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Riserless Drilling with Casing: A New Paradigm for Deepwater Well Design

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Abstract

As the deepwater Gulf of Mexico (GOM) drilling operations move into deeper water and well depths there has been a lack of consistent and sustained drilling performance improvement. This is an evaluation of the GOM deepwater wells in an attempt to understand the reason for this poor drilling performance and propose a solution to adapt the well designs for the specific challenges of deepwater drilling. Execution of these very expensive wells, which often fail to achieve objectives or worse, are lost, requires a step change in drilling performance.

The complex deepwater drilling environment has pushed the typical offshore well construction design model to its limits. Many of the well design philosophies and the well equipment itself are not well suited for the unique deepwater drilling environment. This requires step changes in well design philosophy, and the understanding and acceptance of the associated risks of implementing new practices. The acceptance of change has been a monumental driver in our industry. The goal is to ensure that exploration and development of oil and gas continues to be feasible in this industry subject to volatile commodity prices and ever increasing costs. A paradigm shift in well design philosophy that involves managing the drilling risks in the shallow hole sections, where the well costs are minimum, rather than the current practice of incurring risks after significant investment has been made, is critical to future success and economic viability of deepwater drilling.

The well design model presented uses the shallow and rapid growth of the pore pressure/fracture gradient (PP/FG) environment to optimize casing seats. Drilling with Casing (DwC) is an enabling technology that can be a mitigant for managing shallow hazards. The fundamental premise is to use this technology to set the first, and possibly the second casing strings, significantly deeper than current practice.

The proven ability of DwC to mitigate many similar drilling hazards as those encountered in deepwater drilling would allow the casing seats to be based upon the prevailing PP/FG environments, rather than being influenced by the shallow hazards.

This could allow for the following well design improvements:

- Larger annuli below salt for improved drilling margin management.
- Less total casing strings in the well.
- More use of conventional casing string sizes for drilling and geological contingencies.
- Enhanced planning and use of solid expandable systems.
- Decreasing the risk of not obtaining at least an 8-½ in. ID completion, essential for economic success in deepwater environments.
- Batch drilling into salt, which optimizes horsepower as well as cost, utilizing smaller capacity rigs for the lighter hook load casing lifts.

Introduction

A review of the drilling performance of exploration and appraisal wells drilled in the GOM since 1991 indicates¹ (Weatherford, Dodson Co.) that there has not been any sustained improvement in drilling performance for complex wells. With daily operating cost of these wells often approaching one million USD/day, and requiring up to 100 days or more to drill, it is critical to the economic success of deepwater field development to reduce well costs. Many operators have focused upon operational efficiency for improvement but, as evidenced, the expected improvement has not occurred. This has been noted in the lack of improvement in the well drill times as well as failing to achieve objectives, specifically in the highly complex wells.

In the case of exploration wells, attaining well objectives may be more critical to the operator at that juncture than excellence in performance. That is, it is more important in these wells to define the geoscience aspects of the well, however, this is not happening in the more complex wells. Achieving objectives and excellence in drilling performance are not, and should not be, mutually exclusive. The history of attaining well objective success will not be evaluated because of the privileged nature of this data. Nevertheless, many of the readers will be aware of their own situations in failed wells, which are often not reported in global drilling performance databases, including the data herein. The data does not include well failures, so the representations are more optimistic than reality.

The basis of this proposed well design change is that the current deepwater well design, specifically the casing program, impedes improvements on the overall deepwater drilling performance, especially in the highly complex deepwater wells. This conclusion is based upon the fact that all of the wells in this study were drilled with similar type drilling vessels, similar services and similar drilling practices. However, only wells of a less Complexity Level 1 and 2 (see **Table 1**) have indicated improved drilling performance with experience. The prevalent common denominator in all these wells is the well design itself.

Currently, riserless casing depths are arbitrary and driven by presumed shallow hazards. The shallow strings have the purpose of providing structural integrity, yet ignore the rapid growth of the fracture gradient.

The typical deepwater well design will have the following casing design:

1. **36-in. or 30-in. Structural Casing** — this is required for structural support of the Blowout Preventer (BOP), riser and subsequent casing strings. This string is usually jetted-in to about 250 to 350 ft Below Mud Line (BML), but not deep enough to provide leak-off integrity for drilling through any deeper anticipated shallow hazards.
2. **28-in. and / or 22-in. Conductor Casing** — these casing strings are to provide for sufficient shoe strength to drill deeper with a weighted drilling fluid, and normally set above any perceived shallow hazards. This string is usually drilled-in riserless using a dual gradient drilling fluid, that is, returns to the seafloor with a seawater column on the annulus.
3. **22-in. or 18-in. Surface Casing** — this casing string is often set into the top of salt, to support the high pressure wellhead housing (HPWHH), and subsequently, the BOP's and riser. The section is usually drilled riserless in a dual gradient environment

The proposed approach is to utilize DwC to drill in at least the first casing string to a suitable depth, 1,000 to 1,500 ft BML, to act as a structural and surface casing. This string would be drilled with the low pressure wellhead housing (LPWHH) in place and would be cemented once at section depth. Subsequently, the next casing string would be drilled into place in the same manner to obtain depth determined by the PP/FG environment, and landed inside the LPWHH.

Deepwater Well Complexity

Table 1 is a summary of the complexity level categories used in this study to evaluate the drilling performance of exploration and appraisal wells and categorized according to their water and well depths. For this study, the wells were grouped as indicated in Table 1 of increasing complexity, with water and well depth being the strongest factor in determining well complexity.

Table 1 – Well Complexity Level

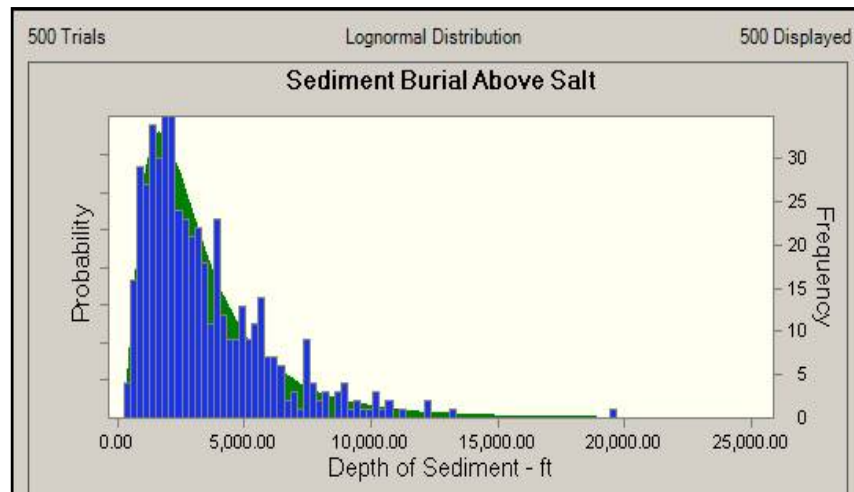
Complexity Level	Key Well Factors - Median			
	WD – ft ss	Well Depth – ft KB	Number of Casing Strings	Percent of Salt Penetration
1	3,200	19,000	5	78
2	4,300	23,000	5	72
3	4,400	28,000	5.5	81
4	6,000	29,500	6	85
5	6,700	30,000	7.5	100

A factor that determines the number of casing strings in the well design is related to the depth of sediment above the salt. A larger thickness of sediment increases the potential for shallow hazards such as shallow gas flows, shallow water flows, hole

instability, loss of circulation and hydrates. In the current well designs it is this potential of shallow hazards that drives the need for additional casing strings between the seafloor and the top of salt. This practice does not optimize casing seat integrity and could be counter productive to ensuring wellbore stability.

Fig. 1 indicates that the sediment depth of the population of exploration and appraisal wells has a lognormal distribution with a median of 2,586 ft and standard deviation of 3,586 ft.

Figure 1 – Sediment Depth



This data indicates that a large population of the wells drilled, (and to be drilled), in the GOM have significant amounts of sediment above the salt requiring more casing strings rather than less unless shallow hazards are mitigated and managed by other designs such as DwC as proposed in this presentation.

Deepwater Learning Curve

Deepwater drilling activity in the GOM has occurred to a large extent in the following fields:

- Atwater Valley
- Alaminos Canyon
- Garden Banks
- Green Canyon
- Keathley Canyon
- Mississippi Banks
- Walker Ridge

The population of wells from these fields for this study includes 85 exploration and appraisal wells from various operators dating from July 1991. These wells have water depths ranging from a minimum of 1,151 ft to maximum of 10,010 ft. The well depths vary from 11,305 ft KB to 36,145 ft KB.

The drilling performance of these wells was compared using the metric of days/10,000 ft. This is a measure of the days to drill and case the wells from spud to time required to reach total depth (TD). This metric includes all time up to, but not including, the evaluation of the last hole section, including any non-productive time due to drilling problems and mechanical issues of the drilling unit or other service. However, it does not include any time associated with waiting on weather (WOW). Some of the data is based upon scouting reports, which may result in less accurate drilling time; however, the general trend in drilling performance is nonetheless evident for all well complexities.

Fig. 2 illustrates the drilling performance of all the 85 wells reviewed for this study. There is no apparent improvement in performance for the population of all wells, regardless of their complexities. There is a lack of sustained and notable learning which the drilling industry has come to expect with continued activity in the same geological basin or area.

To better understand and evaluate this situation, the well population was graded for increasing well complexity, primarily based upon water and well depth. From these complexity levels a more meaningful learning curve relationship can be determined. It became apparent that a more valid discussion is to compare similar wells, in terms of water depth and well depth. These two factors vary the most and have the largest impact among the sample population.

Salt penetration is a common factor increasing the complexity of the well designs. Large salt deposits are a common factor across all the Complexity Levels. This results in two conclusions, first, the studied comparative complexity levels are not an apparent function of the presence of salt, and second, that exploration and development of GOM oilfields will generally have to deal with the presence of salt deposits. Refer to **Table 1**.

Figs. 3 through **7** illustrate clearly that as the water and well depth increases there is a decrease in drilling performance, that is, sustained learning decreases as well complexity increases. However this is only part of the problem: failure to meet well objectives is more common than it should be.

The reason for this phenomenon is explained below in the Deepwater Well Complexity and Operating Window section.

Figure 2

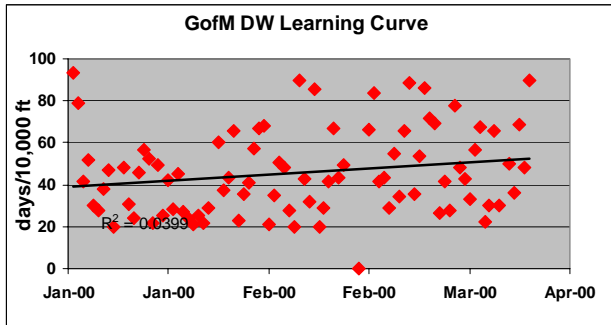


Figure 3

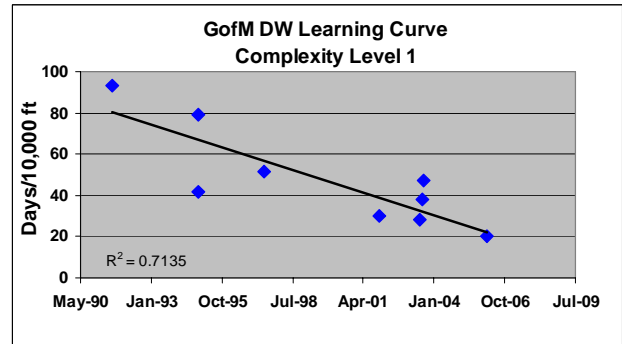


Figure 4

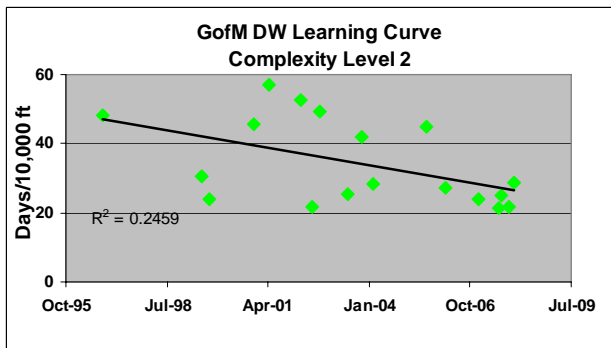


Figure 5

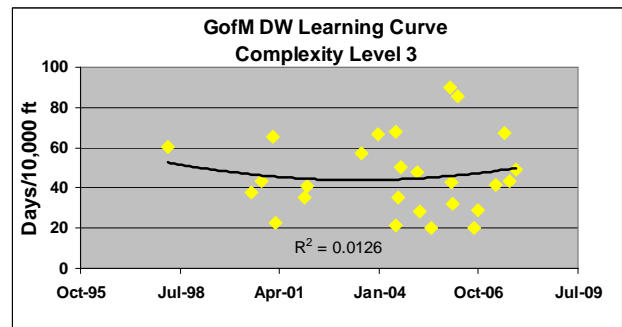


Figure 6

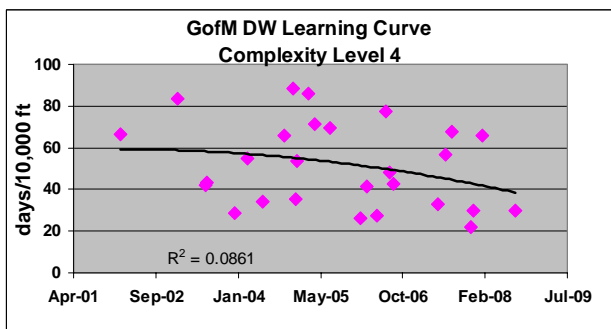
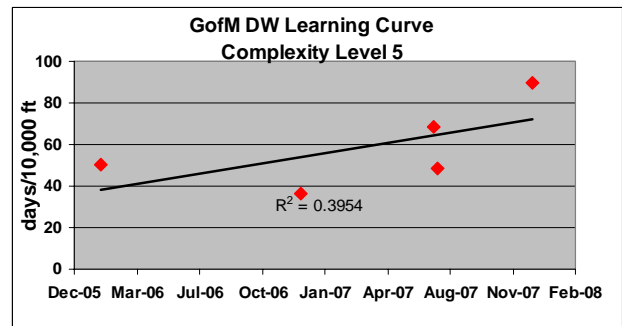


Figure 7



Figs. 3 and **4** indicate a clear learning history of improved drilling performance in these categories. As the water depth and well depths increase, the complexity of wells increases accordingly. **Figs. 5** and **6** indicate the performance for wells of complexity levels 3 and 4. For these wells, improvement in drilling performance becomes less apparent, with random performance within the large band of data. **Fig. 7** indicates that in the most severe well complexity; complexity level 5, it is clear that there is a decrease in drilling performance, albeit the well population is small. However, indications are that the trend is to drill more wells of this higher complexity. Reference to **Table 2** will indicate that all of the complexity level 5 wells were spud since 2006. Nevertheless, this situation of lacking drilling performance also applies to wells for complexity levels of 3 and 4, as indicate in **Fig. 3** and **4**.

The common denominator for all these wells, as described above, is a similar casing design and philosophy, which is:

- Jetting in the 36-in. to a shallow depth of 250 ft to 350 ft BML.
- Setting one or two surface casings to mitigate shallow hazards by providing presumed sufficient shoe integrity.
- Drilling the salt sections with BOPs and riser.
- Exiting the salt sections with 13-5/8-in. or 11-7/8-in. casings to drill through the targets with a 10-3/4-in. or 8-1/2-in. bit.

It can be concluded that this general well design philosophy is not optimum for deepwater wells of higher complexity. The key difference between shallow water and shallow well depth deepwater wells and those in deeper water and of greater well depths is the narrowing of operating margins for the PP/FG environments.

Deepwater Well Complexity and Operating Window

The cause of most drilling problems encountered in deepwater wells is related to managing the narrow drilling or operating window. The narrower the margin, the more difficult it is to execute drilling operations. This margin represents the boundary between the lowest equivalent circulating density (ECD) necessary to assure safe operations and wellbore integrity, and the highest ECD that can be tolerated to avoid fracturing the shoe of the prior casing string. If the shoe strength is not high enough, this obviously impacts the deepest depth which can be accomplished in the next hole section. This is commonly represented as a graph of pressure vs. vertical depth. The reason for decreasing well performance as the complexity level increases is related to water depth and the effect that it has on the pore pressure and fracture gradient (PP/FG) relationship and resultant operating margins. The increasing water depth has the effect of decreasing the margin between pore pressures and fracture pressures. This results in additional casing strings and creates a narrow window for managing wellbore pressures during drilling operations, specifically the ECD. The relationship between the pore pressures and fracture pressures in deepwater environments should be a major factor that drives the well design and drilling practices as opposed to arbitrary setting depths currently being utilized.

In general, the fracture pressure at a given depth increases as the cumulative weight of overburden above it increases. As water depth increases, the hydrostatic pressure exerted by the seawater column, in effect, replaces the pressure that would be exerted by overburden in shallower waters. This reduction in overburden pressure dramatically decreases the fracture gradient, especially in deepwater locations and at shallow well depths. As water depths increase and more casing strings are required, it becomes more critical to use effective drilling practices to maintain wellbore pressures within the operating window, while achieving well objectives. A key challenge to successful deepwater drilling is effective management of wellbore pressures to enable maneuvering through these narrow operating windows, of which the casing design is a major factor. The operating window can be increased by having larger OD casing at these critical depths, thereby decreasing ECD. The operating window can also be influenced by pseudo-stressed environments such as tectonics or salt diapirs.

The smallest margin between PP/FG gradients occurs near the seafloor, which makes drilling the shallow hole section of the well especially difficult, and thus DwC would have a major advantage in managing this situation. DwC has been used over the past several years to successfully drive casing seats deeper through difficult drilling environments ² (Terrazas, M., et al)

Narrow margin drilling is difficult to manage regardless of the drilling environment ³ (Pritchard, et. al.), whether deepwater, shelf or land ⁴ (Plumb et. al.). The drilling or operating margin can also be influenced by pseudo-stresses such as tectonics or salt diapirs. These unpredictable stresses are often unrelated to pore pressure in occurrence or magnitude and require quite different mitigation solutions to manage. Designing the well to accommodate these uncertainties by way of optimizing casing seats is the best way to mitigate such stresses. It stands to reason then that the deeper placement of the initial strings in any environment, the higher the probability of executing the next hole section and the risk profile is improved. It is therefore important to realize that the necessity of deeper initial casing seats is applicable to virtually any narrow margin drilling operation. Understanding the engineering required to optimize pore pressure fracture gradient dynamics is imperative for efficient and safe operations. Safety is paramount in that the height of the shoe tolerance and the ability to ensure well control improves with a deeper, prior casing seat.

Improving initial casing seats using DwC can also only enhances the ability to use other enabling new technologies such as control pressure drilling and solid expandable technology. They can be interdependent. The deeper the prior casing seat, the better the ability to manage pressure in a controlled environment. A known weakness of expandable technology is the reduced collapse resistance inherent to the technology. The collapse resistance profile of solid expandables systems improves with the smaller diameter tubulars, therefore the deeper the conventional casings are set the smaller the diameter of an expandable becomes. Expandable systems utilizing a thicker wall casing, therefore higher collapse, have recently been introduced into the market ⁵ York, P., et al.

Casing Seat Depth Determination

In current well design, riserless casing seats are based upon:

1. Ensuring structural integrity.

This can also be a risky proposition since the 36-in. string is jetted to arbitrary shallow depths, and integrity is dependent on “wait and soak” techniques before drilling ahead. If failures were to occur for example in weight transfer of subsequent strings, catastrophic subsea failure could result.

2. The presumed presence of drilling hazards, shallow gas, shallow water flows, hole instability, loss of circulation and other well specific hazards.

Little, if any consideration is given to optimizing the depth of each casing string. Deeper casing seats would improve the ability to manage each of the aforementioned risks.

3. Material specifications of the casing.

4. Hoisting limitations of the drilling unit.

Referencing **Fig. 8** in the **Appendix**, the current typical deepwater practice is to set the casing seats above the anticipated shallow hazards. This is to be able to have available sufficient casing shoe strength to mitigate these hazards with a drilling fluid and to provide sufficient kick tolerance in the event of an influx. This methodology requires two (2) additional casing strings to mitigate the presumed shallow hazards, which results in the suboptimal hole size through the remaining well objectives.

The 28-in. surface casing shoe is set above the first prognosed hazards since the 36-in. structural casing was jetted in to about 300 ft BML, which does not provide enough shoe strength without the risk of broaching the 36-in. and compromising structural integrity. The 22-in. second surface casing is set above the next anticipated shallow hazard since 28-in. is not set deep enough to provide sufficient shoe strength to drill this section. This practice does not provide for optimum casing seat tolerance, nor does it necessarily provide the safest drilling environment.

Fig. 9 illustrates the situation where the anticipated shallow hazards are mitigated by the use of the DwC technology, and thus the casing seats are determined by the operating window of the PP/FG environment. The 36-in. casing would be drilled to a depth of 1,000 to 1,500 ft BML. This would provide sufficient shoe integrity to allow the next hole section to be drilled into the top of the salt. DwC is therefore an enabling technology that could improve risk management and facilitate a safer and more efficient operation in the supra salt environment.

Drilling with Casing – The Complete Well Design

The use of DwC, in the riserless hole sections creates a vision of a deepwater well design that offers significant improvements over the current well design. **Fig. 10** illustrates one proposal for a comparison of the current deepwater well design compared to one that uses DwC, for at least the first two hole sections. Some of the advantages are:

- **Less casing strings required to meet the well objectives.**

This reduction of hole sections would reduce the time required to construct the well. Flat time activities in deepwater typically are very time-consuming thereby making a reduction of hole sections significant. It has been estimated that the total well time can be reduced by three to five percent per hole section removed in the riserless well sections. As the deeper hole sections are removed the time saving could be even larger.

- **Larger annuli below salt for improved operating margin management.**

This has been discussed in previous paragraphs and is the most important aspect in improved well design. The larger annuli in the narrow operating margin areas can offer a decrease in ECD in well sections where tenths of ppg of mud density is the difference between managing an influx and avoiding fluid losses. There have been a number of exploration wells that have failed to meet the well objectives because of this engineering dynamic. Due to the proprietary nature of the success of wells meeting their objective, it is not possible to offer data. However, many readers will know this from personal experience.

- **Use of conventional casing strings sizes for contingencies in the sub salt narrow operating margin sections.**

Fig. 10 indicates that in this example there are opportunities to use standard oil country tubular goods (OCTG) as contingency strings that would not be possible in the current well design. Each well will have a unique situation. The flexibility is obvious in the DwC case.

- **Enhanced planning and use of solid expandable systems**

The DwC well design allows solid expandable systems to be used in deeper well sections in normal pressure regimes for drilling hazard mitigation rather than trying to use in place of standard tubulars that must withstand high collapse and burst loads.

- **Decreasing the risk of not obtaining at least an 8-1/2-in. ID completion; essential for economic success in deepwater environments.**

Due to the inherent well design issues and current deepwater drilling design and practices there is significant risk and high likelihood that this desired working ID might not be available. This may be even more important for exploration wells, since due to the high cost of deepwater wells, it would be more appropriate to maintain a discovery well as a “keeper” if it had the appropriate hole size across the targets.

- **Possible batch drilling into salt, which optimizes horsepower as well as cost.**

One of the consequences of DwC is that the casing strings referenced in **Fig. 10** have very heavy hook loads. For example, the 22-in., 18-in. and 13-5/8-in. casings with landing strings could be about 1.4 million lb each. Therefore, it may be more effective to use a smaller capacity drilling vessel to drill the riserless sections and the larger vessel could be used for drilling and handling heavier hook loads. This could be a huge benefit to the industry where saving concessions are important, and optimizing horsepower is critical to effective rig scheduling.

The riserless casing drilling well design concept creates a number of design and well equipment challenges that require further additional study and development. The following is a concise, but not exhaustive, summary of some of the key challenges:

- **Casing Specifications**

As illustrated in Fig. 10, this design requires development of readily available higher strength OCTG in the larger diameters, such as P110 and Q125 in 22-in, to decrease the hook loads.

- **Riserless DwC Deployment Equipment**

Currently, the largest casing size used in a similar size has been 18-in OD. This requires development of deployment concepts and tools to be able to drill in and cement the larger sizes proposed in the proposal.

- **Wellhead Landing Issues**

Landing the 28-in DwC section in the LPWHH may require the development of technology to allow the “soft landing” of the 28-in hanger section into wellhead without rotation. This could be resolved with a telescopic shoe joint that is currently under concept design by some service and tool providers.

- **Drilling Issues of DwC**

There are a number of issues that require study, and more only be resolved with a pilot operation, that include: maintenance of suitable vertically of the 36-in while drilling, deviation issues that may cause subsequent casing wear, design of suitable drill shoes that provide economic penetration rates, drilling practice modifications from current practices, selection of suitable casing connections, study of suitable drilling fluid rheology, and appropriate risk assessments of the various issues involved.

Drilling with Casing – The Enabling Technology

DwC ⁶ (Tarr, et. .al.), ² (Terrazas, M., et al) is not new technology or a new drilling practice. It has been applied successfully in a number of different situations for drilling hazard mitigation similar to those experienced in the surface and conductor hole sections of deepwater drilling. The differences in the proposal are:

1. A subsea drilling environment, which requires modifications to drilling practices.
2. The casing sizes are somewhat larger than current technology (a known combination string of 20-in X 24-in behind a 27-in drill shoe bit has been utilized in Norwegian North Sea sector, in addition the largest DwC liner run to date has been 18-in.)

The two main characteristics of DwC that shows its ability as a drilling hazard mitigate are: smear effect ⁷(Fontenot, et. .al.) and dynamic ECD control.

The smear effect is much like a trowel, where due to the side-load forces from the rotating casing, the cuttings are pulverized in the narrow annulus and as they travel toward the surface. The particles become embedded in the wellbore wall and help form a natural seal that is much more impermeable than a wall cake generated by a typical drilling fluid. This works to assist in the control of fluid losses and improves wellbore stability.

The improved ECD, or dynamic mud weights, results from the smaller annular space between the casing and hole, which provides for much better hole cleaning and better control of the ECD with adjustments of flow rate. For example, a typical deepwater surface hole might have a diameter of 32-in. and the drill pipe may be 6-5/8-in. diameter, while DwC this 32-in. hole would be drilled with 28-in. casing. This is a reduction in annular volume of about 75%. This has a significant effect of minimizing any possibility of channeling that could cause shallow influxes to flow behind the drilling fluid.

Managing the Drilling Hazards – The Risk Assessment

This discussion is not meant to be a thorough risk assessment exercise; it should only identify some of the key concerns.

The drilling risks associated with this proposal need to be considered in perspective to the risk currently being accepted with the existing well designs. In most cases the risks associated with managing the narrow operating window and not meeting the geological well objectives are not taken until the well is well underway, with often up to more than USD 100 million having been spent. However, this is currently a normally acceptable risk by most operators in the GOM in an up market. This risk management profile needs to be improved, especially when improved drilling efficiencies may enable projects to be drilled in a leaner market.

The economic value of DwC succeeding is huge with the cost of its failure being relatively small. The risk of a failed riserless DwC operation is USD 10 to 15 million, while the risk of losing a well in the deep narrow operating margin area can be USD 100 million or more. DwC should improve drilling performance and safety resulting in operating cost savings, and prevention of the complete loss of wells and well objectives.

There are a number of DwC associated risks that require evaluation, from design of the required DwC tools to DwC mitigation of shallow hazards. However, the main perceived risk is not being able to drill the casing to its required casing depth thereby leaving the LPWHH too high above the seafloor if the casing is not able to be drilled to the required depth. The deepwater riserless DwC operation is essentially the same as drilling with a liner ^{8(Steppe, et. al.)} with the 36-in. and 28-in. casing made up before reaching the seafloor.

However, this important potential problem has been investigated. In April 2005, the Joint Industry Participation Project (JIPP) on Hydrates had drilled a number of 8-½ -in. holes in Atwater Valley and Keathley Canyon ^{9(Plumb, et. al.)}. There were two wells, KC 151 # 2 and #3 drilled to 1,506 ft and 1,455 ft BML, respectively. This offers proof that it is possible to drill a 36-in. casing to a similar depth. This statement is made based on the fact that the same riserless drilling techniques were utilized as are currently being conducted for riserless sections. Rock compressive strength was not an inhibiting factor, provided weight and drilling dynamics are normalized from 8-½- to 36-in. and applied, which is typical drilling best practice.

Conclusion

In summary the advantages of Drilling with Casing are:

- DwC has a history of being a risk management mitigant for similar shallow hazards present in the GOM.
- Allowing the casing design to be determined by PP/FG operating window, rather than drilling hazards, thereby decreasing the number of casing strings and improving both performance and safety.
- Allowing improvement in management of the PP/FG operating window with larger casing annuli at critical depths.
- Allowing the use of larger size casing to provide more flexibility for mechanical or geological side tracks.

Setting the first casing string significantly deeper than is the current deepwater practice would have a major positive impact on the entire well design. Using DwC to set this first casing string deeper could be the next paradigm shift needed in deepwater well designs to improve the economic value of deepwater developments. It is the drilling hazard mitigating ability of DwC that will make this possible. This could reverse the trend of poor-to-inconsistent drilling performance in these complex wells. Furthermore, the use of DwC in other hole sections could also greatly benefit the overall well design.

The importance of this proposed well design change is also underscored by the fact that operators are drilling increasingly more complex wells as they move into deeper water to investigate geological targets at depths greater than 25,000 ft, in water deeper than 5000 ft.

A forward thinking deepwater operator will further investigate and engineer this opportunity to capitalize on its potential value. With deepwater exploration becoming more important in the search and development of economic oil reserves, the application of such a technology could enhance cost effectiveness in this ever competitive and volatile industry.

Acknowledgements

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Appendices

Table 2 Summary of Studied Deepwater Gulf of Mexico Wells							
Block	Name	Operator	Salt Present	Date Spud	Well Depth - ft KB	Water Depth - ft	Days/10,000'
Complexity Level 1							
AT 222 #1	Blue Ridge #1	BP	Y	Jul-91	18,000	3,150	93.2
GB 216 #1	Bald #1	Hess	Y	Nov-94	20,171	1,611	79.1
GB 259 #2	Bald #2	Hess	Y	Dec-94	16,837	1,611	41.6
GB 216 #3	Penn State #3	Hess	Y	Jun-97	20,500	1,448	51.7
WR 313 #1	Titan South	Devon	N	Dec-01	16,720	6,288	29.9
GC 951 #1	Tiger	BHP	N	Jun-03	19,308	1,844	28.0
GC 435 #2	Yorick #2	ConocoPhillips	Y	Jul-03	19,610	3,813	38.2
GC 823 #1	Puma #1	BP	Y	Aug-03	19,035	4,131	47.0
KC 292 #1	Kaskida	BP	Y	Jan-06	17,952	5,859	20.0
Complexity Level 2							
GB 215 #4	Conger #4	Hess	Y	Oct-96	21,692	1,451	48.1
GB 941 #1	Sumatra #1	Unocal	Y	Jul-99	21,207	3,716	30.4
GC 415 #1	McKinley West #1	Unocal	Y	Sep-99	23,867	2,802	23.8
WR 678 #1	Dana Pt #1	Unocal	Y	Nov-00	20,300	7,036	45.5
AC 903	Trident	Unocal	N	May-01	20,500	9,687	56.9
AC 857 ST1	Great White	Shell	N	Mar-02	19,705	8,009	52.5
GC 485 #1	Concho #1	KM	Y	Jul-02	24,942	2,796	21.8
KC 511 #1	Voss	Conoco	Y	Sep-02	22,377	6,120	49.5
GC 534 #1	Saratogo #1	KM	Y	Jun-03	23,254	3,868	25.4
AC 951 #1	Toledo	Chevron	N	Nov-03	22,693	10,010	42.0
AC 859	Tobago	Unocal	N	Feb-04	18,510	9,627	28.4
WR 29 #2	Big Foot #2	Chevron	Y	Aug-05	25,933	1,611	45.0
MC 696 #3	Blind Faith #3	Chevron	N	Feb-06	24,731	6,945	27.3
GC 902 #1	Big Kahuna #1	BP	Y	Dec-06	26,061	5,233	24.1
GC 953 #1	Big Foot N #1	BHP	Y	Jul-07	22,277	4,790	21.3
GC 949 #1	Corona Del Mar #1	Woodside	Y	Aug-07	26,130	5,372	25.1
GC 452 #1	Terrabone #1	Woodside	Y	Nov-07	26,597	2,720	21.6
GB 778 #1	Clearwater #1	Shell	Y	Dec-07	23,972	3,800	28.9
Complexity Level 3							
GC 416 #1 All	McKinley All	Texaco	Y	Mar-98	27,582	4,019	60.5
WR 456 #1	Loyal	Texaco	Y	Jul-00	24,340	8,100	37.6
WR 425 #2	Chinook	BHP	N	Oct-00	25,109	8,835	43.2
GC 389 #1	Scout All	Shell	Y	Feb-01	26,677	3,595	65.7
KC 774 #1	Ponza #1	Unocal	Y	Mar-01	27,000	6,737	22.8
GC 640 #1	Tahiti #1	Chevron	Y	Dec-01	28,411	4,017	35.4
WR 206 #1	Cascade	BHP	N	Jan-02	27,929	8,140	41.1
GC 435 #2 ALL	Yorick #2 ALL	ConocoPhillips	Y	Jul-03	30,547	3,813	57.4
MC 696 #2	Blind Faith #2	Chevron	N	Jan-04	27,473	6,988	66.9
GC 518 #3	K2 North	Anadarko	Y	Jun-04	27,273	4,049	68.0
KC 681 #1	Sardinia #1	Unocal	N	Jul-04	27,575	6,345	21.3
GC 518 #4	K2 North	Anadarko	Y	Jul-04	29,872	4,035	35.0
KC 919 #1	Hadrian #1	ExxonMobil	Y	Aug-04	27,975	7,307	50.5
GC 320 #1 All	Chilkoot #1 All	KM	Y	Jan-05	32,023	2,596	48.0
GC 651 #1	Genghis Khan	Anadarko	Y	Mar-05	26,338	4,409	28.0
AT 398 #1	Bonsai #1	BP	Y	Jun-05	28,270	3,619	19.9
GC 376 #1 All	Quachita All	Hess	Y	Jan-06	32,023	2,596	90.0
GC 683 #1	Caesar #1	KM	Y	Jan-06	29,721	4,468	42.5
MC 695 #1	Blind Faith #1	Chevron	N	Jan-06	25,324	6,945	32.1
GC 599 #1	Friesian #1	Shell	Y	Mar-06	29,414	3,833	85.5
GB 342 #1	Andros Deep #1	KM	Y	Aug-06	31,803	1,153	20.0
GC 610 BP#1	Shenzi G1-1	BHP	Y	Oct-06	27,204	4,301	29.0
MC 822 #9	TH MC8822 #9	BP	Y	Apr-07	24,531	6,033	41.8
WR 29	Big Foot #3ST1	Chevron	Y	Jun-07	25,300	5,232	67.0
WR 155 #1	Atlas Deep	KM	Y	Aug-07	24,485	5,882	43.2
MC 683 #2	Tubular Bells # 3	BP	Y	Oct-07	26,371	4,262	49.2

Table 2 Cont'd Summary of Studied Deepwater Gulf of Mexico Wells							
Block	Name	Operator	Salt Present	Date Spud	Well Depth - ft KB	Water Depth - ft	Days/10,000'
Complexity Level 4							
WR 285 #1	Spa	ConocoPhillips	Y	Feb-02	27,504	6,654	66.4
WR 469 #1	Chinook Deep	BHP	N	Jan-03	27,652	8,831	83.8
GC 727 #1	Tonga #1	Chevron	Y	Jul-03	31,870	4,672	41.8
WR 678 #2	St. Malo 2	Unocal	Y	Jul-03	29,066	6,853	43.4
GC 943 #1	Myrtle Beach	Unocal	Y	Dec-03	30,435	5,314	28.8
WR 759 #1 All	Jack 1 All	Chevron	Y	Mar-04	29,000	6,965	54.7
WR 724 #1	Das Bump	BP	Y	Jun-04	29,484	7,536	34.2
MC 937 #1	Makulu #1	Chevron	Y	Oct-04	29,895	4,148	65.9
MC 734 #2 BP#2	Thunder Hawk	Murphy	Y	Dec-04	28,474	5,709	88.3
WR 508 #1	Stones	BP	N	Jan-05	26,639	9,576	35.3
AT 267 #1	Vrede #1	Shell	Y	Jan-05	32,627	3,341	53.4
GC 512 #1	Knotty Head #1	Unocal	Y	Mar-05	34,189	3,570	86.2
WR 759 #2	Jack 2	Chevron	Y	Apr-05	28,500	6,960	71.5
GC 390 #1	Pathfinder #1	Shell	Y	Jul-05	31,196	3,443	69.4
Kaskida 1 + ST1	KC 292 #1 + ST1	BP	Y	Jan-06	30,450	5,859	26.5
MC 819 #1	Thunder Bird	Murphy	Y	Mar-06	28,018	5,663	41.6
GB 561 #1	Grand Cayman #1	KM	Y	May-06	32,450	2,398	27.7
MC 782	Caterpillar Deep	Chevron	Y	Jun-06	27,316	6,686	77.5
MC 737 #1 BP1	Thunder Ridge	Murphy	N	Jul-06	26,775	6,109	48.2
GB873 #1	Tamara #1	BP	Y	Aug-06	31,831	4,704	42.5
KC 244 #1	Cortez Bank	BP	Y	May-07	32,462	5,431	33.0
WR 848 #1 All	Hal All	Exxon	Y	Jun-07	28,855	7,635	56.8
WR 667 #1	St Malo #3	Chevron	Y	Aug-07	28,479	6,895	67.7
WR 508 #3	Stones #3	BP	N	Nov-07	29,416	7,476	22.0
WR 371 #1	Greenbay	Anadarko	Y	Dec-07	30,596	6,288	30.1
AT 138	Sturgis North #1	Chevron	Y	Feb-08	29,500	3,480	65.6
WR 581 #1	Damascus	Chevron	Y	Aug-08	28595	6919	30.0
Complexity Level 5							
WR 544 #1	Tucker	BP	Y	Jan-06	29,630	6,844	50.2
WR 627 #1	Julia	Shell	Y	Dec-06	30,151	7,068	36.1
WR 278 #1	Chuck	Devon	Y	Jul-07	36,145	6,464	68.6
MC 860	Bob North #3 BP#1	Chevron	Y	Jul-07	29,821	5,656	48.2
WR 678 #3	St. Malo 4	Chevron	Y	Dec-07	28,479	7,005	89.7

Figure 8

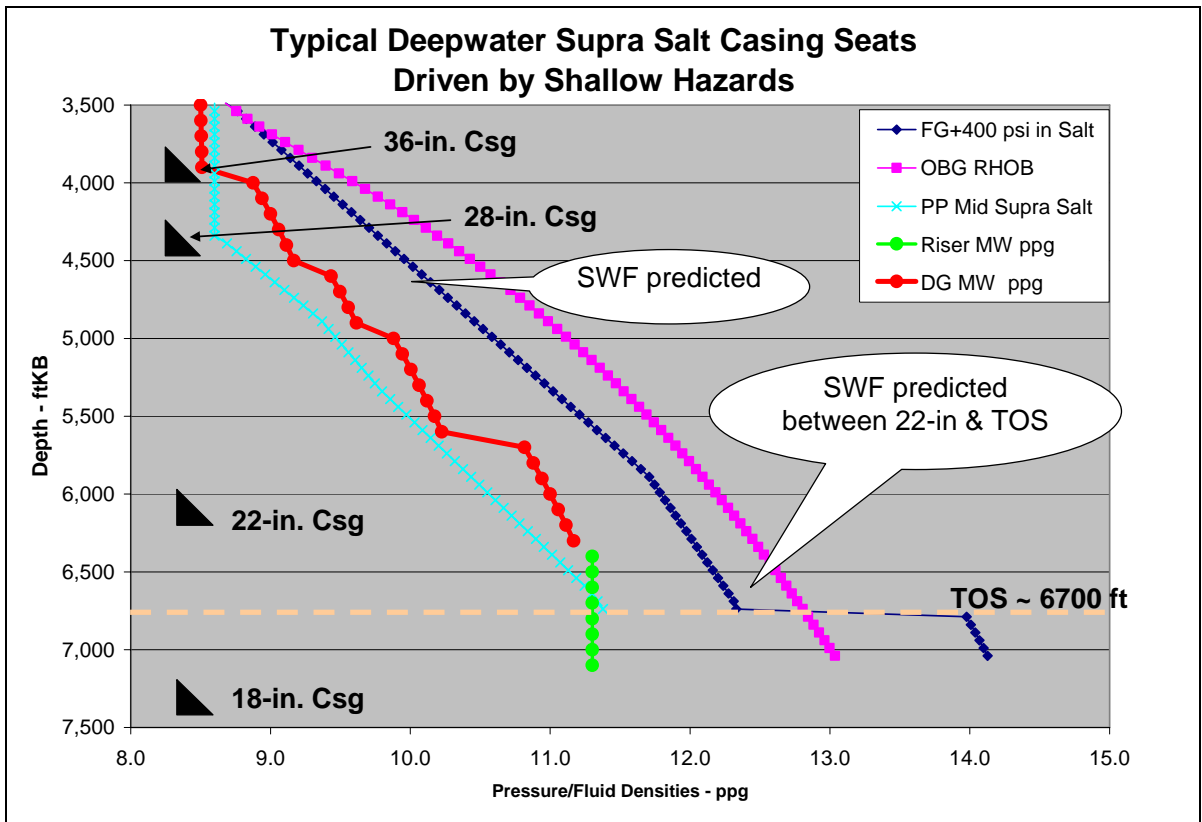


Figure 9

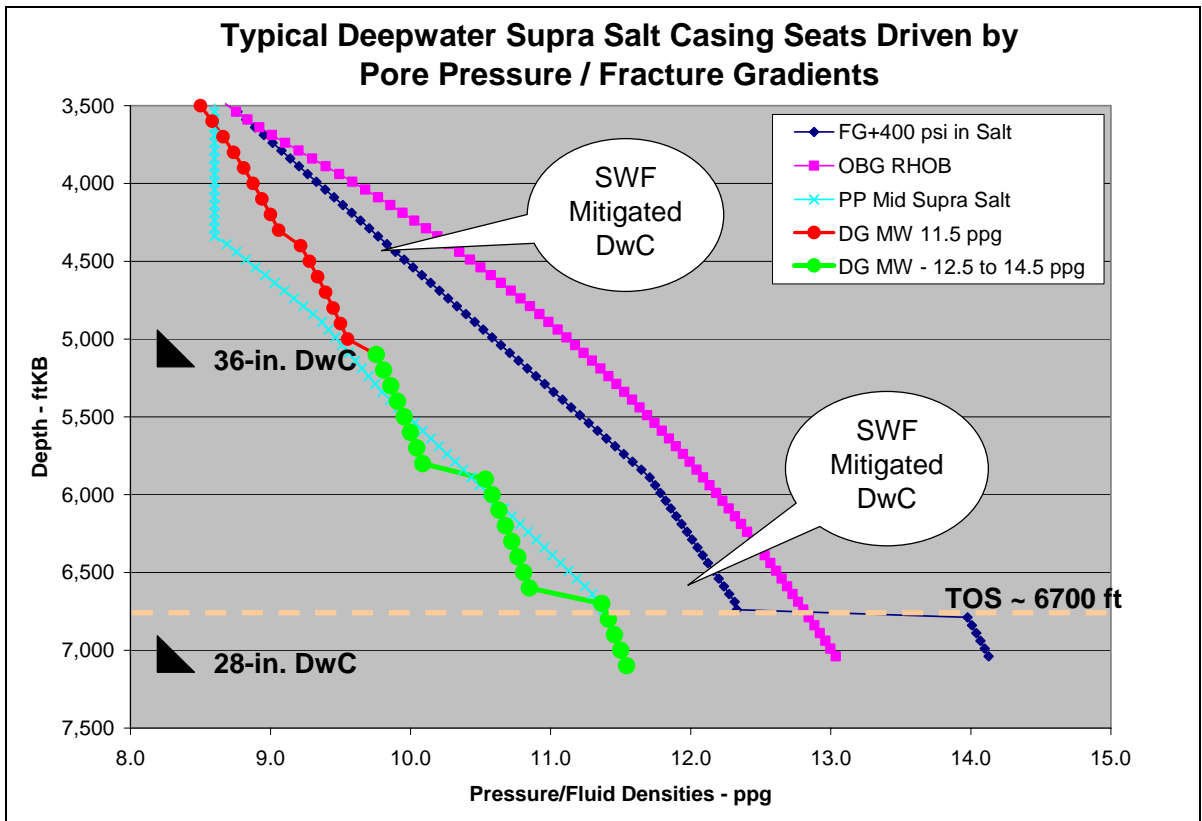


Figure 10

