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DEEPWATER SLIM HOLE WELL CONSTRUCTION

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable.

FIELD OF THE INVENTION

The present invention relates generally to the construction of wells. More particularly, the present invention relates to constructing wells using reduced diameter tubulars, i.e. slim hole technology. Still more particularly, the present invention relates to constructing wells using slim hole technology in deepwater applications.

BACKGROUND OF THE INVENTION

As fields become mature and production rates drop, major oil companies are slowly moving to deepwater fields. However, deepwater operations can be very costly because of the operating environment. Furthermore, deepwater fields are located in uncharted territories, so deepwater exploratory drilling activity is constantly on the rise. Deepwater wells also tend to be very high pressure wells that require heavy duty equipment to safely drill and produce.

Traditional well construction, such as the drilling of an oil or gas well, includes a wellbore or borehole being drilled through a series of formations. Each formation, through which the well passes, must be sealed so as to avoid an undesirable passage of formation fluids, gases or materials out of the formation and into the borehole or from the borehole into the formation. In addition, it is commonly desired to isolate both producing and non-producing formations from each other so as to avoid contaminating one formation with the fluids from another formation.

As the well is drilled deeper, conventional well architecture includes casing the borehole to isolate or seal each formation. The formation may also be cased for borehole stability due to the geo-mechanics of the formation such as compaction forces, seismic forces and tectonic forces. The casings prevent the collapse of the borehole wall and prevent the undesired outflow of drilling fluids into the formation or the inflow of fluids from the formation into the borehole. The borehole may need to be cased due to equivalent circulating density and hydraulics reaching or exceeding the formation pore pressure or exceeding the fracture gradient pressure thus allowing fluids or gases to transfer between formations and borehole. If the formations are non-producing, or not of the desired producing interval, (some intervals are producing but at low levels) the formations can be cased together. If shallow water flows (where water flows several hundred feet below the seabed floor), or if there is potential communication among formations, then the formation is cased. The casings extend downhole and are sequentially placed across the
formations through which the wellbore or borehole passes. The casings may be liners which do not extend to the top of the wellbore, i.e. the wellhead. Traditionally, steel casing has been used to case off formations.

In standard practice, each succeeding casing placed in the wellbore has an outside diameter significantly reduced in size when compared to the casing previously installed, particularly to accommodate hangers for the inner strings, and may be described as a series of nested casing strings. The borehole is drilled in intervals whereby a casing, which is to be installed in a lower borehole interval, is lowered through a previously installed casing of an upper borehole interval. As a consequence of this procedure, the casing of the lower interval has a smaller diameter than the casing of the upper interval. Thus, the casings are in a nested arrangement with casing diameters decreasing in the downward direction.

The use of a series of casings, which have sequentially reduced diameters is derived from long experience. The number of casings required to reach a given target depth is determined principally by the properties of the formations penetrated and by the pressures of the fluids contained in the formations. If the driller encounters an extended series of high pressure/low pressure intervals, the number of liners required under such circumstances may be such that the well cannot usefully be completed because of the continued reduction of the casing diameters required. Along with the downsize serial casing operations, the production tubulars may have to be downsized as well further reducing the delivery capacity of the well.

If the borehole extends through a formation that tends to cave in and thus causes the borehole to be very unstable, casing inserts must be installed to keep the borehole open. A casing insert is a type of emergency casing string which shores up an unstable formation and is an additional section of casing that is set through this unstable portion of the borehole. By requiring a casing insert for this unstable formation, an even smaller size casing than was planned is then required to complete the well. This reduces the diameter of the well and thus the ultimate internal diameter available for the production tubulars. The casing insert may not be possible, requiring that the well be sidetracked, resulting in a substantial reduced diameter wellbore.

The disadvantages of nesting casing and liners is apparent in slim hole drilling. A slim hole well is one in which 90% or more of the length of the well is drilled with bits smaller than 7 inches in diameter. See SPE 19525: An Innovative Approach to Exploration and Exploitation Drilling: The Slim-Hole High-Speed Drilling System by Walker and Millheim, September 1990, hereby incorporated herein by reference. Slim hole drilling focuses on starting with a small borehole and finishing with an even smaller borehole for production.
Conventional deepwater well construction usually starts with the riserless setting of a 30" conductor casing. This conductor is followed by setting an 18-3/4" tree under a 21" ID (inside diameter) riser system. From there, the casing program requires 20" casing, followed by a 16" liner, followed by 13-3/8" casing all the way to the mud line. From there, sometimes either an 11-3/4" or a 9-5/8" liner is hung, followed by 7" casing all the way to target depth.

Some attempts have been made in reducing the size of the riser from 21" to 16". A well drilled using a 16" riser may conventionally have a 30" conductor casing followed by 13-3/8" and 9-5/8" casing leading into a 7-5/8" liner. Using a 16" diameter riser allows for a reduction in cost relative to a 21" riser but is still a complex, expensive well. Smaller diameter risers have been used in production and workover application but are not currently used in drilling.

As a consequence of the nested arrangement of the casings, a relatively large diameter riser and initial borehole are required. High capacity, large diameter pressure control equipment is also required to restrict flow through these large tubulars. Because the riser and the upper casing(s) have to be larger than the lower casing(s) for the lower casing(s) to pass through the upper casing(s), the upper portion of the borehole and riser typically have a much larger diameter than the intended ultimate diameter at the bottom of the borehole. Large boreholes are also disadvantageous in that they generate large amounts of cuttings. The large annular volumes contained by these large tubulars also require increased volumes of drilling fluid and cement, which in turn requires equipment to process and store these fluids.

In the standard well casing configuration, large volumes of cuttings are produced initially and heavy logistics are required during early phases of drilling. Generally speaking, larger borehole sizes take longer to drill than smaller diameter boreholes at equivalent depth. For example, increased drilling rig time is involved due to required cement pumping and cement hardening. Further, a large borehole diameter often takes larger fluid and horsepower capacity rigs generating increased costs due to heavy casing handling equipment and large drill bits. Thus conventional equipment results in larger boreholes drilled for each formation, larger sized equipment, greater fluid volumes, and larger casing strings than is absolutely required to provide a borehole for a well, for an injecting or producing or monitoring.

Utilizing a large borehole often causes the usage of a wide variety of equipment and fluids that might not achieve maximum efficiency for the drilled borehole. If problems arise, additional fluids must be pumped and additional cement must be used to cement the formation to overcome the variances encountered during conventional well construction, otherwise a side track must be performed.
Conventional well architecture, engineering, and planning accounts for potential problem migration, well plan variance, and contingency. Therefore, large tolerances in equipment and procedures are provided in anticipation of variances in the length and/or composition of the formations, geomechanics, and growth/loading design. Compensation in the well architecture, engineering, and planning must be included in the well plan for contingency due to such large tolerances, including drilling for additional casing strings for geomechanical problems and sidetracks and re-drills for the installation of casing inserts prior to reaching the reservoir formation.

The present methods of drilling deepwater exploratory and development wells includes the use of large vessels to support the use of large tubulars. Typically fourth or fifth generation semisubmersibles or drillships are needed in order to accommodate large risers which are needed due to the high hydrostatic pressures in deepwater, and to accommodate large casing programs. Large risers are typically not rated for high pressure and are therefore coupled with wet blowout preventers (BOPs). These wet BOPs are large, heavy, and must be installed on the seafloor where the risk involved in testing them can be quite high since if the BOP does not test properly, it often has to be returned to the surface and several trips may be needed to remedy the problem. Considering it may take a day or two to retrieve a BOP from the seafloor, these trips can be very costly, both in terms of rig time and wear on equipment. Large riser systems also demand large fluid volumes that add to the cost and logistics as all this fluid needs to be stored, treated, and handled on the rig. Larger fluid volumes also impact the method of drilling, casing, and completing the well.

Furthermore, large risers hinder hole cleaning as annular flow decreases. If annular velocities in the open hole annulus are required to be increased to remove the cuttings, the equivalent circulating density (ECD), i.e. the pressure increase in the well due to circulating pressure, could potentially fracture the well. This is not desirable, especially in wells where there is not much difference between the fracture gradient and the pore pressure gradient. Larger risers therefore, sometimes require booster pumps to circulate the fluid, or even running an extra liner with a reduced ID that increases annular velocities. The large annular areas in large riser systems may also allow helical buckling in the drillstring, thus limiting the reach and weight on bit control and affecting the performance and integrity of drilling tools.

Thus, the ability to provide a reduced diameter riser has the potential of improving drilling processes. Of course, a necessary consequence to employing a reduced diameter riser is the inevitable construction of a reduced diameter wellbore. As the wellbore gets smaller, the operator's options regarding equipment and tools he can run into the wellbore becomes limited.
In production wells, the size of the wellbore through the producing zones may limit the flow rates and pressures at which hydrocarbons can be produced to uneconomical levels. In exploration wells, a smaller diameter wellbore may be acceptable but must still be large enough to accommodate the desired logging and measurement tools for thorough formation evaluation.

One concept for maintaining the largest possible wellbore is the monodiiameter well, which seeks to create a wellbore with a single, constant diameter. The monodiiameter well is designed based on the borehole size required across the reservoir. Rig capacity and all the drilling and completion equipment for the entire well is sized to the reservoir borehole size. Upon the advent of the monodiiameter well, the telescoping well design with all its associated and myriad selection of drilling and completions equipment will become obsolete. The monodiiameter well will achieve dramatic reductions in well construction costs. The challenge to the industry is to develop the full suite of enabling and complimentary technologies that will be required to drill and complete a monodiiameter well. This suite of equipment will include drilling equipment, reaming while drilling (RWD), bi-center bits, energy balanced bits, near bit reamers, open hole annular sealing, well control procedures, well control equipment, and wellheads among others.

Expandable tubulars are also being developed to provide casings and liners that can be expanded diametrically after they are placed in wellbores. The ultimate use of expanded tubulars is in a monodiiameter well, whereby the entire well is drilled and cased using effectively one hole size. A solid steel tubular can be readily expanded using forces, either mechanical or hydraulic, available on most drilling and workover rigs. Expandable tubulars can be used in open hole either as a temporary drilling liner or as a permanent liner tied back to the previous casing string. See SPE 54508: "The Reeled Monodiiameter Well" by Pointing, Betts, Bijleveld, and Al-Rawahi, presented at the 1999 SPE/CoTA Coiled Tubing Roundtable, May 25-26, 1999, hereby incorporated herein by reference, and SPE 65184: "Towards a Mono-Diameter Well – Advances in Expanding Tubing Technology" by Benzie, Burge, and Dobson, presented at the SPE European Petroleum Conference, October 24-25, 2000, hereby incorporated herein by reference.

Threaded connections of lengths of expandable casing or liner remain the primary connection of choice. However, the connection has to be internally flush to allow the die member to pass through the connection, and externally flush to allow expansion to occur with constant expansion force. SPE 54508: "The Reeled Monodiiameter Well" by Pointing, Betts, Bijleveld, and Al-Rawahi, presented at the 1999 SPE/CoTA Coiled Tubing Roundtable, May 25-26, 1999, hereby incorporated herein by reference, discloses using coiled casing that maintains a single diameter of well bore throughout. Coiled casing can be used in the production of a monodiiameter
wellbore as well as tubular jointed expandable casing. Coiled casing can be expanded or installed non-expanded. A reeled monodiameter casing or liner has the same throughbore.

Another recent advancement in small diameter drilling technology is coiled tubing. Long used in completion and workover technologies, coiled tubing is gaining increased acceptance in drilling applications. Coiled tubing is a non-jointed, continuous drill string that is stored on a reel and uncoiled to be fed into a wellbore. Because the coiled tubing is stored on a reel, as opposed to standard vertical pipe storage, the required deck space to store the drill string is reduced. Further, because a coiled tubing drill string is a continuous, single length of tubing, which may be continuously fed from the reel into the water and down into the well, the time required to connect and disconnect the joints of a conventional drill string is eliminated, thereby significantly reducing the overall time required to conduct drilling operations.

One particular type of coiled tubing is a non-metal coiled tubing drill string, such as the composite coiled tubing disclosed in US Patent 6,296,066 to Terry et al., hereby incorporated herein by reference for all purposes. Composite coiled tubing may be preferable to metal pipe or metal coiled tubing because it weighs less and is substantially less subject to fatigue inducing stress variations due to trips into and out of the well, movement of the floating platform, and deflection in deviated wellbores. Composite coiled tubing can also be built with integral electrical conductors to facilitate communication between the surface and the bottom hole assembly.

Notwithstanding the foregoing described prior art, there remains a need for a deepwater slim hole drilling system. These and other features and advantages are found in the present invention.

SUMMARY OF THE PREFERRED EMBODIMENTS

The methods and apparatus of the preferred embodiments are for drilling deepwater wells using slim hole technology. A surface platform installs a guide base and a first string of structural casing into the formation using riserless drilling techniques. A small diameter, high pressure riser is used to connect the surface platform to the casing at the seafloor. Pressure control equipment is positioned on the platform at the upper terminus of the riser and drilling is commenced using a composite coiled tubing drilling system. Standard, expandable, or chemical casing may be used as desired as the well is drilled to a target depth. The drilling assembly also preferably includes measurement or logging-while-drilling equipment enabling formation evaluation while drilling continues.

The preferred embodiments provide a cost effective alternative to present deepwater well construction by encompassing various facets of the exploratory/development process,
including drilling, logging and testing, completions, and production. Aside from minimizing costs, the preferred embodiment of the invention minimizes the number of wells drilled by either drilling several laterals from the same wellbore or re-entering previously completed wells.

In certain embodiments, the use of a high pressure riser having an outside diameter of 7" allows for the use of smaller drilling vessels, including the use of second or third generation semi-submersibles for deepwater applications of 5000 ft or more of water. The use of a small diameter riser also decreases the fluid handling requirements of the drilling vessel and improves cuttings lift capability (hole cleaning).

In certain embodiments, the use a highly flexible coiled tubing, such as composite coiled tubing, enables slim hole complex well paths and geosteering; short radius deviations allowing deviated wells within 1000 meters from mud line; and drilling in unconsolidated formations. One preferred composite coiled tubing also has integral electrical conductors to allow real-time communication between the surface platform and a tool disposed in the wellbore. This allows for real-time formation evaluation while drilling. Real-time communication may also allow for increased drilling efficiency by providing real-time pressure data from the bottom of the well.

In certain embodiments, a bi-center bit or reamer may be used to increase the wellbore diameter below the lowermost casing to facilitate the installation of a subsequent casing string. The cased wellbore diameter may be maintained through multiple tubing strings through the use of expandable casing.

Thus, the present invention comprises a combination of features and advantages that enable it to overcome various problems of prior art well construction. The various characteristics described above, as well as other features, objects, and advantages, will be readily apparent to those skilled in the art upon reading the following detailed description of the preferred embodiments of the invention, and by referring to the accompanying drawings.

**BRIEF DESCRIPTION OF THE DRAWINGS**

For a detailed description of a preferred embodiment of the present invention, reference will now be made to the accompanying drawings, which form a part of the specification, and wherein:

Figure 1 is a schematic representation of a deepwater, slim hole well system;

Figure 2 is a schematic elevational view of a floating platform with a coiled tubing system situated over a guide base installed at a subsea wellsite;

Figure 3 is schematic elevational view of the wellsite of Figure 2 with a casing string installed in the well;
Figure 4 is schematic elevational view of the wellsites of Figure 2 with the well completed using telescoping casing;

Figure 5 is schematic elevational view of the wellsites of Figure 2 with the well completed using monodiameter casing; and

Figure 6 is a schematic elevational view of a bottom-hole-assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention is susceptible to embodiments of different forms. There are shown in the drawings, and herein will be described in detail, specific embodiments of the present invention with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein.

The preferred embodiment of the present invention minimizes expenses for deepwater exploration and production wells. Deepwater wells are those wells in water depths exceeding 5000 feet. This cost reduction is achieved by using a much lighter and less complex system. This cost reduction is especially desirable in exploration wells where there is an increased chance of drilling a dry hole and there is no need to provide large, commercially viable, production quantities of hydrocarbons.

In general, referring to Figure 1, a deepwater slim hole well 10 is drilled from a surface platform 20 via riser 30. In the preferred embodiments, riser 30 includes a small diameter, high pressure riser, such a 7" OD high pressure riser, typically having an inside diameter of approximately 5.1 inches. The high pressure riser can be defined as a riser that is rated to the full working pressure of the well being drilled. The use of a small diameter, high pressure riser system allows for the use of a much smaller platform 20 as compared to those platforms required to handle 16" or 21" riser systems.

Specifically, a second or third generation semi-submersible may be used over conventional drill ships and/or fourth or fifth generation semi-submersibles. Smaller, more efficient drill ships may also be used. A second generation semi-submersible typically is used in shallow water, i.e. less than 1500 feet deep, and is often anchored to the ocean floor. A second generation semi-submersible is much smaller than a fourth or fifth generation semi-submersible and has a smaller deck size. With the preferred embodiments, the semi-submersible does not need to support a large load but preferably includes dynamic positioning capability. Dynamic positioning capability is preferred because in deepwater anchoring a vessel to the seafloor becomes impractical.
In one preferred embodiment, the casing program for well 10 begins with a 16" guide base 12. The guide base 12 is set riserless and will support all of the bending loads and other associated loads at the seafloor 11. Once the guide base 12 is secured to the seafloor, an 8-1/2" hole 13 is drilled in order to run 7" casing 14. This 8-1/2" hole 13 is drilled into relatively shallow formations and can therefore also be drilled riserless, with the cuttings being deposited at the seafloor 11. In some embodiments, a 7" casing 14 can be directly attached to the 16" guide base 12, obviating the need to run 9-5/8" casing. In other embodiments, a 9-5/8" casing string between the guide base 12 and 7" casing 14 may be appropriate. The 9-5/8" casing would also be set using riserless drilling techniques.

Once the upper level casings have been completed the 7" high pressure riser 30 is attached to the guide base 12 by connector 16. Because riser 30 is rated for the full working pressure of the well, a wet BOP is not required. Surface control equipment 22, including a surface blowout preventer (BOP), is preferably attached to the upper end of the high pressure riser 30 at the surface platform 20. The high pressure riser 30 may also preferably include a downhole pressure control system 17 to be used in case of a emergency disconnect of the riser from the guide base 12.

A drilling assembly 40 is then lowered through the high pressure riser 30 and initial string of casing 14 to drill additional bore hole. Although drilling assembly 40 may be small diameter drill pipe, the use of slim hole technology for hole sizes 7" and smaller encourages the use of coiled tubing as the basis for drilling assembly 40.

During drilling, additional casing points may be dictated by the formation, such as due to the formation pressure, and may require the setting of intermediate strings of casing. The intermediate casing may be, for example, a casing with a 5 inch inside diameter. The intermediate casing may also be expandable tubular having an outside diameter (OD) of 4.25 inches that is expanded to an OD of 5.5 inches in the borehole.

Once an intermediate casing has been set and cemented, the drilling assembly 40 is again lowered through the high pressure riser 30 and casing 14 to drill additional bore hole to the target depth. As the borehole is being drilled, then the well is available for logging and testing. These activities are preferably carried out using logging/measurement-while-drilling equipment that allows the drilling assembly 40 to remain in the well. Preferably, the bottom hole assembly 42 on the drilling assembly 40 includes logging tools that continuously log the formation around the bore hole as the bore hole is being drilled. Once target depth has been reached, the well can be completed for production purposes or plugged and abandoned as desired.
After the well is completed, or during drilling, various well operations may be conducted. For example, formations samples may be obtained and coring samples may be taken from the borehole. Coring may be conducted using a coring barrel underneath a motor. Percussion and sidewall coring are also possible. Vertical seismic profilling may be conducted such as from one well to another well. Additional wireline logging tools may also be run through the well or other tools may be run through the well to obtain real time data.

The formation may also be tested by producing the formation. For example, a screen may be deployed across the producing formation for controlling any sand production. The screen may be expandable. The screen may be supported from the lower end of the casing or may include a packer that supports the screen in the open bore hole. The screen may also be deployed on coiled tubing extending from the semi-submersible.

One method of the preferred embodiment includes jetting a guide base 12 into the ocean floor. Using riserless drilling techniques, a bore hole 13 is drilled through the guide base 12 and into the ocean floor 11 for installing a first casing 14. The first casing may be a 9-5/8 inch casing or a smaller 7 inch casing, depending upon the well. Once the initial string of casing 14 is lowered and cemented into the bore hole, a slim high pressure riser 30 is lowered from a second or third generation semi-submersible 20. The slim high pressure riser may be a 5 inch, 10k psi riser such as that manufactured by FMC. Preferably the slim high pressure riser 20 includes a down hole pressure control system 17 to be used in case of a emergency disconnect of the riser from the guide base 12. Surface control equipment 22, including a surface blowout preventer, is attached to the upper end of the slim high pressure riser 30 at the semi-submersible 20.

In some embodiments, riserless drilling can be carried out using a coiled tubing drilling system. In certain water depths and current conditions, some coiled tubing systems may suffer from their relative light weight and inability to counteract the effects of the water currents on the lightweight drillstring. Because the drill string is laterally constrained at the platform and at the point of entry into the borehole at the seafloor, the drill string will bow as the water currents impose lateral forces against it.

As the weight of the drill string is reduced, it becomes less resistant to these undesirable effects of the water current, which can lead to unacceptably large bowing deflections and stresses in the drill string. As water depth increases, the bowing effect of the drill string increases because there is a greater length of the drill string upon which the water currents act. The bowing of the drill string exerts an upward force on the BHA, tending to pull the BHA out of the borehole. This upward force reduces weight-on-bit (WOB) and possibly lifts the bit off bottom, thereby preventing successful drilling. This deflection due to water currents may be counteracted by
using deflection limiters as described in U.S. Patent Application 10/264,549, entitled Method and Apparatus for Riserless Drilling, and incorporated herein by reference for all purposes.

Referring now to Figure 2, an offshore floating drilling platform 100 is shown in position above a deepwater well 160. An offshore floating drilling platform 100 comprises a floating vessel 110 having a coiled tubing system 120 with a power supply 122, a surface processor 124, and a coiled tubing spool 126. An injector 128 feeds and directs the coiled tubing 130 from the spool 126 downwardly through the moonpool 125 towards the seafloor 150. In preferred embodiments, the floating platform 100 is not equipped with a conventional sized drilling rig because the weight of the required drilling equipment and pipe can be supported by a lower capacity hoisting system, such as a smaller conventional derrick (not shown) or crane 190. Heave compensator 192 may be disposed adjacent the moonpool 125.

In Figure 2, the floating platform 100 is shown situated adjacent a subsea wellsite 160 in which structural casing 170 and a wellhead housing or guide base 180 have previously been installed via jetting or riserless drilling. Casing 170 forms a cased borehole 172. Due to the preferably smaller diameter drill string hereinafter described, the structural casing 170 is preferably smaller in diameter than structural casing for conventional wells, and most preferably, the structural casing 170 has a diameter less than 30-inches to 36-inches, such as, for example, 16-inches.

Referring now to Figure 3, casing 210 is set in borehole 155 and wellhead 600 and wellhead housing 220 are connected to guide base 180. Conductor casing 210 is also run and set using riserless drilling and may preferably have a diameter of 7-5/8". Riser 230 is then run from vessel 110 and connected to wellhead 600 at connector 224. Connector 224 preferably includes equipment to shut-in the well in the event vessel 110 has to disconnect from the well. This equipment may include tubing shears, emergency disconnect controls, and pressure control equipment to seal off the well.

Once riser 230 is installed, the construction of the well can continue according to the chosen drilling program. Any slim hole capable drilling system, including small diameter tubing, coiled tubing, and composite coiled tubing, may be used in drilling and completing the desired well. One preferred drilling system is the Anaconda composite coiled tubing drilling system. In general the Anaconda system utilizes a highly flexible, small diameter composite coiled tubing string.

Composite coiled tubing allows the use of complex well paths and geosteering; short radius deviations allowing deviated wells within 1000 meters from mud line; and drilling in unconsolidated formations. In the preferred embodiments, the Anaconda system includes one or more communication lines, such as electrical conductors or fiber optic lines, integrated into the coiled tubing string to enhance and enable communication between the bottom hole assembly and
the drilling platform. For a detailed description of an Anaconda drilling system, see U.S. Patent 6,296,066, hereby incorporated herein by reference.

Referring now to Figure 4, there is shown one embodiment of a completed well 800, with the riser 230 still connected to the wellhead 600. In the completed well 800 of Figure 9, the conductor casing 210, an intermediate casing 810, and a liner 820 are cemented into place at 215, 815, and 825 respectively. The intermediate casing 810 is smaller in diameter than conductor casing 210. For example, if the conductor casing 210 has an ID in the range of 4-3/4 inches to 5 inches, the intermediate casing 810 may have an OD of 3-1/2 to 4-1/2 inches, for example. The intermediate casing 810 is installed below the conductor casing 810 and preferably extends almost to the bottom 805 of the well 800. Typically a liner of a smaller diameter may be installed below the intermediate casing 810, such as a liner 820, which may have an OD of 2-7/8 to 3-1/2 inches, for example.

The conductor casing 210 must be large enough to enable passage of the intermediate casing 810 and subsequent liner 820 therethrough. Similarly, the intermediate casing 810 must be large enough to enable passage of the subsequent liner 820 therethrough. Thus, the portion of the well 800 that is lined with conductor casing 210 typically has a larger diameter than the portion of the well 800 where the subsequent liner 820 is positioned. Due to the preferably smaller diameter sizes of the conductor casing 210, intermediate casing 810, and subsequent liner 820 as compared to conventional components, the preferred embodiments of the present invention are best suited for wells that can be drilled with a limited number of required casing strings.

Alternatively, it may be advantageous to use a casing system that does not utilize casings that have sequentially reduced diameters resulting in reductions in the diameter of the well 800 with depth. In cases where an extra casing point is required, a bi-center bit run can be performed. A bi-center bit will pass through the lowermost casing but will open the hole below the casing so that an expandable tubular can be run. This expandable tubular may be of any diameter but preferably as a large enough ID so that the hole is still slim hole accessible, such as 5.5”. The use of expandable tubulars allows the rig to drill a deeper hole without casing size restrictions. Patents related to expandable tubulars include U.S. Patents 3,191,677; 3,191,680; 4,069,573; 4,976,322; 5,348,095; 5,984,568; and 6,029,748, and International Publication WO 98/22690, all hereby incorporated herein by reference. In particular, in preferred embodiments of the present invention, the casings are formed of expandable metal casing, such as the casing disclosed in U.S. Patent 6,085,838 to Vercaemer et al., hereby incorporated herein by reference.

Expandable metal casing is made of a deformable material and is sized to have an outer diameter nearly equal to the inner diameter of previously installed casing strings, yet is small enough to allow the expandable casing to pass through the previously installed casing string.
Thus, the expandable casing can be run through an upper casing string to position the expandable casing in a newly drilled borehole. A mechanical die member is disposed within the expandable casing string and is moved upwardly through the expandable casing in response to fluid pressure. The die member gradually deforms and expands the casing so as to have an internal diameter that is substantially equal to the internal diameter of the upper casing. Subsequent expandable casing strings can be installed as the well is drilled deeper. Therefore, utilizing expandable casing, essentially no limits would apply to the depth of the well 800 below the seafloor 150. Thus, use of expandable metal casing is preferred to avoid reductions in the diameter of the well 800 that would occur using conventional metal pipe components, such as the casings 210, 810 and liner 820 depicted in Figure 4.

Referring now to Figure 5, there is shown another preferred well construction method to construct a monodiameter borehole using a coiled tubing drilling system 120 to drill a monodiameter wellbore 300. Monodiameter wellbore 300 may still contain multiple lengths of casing 210, 310, 315 but each casing string has substantially the same diameter. The hole diameter below the lowermost casing string can be increased through the use of reamers, especially near-bit reamers, bi-center bits, or other tools. Borehole 300 may be cased with chemical casing or expandable casing. Methods and apparatus for drilling a monobore well are shown and described in U.S. Patent Application No. __________ (Att'y. Docket No. 1391-27602), titled Method and Apparatus for a Monodiameter Wellbore, Monodiameter Casing, Monobore, and/or Monowell, and incorporated by reference herein for all purposes.

Referring now to Figure 6, there is shown, by way of example, an enlarged view of a preferred BHA 400. Preferably the BHA 400 is suspended on the end of a composite coiled tubing drill string 135 and a bit 410 is disposed at the lowermost end of the BHA 400. To drill borehole for setting a casing string, the bit 410 must be capable of passing through any previously installed casing and then drill a borehole 155 that is larger than the diameter of the casing will be set next. Also, adequate annular space must be provided for cementing the new casing string into the borehole. In most telescoping well operations, this is relatively easy. In slim bore and monodiameter applications bit 410 is often required to drill a hole diameter that is larger than the smallest casing that is already in the well. In these situations, bit 410 may be a bi-center bit or alternately, a conventional drill bit and underreamer combination, or a conventional drill bit and winged reamer combination. These drilling combinations will perform the same drilling function.

The BHA 400 preferably further comprises a downhole motor 415 for rotating the bit 410, and tools for steering the BHA 400, such as a three dimensional steering tool 420, upper and lower circulation subs 425, 435, and a tractor 430 with borehole retention devices 432, 434. One
exemplary tractor 430 is described in U.S. Patent No. 6,003,606, hereby incorporated herein by reference for all purposes. The tractor 430 acts to anchor the BHA 400 in the borehole 155 and to allow tension to be maintained on the drill string 135 during drilling.

As one of ordinary skill in the art will readily appreciate, gravity-based drilling would work equally well for drilling the borehole 155 through the guide assembly 200. In gravity-based drilling, no tractor 430 is provided, and weight-on-bit is not provided by propulsion, but rather is based on the weight of the drill string 135 and BHA 400. Further, it should be appreciated that weight, such as drill collars, may be added above the BHA 400 to anchor the BHA 400 in the borehole.

The BHA 400 may also include various detectors and sensors, such as, for example, a resistivity sensor 440, a gamma ray sensor 445, a directional sensor 450, upper and lower tension/compression subs 455, 465, a pressure/temperature sub 460, a casing collar locator 470, and/or a voltage-converter sub 475. The BHA 400 may further include various disconnects, such as an electrical disconnect 480 and a ball drop disconnect 485. Accordingly, Figure 6 depicts one representative grouping of components that may comprise the BHA 400. However, one of ordinary skill in the art will readily appreciate that the BHA 400 may be configured to include various components, and may include additional or fewer components than those depicted in Figure 6, depending on the well plan. The bottom hole assembly may include a seismic-at-bit or a testing-while-drilling tool. See U.S. provisional patent application Serial No. 60/381,243 filed May 17, 2002 entitled MWD Formation Tester, hereby incorporated herein by reference.

The preferred wired composite coiled tubing unit with integrated MWD/LWD can provide major benefits during any slim bore construction process, including both monobore and telescoping bore applications. The system enables continuous data transmission during all operational procedures, including procedures during which previous conventional data transmission becomes disabled. Furthermore, the transmission rate is greatly increased, resulting in high-resolution real-time data from sensors for formation evaluation, directional readings, pressure measurement, tension/weight on bit (WOB), for example. The high-resolution and continuous data transmission help to solve the potential challenges introduced when drilling a slim bore well. These challenges include higher ECDs, longer openhole intervals, reduced clearances, and more. The high-quality data also have the potential to enable more effective use of other new technologies that address the geomechanical environment of the well. The wired composite coiled tubing system can identify permeable zones, drilling-induced fractures, and borehole ballooning.

The continuous access to the data, including during trips, can help to provide early indications of potential problems such as fracture initiation or borehole instability. The
knowledge of the location of loss zones can improve the effectiveness of chemical treatments to increase the fracture resistance of the open hole. This knowledge is particularly useful when drill ahead materials or chemical casing materials might have to be used to fill a washed out area before the expandables are set in a sequential well-construction process. Also, it can be quite useful when chemical casing can be used to drill long intervals before any casing is set.

In certain situations, management of ECDs can be important to the success of a slim bore well-construction project. The wired composite coiled tubing with a MWD/LWD bottomhole assembly drilling system can enhance the ability to manage ECDs. The use of coiled tubing as a drill string enables continuous circulation while tripping in the hole and allows continuous optimization of drilling fluid properties throughout the borehole and active drilling fluids system. Continuous access to annular pressure measurements transmitted through the wired coiled tubing provides useful information about ECDs. With this information, drilling parameters and fluid properties are continuously adjusted to remain within the limits of pore pressure and fracture pressure (leakoff). Reductions in pressure resulting from swabbing are eliminated in a smooth, continuous manner by pumping through the coiled tubing drill string while tripping out of the borehole.

In addition to the enhanced ability to control the pressure in the wellbore, the system improves the capability to measure pore pressure and fracture pressure. If gas influx is observed when the pumps are stopped or slowed down, the wellbore pressure during the event can be precisely measured. Likewise, a formation integrity test (FIT) or a LOT can be performed with real-time downhole measurements of the transient pressure behavior during the test. During a LOT, which involves fracturing of the formation, this high-resolution data improves and speeds up the interpretation of the test. During a FIT, in which fracturing is not desired, the high quality of the real-time data can prevent inadvertent fracturing of the formation. Constant PWD measurements obtained through the wired composite drilling system also give a high degree of control.

These characteristics of the system create the potential to more safely operate within a narrower window of pore pressure and fracture gradient than is possible with previous technology. While the reservoir hole is drilled, the improved control of pressure in the wellbore, along with the potential for enhanced understanding of fracture resistance, reduces the chance of losing drilling fluids to the reservoir. This reduction helps prevent production problems associated with such losses.

The wired composite tubing allows the bottomhole assembly to be engineered differently from conventional MWD/LWD systems. Conventional systems are self-powered with either
batteries or turbines. Batteries are expensive, hazardous, and must be periodically changed. Turbines are complex mechanical devices that are susceptible to erosion and plugging. The mud pulser also suffers from these mechanical failures. The pulser is a slow telemetry method. It can send only a fraction of the sensor measurements to surface in real time. It can only operate during circulation, and therefore, it precludes telemetry during tripping with jointed pipe. This attribute requires that these prior art systems store the majority of their acquired data in the downhole tool memory. This data can be obtained only by tripping the bottomhole assembly out of the hole and downloading through a cable at surface. These prior art tools are preconfigured to attempt to optimize the storage and telemetry of the data. Large processors are used in the downhole tools to process the sensor signals and raw data to minimize the size of the stored data. Often, the data needed to make decisions is not transmitted in real time and is left in the tool's memory until the next trip out of the hole.

The wired composite tubing and bottomhole assembly are able to avoid this paradigm due to the embedded wires in the tubing. Power is provided from the surface, eliminating the need for batteries or turbines. All the raw sensor data is transmitted immediately to the surface in real-time, negating the need for a pulser. These three components typically have the highest rate of failure in conventional MWD/LWD systems. Because the raw sensor data is processed at surface, large processors or downhole memory are unnecessary. This benefit reduces complexity and eliminates large components on printed circuit boards in the downhole tools that are susceptible to vibration and shock. Quality assurance is easily monitored for the wired composite tubing and bottomhole assembly. Most importantly, the availability of all the data, all the time, allows accurate, real-time decisions to be made while drilling.

A number of factors are important to the performance and reliability of a horizontal completion. Reservoir characteristics, effective well length, and near-wellbore conditions determine the inflow performance of the completion. Formation characteristics, such as sand uniformity and shaliness, along with the inflow performance, are important to the reliability of completions in unconsolidated formations. More effective placement of the horizontal well in the desired production zone leads to improvements in performance and reliability.

The formation evaluation sensors in the wired composite tubing and bottomhole assembly consist of an azimuthally focused gamma ray sensor for bed dip determination and a resistivity sensor with multiple depths of investigation for optimum wellbore placement. These sensors are particularly suited for high-inclination wells and geosteering the wellpath across or through the reservoir.
Perforations, expandable screens, mechanical completion shutoffs, and chemical solutions/techniques are more efficiently placed using the wired composite coiled tubing and bottomhole assembly. For a slim bore well, the most important goal is to have the most efficient well-construction process possible with the maximum production possible. The wired composite coiled tubing drilling-completion system supports this overall philosophy.

Anaconda's propulsion system and wired composite coiled tubing allows for it to be set as a casing or completion liner directly across the interval. The propulsion system may or may not be removed from the well. The wiring within the wall of the composite tubing can be used to actuate a disconnect at the top of the coil to allow for permanent setting in the well.

It should be appreciated that these embodiments are described for explanatory purposes and that the present invention is not limited to the particular borehole disclosed, it being appreciated that the present invention may be used for various well plans. Operational parameters during the slim bore well construction may include drilling and completion with overbalanced conditions, balanced conditions, or underbalanced conditions. All conditions are met by the apparatus and methods of the present invention.

While underbalance drilling can occur using the traditional rig, the optimum solution in some embodiments for the slim bore is to integrate the wired composite coiled tubing with underbalance drilling. Using underbalance devices, such as a trip valve that allows the bottomhole assembly to be retrieved without killing the well, can allow real-time well testing by flowing the well to a separation vessel. Also, mud-logging data, downhole well-testing data, downhole pressure, and lithologies may be collected from the wired composite coiled tubing and bottomhole assembly drilling system for data acquisition and analyses. This integrated underbalanced wired composite drilling system is an optimum production drilling system for consideration when constructing a Monowell.

Depending on the slim bore's inner wellbore diameters, drilling hydraulics, and production requirements, differential sticking tolerances can be very limited. Underbalance drilling can help reduce, if not eliminate, differential sticking, allowing smaller diameters to be constructed.

In a still another preferred method and apparatus of the present invention, the coil tubing can be utilized as the casing or it can be expanded and used as the casing. Additional details are set forth in U.S. Patent Application Serial No. 10/016,786 filed December 10, 2001 entitled "Casing While Drilling", hereby incorporated herein by reference.

Accordingly, the preferred embodiments of the present invention provide improved methods and apparatus for conducting drilling operations from a bottom-founded or floating platform in any
water depth, and especially for conducting drilling operations in deep or ultra-deep water from a floating platform. In particular, smaller diameter casings and riser, as well as a lightweight, continuous drill string, are preferably utilized such that the required size and capacity of the platform is significantly reduced. These efficiencies are expected to reduce the daily rate for the required floating platform by approximately 50 percent as compared to a conventional vessel for ultra-deep water drilling operations. Further, the preferred embodiments of the present invention enable drilling of a borehole and installing casing into the borehole with minimal time delay between drilling the borehole and installing the casing, thereby reducing the possibility that an open borehole will collapse before casing can be run in.

Although the above described embodiments involve the use of a 7" high pressure riser, it is understood that any size high pressure riser can be used. Any riser that is rated for the full pressure of the well being drilled can be used without departing from the concepts of the present invention as long as that riser provides efficiency benefits over using standard 16" or 21" riser. Such efficiency benefits may be found in enabling the use of a smaller drilling platform by reducing the weight of the riser and/or the amount of drilling fluids that are needed.

There are shown specific embodiments of the present invention with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention, and is not intended to limit the invention to that illustrated and described herein. Various dimensions, sizes, quantities, volumes, rates, and other numerical parameters and numbers have been used for purposes of illustration and exemplification of the principles of the invention, and is not intended to limit the invention to the numerical parameters and numbers illustrated, described or otherwise stated herein.
CLAIMS

What is claimed is:

1. A method for drilling a well on the seafloor into a pressurized formation comprising:
   providing a platform at the sea surface;
   installing a guide base and a conductor casing into the seafloor without using a riser;
   connecting a riser between the platform and the guide base, wherein the riser has a diameter of less than 16" and is rated for the pressure of the formation;
   running a drilling assembly from the platform and through the riser and conductor casing;
   using the drilling assembly to drill into the formation forming an open wellbore below the conductor casing.

2. The method of claim 1 wherein the drilling assembly comprises a composite coiled tubing drill string.

3. The method of claim 2 wherein the drilling assembly also comprises one or more communication lines embedded into the composite coiled tubing and connecting a wellbore tool to the platform.

4. The method of claim 3 further comprising providing real-time data transmission from the wellbore tool to the platform along the one or more communication lines.

5. The method of claim 1 further comprising:
   removing the drilling assembly from the well; and
   installing a second string of casing into the open wellbore below the conductor casing.

6. The method of claim 5 wherein the drilling assembly forms an open wellbore having a larger diameter than the conductor casing and the second string of casing is an expandable casing.

7. The method of claim 6 wherein the drilling assembly includes a bi-center bit.

8. The method of claim 6 wherein the drilling assembly includes a near-bit reamer.

9. The method of claim 1 wherein said installing the guide base and conductor casing further comprises:
   setting the guide base by jetting the guide base into the seafloor;
   affixing the guide base to the seafloor;
   drilling a hole into the formation through the guide base using a riserless drill string; and
disposing the conductor casing into the hole; and
connecting the conductor casing to the guide base and the formation.

10. The method of claim 9 wherein the riserless drillstring comprises coiled tubing.
11. A system for drilling a subsea well into a pressurized formation in the seafloor comprising:
   a surface platform;
   a guide base and conductor casing installed in the seafloor;
   a riser connecting said surface platform to said guide base, wherein said riser has
   a diameter of less than 16" and is rated for the pressure of the formation; and
   a drilling system disposed on said platform.
12. The system of claim 11 wherein said drilling system comprises composite coiled tubing.
13. The system of claim 12 wherein said drilling assembly further comprises:
   one or more communication lines embedded into said composite coiled tubing;
   and
   a wellbore tool disposed at the end of said composite coiled tubing, wherein said
   one or more communication lines provide real-time data transmission between said
   wellbore tool and said surface platform.
14. The system of claim 11 wherein the drilling assembly comprises a bi-center bit.
15. The system of claim 11 wherein the drilling assembly comprises a near-bit reamer.
16. The system of claim 11 further comprising pressure control equipment disposed on said
   surface platform and connected to said riser.
17. A drilling system comprising:
   a drilling vessel having a dynamic positioning system;
   a riserless drilling system adapted to install a guide base into the seafloor forming
   a well;
   a high pressure riser system adapted to be extended from said drilling vessel to the
   well;
   a pressure control system disposed on said drilling vessel adapted to be connected
   to said high pressure riser at said drilling vessel; and
   a coiled tubing system disposed on said drilling vessel and adapted to be extended
   through said pressure control system and said high pressure riser into the well.
18. The system of claim 17 wherein said high pressure riser system has a diameter less than
   16" and is rated for the full pressure of the well.
19. The system of claim 17 wherein said riserless drilling system is adapted drill a borehole from the guide base into the well and install a first casing string into the borehole.

20. The system of claim 17 wherein said coiled tubing system comprises:
   a composite coiled tubing string;
   a bottom hole assembly disposed on one end of said composite coiled tubing string.

21. The system of claim 20 wherein said composite coiled tubing string includes one or more communication lines embedded in said composite coiled tubing string and said bottom hole assembly includes one or more tools adapted to communicate with said drilling vessel along said one or more communication lines.

22. The system of claim 20 wherein said bottom hole assembly includes a bi-center bit.

23. The system of claim 20 wherein said bottom hole assembly includes a near-bit reamer.
Fig. 6