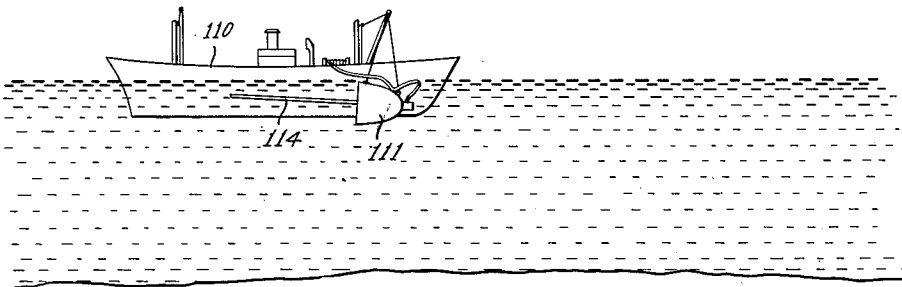
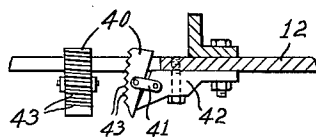


FIG. 7



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UNITED STATES PATENT OFFICE

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EARTH DRILLING APPARATUS

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13 Claims. (Cl. 255—2)

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This invention relates to drilling into earth formations at the bottom of a body of water (for example, into the ocean bottom in coastal waters); and more particularly it is directed to drilling for seismic prospecting in such formations. The invention provides improved apparatus which may be sunk to the bottom of the body of water, and operated from the surface of the water to drill a hole in the underwater earth formation and then to detonate an explosive at the bottom of the hole. The seismic waves created by the explosion are transmitted through the earth formations and are recorded on ship-board instruments connected to geophones placed on the sea floor or suspended from the ship in the usual manner incident to seismic prospecting.

The apparatus of the invention basically comprises a submergible bell which may be sunk to the bottom of the body of water, and a drill pipe extending through the bell and held upright thereby; together with means for rotating the drill pipe while submerged to drill a hole in the ground at the bottom of the body of water, and means for firing an explosive at the bottom of the hole after it has been drilled.

In seismic prospecting on land it is customary to drill a hole twenty to fifty or so feet deep with portable drilling apparatus, and then to detonate a small explosive charge at the bottom of the hole after the drill has been withdrawn. This method is not adaptable to seismic prospecting in underwater formations, because it is not practical to load an underwater drill hole with an explosive charge after withdrawal of the drill. Accordingly, the method heretofore used for seismic prospecting in coastal waters has involved simply dropping a charge of explosive to the bottom of the water, or suspending it in the water and detonating it. While it is possible to obtain some worthwhile information regarding underwater earth formations in this manner, the method is subject to two serious defects.

In the first place, an explosive detonated while simply resting on the sea floor or suspended in the water gives rise to only relatively feeble seismic waves through the underwater earth formations. Such waves often are too weak to be clearly recorded or accurately interpreted. Waves from such explosions that are reflected from the surface of the water and from the sea floor itself, moreover, interfere with the seismic waves traversing the formations whose character is to be ascertained, thus making an already

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difficult task of recording and interpreting the waves even more difficult.

In the second place, explosive charges detonated on the sea floor or suspended in the water in coastal waters often kill many fish. There is frequent conflict between geophysicists seeking authority to detonate explosive charges in coastal waters for seismic prospecting purposes, and fishermen seeking to prevent such explosions in order to protect marine life. There have been occasions when governmental authority has forbidden the detonation of explosives on the floor of the sea in coastal waters because of the harmful effect on fish life.

The invention provides effective apparatus for drilling a hole in earth formations in the bottom of the sea or other body of water, and for detonating an explosive at the bottom of a drill hole when it has been completed. By use of this new apparatus, explosions for seismic prospecting may be produced under conditions giving as reliable and as easily interpreted recordings of seismic waves as can be produced on dry land; and at the same time the explosions are rendered substantially harmless to fish life.

The new apparatus comprises a submergible bell having a closed buoyancy chamber in its upper portion and a broad, flat ballasted bottom which, when the bell is lowered to the sea floor, rests stably thereon. A drill pipe which is rotatable and vertically movable extends through the bell and is held upright thereby. An expandable drill pipe section and bit are provided at the lower end of the drill pipe. The upper end of the drill pipe, above the bell, is closed, and is provided with a swivel connection through which a stream of water may be passed to wash cuttings out of the drill hole. A motor for rotating the drill pipe when the bell is submerged also is provided. The motor preferably is so arranged that it imparts not only a turning moment, but also a downward thrust to the drill pipe, to force the drill down during drilling operations. The drill pipe accommodates a charge of explosive which is placed in position before the apparatus is submerged. Then, when the hole has been drilled to the desired depth, this explosive is detonated at the expandable lower section of the drill pipe, and the seismic waves thereby produced are recorded in the usual manner.

The upper end of the drill pipe normally is closed during drilling operations, so that the water introduced into the pipe will flow down through the pipe to wash the cuttings back up the hole outside the pipe. This closure, however,

is arranged so that it may be opened shortly before or at the time of the explosion, to prevent the back pressure developed in the drill pipe by the explosion from damaging the apparatus.

While the apparatus is submerged, it is connected to a ship at the surface, from which the drilling operations are conducted, by hose lines and electric cables for operating the drilling motors, for supplying water under pressure to the drill pipe, and for detonating the explosive; and it is also connected to the ship by a recovery cable or chain. After the explosive has been fired, the apparatus is raised to the surface, the expendable drill pipe section that was destroyed when the explosive was detonated is replaced, and a fresh charge of explosive is loaded in place. Any other operations necessary to ready the apparatus for drilling and firing a new hole are also performed, and the bell is then again submerged in a new location for repeating the procedure.

Several modifications of the new apparatus, embodying the features briefly mentioned above and other features as well, are shown in the accompanying drawings, wherein

Fig. 1 is a vertical cross section through one form of underwater drilling apparatus shown in position for drilling;

Fig. 2 is a cross section similar to Fig. 1 through another form of underwater drilling apparatus;

Fig. 3 is a view similar to Figs. 1 and 2 of still another modification of the new underwater drilling apparatus;

Fig. 4 is a cross section similar to Figs. 1 to 3 through yet another modification of the apparatus;

Fig. 5 shows schematically the relation between the new underwater drilling apparatus and a ship from which drilling operations are conducted while drilling is in progress;

Fig. 6 shows how the new apparatus may be carried by the ship from one drilling location to another; and

Fig. 7 is an enlarged view of the drill pipe recovery wedges shown in Fig. 1.

Referring first to the form of apparatus shown in Fig. 1, it comprises a submergible bell 10 having a closed buoyancy chamber 11 in its upper portion and a broad, flat bottom 12. A substantial load of ballast 13 is provided to weight the bottom so that the bell will rest stably on the earth at the bottom of the body of water in which it is submerged. A sleeve 14 extends vertically through the bell, and a drill pipe 15 extends through this sleeve. The drill pipe is free to rotate and to move axially in the sleeve, but it is held thereby in upright position when the bell is lowered to the bottom of a body of water. The length of the drill pipe should be substantially equal to the depth of hole it is desired to drill plus the height of the bell. Generally from 25 to 50 feet of drill pipe is sufficient for drilling a hole of adequate depth for seismic prospecting, without becoming unwieldy during use of the apparatus.

The drill pipe is rotated for drilling by hydraulic motors 16 to which water under pressure is supplied from the surface through hoses 17. The motors are arranged to drive a plurality of rollers 18 (advantageously faced with rubber) which are held in tight frictional contact with the drill pipe 15 by the bearings in which they are mounted. When water under pressure is supplied to the motors 16, they cause rotation of the rollers 18 in the directions indicated by the arrows, thereby rotating the drill pipe. The

rollers 18 are mounted with their axes inclined at an acute angle to the axis of the drill pipe, rather than parallel thereto. The direction of inclination with respect to the direction of rotation is such that when the rollers are turned, the force they exert on the drill pipe has a downward component as well as a tangential component. Thus a downward thrust is exerted on the drill pipe while it is being rotated during drilling operations.

The bell includes a floodable compartment 19 between the closed buoyancy chamber 11 and the ballast 13. Valved vent pipes 20 are connected to the top of this compartment, and ports 21 are provided near its bottom. The vent pipes permit air to be vented from the compartment 19 when it is desired to flood it, and the ports 21 provide for the flow of water into and from the compartment. The weight of the bell, when the floodable compartment is filled with water, is substantially greater than the weight of the volume of water it displaces, but is about equal to such weight when the floodable compartment is filled with air. The exhaust from the hydraulic motors is connected through pipes 22 with the interior of the floodable compartment 19. This arrangement is such that when the bell is about to be submerged, the floodable compartment 19 is vented by opening the vent pipe valve until the compartment is filled with water, and then closing it. The water supplied to the hydraulic motors during drilling operations exhausts into the compartment 19, and escapes through the ports 21. When at the conclusion of drilling operations it is desired to raise the bell, compressed air is delivered through the hoses 17 to the motors 16, and it flows thence through the pipes 22 into the compartment 19, displacing the water therein and lightening the bell. It is then comparatively easy to raise the bell to the surface by means of a recovery chain 23 permanently attached to it. The exhaust ports 21 may be fitted with check valves which permit water to escape from the compartment during drilling, but which prevent water from flowing back in after the water has been displaced by air. In such case special provision must be made for flooding the compartment when the vent pipe valve is opened.

A swivel plate 24 is screw-threaded to the upper end of the drill pipe, and is swivelly connected to a water inlet box 25. Water under pressure is supplied from the surface through a hose 26 to the water inlet box and therethrough to the drill pipe. This water travels through the drill pipe and washes cuttings back up out of the hole during drilling operations. The water and the cuttings pass through escape passages 27 in the ballast 13 to the surrounding water.

An expendable drill pipe section 28 is connected to the lower end of the drill pipe 15. A drill bit 29 is fastened to the lower end of this expendable section. In the apparatus of Fig. 1, the expendable lower section comprises a pipe section 30 of the same outside diameter as the drill pipe, and a lower pipe section 31 of smaller diameter secured thereto. A cylindrically formed explosive charge 32 is mounted concentrically about the small diameter pipe section 31, and is itself of such size as not to have an outside diameter greater than the drill pipe.

The explosive 32 is detonated at the proper time by inducing an electric current in a coil 33 surrounding the drill pipe 15 just above the expendable lower section 28. This coil is connected by wires 34 to a detonator imbedded in the

explosive charge. The wires 34 may be taped tightly to the drill pipe before drilling operations begin, to protect them from damage during drilling; and for further protection, they may be received in a longitudinal groove 35 formed in the pipe section 30. For purposes of clarity, the wires 34 are shown outside the groove 35 in Fig. 1.

In order to induce a detonating current in the coil 33, a second coil 36 mounted in the bell also surrounds the drill pipe 15. This second coil is connected to the ship from which operations are conducted by wires 37. The two coils 33 and 36 are inductively coupled by the steel drill pipe 15. Consequently, when a heavy surge of current is passed through the coil 36 in the bell, a current is induced in the lower coil 33, thereby setting off the explosive. The surge of current passed through the upper coil 36 comes, of course, from a battery or generator to which the wires 37 are connected on board the ship.

When the explosive is detonated, a back pressure wave of considerable magnitudes is developed within the drill pipe. To prevent this pressure wave from damaging the equipment, provision is made for opening the normally closed upper end of the drill pipe. In the form of apparatus shown in Fig. 1, this is accomplished by the provision of ears 38 projecting laterally from the swivel plate 24. The ears are arranged to engage with lugs 39 fastened to the top of the bell 10 when the drill pipe has descended far enough through the bell to bring the swivel plate to the level of the top of the bell. This, of course, occurs when the drill hole has been driven to the maximum depth possible with the length of drill pipe used. The swivel plate 24 normally rotates with the drill pipe 15, but as soon as the ears 38 engage with the lugs 39, it is no longer free to do so. Continued rotation of the drill pipe by the motor-driven rollers 18, therefore, causes the drill pipe to be unscrewed from the swivel plate. The swivel plate and inlet box 25 fastened thereto fall off to the side, thus opening the upper end of the drill pipe.

It is apparent that opening the upper end of the drill pipe 15 in this manner occurs as soon as the drill hole has been bottomed, and before the explosive charge is detonated. As soon as the swivel plate 24 is unscrewed from the drill pipe, the pressure of the water fed through the hose 26 decreases. This pressure decrease can be noted on board the operations ship, and provides a clear indication that the hole has been completed. Thereupon the supply of water to the motors 16 can be discontinued and the explosive charge can be detonated. The back pressure wave developed by the explosive inside the pipe passes harmlessly through it, once its upper end has been opened.

The explosion, of course, destroys the lower expendable section 28 of the drill pipe. Consequently, when the bell is brought to the surface after the explosive has been fired, the remnants of the damaged expendable lower section are removed from the drill pipe and a new expendable lower section is fastened in place to prepare the apparatus for the next shot. The pipe section 30 at the upper end of the expendable section is made long enough so that the drill pipe above it is not damaged.

The swivel plate 24 and the water inlet box 25 hang from the end of the hose 26 when the bell is brought to the surface after firing the explosive. It is easily retrieved and screwed back on to the drill pipe for the next drilling operation.

To insure retrieving the drill pipe 15 when the bell 10 is raised to the surface (the grip of the driving rollers 18 may not always be sufficient), a series of wedges 40 are secured about the periphery of the drill pipe by links 41 to wedge blocks 42 fastened to the bottom of the bell. These wedges are shown on an enlarged scale in Fig. 7. When the bell is raised to the surface, the wedges 40 are drawn tightly between the drill pipe and the wedge blocks 42, and by their frictional grip on the drill pipe cause it to be raised with the bell. The pipe-gripping faces of the wedges are provided with teeth 43 pitched like screw threads at an angle to the axis of the drill pipe. When the drill pipe is being rotated during drilling operations, these teeth cause the wedges to be raised enough to permit the turning pipe to pass down through the bell; but when rotation of the drill pipe ceases and the bell is raised, they grip the pipe tightly.

The form of apparatus shown in Fig. 2 is generally the same as that shown in Fig. 1, but with modifications in the construction of the bell itself and in the construction of the water inlet box. The bell 45 shown in Fig. 2 has a buoyancy chamber 46 in its upper portion and a broad, flat bottom 47. A sufficient load of ballast 48 is provided in the lower portion of the bell to impart to it a total weight somewhat greater than the weight of the volume of water it displaces, so that it will rest stably on the ground at the bottom of the water in which it is submerged. A length of drill pipe 49 passes through a vertical sleeve 50 in the bell and is held upright thereby. The drill pipe is rotated during drilling operations by hydraulic motors 51 driving rollers 52, which bear tightly against the drill pipe, all generally in the same manner as in the apparatus shown in Fig. 1. The motors are mounted in the bell in a motor compartment 53. The bell 45 is not provided with a floodable compartment between the buoyancy chamber 46 and the ballast 48. Consequently, the exhaust from the motors discharges directly into the motor compartment 53, and therefrom is exhausted to the surrounding water through ports 54.

An explosive charge 55 is carried on an expendable lower drill pipe section 56, similarly to the corresponding expendable lower section 28 of the apparatus shown in Fig. 1. Firing of the explosive 55 is accomplished by inducing a detonating current in a coil 57 surrounding the drill pipe just above the expendable lower section 56. In the apparatus of Fig. 2, this detonating current is induced by passing a heavy current from the ship at the surface of the water through wires 53 connected to a coil 59 mounted on the bell. The firing arrangement thus is similar to what has been described above in connection with Fig. 1, excepting only that the coil 59 surrounds the entire bell rather than just the drill pipe. The two coils are inductively coupled, however, by the steel drill pipe and the steel of the bell.

Water to facilitate drilling is supplied to the interior of the drill pipe 49 through a hose 60 connected to a water inlet box 61, which in turn is fastened to a swivel plate 62 attached to the upper end of the drill pipe. Unlike the apparatus shown in Fig. 1, the swivel plate 62 is not intended to be unscrewed from the drill pipe when the drill hole has been bottomed. Instead, to relieve the back pressure wave created in the drill pipe when the explosive is fired, a blow-out plate 63 is mounted in the top of the water inlet box. This plate is simply pressed tightly into an aper-

ture for receiving it in the inlet box cover 64. It is held in place frictionally, like the top on a paint can, with sufficient tightness to withstand the pressure of the water forced through the inlet box during drilling, but not tightly enough to withstand a substantially greater pressure created in the pipe when the explosive is detonated. Consequently, upon firing the explosive, the back pressure wave simply blows the plate 63 out of the aperture in which it is pressed, thus opening the upper end of the drill pipe and preventing damage to the apparatus.

When the bell 45 is raised to the surface, after a hole has been drilled and fired, the drill pipe is brought up with it because the swivel plate 62, being larger than the sleeve 50 in which the drill pipe is received, prevents the bell from being pulled away from the drill pipe.

The form of apparatus shown in Fig. 3 is essentially the same as shown in Fig. 2, except for modifications in the arrangement for firing the explosive when the drill hole has been completed, and some modification in the design of the water inlet box. Here the bell 65, the drill pipe 66, and the hydraulic motors 67 by which the drill pipe is rotated are all about the same as shown in Fig. 2. However, the expendable lower section 68 of the drill pipe is simply a short length of the pipe itself, to which a drill bit 69 is attached.

The explosive charge 70 is carried in a receptacle 71 inside the drill pipe at its upper end. For this purpose, the upper end of the drill pipe is provided with a head 72 which serves also as a swivel element. The explosive receptacle 71 is tubular, with an inside diameter no larger than the inside diameter of the drill pipe. Its upper end is mounted in the head on a pivot pin 73, substantially on the axis of the drill pipe. Its lower end is connected by a link or flexible wire 74 to a push rod 75, which in turn is normally acted on by a compression spring 76 to hold the lower end of the explosive receptacle away from axial alignment with the drill pipe. By pushing in on the push rod, however, the lower end of the explosives receptacle 71 may be brought into axial alignment with the drill pipe 66. A guide plate 77 of suitable shape is provided to insure proper alignment of the explosives receptacle with the drill pipe when the push rod is pressed in to its full extent. By making the guide plate 77 in the form of a strong permanent magnet, it can also serve to hold a steel explosives receptacle in the proper alignment into which it guides it.

The head 72 is swivelly connected to a water inlet box 78. Flanges 79 prevent axial movement of the inlet box with respect to the drill pipe, but permit free rotation of these parts relative to one another. Openings 80 in the head adjacent the water inlet box provide for the flow of water between these two elements. A supply of water to facilitate drilling is delivered to the water inlet box through a hose 81, and normally it flows through the openings 80 and thence directly down the drill pipe, washing cuttings back out of the hole.

When the hole has been drilled to the full depth permitted by the length of drill pipe used, its head 72 comes in contact with the top of the bell, where a cam ring 82 is mounted. The cam ring has an inner surface 83 positioned to engage with the push rod 75, and force it inwardly as the head comes into contact with the top of the bell. Thereby the lower end of the explosives receptacle is brought into coaxial align-

ment with the drill pipe, interfering with free flow of water directly from the head 72 into the main length of drill pipe 66. The upper end 84 of the explosives receptacle is open, however, so that as soon as the lower end of the explosives receptacle moves into coaxial alignment with the drill pipe, the pressure of the water delivered through the hose 81 acts on the upper surface of explosive charge 70 in the receptacle and forces it, like a piston, down through the drill pipe to the expendable lower section 68. With the explosive now more or less plugging the drill pipe, an increase in the pressure of the water delivered through the hose 81 will be indicated on pressure gauges connected with the pump on the ship from which the water is supplied, providing thereby an indication that the drill hole has been bottomed and that the explosive charge is in position to be fired.

The explosive is connected by wires 85 to slip rings 86 mounted on the drill pipe head 72. When the explosive charge is first placed in the receptacle 71, these wires are coiled so as to pay out freely when the explosive is forced to the bottom of the drill pipe. The slip rings 86 are in contact with brushes 87 connected by wires 88 to the ship from which operations are conducted, so that a detonating current can be delivered to the explosive charge by closing the circuit through the brushes and the explosive by means of a switch on board the ship.

The upper end of the drill pipe is closed during drilling operations by a blow-out closure plate 89 held in place at the top of the head 72 by spring clips 90. The spring clips hold the closure plate in place tightly enough to withstand the pressure of the water supplied to the interior of the drill pipe during normal drilling operations; but they enable the plate to be blown off by the substantially greater force of the back pressure wave created in the pipe when the explosive is fired.

The apparatus shown in Fig. 4 is generally the same as that shown in Fig. 3, except that different means than the hydraulic motors 67 are provided for turning the drill pipe during drilling, and a somewhat different arrangement for firing the explosive is provided.

The bell 91 of Fig. 4 supports a drill pipe 92 in upright position for drilling, and the drill pipe is provided with an expendable lower section 93 to which a bit 94 is attached substantially as described above. The upper end of the drill pipe is provided with a head 95 swivelly connected to a water inlet box 96. Inside the head 95 is an explosives receptacle 97 of the same type and arranged for operation similarly to that described in connection with Fig. 3. Wires 98, however, connect a detonator 99 in the explosive with a firing coil 100, rather than with slip rings as described in connection with Fig. 3. The coil 100 is mounted on the head 95 and rotates with the drill pipe. A second coil 101 mounted on the water inlet box 96 is electrically connected by wires 102 to the ship from which operations are conducted. The two coils are inductively coupled by virtue of being in close proximity to one another, and by means of the steel of the water inlet box and the head. Consequently, when a heavy surge of current is caused to flow through the coil 101 on the water inlet box, a firing current is induced in the firing coil 100, thus setting off the explosive. This firing arrangement is in principle the same as described in connection with Figs. 1 and 2, but here the

two coils are in close proximity and are closely coupled inductively, so that they operate more efficiently.

Water is delivered to the interior of the head 95 at the upper end of the drill pipe through a hose 103 connected to a pipe 104 which in turn is rigidly connected to the water inlet box 96. Projecting laterally from the head 95 are two or more jet pipes 105 provided at their outer ends with nozzles having apertures 106. The nozzles and nozzle apertures are directed substantially tangentially to the circle described by the outer ends of the jet pipes 105 when the drill pipe rotates, and also they are directed somewhat upwardly. A deflector plate 107 substantially in the form of a truncated cone is mounted in the head 95 of the drill pipe about at the point where the jet pipes 105 communicate with the interior thereof (the deflector plate is formed with a slot to permit the explosives receptacle 97 to occupy the position shown in the drawing). Consequently, a part of the water supplied under pressure to the interior of the head is deflected out through the pipes 105 and escapes as jets through the nozzle apertures 106 into the surrounding water in which the apparatus is submerged. The reaction of these jets imparts a rotating force to the drill pipe, thereby turning it for drilling operations. Since the jets are directed slightly upwardly, as well as tangentially, the reaction to the escaping jets also imparts a downward thrust to the drill pipe, causing the bit 94 to dig into the ground at the bottom of the drill hole.

That portion of the water entering the head 95 which is not deflected through the jet pipes passes down through the drill pipe 92 during drilling, and washes cuttings back up through the drill hole and out through an escape port 108 extending through the ballast in the lower portion of the bell 91.

In order to prevent the wires 102 and hose 103 from becoming entangled with the drill pipe 92 and jet pipes 105 during drilling operations, a mast 109 is firmly secured to the bell 91 and extends upwardly parallel to the drill pipe. This mast is mounted in position to engage with the pipe 104 through which water enters the inlet box 96, preventing any accidental turning of the water inlet box while the drill pipe is rotating. The danger of entangling the hose and wires with the drill pipe can be further reduced by making the mast hollow and by passing the hose, with wires taped thereto, through the mast about to its center, substantially as shown. Then only a length of hose and wires about equal to half the depth of the hole to be drilled need be exposed in the open water to the danger of entanglement.

The way in which the new apparatus is used is shown schematically in Figs. 5 and 6. Fig. 5 shows a ship 110 anchored at the surface of a body of water in which a bell 111 of the character above described is submerged. The ship is connected with the bell by hose lines 112 through which water is supplied to the hydraulic or jet motors for turning the drill pipe, and to the drill pipe for washing cuttings from the hole. Wires taped to the hose lines also connect the ship with the bell for the purpose of detonating the explosive when the drill hole has been bottomed. A recovery chain or cable 113 extends between the bell and the ship, so that the bell can be raised to the surface after the explosive has been fired. The ship or a companion ship

may carry whatever apparatus is necessary for detecting and recording seismic waves provided in the underwater earth formations when the explosive is fired, as is customary in seismic prospecting. The bell 111 is shown in Fig. 5 with the drill pipe 114 projecting up above it, as it does when drilling operations are just getting under way.

Fig. 6 shows how the bell 111 may be carried by the ship from one drilling location to another. When the bell is raised alongside the ship, as shown in Fig. 6, and while it is being moved, the damaged expendable section at the lower end of the drill pipe is replaced, the drill pipe is moved back up through the bell into position for commencing a new drill hole, a new charge of explosive is set in place and connected for firing, the upper end of the drill pipe is again closed (as by reattaching the swivel plate 24 of Fig. 1 or by replacing the blow-out cap of Figs. 2 to 4), and the bell otherwise is readied for drilling and firing a new hole.

The various modifications of the new apparatus shown in the drawings and described above are only illustrative of the invention. The various features of the invention may be combined in other ways than those specifically shown.

I claim:

1. Apparatus for drilling into earth formations at the bottom of a body of water comprising a bell having a closed buoyancy chamber in its upper portion and a ballasted lower portion, a vertical drill pipe extending through and held upright by said bell, said drill pipe being rotatably and vertically movable relative to the bell, a drill bit on the lower end of said pipe, a water inlet box swivelly connected to the drill pipe at its upper end, a hose connected to said inlet box for delivering a stream of water to the interior of the drill pipe, a motor for rotating the drill pipe when the bell is submerged to the bottom of the body of water, a vertical mast extending upwardly from the bell, and a projection extending laterally from the inlet box into engagement with the mast, whereby accidental rotation of the inlet box with the drill pipe and danger of entanglement of the hose with the drill pipe is prevented.

2. In apparatus of the character described, a submergible bell, a completely submergible drill pipe extending completely through said bell and arranged to be held upright thereby, said drill pipe projecting beyond the top and bottom surfaces of the bell and being rotatable and vertically movable relative to the bell, and a jet motor for rotating the drill pipe comprising a jet pipe secured to and extending laterally from the drill pipe at a point above the bell, said jet pipe communicating with the interior of the drill pipe and being provided at its outer end with a nozzle directed substantially tangentially to the circle described by the outer end of the jet pipe during rotation of the drill pipe, and means for delivering a stream of water under pressure through said jet pipe comprising a water inlet box swivelly connected to the drill pipe at its upper end and a hose connected to said water inlet box for delivering a stream of water to the interior of the drill pipe.

3. In apparatus of the character described, a submergible bell, a completely submergible drill pipe extending completely through said bell and arranged to be held upright thereby, said drill pipe projecting beyond the top and bottom surfaces of the bell and being rotatable and vertically movable relative to the bell, and a jet mo-

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tor for rotating the drill pipe and imparting a downward thrust thereto comprising a jet pipe secured to and extending laterally from the drill pipe at a point above the bell, said jet pipe communicating at its inner end with the interior of the drill pipe being provided at its outer end with a nozzle directed both slightly upwardly and substantially tangentially to the circle described by the outer end of the jet pipe during rotation of the drill pipe, and means for delivering a stream of water under pressure through said jet pipe comprising a water inlet box swivelly mounted on the upper end of the drill pipe and a hose connected to the water inlet box for delivering a stream of water to the interior of the drill pipe.

4. In drilling apparatus of the character described, a submergible bell, a drill pipe extending through said bell and arranged to be held upright thereby, said drill pipe being rotatable and vertically movable relative to the bell, a head secured to the upper end of the drill pipe above the bell, a water inlet box swivelly connected to said head and communicating therewith, a plurality of jet pipes extending laterally from said head, the outer end of each of said jet pipes being provided with a nozzle directed slightly upwardly and substantially tangentially to the circle described by the outer end of the jet pipes during rotation of the drill pipe, whereby water admitted under pressure to the water inlet box flows into the head and escapes in part through the jet pipes, imparting a rotating force and downward thrust to the drill pipe, and in part through the drill pipe, facilitating drilling operations.

5. In seismic prospecting apparatus of the character described, a submergible bell, a completely submergible drill pipe extending completely through the bell and arranged to be held upright thereby, an expendable drill pipe section and bit at the lower end of said drill pipe, a water inlet box swivelly connected to the upper end of the drill pipe, a motor for rotating the drill pipe when the bell is submerged to the bottom of a body of water, thereby to drill a hole in the earth formation at the bottom of said body of water, and means for detonating an explosive charge at the expendable drill pipe section when the hole has attained desired depth, said detonating means comprising a first coil mounted on the water inlet box, a second coil rotatable with the drill pipe relative to said first coil, said coils being in close proximity to each other and inductively coupled, wires connecting said second coil to a detonator in the explosive charge, and means for passing an electric current through said first coil, whereupon a detonating current is induced in said second coil.

6. In seismic prospecting apparatus of the character described, a submergible bell having a closed buoyancy chamber in its upper portion and a ballasted lower portion, a drill pipe sleeve extending vertically completely through the bell and opening at both its ends to the outer surface of the bell, a drill pipe extending completely through the drill pipe sleeve and arranged to be held upright thereby, an expendable drill pipe section and bit at the lower end of said drill pipe, an explosives receptacle mounted at the upper end of the drill pipe above the bell, means for normally holding a charge of explosive in said explosives receptacle, a cam operated push rod for moving the charge of explosive from engagement with said holding means into coaxial alignment with the drill pipe, and means for trans-

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ferring the charge of explosive from said receptacle through the drill pipe to the expendable section at the lower end thereof.

7. In seismic prospecting apparatus of the character described, a submergible bell, a drill pipe extending through the bell and arranged to be held upright thereby, an expendable drill pipe section and bit at the lower end of said drill pipe, a tubular explosives receptacle mounted at the upper end of the drill pipe above the bell, means normally holding said receptacle away from coaxial alignment with the drill pipe, a push rod for moving said receptacle substantially into coaxial alignment with the drill pipe, whereby an explosive charge in said receptacle may be delivered into the drill pipe for transfer to the expendable lower end section thereof, means for rotating the drill pipe and causing it to descend relative to the bell, and a cam at the top of the bell positioned to engage with the push rod to actuate movement of the receptacle into coaxial alignment with the drill pipe when the upper end of the drill pipe has descended to the top of the bell.

8. In seismic prospecting apparatus of the character described, a drill pipe having an expendable lower section, a head secured to the upper end of the drill pipe and communicating therewith, a hose connected to said head and communicating with a source of water under pressure for introducing water under pressure into said head, means for normally holding a charge of explosive in said head but away from position to enter the drill pipe, and a cam operated push rod for moving said explosives charge from engagement with said holding means within the head into the drill pipe while water under pressure is being supplied to the head, whereby the water forces the explosives charge through the drill pipe to the expendable lower section thereof.

9. Apparatus for drilling into earth formations at the bottom of a body of water comprising a self-stabilized drill pipe support structure, said drill pipe support structure comprising a broad base member adapted to contact and be supported by the earth floor at the bottom of the body of water, a permanent ballast section positioned directly above and adjacent said base member, a closed buoyancy chamber positioned above said ballast section, and a drill pipe supporting sleeve extending vertically through said buoyancy chamber substantially coterminous therewith, a vertical drill pipe rotatably and vertically movably mounted in the sleeve of the aforesaid drill pipe support structure and extending completely through said sleeve and the ballast section of the drill pipe support structure, a drill bit at the lower end of said vertical drill pipe, a drill drive motor connected to said drill pipe exteriorly of said buoyancy chamber adapted to rotate and to advance the drill pipe downwardly into said earth formation, power supply means connecting said drill drive motor to a source of power above the surface of the body of water, and a supporting element affixed to the exterior of the buoyancy chamber of the drill pipe support structure whereby the drilling apparatus may be lowered from above the surface of the body of water to its operative drilling position on the floor of said body of water, said drill pipe support structure resting stably of its own weight in upright position on the earth floor of said body of water when in said operative position.

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10. Apparatus according to claim 9 having a water inlet box swivelly connected to the drill pipe at its upper end, and a hose connected to said water inlet box for delivering a stream of water to the interior of the drill pipe.

11. Apparatus for seismic prospecting of earth formations at the bottom of a body of water comprising a self-stabilized drill pipe support structure, said drill pipe support structure comprising a broad base member adapted to contact and be supported by the earth floor at the bottom of the body of water, a permanent ballast section positioned directly above and adjacent said base member, a closed buoyancy chamber positioned above said ballast section, and a drill pipe supporting sleeve extending vertically through said buoyancy chamber substantially coterminus therewith, a vertical drill pipe rotatably and vertically movably mounted in the sleeve of the aforesaid drill pipe support structure and extending completely through said sleeve and the ballast section of the drill pipe support structure, an expendable drill pipe section and drill bit at the lower end of said vertical drill pipe, an explosive charge mounted on said drill pipe, means for detonating the explosive charge at the expendable drill pipe section, a drill drive motor connected to said drill pipe exteriorly of said buoyancy chamber to rotate and to advance the drill pipe downwardly into said earth formation, power supply means connecting said drill drive motor to a source of power above the surface of the body of water, and a supporting element affixed to the exterior of the buoyancy chamber of the drill pipe support structure whereby the apparatus may be lowered from above the surface of the body of water to rest stably of its own weight in upright position on the earth floor of said body of water in position to drill a hole into the earth formation therebeneath and to

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detonate said explosive charge adjacent the bottom of the drill hole.

12. Apparatus according to claim 11 having a water inlet box swivelly connected to the drill pipe at the upper end, and a hose connected to said water inlet box for delivering a stream of water to the interior of the drill pipe.

13. Apparatus according to claim 12 in which the water inlet box is provided at its upper end with a water escape opening, an operable closure plate disposed in position to close said water escape opening, and fastener means securing said closure plate in place, said fastener means resisting movement of said closure plate with sufficient force to prevent escape through said water escape opening of water delivered to the interior of the drill pipe during drilling operations and with insufficient force to prevent escape of water through said water escape opening upon detonation of the explosive charge.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,435,140	Rolland	Nov. 7, 1922
2,001,529	Dornier	May 14, 1935
2,058,287	Anderson	Oct. 20, 1936
2,171,672	Plummer	Sept. 5, 1939
2,187,871	Voorhees	Jan. 23, 1940
2,283,200	Flude	May 19, 1942
2,384,851	Reichert	Sept. 18, 1945
2,503,516	Shrewsbury	Apr. 11, 1950
2,512,783	Tucker	June 27, 1950

FOREIGN PATENTS

Number	Country	Date
160,865	Great Britain	Apr. 7, 1921