United States Patent [19]

Wilde

[11] **3,717,113**

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[54] **FLOTATION AND ACCESS APPARATUS FOR SUB-SEA DRILLING STRUCTURES**

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[52] **U.S. Cl.**.....**114/0.5 D,** 114/235 F

[51] **Int. Cl.**.....**B63b 35/00,** B63b 21/00

[58] **Field of Search**.....114/235 R, 235 F

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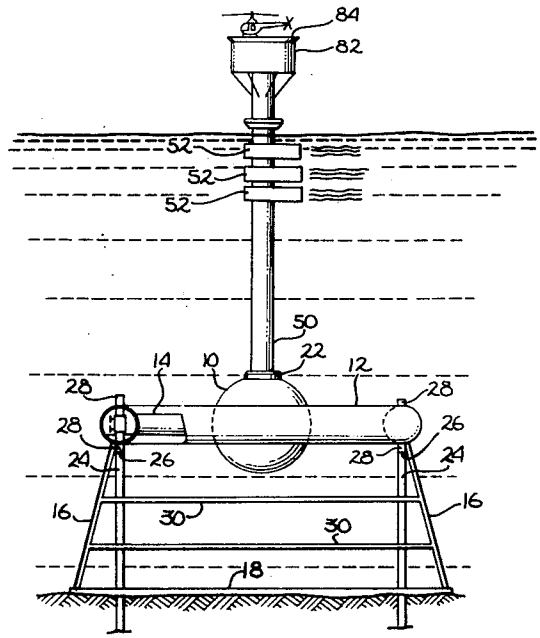
Primary Examiner—Trygve M. Blix

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[57] **ABSTRACT**

The present invention is an apparatus to provide access from the water surface to a submerged structure anchored or moored to the floor of the ocean. This apparatus may be employed, for example, as mining or well drilling rigs having internal compartments and passageways maintained free of water and within which one or more persons may work. The entry is provided by an entry tube of approximately ten feet in diameter with an arrangement on the lower end thereof adapted to provide sealed, flexible attachment to an adjoining portion of the sub-sea structure. Located near the upper end of the entry tube are one or more buoyant members of controllable buoyancy for providing a net positive or negative buoyancy to the entire access apparatus. The buoyant members are rotatably affixed to the entry tube and are shaped with an air-foil like cross-section. The rotatable mounting of the foil to the entry tube is at a point in the foil cross-section located ahead of the center of pressure of the foil so that the foil will rotate in response to ocean currents to present a minimal cross-sectional area to the current and to cause a minimum drag resulting therefrom. The upper end of the entry tube will, in general, contain a removable cover for access to the interior of the entry tube and may further include moorings to facilitate boat landing to the entry tube, a diesel power room and/or a helicopter landing deck.

4 Claims, 9 Drawing Figures



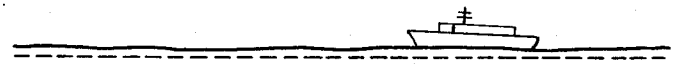


Fig. 1

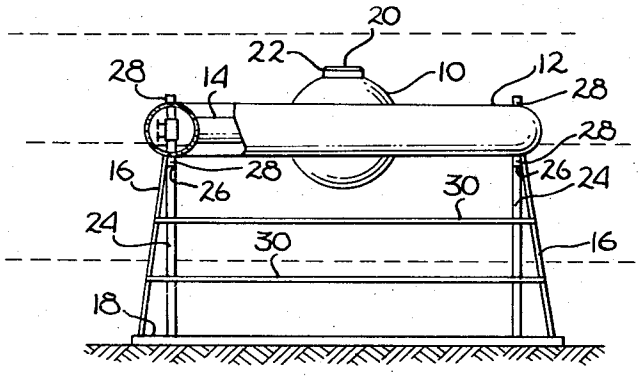
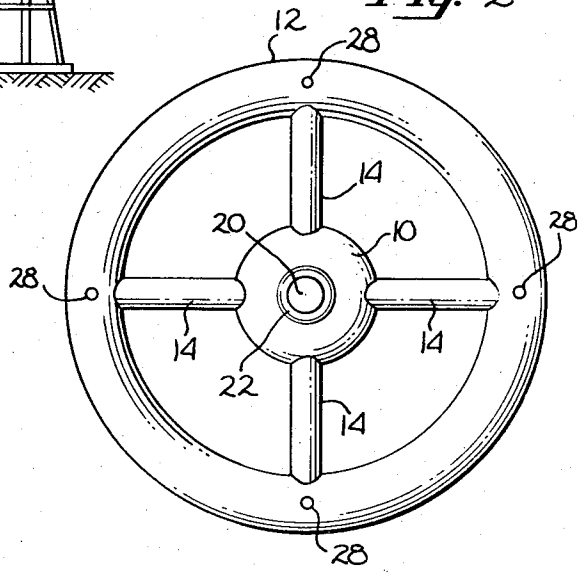


Fig. 2



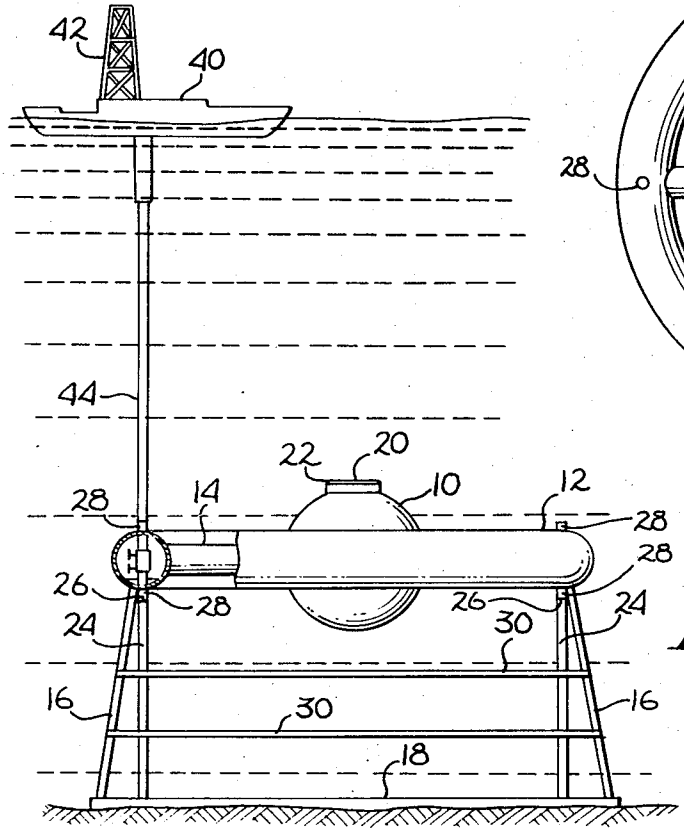


Fig. 3

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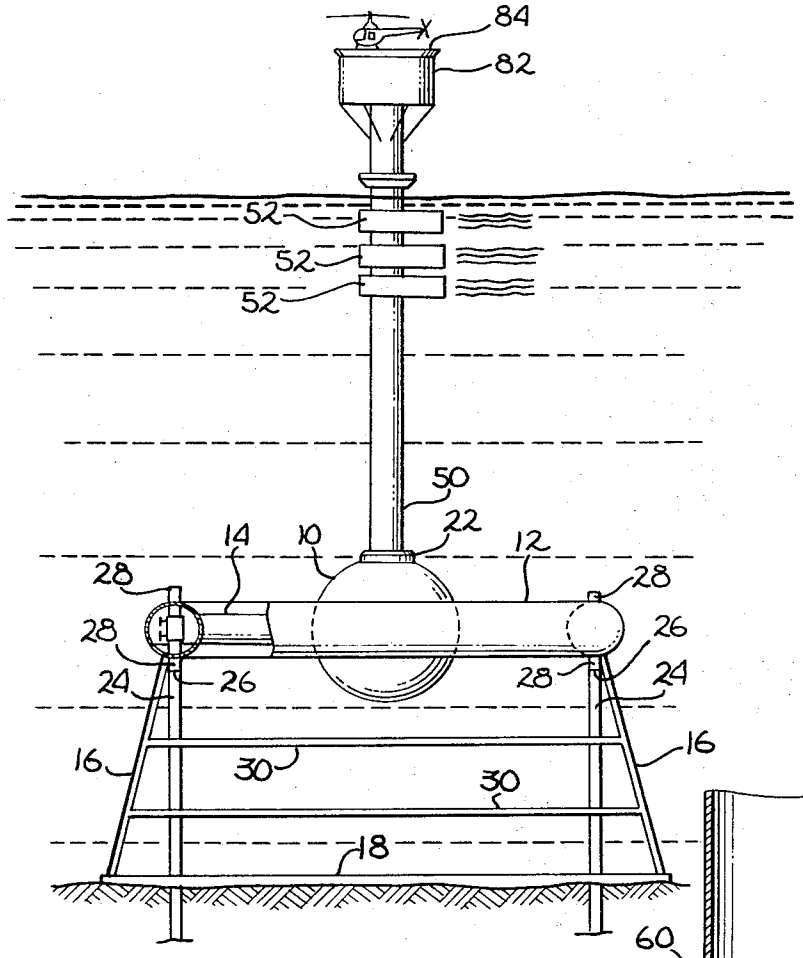


Fig. 4

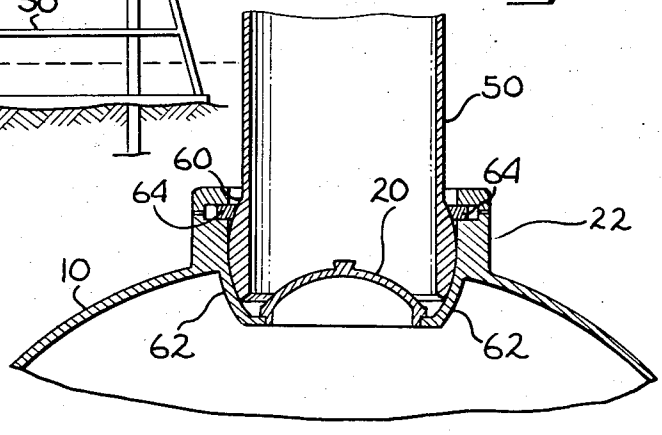


Fig. 5

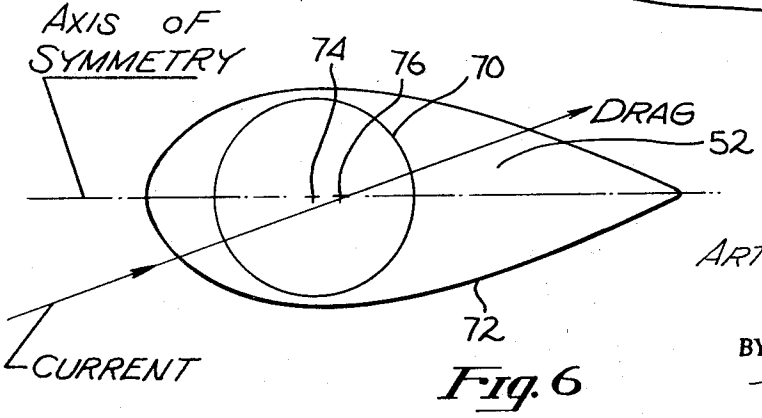


Fig. 6

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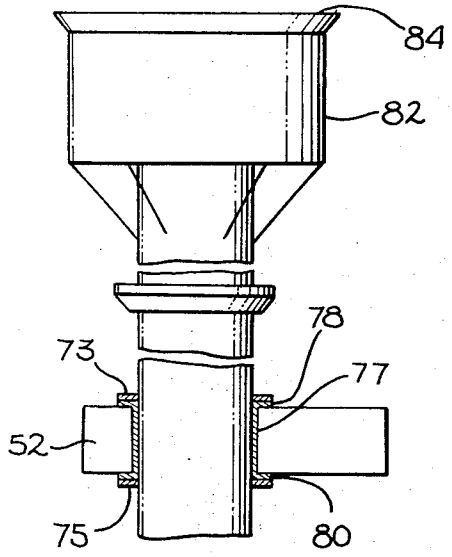


Fig. 7

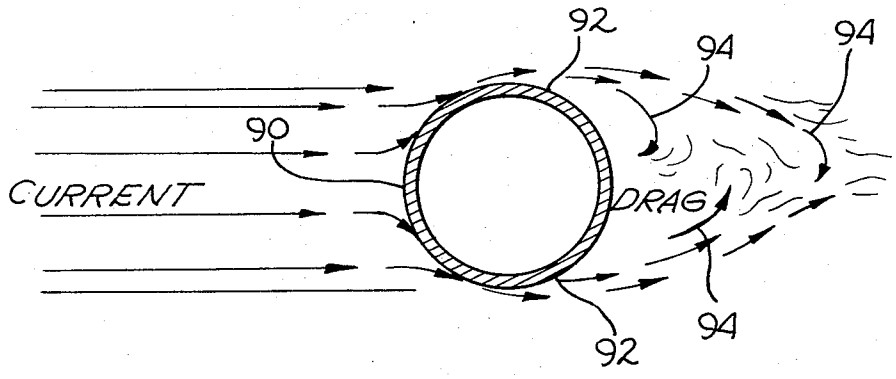


Fig. 8

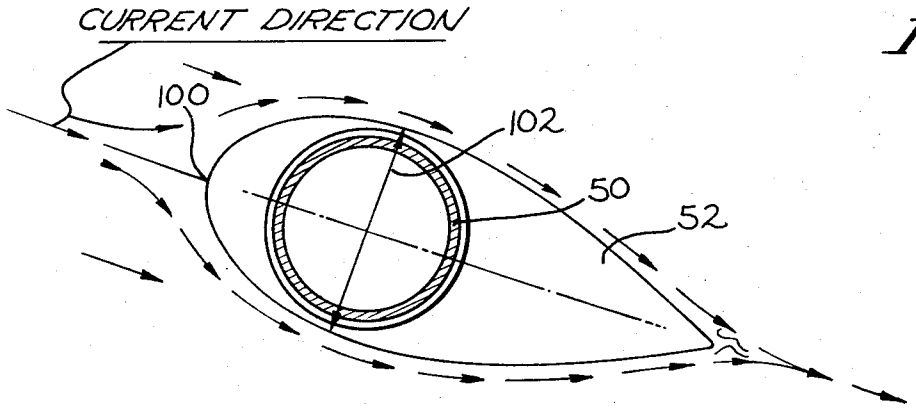


Fig. 9

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FLOTATION AND ACCESS APPARATUS FOR SUB-SEA DRILLING STRUCTURES

BACKGROUND OF THE INVENTION

1. Field of the Invention

The field of the invention is that of mining, drilling, completion, production, and remedial servicing of offshore oil and gas wells.

2. Prior Art

Various structures are known in the prior art for locating apparatus with respect to the ocean floor for purposes of exploration, mining, well drilling and the location of production equipment. Of particular interest is the offshore drilling and servicing of wells for oil and gas. This has generally been performed from either a fixed platform carried by a leg structure resting on the bottom of the ocean and supporting a drilling platform disposed above the upper level of wave action, or by the use of a floating platform which may be either a semi-submersible platform or a vessel, a barge or a moored structure. Newer methods of drilling and servicing of wells include the use of a submerged structure, which is anchored or moored to the floor beneath the body of water, and which may or may not have a permanent entry member protruding above the surface of the water. Some such structures are supported by legs of sufficient strength to support the weight disposed thereon and to resist the water currents to which they shall be subjected. An improved sub-sea structure has been disclosed in various U.S. Patents, as for example, U.S. Pat. No. 3,525,388 issued Aug. 25, 1970 to R. A. McClintock, titled "Sub-Sea Drilling Apparatus." That apparatus consists of a sub-sea structure having a positive buoyancy and being anchored or moored to the floor beneath the body of water by lines or elongate members which are slightly in tension due to the positive buoyancy of the structure. It is to these various forms of sub-sea drilling apparatus, that is, submerged structures that are moored or anchored to the floor of the body of water, that the present invention is directed.

Sub-sea drilling structures are so located so as to not be subject to wave conditions and storm conditions at the surface of the body of water. However, for proper operation and maintenance of such structures, access to the water tight internal compartments of the sub-sea structure is generally required. One structure to provide access is an entry tube attached to the sub-sea structure and extending above the surface of the water. This entry tube, though being smaller than the sub-sea structure itself, is still subject to high forces due to its weight, wave action, currents, surface storms and forces arising from boat landing and mooring, particularly in a high current condition. Such entry tubes have heretofore been rigidly attached to the sub-sea structure and supported thereby in opposition to the hereinbefore stated forces. Consequently, the access tube, because of its length, its rigid attachment to the sub-sea structure at one end, and its being subject to large forces at the other end, transmits large torques to the sub-sea structure, thereby substantially increasing the necessary structural strength, rigidity and anchoring of the sub-sea structure over that which otherwise would be required.

Other devices for access to the sub-sea structure, such as a diving bell capable of locking and sealing to the sub-sea structure, are known in the prior art. However, these devices do not provide ready and convenient access and, therefore, find limited use with such structures.

BRIEF SUMMARY OF THE INVENTION

The present invention consists of an access apparatus for sub-sea drilling apparatus, which is designed to minimize the forces and torques on the sub-sea structure and to provide a convenient and ready access to such structure. The access apparatus consists, in part, of an entry tube of approximately ten feed in diameter which pivotally connects with the sub-sea structure in a water tight manner at one end (the lower end) of the entry tube. Near the other end of the entry tube, at locations normally disposed below the surface of the water, are located one or more buoyant airfoil-like members rotatably mounted to the entry tube at a point on the foil cross-section which is forward of the center of pressure of the foil. Located at the top end of the entry tube is a removable access door or cap and such other equipment and structure as may be desired, such as a diesel power room, boat landing facilities and a helicopter landing deck. The rotatable foils are designed to "weather vane" in the presence of water currents so as to present a minimum cross-sectional area to the flowing current and to minimize drag on the entry tube due to the current, while simultaneously providing substantial buoyancy to the upward end of the entry tube so as to keep the entry tube substantially vertical in the presence of currents or other sources of external forces on the entry tube.

In general, the entry tube will be provided with devices for passing personnel and equipment from the upper end of the tube to the sub-sea structure located at the lower end of the tube, such as a cable lift and/or ladders within the hollow entry tube. In addition, the buoyancy of the foils is generally variable by allowing water to enter the internal structure of the foils, and the flexible connection of the entry tube to the sub-sea structure may be readily released or connected as desired. In this manner, the entire entry apparatus may be floated out to the site of a sub-sea drilling structure and attached thereto, or may be conveniently moved from one sub-sea structure to another should such movement be desired. In order to accomplish such a move from one sub-sea structure site to another sub-sea structure site, a seal cap would first be put on the sub-sea structure so as to prevent water from entering the structure upon removal or flooding of the entry tube. Then by partially flooding the entry tube and/or varying the buoyancy of the foils, the access apparatus is made substantially neutrally buoyant with a sufficient metacentric height to substantially maintain its normal vertical orientation. The lock between the entry tube and the sub-sea structure is then released and the buoyancy of the access means may be made slightly positive so that the entry tube will float free of the sub-sea structure and be ready for towing to another location.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of a sub-sea oil and gas well structure as may be used with the present invention access apparatus;

FIG. 2 is a top view of the sub-sea structure of FIG. 1 showing the toroidal nature of the outer ring and the radial spokes to the central sphere to which the access apparatus attaches;

FIG. 3 is a side view of the sub-sea structure of FIG. 1 showing the drilling of a well at one of the peripheral well drilling sites by the use of a drilling barge positioned over the drilling site;

FIG. 4 is a side view of the sub-sea structure of FIG. 1 with the access apparatus of the present invention;

FIG. 5 is a cross-section of the ball joint between the entry tube and the sub-sea sphere at the lower end of the access apparatus of FIG. 4;

FIG. 6 is a cross-section of one of the buoyant foils showing the shape of the foil and the location of he axis of rotation of the foil with respect to the center of pressure on the foil for minor misalignment between the foil and the current stream;

FIG. 7 is a schematic showing in cross-section the rotatable mounting of a foil to the entry tube;

FIG. 8 is a schematic representation of the flow of water perpendicular to a cylindrical body showing the stream lines around the cylindrical body and the separation and turbulance behind the body which cause the drag of such a body to be relatively high; and,

FIG. 9 is a schematic representation of the flow of water around the buoyant foil of the present invention apparatus showing a minimum separation of the stream lines at the trailing edge of the foil which results in a reduction of the drag over the cylindrical shape shown in FIG. 8.

DETAILED DESCRIPTION OF THE INVENTION

Referring first to FIG. 1, a side view of one form of sub-sea drilling structure may be seen on the floor of the body of water where a well is to be drilled. The principal components of the sub-sea structure are the central sphere **10** and the toroidal ring **12**, which attaches to and supports the central sphere **10** by spokes **14**, as may be seen in FIG. 2. The toroidal ring is supported above the ocean floor by support members **16** which extend between the toroidal ring **12** and the base platform or anchor **18** of the sub-sea structure. The toroidal ring **12** and spokes **14** are hollow, water tight structures which may house well drilling and operating equipment and provide an air environment in which men may work without special breathing (e.g., diving) equipment. The central sphere **10** has a seal cover **20** and a locking mechanism **22** at the outermost portion of the sphere, details of which will be subsequently described.

At four positions around the periphery of the toroid **12** are conduits **24** extending vertically through the base **18** up to a point **26** just below the toroid **12**. At point **26** the conduits **24** connect to tubes **28** which extend vertically through the working structure of toroid **12** terminating just above the toroid **12**. Connected to and forming part of the tubes **28** within the working space of the sub-sea structure may be various valves, connections, a blow-out preventor stack and/or a production Christmas tree, all of which are commonly employed and well-known to the prior art. The arrangement and function of such devices is described in the hereinbefore referred to U.S. Pat. No. 3,525,388 and, therefore, will not be repeated in detail herein.

In the preferred embodiment, the central sphere **10** is approximately 35 feet in diameter and connects to four spokes **14** which are approximately **8** feet in diameter. The toroidal ring **12** has a cross-sectional diameter of approximately 15 feet and a toroidal diameter of approximately 120 feet. All of these principal structural elements are interconnected, sealed and maintained free of water so that men and equipment may conveniently work within this structure. The height at which the equipment is maintained above he floor of the body of water by support members **16** and base platform **18** will depend somewhat on the depth of water in which the equipment is placed. However, the structure is particularly well suited for placement in deep water and in such instances, the support structure should be such so as to support the toroidal ring **12** at a depth of approximately 150 to 250 feet below the surface of the water. At such a depth, the structure is substantially free from the effect of wave action or other current conditions at the surface of the water and yet may be reached by divers for such purposes of external maintenance and repair if and when the need arises. Therefore, the length of support members **16** will be determined by the depth of the water in which the sub-sea structure is employed. An additional support structure, such as lateral support members **30** or other structural support or anchors may be employed as conditions dictate. Such anchoring or support of objects above the ocean floor is well known in the prior art and, therefore, will no be further described herein.

Now referring to FIG. 3, a structure for drilling an oil and gas well using the sub-sea structure of FIG. 1 in connection with a drilling barge **40** may be seen. The drilling barge **40** with derrick **42** is located over one of the tubes **28** projecting through the top surface of the toroidal ring **12**. A conventional drilling vessel riser system **44** is connected to the upper end of one of the tubes **28**. Thus, the tubes **28** are utilized to enable a continuous conduit to be formed from the drill barge to the well bore during drilling or well bore operations, and from the well bore to the interior of the toroidal ring **12** during completion or production operations. In general, the riser tube **44** will include a deflection joint (not shown) to allow for horizontal movement of the vessel relative to the sub-sea structure and a slip joint to allow for vertical movement of the vessel with respect to the sub-sea structure. Such deflection and slip joints are not shown in the figures but are again of the type well know to the art.

Once the riser system **44** is in place and properly connected, a continuous tube extends from above the surface of the water through the working chamber in the toroidal ring **12** to the floor of the body of water. A conventional spudding string is then lowered from the drilling vessel through the riser system **44**, one of the tubes **28** and through the conduit **24** extending from the toroidal ring to the floor beneath the body of water. Spudding operations are then carried out by rotating the drill until the desired depth to which the conductor pipe is to be set is reached. The conductor pipe is then lowered, typically by stripping over the drill string until the required length of conductor pipe has been lowered. The upper end of the conductor pipe is then seated by a landing seat (not shown) into the lower portion of the tube **28** at point **26**. At this stage the con-

ductor pipes extend into the well bore to the desired depth and cementing operations are carried out. Additional casing or service pipe can be set in the conventional manner. With the conductor pipe thus in position, drilling operations with circulation can then be commenced. It should be noted that during these operations, the valves generally located on tubes **28** within the toroidal ring **12** are open to provide a through conduit through the toroidal ring **12**. When production of a well is obtained, production trees can be intalled in the tube **28** by closing the lower valve in the access tube within the toroidal ring **12** and replacing a section of the tube **28** with a section containing a production Christmas tree. This method, as well as other suitable methods for drilling wells using a sub-sea structure as described in greater detail in previously issued U.S. Pat. No. 3,525,388 entitled, "Sub-Sea Drilling Apparatus," is presented or referred to here to show the interrelationship between the present invention sub-sea structure access apparatus and the sub-sea structures and drilling devices known in the prior art.

Now referring to FIG. **4**, a side view of the sub-sea apparatus of FIG. **1** with the access apparatus of the present invention may be seen. Access tube **50** is substantially vertically disposed above central sphere **10** and is pivotally connected (e.g., flexibly connected) by lock **22** to the central sphere **10** in a water tight manner. Details of this pivotal connection are shown in FIG. **5**, and will be subsequently described in detail. Also shown in FIG. **4** are three foil members **52**, which are rotatably connected to the entry tube **50** at a location along the tube which will be located beneath the surface of the water for all normal wave and tide conditions. These foil members are water tight members having substantial buoyancy to provide floatation and a righting moment to maintain the access apparatus in a substantially vertical orientation. In addition, the rotatable mounting of foil members **52** to the access tube **50** allow the foil members **52** to change orientation in response to changing currents, so as to present a minimum cross-sectional area to the flow of water and to result in a minimum drag on the entry tube due to these currents. Further details of the structure, mounting and function of these foils will be subsequently described with the aid of FIGS. **6** through **9**.

The length of access tube **50** is chosen so that the upper end of the access tube will be located above the surface of the water for all normal wave and tide conditions. As a minimum, the upper end will generally be fitted with a removable sealed cap, which in the event of storms, splashing waves etc. will prevent water from entering the interior of the entry tube **50**. In general, the portion of the access tube extending above the surface of the water may also contain such facilities as some form of elevator or cable lift, a source of power such as diesel generating equipment, and moorings for service ships and perhaps a small helicopter landing pad formed by the upper surface of the structure at the top of the entry tube.

It may be seen that the flexible connection of the entry tube **50** to the central sphere **10** in conjunction with the buoyant foil members **52** avoids one of the problems inherent in the prior art structures that had access tubes similar to access tube **50** but rigidly attached to the undersea structure. The problem with these prior art structures may be best illustrated with reference to FIG. **4**. It may be readily appreciated that if entry tube **50** were rigidly connected to central sphere **10**, the forces exerted at or near the top portion of entry tube **50** due to currents, wave action, surface storms and the pitching, yawing and heaving of ships moored to the tube would exert very large moments on the lower portion of entry tube **50**, on central sphere **10** and on the rest of the sub-sea structure. To adequately resist these moments, the strength, weight and complexity of the sub-sea structure and the entry tube **50** would have to be substantially increased over that required for the present invention. Therefore, by use of the present invention, the weight and complexity of the sub-sea structure is minimized, resulting in lower cost of construction and placement at the proper location on the floor of the body of water. The present invention also increases the sub-sea structure's potential mobility for movement to a new drilling site, if and when such movement is desired.

Buoyant members **52** are generally hollow structures and their effective buoyancy may be varied by allowing water to flow into or forcing water out of the internal spaces within the foil members. In this way, the net buoyancy of entry tube **50** and the various structures connected thereto (not including central sphere **10**) may be adjusted about a neutral buoyancy so as to be capable to providing a net positive or a net negative buoyancy of entry tube **50** and the attached structures. It should be noted that when the access apparatus (e.g., entry tube and attached structures), are in functional relationship to the sub-sea structure as shown in FIG. **4**, the access apparatus may have either a negative or a positive net buoyancy and still achieve the desired righting action by means of buoyant foil members **52**. This may be best illustrated by noting that increasing the weight at the lower end of entry tube **50** will decrease the buoyancy of the access means and still give the desired vertically floating characteristic as a result of buoyant foils **52**. Therefore, the choice of positive, negative or neutral buoyancy for the access means when in functional disposition with respect to the sub-sea structure will depend on the structural details and the anchoring or mooring for the sub-sea structure.

Now referring to FIG. **5**, the details of the flexible connection between entry tube **50** and central sphere **10** may be seen. The lower end of entry tube **50** contains a spherical mounting surface **60** which mates with a similar surface on central sphere **10**, generally defined as the inner surface of protrusions **62**. When spherical surface **60** is properly mating with the inner surface of protrusions **62** the entry tube may be pivotally locked to central sphere **10** by lock dogs **64** which engage the upper portion of spherical surface **60** so as to lock spherical surface **60** within the space defined by the inner surface of lock dog **64** and the inner surface of protrusion **62**. This pivotal connection may be made water tight by the use of plastic or rubber seals or by other sealing means well known in the prior art. Seal cover **20** which normally seals the central sphere **10** and prevents water from entering therein is so located and proportioned so as to be accessible and removable from within the entry tube. Therefore, once the entry tube is properly pivotally locked and sealed to

central sphere 10 and all water therein removed, the seal cover 20 may be removed so that access is provided to central sphere 10 and other internal compartments in the sub-sea structure from the surface of the water by way of entry tube 50.

Now referring to FIG. 6, a cross-section of one of the buoyant foil members 52 may be seen. The foil member 52 has an internal diameter 70 generally defining a cylindrical surface through the foil structure. The outer surface of the foil 72 is of a generally stream-lined shape having a cross-section similar to that most commonly used in the field of aerodynamics. The inner diameter 70 defines a center 74. Point 76 as identified in FIG. 6 is the so-called center of pressure on the foil, that is, it is the point on the axis of symmetry through which the effective drag force on the foil due to a current acts. This is also illustrated in FIG. 6 where it may be seen that a current, generally indicated by the arrow and misaligned with the axis of symmetry of the foil cross-section, will result in a drag on the foil which is in the direction of the current and passes through point 76. It may be seen that if foil member 52 were rotatably supported about an axis through point 76, that the drag resulting from the current would not create any torques on the foil member 52 and would not tend to rotate foil member either into better alignment with the current or into further misalignment with the current. However, if foil member 52 is rotatably supported about an axis through point 74 which is disposed on the axis of symmetry of the foil at a location forward of point 76, the drag acting through point 76 as the result of the current will create a moment or torque on the foil about the axis of support through point 70 which will tend to bring the foil 52 into better alignment with the current. In this manner, foil member 52 is made rotatably responsive to current direction in a manner so as to bring the foil member 52 into substantial alignment with the current, thereby presenting a minimum frontal area to the current and a minimum drag as a result of the stream-lined shape of the foil.

A further feature of the foil design may also be seen in FIG. 6. This feature arises from the fact that the width of the foil cross-section (e.g., the maximum width of the outer surface of the foil member 52 as measured in a direction perpendicular to the axis of symmetry of the foil member) is not much larger than the inner diameter 70 of the foil member or consequently, the outer diameter of entry tube 50. Therefore, though foil member 52 has a considerable cross-sectional area, as may be seen in FIG. 6, and thus, for any substantial height of foil member 52, may provide substantial buoyancy, the frontal area foil member 52 is only slightly larger than the frontal area of an equivalent length of entry tube 50.

Now, referring to FIG. 7, a cross-section of the rotatable mounting of one foil member 52 to the entry tube 50 may be seen. The foil member is retained in position on the entry tube by an upper flange 73 and a lower flange 75, which are rigidly attached to the entry tube 50. Surrounding the entry tube 50 in the region between the entry tube and the foil member 52 is a self-lubricating material 77, which prevents contact between foil member 52 and entry tube 50 and allows free rotation of foil member 52 with respect to the entry tube 50 with a minimum of frictional resistance.

In a similar manner, layers of self-lubricating material 78 and 80 are disposed between flange members 73 and 75, respectively, so as to provide a thrust bearing surface for transmission of the buoyant forces of foil member 52 to the entry tube 50 in a manner causing minimum resistance to the free rotation of foil member 52 with respect to entry tube 50. A number of materials, such as nylon and teflon, have self-lubricating characteristics when used as a bearing surface and are well adapted for use in the present invention as the self-lubricating material 77, 78 and 80 because of their low frictional characteristics, their relative ease of handling and their resistance to attack and deterioration due to exposure to adverse environments, such as sea water.

Also shown in FIG. 7 is an enlarged enclosure 82 located at the upper end of entry tube 50. The top surface 84 of enclosure 82 may serve as a helicopter landing pad and the enclosure itself may house a diesel power plant for the generation of power for such purposes as lights, pumps and the circulation of air through the sub-sea structure.

Now referring to FIGS. 8 and 9, a further advantage of using the rotatable foil members 52 instead of fixed circular or cylindrical members may be illustrated. FIG. 8 shows the streamlines characteristics of the flow of water around a cylindrical shape. It may be seen that the flow divides at the forward most point 90 on the circular cross-section, commonly referred to as the stagnation point, and flows around the circular cross-section in the manner indicated in the FIGURE. At some region slightly aft of the center of the cross-section, generally indicated by regions 92, the flow separates from the surface of the cylinder in a manner so as to create the vortices 94 in the wake behind the cylinder. These vortices are created in a cyclical manner, that is, first a clockwise vortex is shed, then a counter-clockwise vortex, then another clockwise vortex etc. at a rate and in a manner dependent on such factors as the current and the size of the cylinder. Because of the separation and the resulting vortices, a cylindrical shape as shown in FIG. 8 has a substantial drag when exposed to the flow of fluid perpendicular to the cylinder.

FIG. 9 shows the flow of fluid around a streamlined shape as is used for foil members 52. as in the flow fast a cylindrical shape, the flow divides at the stagnation point 100 and flows smoothly over the surfaces of the foil. Because of the streamlined shape, the gross separation exhibited in the flow past a cylindrical shape is not experienced in the flow past a streamlined shape, but instead the flow remains substantially parallel to the local surface of the streamlined shape until it reaches a region near the trailing edge of the shape, at which point separation will occ, resulting in a small vortex pattern behind the streamlined shape and yielding a relatively low drag for the entire streamlined body. Consequently, a streamlined shape such as that shown in FIG. 9 will experience a substantially smaller drag than a cylindrical shape as shown in FIG. 8 if the diameter of the cylindrical shape is the same as the thickness of the streamlined shape, generally indicated by the length of arrow 102 in FIG. 9. Also, since the thickness of the streamlined shape of foil member 52 need be only slightly larger than the diameter of the entry tube 50, the drag experienced by foil member 52

when exposed to a current is about the same as, or even less than, would have been caused by the entry tube without the flotation created by the foil members. Thus, a flotation device has been provided for the upper portion of entry tube **50** which due to its presence does not significantly add to, and may even reduce, the net drag force on the entry tube due to the currents it experiences. This is to be compared with the drag that would have resulted had spherical or cylindrical buoyant members been attached to the entry tube. Such spherical or cylindrical buoyant members would unduly enlarge the entry tube **50** at a position of the entry tube which is most subject to currents, that is, a position near the surface of the water, and would cause a very high drag due both to their size and their lack of streamlining.

It is to be understood that though the preferred embodiment of the present invention access apparatus is of a size to accommodate the passage of men therethrough, the terms access, access apparatus and access means are not so limited. In the broadest sense, these terms refer only to an apparatus for communicating with the sub-sea structure, such as an apparatus for the transmission of gas or oil to the surface of the water. Similarly, the terms entry tube and entry means are used herein in a general sense, the word entry being chosen as particularly descriptive of the preferred embodiment and least subject to confusion with references to the access apparatus as a whole. These words, however, apply to the communicating member in general and are not limited to one for the passage of men and equipment.

Having now described the details of the present invention access apparatus, the manner in which the access apparatus may be moved from one site to another site will now be described. Referring to FIG. **4**, the access apparatus of the present invention is shown in functional engagement with a sub-sea drilling structure. To move the access apparatus from one site to another site, the following procedure may be used. First seal cover **20**, as shown in FIG. **5**, is locked in place on central sphere **10** so that water which may be allowed into the entry tube **50** will not pass into the central sphere. Then the access apparatus is given a slight negative buoyancy by partial flooding of the buoyant members **52** and/or allowing some water to enter the lower region of entry tube **50**. After this is done, lock dogs **64**, as shown in FIG. **5**, may be released, either remotely or by divers, and thereafter the buoyancy of the entire access apparatus adjusted to be positive so that the access apparatus will float out of and free of the sub-sea structure and be ready for towing to the next site. Throughout this procedure, the center of buoyancy of the access apparatus should be maintained above the center of gravity of the access apparatus so as to maintain the tendency of the access apparatus to remain in a substantially vertical orientation.

Though the access apparatus of the present invention is not often moved from one location to another, the ability to do so in a rather simple manner allows the positioning of the sub-sea structure and the convenient later attachment of the access apparatus either before or after the well has been drilled, and further facilitates the salvage of the equipment from an unproductive well location and movement to a new drilling site. In this regard, it should be noted that a sub-sea structure, such as that shown in FIG. **1**, is generally located at some fixed depth below the surface of the water, such as 150 to 250 feet, so as to be substantially immune from the surface wave action and yet be readily accessible by divers. Consequently, the sub-sea structures at various well sites will, in general, be located at substantially the same depth below the surface of the water regardless of the overall water depth at that location, so that the access apparatus of the present invention with a given length of entry tube **50** may be used interchangeably at a number of sites.

In the preferred embodiment previously described, a relatively rigid entry tube is pivotally connected to the sub-sea structure. However, it is to be understood that other connections and other types of entry tubes may be used with the present invention. By way of example, if a relatively rigid tube is rigidly connected to the sub-sea structure, the flotation devices located under the surface of the water will maintain the tube in tension, thereby tending to prevent buckling and to maintain the tube in a substantially erect position. Furthermore, the use of the airfoil shaped, rotatable flotation devices described herein will substantially reduce the current drag on such an apparatus. Also, if it is desired to minimize the torques exerted by the entry tube on the sub-sea structure about its horizontal axis, the entry tube may be connected to the sub-sea structure by types of flexible couplings, other than the described ball joint, or may be connected through a flexible length of tubing (e.g., a distributed flexibility rather than a ball joint or substantially localized flexibility), or in the extreme, may itself be flexible. The word flexible is used herein and in the claims to indicate rotational flexibility, e.g., that the longitudinal axis of the entry tube may be inclined with respect to vertical without imposing large torques on the sub-sea structure. (Flexibility in the sense of the ability to undergo significant elongation and compression along the longitudinal axis of the entry tube is not included in the use of such term, though such flexibility would be advantageous in some cases for such purposes as to absorb shocks when the entry tube first contacts the sub-sea structure when the two are being connected).

I claim:

1. In combination, an elongate supported member extending generally vertically in a body of water and buoyancy means for providing buoyant forces to said supported member, said buoyancy means comprising at least one buoyant member having a streamlined shape, and means for rotatably mounting said buoyant member to said supported member so as to enable said bouyant member to align itself by and with the flow of water with respect to the supported member, said mounting means comprising a bearing formed by radially spaced apart facingly disposed surfaces of revolution on said supported member and said buoyant member, self-lubricating material between said surfaces of revolution, said supported member being of uniform external diameter adjacent said bouyant member and having a radially outwardly extending flange secured to said supported member above said buoyant member, and means on said buoyant member for engaging said flange, at least one of said flange and said last mentioned means being of self-lubricating

material so that buoyancy forces from said supported member may be provided through said flange to said supported member while permitting said alignment of said buoyancy member.

2. The buoyancy means of claim 1 wherein said interposed self-lubricating material is a plastic material.

3. The buoyancy means of claim 2 wherein said plastic is nylon.

4. The buoyancy means of claim 2 wherein said plastic is teflon.

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