Use of Drilled-in Casing in Slim Deepwater Exploration Wells
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Abstract

A new type of seabed support system is being developed that incorporates a subsea shut-off system and surface BOP. This enables slim, “finder wells” to be established in deepwater with drilled-in casing. By minimizing the loads that must be supported by the vessel, the operator has a much greater choice of vessels for a given water depth. The system as described is aimed at “simple” deepwater wells, such as those found in West Africa – the impact of the approach described in this paper is to reduce exploration well costs by more than 50% when compared to the cost of deploying a “conventional” approach.

With this system, a 7 5/8” casing string is drilled into place (becoming the first pressure containing barrier) and converted into a riser. This is all done on a single trip to speed up the operation and reduce the risk. The casing string is captured and sealed within the subsea shut-off system, only after installing and spacing out a surface BOP. This approach has many advantages.

A surface BOP is used for primary well control, but in the event an emergency disconnection is required, dual shear rams cut the 7-5/8” casing and seal in the well. The system then allows a conventional subsea reconnection of the riser (casing).

This paper describes:

- Improving the reliability of the pipe shearing system
- A description of other key components of this new drilling system is included. It is intended to utilize composite coil tubing to perform the drilling below the 7 5/8” casing, though conventional slim jointed pipe could be used.

Introduction

The use of surface BOP’s when drilling from a floating vessel is well documented (Ref.1). Pre-installed anchors and lightweight moorings have increased the depth range of 2nd or 3rd generation semi-submersibles.

Unocal and others have demonstrated the efficiencies that can result from establishing the well with drilled-in casing and eliminating the subsea BOP stack altogether.

However many operators do not accept the risks associated with using surface BOP’s with a moored vessel alone, citing many un-predictable weather events that require disconnection from the well. Furthermore using surface BOP’s from a dynamically positioned vessel is clearly unacceptable. Shell Oil developed a shut off system to be used in conjunction with surface BOP’s (Ref. 2). This system is based on the use of a conventional wellhead and does not permit the advantages of establishing the well with drilled-in casing.

The Geoprober Shut-Off System (Geo-SOS™) eliminates the conventional wellhead and combines the advantages of slim, drilled-in surface casing with the ability to disconnect the well at the seafloor.

The Geoprober Shut-Off System has been designed as part of a slim well coiled tubing exploration system, but it could equally be used with conventional jointed pipe.

The Concept

Overview of the Geoprober Shut-off System

Figure 1 is a schematic overview of the Geoprober Shut-Off System. The entire system is deployed in one trip on the drilled-in casing, in this case 7-5/8” OD. However sizes up to 9-5/8” are equally feasible. Typically the
casing is equipped with a Weatherford Drill Shoe which can be extruded and allow further drilling through it once total depth has been reached (Ref. 3) Other casing drilling methods can also be used.

The well is established by jetting in a short section of 13-3/8" casing which is swedged to a 22" receptacle installed in the anchor base or template. The Geoprober Shut-Off System has a lower housing which is installed and connected to the 22" receptacle. Dual 4" OD return lines ensure that cuttings are routed away from the critical seals and gripping devices.

The lower housing is bolted directly to a set of 13-5/8" shear rams. A side outlet with a non-return valve provides the means of connecting a kill line with an ROV.

In the event of an emergency disconnection the shear rams must sever the 7-5/8" casing together with the internal drill string or liner.

At the top of the Geoprober Shut-off System is a 13-5/8" re-entry hub with the machined profile of an industry standard external wellhead connector. Internally, a bellmouth fabricated from composite material provides a means of distributing the bending loads on the 7-5/8" casing.

The Lower Geo-SOS™ Housing

The essential functions of the Lower Geo-SOS Housing (Figure 2) are as follows:

- To provide a means of connecting to the template. This is done by means of an external male ball-gripping device of the type described by Dillon (Ref. 4). This device allows automatic connection and hydraulic disconnection from the template. The latter is achieved by means of the hydraulic cylinder actuators (item 45 in yellow)
- To grip the casing and support the load of the shut off system during deployment and recovery. This is accomplished by the female upper Ball-gripping device. It has two rows of tapered ball-gripping devices. This can be released on acoustic command from surface which directs hydraulic fluid to the actuator piston (item 15) once the load of Shut-off System has been transferred to the seafloor.
- To provide a clear unobstructed passage for the Drilled-in 7-5/8" casing and its 8-1/2" OD connectors. The system bore is 9" ID. Cuttings Solids are prevented from entering the system by means of the environmental seal fabricated from special elastomer material. (item 14)
- To suspend the casing at the seal floor and in the event of an emergency disconnection, support the full force applied by 5,000 psi wellbore pressure, (7,500 psi Test) acting on the entire end area of the casing. This is accomplished by the lower ball-gripping device which has three rows of balls to support the higher loads. This is also set and released by acoustic signal operating a hydraulic cylinder.
- To provide dual seals that bridge the gap between the 9" bore and the body of the 7-5/8" drilled casing. These seals are extruded by means of a hydraulic piston (item 10) that locks in place once actuated to prevent the seals from being inadvertently relaxed. Integral collet fingers provide the means of backing up the elastomers and preventing their extrusion under pressure load. The dual seal can be tested by means of a port between the seals which is connected to the ROV interface.

The Lower Geo-SOS Housing has porting to allow the passage of the hydraulic lines to operate these functions. These lines are set in a groove at the top of the housing and laid underneath a series of protective "donuts" (Item 26) to the required port.

Four point strain gauges at location “B” allow the tensile and bending loads to be monitored and transmitted via the broadband control system to surface.

Control System – Dual modes of operation

The control system being implemented for the Geoprober Shut-off System has a dual mode of operation:

- Acoustic Only Mode - Broad Band acoustics control and data feedback to the surface. This mode of control provides direct feed back from subsea instrumentation of the tensile and bending loads during deployment and operation. The small volumes of fluids required to operate hydraulic functions are stored in subsea accumulators. These are directed via the solenoids in the valve pack to the appropriate subsea functions.
- Acoustic with ROV back up Mode – Once the Geoprober Shut-off system has been deployed to the seafloor and the casing drilled to total depth (TD), the ROV docks on and thereafter provides back up control services. The ROV will have on board a suitable hydraulic fluid volume that can recharge subsea accumulators in preparation for actuation. First the ROV will provide the fluid volumes required to extrude the dual seals. Thereafter the ROV will be ported to pressure test between the two seals. The ROV will be used in weekly function tests and other health checks of the system.

Figure 3 shows a schematic overview of the control system.
Shear Rams – “HMD” Actuator

The configuration of shear rams is critical to the operating success of the system. The internal size of the BOP stack is governed by the OD of the pipe to be sheared. With conventional shearing where the pipe is first flattened before it is sheared, the shear ram blade must have a dimension that accommodates the flattened pipe. Hence the bore of the shear rams were specified 13-5/8” to accommodate 7-5/8” casing.

The system philosophy is one of a double barrier in place at all times together with a primary and secondary (contingent) shear device.

In the Geoprober Shut-off system the hydraulic operating mechanism of the shear rams will be backed up by a mechanical actuator using Bellville springs to provide exceptional high forces over short distances. The HMD actuator is described in more detail below.

Engineering Design & Challenges

The development of Geoprober Shut-off System has provided a range of engineering challenges. These can be classified as follows:

- Extending the water depth capability of the control system has a major impact on the accumulator fluid volumes. This has a major impact on the weight and hence the design of the system. Water depth also impacts the design of the acoustic transponder system.
- The reliability of the pipe shearing system is crucial to the safe operation of the system. For this reason and the need to reduce the weight of the system, alternative mechanical shearing actuators have been developed by Geoprober Drilling (HMD Actuator)

Soil Analysis

Soil Strength Profile

The Geoprober system is intended to be suitable for a wide variety of soil conditions, primarily associated with deepwater developments. Table 1 presents an overview of typical soil strength profiles based on experience in these deepwater fields. The soil conditions on deepwater developments are overwhelmingly soft clay, with an increasing shear strength profile with depth.

<table>
<thead>
<tr>
<th>Development Area</th>
<th>Water Depth (m)</th>
<th>Typical Strength Profile (kPa)</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Africa</td>
<td>800 - 1500</td>
<td>$S_u = 3 + 1.4z$</td>
<td>2 - 4</td>
</tr>
<tr>
<td>Gulf of Mexico</td>
<td>500 - 1500</td>
<td>$S_u = 1 + 1.5z$</td>
<td>3 - 5</td>
</tr>
<tr>
<td>Trinidad</td>
<td>60 - 500</td>
<td>$S_u = 10 + 1.2z$</td>
<td>Approx 3</td>
</tr>
<tr>
<td>East Timor Sea</td>
<td>400</td>
<td>$S_u = 10 + 1.8z$</td>
<td>2 - 3</td>
</tr>
<tr>
<td>Brazil</td>
<td>1000</td>
<td>$S_u = 2 + 2.0z$</td>
<td>2 - 5</td>
</tr>
</tbody>
</table>

Table 1: Example Soil Strength Profiles

For this assessment, the West Africa strength profile has been adopted. As can be seen from Table 1, this profile is representative of many deepwater fields.

Installation Loads

The Geoprober Shut-off System will be run as a single unit including the template and a predetermined length of conductor (13 3/8” OD). The approximate weight of this combined unit is 30Te.

The full system will be suspended on the 7 5/8” casing and the conductor will be stabbed into the seabed and allowed to penetrate under self weight.

Once in position, the combined template and conductor will provide vertical and lateral stability to the system. Shallow fins, connecting the underside of the base plate may be used to enhance lateral stability of the system.
Loads for a 2,500 m water depth load case have been provided by Orcina (Orcaflex). The results may be summarised as:

| Moment (kNm) | 30 – 50 |
| Tension (kN) | 20 – 110 |
| Shear (kN)   | 2 – 8    |

Note that these loads have been assumed to apply at the top of the Geoprober Shut-off System, as this is a more onerous load combination than applying them at the seabed.

A further load combination has to be considered for an emergency disconnection. In this case, additional lateral loads may be imparted to the shut-off system. These limits are currently being modelled.

**Geotechnical Calculations**

Separate geotechnical calculations have been performed for the installation and the lateral stability of the system, once in place and with a moment and shear load applied at the top of the system. These aspects are discussed below.

**Installation**

For installation, the optimum length of the conductor is that which can be reliably penetrated under the self weight of the system. Weight in excess of that used to drive the conductor, would then be supported by the template.

Penetration resistance of the conductor will be a combination of adhesion of the clay on the inside and outside of the conductor, and end bearing resistance over the cross sectional area of the conductor pipe, or, if ‘plugging’ occurs over the full area of the conductor.

To maximise the depth of self weight penetration, the casing drill shoe is run down inside the conductor to within approximately 1m of the conductor shoe, and soil cleaned out from inside. This will prevent plugging and minimise penetration resistance and loss of capacity when the well is advanced.

Calculations show that the Geoprober self weight of 30Te is just sufficient to achieve a conductor penetration of 20m, using the West Africa soil strength profile and assuming a conservative soil sensitivity of 2. A higher value would suggest a greater reduction in soil strength during penetration of the conductor and hence a longer length of conductor could be installed.

Following installation, 'set up' will occur around the conductor. Set up is a recovery of strength of disturbed soil. Based on published experience, approximately 80% recovery of strength will be achieved after 36 hours. This will give an additional vertical capacity to the conductor.

Assuming 80% strength recovery of soil along the conductor, with allowance made for the base plate, it is anticipated that a factor of safety of 1.5 on penetration under an emergency loading of 60Te will be available.

**Lateral Stability**

The drill string will impart a shear force and moment at the top of the conductor. These loads have been computed by Orcina, and have been stated above. To assess the lateral stability, the software programme “Oasys ALP” has been used. This is a laterally loaded pile programme which computes displacement and forces in the pile.

Analyses performed for embedment depths of 15m and 20m show a head deflection of approximately 40mm and two points of zero displacement. This indicates that there is sufficient lateral capacity and that the conductor is behaving as a deep pile.

**Development in soil strength**

Figure 4 shows a spreadsheet which illustrates the penetration resistance of the combined Geoprober Shut-off System including the template and conductor. This sheet assumes the soil plug within the conductor is cleaned out by jetting, and ideally rotation of the drill bit.

The graph shows the penetration resistance of the conductor gradually increasing as it penetrates into the seabed. When the template contacts the seabed, there is an increase in penetration resistance associated with its bearing pressure. With a knowledge of the soil strength profile, it is possible to select a conductor length which achieves penetration under self weight, but stops penetrating when the conductor contacts the seabed. Further capacity is obtained as set up occurs around the conductor and the clay recovers in strength.

**Metocean Conditions - Riser Load Cases**

Two main load cases have been developed for the installation and operation of the Geoprober Shut-off System:

- **Deepwater Case** – A water depth of 2,500 m was selected in the target market areas to test the operating envelop of the system. A current profile was selected based on 100 year return period currents. A regular sea of H=5.80m and t=8.68s was used. The maximum top tension on the compensator during deployment of the
Geoprober Shut-off System is 1,350 kN. This defines the tensile capacity of the 7-5/8” casing.

- **Shallow water case** – A water depth of 100 m was assumed operating during the winter months in the Brent area of the North Sea. This case was selected on the basis that it presented severe bending and fatigue loads on the 7-5/8” riser. At the time of writing the results are still in preparation.

**Design of the 7-5/8” casing and the connectors**

The properties of the 7-5/8” casing and casing connector are selected based on the following criteria:

- The maximum tensile capacity is at the surface, based on the tensile loads and maximum shut in pressures. A wide range of casing grades are available to withstand these loads e.g. P110 in Table 2 below.
- For the selection of the pipe in the hole and in the vicinity of the shear rams a lower grade of steel is desirable with Charpy values in the region of 25-30. Consideration could be given to positioning special low Charpy value casing opposite the shear rams to reduce the shearing force required.

To perform the riser fatigue study described above, it was necessary to use realistic input data. Unfortunately no fatigue data was available for 7-5/8” casing. However full scale fatigue tests data was obtained on drilled-in connectors in the 13-3/8” size (54.5 ppf, X80 grade pipe). This data is thought to represent a worst case scenario because, for a given curvature, the relative stresses on the larger diameter pipe are much higher.

### Table 3 below gives the results for the fatigue tests on Tenaris MS XT/ XC 13-3/8” connector

<table>
<thead>
<tr>
<th>Specimen Number</th>
<th>Nominal Stress range on OD (N/mm²)</th>
<th>Test Life N, Cycles</th>
<th>Target Life, Cycles</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>201</td>
<td>88620</td>
<td>120064</td>
</tr>
<tr>
<td>2</td>
<td>138</td>
<td>176500</td>
<td>542825</td>
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<tr>
<td>3</td>
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<td>1400160</td>
<td>2433008</td>
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<tr>
<td>4</td>
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<td>5860080</td>
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<td>5</td>
<td>78</td>
<td>10527610</td>
<td>5378535</td>
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<td>6</td>
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<tr>
<td>6a</td>
<td>145</td>
<td>693470</td>
<td>438934</td>
</tr>
</tbody>
</table>

At the time of publication, the fatigue results from the riser study were not available. However an indication of the performance of the pipe can be obtained by simple calculation. Taking the design life for the well as 100 days at a wave period of 8 seconds the number of cycles is calculated to be 1,080,000. It can be seen from the above table that provided the stress range on the casing is kept below 100 N/mm² the casing should last well in excess of the maximum well design life of 100 days.

### Extending the water depth capability of the control system

**Accumulators**

The additional stored hydraulic fluid needed to activate the shear rams in the event of an emergency has a major impact on the weight of the Geoprober Shut-off System.

With increasing water depth more accumulator capacity is required. The discharge pressure/ volume relationship of an accumulator is governed by the properties of the driving gas, which is an absolute phenomenon. The output hydraulic pressures and volumes to drive the subsea functions are related to the ambient pressure.

As can be seen from the graph in (Figure 5), no matter how carefully the accumulator system is designed, there will be a loss of pressure / volume performance as ambient pressure increases.

There are a number of strategies that can reduce the volume and hence the number of accumulator bottles required:

- Use of a cascade system
- Use electrically driven subsea pumps
- Pressure sensitive load regeneration
- Using accumulators fabricated from lightweight composite materials
Each of these strategies has been examined critically in turn during this development programme. The goal is to reduce the weight to a target of 25-30 tons, through this work and by challenging conventional. Use of a combined hydraulic and mechanical activator (see below) should allow this goal to be achieved.

**Acoustics**

Broadband acoustic communications are an essential part of making the Geo-SOS system work. Before the advent of broadband acoustics it was not possible to transmit and receive data through the water column with absolute reliability. The noise generated by the ships thrusters tended to interfere with the signal.

Broadband volume of data transmitted inherently allows much greater error checking and matching of signals. Now with low cost instrumentation landing the equipment on the seafloor can be done with much more accuracy to control the loads.

However with increasing depth the acoustic modem needs much more power to transmit reliable signals. Under certain conditions, where the sea is flat calm or the bottom conditions hard, the signal can become attenuated.

**The reliability of the pipe shearing system**

The desire mentioned above, to reduce the number of accumulator bottles is fundamentally at odds with the requirement to have sufficient pressure and volume to shear the pipe in the event of an emergency disconnection.

Due to a number of high profile recent incidents, the shearing of casing has received renewed attention from operators. An engineering report distributed to Shaffer customers highlighted the importance of checking the Charpy notch values of the tubulars that are run in the wellbore.

For Charpy V notch values of 50 Ft/ lbs or less Shaffer provides the following formula:

\[
F_{\text{shear}} = 0.577 \times S_{\text{yld}} \times A_{\text{dp}}
\]

Where:

- \(F_{\text{shear}}\) = Shear Force (lbs)
- \(S_{\text{yld}}\) = Pipe Yield Strength in psi
- \(A_{\text{dp}}\) = Cross sectional area of the pipe

Additional shearing force is required to compensate for the effects of wellbore pressure on the ram shaft and for the effects of water depth.

It is planned as part of the development strategy of the Geoprober shut off system to carry out a series of shearing tests of the worst case 7-5/8” casing with 5-1/2” liner inside. The combined weight per foot of this pipe in pipe combination is 29.7 + 17.0 = 46.7 ppf. The combined cross sectional areas is 13.5 sq inches. This is equivalent to shearing 9-5/8” 47 ppf casing.

A worst case indication of the shearing force required for a range of S135 HC (High Charpy) pipe can be determined from the Shaffer testing programme.

To shear 6.625” OD pipe with a weight 27.72 ppf requires a shearing force of 824,000 lbs F. This requires a 14” operator and a 16” booster operating at 3,000 psi (204 bar)

The volume of fluid required to close would be 24.3 gallons per ram or 48.3 gallons for two rams. To open the rams the fluid volume is 24.63 per ram or 49.26 gallons for two rams. An open-close-open requirement for two rams would utilise a total of 145 gallons. Operating at the pressure discharge range of 200 to 150 bar (2,920 to 2,205 psi) would require approximately 1450 gallons of fluid (145 bottles) stored at 200 bar.

**The Geoprober HMD Actuator™**

To address this issue Geoprober Drilling is developing a combined hydraulic and mechanical actuator to retrofit to existing shear rams. This invention (patent applied for) uses mechanical energy stored in a Bellville spring to supplement hydraulic piston force used to operate the shear rams.(Figure 6) The Bellville springs are contained in an actuator with a shaft that is connected to the hydraulic piston.

Under normal circumstances Bellville springs would not be considered suitable for use on a shear ram. The reason for this is that, although Bellville springs can store enormous amounts of energy, the applied force drops off rapidly over a few centimetres of spring travel. The length of travel can be increased by adding more Bellville springs but this can make the actuator very long and heavy, defeating the purpose.

However this invention allows for a two stage approach to shearing the tubular in the well-bore. First the conventional hydraulic piston drives the shear-ram inwards to crush and deform the pipe. At the point requiring the maximum shearing force, the stored mechanical energy in the Bellville spring actuator is released by a special retaining pin described in this invention. The release of this retaining pin is automated by mechanically linking it to the shaft.

The design of the Bellville springs is illustrated in Figure 7. This shows that a series of 30 Bellville springs each with outer diameter of 250 mm stacked 4 times for each set can produce a force of 3,000,000 kN (674,000 lbs).
The system for releasing the Bellville springs is illustrated in Figure 8. On release of the retaining pin, the piston retaining the Bellville springs drives forward applying the force to the shaft and to the shear rams via a female ball-gripping device. This force is applied in addition to the hydraulic shearing force.

The Bellville Springs can be re-set by applying 5,000 psi to the opening side of the hydraulic chamber. This fluid acting on a piston area of 138 sq inches produces a force of 690,000lbs.

The use of the HMD actuator allows the open-close-open philosophy of shear ram operation to be challenged. The impact on accumulator volume requirements would be dramatic as the shear rams would only be designed for closure. Hence the fluid volumes would be 22 gallons / 0.2 = 110 gallons or 11 conventional bottles. At an ambient pressure of 150 bar (2205 psi) it would require 220 gallons or 22 conventional bottles.

Running Procedure – Control & Monitoring Requirements

A comprehensive set of running procedures is beyond the scope of this paper. A summary of the steps that will be required is given below.

Phase One – Establishing the well, drilling in the 7-5/8" casing Acoustic control mode

- Make up on rig floor
- Running through the splash zone
- Landing on the seafloor – ensuring verticality (gyro) and load transfer (Four point strain gauges)
- Jetting in the 13-3/8
- Disconnection from the SOS and drilling ahead
- Dealing with returns
- Shallow water flow or shallow gas flow
- Re-gripping the casing
- Handling a drive off when drilling with casing – Procedures for deepwater or shallow water
- Rigging up Surface BOP extruding the bit & cementing.

Phase Two – Hang off & Seal casing – Acoustic mode with ROV back up.

- Establishing the ROV Interface
- Hanging off and sealing the casing – Pressure testing – emergency back-up sealing.
- Routine testing – challenges

Comparison of Operating Times & Costs

Overall System

The “typical” exploration well using this system will consist of

1. The seafloor equipment to establish the well and install the first pressure containing casing as described previously.
2. The intermediate hole sections requiring one or more liners for pressure control purposes.
3. Drilling from the casing shoe to the zone of interest with smart composite coiled tubing. In some cases, the objective can be reached by setting the conductor and then drilling to the well TD with one hole section. In other cases, either a single liner will be required (for example a 5 ½” liner), or a couple of nested liners may be used. If nested liners are required then these would be of the expandable type.

Drilling of such a well requires some element of rotary drilling and use of coil tubing – in this case it is planned to drill the formation of interest with a 4-3/4” hole by using “Anaconda”, the composite coiled tubing drilling system developed by Halliburton (Ref. 5).

The well will be controlled via a surface BOP with a subsea shut-off device (previously described in detail) to be activated only in an emergency and specifically when the vessel is driven off location.

For the purposes of this work and based on identifying a vessel that would require very little (if any) modification, the Cal dive Q4000 was selected as the example platform from which drilling operations would take place. This vessel has a large deck area, is very stable and highly mobile, has DP3 capability, excellent ROV capability and support and is equipped with a derrick and pipe handling system, including a top drive. It is not encumbered with large mud pumps and pits and other equipment (such as an 18 ¾” BOP and 21” riser) which would not be used and would have to be paid for if a “conventional” drilling rig were employed. For wells in the future, it will also be possible to deploy the drilling system from a mono-hull equipped with DP3 positioning capability. This will reduce the well costs even further compared to the costs given in this paper and which include the use of the Q4000.

Costs

A cost comparison between a well drilled with this system and one drilled with a conventional approach is given in Figure 9.

Figure 10 shows the well that has been used for cost comparison purposes. The well on the left is similar to
those that are being drilled in some parts of the Gulf of Mexico. The well on the right is the comparable well as would be drilled by this new drilling system.

For the conventional well a 5th generation dynamically positioned drilling rig is required – in this case a semi-sub has been selected. This is largely due to the water depth and the requirement to be able to store on deck and run approximately 7580 ft of riser.

The “dry hole” cost for the composite coil approach is estimated to be $5.7 mm. This compares with the cost for drilling the well using the conventional approach of $13.9 mm. The savings amount to 59%.

The savings are due to:

1. Savings in days to drill – in particular, it takes far less time to establish (or retrieve) the Geo-SOSTM and riser compared to the conventional riser and BOP – See Figure 11 for the detailed time breakdown.
2. The overall spread rate is less (overall cost per day is about 15% less – this would be even less when the system was moved from the Q4000 to a lower cost monohull)
3. Lower consumable costs (casings/wellhead/mud etc..)

Note that in addition to monetary savings, the footprint of the composite coil drilling system will be much smaller than for the comparable conventional system. This will result in significantly less impact upon the environment.

Conclusion

A significant amount of engineering has been carried out to prove the design of an alternative drilling system for drilling slim deepwater exploration wells. This work has produced a robust system based on drilled-in casing.

The cost of drilling an exploration well using this approach has been demonstrated to be less than 50% of the cost of drilling the well using current technology and methods.

Acknowledgements

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Figure 1

Shut-off System (Geo-SOSTM)

- Bellmouth
  - For bending transition & seal
- 13-5/8" Double Shear Ram
- Upper Gripper
  - (Supports the Geo-SOS Deployment)
- Lower Gripper
  - (Supports installed casing)
- Seal
- Flexible Pipe 3-4" OD to route drill cuttings & cement away from the anchor base
- 13-3/8" casing length to provide friction fit to support 30 tons

Figure 2

- 9-7/8" Bit
- 7-5/8" OD casing
- ROV Kill Line
- Dual Casing Seals with test port
- ROV Interface Plate
  - (Blue = Ballcage control)
- Template gripper
- Template 2m high, radius 2 m

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REMOVE ALL SHARP EDGES
IF IN DOUBT ASK

SECTION A-A
UNIT WEIGHT = 22 KGS
**Figure 9: Cost Comparison**

<table>
<thead>
<tr>
<th>Cost ($mm)</th>
<th>Conventional</th>
<th>Geoprober</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport</td>
<td>0.5</td>
<td>0.5</td>
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<tr>
<td>Rig</td>
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<tr>
<td>Evaluation</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tangibles</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Total Costs:
- Conventional = $13.9 mm
- Geoprober = $5.7 mm  (59% Savings)

**Figure 10: Comparison Well**

<table>
<thead>
<tr>
<th>Water Depth = 7500'</th>
<th>Water Depth = 7500'</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Gap = 80'</td>
<td>Air Gap = 80'</td>
</tr>
</tbody>
</table>

- **Conventional Well – GOM Semi**
  - 36" – 340 ft RML
  - 20" – 3200 ft RML
  - 13 5/8" – 12500 ft BRT
  - 12 1/4" – 15000 ft BRT

- **Geoprober Well – GOM Q4000**
  - 13 3/8" – 340 ft BML
  - 7 5/8" – 3200 ft BML
  - 5 1/2" – 12500 ft BRT
  - 4 3/4" – 15000 ft BRT

**Figure 11: Days vs Depth**

Note that drilling below the conductor commences on Day 3 when using the “Geoprober” system and on Day 12 when using a conventional BOP and riser system.