AADE-07-NTCE-48

# Impact of Rotary Steerable Systems in the Gulf of Mexico

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This paper was prepared for presentation at the 2007 AADE National Technical Conference and Exhibition held at the Wyndam Greenspoint Hotel, Houston, Texas, April 10-12, 2007. This conference was sponsored by the American Association of Drilling Engineers. The information presented in this paper does not reflect any position, claim or endorsement made or implied by the American Association of Drilling Engineers, their officers or members. Questions concerning the content of this paper should be directed to the individuals listed as author(s) of this work.

## Abstract

Expectations of an order of magnitude improvement in drilling days have been implied with the use of Rotary Steerable Systems (RSS) in directional hole sections. In a recent publication, Spears and Associates estimated that "the typical Gulf of Mexico well saw drilling days fall by 50% due to Rotary Steerable Technology (RST)", but qualified the statement by stating that the data to support it may not be available for several years.[1]

Many complex factors contribute to a successful hole section making it difficult to quantify the benefits of RSS. The overall impact that RSS has on the industry is even more involved. Service companies are forced to compare their results to motor-derived drilling estimates; benchmarking their performance to wells drilled years earlier and under what sometimes prove to be dramatically different environments. Often the motor estimates for a section are either dramatically higher or lower than what actually would have occurred giving a false impression of the RSS performance.

This paper will review Gulf of Mexico (GOM) examples where motors and rotary steerable systems have been used under similar conditions (i.e. depth, rig, and mud system). The RSS and bit will be viewed as one system, because the success of one is directly impacted by the success of the other. This investigation will serve to compare the anecdotal statement suggested by Spears with actual industry data and in so doing will begin to quantify the overall benefits of RSS in the GOM.

## Introduction

When rotary steerable services were first introduced to the market in 1996, they were heralded as the enabling technology of the future. This technology was applied readily to the Extended Reach Drilling (ERD) and Ultra Deep Water Markets, allowing the drilling world to overcome technical barriers that motors simply are not capable of breaking. Due to high cost and low reliability, RSS were not viewed by the general community as a direct motor replacement technology. Figure 1 shows the wells where Rotary Steerables were first utilized.

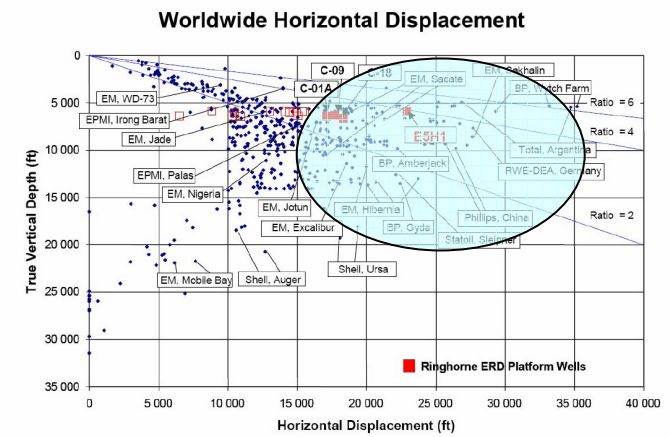



Figure 1: ERD wells (from SPE 99124), the blue circle represents wells where RSS may have been an enabling technology.

Improvements in tool reliability over the next 8 years, see Figure 2, pushed RSS to expand to other high tier markets, areas where a few days of savings (faster drilling with a RSS versus a motor) and high spread rates could easily offset the new tool's higher operational cost.

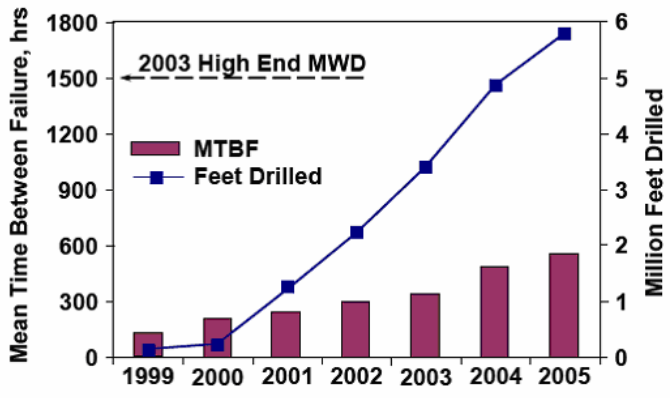



Figure 2: From SPE 98150, Shows the improvement in RSS reliability over the last 7 years.[3]

This increase in market share, see Figure 3, shows an increase in the amount of footage drilled directionally with RSS from only 2% in 2000 to almost 15% in 2005. [1,4]

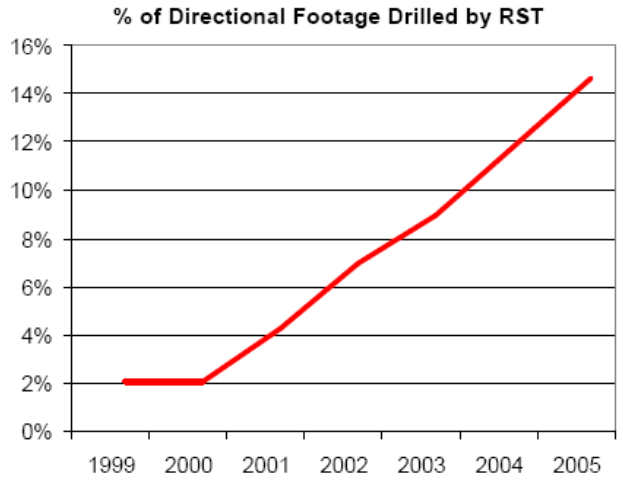



Figure 3: Rate of RSS growth in the last 5 years.[1]

Today, RSS has captured more than 75% of the floating rig market, leading to a debate over the future for RSS growth. Some believe simple economics are going to slow down the RSS market expansion since it is difficult to justify the high day rate on land or the Gulf of Mexico (GOM) shelf where savings at lower spread rates will not always outweigh the tool cost.[4] Spears & Associates, on the other hand, have made some very powerful statements about the effect they are seeing from RSS on the directional drilling market stating that "…the typical Gulf of Mexico well saw drilling days fall by 50% due to the use of RST." They went on to support this fact with the drop in rig count throughout the GOM, adding that "drilling is simply more efficient," but concluded that data to support that statement may not be available for several years.[1]

Quantifying the effects RSS has is having in the GOM is a difficult task. First, there is no comprehensive public database readily available to compare a large number of wells at the same time. On a smaller scale it is often difficult to make these comparisons because so many variables change from well to well. Second, the rig, the crew's experience, the operator's experience in the area, as well as the environmental factors (formation lithology, mud type and mud weight for example) all play an important role in drilling a successful hole section. In general, operators and service companies determine RSS success by comparing with the AFE curves, which may not always be representative of what a motor would have actually done in the area.

This paper will quantify the overall impact of RSS in the GOM by comparing RSS and motor performance at 3 levels:

- Gulf of Mexico Wide Analysis – includes drilling statistics from one major service company for all the wells drilled in the GOM with RSS and motors over the last 3 years.
- Area Wide Analysis – analyzes data from one operator in the GOM who have used a combination of 2 major RSS suppliers as well as motors to drill in a localized area.
- Offset Well Analysis – compares RSS and motor in 2 wells where the tools were run in the same depth intervals under nearly the same environmental conditions.

## Gulf of Mexico Wide Analysis

The largest RSS supplier in the Gulf has been tracking a number of drilling statistics for every well drilled using both motors and rotary steerables in the GOM for the last 3 years. Using the total footage drilled and the total operating (circulating) times for each tool size, it is possible to get an overview on how RSS is impacting the total market. In Table 1, this data is used to calculate an effective Rate of Penetration (ROP) based on the total footage divided by the circulating hour. A 6 ¾-in. tool is commonly used to drill hole sizes from 9 7/8-in. – 8 ½-in. for both motors and rotary steerables. Here, the 3-year average of this "circulating ROP" shows a 38% improvement in the drilling speed when using a RSS over a motor. For the smaller hole size, 6 ¾-in. – 6-in. hole, which typically uses a 4 ¾-in. tool size, the advantage increases to 85%. This is because RSS is able to apply more weight on bit, higher flow rate, and does not have the alignment troubles commonly associated with a motor in these hole sizes.

Table 1: ROP comparison based on footage per circulating hour figures for the last 3 years

| | Motor Vs.RSS - GOM Wide | | | |
|---|---|---|---|---|
| | 6 3/4-in. Tool Size | | 4 3/4-in. Tool Size | |
| | **Motor** | **RSS** | **Motor** | **RSS** |
| 2004 | 23 | 35 | 16 | 21 |
| 2005 | 31 | 37 | 10 | 27 |
| 2006 | 19 | 29 | 11 | 20 |
| **3-Year Average** | **24** | **33** | **12** | **22** |

Graphically, this phenomenon can be seen in a days vs. depth curve. Assuming that an operator drills a hypothetical well with an 8 ½-in. section that is 5,000 ft long and a 6 ½-in. section, also 2,500 ft long, with a 5-day long casing run in between; the days vs. depth curve would appear similar to the one in Figure 4.

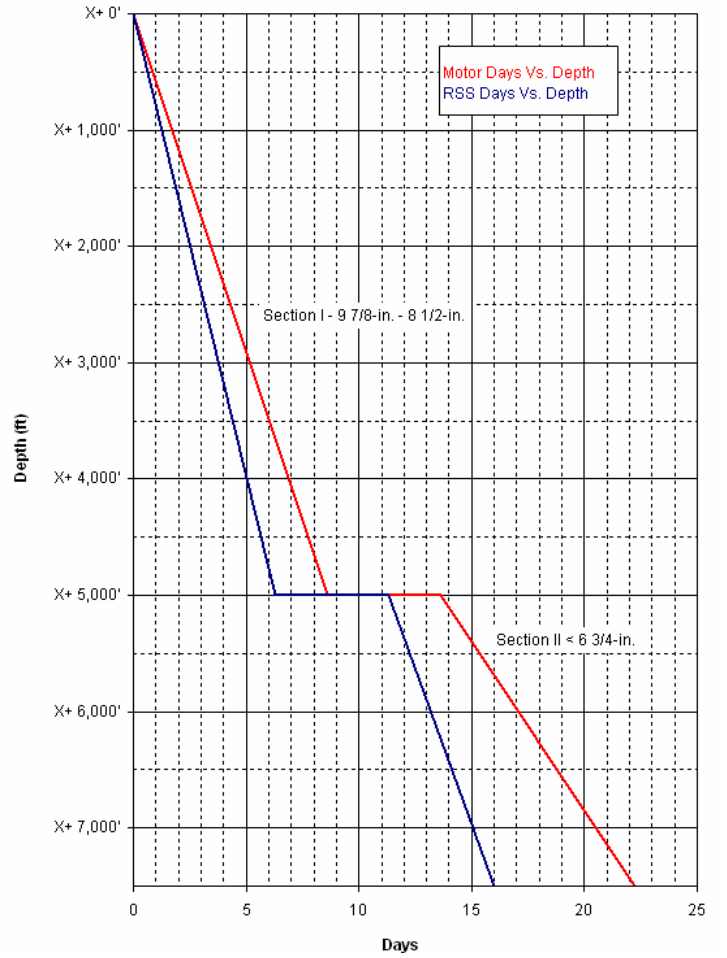



Figure 4: Days vs. depth based on total GOM data.

This data shows a reduction in drilling days over the hole of approximately 6-days or 28%; 27% in Section I (9 7/8-in. – 8 ½-in. hole size) and 46% in Section II (< 6 ¾-in. hole size). Assuming a spread rate of $250,000/day this translates into more than $1.5 million saved in these 2 hole sections.

## Area Wide Analysis

In a recent study, an operator in the GOM asked for a review of RSS versus motors for 3 areas that they were planning to increase activity in. The areas that were reviewed included: Grand Isle (GI), West Delta (WD), and Mississippi Canyon (MC). The reviewed areas can be seen in Figure 5.

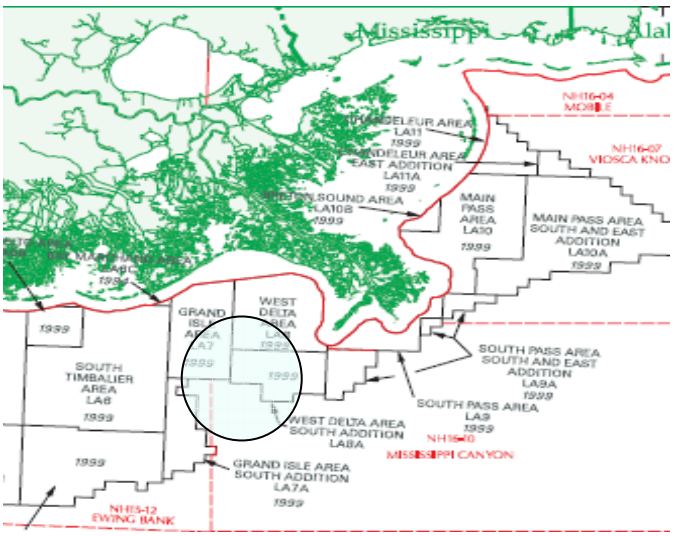



Figure 5: Shows area where well information was gathered.

In these areas, the operator had drilled 19 wells; information was available for 15 of these. A general breakdown of the directional information that was reviewed can be seen in Table 2 below:

Table 2: Summary of 15 Well Analyses Performed in GI, WD, and MC

| | Total Runs | Total Footage | Drill Time | ROP | Avg Footage/BHA | Number of Failures |
|---|---|---|---|---|---|---|
| **9-in. RSS** | 4 | 17,351 | 270 | 64 | 4,338 | 1 |
| **6 3/4-in. RSS** | 27 | 108,382 | 1,251 | 87 | 4,014 | 7 |
| **4 3/4-in. RSS** | 6 | 4,421 | 145 | 31 | 737 | 0 |
| **9-in. Motor** | 10 | 44,834 | 607 | 74 | 4,483 | 0 |
| **6 3/4-in. Motor** | 15 | 34,569 | 655 | 53 | 2,160 | 0 |
| **4 3/4-in. Motor** | 6 | 3,125 | 134 | 23 | 521 | 0 |

Different tool sizes are capable of drilling a range of hole sizes. In this example, the 9" Motors were used to drill a combination of 17 ½-in. and 14 ¾-in. hole. The 9-in. RSS was used to drill a 12 ¼-in. hole. As a result, no data is available to compare the larger hole sizes. Also, in this area most of the 6 3/4-in. tools were used to drill 9 7/8-in. hole, the runs from the 8 ½-in. section performed remarkably well, but do not follow the trends set by the other hole sizes.

Figure 6, shows the average ROP averaged over each hole size. In the 9 7/8-in. hole the RSS had a relative increase in ROP of 15%. The 8 ½-in. had an increase of nearly 160% improvement over a motor, this increase is significantly higher than expected and is being caused by the relatively few runs that were available in this hole size for this area. In the 6 ½-in. hole the increase was closer to 31%.

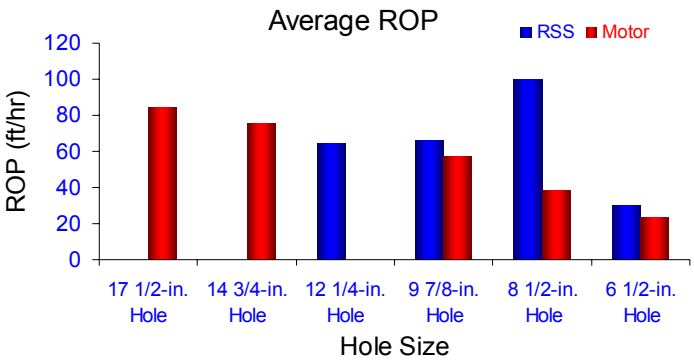



Figure 6: RSS and motor ROP comparison averaged by hole size

Using these ROP numbers and the same footage and casing assumptions used in the Gulf of Mexico Wide study, it is possible to construct a days versus depth curve as seen in Figure 7. The 9 7/8-in. and 8 ½-in. sections were combined together weighting them based on the number of runs performed.

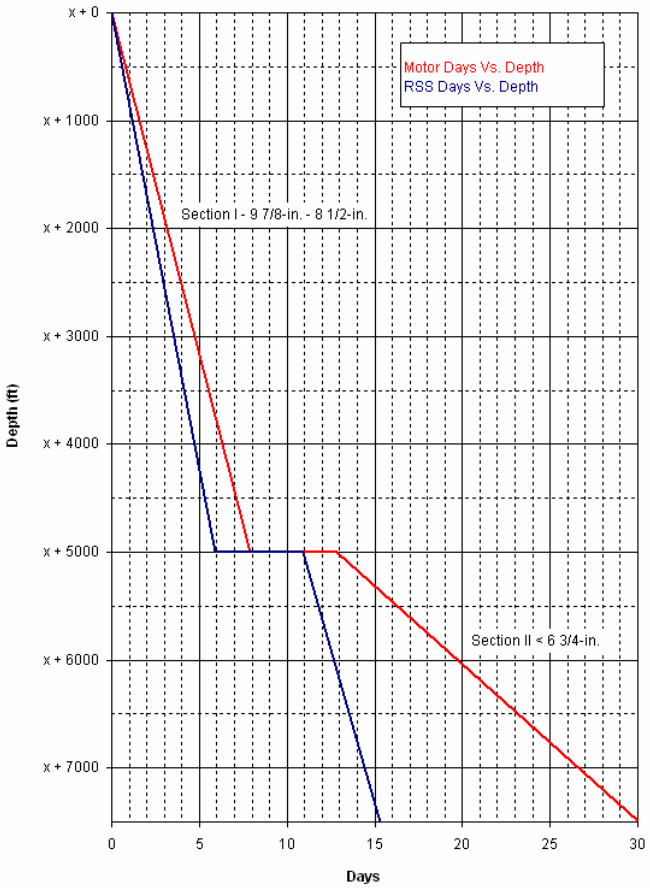



Figure 7: Days vs. depth based on area wide analysis

In Section I, which combines the data from the 9 7/8-in. and 8 ½-in. holes, the reduction in drilling days is about 2 days or 25% over the section. This is the nearly the same result that was seen in the Gulf of Mexico Wide analysis. In the smaller hole size, Section II, the reduction in drilling days is over 74%. In this example, the reduction in drilling days over the well is 15 days about 50%.

The reliability of RSS is often brought into question when making the RSS and motor comparisons. Rotary steerables are newer, more complicated and contain more moving parts than a motor, so it stands to reason that it would have a higher failure rate. In Table 2, the motors had 31 runs and 0 reported tool failures compared to the RSS which had 37 runs and 8 tool failures (a 21.6% failure rate). However, a hole size analysis on the same data. Figure 8, reveals that the RSS actually had a higher average footage per BHA than the motors run in similar sections.

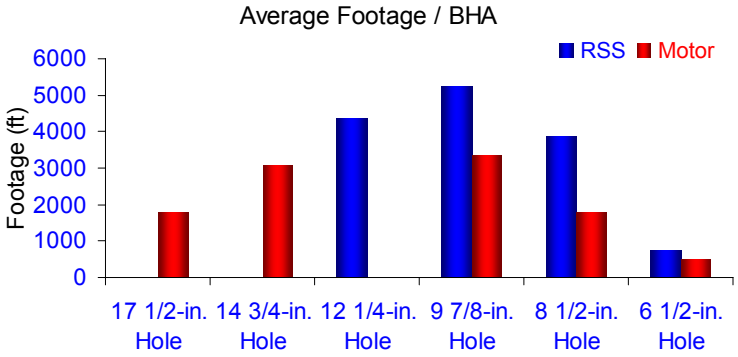



Figure 8: Avg. footage per BHA compared by hole size

Ultimately, the decision of which method to use is going to be a question of economics. In Figure 9, the motor versus RSS comparison was done by comparing only the closest fields and blocks to one another. The RSS runs in the GI 4*/4* for the 9 7/8-in. hole had many problems (including hole stability issues, reamer issues, and one RSS failure), making them a poorer choice for motor comparison. However, even including the data from this well, where the economics were not favorable for the RSS the operator saved more than $3million overall from the use of RSS.

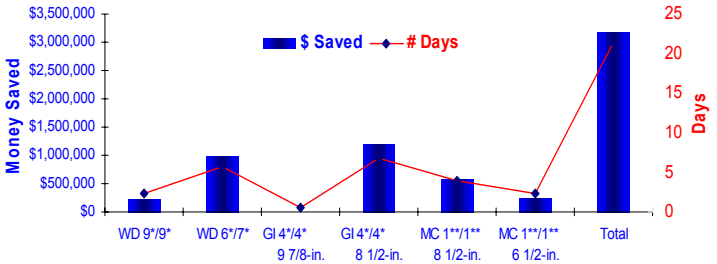



Figure 9: Area financial analysis based on blocks and hole size

## Offset Well Analysis

### *Sidetrack Analysis*

The following example shows a series of sidetracks in Mississippi Canyon which were drilled over a series of 5 years. Two of these sidetracks (ST03BP00 and ST04BP00) were drilled in succession, the first with a motor and the second with a rotary steerable system. These wells were drilled from the same rig, using comparable mud systems and covering comparable MD/TVD depths. The logs indicated that the geology (based on TVD) did not change significantly between the two wells.

Below are the days versus depth curves for all of the sidetracks that were drilled. The yellow curve represents the first side track from the original hole which was drilled with a motor and water based mud (WBM) in 2001. It drilled 5,800 ft in 14 days. The ST02 well, represented by a green curve, was also drilled in 2001 with a motor and WBM; completing 5,395 ft MD in 16 days. The final 2 sidetracks were drilled with oil based mud, the ST03 (red curve) was drilled with a motor for a total footage of 5,374 ft in 16 days. The ST04 (blue curve) used an RSS to drill 8,661 ft MD in 11 days.

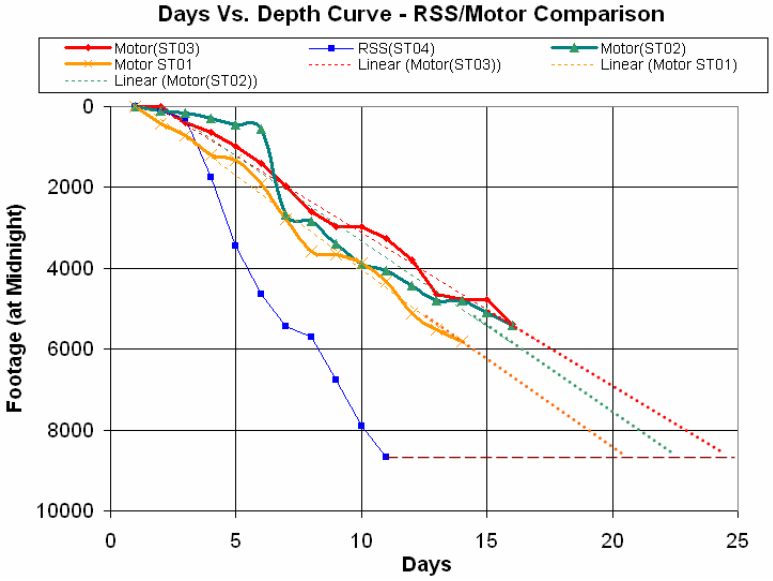



Figure 10: Days vs. Depth MC Well Analysis.

Assuming that the other motor sidetracks would be able to maintain the ROP they established from the earlier section of the well to the same TD as the final ST04, it stands to reason that the earliest a motor could have completed that sidetrack is almost 21 days (10 days longer than the RSS), based on the ST01. The ST03, which was drilled immediately before the ST04 and under the same conditions, would have taken more than 24 days to reach the same TD. Using the same relative ROP comparison methods used earlier this translates to a 134% increase in ROP from the hole drilled with motors to the hole drilled with RSS. Computing the days saved over the drilling section that is a 47% reduction in days.

Using the operator spread rate for the well, the cost per foot of ST03 and ST04 can also be compared. In ST03 the cost per foot was $413.81 a significant increase over ST04 which cost $251.60 per foot.

RSS offers many improvements to the wellbore besides ROP enhancement, including an increased ability to steer toward the reservoir.[4] In Figures 11 and 12, the planned well path and the actual well path drilled for both the ST03BP00 and ST04BP00 can be seen. The motor had trouble holding the azimuth tangent angle.

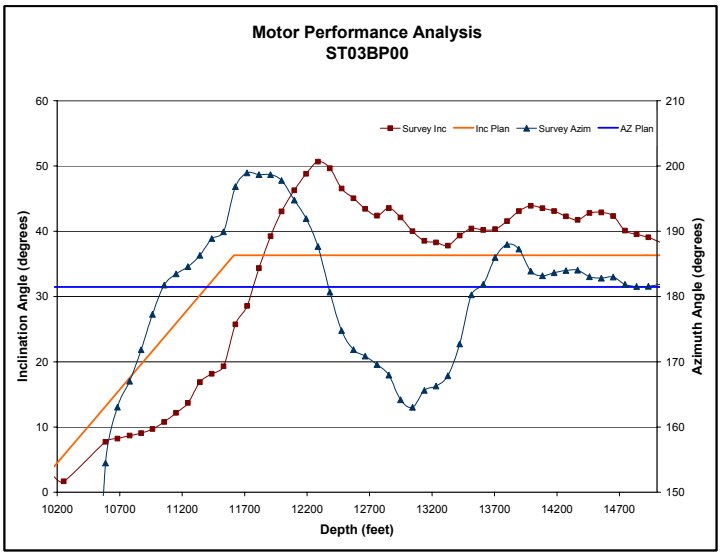



Figure 11: ST03BP00 well path planned vs. actual.

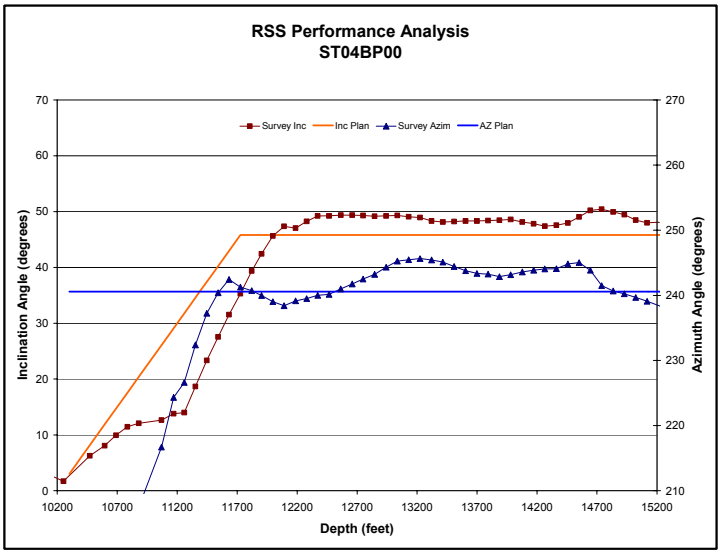



Figure 12: ST04BP00 well path planned versus actual.

The operator in this example also had trouble in the ST03BP00 well encountering many tight spots, and raising concerns about getting the casing smoothly to bottom. Using

RSS operators drill a smoother borehole eliminating spiraling and reducing micro doglegs, operators are more likely to get casing to bottom on the first run, avoiding time delays and costly sidetracks if the casing gets stuck and cannot reach bottom.

### *9 7/8-in. Section Analysis*

One operator in the GOM prefers to use the point the bit RSS systems since they do not require a specific pressure drop at the bit allowing them to increase HSI at the bit. For the first run in this well the HSI was planned at over 6-hp/in$^2$. The operator considered it a "best case" to be able to KO and drill this section at the same speed as the vertical offset well, see Figure 12.

After completing the build the RSS entered an unconsolidated sand, the high HSI caused the hole to washout making it impossible for the RSS to maintain angle. After pulling out of the hole, the service company suggested that if the client wanted to maintain the HSI at the bit a motor should be used to get past the unconsolidated sand.

Looking at Figure 12, the slope of the RSS and the motor curves show that there was not a significant difference between the two rates of penetration. Maintaining the tangent angle only required sliding 6% of the time (based on footage) and during the slides the ROP was not greatly affected.

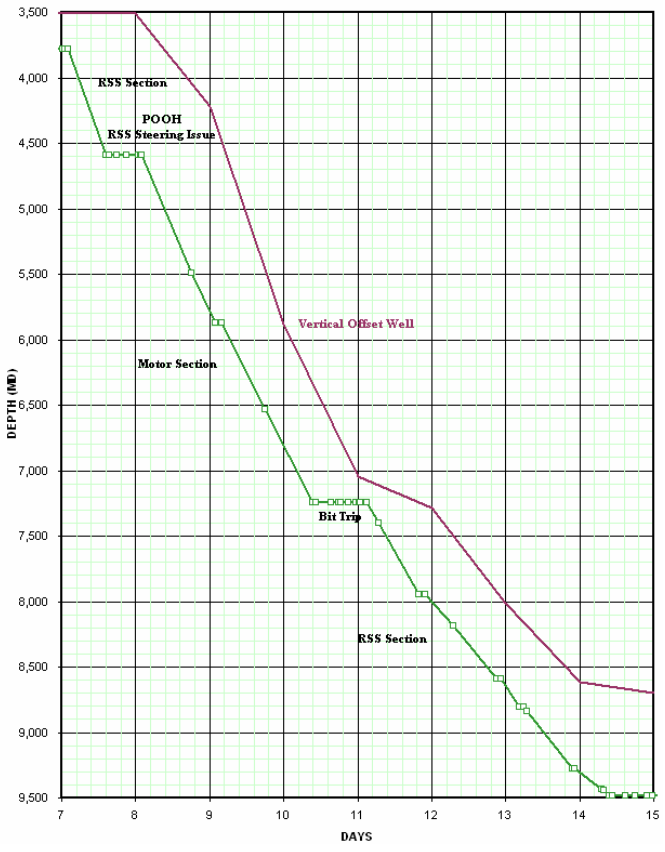



Figure 13: RSS versus motor section analysis

At the end of the motor run there were many tight spots and the operator backreamed the entire way out of the hole. The RSS did not experience any of those hole issues, implying that the quality of the hole was better in the RSS section.

ROP was not the only reason for this operator making the decision to run RSS. After the bit trip, the client elected to run the RSS in the final run, citing RSS directional control in the drop section and hole quality being worth the additional cost.

## Additional Benefits of RSS

RSS offers many benefits beyond the more often cited ROP enhancement. One operator in the GOM claims that since they began using RSS for their deepwater applications they no longer have problems with casing runs. Another major operator uses it in tight hydraulic windows to ensure good hole cleaning and ECD management. While this does offer "time" savings by reducing non-productive time (NPT), it is impossible to quantify those benefits on a larger scale.

Some of the additional benefits from RSS include:

- Better hole cleaning, for safer operating in a tight hydraulic windows and less circulating time at the end of each run to clean the hole.[5]
- Improved real-time log quality, enabling operators to use LWD log data and eliminate wireline runs.[6]
- Faster casing runs with fewer problems. RSS eliminates ledges and reduces tortuosity allowing for a smooth engage wellbore.[5]
- Stronger cement jobs and casing shoes, allow for safer and deeper drilling in the next section.

## Identifying Opportunities

While RSS may not always generate a higher ROP than a motor, overall operators will see a significant reduction in days and cost by using an RSS instead of a motor. To increase the chances of success there are several methods being used by service companies and operators to determine the steering method that best matches their well.

The flowchart in Figure 13 is meant to be a guide in making a steering selection that best fits each application.

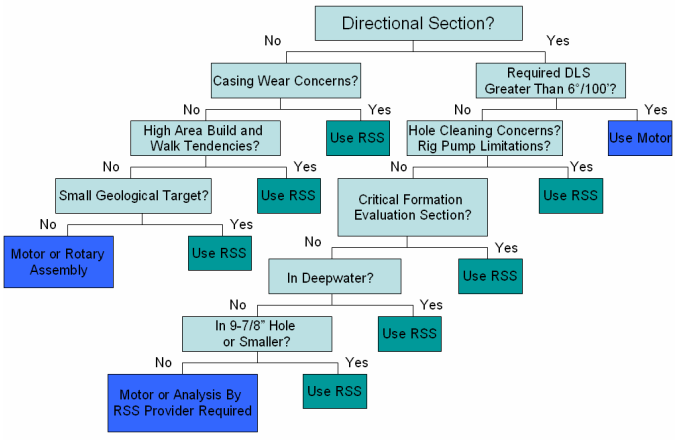



Figure 14: RSS vs. motor decision flowchart.

If ROP is the main driver for selecting RSS or a motor then some service companies use previous field performance and a favorable bit recommendation, similar to the analysis being performed by bit companies today. If no information is available the motor-derived days estimate will be verified and then often time they will use the "30% rule" which simply reduces the motor estimate by 30%. Based on this analysis, 30% is optimistic, in general for 9-7/8" – 8-1/2" hole 25% would be a more accurate assumption.

## Conclusions

Spears & Associates suggested that the use of RSS had led to a 50% decrease in drilling days of the typical GOM well.

- The evidence presented in this paper suggests that overall the typical Gulf of Mexico well saw drilling days fall by over 25% due to the use of Rotary Steerable Services in the 9-7/8" – 8-1/2" hole (where RSS is primarily applied today).
- There is not enough data in the larger hole sizes to quantify the total savings from RSS over motors, but data did indicate that savings increase significantly as hole size decreases.
- In the 6-3/4" – 6" hole size the evidence suggest that wells saw a reduction in days over the section of at least 46%.

Several of the examples in this paper showed that some wells will perform far better than the 25% and for some wells RSS will never be the right technological solution. The important thing is to properly analyze the planned wells and select the proper technology for each application.

## Acknowledgments

The authors wish to thank, PPI Managed Risk, Hall-Houston Exploration, Walter Oil & Gas Corporation, and Schlumberger for allowing us to publish the information in this paper.

## References

1. Spears, R., "Oilfield Market Report 2005 – Covering the Years 1999-2006", Sept., 2005

2. Musaeus, N., "Ringhorne Development: Technologies Applied in Extended Reach Drilling – Successes, Failures, and Communicating Risks", IADC/SPE 99124, presented at the 2006 IADC/SPE Drilling Conference, Miami, FL, 21-25, Feb., 2006.

3. Wand, P., Bible, M.m and Sivester, I., "Risk-Based Reliability Engineering Enables Improved Rotary Steerable System Performance and Defines New Industry Performance Metrics", IADC/SPE 98150, presented at the 2006 IADC/SPE Drilling Conference, Miami, FL, 21-23 Feb., 2006.

4. Warren, T., "Steerable Motors Hold Out Against Rotary Steerables", SPE 104268, presented at the 2006 SPE Annual Technical Conference and Exhibition, San Antonio, TX, 24-27 Sept., 2006

5. Johnstone, J. A., Allan, D., "Realizing True Value From Rotary Steerable Drilling Systems", SPE 56958, presented at the 1999 Offshore Europe Conference, Aberdeen, Scotland, Sept., 1999

6. Neuschaefer, Sirkin, Tollefsen, "Realizing Substantial Rig Time Savings with Next Generation LWD and Directional Services", presented at the Global Drilling Conference, April, 2005