United States Patent [19]

Rininger

[11] **3,796,273**

[45] **Mar. 12, 1974**

[54] **UNDERWATER WELL STRUCTURE**

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[73] Assignee: **Global Marine Inc.,** Los Angeles, Calif.

[22] Filed: **Oct. 22, 1971**

[21] Appl. No.: **191,712**

[52] **U.S. Cl.** **175/7,** 166/.5, 61/41

[51] **Int. Cl.** **E21b 48/01**

[58] **Field of Search** ..... 175/5–9; 166/.5, .6, DIG. 1; 61/40, 41

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Primary Examiner—Marvin A. Champion
Assistant Examiner—Richard E. Favreau
Attorney, Agent, or Firm—Christie, Parker & Hale

[57] **ABSTRACT**

A substantially cylindrical container has opposite ends one of which is at least partially closed and the other of which is open. The container has an interior sized to receive entirely therein a blowout preventer and associated equipment related to the drilling of oil and gas wells at submerged locations. The one end of the container carries cutting means which are operable upon rotation of the container to penetrate an earth formation engaged by the cutting means. Means are provided for rotating the container about its axis and for circulating fluid under pressure through the one end of the container for removing cuttings from the cutting means.

35 Claims, 12 Drawing Figures

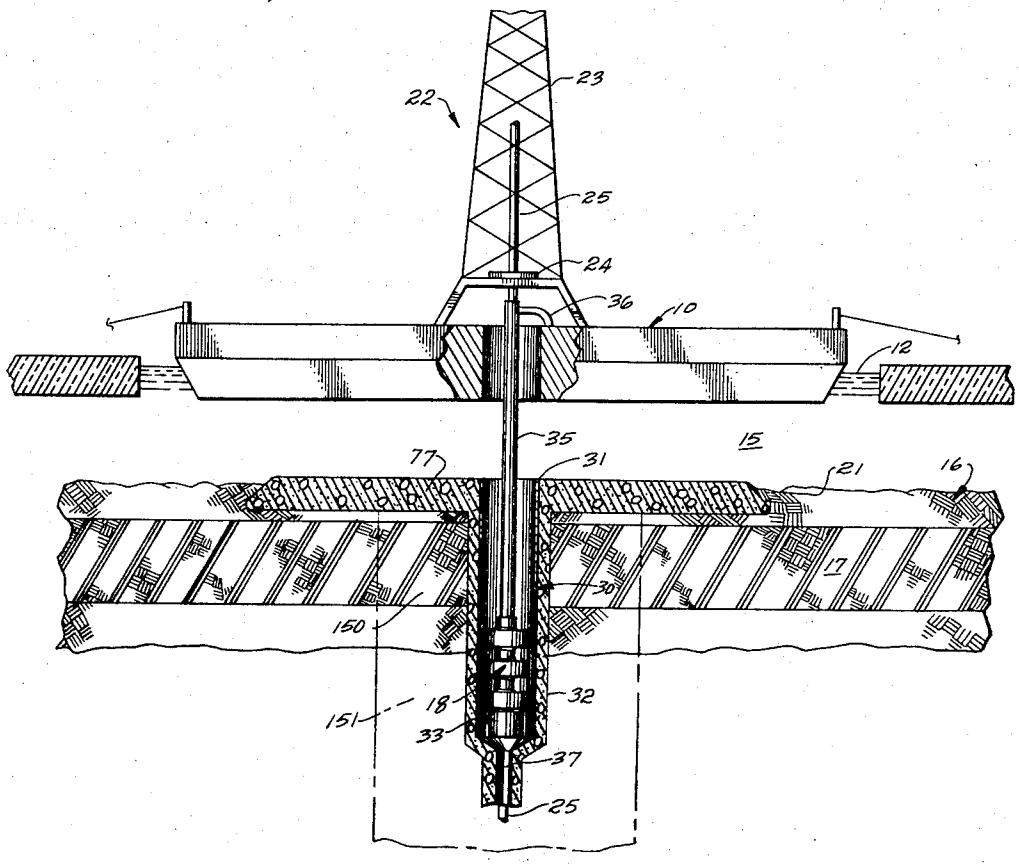


FIG. 1

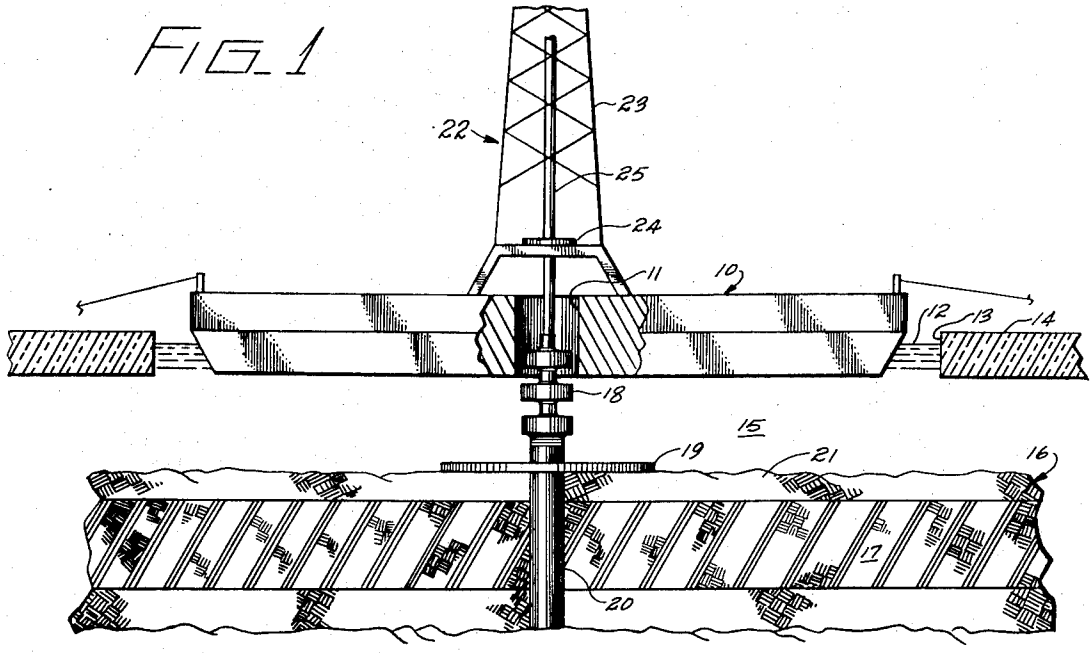
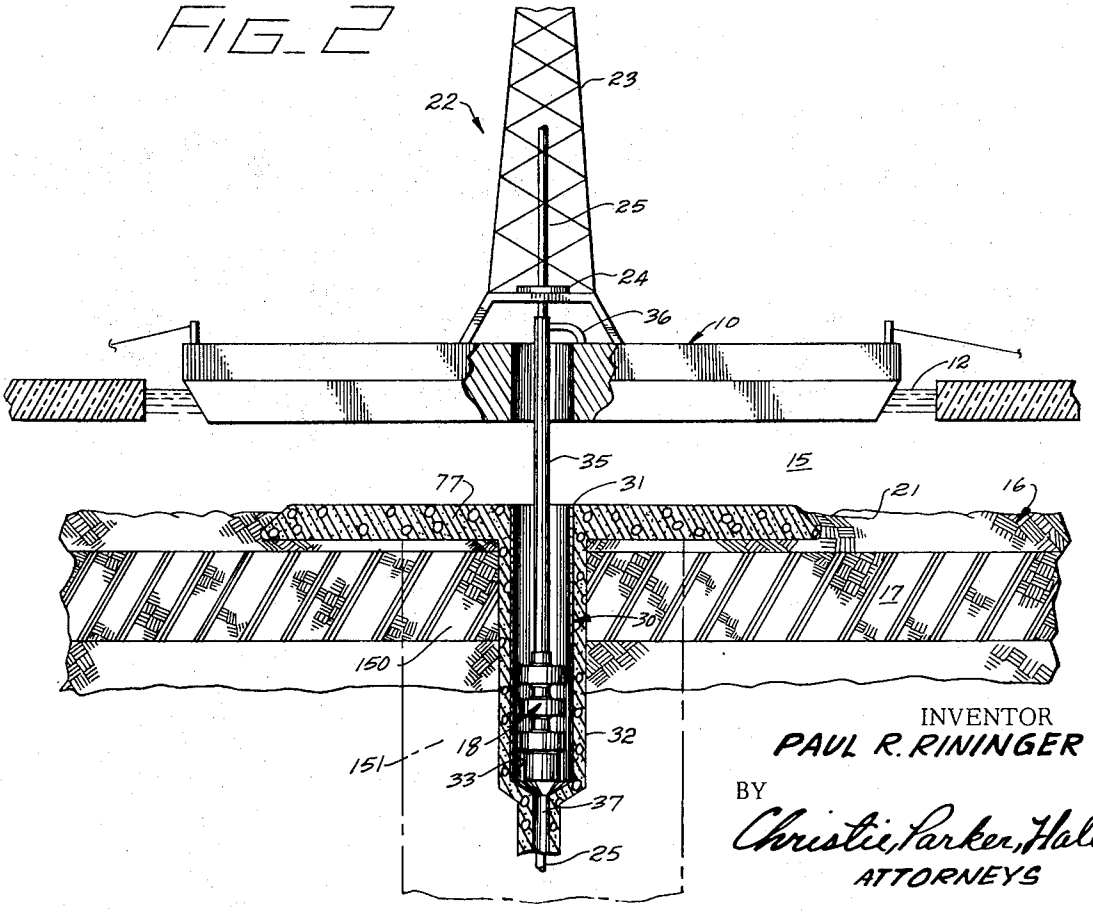


FIG. 2



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FIG. 3

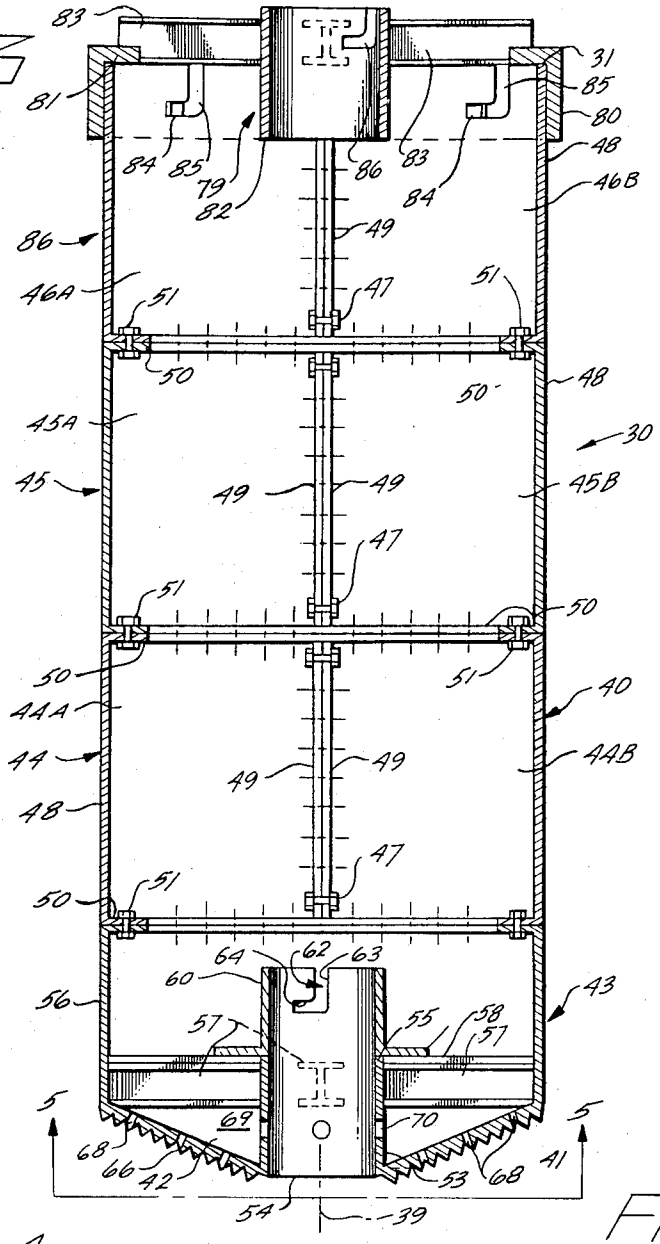


FIG. 4

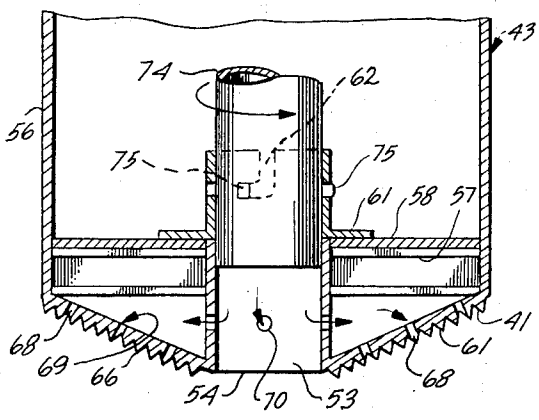


FIG. 6

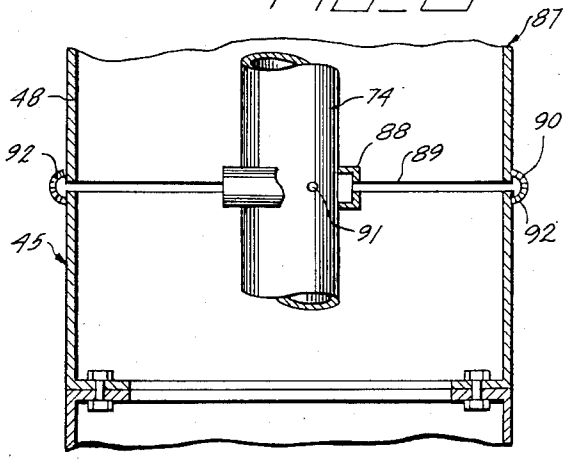


FIG_5

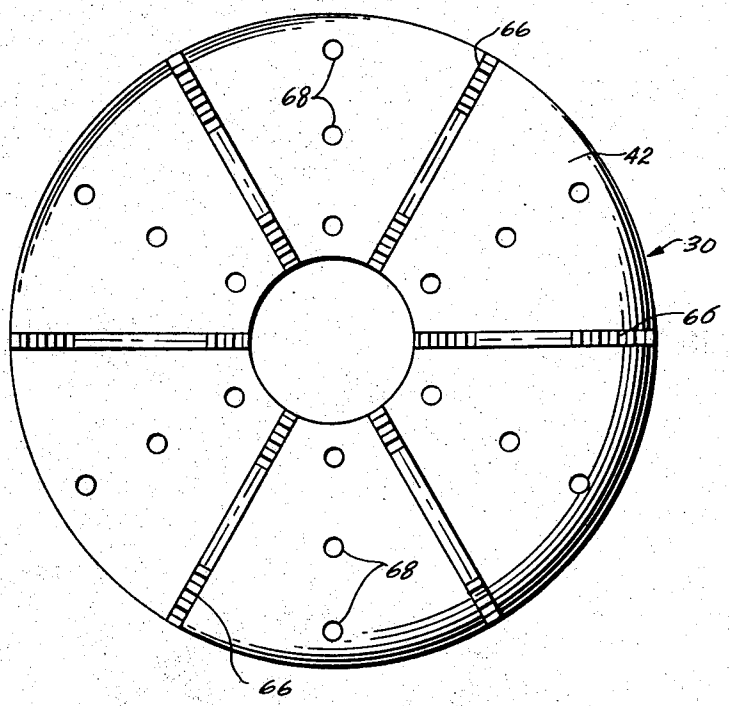

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FIG_7

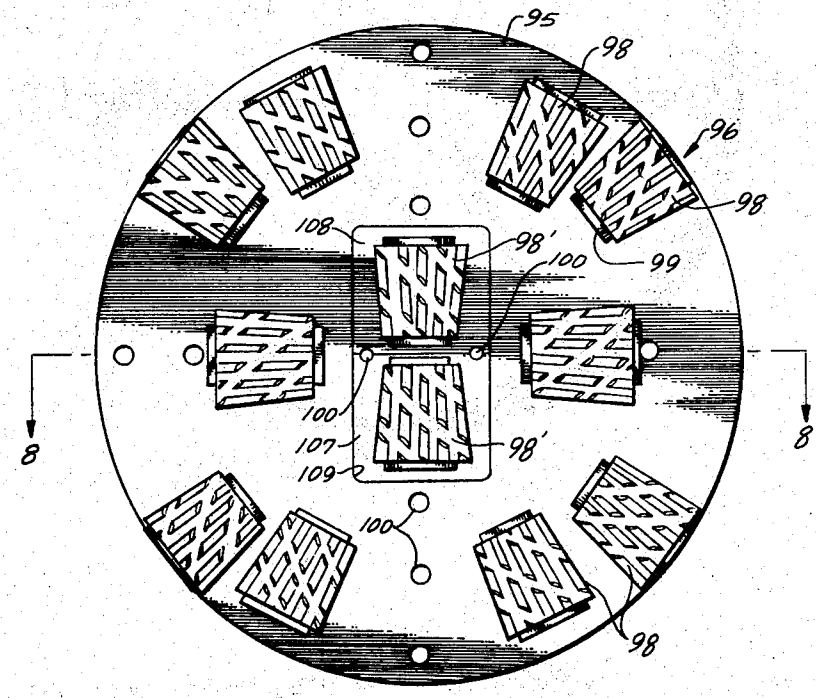

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FIG. 8

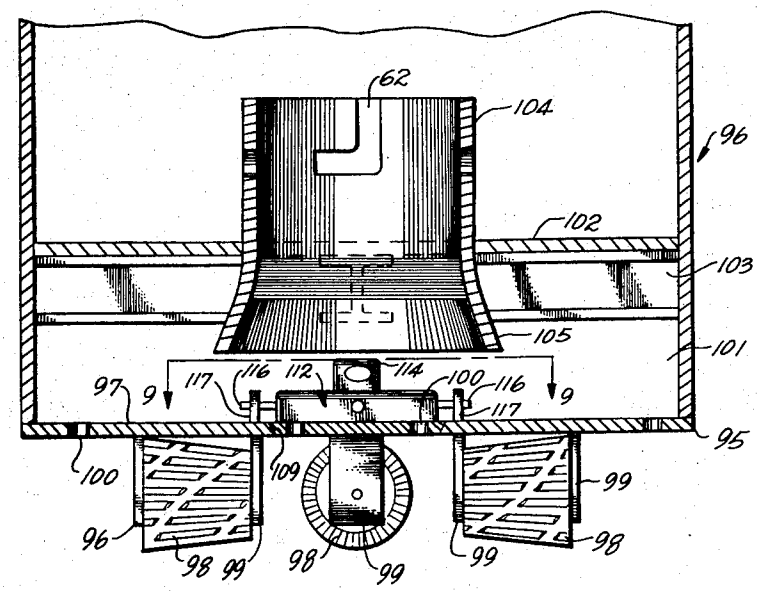

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FIG. 9

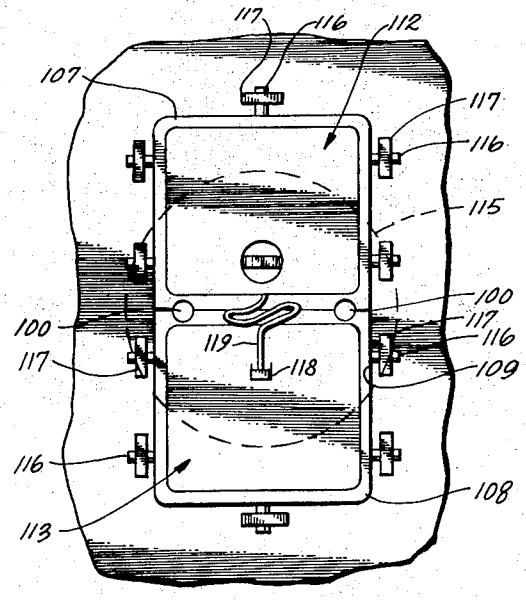

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FIG. 10

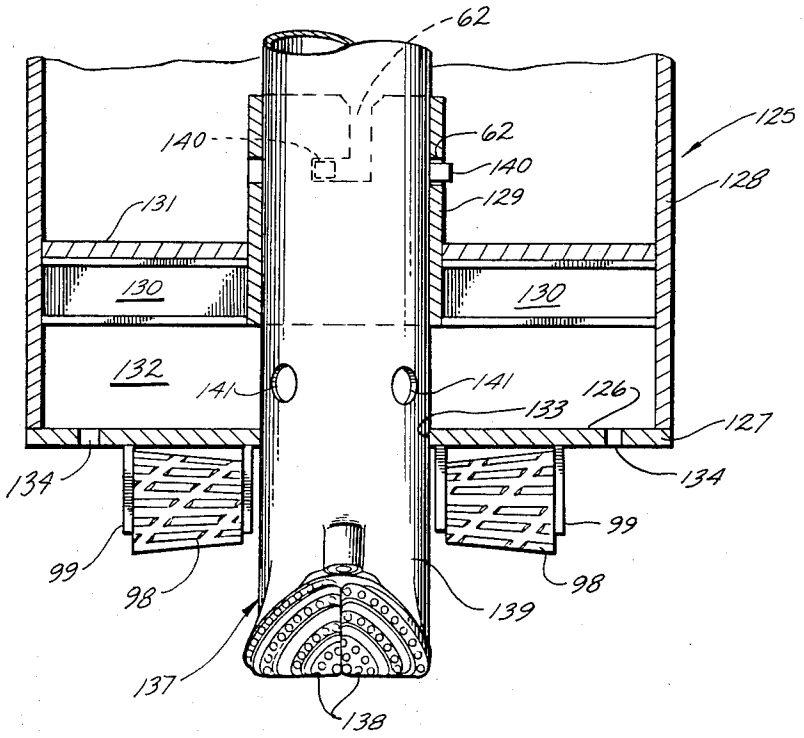

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FIG. 11

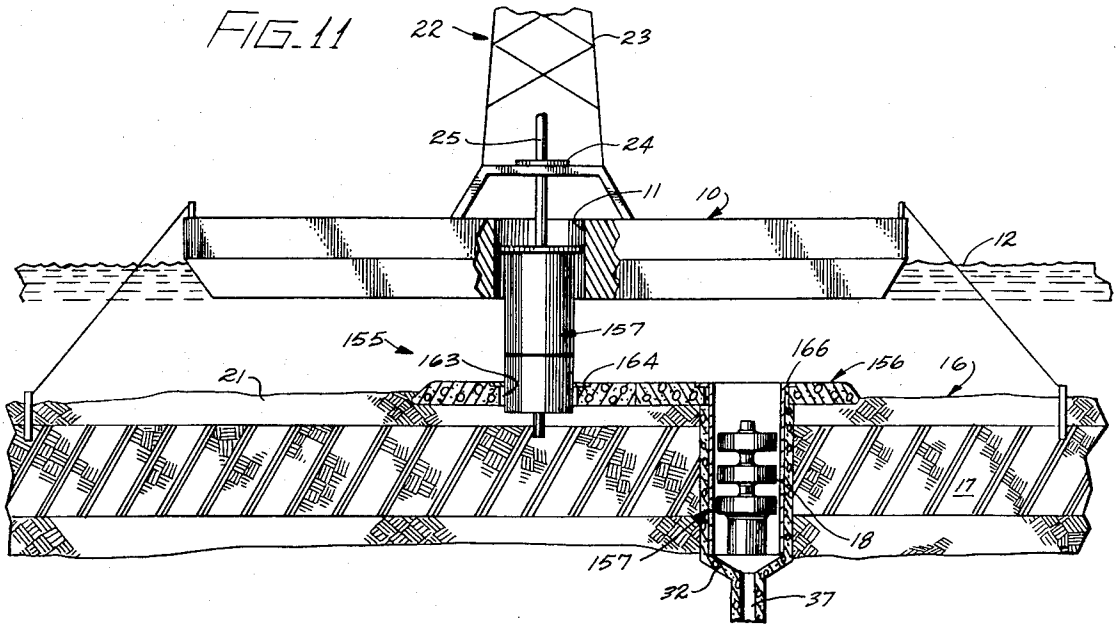
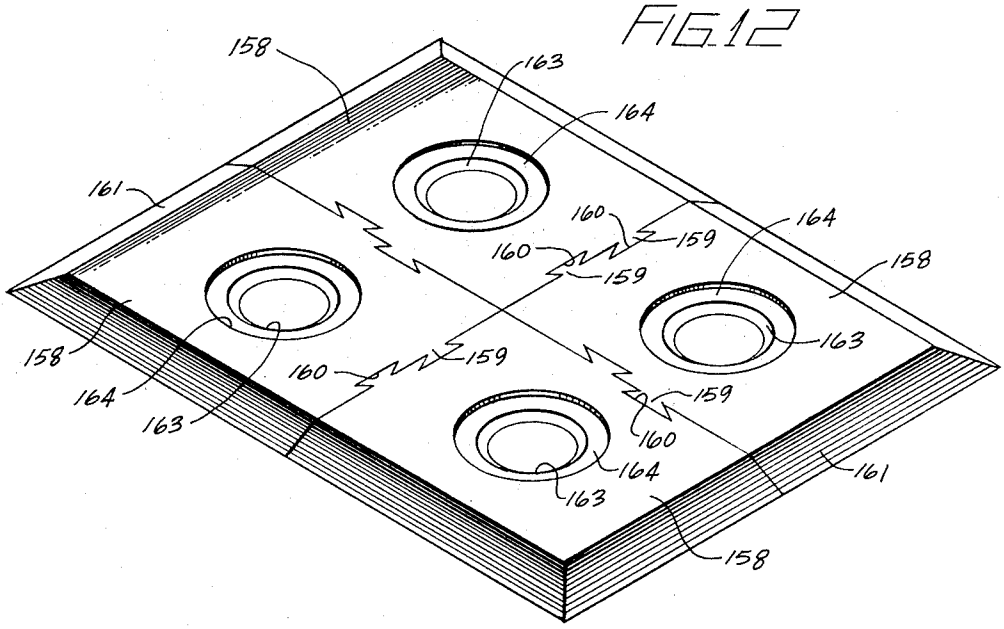

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FIG. 12


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UNDERWATER WELL STRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention pertains to submerged oil and gas wells and, more particularly, to method and apparatus having particular utility in the context of submerged oil and gas wells in the polar zones in which the equipment associated with the wellhead during drilling of the well and during subsequent operation of the well is housed in a container disposed below the bottom of the water body.

2. Review of the Prior Art

U.S. Pat. No. 3,344,612 describes a caisson useful during the drilling and subsequent operation of a well at an offshore location from a floating drilling vessel. A principal purpose of the caisson described in this patent is to artificially lower the bottom of the body of water over the well site so that blowout preventers, normally associated with the wellhead during the drilling operation, may be disposed clear of the bottom of the drilling vessel from which drilling operations are carried out. A blowout preventer has substantial height and is required in the drilling of offshore wells. A blowout preventer is a mechanism for sealing off the well in the event that high pressure oil or gas pockets are encountered in the earth formation being drilled. Floating drilling vessels conventionally have a centerwell through the hull thereof through which the drilling operations are performed from a drilling rig mounted to the vessel over the centerwell. In areas where shallow water exists, the height of the blowout preventer may be greater than the vertical distance between the wellhead and the bottom of the floating drilling vessel; where this situation exists, the floating drilling vessel is captive to the blowout preventer during drilling operations and cannot be removed from the well site during a storm or in the event of an emergency.

U.S. Pat. No. 3,344,612 teaches that, in such shallow water conditions, the bottom of the body of water is artificially lowered by the use of a caisson so that the distance between the wellhead, located at the bottom of the caisson, and the bottom of the drilling vessel exceeds the height of the blowout preventer. Thus, it is possible for the floating drilling vessel to be removed from the well site in the event of an emergency prior to installation of a production valve assembly (known in the industry as a "Christmas tree") in place of the blowout preventer on completion of the well drilling operation. The principal purpose of the caisson shown in U.S. Pat. No. 3,344,612 is merely to lower the bottom of the body of water sufficiently that the blowout preventer is located below the hull of the drilling vessel; the top of the blowout preventer stack, as connected to the wellhead during drilling operations, may project above the bottom of the body of water.

The caisson illustrated in U.S. Pat. No. 3,344,612 has the subsidiary advantages and utilities of functioning as a housing for partially receiving the Christmas tree upon completion of the well. Accordingly, the Christmas tree for the completed well does not present an obstruction to navigation in the area.

U.S. Pat. No. 3,344,612 discloses that the caisson described therein may be placed in position below the water body by circulating fluid under pressure through the lower end of the caisson, either by discharging water under pressure through the bottom of the caisson

for flow upwardly around the walls of the caisson or by sucking up water through the bottom of the caisson. That is, the patent teaches that the caisson may be used to advantage only in instances where the bottom of the body of water is defined by a layer of mud or silt so that fluid circulation or jetting techniques may be relied upon to install the caisson.

Substantial reserves of oil and gas are known to exist, or are believed with a reasonable degree of certainty to exist, at underwater locations adjacent the northern shore line of Alaska and Canada. The slope of the land in these areas is very gradual and continues for many miles offshore. The result is that substantial fractions of the known or suspected Arctic oil and gas reserves lie below very shallow bodies of water. The caisson described in U.S. Pat. No. 3,344,612 cannot be used to advantage because of the peculiarities of the environment in these areas, all of which lie within the northern polar zone, i.e., north of the Arctic Circle.

It is known that on land a thick layer of permafrost exists a short distance below the tundra. Permafrost is a layer, often many feet thick, of frozen soil which, because of the presence of soil particles therein, has a hardness considerably greater than that of ice. It is known that permafrost extends offshore and under the shallow Arctic lakes and bays. The jetting techniques described in U.S. Pat. No. 3,344,612 for the installation of the caisson described therein cannot be used in the Arctic because of the existence of permafrost in the soil formations under shallow water.

SUMMARY OF THE INVENTION

This invention provides effective, simple, economic and reliable method and apparatus which have all of the benefits and subsidiary advantages of the caisson described in U.S. Pat. No. 3,344,612, but are also particularly suitable for use in connection with the formation and operation of submerged oil and gas wells in polar zones. Specifically, this invention provides an improved shallow water caisson which may be installed through permafrost encountered as a part of a soil formation underlying an arctic body of water. The present caisson also provides protection from icebergs for the blowout preventers and for Christmas trees encountered with submerged oil and gas wells.

In terms of structure, this invention provides apparatus for use in submerged oil and gas wells. The apparatus includes a substantially cylindrical container. One of the ends of the container is at least partially closed, while the other end of the container is open. The interior of the container defines a chamber sized to receive wholly therein a blowout preventer and associated equipment for a desired well. Cutting means are carried by the one end of the container and are operable upon rotation of the container about its axis to penetrate an earth formation engaged by the cutting means. The apparatus also includes means for rotating the container about its axis, and means for circulating fluid under pressure through the one end of the container for removing cuttings from the cutting means.

In terms of method, the container as described above is disposed in a substantially vertical attitude so that the cutting means carried by the container are disposed at the lower end of the container. The container is to cause the cutting means to penetrate the earth formation below the water body in which the oil or gas is being defined. As the container is rotated, it is lowered

until the other end of the container is disposed proximate to, and preferably below, the top of the earth formation, i.e., the bottom of the body of water. The container is then secured in position in the earth formation. The desired well is then drilled in the earth formation through the lower end of the container, the drilling operation including disposing the blowout preventer and its associated equipment wholly within the container below the top of the earth formation.

DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features of the present invention are more fully set forth in the following detailed description of presently preferred embodiments of the invention, which description is presented with reference to the accompanying drawing, wherein:

FIG. 1 is a fragmentary cross-sectional elevation view of a drilling vessel floating over a submerged arctic earth formation and illustrates the problems to which this invention is addressed;

FIG. 2 is a cross-sectional elevation view similar to FIG. 1 showing a well site which includes an improved shallow water caisson according to this invention;

FIG. 3 is a cross-sectional elevation view of a caisson according to this invention;

FIG. 4 is a fragmentary cross-sectional elevation view of the lower end of the caisson of FIG. 3 showing the mechanism for rotating the caisson;

FIG. 5 is a bottom plan view taken along lines 5—5 in FIG. 3;

FIG. 6 is a cross-sectional elevation view of another caisson according to this invention;

FIG. 7 is a bottom plan view of another caisson according to this invention;

FIG. 8 is a cross-sectional elevation view taken along lines 8—8 in FIG. 7;

FIG. 9 is a fragmentary plan view taken along line 9—9 in FIG. 8;

FIG. 10 is a fragmentary cross-sectional elevation view of another caisson according to this invention;

FIG. 11 is a cross-sectional elevation view of a caisson being installed through a shield structure previously installed on the bottom of an arctic body of water to receive a plurality of caissons; and

FIG. 12 is a perspective view of a shield structure according to this invention.

DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

FIG. 1 illustrates the situation which exists when conventional techniques for drilling underwater wells from floating vessels in deep water are followed directly in drilling an oil well in shallow water in a polar zone. Thus, a floating drilling platform **10**, having a centerwell **11** vertically through its hull at a central location, floats in a pool of water **12** which results from the formation of an opening **13** in an ice sheet **14** covering the surface of a body of water **15**. An earth formation **16**, which includes a layer of permafrost **17**, forms the bottom of body of water **15**; the layer of permafrost is covered by a layer of silt or mud **21**. The depth of water over the earth formation is shallow in that a blowout preventer **18** mounted to a wellhead structure **19** at the upper end of a well **20** through earth formation **16** projects into centerwell **11** of platform **10**. Drilling platform **10** includes a drilling rig **22** on its upper deck over centerwell **11**. The drilling rig includes a derrick **23** and a conventional rotary table **24** for rotating a string of drill pipe **25** which extends through the rotary table and the blowout preventer **18** into well **20**. The drilling rig also includes a drawworks and a travelling block (not shown) for raising and lowering the string of drill pipe.

It will be observed from an examination of FIG. **1** that drilling platform **10** is captive to the well site since blowout preventer **18** has its upper end disposed within centerwell **11**. Accordingly, in the event of an emergency or storm, the platform cannot be removed from the well site. Upon completion of the drilling operations at the well, the blowout preventer is removed from wellhead structure **19** and a production valve assembly, known as a "Christmas tree", is mounted to the wellhead assembly in the place and stead of the blowout preventer. The vertical height of the Christmas tree usually is less than the height of the blowout preventer and less than the distance between the wellhead assembly and the bottom of platform **10**. Accordingly, the drilling platform can be removed from its position over well **20** only upon completion of the drilling operations following removal of the blowout preventer. The blowout preventer, because of the existence of governmental regulations to the contrary, cannot be removed readily from the wellhead assembly at an interim stage during the drilling operations.

FIG. **2** shows that, according to the practice of this invention, blowout preventer **18** is located wholly below the top of mud layer **21** within the interior of a caisson **30** which has an upper end **31** disposed essentially at the bottom of body of water **15** as defined by the top of mud layer **21**. The caisson is held in position in earth formation **16** by cement **32** which surrounds the caisson along substantially its entire length within an annular chamber **33** formed circumferentially of the exterior of the caisson.

FIG. **2** also shows that the blowout preventer **18** is connected to drilling platform **10** via a riser pipe **35** which extends circumferentially of drill string **25** from the top of the blowout preventer to below rotary table **24**. The upper end of the riser pipe is connected via a suitable duct **36** to a drilling mud recirculation system (not shown). As is conventional, high density drilling mud is circulated downwardly through drill string **25** as the string is rotated to form well **20**. The injection of drilling mud into drill string **25** is facilitated by the use of a swivel (not shown) connected between the top of the drill string and the travelling block (not shown) within the derrick. The drilling mud flows out of the conventional rotary drill bit at the lower end of the drill string and back up through the hole formed by the drill bit. The drilling mud approaches the lower end of blowout preventer **18** through a length of suitably sized casing **37** which extends downwardly from the bottom of the caisson for a distance which is appropriate to the character of the geology in which the well is being drilled. The drilling mud flows upwardly through the blowout preventer around the exterior of the drill string, and then from the blowout preventer to the platform through riser pipe **35**.

Caisson **30** (see FIG. **3**) preferably is provided as an elongate, hollow, circularly cylindrical container which is symmetrical about a central axis **39**. The caisson has a tubular body **40** having an open upper end **31** and a lower end **41** which is at least partially closed. In caisson **30**, the lower end of the caisson is defined by a con-

ical closure 42 which is convex downwardly from body 40 and which is integrally connected to the lower end of the body around the circumference of the body. Body 40 preferably is defined by a plurality of sections 43, 44, 45 and 46 which are bolted serially together to form the structure shown. It is also preferred that caisson lower end section 43 be of one-piece construction, whereas caisson sections 44, 45 and 46 are provided in essentially identical halves 44A, 44B, 45A, etc. Caisson sections 44 and 45 are identical; any additional sections of the caisson, required to provide a caisson having a length greater than that illustrated in FIG. 3, would be provided by additional sections essentially identical to sections 44 and 45.

The halves 44A and 44B of caisson section 44, for example, are arranged so that when they are connected, as by bolts 47, elements 44A and 44B define a portion of the tubular length of the caisson. Accordingly, each half-section element 44A has a wall 48 which is of semi-circular curvature and which carries a bolting flange 49 along each straight edge thereof; flanges 49 lie within the caisson so that the caisson has a smooth cylindrical exterior surface. To assemble elements 44A and 44B to define caisson section 44, flanges 49 are mated with each other and are interconnected by bolts 47. Similarly, each element 44A and 44B includes a flange 50 which extends inwardly from wall 48 along each of the opposite semi-circularly curved edges of the wall. Flanges 50 adapt caisson section 44 to be connected, as by bolts 51, to caisson lower end section 43 and to adjacent caisson body section 45. The halves 46A and 46B of caisson upper end section 46 are identical to halves 44A and 44B and 45A and 45B of sections 44 and 45, respectively, except that the halves of section 46 do not include flanges 50 in association with caisson upper end 31.

As will become apparent from the following description, it is the intent of this invention that caisson 30 become a permanent element of well 20. Therefore, it is necessary that the caisson be structured to enable the largest diameter casing contemplated for well 20 to be passed through the lower end of the caisson. Accordingly, caisson lower end section 43 includes a hollow sleeve 53 disposed concentric to caisson axis 39. The sleeve opens at its lower end 54 through closure 42 at the lower end of the caisson. Thus, closure 42 resembles a truncated cone to which the lower end of sleeve 54 is permanently connected, as by welding, at its inner diameter. Sleeve 53 has an upper end 55 which is located intermediate the length of caisson lower end section 43. The sleeve is rigidly braced to the cylindrical wall 56 of section 43 by a plurality of braces 57 which extend radially from the sleeve, adjacent its upper end, to the inner surfaces of wall 56. Preferably braces 57 are defined by I-beam sections or the like and are welded between the sleeve and the wall of caisson section 43. It is also preferred, as shown in FIG. 3, that braces 57 be disposed closely adjacent to sleeve upper end 55 and carry a circular floor plate 58 which seals the annulus between sleeve 53 and wall 56.

A landing stump 60 for blowout preventer 18 is mounted to the upper end of sleeve 53 concentric to axis 39. Preferably stump 60 is provided in the form of a circular sleeve which has an inner diameter at least equal to that of sleeve 53 and which is configured in conjunction with blowout preventer 18 and its associated equipment to receive the blowout preventer in the conventional manner. Stump 60 is rigidly affixed to the structure of caisson lower end section 43, as by a lower end flange 61 connected to floor plate 58 as by bolting or welding, for example. A strong and secure connection between stump 60 and the remaining structure of caisson lower end section 43 is required in order that the torque necessary to enable installation of the caisson through permafrost layer 17 may be transmitted to the caisson from the stump, and also because it may be necessary to support the entire weight of caisson 30 from stump 60.

A plurality of L-slots 62 are provided in the upper end of stump 60 at regular intervals around the circumference of the stump. As shown in FIG. 3, each L-slot has an entrance portion 63 aligned parallel to caisson axis 39 and open to the upper end of the stump. Each L-slot also has a locking portion 64 which extends from the lower end of the entrance portion for a selected distance around the circumference of the stump. All of the L-slots provided in stump 60 have their locking portions 64 extending in the same direction, ie., either clockwise or counterclockwise, relative to axis 39.

A plurality of hardened cutting teeth 66 are carried by the convexly curved surface of lower end closure 42. As shown in FIG. 5, the cutting teeth preferably are disposed along selected regularly spaced radii of the closure. The individual ones of teeth 66 may be defined of hardened steel or steel alloy, or by diamonds, as desired. Teeth 66 function, upon engagement of the lower end of the caisson with permafrost layer 17, to cut through the permafrost as the caisson is rotated about axis 39.

To facilitate the removal of cuttings from adjacent cutting teeth 66 during installation of caisson 30, a plurality of openings 68 are provided through caisson lower end closure 42. Preferably, as shown in FIG. 5, openings 68 are located at intervals spaced circumferentially and radially of the caisson intermediate the rows of cutting teeth. Openings 68 communicate from the exterior of the caisson adjacent its lower end to a chamber 69 between floor plate 68 and the closure. Chamber 69 is communicated to the interior of sleeve 53 by a plurality of holes 70 formed through the sleeve between the floor plate and closure 42. Accordingly, during rotation of the caisson in the process of cutting through permafrost 17, or through a geological formation which may lie between the permafrost layer and mud layer 21, a circulating liquid is introduced into chamber 69 through opening 70 and flows through openings 68 to wash cuttings away from teeth 66.

To define well 20 by the use of caisson 30, drilling platform 10 is first disposed at the desired location over the intended well site. The caisson lower end section 43 is then positioned below rotary table 24 over centerwell 11, and the lower end of drill string 25 (which passes through rotary table 24) is connected to caisson section 43 via blowout preventer mounting stump 60. The connection of the drill string to the stump is accomplished via an adapter 74 (see FIG. 4) which preferably is fabricated of a length of oil well casing having a diameter corresponding to the largest diameter of casing 37 desired in the completed well. It will be recalled from the foregoing description that sleeve 53 of caisson lower end section 43 is sized to permit the passage of such casing through it. Adapter 74 preferably is secured to the lower end of the drill string via a bell reducer structure or the like. Adapter 74 is connected to stump 60

via a plurality of projections **75** which extend radially outwardly from the exterior of the adapter. Projections **75** correspond in number to the number of L-slots **62** defined in the stump and are spaced apart from each other around the circumference of the adapter according to the spacing of L-slot **62** around stump **60.** Projections **75** each have a height, i.e., dimension parallel to the axis of the adapter, which is no greater than, but preferably approaches, the dimension of locking portions **64** which are parallel to caisson axis **39.** Also, projections **75** have a width, i.e., a dimension circumferentially of the adapter slightly less than the dimension of entrance portions **63** around the circumference of stump **60.** Thus, slots **62** and projections **75** provide for a bayonet-type releasable connection between the caisson and the drill string.

As shown in FIG. **4,** the adapter is connected to stump **60** by aligning the adapter coaxially with sleeve **53** in such manner that projections **75** are aligned with the entrance portions of respective ones of L-slots **62.** The adapter is then moved axially of the stump until the projections reach the bottom of the L-slot entrance portions, whereupon the adapter is turned angularly relative to the stump to move projections **75** into locking portions **64** of the L-slots. Thereafter, the drill string is lowered through rotary table **24** to move the lower end section of the caisson downwardly through centerwell **11.** As this occurs, caisson body sections **44, 45** and **46** are connected to caisson lower end section **43** in the manner described above. In this way, the caisson is built up to the desired length and lowered into contact with the silt or mud layer which defines the bottom of body of water **15.** A suitable circulating fluid is then pumped down through drill string **25** and adapter tube **74** to flow out through the lower open end of sleeve **53** and through openings **68** via chamber **69;** this occurs as the caisson is rotated in response to operation of rotary table **24** in the conventional manner.

Operation of the rotary table causes the drill string to rotate, which rotation is in turn transmitted to the caisson via projections **75** and stump **60.** Because of the flow of circulating fluid through the lower end of the caisson, penetration of mud layer **21** is relatively easily accomplished in view of the jetting action of the discharged circulating fluid. Therefore, it may be possible to penetrate mud layer **21** without relying upon rotation of the caisson and the operation of cutting teeth **66.** When permafrost layer **17** is reached, however, this jetting action of the circulating fluid will be ineffective to cause the caisson to penetrate the permafrost layer at a satisfactory rate. At this time, rotation of the caisson is relied upon to cause the caisson to bore into the permafrost, and cuttings generated by teeth **66** during this process are removed from adjacent the lower end of the caisson by the circulating fluid. Discharged circulating fluid flows upwardly along the outer walls of the caisson, thereby providing annular chamber **33** (shown in FIG. **2**). Penetration of the caisson into and possibly through permafrost layer **17** is continued until the open upper end **31** of the caisson is disposed at or below the top of mud layer **21.**

Once the caisson reaches its intended position within earth formation **16,** drill string **25** and adapter **74** are not immediately removed from the caisson. Instead, suitable cement is pumped down through the drill string into the adapter to flow out through the bottom of the caisson into annular space **33** and back up through space **33** to mud layer **21.** Preferably the concrete is sufficiently heavy that it spreads laterally through mud layer **21** adjacent the top of the caisson, thereby to define a protective shield **77** which extends horizontally in all directions for a desired distance from the caisson. If the density of the concrete is insufficient to displace mud layer **21** circumferentially of the upper end of the caisson in the manner contemplated by FIG. **2,** then, mud layer **21** is dredged out circumferentially of the well site before penetration of the earth formation by caisson **30** is commenced; in this way, it is assumed that protective shield **77** will be formed in the desired manner and will cover the desired area around the caisson. It is desired that caisson upper end **31** be flush with or disposed below the upper surfaces of shield **77.**

Once the cementing process has been completed, adapter **74** is removed from the caisson by reverse angular indexing of the adapter relative to stump **60** and by raising the drill string clear of the caisson. Blowout preventer **18** is then lowered into its intended position wholly within caisson **30** and is connected to stump **60.** After the blowout preventer has been installed in the caisson, riser pipe **35** is connected between the blowout preventer and the drilling vessel and drilling operations are carried out in the conventional manner through blowout preventer **18.**

The foregoing description assumes that caisson **30** is maintained coaxial with drill string **25** during the penetration of earth formation **16** by the caisson, and this coaxial alignment is achieved by reliance solely upon connection of the drill string to the caisson via adapter **74** and stump **60.** The foregoing description also involves the assumption that the torque necessary to cause cutting teeth **66** to penetrate permafrost **17** is transferred from the drill string to the caisson solely by means of adapter **74** and pump **60.** It may be, however, that additional structure is required to maintain the caisson coaxial with the drill string and to transfer torque from the drill string to the caisson during penetration of the earth formation. Accordingly, as shown in FIG. **3,** a positioning and torque transmitting spider **79** is removably connected to caisson upper end **31.**

The spider includes a ring **80** sized to slip over the exterior of caisson **30** adjacent its upper end, circumferentially of the caisson until movement of the ring axially of the caisson is limited by engagement of the lower surface of a peripheral flange **81** with caisson upper end **31.** Flange **81** projects inwardly of ring **80** around the entire circumference of the ring. A guide sleeve **82,** which preferably has a diameter equal to that of stump **60,** is supported within ring **80** in coaxial alignment with the ring by a plurality of braces **83.** Braces **83** are disposed radially of the spider between the exterior of sleeve **82** and ring **80,** and the connection of the braces to the ring preferably is via flanges **81.** The spider is connected in torque transmitting relation to the upper end of the caisson by a plurality of projections **84** which extend radially inwardly from ring **80** at regularly spaced intervals around the circumference of the ring. Projections **84** cooperate with corresponding ones of a plurality of L-slots **85** which open to the upper end of the caisson; L-slots **85** are similar to L-slots **62** and therefore are not described in further detail. Sleeve **82** is adapted to be coupled in torque transmitting and caisson aligning relation to drill string **25** by means of a plurality of L-slots **86** which are formed in the sleeve

at regularly spaced locations around its circumference so as to open to the upper end of the sleeve. L-slots **86** cooperate with a corresponding plurality of projections (not shown) similar to projections **75** which may be carried either directly by the drill string, or upon a separate adapter (similar to adapter **74**) carried by the drill string at the appropriate location above adapter **74** or directly by adapter **74** where adapter **74** has a length great enough to extend through both sleeve **82** and stump **60.** The locking portions of L-slots **62, 85** and **86** all extend in the same direction about the circumference of caisson **30.**

In areas where water **15** is very shallow, or where the hazards of icebergs are great, it may be desirable to locate caisson upper end **31** some distance below the upper surface of shield **77.** In such a circumstance, it is preferred to equip spider **79** with a cylindrical skirt (not shown) of the same exterior diameter as ring **80.** Where present, the skirt is carried by ring **80** at its upper end so that the exterior surfaces of the skirted spider define a smooth circular cylinder of desired length. The skirted spider is maintained in connection with caisson **30** during the above-described process of pumping concrete into space **33** so as to define shield **77.** Preferably the exterior surfaces of the skirted spider are coated with a lubricant or other material (such as tetrafluorethylene) to which cement **77** deos not bond, thereby facilitating removal of the skirted spider from the caisson after the cement has set sufficiently to maintain the integrity of the shield.

Also, L-slots **85** may be relied upon to connect a suitable cover to the caisson after the well drilling operations have been completed and the appropriate Christmas tree has been installed on the completed well, thereby to provide protection to the Christmas tree during production of oil or gas from the well.

Another caisson **87** according to this invention is illustrated in FIG. **6.** Caisson **87,** except for the aspects thereof illustrated in FIG. **6,** may be constructed according to the preceding description of caisson **30** or maybe constructed to resemble the caissons shown in FIGS. **7** through **8,** or FIG. **10,** for example. In caisson **87,** connection adapter **74** is sufficiently long to extend to within caisson body section **45** where it passes through a circulating fluid manifold ring **88.** Manifold ring **88** has an inner diameter which is sized to mate intimately with the outer diameter of connection adapter **74.** The interior of manifold ring **88** is open to the exterior of adapter **74.** The manifold ring is supported within body section **45** by a plurality of circulating fluid ducts **89** which extend from the ring to outer ends which communicate through body section wall **48** to a circulating fluid discharge manifold **90** carried by the caisson around its circumference. Manifold ring **88** receives circulating fluid from the interior of adapter **74** via a plurality of ports **91** formed through the adapter at a position defined along the length of the adapter such that, when the adapter is connected to stump **60,** ports **91** register with the interior of the manifold ring. Discharge manifold ring **90** is provided in a caisson according to this invention where the nature of the geological formation to be penetrated by the caisson is such as to require additional lubrication between the caisson and the formation during the penetration process.

To facilitate the passage of connection adapter **74** through manifold ring **88** (or through spider **79**), it may be desirable to size the inner diameter of adapter **74** to mate with the outer diameter of stump **60,** in which case projections **75** extend from the inner walls of the adapter rather than from the outer walls of the adapter, as shown in FIG. **4.**

The caissons shown in the accompanying drawings all provide for passage of a circulating fluid through the lower end of the caisson to facilitate removal of cuttings generated by the cutting means carried by the lower end of the caisson. Sea water may be used to advantage as a suitable circulating fluid for cuttings removal. To increase the rate of penetration of the caisson through permafrost, it may be expedient to use heated sea water so that the caisson both cuts and melts its way through the permafrost. In addition to, or as an alternative to heating the circulating fluid, the circulating fluid may be a mixture of sea water and ethylene glycol, for example; ethylene glycol is effective to reduce the melting point of ice.

FIG. **7** is a view of the lower end **95** of another caisson **96** according to this invention; caisson **96** is also shown in FIGS. **8** and **9.** Caisson **30** (shown in FIG. **3**) preferably has a lower end defined as a truncated cone, whereas caisson **96** has a flat lower end. Caisson **96** is adapted for use in situations where permafrost layer **17** may be extremely hard or very thick. Caisson **96** may also be used where it is desired to locate the caisson in an earth formation which includes a stratum of rock, such as shale, with which the drag-type teeth **66** of caisson **30** may not be used effectively.

Caisson **96** includes a flat closure plate **97** disposed across its lower end **95.** The closure plate is permanently secured around its outer circumference to the cylindrical body of caisson **96.** A plurality of cutter cones **98** are carried by the caisson at its lower end. The cutter cones are of conventional manufacture and are of the type encountered in tunneling bits or in large-hole bits, for example. Each cutter cone **98** is rotatably mounted between a pair of mounting lugs **99** which depend from the underside of the caisson at appropriate locations of the closure plate. As shown in FIG. **7,** several cutter cones **98** are arranged over the lower end of the caisson in such a manner that all arcs about the center of the caisson pass through at least one cutter cone. Thus, upon rotation of the caisson when its lower end is engaged with permafrost layer **17,** for example, an area equal to the bottom end area of the caisson will be engaged by the cutter cones during one rotation of the caisson.

A plurality of circulating fluid discharge holes **100** are provided through closure plate **97** at selected locations of the plate. Discharge openings **100** communicate to the exterior of the caisson from a chamber **101** formed within the interior of the caisson at its lower end below a floor plate **102.** The floor plate is carried by the upper edges of a plurality of radial braces **103,** similar to braces **57,** which support a blowout preventer mounting stump **104** coaxially of the interior of the caisson. Stump **104** is essentially identical to stump **60** except that stump **104** extends through floor plate **102** to an outwardly belled lower end **105.** Like stump **60,** stump **104** defines a plurality of L-slots **62** at uniformly spaced locations around its upper circumference.

As shown best in FIG. **7,** the two cutter cones **98'** which are disposed closest to the axis of caisson **96** are carried on respective ones of a pair of removable doors

107 and 108. Doors 107 and 108, as shown in FIGS. 8 and 9, are held in their closed position to close an opening 109 formed in the central portion of closure plate 97 in line with the axis of the caisson. Doors 108 and 107 are sized, in cooperation with the inner diameter of blowout preventer mounting stump 104, so that the doors may be passed upwardly through the stump once they are released from their closed position. Preferably, the minimum dimension of opening 109 is large enough to permit the largest casing for well 20 to be passed through opening 109 after doors 108 and 107 have been removed from within the opening.

Doors 107 and 108 are locked in opening 109 by a pair of latching mechanisms 112 and 113, respectively. Latching mechanism 112 for door 107 includes a rotatable operating member 114 which extends upwardly from the latching mechanism at a location within the cylinder defined by the upper portion of blowout preventer mounting stump 104; the inner diameter of stump 104 at its upper end is represented by the dashed line 115 in FIG. 9. Operating member 114 is arranged to be rotated by a suitable tool brought into engagement with it through the drill string used to rotate the caisson during penetration of earth formation 16, for example. Accordingly, operating member 114 is located as close as possible to the central axis of caisson 96.

Latching mechanism 112 includes a plurality of retractable pins 116 which cooperate within apertures defined in corresponding lugs 117 mounted to the upper surface of closure plate 97 adjacent central opening 109. When pins 116 are engaged with lugs 117, as shown in FIG. 9, door 107 is maintained within opening 109 with the lower surface of the door essentially flush with the lower surface of closure plate 97. Upon rotation of actuating member 114, however, pins 116 are retracted from their engagement with lugs 117 so that the tool used to rotate actuating member 114 may also be used to lift door 107 out of hole 109. Such removal of door 107, and similarly of door 108, from opening 109 is facilitated by providing an upwardly open bevel around the periphery of opening 109.

Latching mechanism 113 also includes a plurality of retractable pins 116 which cooperate in suitable apertures in a corresponding plurality of lugs 117 carried by the closure plate adjacent opening 109. Latching mechanism 113 includes an actuating member 118. The workings of latching mechanism 113 are arranged so that when actuating member 118 is pulled upwardly, the latching mechanism functions to retract pins 116 thereof from lugs 117. Actuating member 118 is connected to latching mechanism 112 by a lanyard 119. Accordingly, as door 107 is being raised from its closure position in opening 109 by movement upwardly through stump 104, lanyard 119 is effective to operate latching mechanism 113 to release door 108 from opening 109.

In view of the foregoing description, it is apparent that caisson 96, with doors 107 and 108 locked into position shown in FIG. 8, may be used to advantage to position the caisson into or through a geological formation containing a rock stratum or the like.

Another caisson 125 is shown in FIG. 10 and is similar to caisson 96 in that it has a flat closure plate 126 permanently connected to the lower end 127 of the right circularly cylindrical hollow body 128 of the caisson. A blowout preventer mounting stump 129, having an inner diameter at least as great as the outer diameter of the largest diameter casing intended to be used in defining well 20, is disposed coaxially of caisson 127 above closure plate 126. A plurality of L-slots 62 are formed in the upper end of the mounting stump. The mounting stump is positioned within caisson 125 by a plurality of braces 130 which extend radially of the caisson between the exterior of the mounting stump and the caisson body above closure plate 127. A floor plate 131 is carried by braces 130 and closes the interior of the caisson between the exterior of the mounting stump and the inner walls of the caisson body to define a circulating fluid chamber 132 between the floor plate and the closure plate.

A hole 133 is formed through the center of closure plate 126 and preferably has a diameter equal to the inner diameter of blowout preventer mounting stump 129. A plurality of cutter cones 98 are mounted by corresponding pairs of mounting lugs 99 to the bottom of closure plate 126 so as to effectively cover the entire area of the closure plate around opening 133. A plurality of circulating fluid discharge openings 134 are formed through closure plate 126 from chamber 132 at selected locations of the closure plate.

Like caisson 96, caisson 125 is especially useful where it is desired to locate a blowout preventer wholly below the bottom of water body 15 and it is necessary to penetrate an extremely hard or very thick layer of permafrost or a layer of rock which lies close to the bottom of body of water 15. Accordingly, caisson 125 is connected to a length of drill string 25 for support of the caisson and for rotation of the caisson by an adapter 137. The adapter is provided in the form of an elongate tri-cone drill bit having an outer diameter sized to mate closely within mounting stump 129 and closure plate opening 133. The adapter bit 137 includes three conical drilling cones 138, only two of which are shown in FIG. 10, mounted to the elongate body 139 of the drill bit in a manner similar to the conventional tri-cone rotary tool bit, such as is manufactured by Hughes Tool Company. The body 139 of the adapter is sufficiently long that when it is connected to the caisson by projections 140 which cooperate with L-slots 62, drilling cones 138 are disposed below cutter cones 98. Adapter 137 is hollow for the passage of suitable circulating fluid or drilling mud through the drill string to cones 138 in the manner described above. Also, the body of the adapter defines a plurality of holes 141 which communicate to the circulating fluid chamber 132. Thus, a portion of the circulating fluid supplied to the adapter through the drill string flows into chamber 132 and through openings 134 to facilitate removal of cuttings from the teeth of cutter cones 98 in response to rotation of caisson 125.

After caisson 125 has penetrated to the desired depth through earth formation 16, adapter 137 is removed from the caisson by disengaging projections 140 from L-slots 62. After the caisson has been cemented into the earth formation, further operations are carried out from drilling vessel 10 through opening 133 to complete well 20.

A shield 77 is desired around the upper end of the above-described caissons to protect the caisson and any wellhead equipment therein from damage. In shallow water installations in arctic and near-arctic areas, a hazard exists that the caisson may be damaged by icebergs or berger bits (small icebergs or pieces broken

from icebergs) which often scour tracks several feet deep in the mud and silt covering the area where the caisson is installed. The shield serves as a deflector or barrier for such icebergs. Even if the iceberg should drag across the shield, the presence of the shield around the caisson prevents the caisson from being bent, crushed or tipped.

Shield **77** also provides other advantages independent of the problem of icebergs. The performance of drilling and production operation in and through caisson **30**, for example, may result in heat being transferred to the permafrost **17** adjacent the caisson sufficient to thaw the permafrost. Any appreciable thawing of the permafrost, as within the zone **150** represented by broken lines **151** in FIG. **2**, may result in subsidence of the formation around and below the caisson. Such subsidence may produce sinking of the caisson in the formation or tilting of the caisson, thereby impairing or preventing continued operations.

To overcome the hazards of thermally-induced subsidence of the formation, shield **77** extends circumferentially of the caisson a substantial distance radially beyond the anticipated limits of zone **150**, as shown in FIG. **2**. The shield, therefore, provides support for the caisson from over unthawed permafrost and assures that the installed position of the caisson does not change even if the permafrost closely adjacent the caisson should thaw completely.

FIGS. **11** and **12** illustrate another underwater well structure **155** according to this invention. Well structure **155** incorporates a shield assembly **156** and a plurality of caissons **157** arranged in a predetermined pattern through the shield. FIG. **11** shows that a number of caissons may be used in association with a single shield, but it will also be appreciated that a single caisson may be used with shield assembly **156** if desired.

As shown best in FIG. **12**, shield assembly **156** is composed of a plurality of slab-like component sections **158** which preferably are precast of concrete (with or without internal reinforcing) at a remote location and carried to the site of the well structure aboard drilling vessel **10**. Each of the sections **158**, along selected ones of its edges, defines at least one tongue projection **159** and at least one receptacle **160**. Each projection is arranged to mate, in mortise-and-tenon fashion, within a corresponding receptacle of another section so that the several sections may be interlocked in the manner shown in FIG. **12** to define the complete shield assembly. Those shield sections which define the outer limits of the shield have their corresponding edges sloped or chamfered upwardly, as at **161**, so that the bottoms of passing icebergs and the like may ride up and over the shield and not become caught on and damage the shield.

Shield assembly **156** is illustrated as being composed of four sections **158**, each of which has a caisson receiving hole **163** formed through it centrally of its length and width. Each hole has a diameter slightly greater than the outer diameter of a caisson **157** over a major portion of the length of the caisson. At its upper end, each hole **163** opens to a circumferential recess **164** formed in the upper surface of the shield section concentric to the hole.

Underwater well structure **155** is erected following arrival of vessel **10** over the desired submerged site by first assembling shield sections **158** into the desired shield on top of the silt or mud layer **21** which overlies permafrost layer **17**. Once the shield has been assembled, the several caissons **157** are drilled into formation **16**, in the manner described above, through respective ones of shield holes **163**. Each caisson **157** is similar to caisson **30**, for example, (or any of the other caissons described above), in that it may be made up in sections as shown in FIG. **11**. Each of caissons **157**, however, differs from the previously described caissons in that it includes an outwardly extending flange **166** circumferentially of its upper end. Flanges **166** are sized to mate within shield recesses **164** so that the caissons are hung from the shield after the caissons reach their desired positions in formation **16** and before the caissons are secured in the formation by cement **32** as already described. Once the several caissons have been installed in the formation through the shield, the several wells may be drilled and completed as described above using conventional procedures.

It will be understood that where each section of the multisection prefabricated shield assembly defines a receiving hole for a caisson **157**, it is desirable that the shield section have sufficient width and length radially from the hole to provide the above described anti-subsidence support function for its caisson independently of the other sections of the shield. It will also be understood that two or more sections of a multi-section shield may cooperate to define the receiving hole and recess for a single caisson if desired, and that a multi-section shield may be provided for use with a single caisson without departing from the scope of this invention.

The foregoing explanation of this invention has been presented with reference to the description of presently preferred embodiments of the invention. These embodiments represent only a few of the many possible embodiments of the invention. Accordingly, the preceding description should not be considered as limiting the scope of the invention since workers skilled in the art to which this invention pertains will readily recognize that modifications and alterations to the above-described procedures and structures may be made within the context and spirit of this invention.

What is claimed is:

1. a wellhead caisson for submerged oil and gas wells comprising

a substantially cylindrical container having opposite ends one of which is at least partially closed and the other of which is open, the container having an open interior sized to receive therein through the open end of the container a blowout preventer and associated equipment,

cutting means carried by the one end of the container operable upon rotation of the container about its axis to penetrate a consolidated earth formation and the like engaged thereby,

means for rotating the container about its axis, and

means for circulating fluid under pressure through the one end of the container for removing cuttings from the cutting means.

2. Apparatus according to claim **1** including means disposed circumferentially of the container intermediate the ends thereof for discharging fluid along the exterior of the container toward the ends thereof.

3. Apparatus according to claim **1** including means rigidly mounted within the container coaxially thereof for releasably receiving an elongate rotatable torque transmitting member engaged therewith through the

container open end and for transmitting to the container torque applied thereto.

4. Apparatus according to claim 3 wherein the rigidly mounted means provide a bayonet-type releasable connection to the torque transmitting member.

5. Apparatus according to claim 3 wherein the rigidly mounted means is disposed adjacent said one end of the container and is arranged to receive and support a blowout preventer assembly.

6. Apparatus according to claim 3 wherein the rigidly mounted means comprises an open-ended tubular sleeve disposed coaxially within the container adjacent the one end thereof, means cooperating between the sleeve and the container defining a circulating fluid chamber within the container adjacent the one end thereof, and fluid passage means communicating from the chamber in association with the cutting means.

7. Apparatus according to claim 6 wherein said one end of the container is of conical configuration concentric to said axis to provide an upwardly and outwardly sloping container lower end surface.

8. Apparatus according to claim 7 wherein said cutting means comprise a plurality of drag teeth projecting from the container lower end surface.

9. Apparatus according to claim 6 wherein the cutting means comprise a plurality of rotatable cutter cones rotatably mounted to the one end of the container and effectively distributed over the closed area of said one end.

10. Apparatus according to claim 9 including an opening defined through the one end of the container and centered on the container axis, the cutter cones effectively covering the one end of the container about the opening.

11. Apparatus according to claim 10 including door means for closing the opening, cutting means carried by the door means, and means for releasably securing the door means in closure relation to the opening.

12. Apparatus according to claim 6 wherein the means for rotating the container includes said elongate rotatable torque transmitting member and said member comprises a length of hollow drill pipe, connector means carried by the drill pipe for releasably connecting the drill pipe to the sleeve, and means for communicating the interior of the drill pipe to the circulating fluid chamber.

13. Apparatus according to claim 12 wherein the torque transmitting member is arranged to extend through the one end of the container to an end thereof when the connector means is coupled to the sleeve, and cutting means carried by the end of the torque transmitting means.

14. Apparatus according to claim 3 including means releasably engageable to the container open end for cooperating with an elongate torque transmitting member engaged with the container to maintain a coaxial relation between the container and the torque transmitting member.

15. Apparatus according to claim 14 wherein means engageable to the container open end is arranged to cooperate with the torque transmitting member for transmitting torque from said member to the container.

16. In a wellhead for a submerged arctic oil well and the like installed in an earth formation underlying a body of water, the combination of

a. a hollow container substantially wholly disposed in the earth formation adjacent the upper extent thereof for receiving a blowout preventer wholly therein,

b. cement securing the container in the earth formation, and

c. a protective shield for the container, the shield being of selected thickness and extending radially from the container over the earth formation around the container, the shield and the container cooperating for support of the container in the formation independently of the cement.

17. A wellhead according to claim 16 wherein the shield extends radially from the container over the formation for a distance substantially greater than the radius of a zone in the formation circumferentially of the container subject to thermal influence in response to operations performed in or through the container.

18. A wellhead according to claim 16 wherein the margins of the shield remote from the container are sloped upwardly and inwardly.

19. A wellhead according to claim 16 wherein the shield is defined integral with the cement and is provided in the wellhead in conjunction with providing said cement.

20. A wellhead according to claim 16 wherein the container is installed in the formation through the shield.

21. A wellhead according to claim 20 wherein the shield is prefabricated.

22. A wellhead according to claim 21 wherein the shield is comprised of a plurality of interlocking slab-like sections.

23. A method of installing an oil or gas well at a submerged location in arctic waters in an earth formation which includes a stratum of permafrost near the top of the formation comprising the steps of

a. providing a substantially cylindrical container sized to receive therein a blowout preventer for a desired well at the submerged location and having earth formation cutting means carried by one end thereof, the other end of the container being open,

b. lowering the container on a rotatable tube in a vertical attitude from a floating vessel into engagement of the cutting means with the earth formation underlying the water at the submerged location,

c. rotating the container by rotation of the tube at the vessel to cause the cutting means to penetrate the earth formation,

d. further lowering the container from the vessel during rotation thereof until the other end of the container is disposed proximate the top of the earth formation,

e. securing the container to the earth formation, and

f. drilling a well into the earth formation through the lower end of the container, including disposing a blowout preventer and associated equipment wholly within the container.

24. The method of claim 23 including circulating fluid through the one end of the container and upwardly along the exterior of the container during the rotating and further lowering steps.

25. The method of claim 23 wherein the rotating and lowering steps are effective to define an annular space around the container in the earth formation, and the securing step is performed by disposing cement in said space.

26. The method of claim 25 wherein the cement is disposed in the space by pumping cement through the one end of the container.

27. The method of claim 23 including forming a protective cement shield for the container to a desired depth over the earth formation and for a desired distance laterally around the container.

28. The method of claim 27 including forming the shield after termination of the lowering step.

29. The method of claim 28 including forming the shield by flowing cement through the one end of the container, upwardly along the exterior of the container through the earth formation, and over the formation.

30. A method of installing an oil or gas well at a submerged location under a body of water comprising the steps of

a. providing a protective shield over the top of an earth formation underlying the body of water so that the shield extends a desired distance radially from a desired well site,

b. installing in the earth formation through the shield a container sized to receive therein a blowout preventer for a desired well,

c. securing the installed container relative to the shield, and

d. drilling a well into the earth formation through the lower end of the container, including disposing a blowout preventer and associated equipment wholly within the container.

31. A method according to claim 30 wherein the earth formation includes a stratum of permafrost, and including providing the shield to extend radially over said stratum from the location of the container for a distance substantially greater than the radius from the container in the stratum of a zone of significant thermal influence associated with operations performed in or through the container.

32. A method of installing an oil or gas well at a submerged location in arctic waters comprising the steps of

a. providng a substantially cylindrical container sized to receive therein a blowout preventer for a desired well at the submerged location and having earth formation cutting means carried by one end thereof, the other end of the container being open and carrying a removable upwardly extending skirt therearound,

b. engaging the cutting means with the earth formation underlying the water at the submerged location while disposing a container in a substantially vertical attitude,

c. rotating the container to cause the cutting means to penetrate the earth formation,

d. lowering the container during rotation thereof until the other end of the container is disposed proximate the top of the earth formation,

e. securing the container to the earth formation,

f. forming a protective cement shield for the container to a desired depth over the earth formation and for a desired distance laterally around the container, said depth adjacent the container being greater than the spacing of the other end of the container above the earth formation but less than the spacing of the skirt above the earth formation,

g. removing the skirt from the container after the shield is formed, and

h. drilling a well into the earth formation through the lower end of the container, including disposing a blowout preventer and associated equipment wholly within the container,

33. The method of claim 32 including coating the exterior of the skirt before forming the shield with a material to which the cement does not securely bond.

34. A method of installing an oil or gas well at a submerged location in arctic waters comprising the steps of

a. providing a substantially cylindrical container sized to receive therein a blowout preventer for a desired well at the submerged location and having earth formation cutting means carried by one end thereof, the other end of the container being open,

b. forming a protective cement shield for the container to a desired depth over the earth formation and for a desired distance laterally around the intended location of the container,

c. engaging the cutting means through the shield with the earth formation underlying the water at the submerged location while disposing the container in a substantially vertical attitude,

d. rotating the container to cause the cutting means to penetrate the earth formation,

e. lowering the container during rotation thereof until the other end of the container is disposed proximate the top of the earth formation and not appreciably above the top of the shield,

f. securing the container to the earth formation, and

g. drilling a well into the earth formation through the lower end of the container, including disposing a blowout preventer and associated equipment wholly within the container.

35. In a wellhead caisson for submerged oil and gas wells in which the caisson includes a substantially cylindrical container adapted to be substantially wholly disposed in an earth formation under a body of water and having opposite ends one of which is at least partially closed and the other of which is open, the container having an open interior sized to receive wholly therein through the open end of the container a blowout preventer and associated equipment, the caisson also including means for circulating fluid under pressure through the one end of the container, the improvement comprising cutting means carried by the one end of the container over the closed area thereof operable in response to rotation of the container about its axis to penetrate a consolidated earth formation and the like engaged thereby, the cutting means being disposed in association with the fluid circulating means for removal of cuttings from the cutting means by fluid circulated through the one end of the container, and means for rotating the container about its axis including means rigidly mounted within the container coaxially thereof for releasably receiving an elongate rotatable torque transmitting member engaged therewith through the container open end and for transmitting therefrom to the container sufficient torque to produce effective operation of the cutting means on a consolidated earth formation, the fluid circulating means including the rigidly mounted means.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,796,273 Dated March 12, 1974

Inventor(s) Paul R. Rininger

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2, line 65	After "is" read -- rotated --.
Column 8, lines 11, 12	For "assumed" read -- assured --.
Column 9, line 27	For "deos" read -- does --.
Column 17 line 41	For "providng" read -- providing --.
Column 18 line 5	Change the comma to a period.

Signed and sealed this 23rd day of July 1974.

(SEAL)
Attest:

McCOY M. GIBSON, JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents