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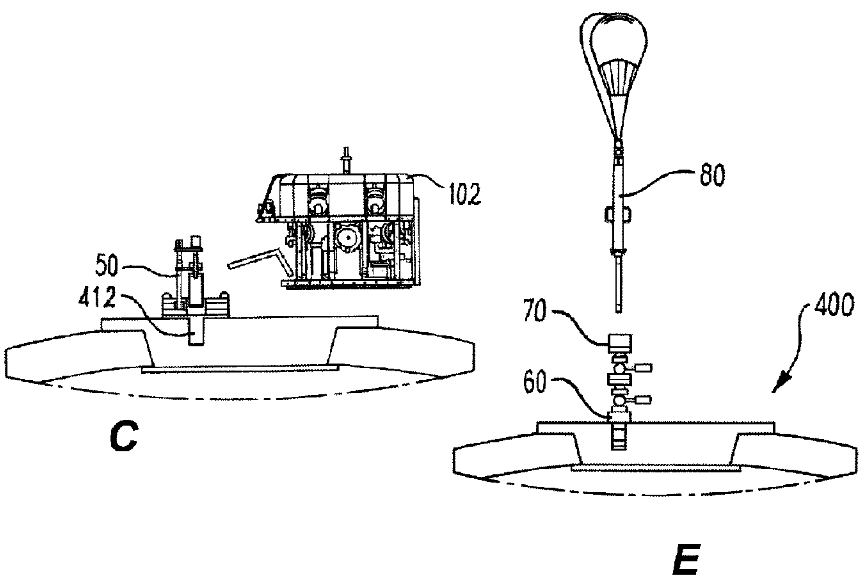
(54) Title: METHOD AND APPARATUS FOR ACCESS AND REMEDIATION OF HYDROCARBON STORAGE TANKS



(57) Abrégé/Abstract:

The invention provides a method and apparatus for accessing a hydrocarbon storage cell (400) and/or removing hydrocarbons therefrom. An access method comprises installing an anchor hub (60) in a capping plate (408) of the hydrocarbon storage cell (400), and drilling a bore (80) to penetrate an internal volume of the storage cell by passing a drilling apparatus through the anchor hub. A removal method comprises providing a first hydrocarbon storage cell comprising a first anchor hub and providing a second hydrocarbon storage cell comprising a second anchor hub. The first and second anchor hubs are connected to one another with a flowline, and hydrocarbons are pumped from an upper portion of an internal volume of the second hydrocarbon storage cell to an internal volume of the first hydrocarbon storage cell.

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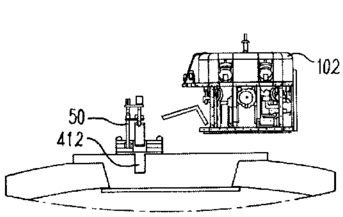

Fig. 4C

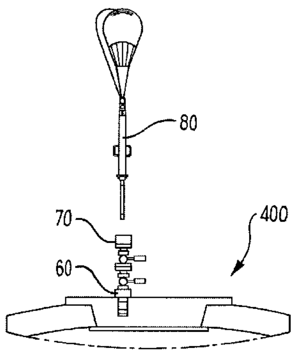

Fig. 4E

(57) Abstract: The invention provides a method and apparatus for accessing a hydrocarbon storage cell (400) and/or removing hydrocarbons therefrom. An access method comprises installing an anchor hub (60) in a capping plate (408) of the hydrocarbon storage cell (400), and drilling a bore (80) to penetrate an internal volume of the storage cell by passing a drilling apparatus through the anchor hub. A removal method comprises providing a first hydrocarbon storage cell comprising a first anchor hub and providing a second hydrocarbon storage cell comprising a second anchor hub. The first and second anchor hubs are connected to one another with a flowline, and hydrocarbons are pumped from an upper portion of an internal volume of the second hydrocarbon storage cell to an internal volume of the first hydrocarbon storage cell.

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Method and Apparatus for Access and Remediation of Hydrocarbon Storage Tanks

Field of the disclosure

The present invention relates to a method and apparatus for access and remediation of hydrocarbon storage tanks, and in particular to a method and apparatus for the removal of hydrocarbon fluids from subsea storage tanks associated with offshore installations in the hydrocarbon exploration and production industry. Aspects of the invention relates to methods used in the abandonment and/or decommissioning of offshore hydrocarbon production installations. The invention also relates to equipment used in abandonment and/or decommissioning applications.

Background to the Invention

When a hydrocarbon production well reaches the end of its economic or technical viability, it is plugged and abandoned. As all the wells associated with a particular hydrocarbon production platform become abandoned, the platform can be decommissioned and removed.

One particular type of offshore platform structure is a Gravity Base Structure or GBS, which are prevalent in North Sea oil fields. To provide a better understanding of the subject matter of the present application, the prior art is schematically illustrated in Figures 1A, 1B and 2. Figure 1A and 1B show schematically a Gravity Base Structure of the type found in the North Sea, and thus forming part of the prior art. The Gravity Base Structure, shown generally at 1, comprises a number of storage cells 2 that stand on the seabed. The storage cells 2 are formed from steel reinforced, pre-stressed concrete, and are substantially cylindrical and arranged in a honeycomb formation. In this example, three cells extend in to legs 3 which support the top sides 4 of the platforms. The remaining sixteen cells are used for oil/water separation and oil storage.

In a typical example, the cells 2 have an approximate outer diameter of around 20 meters, and are approximately 61 meters high. At the upper end, each cell has an elliptical domed surface. The cells are flooded and held at a lower internal pressure which is lower than the seawater ambient pressure. This keeps the concrete forming the cells in compression.

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Typically, the pressure inside the cells is 4 bar (approximately 59 Psi) below the seawater ambient pressure.

Figure 2 is a sectional view through cell number nineteen and leg number one of the prior art GBS of Figures 1A and 1B. The leg 2 comprises a cell draw down system 5 which functions to introduce fluids into the internal volume of the storage cell via a flowline 6, and an extraction system 7 for removal of hydrocarbons. Ballast sand 8a and sediments 8b are present in the bottom of the cell volume. When the cell is substantially depleted, a volume of oil 9 is present at the top of the cell volume above the relatively high density seawater and it is necessary to remove this so-called attic oil from the cell volume prior to removal of the cell.

There is a need for a method and apparatus for accessing the storage cell in a manner which is safe, effective, convenient, and economical. Furthermore, there is a need for safe, effective, convenient, and economical methods and apparatus for removal of stored oil from a storage cell.

Summary of the invention

It is amongst the aims and objects of aspects of the invention to provide a method and apparatus which meets the above-described needs in storage cell access and/or remediation applications.

It is amongst the aims and objects of aspects of the invention to provide a method of and apparatus for securing equipment to a concrete component of an offshore structure.

Further aims and objects of the invention will become apparent from the following description.

According to a first aspect of the invention, there is provided a method of accessing a hydrocarbon storage cell, the method comprising: forming a blind hole in a capping plate of the hydrocarbon storage cell; installing an anchor hub in the blind hole; and drilling a bore to penetrate an internal volume of the storage cell by passing a drilling apparatus through the anchor hub.

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Preferably, the method comprises providing a flow access path through the anchor hub.

The method may comprise installing a valve manifold on the anchor hub, and may comprise passing the drilling apparatus through the valve manifold.

The method may comprise forming a blind hole in the capping plate by removing a plug of material from the capping plate. The blind hole may be formed by operating a plug drilling apparatus disposed on an upper surface of the capping plate. The plug drilling apparatus may be powered from a Remotely Operated Vehicle (ROV) or from surface.

The method may comprise penetrating an internal volume of the storage cell by drilling through the base of the blind hole.

The method may comprise providing a core drill bit, drilling a hole into the capping plate with the core drill bit, and retaining the core drill bit in the capping plate to provide the anchor hub.

The method may comprise pumping a sealant to form a seal between the core drill bit and the capping plate. Preferably, the sealant is a resin. The sealant may be pumped into a micro-annulus between the core bit and the concrete capping plate.

The method may comprise penetrating the capping plate by locating a through drilling apparatus on the anchor hub. The method may comprise creating a low pressure on a lower side of the through drilling apparatus to create a downward force on the drill bit.

The method may comprise circulating seawater through the drilling apparatus and the valve manifold.

The method may comprise circulating seawater through the drilling apparatus and the valve manifold to a further hydrocarbon storage cell. The further hydrocarbon storage cell may comprise an anchor hub installed in a capping plate of the further hydrocarbon storage cell, and may further comprise a bore formed through the anchor hub to penetrate the further hydrocarbon storage cell.

The anchor hub of the further hydrocarbon storage cell may have been installed in a previous operation. Alternatively, the method may comprise accessing the further hydrocarbon storage cell by installing an anchor hub in a capping plate of the hydrocarbon storage cell and drilling a bore to penetrate an internal volume of the storage cell by passing a drilling apparatus through the anchor hub.

Preferably, the method of accessing the further hydrocarbon storage cell comprises forming a blind hole in the capping plate; and installing the anchor hub in the blind hole.

The through drilling apparatus may be powered from an ROV or from surface.

According to a second aspect of the invention, there is provided a method of removing hydrocarbons from a hydrocarbon storage cell, the method comprising: accessing a first hydrocarbon storage cell by the method as described above,
accessing a second hydrocarbon storage cell by the method as described above,
connecting the anchor hub on the first hydrocarbon storage cell to the anchor hub on the second hydrocarbon storage cell with a flowline;
pumping hydrocarbons from an upper portion of an internal volume of the second hydrocarbon storage cell to an internal volume of the first hydrocarbon storage cell.

Preferably, the method comprises providing a flow access path through the anchor hub.

The method may comprise accessing the first hydrocarbon storage cell via a first valve manifold on the first anchor hub. The method may comprise accessing the second hydrocarbon storage cell via a second valve manifold on the second anchor hub.

The method may comprise providing a subsea pump assembly on the anchor hub of the first hydrocarbon storage cell.

The method may comprise:
accessing a third hydrocarbon storage cell by the method as described above;
disconnecting the flowline from the anchor hub of the second hydrocarbon storage cell;

connecting the anchor hub of the first hydrocarbon storage cell to the anchor hub of the third hydrocarbon storage cell via the flowline; and
pumping hydrocarbons from an upper portion of an internal volume of the third hydrocarbon storage cell to an internal volume of the first hydrocarbon storage cell.

The method may comprise:
accessing a further hydrocarbon storage cell by the method as described above;
disconnecting the flowline from the anchor hub of the second hydrocarbon storage cell;
connecting the anchor hub of the first hydrocarbon storage cell to the anchor hub of the further hydrocarbon storage cell via the flowline; and
pumping hydrocarbons from an upper portion of an internal volume of the further hydrocarbon storage cell to an internal volume of the first hydrocarbon storage cell.

The method may comprise plugging the anchor hubs of second, third and/or further hydrocarbon storage cell(s) after removal of hydrocarbons from the second, third and/or further hydrocarbon storage cell(s).

The method may comprise disconnecting the flow line from the anchor hub of the first hydrocarbon storage cell. The method may comprise providing a return line from the anchor hub of the first hydrocarbon storage cell to a hydrocarbon tank or pipeline, and may further comprise pumping hydrocarbons from the first hydrocarbon storage cell to the tank or pipeline.

Embodiments of the second aspect of the invention may include one or more features of the first aspect of the invention or its embodiments, or vice versa.

According to a third aspect of the invention, there is provided an anchor hub for providing an access point in a capping plate of a hydrocarbon storage cell, the anchor hub comprising:
a main body comprising an upper opening, a lower opening and a throughbore extending between the upper and lower openings, the main body comprising a lower portion configured to be located in and extend into a blind hole formed in an upper surface of the capping plate;
securing means configured to fix the lower portion of the anchor hub in the blind hole;
an annular seal arranged around the lower portion to provide a seal between the lower portion and the blind hole; and

an attachment point for connecting an item of process or flow equipment to the anchor hub such that the item of process of flow equipment is in communication with the throughbore.

The throughbore of the anchor hub may enable the passage of a drilling apparatus through the anchor hub, operable to drill through the blind hole and penetrate the capping plate.

Preferably, the anchor hub provides an attachment point for an item of process or flow equipment.

Preferably, the anchor hub comprises an upper portion which is upstanding from an upper surface of the capping plate. The upper portion may provide the attachment point for an item of process or flow equipment.

Preferably, the lower portion is configured to form a seal with the recess of the capping plate. Preferably, the anchor hub comprises an annular seal around the lower portion. Alternatively, or in addition, the anchor hub may comprise a seal between an upper portion of the anchor hub and an upper surface of the capping plate.

The anchor hub may comprise an upper connector, which may be a connector for a valve manifold.

Preferably, the throughbore of the anchor hub comprises a seat for a sealing plug.

In embodiments of the invention, the anchor hub comprises one or more anchor ring assemblies.

The one or more anchor ring assemblies may comprise a plurality of segments, which together form a ring disposed around a lower portion of the body.

Preferably, the anchor hub comprises a pair of anchor ring assemblies axially separated on the main body. The pair of anchor ring assemblies may be connected via a plurality of bolts. The bolts may be tensioning bolts, and may be designed to be tightened to bring the anchor ring assemblies towards one another in an axial direction of the hub.

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The one or more anchor ring assemblies may comprise a tapered profile, which may correspond to a tapered profile of the main body. The one or more anchor ring assemblies (or their segments) may function as wedges or slips, and may be configured such that relative axial movement of an anchor ring assembly with respect to the main body results in engagement of an anchor element with the recess. Relative axial movement of an anchor ring assembly with respect to the main body may result in radial displacement of the anchoring ring.

Embodiments of the third aspect of the invention may include one or more features of the first or second aspects of the invention or their embodiments, or vice versa.

As described above, the anchor hub may provide an attachment point for an item of process or flow equipment, but the principles of this aspect of the invention also have application to other types of equipment. Therefore according to a fourth aspect of the invention, there is provided an anchor hub for an offshore installation, the anchor hub comprising:
a main body comprising an upper end and a lower end;
a lower portion configured to be located in and extend into a recess formed in a surface of a concrete structure of the offshore installation;
securing means configured to fix the lower portion of the anchor hub in the recess;
and at least one attachment point for attachment of an item of equipment.

The concrete structure may be a capping plate of a hydrocarbon storage cell, or may be another structural component including but not limited to a leg or foundation. In this aspect of the invention, the main body may comprise upper and lower openings and a throughbore therebetween, but such a throughbore is not an essential feature. Preferably the equipment is subsea equipment, which may form a part of a permanent or temporary subsea installation.

Embodiments of the fourth aspect of the invention may include one or more features of the first to third aspects of the invention or their embodiments, or vice versa.

According to a fifth aspect of the invention, there is provided a valve manifold for a hydrocarbon storage cell, the valve manifold comprising:

a main body comprising an upper opening, a lower opening and a throughbore extending between the upper and lower openings;
a connector configured to connect the valve manifold to an anchor hub installed in a capping plate of the hydrocarbon storage cell; and
at least one isolation valve disposed in the throughbore.

The valve manifold preferably comprises a throughbore with sufficient to receive a drilling tool, and may comprise a seat for a drilling apparatus. The valve manifold may comprise an upper connector configured for connection to a drilling apparatus.

In one embodiment, the at least one isolation valve is operable to be actuated by an ROV torque bucket. Alternatively, the at least one isolation valve is operable to be actuated by a diver.

Preferably, the valve manifold comprises upper and lower isolation valves in the throughbore of the apparatus.

The valve manifold may comprise a flow port or flow conduit which is in fluid communication with the throughbore between the upper and lower isolation valves.

The flow port or conduit may be coupled to a third isolation valve in a flow line.

Embodiments of the fifth aspect of the invention may include one or more features of the first to fourth aspects of the invention or their embodiments, or vice versa.

According to a sixth aspect of the invention, there is provided a subsea installation comprising:
a hydrocarbon storage cell comprising a capping plate;
an anchor hub installed in the capping plate of the hydrocarbon storage cell, such that a lower portion is located in and extends into a blind hole formed in an upper surface of the capping plate;
wherein the anchor hub is configured for a drilling apparatus to be located thereon; and
wherein the anchor hub comprises a throughbore which enables the passage of the drilling apparatus through the anchor hub to drill through the base of the blind hole to form a bore

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extending through the capping plate, which penetrates an internal volume of the hydrocarbon storage cell and provides a flow access path from an upper opening of the anchor hub to the hydrocarbon storage cell.

The subsea installation may comprise a valve manifold connected to the anchor hub.

Embodiments of the sixth aspect of the invention may include one or more features of the first to fifth aspects of the invention or their embodiments, or vice versa.

According to a seventh aspect of the invention, there is provided a drilling apparatus comprising:
a drill motor;
a drill shaft have a drill axis and coupling the drill motor to a drill bit; and
a drill support frame;
wherein the drill support frame comprises a plurality of discrete longitudinal support elements distributed around the drill axis;
wherein the drill shaft and drill bit are configured to move axially within an internal volume defined by the support elements.

The drilling apparatus may comprise a carriage configured to move axially within the internal volume defined by the support elements with the drill shaft and drill bit.

The drilling apparatus may comprise a torque reaction block, the torque reaction block configured to be rotationally keyed with the support frame. The torque reaction block may be axially movable with respect to the support frame, and may be integral, or may be unitary, with the carriage.

Preferably, the torque reaction block comprises a plurality of recesses, and the recesses may be shaped and positioned to locate the support elements.

Preferably, the drilling apparatus comprises a lower bearing assembly, which may be configured to permit rotation and axial movement of the drill shaft. The drilling apparatus may comprise a centraliser, which may be disposed at the lower bearing assembly. The centraliser may comprise a sacrificial material.

The drilling apparatus may comprise a seat configured to prevent downward movement of the drill shaft and drill bit beyond a predetermined distance. The seat may be configured to receive the carriage. The seat and the carriage may be configured to locate together to form a seal. The seat and/or the carriage may be provided with sealing elements.

Preferably, the support frame is open, and IT may provide flow spaces for fluid to flow freely between the internal volume and a volume outside of the support frame.

The drill shaft may be at least partially hollow. The drilling apparatus may provide a fluid circulation through the drill shaft and/or drill bit.

Embodiments of the seventh aspect of the invention may include one or more features of the first to sixth aspects of the invention or their embodiments, or vice versa.

According to an eighth aspect of the invention, there is provided a method of accessing a hydrocarbon storage cell substantially as described herein.

According to a ninth aspect of the invention, there is provided a method of removing hydrocarbons from a hydrocarbon storage cell substantially as described herein.

According to a tenth aspect of the invention, there is provided a method of removing hydrocarbons from a hydrocarbon storage cell substantially as described herein.

According to an eleventh aspect of the invention, there is provided an anchor hub substantially as described herein.

According to a twelfth aspect of the invention, there is provided a valve manifold substantially as described herein.

According to a thirteenth aspect of the invention, there is provided a drilling apparatus substantially as described herein.

According to a fourteenth aspect of the invention, there is provided an apparatus for accessing a hydrocarbon storage cell, the apparatus comprising an anchor hub as described above and a valve manifold attachable to the attachment point of the anchor hub such that the valve manifold is in communication with the throughbore of the anchor hub.

Brief Description of the Drawings

There will now be described, by way of example only, various embodiments of the invention with reference to the drawings, of which:

Figure 1A is a schematic view of a drilling rig with storage tanks, which forms part of the prior art, to which the method of the invention may be applied;

Figure 1B is a sectional view through the storage tank configuration of the drilling rig of Figure 1A, which forms part of the prior art;

Figure 2 is a schematic section through leg 1 and storage cell 19 of the drilling rigs of Figures 1A and 1B, which forms part of the prior art;

Figure 3 is a sectional overview of the equipment used in one embodiment of the invention;

Figures 4A to 4F schematically show the steps of an access method according to an embodiment of the invention;

Figure 5 is a sectional view of a gravity based plug drilling machine used in accordance with an embodiment of the invention;

Figure 6A is a longitudinal sectional view of an anchor hub in accordance with an embodiment of the invention;

Figure 6B is an alternative sectional view of the anchor hub of Figure 6A;

Figure 7 is a sectional view through the valve manifold of Figure 3;

Figure 8A and 8B are sectional views through a drilling machine of Figure 3 in accordance with an embodiment of the invention, shown in initial retracted condition and extended condition respectively;

Figure 9 is a schematic sectional view through the hose connection assembly in accordance with an embodiment of the invention;

Figure 10 is a sectional view through a hose connection assembly in accordance with an alternative embodiment of the invention;

Figures 11 to 14 are sectional views through anchor hubs, each in accordance with alternative embodiments of the invention;

Figures 15A to 15G schematically show sequential steps of a remediation method in accordance with an embodiment of the invention;

Figure 16 is a schematic sectional view of a valve manifold in accordance with an alternative embodiment of the invention, as shown in the method of Figures 15A to 15G;

Figure 17 is a sectional view through a sealing plug and running tool assembly in accordance with an embodiment of the invention;

Figure 18 is a schematic view of a valve manifold as may be used in a diver-oriented operation according to an alternative embodiment of the invention;

Figures 19A to 19H schematically show sequential steps of a remediation method according to an alternative embodiment of the invention.

Detailed description of preferred embodiments

As described above, Figures 1A, 1B and 2 are representative of a drilling rig with a hydrocarbon storage facility to which the equipment and methods of the present invention may be applied. A primary objective of the invention is to provide equipment and/or methods for the safe and cost-effective access of a hydrocarbon storage cell, to facilitate remediation of attic oil from the cell, and accordingly, exemplary embodiments of the invention will be described in that context. It will be appreciated that aspects of the invention may be used in alternative applications, for example, the anchor hub may provide an attachment point for an item of equipment, on a surface of a concrete structure of an offshore installation, including but not limited to a leg or foundation.

Figure 3 shows schematically an overview of equipment 100 used in accordance with an embodiment of the invention to form an opening in a subsea hydrocarbon storage cell. The equipment comprises an anchor hub 60 shown in a loose condition 60A and a tightened condition 60B respectively. The equipment also comprises a valve manifold 70, configured to be connected to the anchor hub 60, and a drilling tool 80, configured for attachment on an upper coupling of the valve manifold 70. The drilling tool is shown in a first condition 80A in which the internal drill components are retracted and a second condition 80B, in which the internal drilling components are extended.

The equipment shown in Figure 3 is designed to provide an isolated attachment and access point for safe and efficient penetration of a hydrocarbon storage cell, and subsequent remediation or disposal of hydrocarbons. An overview of an access method will be described with reference to Figures 4A to 4F and the subsequent drawings which show equipment details.

This example method will be described in the context of a Remotely Operated Vehicle (ROV) -based operation; in other words one which predominantly uses ROVs to carry out subsea operations with reduced and/or minimal diver support. Typically, such operations take place in relatively deep water; in sea conditions which diver operations are undesirable; or over extended periods which may be unsuitable for diver-based work. However, alternative embodiments of the invention may have an increased reliance on diver-based operations, as will be clear from the following description.

Figure 4A shows schematically an initial stage of a storage cell access operation. Storage cell, generally shown at 400, comprises a main wall and a domed upper surface 402 with a central opening 404. The opening is filled with a prefabricated concrete slab 406, and a capping plate 408 fills the opening and extends outwards over the wall of the domed surface 402 of the cell. The capping plate is formed from concrete, and is approximately 90cm to 120cm thick.

The upper surface 410 of the capping plate 408 has a rough hand-tamped finish, and over the lifetime of the storage cell, debris and marine fouling has accumulated on the surface. In stage one of the operation, a work-class ROV 102 is deployed to the storage cell 400 and is used to clean the upper surface of the capping plate 408. In this example, the cleaning is carried out by the jetting of high pressure seawater to the surface of the capping plate to remove debris and accumulated material such as drill cuttings.

When the surface 410 of the capping plate is cleaned, a plug drilling apparatus 50 is deployed from surface and landed on the cleaned surface of the concrete plug. The plug drilling apparatus is shown in more detail in Figure 5. The apparatus 50 comprises a gravity base 52 which supports the apparatus on the capping plate 408, and a pillar 54 extending upwardly from the gravity base 52 and supporting the drilling components. The gravity base 52 comprises a central aperture 55 for extension of the drilling components through the gravity base, and a number of integrated pegs with dedicated hydraulic motors (neither being shown) in the gravity base 52 to retain the apparatus in position on the concrete cap. The drilling components of the apparatus 50 comprise a drill motor 56, drill shaft 57 and core bit 58, which are supported over the central aperture 55 aligned in parallel with the pillar by a pair of laterally extending swing arms 59.

Drilling operations may be carried out via the work class ROV 102, which provides a source of hydraulic power for the drilling apparatus. The core bit 58 is a cylindrical sleeve comprising at its lower end 51 cutting serrations which, when the bit is rotated by the drill motor via the drill shaft and when down weight is applied, penetrate the surface of the concrete cap to drill out an annular recess to the penetrating depth of the bit.

When the core bit 58 has penetrated the concrete cap to the required depth, the column of concrete within the core bit is removed by pulling the core bit upwards. A formation 53 at the distal end of the core bit functions as a core catcher to engage the concrete, enabling it to break a concrete plug from the surrounding capping plate, which can then be retrieved by upward movement of the drilling components to leave a blind hole 412 in the capping plate.

Figure 4C shows the drilling apparatus 50 on the capping plate, having removed a concrete plug using the drilling apparatus 50 in the manner described above.

The next stage of the operation, shown most clearly in Figure 4D, is the installation of an anchor hub 60 into the blind hole 412 of the capping plate. The anchor hub of this embodiment of the invention is shown most clearly in Figures 6A and 6B.

The anchor hub 60 comprises a substantially cylindrical body 61 having an upper portion 62 and a lower portion 63. The upper portion 62 is formed to an outer diameter which is greater than the outer diameter of the lower portion 63. The lower portion is sized to be received in the blind hole 412 in the capping plate, whereas the upper portion is designed to be upstanding from the surface 410 of the capping plate to provide an attachment point for additional equipment. A shoulder 64 is defined at a lower edge of the upper portion 62 and provides an abutment surface for the surface 410 of the capping plate.

The anchor hub 60 comprises a central throughbore 65 which extends through the upper and lower portions. Partway along the throughbore, the inner diameter is reduced from a relatively large inner diameter to a relatively smaller inner diameter. The transition between the large and small inner diameter proportions defines a seat 66 for equipment inserted into the anchor hub during use. Inwardly protruding locking members 67 are located in the lower portion below the seat 66, and provides a second locating formation for landing and/or locking equipment inserted into the hub during use. The outer surface of the anchor hub is also provided with an annular locating groove 611 for the attachment of additional equipment in use.

The upper portion 62 of the anchor hub defines an annular body through which are formed a plurality of circumferentially-distributed holes 68 which provide access for anchoring bolts

69. The anchoring bolts are oriented longitudinally and parallel to the axis of the hub, and are distributed around the exterior of outer surface of the lower portion of the hub.

The anchoring bolts 69 extend between and connect upper anchoring ring assembly 602 and lower anchoring ring assembly 603. The upper and lower anchoring ring assemblies are axially separated on the lower portion of the anchor hub. The lower anchoring ring assembly 603 is substantially annular and is located around the lower portion 63 at a lower end 605 of the anchor hub. Upper anchoring ring assembly 602 is substantially annular and is located around the lower portion at an axial position between the upper portion 62 and the lower anchoring ring assembly 603.

Each of the upper and lower anchoring ring assemblies is formed from a number of part annular segments, which together form a split annular ring. The number of part-annular segments corresponds to the number of anchor bolts 69 (which in this case is eight).

Each of the upper and lower anchoring ring assemblies 602, 603 has a tapered or conical profile which corresponds with an outer surface profile of the lower portion of the anchor hub at the point at which it is mounted. In the case of the lower anchoring ring 603, the inner surface of the anchoring ring is shaped such that the inner diameter decreases moving from an upper end 604 of the anchor hub to a lower end 605 of the anchor hub. The inner surface of the lower anchoring ring therefore has the shape of the inner surface of a truncated cone. The corresponding shape on the lower portion 63 of the main body is an outer diameter which decreases moving in a direction from the upper end of the anchor hub to the lower end of the anchor hub.

The upper anchoring ring 602 has an inner surface profile which has an inner diameter which increases in a direction from the upper end 604 of the anchor hub to the lower end 605 of the anchor hub. The corresponding profile on the lower portion of the main body has an increased outer diameter moving from an upper end of the anchor hub to a lower end of the anchor hub. The segments of the upper and lower ring assemblies therefore each function as cooperating wedges, joined by the anchoring bolts. Outer surface of the lower and upper anchoring rings are provided with arrangements of axially distributed ridges 606, 607.

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Between the ring assemblies is disposed a sealing arrangement 608. The sealing arrangement comprises a compressible elastomeric material 609, which is oversized, and which in use is compressed to provide a seal between the anchor hub 60 and the hole in which it is located. It will be appreciated that a wide range of sealing configurations may be used within the scope of the invention. In this embodiment, the anchor hub is also provided with a port 610 which provides fluid communication between the internal throughbore 65of the anchor hub and the seal arrangement. The port enables a liquid sealant to be pumped from the throughbore into the sealing arrangement to enhance the seal.

In use, the anchor hub 60 is located in the blind hole 412 in the capping plate 408. Conveniently, this can be achieved by using the gravity base and support pillar of the drilling apparatus 50. A second set of swinging support arms (not shown) may support the anchor hub 60 off-axis from the bore, and when the drilling phase is complete, the drilling components can be swung away from the bore axis, before the support arms for the anchor hub 60 are swung into place over the bore axis to lower the anchor hub into the bore. It will be appreciated that in alternative embodiments, other mechanisms may be used for lowering the anchor hub into the bore.

With the anchor hub 60 in the bore, in the position shown in Figure 3, the lower end of the hub supports the weight of the hub, the upper and lower anchoring ring assemblies 602, 603 are axially separated and the shoulder 64 defined at the lower edge of the upper portion 62 is upstanding from the surface of the concrete cap. The drilling apparatus 50 (if used) is removed by recovery to surface using a recovery line and the assistance of a ROV. The anchoring bolts 69 are then sequentially tightened by accessing the bolts through the holes 68 in the upper portion 62. The tightening of the bolts brings the upper and lower anchoring rings axially closer together, causing the separate ring segments to ride up on the corresponding tapered profile of the lower member 63. The anchoring ring elements therefore move radially outwards to engage with the wall of the blind hole 412 and anchor the hub 60 in position. Axial movement of the upper and lower rings also causes compression of the elastomeric seal elements 609.

Figure 6B is a section through the anchor hub in a tightened and anchored condition with the seal elements compressed. Optionally, port 610 could be used to pump additional liquid sealant into the sealing arrangement 608. Alternatively, or in addition, sealant material could be provided at the base of the throughbore 650 in the anchor hub, to seal between the lower end 605 of the hub and the bottom of the hole 412.

With the anchor hub 60 secured in the bore, the upper portion of the anchor provides an attachment point with a connector 612 for additional equipment as now will be described.

The next stage in the access operation is the location and installation of the valve manifold 70 onto the anchor hub. The valve manifold 70 is deployed from surface and landed on the anchor hub 60 with the assistance of a work class ROV 102.

Figure 7 shows the features of the valve manifold 70 in more detail. The valve manifold of this embodiment is configured as a double block isolation valve arrangement. A lower connector 702 is configured to be mounted on the connector 612 defined by the upper portion 62 of the anchor hub 60. The lower connector 702 comprises a dog and window locking arrangement, in which an ROV (not shown) is operated to raise or lower the locking dogs to enable ball bearings to extend into or be retracted from the annular groove 611 on the anchor hub connector 612.

An upper male connector 704 is provided for the connection of additional equipment. In this case, the upper connector 704 is identical to the connector 612 defined by the upper portion 62 of the anchoring hub. A longitudinal throughbore 706 extends between the upper and lower connectors. Between the upper and lower connectors are arranged upper and lower isolation valves 708, 710, which in this embodiment are ball valves configured to be actuated by ROV torque buckets 712. Located between the upper and lower valves is a port 714 which is configured to be connected to a flowline 716 via an ROV operated isolation valve 718 and an optional check valve 720. With the upper and lower isolation valves 708, 710 open, the valve manifold provides full bore access to the anchoring hub 60. This facilitates intervention through the valve manifold 70, for example to insert a macerator, agitator, or pump into the storage cell to facilitate removal of materials.

With the valve manifold 70 in place, the port 714 is used to pressure test each of the isolation valves via a hot stab operated from the ROV.

To complete the access operation, it is necessary to drill through the base of the blind bore 412 to penetrate the storage cell. This is achieved using drilling tool 80, which is lowered from the surface and again landed with the assistance of a ROV, as shown in Figure 4E. The drilling tool 80 will be described in more detail with reference to Figures 8A and 8B. The drilling components of the tool may be free to drop under their own weight to the lower position as shown in Figure 8B, or may be retained in the upper position shown in Figure 8A.

The drilling tool 80 comprises a drill shaft 802 coupled to a drill bit and a drill support frame 804. The drill bit is a conventional core bit comprising a core catcher at its lower end. Provided on the drill support frame 804 is a lower connector 806, which is of the same type as the connector 702 on the valve manifold 70, and is designed to be connected to the upper connector 704 of the manifold. The lower connector 806 comprises a dog and window locking arrangement to secure the drilling tool 80 on the valve manifold.

At an upper end of the drill support frame 802, a tie 816 supports four drill support bars 818 which extend from the lower connector 806 to the tie 816. The tie 816 retains the support bars 818 in a position which defines a central bore through which the drill shaft 802 moves between extended and retracted positions. The support frame 804 also comprises an intermediate tie 817 with joins the support bars on their exterior.

Located above the lower connector is a bearing assembly 810 which enables the drill shaft to be freely rotated in the drill support frame. Above the bearing assembly 810 is a seat 812 which is configured to receive a carriage 814 of the drilling components. Below the bearing assembly and extending through the lower connector 806 is a centraliser 808 which is received in the bore defined by the valve manifold connector 704, and defines a throughbore for the passage of the drill shaft 802. The centraliser is a sleeve formed from a sacrificial material, such as a plastic, which facilitates longitudinal alignment of the drill during the early stages of drilling, but which may be damaged during the course of drilling.

The drilling tool carriage 814 is shaped to be accommodated within the drill support frame 804, and comprises recesses (not shown) arranged around the outer surface of a torque reaction block 822. The recesses correspond to the position and profile of the support bars 818. The carriage 814 supports and carries a hydraulic drill motor 824, which is powered by a hydraulic hose 826 that runs out of the drilling tool behind the drill motor and carriage. The carriage 814 is able to slide with respect to the support bars, but due to interaction of the block and the bars, is rotationally keyed with respect to the support frame.

Disposed between the drill shaft 802 and the torque reaction block 822 is an arrangement of ports 828 which provides through connection through an interior of the drill shaft and the open space between the support bars. A lower surface of the carriage 814 is provided with a seal 830 for sealing the carriage 814 against the seat 812 when in a lowered position.

The drilling operation proceeds as follows. With the drilling tool 80 located on the valve manifold block 70 , and the first and second isolation valves 708, 710 fully open, the drill shaft 802 extends into the valve manifold block and into the blind hole 412 to the base of the blind hole. Valve 718 is opened, and a vacuum is drawn on the port 714 by a pump (not shown) powered from surface or a local ROV, causing circulation of seawater through the open structure of the drill support frame 804, and into the hollow drill shaft 802 via the ports 828, and out of the port 714 to be returned to the sea. The hydraulic drill motor 824 is powered from surface or a local ROV to cause the drill shaft 802 and bit to rotate.

The weight of the drill shaft, in conjunction with the low pressure drawn through the valve 718, provides sufficient weight-on-bit to progress the drilling of a hole through the base of the blind hole. The carriage 814 slides downwards on the support bars, carrying with it the drill motor 824 and the distal end of the hydraulic hose 826 as the drill bit progresses through the concrete capping plate. When the drill penetrates the concrete capping plate to access the storage cell 400, a pressure differential between the hydrostatic pressure and the storage cell pressure (the latter being relatively low pressure) causes the drill shaft 802 and carriage 814 to be drawn downwards until the lower surface of the carriage engages with the seat 812 and seals the ports 828, preventing further inflow of seawater. Valve 718 is closed to prevent inflow of seawater through the port 714.

With the storage cell now penetrated, the drill bit and shaft 802 are ejected into the storage cell, as shown in Figure 4F (although they may be retained and recovered in alternative embodiments of the invention). The valve 718 is vented to partially pressure balance the system and ease the pulling of the drill shaft 802 and carriage 814 against the seal with the seat 812. With the carriage fully retracted, it is latched against the support frame (latch not shown) and the isolation valves 708, 710 in the valve manifold block are closed. The port 714 enables pressure testing of the valve manifold block, and optionally the valve manifold can be flushed by liquid or gas to remove any hydrocarbons from the flow lines. The drilling tool may then be decoupled from the valve manifold block and retrieved to surface.

The drilling tool 80 has a number of benefits in the envisaged applications to the penetration and/or access of a hydrocarbon storage cell. Firstly, by adopting a staged process of forming a blind hole and a secondary penetrating bore, the penetration distance required by the drill 80 is relatively low. This enables the use of a compact and relatively lightweight drilling tool. This is in contrast with a conventional drilling approach which would require the use of heavy drilling equipment, deployed to and supported by the upper surface of the storage cell.

The two stage process may also enable performance of the operation on multiple storage cells at convenient times. For example, multiple blind holes may be sequentially formed on adjacent storage cells during one phase of operation, prior to penetration drilling being carried out in a second phase. This facilitates optimal use of resources. This is in contrast with convention single stage drilling, which may take a considerable amount of time from start to finish with no convenient point to pause or interrupt the operation.

By providing an anchor hub installed into a hole the capping plate in a first phase, a secure, sealed attachment point for isolation and process equipment is provided. Significantly, this equipment is not required to seal against the relatively coarse upper surface of the capping plate. To do so would require a time-consuming and technically challenging surface polishing operation, so that the surface is sufficiently smooth to enable drilling equipment to be sealed on the surface.

The drilling support frame is designed to provide sufficient support to the drilling equipment, but remaining weak enough to be distorted or damaged if impacted during use, for example by a ROV or another subsea object or item of mobile infrastructure. This prevents large forces being transferred to the valve manifold and/or capping plate of the storage cell.

A further advantage arises from the distribution of support elements around the drill access. This is in marked contrast to a conventional pillar drilling tool, in which support pillars are provided on a single axis offset from the drilling axis. Providing support frame elements arranged around the drill axis results in equipment with reduced bulk, reduced footprint, which may be easier to manipulate and handle by personnel at surface, divers and/or ROVs.

The foregoing description relates to a method of providing penetration and access to a hydrocarbon storage cell, and results in the provision of an access point in the form of an anchor hub 60 and an isolation valve manifold 70. The valve manifold provides a connection point for a hose connector to enable hydrocarbons to be transferred from and/or to the storage cell during a remediation operation.

An example of such a hose connector assembly is shown in Figure 9, generally at 90. The hose connector assembly 90 comprises a lower connector 91, which is of the dog and window locking type described above in the context of the valve manifold and the drilling tool. The hose connector assembly comprises a T-piece 92 defining a throughbore 95 between the lower connector 91 and an upper flange plate 93. A blind flange 94 is joined to the flange plate to close the throughbore.

A side arm 96 of the T-piece 92 comprises a side bore 97 to a side flange 98. Joined to the side flange 98 is a receptacle 99 of a hot stab connector 107, which enables the coupling of a transfer hose 108 with the hose connector assembly 90.

The hose connector assembly 90 is configured for attachment to a vertically oriented hot stab, which has an elbow joint for connection to a horizontally-oriented hose. The configuration of the hose connector assembly 90 also enables convenient coupling of a hose to the valve manifold while maintaining full bore access to the manifold via the throughbore 95 if required. This facilitates intervention through the valve manifold 70, for example to insert a macerator, agitator, or pump into the storage cell to facilitate removal of materials, optionally while a hose is connected.

An alternative hose connector assembly is shown in Figure 10 of the drawings, generally depicted at 101, and configured for attachment to a horizontally-oriented hot stab for in-line or on-axis connection to a horizontally-oriented hose. The hose connector assembly 101 comprises a lower connector 103, which is of the dog and window locking type described above in the context of the valve manifold and the drilling tool. In this embodiment, the hose connector assembly lacks a T-piece, and instead defines an axial throughbore 104 between the lower connector 91 and an upper flange plate 105. Joined to the upper flange plate 105 is a receptacle 106 of a hot stab connector 107, which enables the coupling of a transfer hose 108 with the hose connector assembly 100.

It will be appreciated that a variety of different anchor hubs may be used in different embodiments of the invention. Examples of anchor hubs in different forms are shown in Figures 4 to 11.

Referring to Figure 11, the anchor hub 110 is similar to the anchor hub 60, and will be understood from Figures 6A and 6B and the accompanying description. In particular, the anchor hub 110 comprises upper and lower rings 111, 112 with inner tapered surfaces which correspond to tapered surfaces on the outer surface of the main hub body 114. The rings 111, 112 are brought together by the tightening of anchor bolts, and compress an intermediate seal arrangement 116. The anchor hub 110 differs from the hub 60 of Figure 6 in that the upper portion 117 of the anchor hub comprises a J lock spigot 118 for mounting equipment, such as a valve manifold, on the concrete capping plate.

Figure 12 is a sectional view through an anchor hub according to an alternative embodiment of the invention, generally shown at 120. This embodiment is again similar to the anchor hubs 60 and 110 of Figures 6 and 11 in that it has an arrangement of corresponding tapered profiles. However, this embodiment differs in that the upper and lower tapered rings 121, 122 are solid rings, and a segmented anchor ring 123 is arranged around the exterior of the main body 124 of the anchor and rings 121, 122. In use, the anchor hub 120 is internally actuated by a threaded engagement of the main body with the lower anchor ring 122. This causes the lower anchor ring to move axially upwards and forces the external anchor ring 123 to engage the bore. The upper portion of the anchor hub provides a flange attachment.

Figure 13 is a sectional view through an anchor hub 130 according to a further alternative embodiment of the invention. In this embodiment, the anchor hub is formed from the core drill bit itself, which is retained in the concrete capping plate. The anchor comprises a hollow cylinder 131 which forms an annular groove during drilling. The upper part of the anchor hub is provided with a J lock spigot 132 for mounting equipment, such as a valve manifold.

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A resin is pumped into the micro-annulus between the core bit and the concrete capping plate in order to seal between the lower end of the sleeve and the plate.

This configuration has the advantage of fewer operation steps in order to mount the hub, but does require drilling through the full thickness of the capping plate in the subsequent drilling operation in order to penetrate the storage cell.

Figure 14 is a sectional view through an anchor hub 140 according to a further alternative embodiment of the invention. In this embodiment, the anchor hub is mounted into a blind hole. The main body 141 of the hub is externally bolted to the capping plate via a flange 142. Sealing elements 143, 144 are provided beneath the flange plate and surrounding the lower portion of the anchor in axially separated positions. The upper portion of the anchor hub is provided with a J lock spigot 145 for the mounting of equipment, such as a valve manifold.

As noted above, a principal application of the invention is in the remediation of hydrocarbons from the storage cell, and a remediation method will be described with reference to Figures 15A to 15G, with additional equipment details shown in Figures 16 and 17.

Figure 15A shows the top of a second storage cell 1500, which has an anchor hub 110 installed in a blind hole in a capping plate 1508. The storage cell 1500 is the same as the storage cell 400, and the blind hole is formed by the method described with reference to Figures 4B and 4C. The anchor hub 110 in this example is the anchor hub 110 of Figure 11, and as shown in Figure 15A has been fixed into the capping plate to provide access and attachment point.

Figure 15B shows a valve manifold 1600 and drilling tool 180 deployed from surface and landed with the assistance of ROV 102. The valve manifold 1600 is shown in more detail in Figure 16. The manifold comprises a main body 1602, and a lower connector 1604, which in this case is configured for attachment to a J lock spigot of the anchor hub 110. A throughbore 1606 extends from the lower connector 1604 to an upper opening 1608, which includes a guide funnel 1610 for assisting with the placement of the drilling apparatus 180 in the manifold 1600. Between the upper opening 1608 and the lower connector 1604 is an isolation valve 1612, which in this case is a ball valve operable to be actuated by a ROV torque bucket 1614. Disposed between the upper opening 1608 and the valve 1612 is a seat 1615 defined by a reduced inner diameter. The seat provides a landing point for the drilling tool 180 and a sealing plug running tool. Disposed between the isolation valve 1612 and the lower connector 1604 is a side conduit 1616 which extends from the throughbore 1606 to a side flange 1618. The side flange 1618 is configured for the attachment of a hot stab hose connection receptacle 1620, in this case in a vertical orientation, which enables a ROV to connect a hot stab of a transfer hose 108 to the valve manifold (Figure 15B).

The valve manifold 1600 also provides a guide for the drilling tool 180 to drill a hole which penetrates the storage cell 1500. The drilling tool 180 is similar in form and function to the drilling tool 80 described in detailed reference to Figures 4E, 4F, 8A and 8B and will not be described in detail here. However, the drilling tool 180 differs in that a lower bearing assembly on the drilling support frame is configured to be received in the seat 1615. The lower bearing assembly of the drilling tool is located on the seat, and provides support and centralisation for passage and rotation of the drill shaft.

The drilling tool 180 is operated to drill a hole through the base of the blind hole and into the storage cell. The method of drilling is similar to the method described with reference to Figures 4E, 4F, 8A and 8B and will not be described in detail here. However, in this embodiment, the drilling of the penetrating hole is performed with the side conduit 1616 of the valve manifold 1600 connected to a storage cell 400 which has already been penetrated.

In this example, the cell 1500 is to be remediated by transferring hydrocarbons contained in the storage cell 1500 to a disposal cell, which in this case is cell 400. Cell 400 has been provided with an anchor hub 60 and valve manifold 70 by the method described with reference to Figure 4. Figure 15D shows schematically the equipment installed on the remediating cell 1500 and the disposal cell 400. With the hose 108 connecting the valve manifolds 1600 and 70, the isolation valves 708 and 710 are opened to provide fluid communication between the internal volume of the storage cell 400 and the manifold 1600. The relatively low pressure of the cell 400 draws seawater through the open structure of the drill support frame, and into the hollow drill shaft via ports, and through the hose 108 to the disposal cell 400. The low pressure also causes the drill shaft and core bit of the drilling tool 180 causes the drill shaft and carriage to be drawn downwards until the lower surface of the carriage engages with a seat.

When the storage cell is penetrated, pressure is equalised between the cell 1500 and the cell 400, and the valve 1614 is closed to prevent further in-flow of seawater. The drill bit and drive shaft are ejected into the cell. The carriage of the drilling apparatus 80 is retracted and latched in an upper position, enabling isolation valve 1612 to be closed, and the drilling apparatus 180 to be removed.

The storage cell 1500 is now ready to be remediated. On the valve manifold 70 of the disposal cell 400 is mounted a transfer pump assembly 1520. The pump assembly comprises a progressive cavity multiphase pump and a connector which corresponds to the upper connector 704 of the valve manifold. The pump assembly 1520 comprises a viewing window to enable a ROV (or diver) to monitor the fluid being pumped through the assembly. With the transfer hose 108 installed between the valve manifold 1600 and the valve manifold 70, the isolation valves 708 and 710 of manifold 70 are opened, and power is provided to the pump via the ROV 102. The low pressure on the inlet side of the pump 1520 causes hydrocarbons to be drawn from the remediating cell 1500 along the transfer hose and through the valve manifold 70 into the disposal cell 400. The ROV monitors the fluid being pumped through the pump assembly, until it is observed that seawater (rather than hydrocarbons) is being pumped through the transfer hose 108. The remediating cell is isolated, and the transfer hose is flushed into the disposal cell. The remediating cell valve manifold 1600 is pressure tested, and the hose connector is removed from the valve manifold, ready for transfer to another remediating cell.

Figure 15E shows an optional step of injecting dispersible chemicals into the remediating cell via a second hose 109, which in this case is run from surface.

When the hydrocarbons have been successfully remediated from cell 1500, the cell 1500 can be plugged and capped. Figure 15F shows a sealing plug and running tool assembly 1700 which is deployed from surface and landed with the assistance of the ROV 102. The sealing plug and running tool assembly 1700 is shown in more detail in Figure 17. The running tool 1701 comprises a cylindrical sleeve 1702 with a lower seal assembly 1704, shaped and sized to fit into the seat 1615 defined by the valve manifold 1600. A shaft 1706 extends through the sleeve 1702 and the seal assembly 1704 to support a plug 1703 at its lower end. In use, the sealing plug and running tool assembly 1700 is received in the upper part of the valve manifold 1600, and the lower seal assembly is landed on the seat. The seal is pressure tested, and subsequently the shaft 1706 is extended to mount the sealing plug 1703 in an upper part of the anchor hub 110. With the plug set, the equipment is again pressure tested, and the shaft 1706 is removed from the sealing plug 1703 to leave it in the anchor hub 110. The running tool 1701 is then recovered to surface through the valve manifold.

With the sealing plug 1703 in place, the valve manifold 1600 is removed from the anchor hub and recovered to surface. A blind cap is installed over the anchor hub, and optionally the anchor hub is capped with concrete to complete the plugging and capping operation. The storage cell 400 is then fully remediated.

It will be appreciated that the steps depicted in Figures 15A to 15G may be repeated for multiple storage cells. Each time, oil contained in the remediating cell is transferred to a disposal cell. Conveniently, the pump assembly can remain in place on the valve manifold of the disposal cell while the transfer hose is relocated to valve manifold installed on the various remediating cells. The operational sequence may be repeated until all cells have been remediated of attic oil, with the contents transferred to the disposal cell.

Subsequently, when it is necessary to remediate the disposal cell, a hose may be deployed from surface and connected to the valve manifold of the disposal cell. A surface or subsea pump is operated to remove the attic oil from the disposal cell, before the hose is removed. The sealing and plugging operations described with reference to Figures 15F and 15G may then be repeated to plug and cap the remediated disposal cell.

The methods described above are primarily ROV operated, but it will be appreciated that in alternative embodiments of the invention, the operational steps, or at least some of them, may be performed by a diver. Some modifications to the equipment may be necessary to facilitate convenient diver operation. Figure 18 is an example of a valve manifold, according to an alternative embodiment of the invention, which is configured for diver-based operations. The valve manifold, generally shown at 1800, is similar to the valve manifold 70, and will be understood from Figure 7 and the accompanying description. The valve manifold 1800 is shown installed on an anchor hub, which is the anchor hub 120 described with reference to Figure 12. The valve manifold 1800 comprises upper and lower isolation valves 1808, 1810, and an intermediate port 1814 coupled to an isolation valve 1818. The upper and lower connectors of the valve manifold are flange plate connectors, which may be attached by the diver. The valves 1808, 1810 and 1818 function in a similar way to valves 704, 718 and 710, although are provided with manually actuated levers 1809, 1811, 1819 to facilitate diver-based operations.

Referring to Figures 19A to 19H, there are shown sequentially the steps of installing an anchor hub on a storage cell, penetrating the storage cell, and remediating the storage cell according to an alternative embodiment of the invention. The sequence shown is similar to the sequences shown in Figures 4A to 4F and 15A to 15G, but differs in that they are primarily operated by divers.

In Figure 19A, a diver 1901 operates the drilling apparatus 50 to form a blind hole in the capping plate 408. In Figure 19B, the diver installs a valve manifold 1800 on an anchor hub 120 in the blind hole. In Figures 19C and 19D, a drilling apparatus 80 is located in the valve manifold, and the diver performs the drilling operation to penetrate the storage cell.

Figure 19E shows diver-supervised remediation of a storage cell 1501 to a disposal cell 401, the latter having a transfer pump assembly 1520 installed. The diver monitors the transfer of fluids through the transfer hose 108 via a viewing window provided in the hose connector assembly 1903.

In Figure 19F, injection of dispersible chemicals is carried out by the connection of the surface hose 109 to the valve manifold assembly 1800’ by the diver, and in Figures 19G and 19H, the diver operates a sealing plug and running tool assembly 1700 to plug the anchor, and then caps the anchor following removal of the valve manifold 1800’ and drilling equipment 180.

The invention provides a method and apparatus for accessing a hydrocarbon storage cell and/or removing hydrocarbons therefrom. An access method comprises installing an anchor hub in a capping plate of the hydrocarbon storage cell, and drilling a bore to penetrate an internal volume of the storage cell by passing a drilling apparatus through the anchor hub. A removal method comprises providing a first hydrocarbon storage cell comprising a first anchor hub and providing a second hydrocarbon storage cell comprising a second anchor

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hub. The first and second anchor hubs are connected to one another with a flowline, and hydrocarbons are pumped from an upper portion of an internal volume of the second hydrocarbon storage cell to an internal volume of the first hydrocarbon storage cell. An anchor hub in one aspect of the invention comprises a main body comprising an upper opening, a lower opening and a throughbore extending between the upper and lower openings. Securing means are configured to fix the anchor hub to a surface of a capping plate of the hydrocarbon storage cell, and the main body comprises a lower portion configured to be located in and extend into a recess formed in an upper surface of the capping plate.

The invention provides methods and apparatus for accessing and/or removal of hydrocarbons from a storage cell in a manner that is safe, effective, convenient, and economical.

The two stage access and penetration process enables performance of the operation on multiple storage cells at convenient times optimising use of resources. By providing an anchor hub installed into a hole the capping plate in a first phase, a secure, sealed attachment point for isolation and process equipment is provided. Significantly, this equipment is not required to seal against the relatively coarse upper surface of the capping plate. The drilling support frame of embodiments of the invention is designed to provide sufficient support to the drilling equipment, but prevents large forces being transferred to the valve manifold and/or capping plate of the storage cell.

It will be appreciated that various combinations of the above-described equipment and method steps may be used in alternative embodiments of the invention to suit a particular application or environment. For example, diver-oriented operations may be interchanged with ROV-based operations in certain embodiments. Modifications to the process and/or flow equipment can be made to render it suitable for use with different anchor hubs or connector types.

Other modifications to the above-described embodiments may be made within the scope of the invention, and the invention extends to combinations of features other than those expressly claimed herein.

Claims

1. A method of accessing a hydrocarbon storage cell, the method comprising:
forming a blind hole in a capping plate of the hydrocarbon storage cell;
installing an anchor hub in the blind hole; and
drilling a bore to penetrate an internal volume of the storage cell by passing a drilling apparatus through the anchor hub.

2. The method according to claim 1, comprising providing a flow access path through the anchor hub.

3. The method according to claim 1 or claim 2, comprising installing a valve manifold on the anchor hub.

4. The method according to claim 3, comprising passing the drilling apparatus through the valve manifold.

5. The method according to any one of claims 1 to 4, comprising forming the blind hole in the capping plate by removing a plug of material from the capping plate.

6. The method according to claim 5, comprising forming the blind hole by operating a plug drilling apparatus disposed on an upper surface of the capping plate.

7. The method according to claim 6, comprising powering the plug drilling apparatus from a Remotely Operated Vehicle (ROV) or from surface.

8. The method according to any one of claims 4 to 7, comprising penetrating an internal volume of the storage cell by drilling through the base of the blind hole.

9. The method according to any one of claims 1 to 4, comprising providing a core drill bit, drilling a hole into the capping plate with the core drill bit, and retaining the core drill bit in the capping plate to provide the anchor hub.

10. The method according to claim 9, comprising pumping a sealant to form a seal between the anchor hub and the capping plate.

11. The method according to claim 10, comprising pumping the sealant into a micro-annulus between the core bit and the concrete capping plate.

12. The method according to any one of claims 1 to 11, comprising penetrating the capping plate by locating a through drilling apparatus on the anchor hub.

13. The method according to claim 12, comprising creating a low pressure on a lower side of the through drilling apparatus to create a downward force on the drill bit.

14. The method according to claim 12 or claim 13, comprising circulating seawater through the drilling apparatus and a valve manifold.

15. The method according to claim 14, comprising circulating seawater through the drilling apparatus and a valve manifold to a further hydrocarbon storage cell.

16. The method according to claim 15, wherein the further hydrocarbon storage cell comprises a further anchor hub installed in a capping plate of the further hydrocarbon storage cell, and further comprises a bore formed through the further anchor hub to penetrate the further hydrocarbon storage cell.

17. The method according to claim 16, wherein the further anchor hub of the further hydrocarbon storage cell is installed in a previous operation.

18. The method according to claim 16, wherein the method comprises accessing the further hydrocarbon storage cell by installing an anchor hub in a capping plate of the hydrocarbon storage cell and drilling a bore to penetrate an internal volume of the storage cell by passing a drilling apparatus through the anchor hub.

19. The method according to claim 18, wherein the method of accessing the further hydrocarbon storage cell comprises forming a blind hole in the capping plate; and installing the anchor hub in the blind hole.

20. The method according to any one of claims 11 to 19, wherein the through drilling apparatus is powered from an ROV or from surface.

21. A method of removing hydrocarbons from a hydrocarbon storage cell, the method comprising:
accessing a first hydrocarbon storage cell by the method of any one of claims 1 to 20;
accessing a second hydrocarbon storage cell by the method of any one of claims 1 to 20;
connecting the anchor hub on the first hydrocarbon storage cell to the anchor hub on the second hydrocarbon storage cell with a flowline;
pumping hydrocarbons from an upper portion of an internal volume of the second hydrocarbon storage cell to an internal volume of the first hydrocarbon storage cell.

22. The method according to claim 21, comprising accessing the first hydrocarbon storage cell via a first valve manifold on the first anchor hub.

23. The method according to claim 22, comprising accessing the second hydrocarbon storage cell via a second valve manifold on the second anchor hub.

24. The method according to any one of claims 21 to 23, comprising providing a subsea pump assembly on the anchor hub of the first hydrocarbon storage cell.

25. The method according to any one of claims 21 to 24, comprising:
accessing a third hydrocarbon storage cell by the method of any one of claims 1 to 20;
disconnecting the flowline from the anchor hub of the second hydrocarbon storage cell;
connecting the anchor hub of the first hydrocarbon storage cell to the anchor hub of the third hydrocarbon storage cell via the flowline; and
pumping hydrocarbons from an upper portion of an internal volume of the third hydrocarbon storage cell to an internal volume of the first hydrocarbon storage cell.

26. The method according to any one of claims 21 to 25, comprising:
accessing a further hydrocarbon storage cell by the method of any one of claims 1 to 20;

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disconnecting the flowline from the anchor hub of the second hydrocarbon storage cell;
connecting the anchor hub of the first hydrocarbon storage cell to the anchor hub of the further hydrocarbon storage cell via the flowline; and
pumping hydrocarbons from an upper portion of an internal volume of the further hydrocarbon storage cell to an internal volume of the first hydrocarbon storage cell.

27. The method according to any one of claims 21 to 26, comprising plugging the anchor hubs of second, third and/or further hydrocarbon storage cell(s) after removal of hydrocarbons from the second, third and/or further hydrocarbon storage cell(s).

28. The method according to any one of claims 21 to 27, comprising disconnecting the flow line from the anchor hub of the first hydrocarbon storage cell.

29. The method according to any one of claims 21 to 28, comprising providing a return line from the anchor hub of the first hydrocarbon storage cell to a hydrocarbon tank or pipeline, and further comprises pumping hydrocarbons from the first hydrocarbon storage cell to the tank or pipeline.

30. An anchor hub for providing an access point in a capping plate of a hydrocarbon storage cell, the anchor hub comprising:
a main body comprising an upper opening, a lower opening and a throughbore extending between the upper and lower openings, the main body comprising a lower portion configured to be located in and extend into a blind hole formed in an upper surface of the capping plate;
securing means configured to fix the lower portion of the anchor hub in the blind hole;
an annular seal arranged around the lower portion to provide a seal between the lower portion and the blind hole; and
an attachment point for connecting an item of process or flow equipment to the anchor hub such that the item of process of flow equipment is in communication with the throughbore.

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31. The anchor hub of claim 30, wherein the throughbore of the anchor hub enables the passage of a drilling apparatus through the anchor hub, operable to drill through the blind hole and penetrate the capping plate.

32. The anchor hub according to claim 30 or claim 31, wherein the anchor hub comprises an upper portion which is upstanding from an upper surface of the capping plate.

33. The anchor hub according to claim 32, wherein the upper portion provides the attachment point for an item of process or flow equipment.

34. The anchor hub according to any one of claims 30 to 33, further comprising a seal between an upper portion of the anchor hub and an upper surface of the capping plate.

35. The anchor hub according to any one of claims 30 to 34, comprising a core drill bit.

36. The anchor hub according to any one of claims 30 to 35, comprising an upper connector.

37. The anchor hub according to claim 36, wherein the upper connector is a connector for a valve manifold.

38. The anchor hub according to any one of claims 30 to 37, wherein the throughbore of the anchor hub comprises a seat for a sealing plug.

39. The anchor hub according to any one of claims 30 to 38, wherein the anchor hub comprises one or more anchor ring assemblies.

40. The anchor hub according to claim 39, wherein the one or more anchor ring assemblies comprises a plurality of segments, which together form a ring disposed around a lower portion of the body.

41. The anchor hub according to claim 39 or claim 40, wherein the anchor hub comprises a pair of anchor ring assemblies axially separated on the main body.

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42. The anchor hub according to claim 41, wherein the pair of anchor ring assemblies is connected via a plurality of bolts.

43. The anchor hub according to claim 42, wherein the bolts are tensioning bolts, and are arranged to be tightened to bring the anchor ring assemblies towards one another in an axial direction of the hub.

44. The anchor hub according to any one of claims 39 to 43, wherein the one or more anchor ring assemblies comprise a tapered profile which correspond to a tapered profile of the main body.

45. The anchor hub according to any one of claims 39 to 44, wherein one or more anchor ring assemblies function as wedges or slips, and are configured such that relative axial movement of an anchor ring assembly with respect to the main body results in engagement of an anchor element with the recess.

46. Apparatus for accessing a hydrocarbon storage cell, the apparatus comprising an anchor hub according to any one of claims 30 to 45 and a valve manifold attachable to the attachment point of the anchor hub such that the valve manifold is in communication with the throughbore of the anchor hub.

47. A subsea installation comprising:
a hydrocarbon storage cell comprising a capping plate;
an anchor hub installed in the capping plate of the hydrocarbon storage cell, such that a lower portion is located in and extends into a blind hole formed in an upper surface of the capping plate;
wherein the anchor hub is configured for a drilling apparatus to be located thereon; and
wherein the anchor hub comprises a throughbore which enables the passage of the drilling apparatus through the anchor hub to drill through the base of the blind hole to form a bore extending through the capping plate, which penetrates an internal volume of the hydrocarbon storage cell and provides a flow access path from an upper opening of the anchor hub to the hydrocarbon storage cell.

48. The subsea installation according to claim 47, comprising a valve manifold connected to the anchor hub.

49. The subsea installation according to claim 48, wherein the valve manifold comprises:
a main body comprising an upper opening, a lower opening and a throughbore extending between the upper and lower openings;
a connector configured to connect the valve manifold to an anchor hub installed in a capping plate of the hydrocarbon storage cell; and
at least one isolation valve disposed in the throughbore.

50. The subsea installation according to claim 48 or claim 49, wherein the valve manifold comprises a throughbore with sufficient diameter to receive the drilling tool, and further comprises a seat for the drilling apparatus.

51. The subsea installation according to any one of claims 48 to 50, wherein the valve manifold comprises an upper connector configured for connection to the drilling apparatus.

52. The subsea installation according to claim 49, wherein the at least one isolation valve is operable to be actuated by a Remotely Operated Vehicle (ROV) torque bucket.

53. The subsea installation according to any one of claims 49 to 52, wherein the valve manifold comprises upper and lower isolation valves in the throughbore of the apparatus.

54. The subsea installation according to claim 53, wherein the valve manifold comprises a flow port or flow conduit which is in fluid communication with the throughbore between the upper and lower isolation valves.

55. The subsea installation according to claim 54, wherein the flow port or conduit is coupled to a third isolation valve in a flow line.

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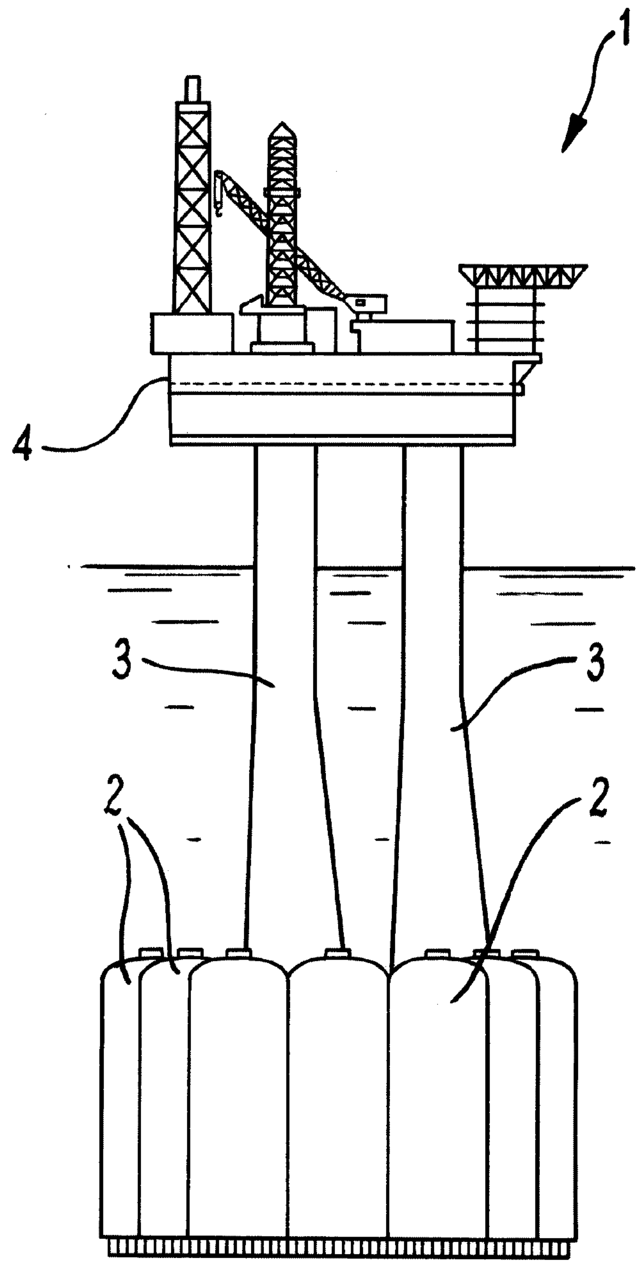

Fig. 1A
PRIOR ART

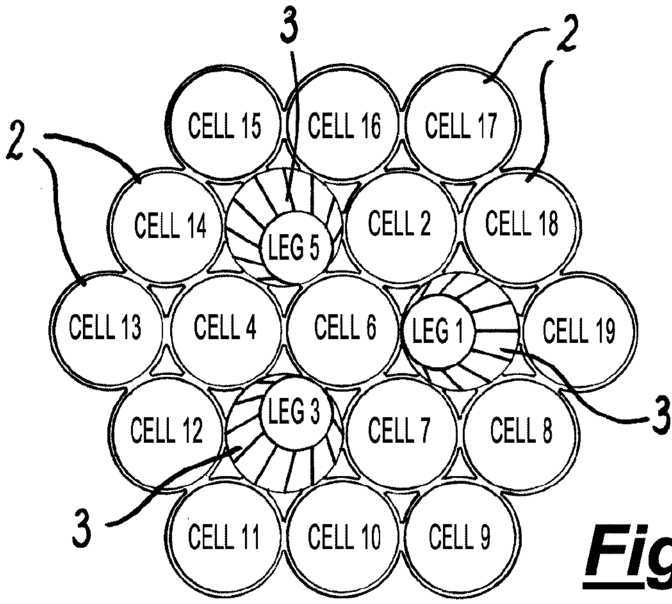

Fig. 1B

PRIOR ART

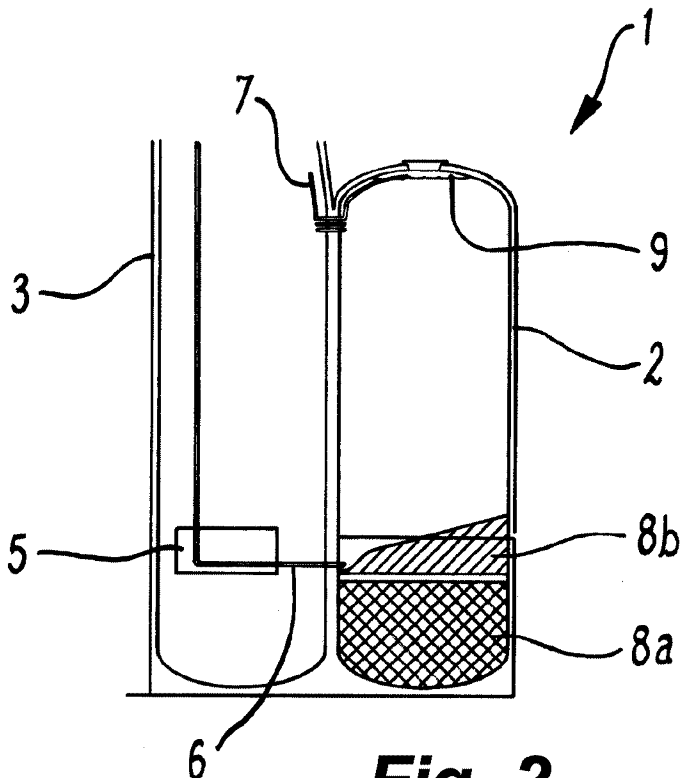

Fig. 2

PRIOR ART

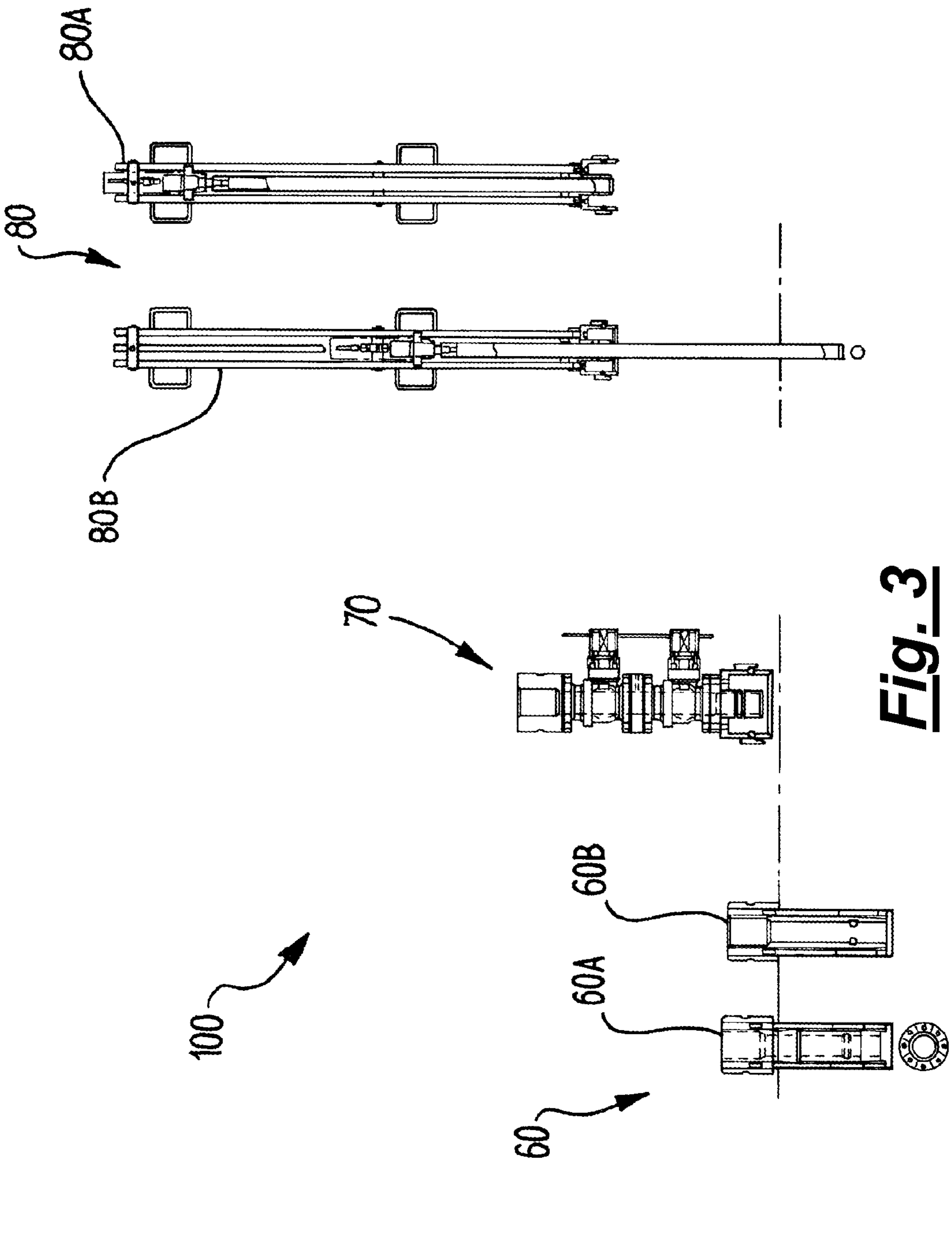

Fig. 3

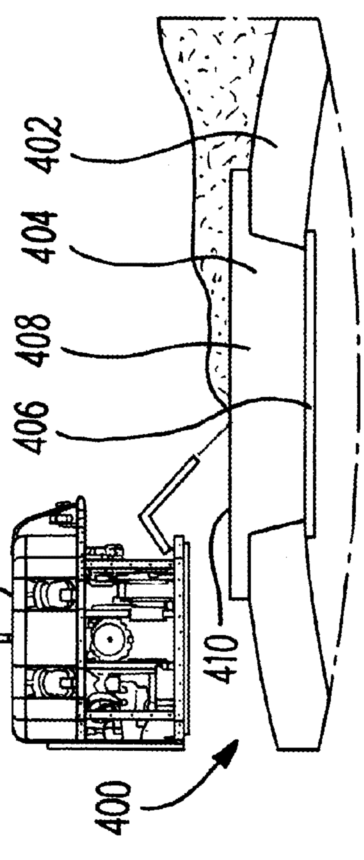

Fig. 4A

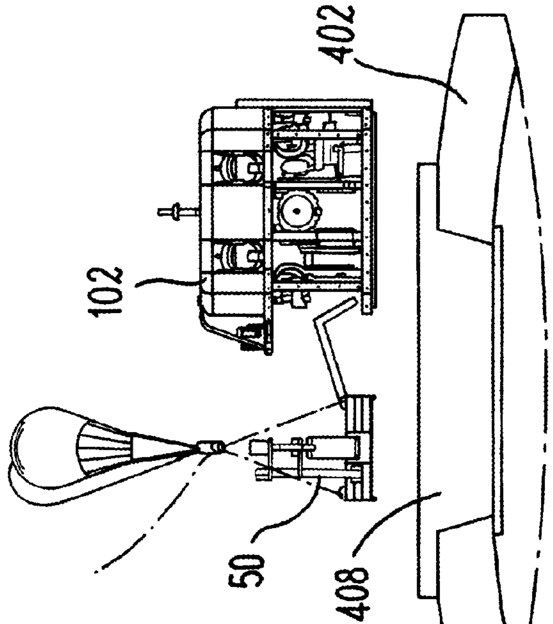

Fig. 4B

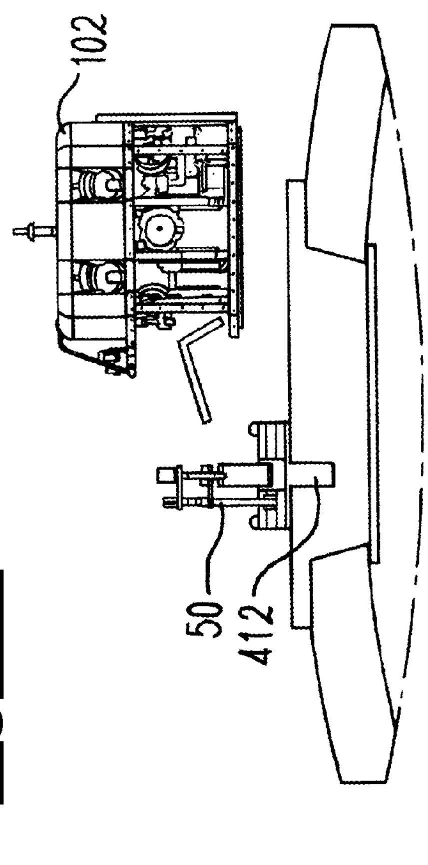

Fig. 4C

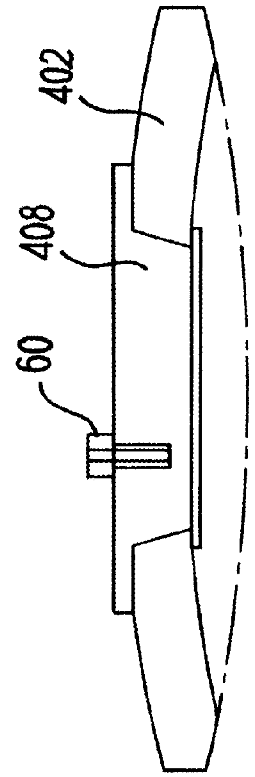

Fig. 4D

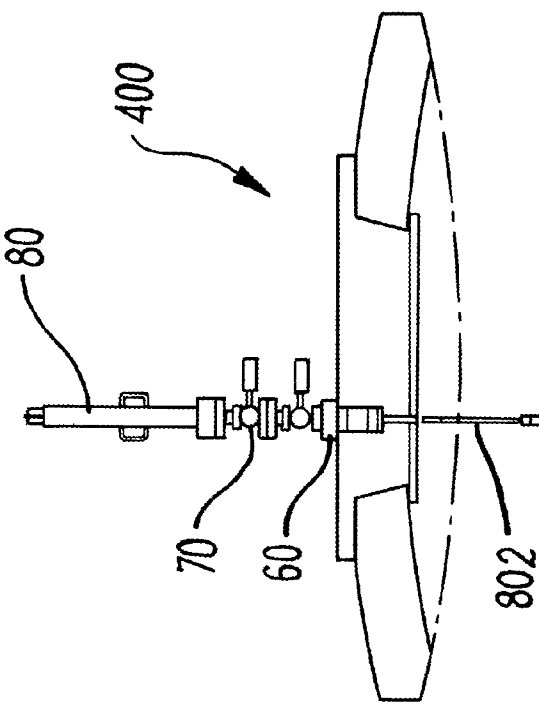

Fig. 4F

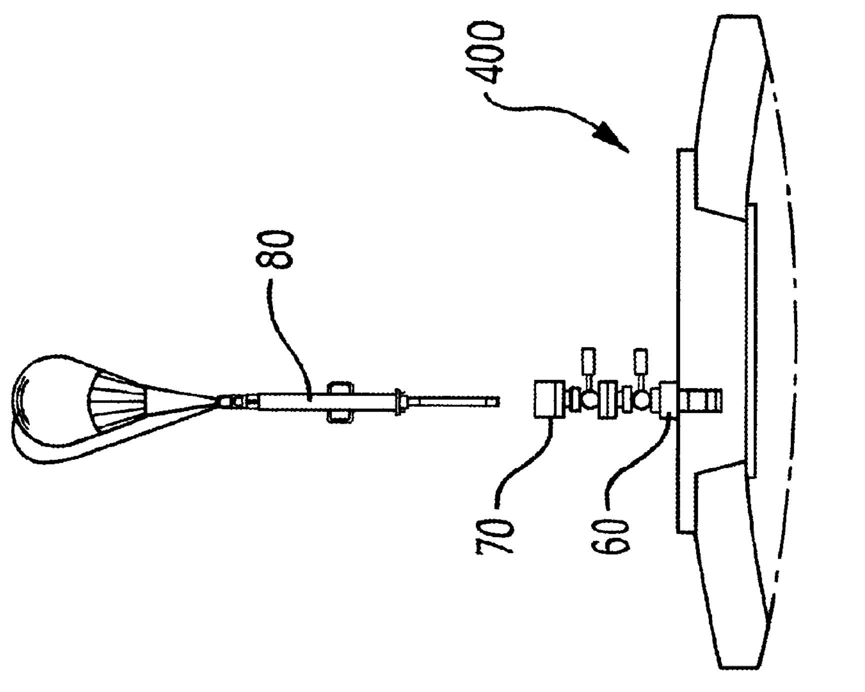

Fig. 4E

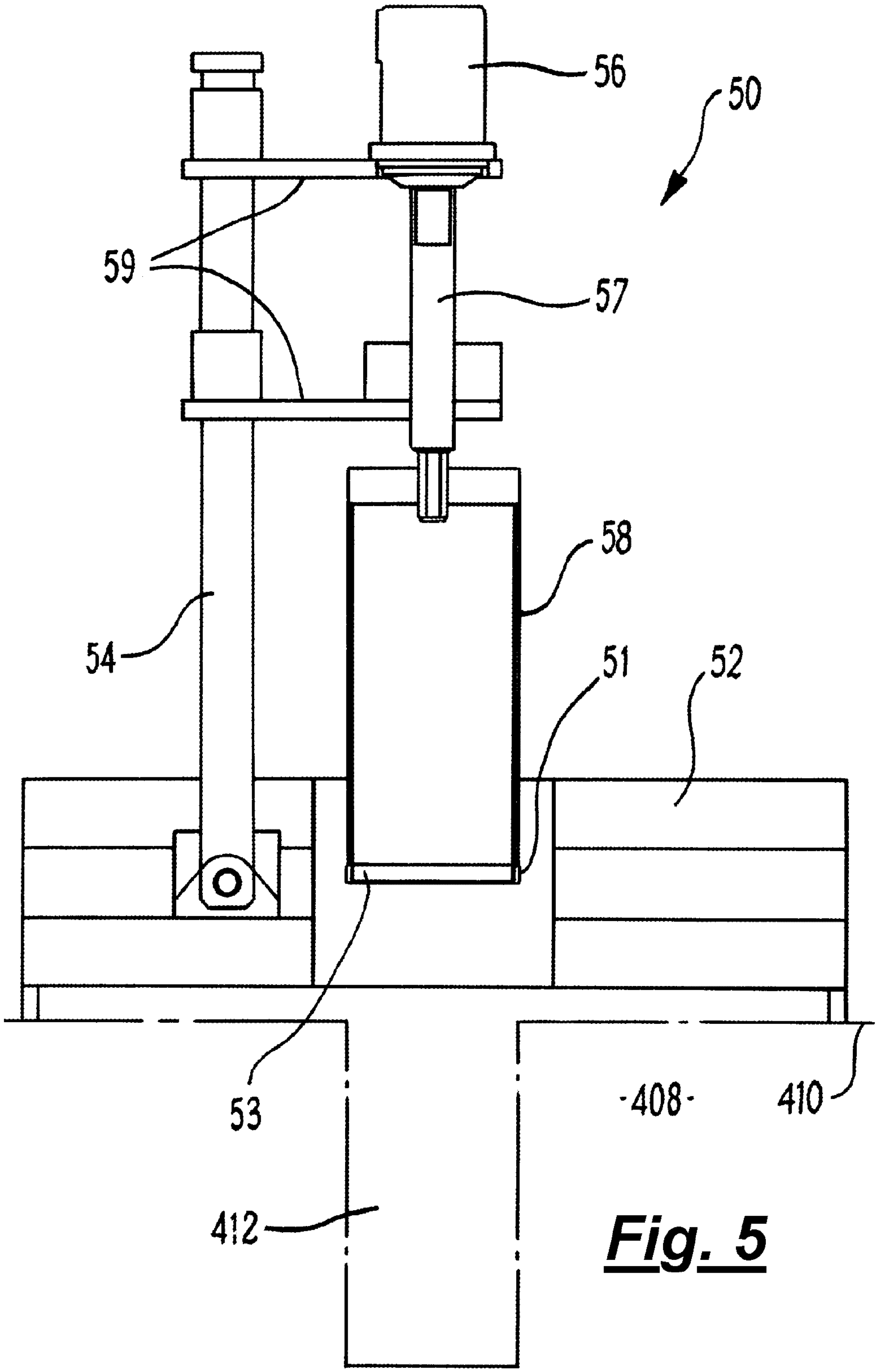

Fig. 5

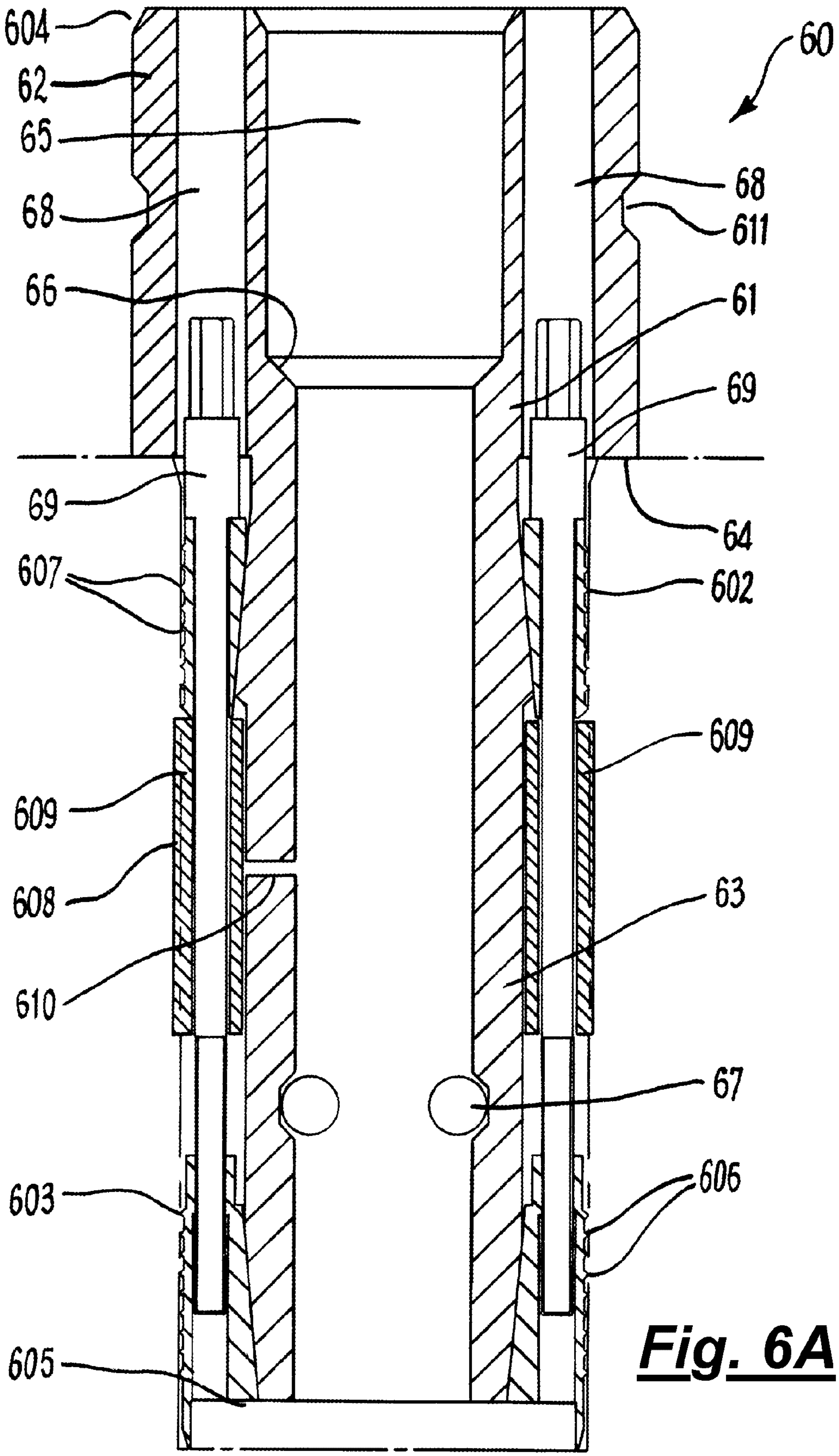
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Fig. 6A

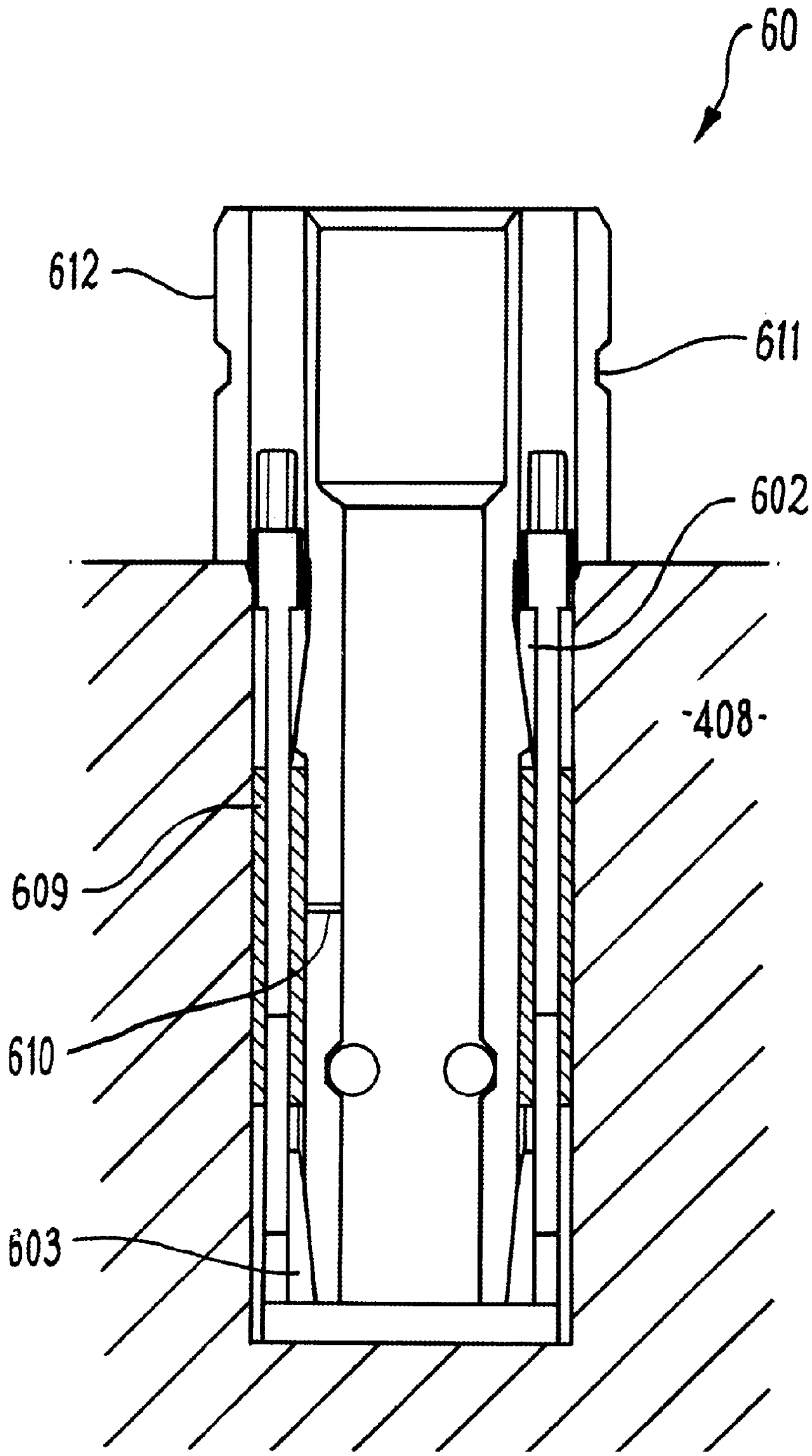

Fig. 6B

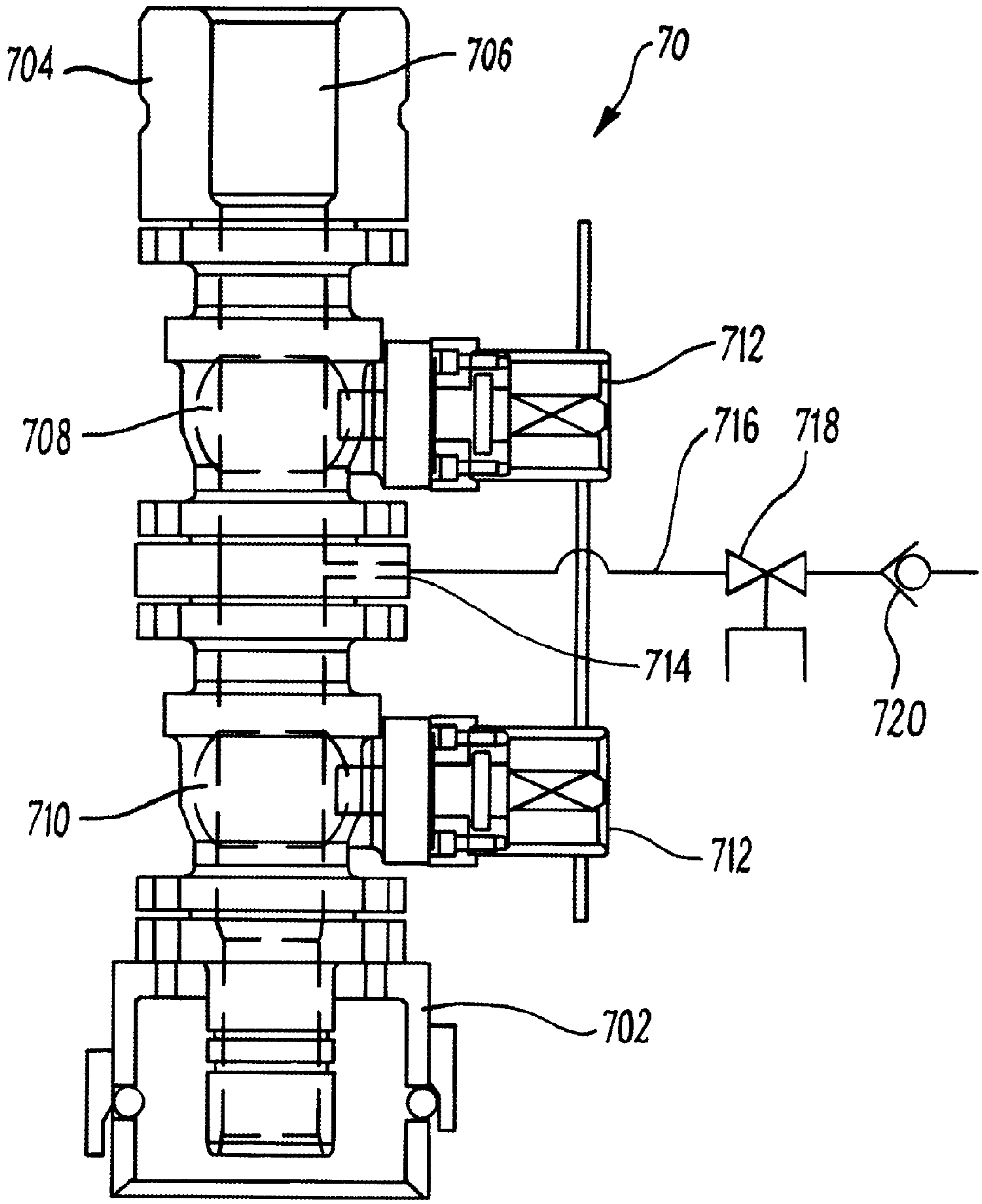

Fig. 7

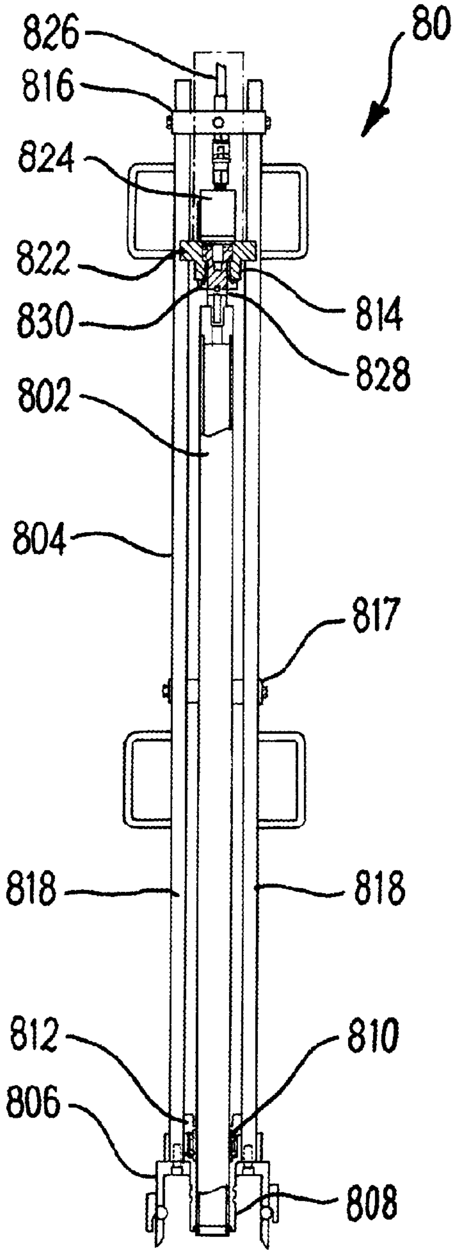
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Fig. 8A

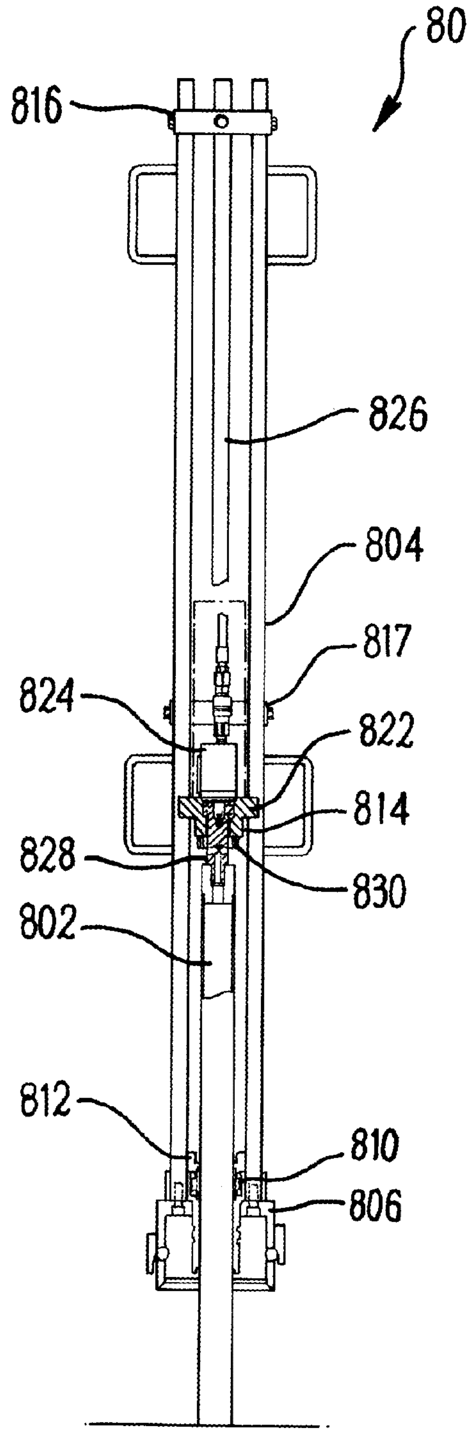
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Fig. 8B

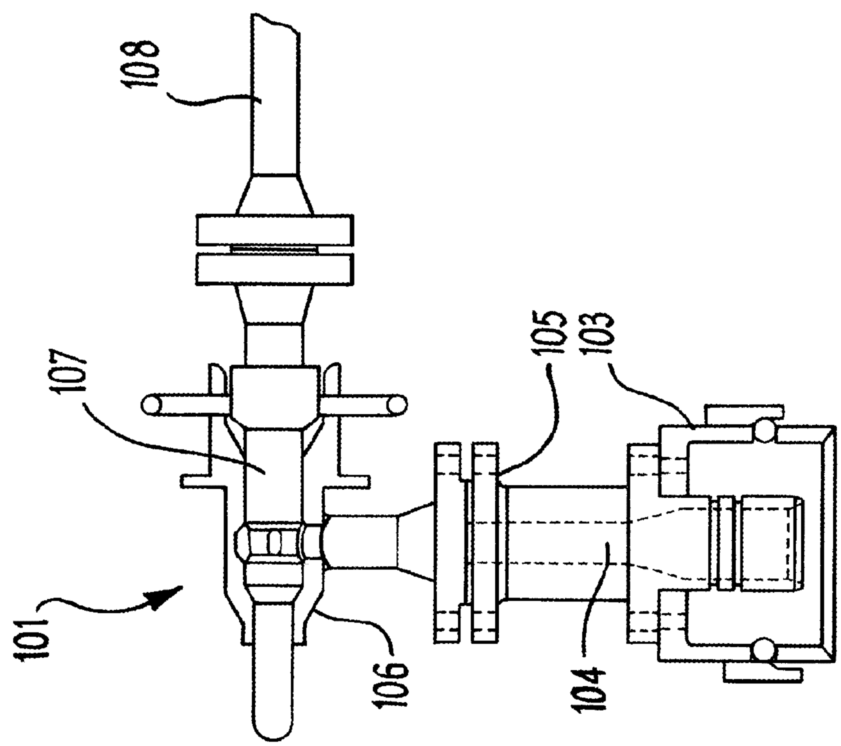


Fig. 10

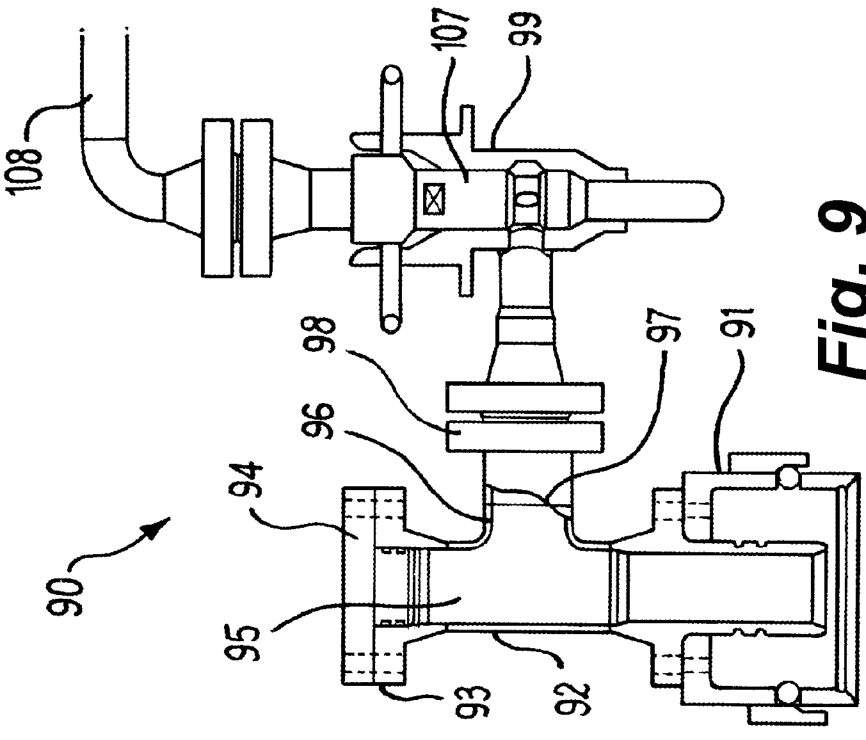


Fig. 9

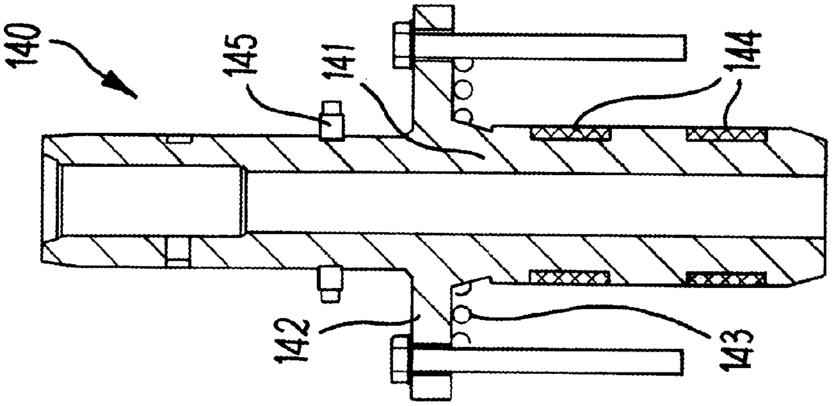


Fig. 14

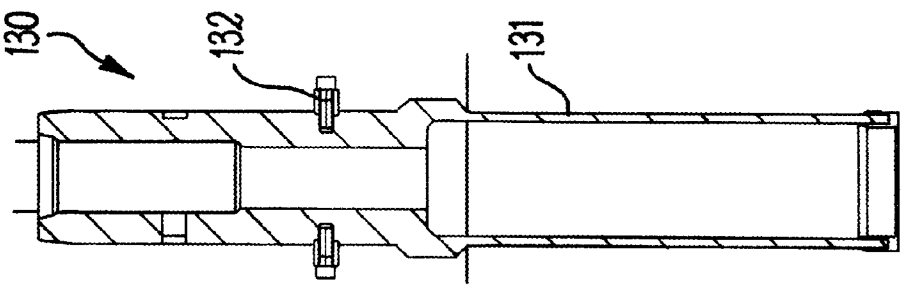


Fig. 13

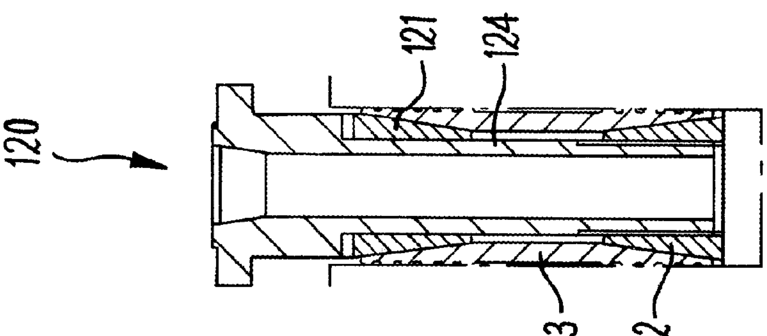


Fig. 12

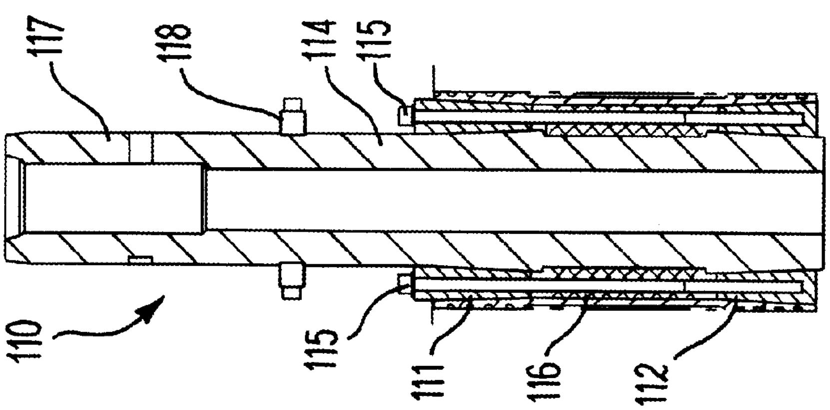


Fig. 11

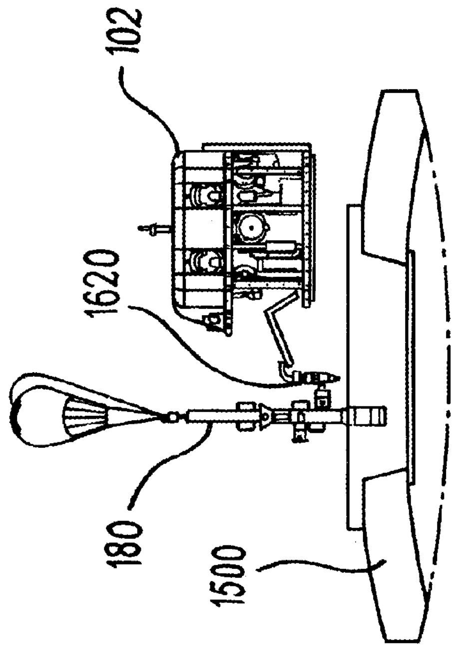


Fig. 15B

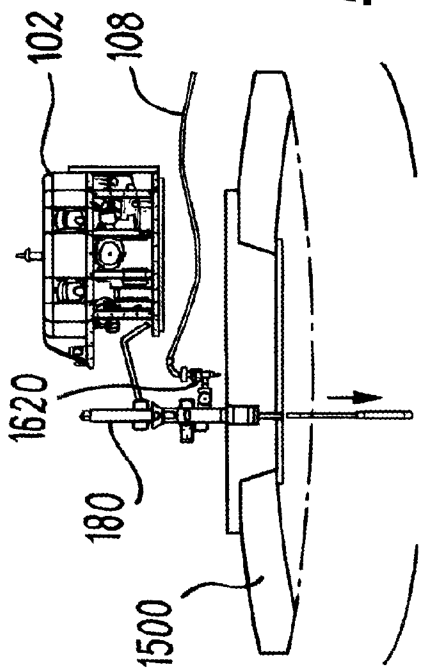


Fig. 15C

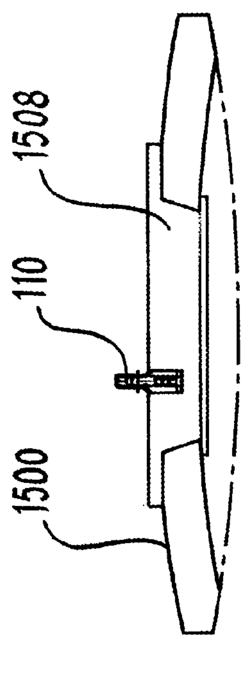


Fig. 15A

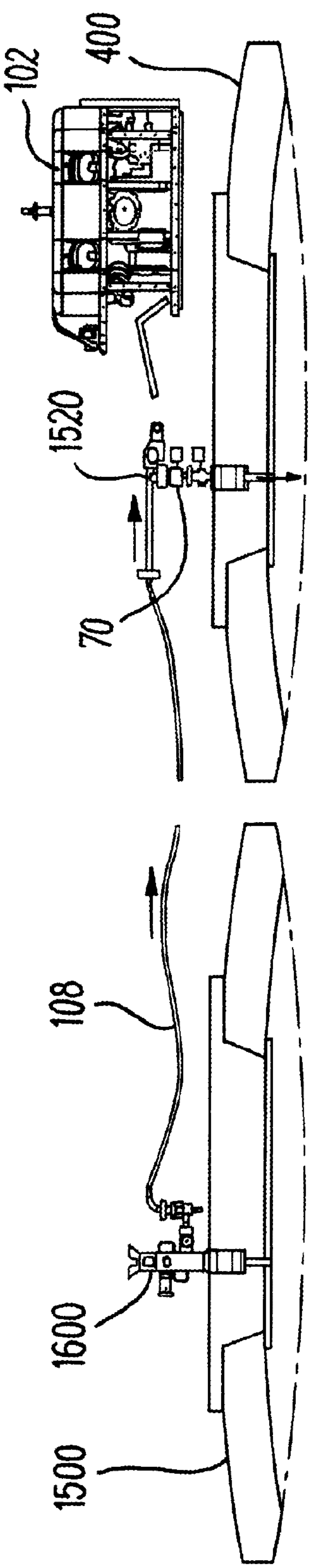


Fig. 15D

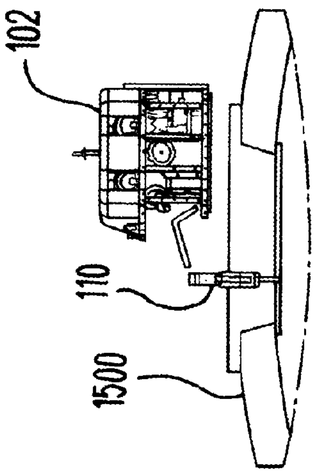


Fig. 15G

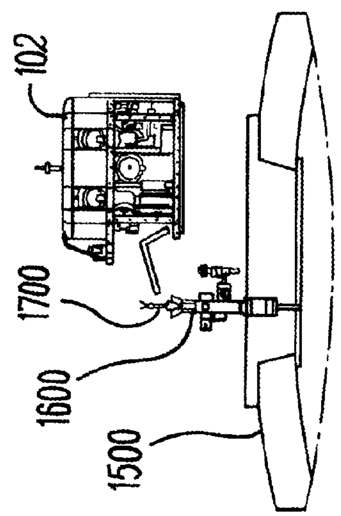


Fig. 15F

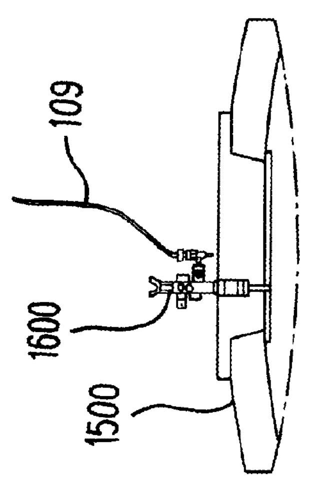


Fig. 15E

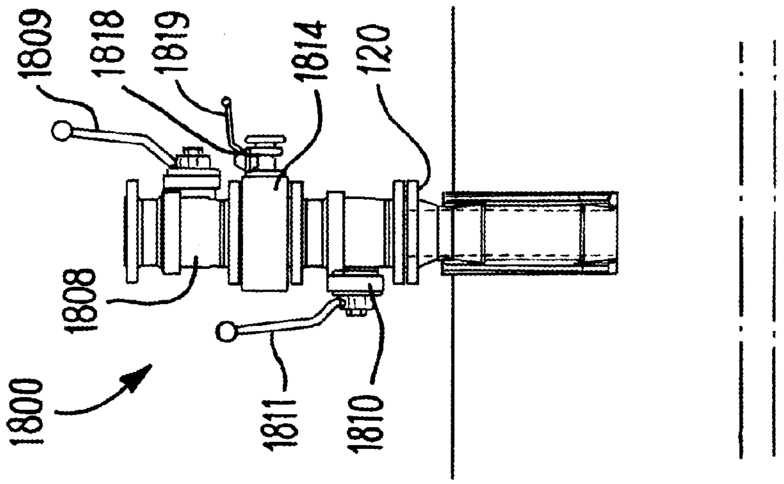


Fig. 18

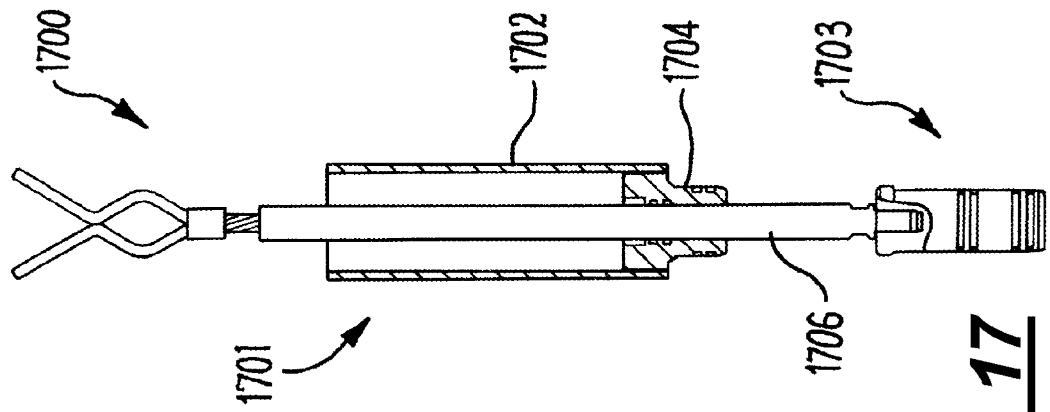


Fig. 17

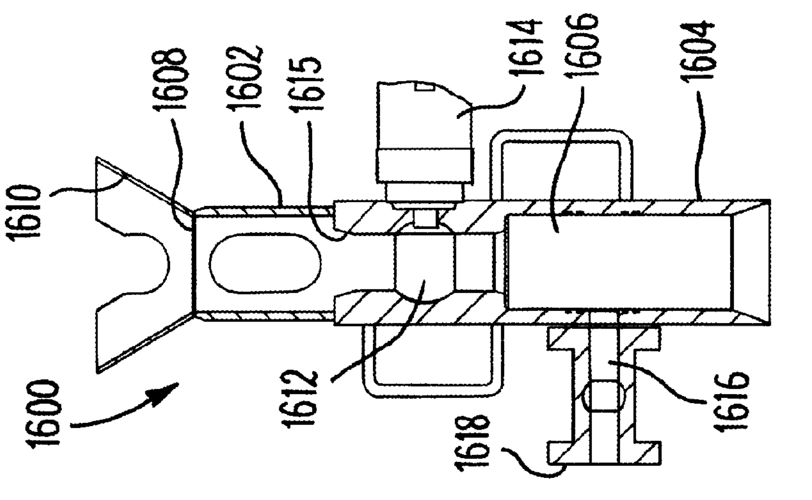


Fig. 16

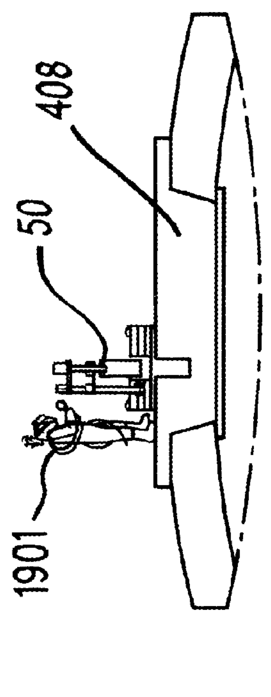


Fig. 19A

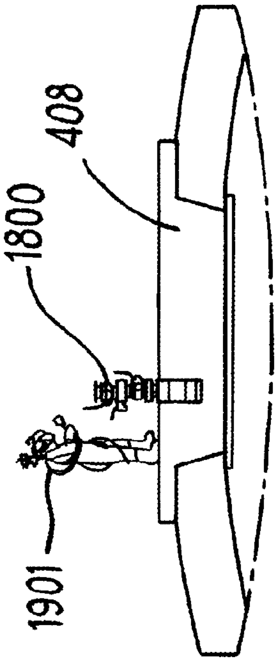


Fig. 19B

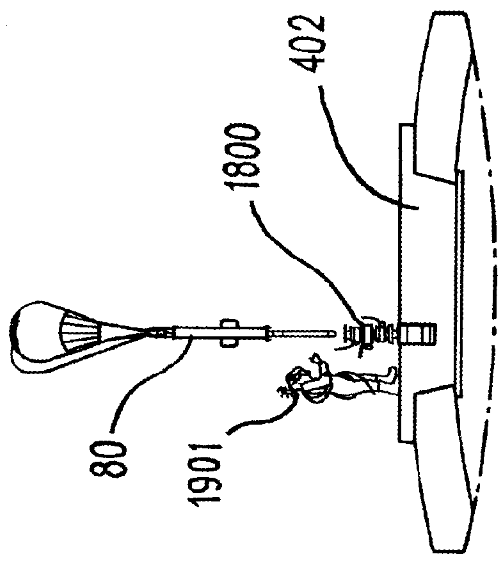


Fig. 19C

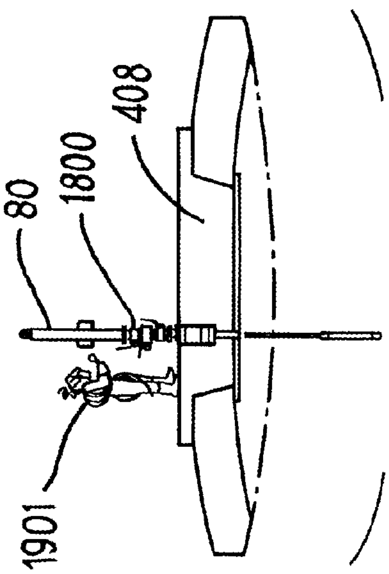


Fig. 19D

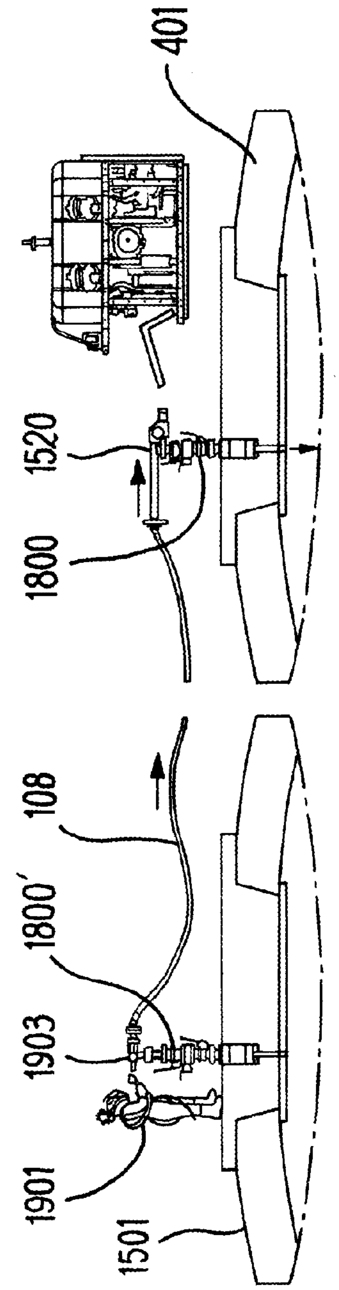


Fig. 19E

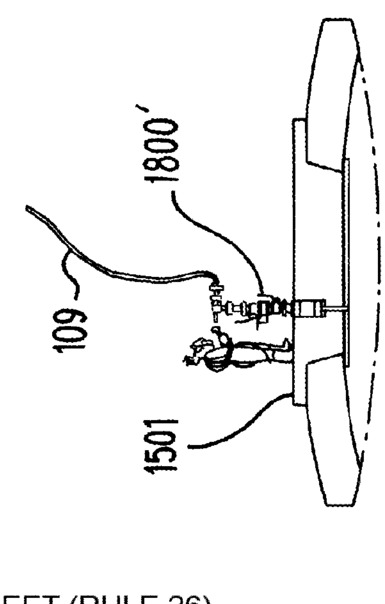


Fig. 19F

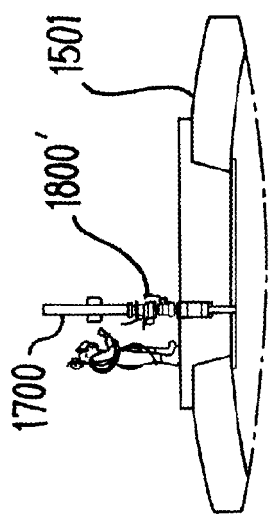


Fig. 19G

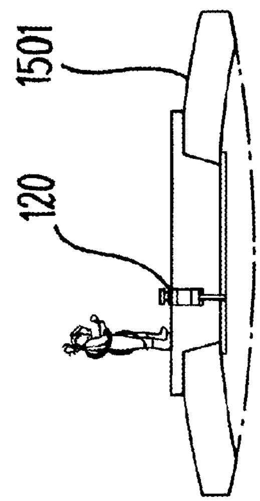
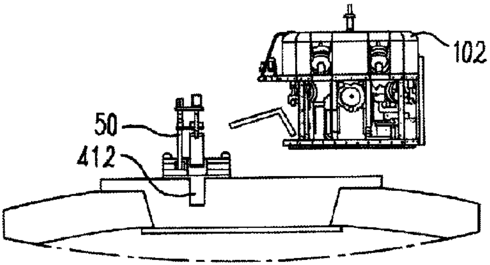


Fig. 19H



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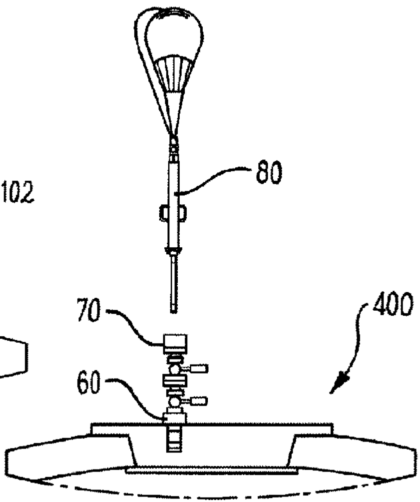

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