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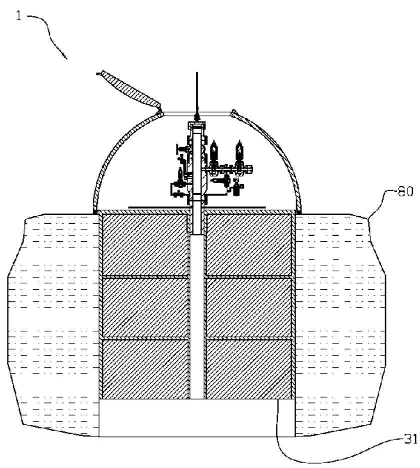
(54) Title **An apparatus for performing at least one operation to construct a well subsea, and a method for constructing a well**

(57) Abstract

An apparatus (1) for performing at least one operation to construct a well subsea, the apparatus (1) comprising a plurality of valves (203, 204, 15, 10, 404) such that the apparatus forms a flow control assembly for controlling fluid flow during production of hydrocarbons from the well, the apparatus (1) characterized in being arranged with a through bore (100) configured for allowing drilling and installation of casings and casing hangers (12, 13) to be performed through the bore (100). A method for constructing a well, the method comprising the step of: drilling a hole into a formation for a subsequent installation of a casing, wherein the drilling is performed through a bore (100) in an apparatus (1) according to the first aspect of the invention.



AN APPARATUS FOR PERFORMING AT LEAST ONE OPERATION TO CONSTRUCT A WELL SUBSEA, AND A METHOD FOR CONSTRUCTING A WELL

The present invention relates to an apparatus for performing at least one operation to construct a well subsea, the apparatus comprising a plurality of valves such that the apparatus forms a flow control assembly for controlling fluid flow during production of hydrocarbons from the well. The invention further relates to a method for constructing a well.

Using subsea systems is well known in the petroleum industry. With advancements in technology, it is becoming increasingly common to use such systems for exploring and developing and producing hydrocarbons from oil and/or gas fields. These subsea systems can replace systems that were previously typically placed on platforms, doing so in a reliable, safe and cost-efficient manner. Using subsea systems is particularly advantageous in deep waters and/or remote locations, but can also offer cost-efficient solutions elsewhere.

Conventionally, subsea well drilling and production systems consist of multiple mechanical components with specific design features with low level of integration and optimization both for manufacturing and installation. To install a conventional subsea drilling and production system, it is required to run multiple independent installation steps, where several independent components of the subsea system are installed individually throughout a well construction process. The systems are not optimized with respect to interfaces to allow for more efficient installation sequences and/or choices of installation methods.

When this text refers to a conventional subsea system, it refers to a typical subsea system known to a person skilled in the art of installing such systems.

A typical installation sequence for a conventional subsea system is as follows:

A foundation is installed. This is done by drilling a hole with a diameter of 36 inches, 60 to 80 meters deep, vertically from the seabed. A conductor with a diameter of 30 inches is run into the hole. The conductor has a length such that, when a first end of the conductor reaches the bottom of the hole, an opposite end extends approximately two meters above the seabed. The end portion extending above the seabed is arranged with a low-pressure wellhead housing. The low-pressure wellhead housing has typically been arranged to the conductor aboard the drilling rig or drilling vessel which is required for this foundation installation. To finalize the foundation, the conductor is cemented in place.

The next step is to install a surface casing and a high-pressure wellhead housing. A hole with a diameter of 26 inches is drilled, extending further downwards from the existing hole. A surface casing with a diameter of 20 inches is run into the hole. The surface casing has a length such that when a first end of the surface casing reaches the bottom of the hole the opposite end extends somewhat above the conductor. The surface casing has been arranged with the high-pressure wellhead housing which interfaces against the low-pressure wellhead housing. The high-pressure wellhead housing is typically arranged with the surface casing aboard a drilling vessel or drilling rig used for this part of the installation sequence. Finally, the surface casing is cemented in place in the well.

Then, a blowout preventer (BOP) is mounted onto the high-pressure wellhead housing, and a riser is attached to the subsea system.

Several casings are then installed. First, a hole with a diameter of 17.5 inches is drilled, extending further from the existing hole. A first casing is run into the hole, the first casing having a diameter of 13.375 inches. The first casing is suspended from a first casing hanger in the high-pressure wellhead housing. To complete the installation of the first casing, it is cemented in place.

A hole with a diameter of 12.25 inches is then drilled, extending further from the existing hole. A second casing, having a diameter of 9.625 inches, is run into the hole. The second casing is suspended from a second casing hanger in the high-pressure wellhead housing. Cementing is then performed to complete the installation of the second casing.

Finally, a hole with a diameter of 8.5 inches is drilled, extending from the existing hole. A lower completion is run into the hole, the lower completion being suspended from the lower part of the second casing. Then upper completion is performed.

To finalize the installation, the BOP is removed, and a production flow base and a Christmas tree is installed onto the high-pressure wellhead housing.

A problem with the conventional subsea system is that it offers little flexibility. Details in the installation may vary, of course, such as the length of each size (diameter) of casing. However, whether the subsea system is to be used for a shallow well or a deep well, the components and the installation sequence are mainly the same.

The limitation of the conventional system is partly due to that it is designed for the sequential installation procedure described. Typically, the low-pressure wellhead housing needs to be installed with the conductor. The high-pressure housing needs to be installed with the surface casing. The two wellhead housings then need to be arranged with means to connect to each other, and they have to be assembled together subsea as part of the installation procedure. Furthermore, later on in the installation process, the production flow base and the Christmas tree need to be mounted on and connected to the high-pressure wellhead housing, and these components too have to be arranged with means to connect to each other.

It is known to replace the conventional foundation of the system, the 60-80 meters long conductor, with a suction caisson. By doing so, it is possible to perform the installation of the foundation using an anchor-handling vessel instead of a drilling rig. However, the system is still less than ideal, still over-dimensioned for shallow wells, still overly cumbersome to install.

The invention has for its object to remedy or to reduce at least one of the drawbacks of the prior art, or at least provide a useful alternative to prior art.

The object is achieved through features, which are specified in the description below and in the claims that follow.

According to a first aspect of the invention, there is provided an apparatus for performing at least one operation to construct a well subsea, the apparatus comprising a plurality of valves such that the apparatus forms a flow control assembly for controlling fluid flow during production of hydrocarbons from the well, the apparatus being arranged with a through bore configured for allowing drilling and installation of casings and casing hangers to be performed through the bore.

The term “through the bore” includes both partly through the bore and fully through the bore. Typically, drilling will involve running a drill bit through the bore of the apparatus and into a formation below the apparatus for drilling a hole in the formation. Installation of casing hangers will typically involve moving a casing hanger into the bore, leading partly through the bore to a casing hanger latching profile, and latching the casing hanger onto the latching profile.

The apparatus may constitute a subsea system having an integrated flow control assembly, and it may provide all of or some of the functionality of a conventional subsea system, and it may provide additional functionality not normally provided by a conventional subsea system.

The Christmas tree in a conventional subsea system covers several important functions, such as controlling fluid flow during production, providing barriers and monitoring fluid flow. The flow control assembly that the apparatus forms is to be understood, herein, as a replacement for a conventional subsea Christmas tree. The flow control assembly may cover all of or a selection of the main functions covered by a Christmas tree in a conventional system, such as control of flow during injection into the well, pressure relief and monitoring functions such as sand detection and measurements of pressure, temperature, velocity of flow and more. In addition, the flow control assembly that the apparatus forms, may provide functionality not offered by a conventional flow control assembly such as a Christmas tree. Note that a less complex arrangement, e.g. comprising two valves to form barriers against blowouts or other accidents during well development does not constitute what is referred to herein as a “flow control assembly”.

The flow control assembly may comprise all of or a combination of a master valve, a wing valve, a crossover valve and a choke valve required to perform the functions offered by a Christmas tree in a conventional subsea system. It may further comprise other valves and other equipment, such as one or more sensors, one or more fittings, one or more spools and/or one or more flanges required to perform the fluid control function offered by a Christmas tree in a conventional subsea system.

One of the limiting features in terms of flexibility of a conventional subsea system is the bore in the Christmas tree of the conventional subsea system. The Christmas tree typically has a bore with a diameter of up to approximately 8 inches, which means the Christmas tree cannot be installed until the majority of the drilling of the well is completed. After the installation of the Christmas tree, the bore in the Christmas tree is typically used for well intervention and other well manipulation tasks, not for further drilling.

The apparatus according to the invention has at least the flow control functionality of a conventional Christmas tree, while having a bore of a diameter large enough to allow drilling and installation of casings to be performed through the bore. This makes the apparatus according to the invention advantageous, as it allows for a simpler and more cost-efficient subsea well construction procedure, as it may be assembled onshore and subsequently installed on a seabed in one operation prior to drilling.

The apparatus may comprise a casing hanger landing profile. Preferably, the apparatus may comprise two casing hanger landing profiles, but it may also comprise more than two casing hanger landing profiles. A casing hanger landing profile offers a landing profile from which a casing may be suspended. The apparatus may further comprise a tubing hanger latching profile. The tubing hanger latching profile is a latching profile from which a tubing may be suspended. Furthermore, the apparatus may comprise a seal assembly latching profile. The seal assembly latching profile is a latching profile to which a seal assembly may be latched. Having a combination of such profiles will allow for hanging and/or latching a combination of one or more casings, tubings and/or seal assemblies. Having such features comprised by the apparatus is beneficial, particularly during well construction, as it means no external parts have to be connected to the apparatus to provide such features.

The apparatus according to the first aspect of the invention may further comprise connection means for connecting to a riser and/or a blowout preventer (BOP). Having such connection means may be advantageous as it may become necessary to connect a BOP and/or a riser to the apparatus during well construction and/or production.

The apparatus may further comprise a flow-line connector for connecting to a flow-line. The flow-line may typically be a line of tubing or casing through which fluid may flow. It is advantageous for the apparatus to comprise a flow-line connector for connecting to a flow-line, as it will provide a route for flow from the apparatus to an external receiver.

The apparatus may further comprise a suction caisson for forming a well foundation. Installing a suction caisson as foundation requires no drilling, meaning an anchor-handling vessel or other types of light construction vessels may be used instead of a drilling rig or drilling vessel. This is a great advantage, particularly when several wells are to be drilled in a field, as it allows for more efficient use of resources in a field development project: An anchor-handling vessel or other types of light construction vessels are significantly cheaper in use than a drilling rig or vessel, and the installation process of a suction caisson as well foundation is significantly simplified compared to that of establishing a conventional foundation comprising a conductor and a low-pressure wellhead housing. The apparatus, comprising a suction caisson, will not need a pre-installed foundation to which to attach. Instead, the apparatus can simply be installed through suction, and form its own foundation.

The apparatus may use other forms of well foundations. It may use a conventional conductor foundation as a foundation, or it may use any other structure fit to act as a foundation.

Furthermore, the apparatus may comprise a full-bore isolation valve. The full-bore isolation valve may be used as a barrier, e.g. for periods when a well is to be temporarily abandoned, and may thus offer a very efficient alternative to setting a plug in a well, which is currently the conventional method of establishing a well barrier element. Setting a plug for temporary abandonment may typically take 12 hours, whereas closing a full-bore isolation valve takes very little time.

The apparatus may further comprise a protective structure, for protecting the apparatus against external forces, corrosion, pollution, or other unwanted effects. The seabed may be a harsh environment, and a protective structure may help preserve the integrity of the apparatus and increase its longevity. The protective structure may be assembled to the apparatus prior to installation subsea.

The apparatus may further comprise an ROV-receptacle. ROV is short for remotely operated vehicle. The ROV-receptacle may be for receiving a hose from an ROV, for injection or extraction of a fluid. Having an ROV-receptacle is advantageous as it allows an ROV to connect to and manipulate the apparatus or a well to which the apparatus belongs. The ROV receptacle may be a hot stab receptacle. A hot stab receptacle may be beneficial as it is designed for connecting or disconnecting under pressure while causing little to no spill.

Furthermore, the apparatus may comprise a bore protector and/or a wear bushing for preventing wear and/or blocking pollution from entering valves, profiles and/or latches during drilling or cementing. The bore protector may be placed in the bore of the apparatus prior to drilling, and removed after drilling. This may be done using a winch, or by use of any other means suitable for the purpose. It is highly advantageous to use a protective element such as a bore protector during drilling, to prevent mud, sand, rocks, cement and/or other unwanted objects from damaging the integrity of sensitive components of the system. The bore protector and/or the wear bushing may comprise an upper and a lower seal, for sealing a portion of the bore, for protection of sensitive equipment and/or for pressure testing to be performed in the sealed-off portion of the bore.

The apparatus may further comprise an interface spool for forming an interface between a main body of the apparatus and a well foundation. The foundation may be the suction caisson. The main function of the interface spool is to mate the main body with the foundation and to transfer structural loads onto the foundation. The interface spool may comprise an outlet for cement returns for routing cement onto a seabed for preventing cement returns from returning through the main body of the apparatus during cementation. Having an interface spool with such features decreases the risk of having cement returns pollute valves, latching profiles and other sensitive equipment in the apparatus. The interface spool solution thus eliminates potential problems related to performing a cementing operation through the apparatus. The interface spool may comprise a plurality of outlets for cement returns. It may comprise one, two, three, four, five, six, seven, eight, or more than eight outlets for cement returns.

The outlet for cement returns may be a pipe running from an annulus of a wellbore, through the foundation, to an opening towards a sea floor. The pipe may comprise a valve for blocking the outlet, for creating a barrier between the sea and the annulus. The pipe may comprise a plurality of valves for creating a plurality of barriers.

The interface spool may further comprise a casing latching system for latching a casing in place after installing the casing in a wellbore. This is advantageous as it prevents upward movement of a casing string.

The interface spool may comprise an interface spool extension. The interface spool extension may be a pipe having a first end arranged to a lower end of the interface spool. The pipe may extend from the lower end of the interface spool to a bottom end of a foundation, such as a suction caisson, and may be arranged via structural support to an exterior portion of the foundation.

The apparatus may further comprise an annulus line forming an inlet to and an outlet from the main bore in a position of the bore below the tubing hanger latching profile for providing access to an annulus of a well. The apparatus may further comprise an annulus master valve, and the annulus line may extend radially from the main bore through a body of the apparatus to the annulus master valve. The annulus line may typically be arranged in a position between a tubing hanger latching profile and a casing hanger latching profile. In embodiments of the system having a plurality of casing hanger latching profiles, the annulus line may typically be an inlet to and an outlet from a portion of the main bore between the uppermost casing hanger latching profile and the tubing hanger latching profile.

The apparatus may further comprise a crossover line, for providing a crossover line from an annulus of a well to the flow line of the apparatus. The crossover line may comprise the annulus line. The crossover line may further comprise a crossover valve, for forming a barrier to the flow line.

Furthermore, the apparatus may comprise an external circulation line for accessing an annulus and/or the flow line. The external circulation line may be used as a bleed line for bleeding off pressure from an annulus, as an injection line for injecting a fluid into the annulus, as a circulation line for improving circulation in a well, and/or as a cementation line for a cementation task e.g. during a well abandonment phase. The external circulation line may have further uses.

The external circulation line may be arranged with connection means for connecting to a fluid flow means, such as a hose, pipe, tubing, or any other type of means through which fluid may securely flow. The fluid flow means may be connected to the external circulation line by use of an ROV. This allows for efficient access to the external circulation line by use of the fluid flow means and an ROV, for injecting fluid into or extracting fluid from the external circulation line. The connection means may be a hot-stab connection. The hot-stab connection may comprise a valve that may act as a barrier. The hot-stab connection may herein be referred to as an ROV valve stab receptacle.

The external circulation line may comprise a tubular structure having the above-mentioned connection means arranged in a first end portion of the tubular structure. A second end of the tubular structure of the external circulation line may connect to the crossover line. Thus, the circulation line may access, through the crossover line, both the annulus line and the flow line. The external circulation line may typically connect to the crossover line in a position in the crossover line between a crossover valve and an annulus master valve.

The external circulation line may further comprise a second valve for forming a barrier between the crossover line of the apparatus and the connection means of the external circulation line. The second valve may be any type of valve suitable for forming a barrier.

It may be said that the external circulation line comprises at least a portion of the crossover line and/or the annulus line, to form a complete line from the connection means of the external circulation line to the flow line and/or the bore of the apparatus below the production hanger latching profile.

In a conventional subsea system, a significant portion of a circulation line typically runs within a wall of a body of the Christmas tree and/or the high-pressure wellhead. As the wall typically offers little space, this conventional design limits the diameter of the circulation line. Except for radial penetration of the body of the apparatus, the external circulation line runs externally from any wall of the main body of the apparatus. The area where the external circulation line does penetrate the wall radially may be spacious. This means that the external circulation line of the apparatus may not have the same restrictions to its diameter as the circulation line of a conventional subsea system. This allows for a greater diameter of the external circulation line compared to that of a conventional circulation line. A greater diameter of the circulation line allows for greater fluid flow rates, which may be beneficial e.g. for well circulation jobs and for setting of cement plug during a well abandonment phase.

The external circulation line may form a line into the flow line and/or the main bore below the tubing hanger latching profile running separately from the crossover line and/or the annulus line. The external circulation line may comprise one or more valves for forming one or more barriers.

The apparatus may further comprise a radial bore through the body below a casing hanger latching profile for monitoring well parameters such as pressure and/or temperature. The bore may be arranged with a B annulus line for bleeding of pressure and/or for circulation.

The B annulus line may comprise a valve for providing a barrier. The B annulus line may comprise a plurality of valves. The B annulus line may be connected to the production line, to the crossover line and/or the external circulation line. The B annulus line may comprise one or more sensors, e.g. for monitoring pressure, temperature, flow rate or any other fluid characteristics that it may be beneficial to monitor. The B annulus line may be used e.g. for circulating drilling fluid, and/or for cementing during a well abandonment phase. The B annulus line may further comprise connection means for connecting to fluid flow means, such as a hot-stab connection. The fluid flow means may be any means through which fluid may flow, suitable for the purpose, such as a hose, a tubing and/or a pipe.

In an embodiment having more than one casing hanger latching profile, the apparatus may comprise further annulus lines, such as a C annulus line and/or a D annulus line, having one or more of the features of the B annulus line. The apparatus may typically have an annulus line above and below each casing hanger latching profile. In an example embodiment having a first and a second casing hanger latching profiles, and a tubing hanger latching profile, the apparatus may typically have the annulus line between the tubing hanger latching profile and the second casing hanger latching profile, the B annulus line between the second casing hanger latching profile and the first casing hanger latching profile, and the C annulus line below the first casing hanger latching profile.

The annulus lines may be greatly advantageous. Legislation is expected to be implemented as soon as reliable technology is available, requiring monitoring of the B-annulus. A direct access monitoring system, made possible by the B annulus line has the benefit that it may last for the lifetime of a well, something which remote systems powered by batteries may not be able to offer. Furthermore, the annulus lines may offer a direct flow path to an annulus, which may allow for more efficient cementation techniques.

The apparatus may further comprise one or more chokes, one or more sensors, one or more crossover valves, one or more of other types of valves, one or more flanges, one or more spools, and/or the apparatus may comprise other components that may increase the apparatus’ functionality as a subsea drilling and production system or that may be beneficial for other reasons.

Embodiments of the first aspect of the invention may comprise all the necessary components for the apparatus to fulfil all requirements of a subsea drilling and production system, and to fulfil partly or completely the functionality of a conventional subsea system, including that of the low-pressure wellhead housing, the high-pressure wellhead housing, the production flow base and the Christmas tree. Furthermore, the apparatus may have functionality not typically offered by a conventional subsea system, such as some of the functionality offered by the B annulus line, the external circulation line and the interface spool. The great advantage of the apparatus according to the first aspect of the invention is that it allows for onshore assembly of a far greater portion of a complete subsea system than does prior art. Only drilling, installation of casings and tubings, completion, and manipulation of the system may be necessary to construct and operate the well. All of or a selection of the following may be assembled as the apparatus onshore: a flow control assembly, a protective structure, a suction caisson, a flow line, an external circulation line, a plurality of annulus lines, an ROV receptacle, latching profiles, and more.

The apparatus according to the first aspect of the invention thus allows for a simpler, more efficient installation and well development procedure than the conventional subsea system. An embodiment of the invention comprising a suction caisson will offer a simpler foundation establishment, as it will require no drilling. The suction caisson will form the foundation of the well. Secondly, the step of installing a surface casing and a high-pressure wellhead housing may be skipped, as the functionality of the high-pressure wellhead housing may be fulfilled by the subsea system according to the invention. Skipping the step of establishing the 26 inches hole and 20 inches surface casing may limit the size of the well, though, and is thus mainly a good option for a relatively shallow well. Finally, the last step of installing the Christmas tree may also be skipped, as the functionality of the Christmas tree is covered by the apparatus according to the first aspect of the invention.

The apparatus may further comprise a concentric tubing hanger, having a concentric shape. The concentric tubing hanger may comprise circumferential upper and lower tubing hanger seals. The concentric tubing hanger may further comprise an internal isolation valve and/or profiles for crown plug. Ports for the isolation valve may be drilled into a body of the concentric tubing hanger. The concentric shape may be advantageous over conventional casing hanger solutions, as a conventional hanger typically requires orientation means to be implemented to allow orientation of the tubing hanger during installation. The concentric tubing hanger does not require such orientation, and therefore does not require orientation means. By not requiring orientation means to be installed, the concentric tubing hanger solution is advantageous as it requires less space in the main bore than a conventional tubing hanger solution.

The apparatus may comprise a casing and/or casing string. The apparatus may comprise a plurality of casings and/or casing strings. The apparatus may further comprise a production tubing, and/or it may comprise other forms of tubing. The apparatus may comprise an annulus between a casing and a tubing, an annulus between a casing and another casing, an annulus between a casing and a formation and/or an annulus between a tubing and a formation. The apparatus may comprise a partly or fully developed hydrocarbon well. The apparatus may comprise any downhole equipment in the well.

In a second aspect, the invention relates to a method for constructing a well, wherein the method comprises the step of:
- drilling a hole into a formation for a subsequent installation of a casing, wherein the drilling is performed through a bore in an apparatus according to the first aspect of the invention.

A method wherein a hole is drilled into a formation through a bore in an apparatus comprising a flow control assembly may be beneficial as it allows the flow control assembly to be installed prior to the step of drilling the hole.

The method may further comprise the step of installing a casing into the hole in the formation through the bore of the apparatus. Furthermore, the method may comprise the step of cementing the casing in place in the hole in the formation, wherein the cementing operation is performed through the bore. The method comprising the steps of installing a casing through the bore and cementing the casing in place through the bore means a subsea system may comprise a flow control assembly prior to the installation of a casing, which means that a subsea system with an integrated flow control assembly may be assembled onshore.

The method may further comprise the step of installing a production tubing in a well, wherein the operation is performed through the bore of the apparatus.

The hole drilled through the bore of the apparatus may be for the installation of a casing with a diameter greater than the diameter of a production tubing to be installed subsequently during the well construction process. The hole may have a diameter large enough for the installation of the largest casing to be installed during the construction of the well.

The diameter of the hole drilled through the bore may be at least 12.25 inches.
The diameter of the hole drilled through the bore may be at least 15 inches. The diameter of the hole drilled through the bore may be at least 17.5 inches.

The method may further comprise the step of installing an apparatus comprising a flow control assembly on a seabed, wherein the bore through which the drilling is performed is a bore though the apparatus, and wherein the installation of the apparatus is performed prior to a step of drilling for a subsequent installation of a casing for the well. Installing the apparatus prior to drilling operations may be advantageous for reasons mentioned in the previous paragraph.

The step of installing the apparatus may comprise the step of establishing a foundation for a well. Thus, the foundation may be comprised by the apparatus, as in the case of the apparatus according to the first aspect of the invention in an embodiment where it comprises a suction caisson. This may be particularly advantageous when developing an oil field with multiple wells to be constructed, as it allows for a smaller vessel, such as an anchor-handling vessel, to perform the task of installing the foundations of the wells, as drilling may not be necessary during the establishment of the foundations. Alternatively, the foundation may be a conventional conductor, wherein the conductor is configured for receiving the apparatus and wherein the apparatus is configured for having the conductor as a foundation.

The method may further comprise the step of performing a cementing operation in a well, wherein the cementing operation is performed through the bore of the apparatus.

The step of performing a cementing operation in a well may comprise the step of releasing cement returns onto a seabed through an outlet for cement returns. The outlet for cement returns may be an outlet in an interface spool of the apparatus.

Furthermore, the method may comprise the step of inserting into the bore of the flow control assembly a bore protector for protecting the bore and other parts of the apparatus against wear and/or pollution from mud, sand, rocks, cement, and/or other unwanted objects.

The method for constructing a well according to the second aspect of the invention is advantageous compared to the conventional installation method, particularly in that the method according to the invention does not require a Christmas tree to be installed after completing the drilling process.

Furthermore, the method according to the second aspect of the invention is advantageous compared to the installation of a conventional subsea system, as the method does not require assembly of components of the system on the seabed. A conventional system typically requires the low-pressure wellhead housing to connect to the high-pressure wellhead housing, and the high-pressure wellhead housing to connect to the production flow base and the Christmas tree. These are all typically installed at different stages of the well development process for a conventional system. Having to assemble the low-pressure wellhead housing, the high-pressure wellhead housing, the production flow base and the Christmas tree of a conventional subsea system together with each other subsea is inefficient, and necessitates that the components are designed for such subsea assembly, with connection- and interface means that may otherwise not be necessary in an apparatus assembled onshore.

There is also described an interface spool for acting as an interface between a main body of an apparatus for performing at least one operation to construct a well subsea and a well foundation. The well foundation may be a suction caisson, or it may be any other suitable foundation, such as a conductor. The main functions of the interface spool is to mate the main body with the foundation, and to transfer structural loads onto the suction caisson. The apparatus may be the apparatus according to the first aspect of the invention presented herein. The apparatus may comprise both the main body and the well foundation.

More specifically, there is described an interface spool for acting as an interface between the main body of the apparatus and the foundation, wherein the interface spool comprises an outlet for cement returns for routing cement onto a seabed outside of the foundation for preventing cement returns from returning through the main body of the apparatus during cementation when the apparatus is installed subsea. Having an interface spool with such features decreases the risk of having cement returns pollute valves, latching profiles and other sensitive equipment in the apparatus. The interface spool solution thus eliminates potential problems related to performing a cementing operation through an apparatus comprising a flow control assembly. The interface spool may comprise a plurality of outlets for cement returns. It may comprise one, two, three, four, five, six, seven, eight, or more than eight outlets for cement returns.

The outlet for cement returns may be a pipe running from an annulus of a wellbore, through the foundation, to an opening towards a sea floor. The pipe may comprise a valve for blocking the outlet, for creating a barrier between the sea and the annulus. The pipe may comprise a plurality of valves for creating a plurality of barriers.

The interface spool may further comprise a casing latching system for latching a casing in place after installing it in a wellbore. This is advantageous as it prevents upward movement of a casing string.

The interface spool may comprise an interface spool extension. The interface spool extension may be a pipe having a first end arranged to a lower end of the interface spool. The pipe may extend from the lower end of the interface spool to a bottom end of a foundation, such as a suction caisson, and may be arranged via a structural support to an exterior portion of the foundation.

There is further described an apparatus according to the first aspect of the invention, wherein the apparatus comprises the interface spool.

Furthermore, there is described a method for cementing a casing in place in a wellbore by substantially filling an annulus between the casing and a surrounding formation with cement, wherein the method comprises the steps of:
- providing cement into the wellbore through the casing;
- running cement from inside the casing to the annulus; and
- running return cement through an outlet for cement return onto a seabed, wherein the cement return is comprised by an interface spool, and the interface spool is comprised by a subsea system.

The subsea system may be the apparatus according to the first aspect of the invention.

The method may comprise the step of opening a valve to allow return cement to run from the annulus, through the outlet, to the seabed. The valve may be a valve in the outlet for cement return.

The method described above may be advantageous for use with an apparatus wherein a flow control assembly and/or other sensitive equipment is installed and/or integrated prior to performing a cementing operation. During cementing, return cement may, by use of this method, escape to the seabed prior to reaching sensitive equipment, such as valves, sensors or hanger profiles, thus limiting the risk of having the sensitive equipment polluted by the cement.

There is further described an external circulation line for accessing an annulus and/or a flow line of an apparatus for performing at least one operation to construct a well subsea. The external circulation line may be used as a bleed line for bleeding off pressure from an annulus, as an injection line for injecting a fluid into the annulus, as a circulation line for improving circulation in a well, and/or as a cementation line for a cementation task in a well, e.g. during a well abandonment phase. The external circulation line may have further uses. The apparatus may be a subsea system. The subsea system may comprise a fully or partly developed hydrocarbon well.

The external circulation line may be arranged with connection means for connecting to a fluid flow means, such as a hose, pipe, tubing, or any other type of means through which fluid may securely flow. The fluid flow means may be connected to the external circulation line by use of an ROV. This allows for efficient access to the external circulation line by use of the fluid flow means and an ROV for injecting fluid into or extracting fluid from the external circulation line. The connection means may be a hot-stab connection. The hot-stab connection may comprise a valve that may act as a barrier. The hot-stab connection may be referred to as an ROV valve stab receptacle. The connection means may further be referred to as an ROV receptacle.

The external circulation line may comprise a tubular structure having the above-mentioned connection means arranged in a first end portion of the tubular structure. A second end of the tubular structure of the external circulation line may connect to another line of the apparatus, such as a crossover line, an annulus line, a flow line and/or a main bore. Thus, the circulation line may access, either directly or through other lines, both or either one of an annulus line and a flow line. The external circulation line may typically connect to a crossover line in a position in the crossover line between a crossover valve and an annulus master valve. The external circulation line may further comprise a second valve for forming a barrier between the crossover line of the apparatus and the connection means of the external circulation line. The second valve may be any type of valve suitable for forming a barrier. The external circulation line may connect to a flow line, either directly or indirectly, and to an annulus, either directly or indirectly.

The external circulation line may comprise at least a portion of a crossover line and/or an annulus line to form a complete line from the connection means of the external circulation line to the flow line and/or the bore of the apparatus below the production hanger latching profile.

In a conventional subsea system, a significant portion of a circulation line typically runs within a wall of a body of the Christmas tree and/or the high-pressure wellhead. As the wall typically offers little space, this conventional design limits the diameter of the circulation line. Except for radial penetration of a body of an apparatus, the external circulation line runs externally from any wall of the main body of the apparatus. The area where the external circulation line does penetrate the wall radially may be spacious. This means the external circulation line of the apparatus may not have the same restrictions to its diameter as the circulation line of a conventional subsea system. This allows for a greater diameter of the external circulation line compared to that of a conventional circulation line. A greater diameter of the circulation line allows for greater fluid flow rates, which may be beneficial e.g. for well circulation jobs and for setting of a cement plug during a well abandonment phase.

There is further described a method of setting a cement plug in a well, wherein the method comprises the step of injecting cement into the well through an external circulation line. The cement plug may be a well abandonment cement plug.

Furthermore, there is described an apparatus for performing at least one operation to construct a well subsea comprising said external circulation line. The apparatus may be the apparatus according to the first aspect of the invention presented herein.

There is further described a method of establishing a cement well abandonment plug, wherein the method comprises the step of providing cement into a wellbore through an external circulation line. Furthermore, the method of establishing the cement well abandonment plug may comprise the step of feeding cement into the annulus vent/injection through a hot stab connection. Further steps involved in the method for establishing the cement plug may be steps known to a skilled person.

Furthermore, there is described a subsea drilling system for drilling exploration wells, wherein the drilling system comprises a foundation, an interface spool and a high-pressure mandrel arranged to form an interface between the subsea system and a drilling blowout preventer and/or a Christmas tree.

The interface spool may be the aforementioned interface spool. The foundation may be a suction caisson, or any other foundation suitable for the purpose.

The foundation may form a low-pressure system for carrying loads such as vertical loads, horizontal loads and torque, the interface spool forms an interface between the foundation and the mandrel, and the high-pressure mandrel forms a high-pressure system for enduring pressure loads and forms an interface for further parts to be connected to the subsea system.

The subsea drilling system for drilling exploration wells is advantageous compared to prior art, as it allows for assembly of the drilling system to be performed onshore, and for the subsea system to be installed on a seabed in one operation. A conventional subsea system comprising a foundation, a low-pressure wellhead and a high-pressure wellhead typically needs several installation steps to be performed, as has been previously discussed.

There is further described an apparatus for performing at least one operation to construct a well subsea comprising a B annulus line, wherein the B annulus line forms a flow path for monitoring fluid characteristics in an annulus of a subsea well. The B annulus line comprises a bore through a wall of a body of the apparatus, below a casing hanger latching profile, for providing a flow path from an annulus on the outer side of a casing suspended from a casing hanger latched to the latching profile. The B annulus line may comprise a line of tubing for bleeding off pressure from the annulus and/or for circulation of fluid in the annulus. The B annulus line may comprise a valve for providing a barrier. The B annulus line may comprise a plurality of valves. The B annulus line may be connected to a production line, to a crossover line and/or a circulation line such as an external circulation line. The B annulus line may comprise one or more sensors, e.g. for monitoring pressure, temperature, flow rate or any other fluid characteristics that it may be beneficial to monitor. The B annulus line may be used for circulating drilling fluid and/or for cementing during a well abandonment phase, or for any other relevant tasks. The B annulus line may further comprise connection means for connecting to fluid flow means, such as a hot-stab connection. The fluid flow means may be any means through which fluid may flow, suitable for the purpose, such as a hose, a tubing and/or a pipe.

The apparatus comprising the B annulus line may comprise further annulus lines, such as a C annulus line and/or a D annulus line, having one or more of the features of the B annulus line. The apparatus may typically be provided with an annulus line above and below each casing hanger latching profile. In an example embodiment having a first and a second casing hanger latching profiles, and a tubing hanger latching profile, the apparatus may typically have an annulus line between the tubing hanger latching profile and the second casing hanger latching profile, a B annulus line between the second casing hanger latching profile and the first casing hanger latching profile, and a C annulus line below the first casing hanger latching profile.

The annulus lines may be greatly advantageous. Legislation is expected to be implemented as soon as reliable technology is available, requiring monitoring of the B-annulus. A direct access monitoring system, made possible by the B annulus line has the benefit that it may last for the lifetime of a well, something which remote systems powered by batteries may not be able to offer. Furthermore, the annulus lines may offer a direct flow path to an annulus, which may allow for more efficient cementation techniques.

In the following are described examples of preferred embodiments illustrated in the accompanying drawings, wherein:

Fig. 1 illustrates an embodiment of the apparatus for performing at least one operation to construct a well subsea;

Fig. 2 shows a portion of the apparatus of Fig. 1, prior to insertion of a bore protector;

Fig. 3 shows the portion of the apparatus of Fig. 1 comprising the bore protector;

Fig. 4 shows the portion of the apparatus of Fig. 2 comprising a wear bushing;

Fig. 5 shows the apparatus comprising a suction caisson, an interface spool and a protective structure, as the apparatus is lowered to a seabed;

Fig. 6 shows the apparatus installed in a seabed, with the suction caisson forming a foundation;

Fig. 7 shows the apparatus having been installed in the sea floor, with a hatch of the protective structure having been closed;

Fig. 8 shows the apparatus in place in the seabed, with the protective structure opened;

Fig. 9 shows an embodiment of the apparatus comprising a B annulus line; and

Fig. 10 shows a subsea drilling system for drilling exploration wells.

Figure 1 illustrates an embodiment of the apparatus 1 according to the first aspect of the invention, wherein the apparatus 1 comprises several advantageous features that separates it from prior art.

The apparatus 1 is arranged with a bore 100, a flow line 200, an external circulation line 300, and a crossover line 400. The flow line 200, the external circulation line 300 and the crossover line 400 all form flow paths from the bore 100.

The flow line 200 comprises a production master inner valve 203 and a production wing valve 204, which are both fail-safe valves. Furthermore, the flow line 200 comprises a production bore pressure and temperature sensor 205, enabling reading of pressure and temperature between the production master inner valve 203 and the production wing valve 204. The flow line further comprises a flow line connector 206, for connecting to an external flow line. The flow line 200 is connected to the main bore of the apparatus 1, such that a flow path is formed from the main bore 100 to and from the flow line 200.

The external circulation line 300 and the crossover line 400 shares a fail-safe annulus master valve 15 and an annulus bore pressure and temperature sensor 14, enabling reading of pressure and temperature in the lines 300, 400. The line shared by the external circulation line 300 and the crossover line 400 may be referred to as an annulus line. The annulus line comprises a bore 3 through a wall of a body 2 of the apparatus 1. Through the bore 3 through the body 2 of the apparatus 1, the annulus line connects to the main bore 100 of the apparatus 1. The crossover line 400 further comprises a crossover valve 404.

The external circulation line 300 comprises an ROV valve stab receptacle 301 comprising a male hot-stab receiver 303 and a female hot-stab receiver 302. As there may be a need for a double barrier between the end of the external circulation line 300 leading into the bore 100 and the end of the external circulation line 300 adapted to receive an ROV, this embodiment comprises a not shown fail-safe barrier valve comprised by the ROV valve stab receptacle 303.

The apparatus 1 in this embodiment further comprises an mandrel 9 which may be an 18 ¾" mandrel with H4 profile, for forming an interface to a drilling BOP or a Cap connector or other equipment and a full-bore isolation valve 10 for isolating the main bore 100,

Furthermore, the apparatus 1 comprises a control line system 500 comprising an ROV valve stab receptacle 501, a male hot-stab receiver 503 and a female hot-stab receiver 502, three control lines 507 and three tubing hanger down hole line seals 510 for sealing off down hole tubing hanger ports.

The apparatus 1 further comprises an inductive downhole line pressure sensor system 600, for reading pressure on downhole sensors. The system comprises means for inductive communication for sending power to and sending and/or receiving signals from a not shown downhole gauge system.

Furthermore, the apparatus comprises an upper tubing hanger seal 5 and a lower tubing hanger seal 6, providing a sealing system for sealing off the flow line 200.

The apparatus further comprises a concentric tubing hanger 19, for forming an interface between production outlet and production tubing, latching grooves 11 for enabling casing hanger latching rings to lock casings to the apparatus 1, an upper casing hanger 13 and a lower casing hanger 12, and two casing hanger seal and lock assemblies 18 for enabling hangers to be locked and sealed to the apparatus 1.

Figure 2 is included to show an embodiment of the apparatus 1, prior to insertion of a bore protector into the bore 100. Figure 3 shows the same embodiment of the apparatus 1, wherein the apparatus 1 comprises the bore protector 101. The bore protector 101 may be inserted into the bore 100 to protect it and particularly sensitive equipment connected to the bore 100 from being polluted or otherwise damaged by drilling or cementing operations being performed through the bore 100. The bore protector 101 may be a wear bushing 102, as illustrated in figure 4. A wear bushing 102 is a type of bore protector 101 having a slightly smaller diameter than the bore protector 101. Wear bushings 102 are typically chosen to fit the size of drill bit to be used or casing or tubing to be installed through the bore 100.

Figures 5 shows an embodiment of the apparatus 1 comprising a suction caisson 31, an interface spool 700, a protective structure 800 and a lifting cap 25. The lifting cap 25 is fitted onto the 18 ¾" H4 mandrel with a H4 profile 9. Figure 5 further shows a wireline 70 connected to the lifting cap 25, for lowering the apparatus 1 onto a seabed 80.

The protective structure 800 comprises a hatch 801 that can be open or closed. In the scenario illustrated in figure 5 it is open for allowing the wireline 70 to be connected to the lifting cap 25.

The interface spool 700 mates a main body 2 of the apparatus 1 to the suction caisson 31. The suction caisson 31 is arranged to form a foundation for the apparatus 1, and to carry structural loads such as vertical loads, horizontal loads and torque, and the interface spool 700 is arranged to transfer such loads from the main body 2 of the apparatus 1 to the suction caisson 31 foundation. The interface spool comprises two pipes forming two outlets 701 for cement returns for routing cement onto the seabed 80 during cementing operations. The outlets 701 allow cement returns to flow onto the seabed 80 instead of returning into the apparatus 1, which may be beneficial e.g. to avoid pollution of the bore and sensitive equipment comprised by the apparatus 1, such as valves and latches.

The protective structure 800 forms a protective shield for the apparatus against the subsea environment.

Figure 6 shows the apparatus 1 when installed in the seabed 80. The suction caisson 31 has sucked into the seabed 80 and created a foundation for the apparatus 1.

Figure 7 shows an embodiment of the apparatus 1 installed in the seabed 80, wherein the wireline has been disconnected from the apparatus and the hatch 801 of the protective structure 800 has been closed.

Figure 8 illustrates an embodiment of the protective structure 800 that may be opened more completely than just by opening a hatch. The protective structure 800 is pivotally connected to the suction caisson 31, and may pivot so that it opens up for a more complete access to the apparatus 1 for external equipment, for maintenance, for manipulation of the system, or for other reasons.

Figure 9 shows the apparatus 1 comprising a B annulus line 900 for monitoring fluid characteristics in and/or bleeding off pressure from and/or circulating fluid in and/or for injecting cement into an annulus in a well. The annulus line 900 comprises a bore 901 through a wall of a body 2 of the apparatus 1. Furthermore, the annulus line comprises a pressure and temperature sensor 905 between two valves 902, 903, and an ROV hot-stab receptacle 904.

Figure 10 shows a subsea drilling system 1000 for drilling exploration wells, wherein the drilling system comprises a suction caisson 31, an interface spool 700 and a high-pressure mandrel 1001 arranged to form an interface between the subsea system and a not shown drilling blowout preventer and/or a not shown Christmas tree. The interface spool 700 comprises cement outlets 701.

Note that the drawings are shown highly simplified and schematic and the various features therein are not necessarily drawn to scale. Identical reference numerals refer to identical or similar features in the drawings.

It should further be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements.

The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

C l a i m s

1. An apparatus (1) for performing at least one operation to construct a well subsea, the apparatus (1) comprising a plurality of valves (203, 204, 15, 10, 404) such that the apparatus (1) forms a flow control assembly for controlling fluid flow during production of hydrocarbons from the well, the apparatus (1) characterized in being arranged with a through bore (100) configured for allowing drilling and installation of casings and casing hangers (12, 13) to be performed through the bore (100).

2. The apparatus (1) according to any one of the previous claims, further comprising a suction caisson (31) for acting as a well foundation.

3. The apparatus according to any one of the previous claims, further comprising a full-bore isolation valve (10).

4. The apparatus (1) according to any one of the previous claims, further comprising a protective structure (800).

5. The apparatus (1) according to any one of the previous claims, further comprising an external circulation line (300).

6. The apparatus according to claim 5, wherein the external circulation line (300) comprises an ROV receptacle (303).

7. The apparatus (1) according to claim 6, wherein the ROV receptacle (303) is a hot stab receptacle (303).

8. The apparatus (1) according to any one of the previous claims, further comprising an interface spool (700) for forming an interface between a main body of the apparatus and a foundation (31).

9. The apparatus (1) according to any one of the previous claims, further comprising a B annulus line (900) for providing a flow path to an annulus on an outer side of a casing for monitoring fluid characteristics in the annulus.

10. A method for constructing a well, the method comprising the step of:
   1. drilling a hole into a formation for a subsequent installation of a casing, wherein the drilling is performed through a bore (100) in an apparatus (1) according to any one of the claims 1-9.

11. The method for constructing a well according to claim 10, the method further comprising the step of:

2. installing a casing into the hole in the formation through the bore (100) of the apparatus (1).

12. The method for constructing a well according to claim 11, the method further comprising the step of:
3. performing a cementing operation in a well, wherein the cementing operation is performed through the bore (100) of the apparatus (1).

13. The method according to any one of the claims 10-12, wherein the hole in the formation is for the installation of a casing with a diameter greater than the diameter of a production tubing to be installed subsequently during the well construction process.

14. The method for constructing a well according to any one of the claims 10-13, the method further comprising the step of:
4. installing an apparatus (1) comprising a flow control assembly on a seabed, wherein the bore (100) through which the drilling is performed is a bore (100) through the apparatus (1), and wherein the installation of the apparatus (1) is performed prior to the step of drilling a hole into a formation for a subsequent installation of a casing.

15. The method according to claim 14, wherein installing the apparatus (1) comprises the step of establishing a foundation (31) for a well.

16. An apparatus for performing at least one operation to construct a well subsea (1) comprising a B annulus (900) line for monitoring fluid characteristics in an annulus formed on an outer side of a casing in a well.

17. An interface spool (700) for mating a main body (2) of an apparatus for performing at least one operation to construct a well subsea with a well foundation (31), the interface spool comprising an outlet for cement returns (701) for releasing cement returns onto a seabed.

18. An external circulation line (300) for a subsea system (1), wherein the external circulation line (300) comprises an ROV receptacle (303) for connecting a hose to the external circulation line (300) by use of an ROV.

19. The external circulation line (300) according to claim 18, wherein the ROV receptacle (303) is a hot stab receptacle (303), and wherein the hot stab receptacle (303) comprises a valve.

20. The external circulation line (300) according to claim 18 or 19, wherein the external circulation line (300) connects to a flow line (200) of the subsea system through a valve (404).

21. The external circulation line (300) according to any one of the claims 18-20, wherein the external circulation line (300) connects to an annulus of the subsea system (1) through a valve (15).

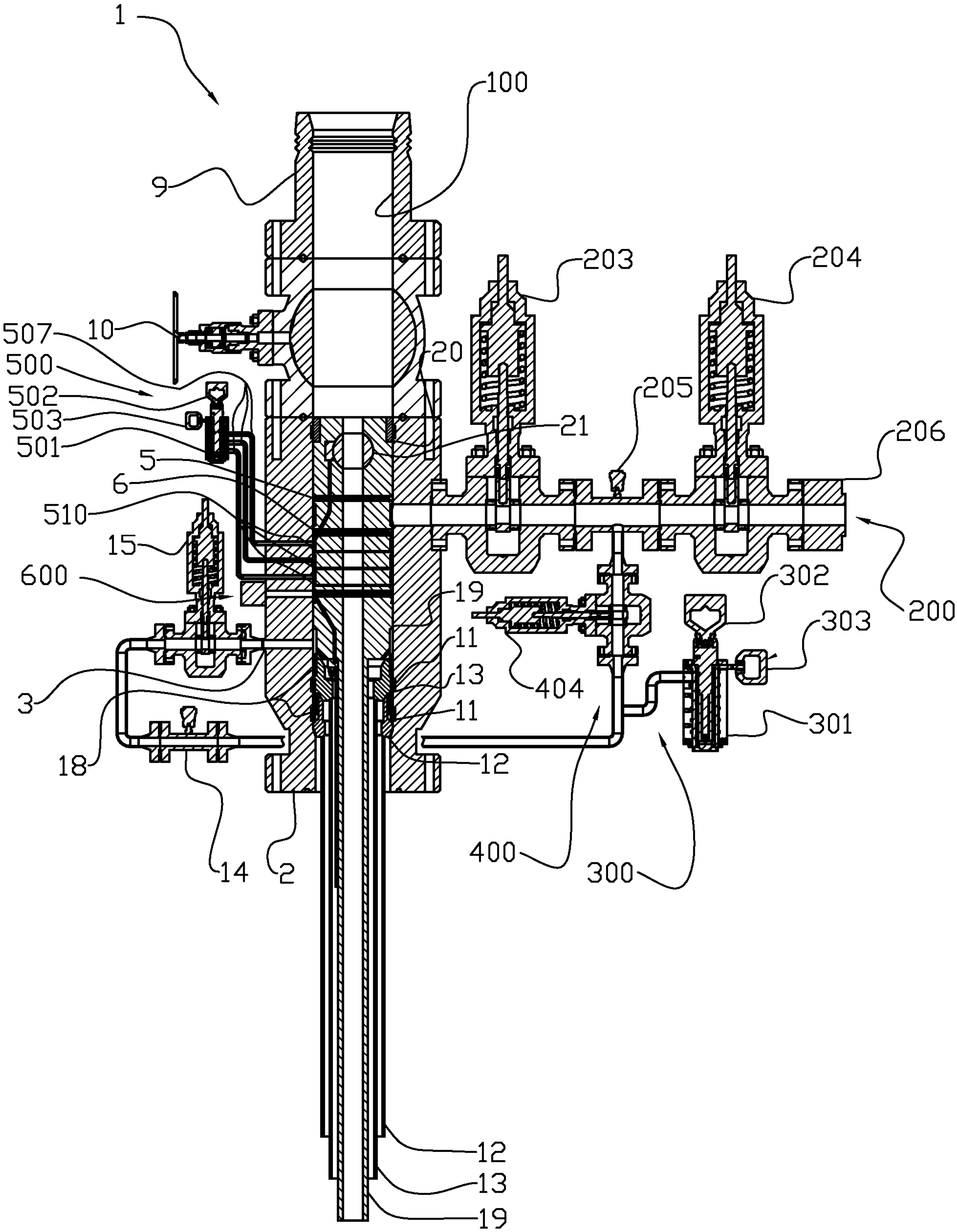

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Fig. 1

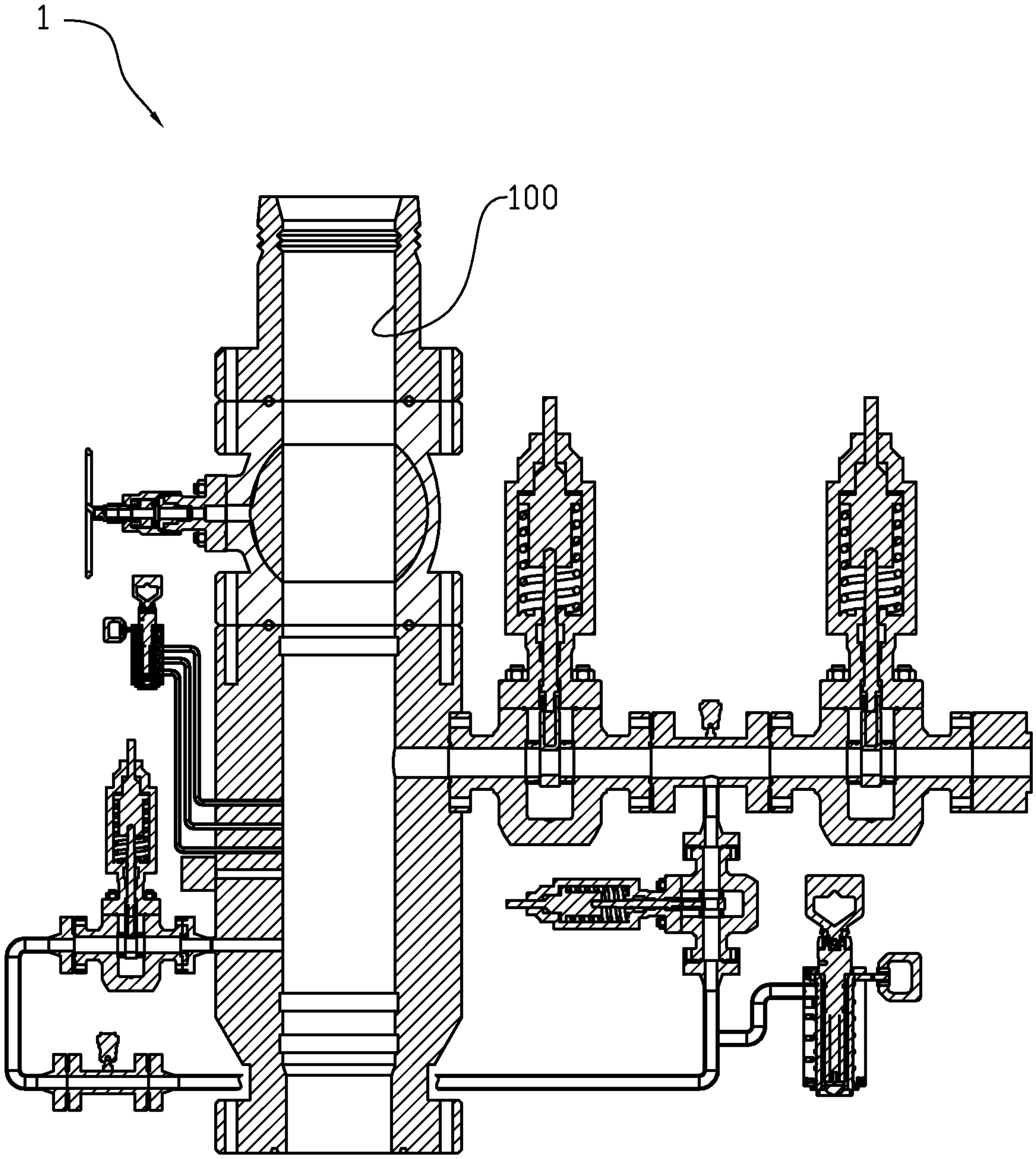

Fig. 2

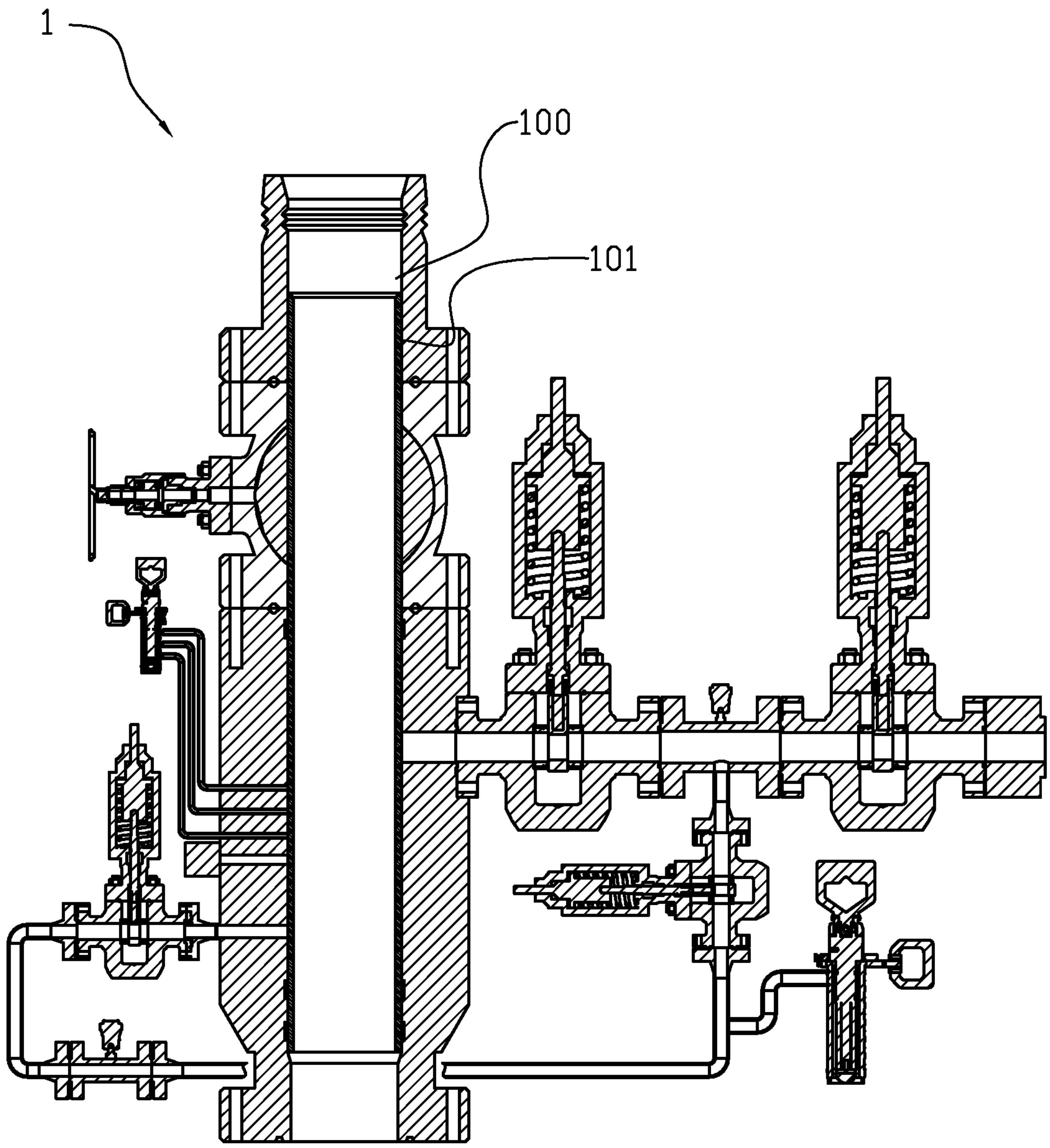

Fig. 3

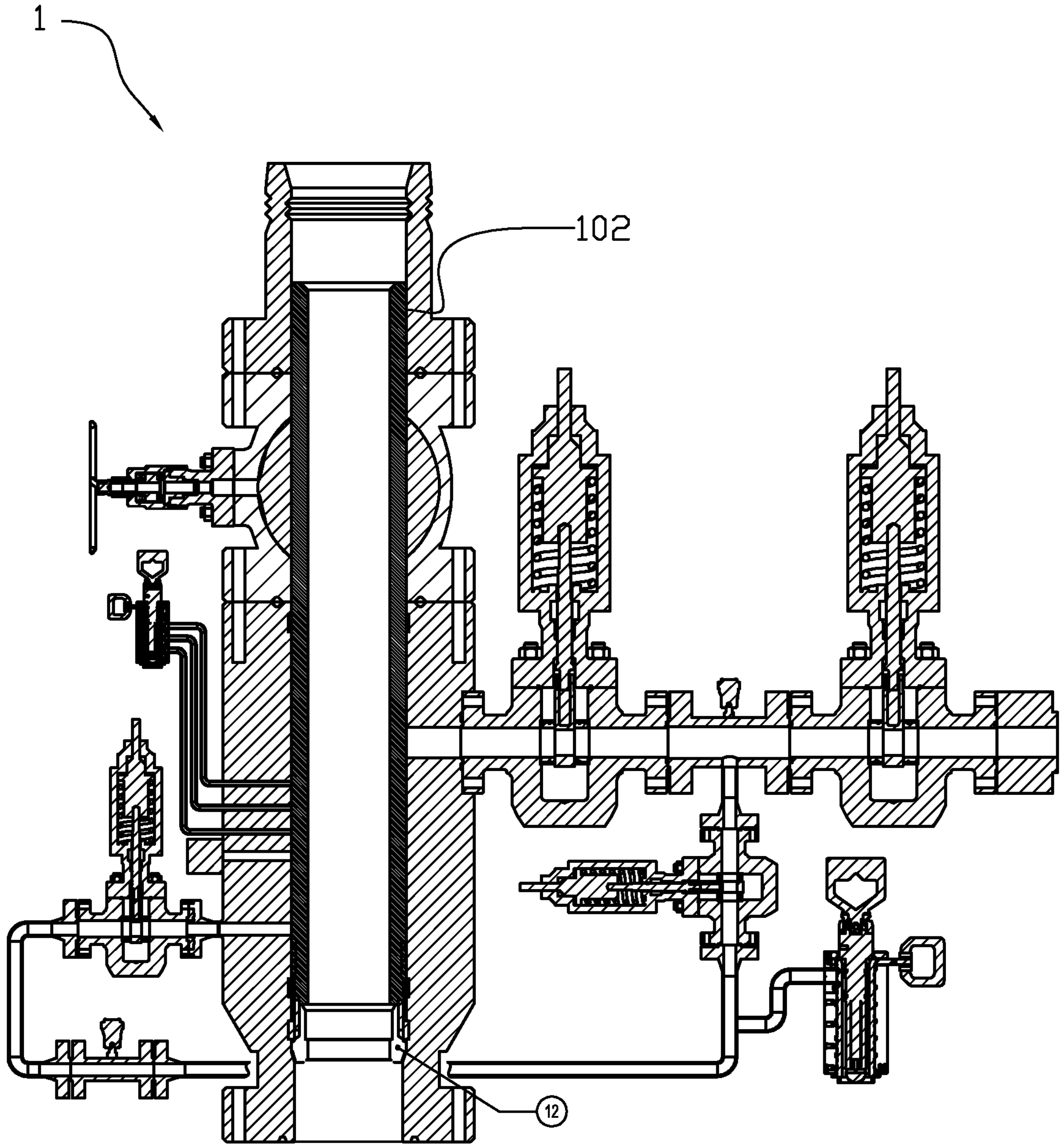

Fig. 4

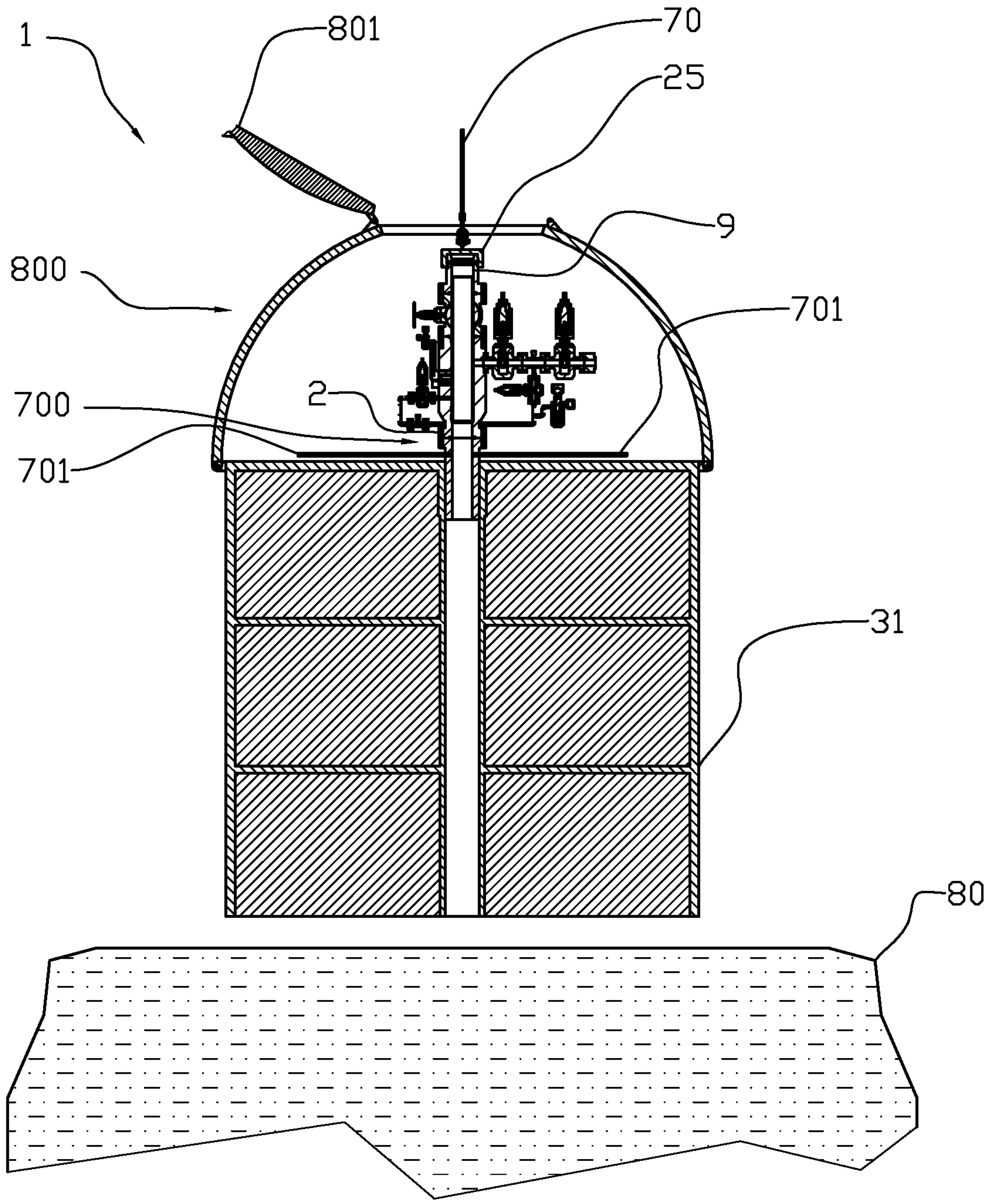

Fig. 5

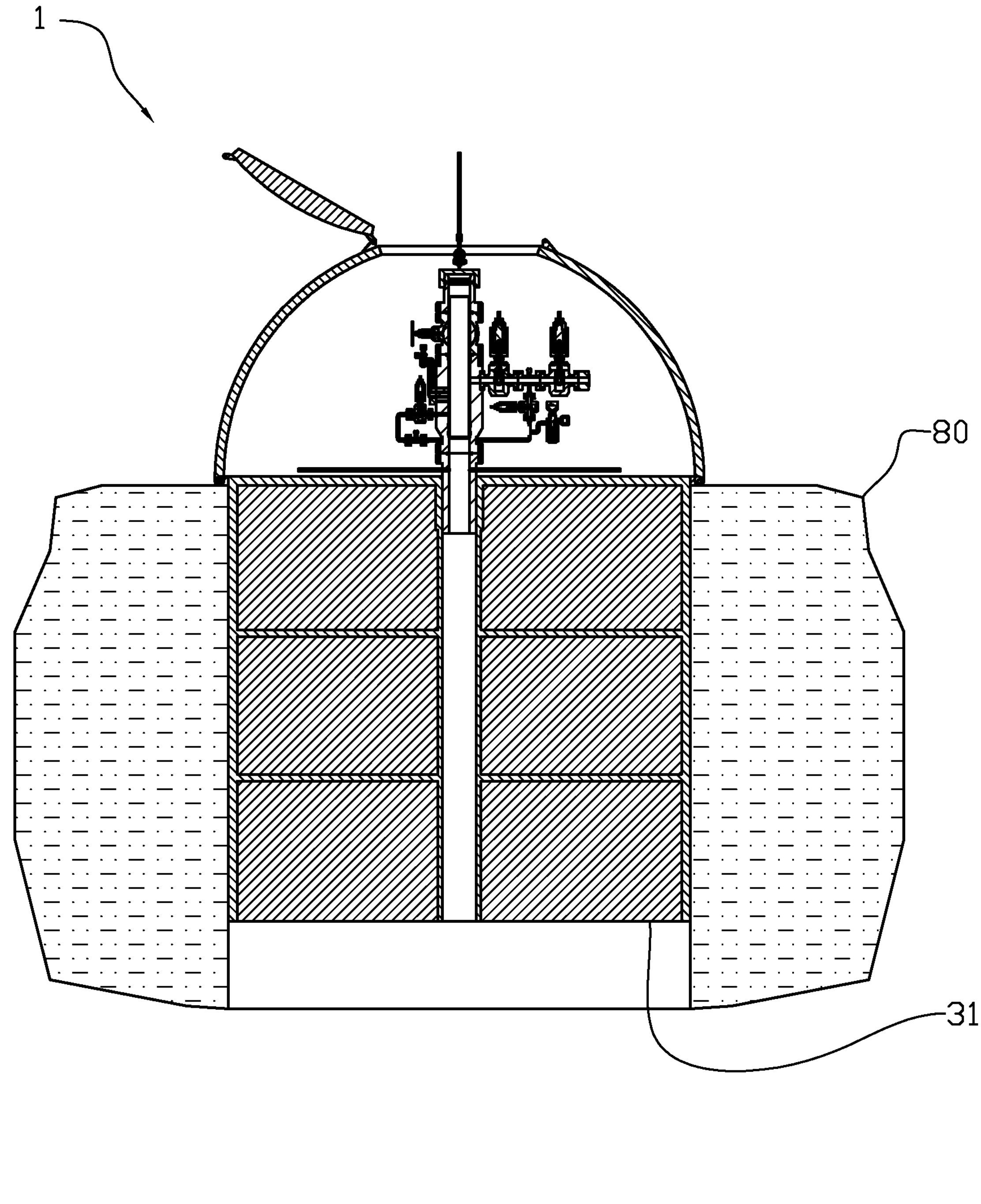

Fig. 6

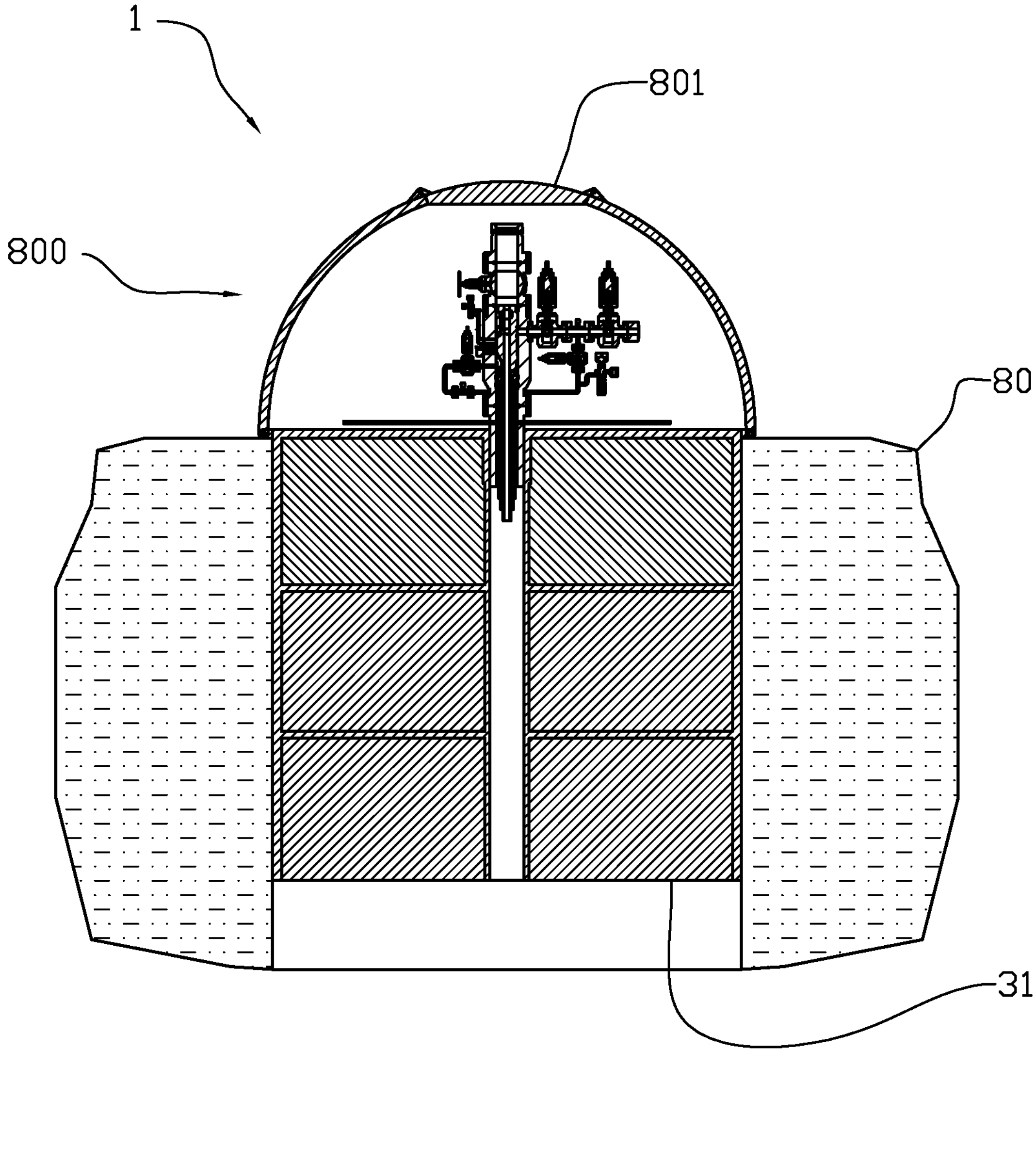

Fig. 7

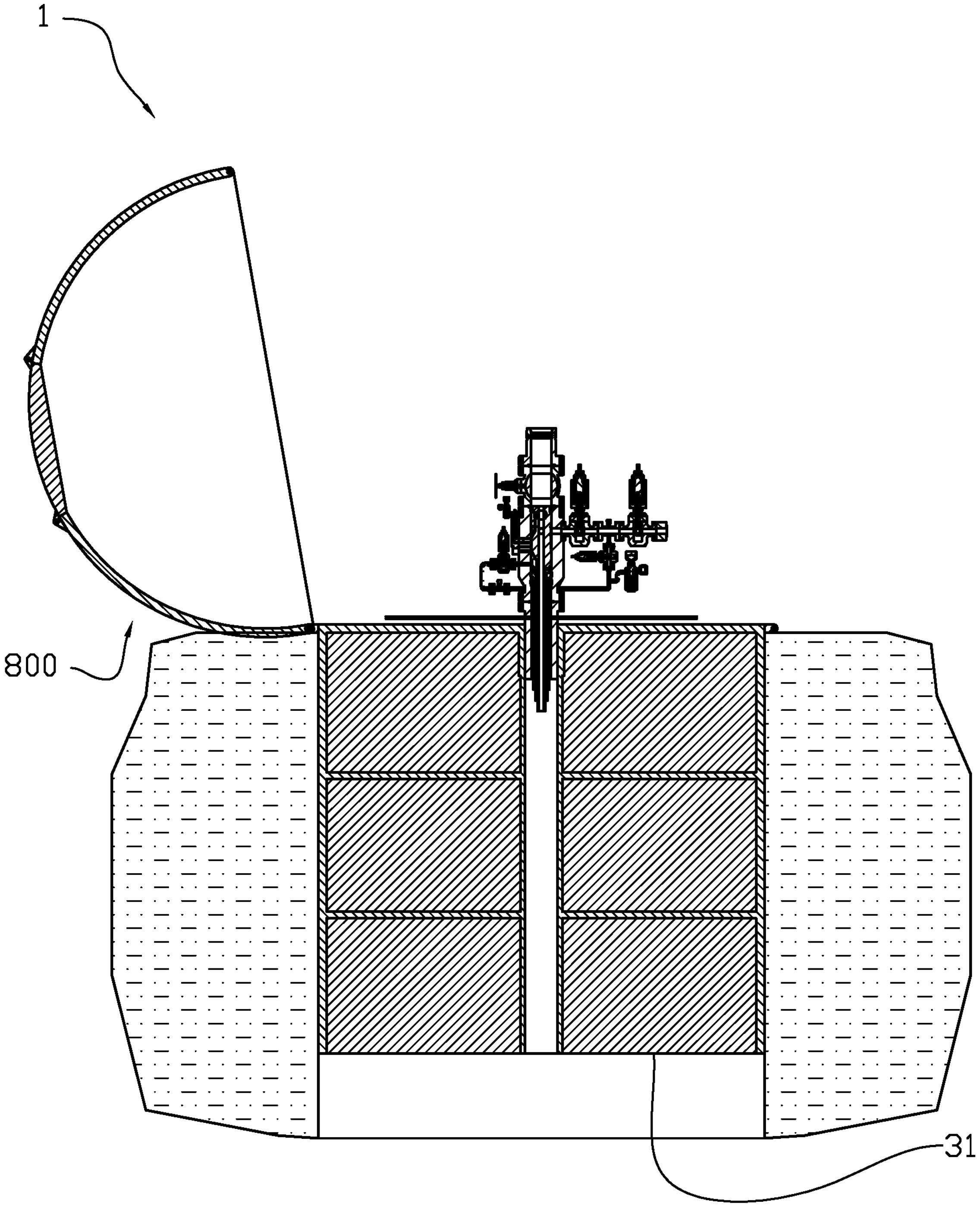

Fig. 8

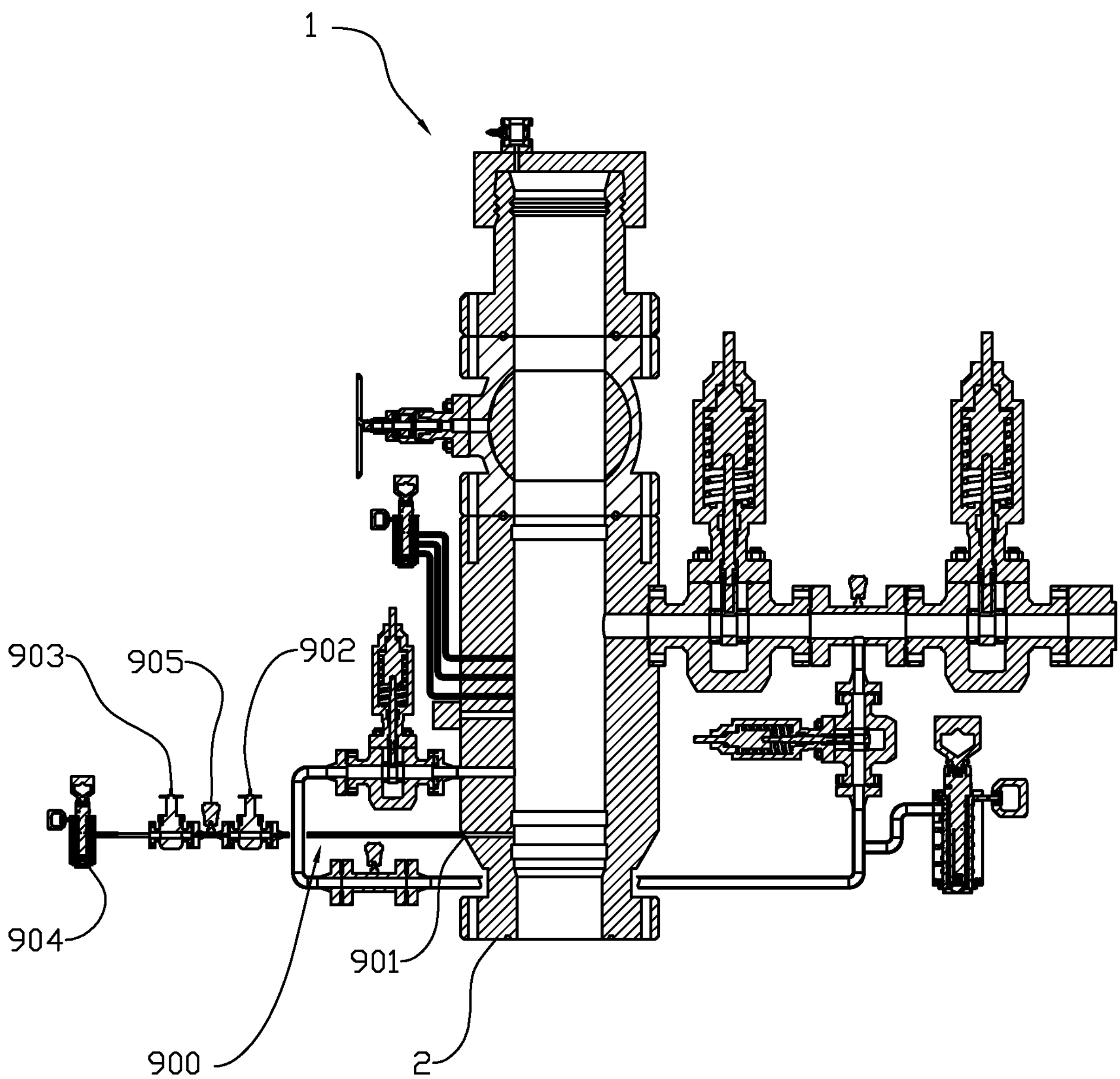

Fig. 9

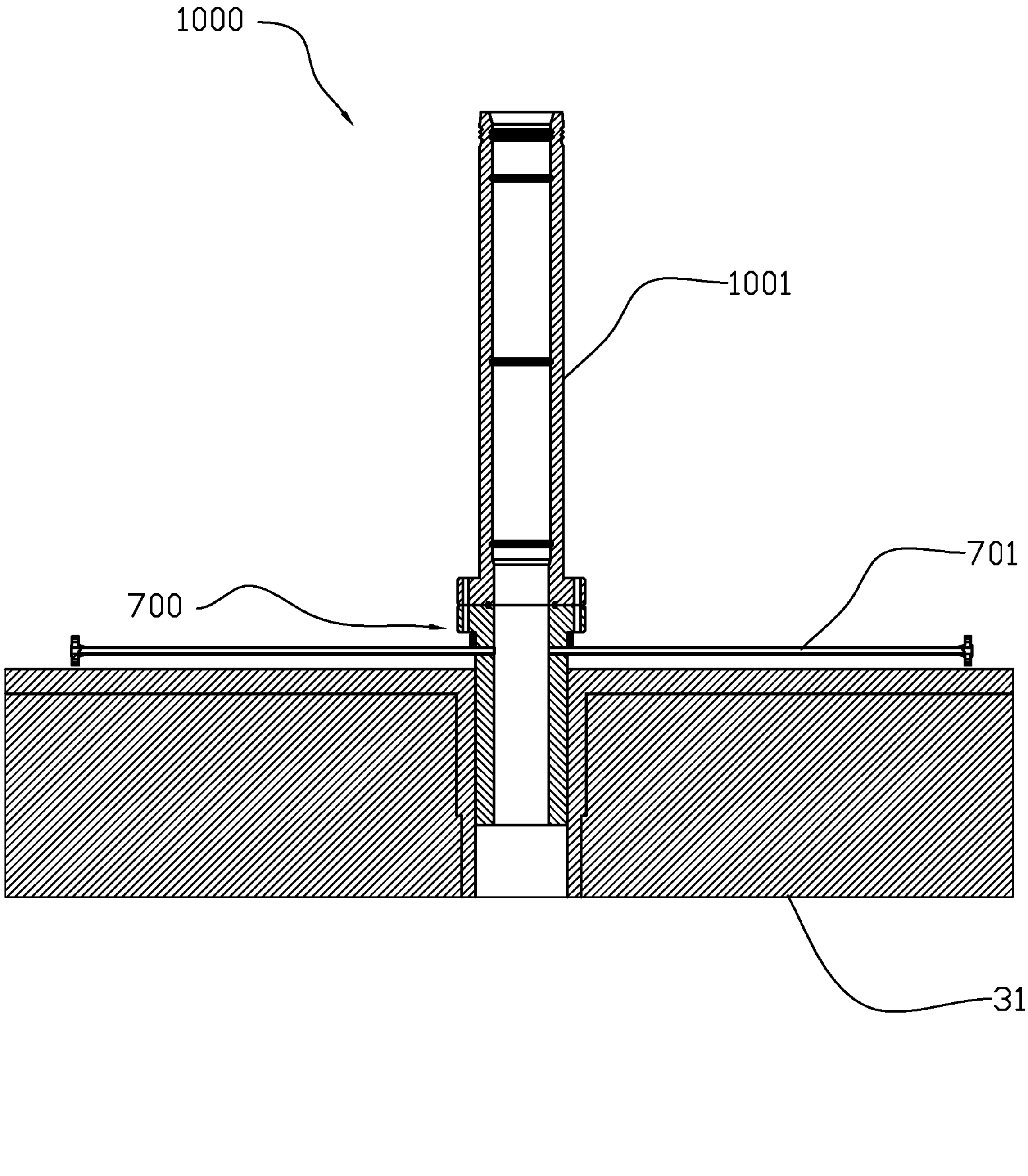

Fig. 10