Abstract

This project describes the successful introduction and application of a rotary steerable system in Libya. The development of rotary steerable capability was seen to be mutually advantageous to both Agip gas and Schlumberger in Libya.
- Also the technical Support to run this tool successfully for first time after doing study for the common drilling problems in Libya and suggesting drilling engineering solution for that, one of these solution using rotary steerable system.
- Doing help and support the operations by providing drilling engineering support - PowerDrive has the potential for making us a great deal of revenue but it will not do that if the tools do not deliver what they are expected to deliver. DEC took the lead in the planning and analysis of all PD runs in our Geomarket.
- The change from steerable motor to rotary steerable system has been both technically and commercially successful in Libya. Through this project the paper will demonstrate benefits resulting from the first use of rotary steerable systems that have led to a step change in overall drilling performance in Libya.
- The combination of improved rates of penetration, reduced stuck pipe incidents, enhanced hole cleaning and better hole quality have all contributed to the adoption of these systems in preference to traditional directional assemblies that use motors in Libya.
- Rotary steerable systems are gaining acceptance in Libya. As more and more systems become available, the range of potential applications continues to expand.

Project Objectives

• Improve Service Quality to Agip Gas
• Introduce Rotary Steerable system in Libya
• Promote RSS sales through Technical studies

The Central C field:

The Project was by Agip Gas BV offshore in NC 41 Central field of the main Bouri field, The reservoir is a fractured Limestone formation called Metlaoui, at app. 8250ft TVD, it contains a huge gas cap.

Libya Schlumberger is using the next services:
• Services provided: DD, MWD, Resistivity
• Motors: PowerPak and Vector
• MWD: M1, Slim1, Orienteer (Geolink and Target), SlimPuls
• Resistivity: Propagation Wave Resistivity (Target), Array Resistivity Compensated(ARC)
• RSS (PowerDrive): D&M RSS Market Share (Rigs)=100%

Introduction

Rotary steerable systems have progressed dramatically over the past few years as their reliability has improved and the range of applications has increased. The benefits of these systems are well documented. It has become very clear in recent years that the systems play not just a major role for drilling through the reservoir, but also, in optimizing drilling performance to the reservoir.

Steerable motor drilling is a relatively inefficient process, with associated problems in Libya ranging from trajectory control in unstable shale’s, pipe sticking in lost circulation zones. Rotary steerable systems are in many cases able to overcome these difficulties through continuous drillstring rotation and optimized bit and drilling parameter selection. Rotary steerable systems are now in use in all common hole sizes from 6” to 17 1/2” allowing problems to be addressed throughout the well.

Initially rotary steerable systems were utilized primarily in extended reach drilling (ERD) wells, where the ability to slide steerable motors was limited by hole drag. Today, drilling engineers are considering such systems for additional reasons. These include performance drilling, improved hole cleaning and geologic steering.

The combination of improved rates of penetration, reduced stuck pipe incidents, enhanced hole cleaning and better hole quality have all contributed to the adoption of these systems in preference to traditional directional assemblies that use motors in Libya.

Rotary steerable systems are gaining acceptance in Libya. As more and more systems become available, the range of potential applications continues to expand.
In Libya the mean clients is Agip gas and Agip oil, Agoco, Waha, Zueitina and Total.

Formation

- Sloughing clays grading to shale's usually cause excessive stabilizer and bit balling in the 17½" phase.
- Sloughing and unstable shale's in the Mahmoud formation (usually drilled in 12 ¾" and/or 8½" holes) result in hole cleaning problems.
- Fractured and depleted Limestone in the reservoir may cause partial to severe (total) mud losses.

All the sections were drilled before with the conventional PDM with a culmination of problems caused by erratic doglegs and also a major problem was encountered in hole cleaning:

- High or fluctuating torque
- Sticking pipe (over pull/weight transfer)
- Hole packing-off
- Poor directional control
- Inconsistent (slow) ROP
- Poor motor or bit performance
- Washouts, twist-offs or fatigue cracks
- Enlarged boreholes
- Wear on collars or drill pipe

These problems are a drawback with the use of the motor as to build we have to slide so when the drill pipe is stationary we cause a build up cutting's also due to the Bent housing used on the motor the surface RPM is low again hindering cutting’s evacuation. We found many problems mainly due to hole cleaning. The Powerdrive due to its nature would be the possible solution to many of the problems as the permanent rotation is higher than the motor and also because the removal of sliding to build the angle.

The Drilling Strategy

- Vertical well: 1 x 37 days 37 days
- CB1 wells: 3 x 42 days 126 days
- CB2 wells: 3 x 49 days 147 days
- CB3 wells: 6 x 64 days 384 days High Deviated wells
- CB4 wells: 2 x 75 days 150 days ERD

884 days

The wells are generally drilled in following steps:

1. Nudge the well in the desired direction either in 23” or in 171/2” hole. Use of Gyro surveys required due to proximity of other wells.
2. Commence kick off sometime into the 17 ½” hole, usually with the aid of a Gyro survey, until sufficient separation from neighboring wells achieved for interference-free MWD surveys. Also, any directional alignment corrections usually performed in this phase.
3. Drill through the sloughing shale to the 13 3/8” casing point. The main objective is to overcome the sticking and sloughing shale, and set the casing at a depth sufficient for increasing the mud weight.
4. Drill the 12 ¾” & 8.5 holes into Sloughing and unstable shale’s in the Mahmoud formation, and set the 9 5/8” casing shoe. The main problem in this phase is hole cleaning, 7” liner is set in the top of the reservoir after drilling in 8 ½” hole.
5. Drill the pay zone in the reservoir with light mud, due to the low pore pressure of the reservoir (heavily depleted). In the case of extended reach wells, this phase is drilled in 6” size.
Planning The Wells: What we need to optimize:

1. Well Profile
   - KOP
   - Build Up Rates
   - Tangent Angle

2. Hydraulics
   - Equivalent Circulating Density (ECD)
   - Bit Horsepower per sq/in² (HSI)
   - Maximum Pump Pressure
   - Annulus Velocity (Hole Cleaning)
   - Acceptable PowerDrive Output range

3. Drag and Torque
   - Surface Torque – Rotating Horsepower required
   - Maximum Pick Up Weight – Hoisting requirement
   - Maximum Contact Force
   - Minimum Allowable Stress of the String

4. Trip Drag Chart
   - Maximum allowable Over pull
   - Maximum allowable Slack Off

5. Casing Wear
   - As the contact force is one of the most important factors contributing to Casing Wear, planning the well profile and designing the Drill String will be done to minimize this contact force

6. Fishing
   - Jar position
   - Torque transfer to Stuck Point in relation to Surface Tension and Surface Torque.

Drilling The Well: What we need to monitor:

1. Well Profile
   - Check Dog Leg Severity
   - Following the Well Path? Data Quality
   - Reaching the Target, Correction needed? When?
   - Potential Well Collision

2. Hydraulics
   - Monitor Equivalent Circulating Density (ECD)
   - Check Pump Pressure, Warning for Jet plugged, Washout?
   - Mud Pump Calibration

3. Drag and Torque
   - Check Surface Torque
   - Contact Force Evaluation (Potential Key Seat, Casing Wear)
   - Check Stress of the Drill String

4. Trip Drag Chart
   - Record Pick Up, Rotating and Slack Off Weight
   - Friction Factors Back Calculation
   - Monitor Hole Cleaning
   - Allowable Overpull & Slack Off

5. Casing Wear
   - Casing Wear Monitoring – shakers?
   - Casing Protectors requirement?

6. Fishing
   - Tension requirement on Jar
   - Torque transfer to Stuck Point in relation to Surface Tension and Surface Torque.
Bit Selection

- Field study and Evaluation
- Correct bit selection can overcome on the formation problems and suitable for RSS, less vibration
- Dull grading: 1-1-NO-A-X-I-NO-TD

We have seen the offset bit records for the field or a nearby well, to see what has worked in the past, also get the opinion of local bit experts to see what they would recommend and we can then get something that will work on PD. What are the client’s requirements for bits? To do:

Enhanced durability

![Average ROP Graph]

Superior performance
Cutters stay sharp longer
Higher ROP is achieved
Bit life is extended

Sloughing and unstable shale’s in the Mahmoud formation (usually drilled in 12 ¼” and/or 8½” holes) result in hole cleaning problems.

Bit Recommendation

The RSX 130 is recommended to drill the Shale and Marl with large junk slot area to avoid any balling been counteracted on the previous wells with other PDC bits, we maintained the blade count with premium cutter quality to stand some hard strangers by end of the run.

A Steel body bit is highly recommended not only to minimizing the possibly of balling but also to stand the lateral, Axial, Torsional Vibrations Strength

Matrix is not as strong in tension as steel and, consequently this reflected in the body designs. Steel-bodied bits can be designed to incorporate high relatively thin blades, which can be useful especially in water base mud, soft formation applications. Such design is generally not feasible if the bit is manufactured from matrix because of the risk of blade breakage if a harder stringer is encountered.

Cutter Size
The large cutter size is generally is associated with fast drilling, 19-mm cutters are most suitable for drilling soft to medium formations, because larger the cutters produce large cuttings, they are extremely useful when drilling in hydratable formation, as less surface area of cutting is produce per unit volume of rock removed

- Bit designed for rotary, motor and steerable applications on soft to medium hard formation with
- Harder stringer at high penetration rates using predominantly water, and oil based mud. The transformation feature allows the bit to drill soft to medium hard formations with harder stringer at high ROP, the bit design features 8 Blades served with 8 nozzles and, steel body with 13 mm cutters on a short taper and medium Cone profile for better steer ability.

Large junk slot area (39.60 sq.in) will ensure maximum cleaning and cooling of the cutters. The bit is also fitted

In old Bouri project and first NC 40 wells they were using:
PDC bit has 6 blades, 13mm cutters, 6 primary gage blade and 6 secondary gage blades. The overall length of the gage pad is 9.5”. it is very aggressive for low speed-high torque mud motor and it creates too much reactive torque and unstable tool face.

This Hycalog bit RSX130 was drilling at instantaneous ROP of 55 ft/hrs it did prove to be the most suitable for PowerDrive applications in the 12 ¼ & 8 ½” hole especially in this extended reach wells.

Every bit drilled about 14000-17000 ft, Avg 4000 ft in one bit, and 4 bits total project.
BHA Design:

- Design new PD BHA to finish every section in one run.
Before it was 6 BHAs to complete every section

BHA design (particularly control stabilizer & flex joint design and placement) will also affect the performance of the tools and determine success or failure. Basically we will need to get a UG (12") stab to use as the control stab, it should be spiral and have a reasonably short gauge section. If we only want to hold the stab design is probably not crucial.

MWD tool - It we will not be running PowerPulse due to the embargo, we will not get much in the way of drilling mechanics data from M1, M3 or the Geolink tool. We suggested therefore having as a minimum surface torque, surface RPM and surface WOB to help us see any problems down hole. Continuous D&I is a big help with our M3’s.

Flex - we just want to hold so we will not need a flex joint in the BHA.

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Field Run Summary

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<td>CC-03</td>
<td>10</td>
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<td>CC-01</td>
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12 ¼" Section
From Inc 72 deg Azm 249deg at 5875ft to 70.4 deg 249.1Azm at 12270ft
PDC Bit 12 1/4” HYCALOG RSX130DF+GSV (4 x 12 + 4 x 14) + 9” PD900 + Float Sub + Stab. 12” + 8 3/8” RidgidMount MWD SlimPulse (gamma ray) + 8” Monel + 2 x 8 ¾” Spiral DC + Flex Joint + EQ Jar + 1 x 8 ¼” Spiral DC + X-Over + 15 x 6 5/8” HWDP’s + X-Over + 1 x 5 ½” Drill Pipe + Drop-in Valve + 5 ½” Drill Pipes

The PowerDrive was adjusted according to the survey results to stay on track with the well plan. The ROP was controlled to around 50 ft/ph to enable a good gamma-ray plot. At a depth of 15024ft we performed a wiper trip to the casing shoe.

It was no standard BHA before depend on the personnel and tendency of the formation, We recommend to use the mention BHA as standards here in such this formation in Libya and to remove the FG Stab on the top of MWD to prevent the drop tendency in case of PD failure, because will drop one degree in one stand.

8 ½” section
from 12270ft 70.68° Incl. 248.93° Az. to 17580ft 72.1 Inc. 250.21 Az.
PDC Bit 8 ½” RSX130DF (8 x 13) + 8 ½” PD Bias unit + 6 ¾” PD Control unit + 8 1/8” NonMagn. String Stab + Float sub + 6 3/8”

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Monel MWD (SlimPulse) + 6 3/8” Spiral Monel + 8 ½” String Stab + X/Over + 2 x 6 ¾” Spiral Drill Collars + X/Over + Flex Joint + EQ Jar - 15 x 5” HWDP’s + 1 x 5” Drill Pipe + DIV

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12 ¼ BHA

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8 ½ BHA

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Hydraulics & drilling parameter planning

- Redesign the mud program again to have optimum hole cleaning and suitable with PD, Solids control equipments
- Hydraulics optimization: the parameters to have 650-750 PSI pressure drop across the bit. Correct nozzles/restrictor can be fitted, Make sure rig is capable of delivering the required flow for the whole run.
- Plan the optimum drilling Parameters (WOB, RPM, ROP) are monitored, recorded and acted upon if Required.

The pressure drop below the RSS determines the amount of pressure that the pads exert and therefore the amount of DLS that the tool produces. Flow restrictors may be required to manage the HSI. This is something that has to be determined before the run so the correct nozzles/restrictor can be fitted or sent to the rig.

We ensured that we have 650-750 psi pressure drop across the bit to make the tool work, also doing a rough one with any hydraulics program or the following equation:

\[
\text{PD psi} = \frac{\text{GPM}^2 \times \text{mud weight} \times \text{PPG}}{10,858 \times (\text{TFA})^2}
\]

some of the flow is bypassed to the pads in pd so you get a lower number than the total flow.

Make sure rig is capable of delivering the required flow for the whole run and is not going to have to cut back the flow at the end of the run, cutting back the flow reduces the pressure on the pads and the tool may have reduced performance.

Drilling parameter monitoring and adjustment - surface-drilling parameters can play a big role in determining the success of PD (WOB, RPM and ROP) - as with the Down hole vibration data we need to ensure that the parameters are monitored, recorded and acted upon if required. Down hole vibration - there are numerous examples where we have seen vibration damage tools to the extent that they fail to work as well as vibration that reduces the effectiveness of the system. It is our job to make sure that the MWD tools are programmed correctly so the right data is available, the data is interpreted correctly and the appropriate action is taken - before it becomes a failure investigation.

Always we monitored the MW vs TVD on experienced from previous wells—avoid losses and let PD work correctly.

Actual Drilling Parametres have been used:
- RPM 150-175 all
- WOP=5 Avr
- ROP control for hole cleaning
- 70 ft 12.25
- 40 ft 8.5 including connection, survey everything

Analyzing problems

- Daily monitoring for the daily operation, analyzing problems, Investigate the problems and recommend solution
- Reduction in Torque due to smoother well bore & increases the Reach

Analyzing problems is the only way we are ever going to improve our service delivery - this means getting to the bottom of all service delivery problems not just hard tool failures, any system failures must be investigated and the root cause found.

Rotary steerable system application in Libya:

The RSS PowerDrive was first used on the 12th of May 2003 to drill the 12 ¼" section of well CC-14. The section was drilled in 2 runs due to an MWD Failure otherwise it would have completed in the expected 1 run. It drilled a total of 4341ft with an ROP of 74.86 ft/ph. Also having the benefit of continually low Doglegs. To put this into perspective when you look at the previous wells we averaged 5 trips per section and the ROP was between 25 –35 ft/ph. Also the off bottom time decreased due to the fact we don’t have to pick up of bottom to orientate the motor. Add to this the fact the BHA is very simple so due to minimal handling by the rig crew make up time is less. The rig time saved is tremendous.

The PowerDrive has been operational here on Zagreb for the last 8 months in that time we have managed to drill the following over 7 wells. In the 12 ¼” Sections using the PD 900 we have drilled 36932 ft giving an average ROP of 65 ft/ph. The longest single run was 6395ft using a 12 ¾” Hycalog RS-130DF=GSV. This is the bit used here for all the wells and would be recommended in situations as found here on this rig.

The PD 675 used in the 8 ½” Section has drilled a Total of 31490 ft with an average ROP of 45 ft/ph. The longest run was 5310ft again with a Hycalog RS-130DF+GSV

Drilling with rotary Steerable motor with a requirement to slide the bottom hole assembly in order to steer the well path drilling becomes slower and potentially more problematic. ROP is impacted as a result of wellbore friction and BHA and drillstring components hanging up. Hole cleaning, without drillstring rotation, is adversely
affected, as cuttings will drop out of suspension to the low side of the hole. The transition from slide back to rotate requires rotating the motor bend through the section steered. This can result in hole spiraling.

Steering a steerable motor requires maintaining the orientation of the bend in the desired tool face setting. Reactive torque from the motor itself works against good tool face control with the force turning the string in a counterclockwise direction. The magnitude of reactive torque will depend on the torque being generated at the bit which itself is a function of bit aggressivity, motor torque output and the formation being drilled. Tool face control using a light set PDC bit with large cutter diameter run on a low speed high torque motor can be extremely difficult. As a result a compromise on bit selection is frequently made for steerable motor drilling. It is not unusual for a roller cone bit to be run for a critical directional section of the well due to problems controlling tool face with a PDC bit. Orienting a PDC bit can be time consuming with frequent time spent off-bottom in order to control reactive torque.

The rotary sections with a steerable motor can also result in inefficient drilling. As with a rotary bottom hole assembly the directional behavior of a steerable motor assembly will be a function of stabilizer gauge and spacing as well as drilling parameters used. As a result the drilling parameters will be set to control the directional tendency of the assembly as opposed to maximizing ROP. Micro-tortuosity associated with a slide rotate sequence is of particular significance in many regional reservoirs. Coiled tubing accessibility can be severely impacted by a tortuous well path in the reservoir. In 6" hole, today’s extended power motors are susceptible to formation effects and can be difficult to stabilize and highly tortuous well path can result in the reservoir, often masked by a survey interval of every stand.

Reducing tortuosity through the build section can reap rewards later in the well. Side forces induced by large micro dog-legs from slide rotate drilling will greatly impact torque levels and casing wear later in the well. Next charts will show how such sliding dog-legs created large side forces in the 13 3/8 casing while drilling 12 1/4 hole in a well offshore in Libya. In this case high torque was the issue although the side forces were approaching a magnitude where casing wear could also have become a problem.
may result in problems while running casing, liners and completions. In addition, the increase in drillstring-casing contact can add to drillstring and casing wear. In specific applications, excessive tortuosity in horizontal wells can even impair productivity.

Comparing to steerable motor drilling the rotary steerable system should be able to deliver:

- Increased ROP:
  - No sliding interval
  - More aggressive bits
  - Optimized used of drilling parameters
  - Reduced trip time through better hole quality:
    - Improve hole cleaning
    - Reduced tortuosity
    - Improve hole gage

Improving Drilling Performance

PowerDrive was first introduced on these wells had eliminated the sliding, hole cleaning and frequent BHA changes. Also as indicated on the charts below, has improved the rate of penetration.

**Drilling 12 ¼ Hole with RSS**

The use of rotary steerable system in 12 ¼ hole first time in Libya is typically used to drill soft formation from Mahmoud to Salambô as mixture of clay and shale of the upper part and marl in the lower part, providing improved directional control and significantly improved penetration rates.

To kick off, build angle to 60-70 deg and hold to 9 5/8 casing setting depth using a steerable motor would normally take a minimum of two bit runs with an average penetration rate in the region of 35 feet per hour. This formation sequence is perhaps a classic for responding to benefits of a rotary BHA.

High penetration rates are achieved through maximizing drilling parameters. Using an eight blade PDC bit with 19 mm cutters, such as an RSX130, on a fully rotating system such PowerDrive 900 requires weight on bit to be kept to the top end of the range suitable for the bit: 4.5-13.5 KLBS. Rotary speed should be as high as possible to limit stick slip vibration between 120-140 RPM. These parameters are very difficult to achieve using a steerable motor explaining why the rotary steerable systems drill the section so much faster. The shale ROP has been seen to double purely based on bit hydraulics and with best performance to date of 70 feet per hour average.

Here the benefits of fully rotating system are seen-meaning systems with no stationary or slow rotating external parts. Fully rotating systems assist in hole cleaning and will facilitate tripping in and out of the hole. Frequently additional time saving is achieved through a reduction in tripping time and in particular the eliminations of wiper trips, as well the case at section TD of this example well.

In Libya the recent introduction of rotary steerable system in 12 ¼ hole has been equally significant, The first well to be drilled using a rotary steerable system (PowerDrive900) in Libya was targeted to make a significant reduction in drilling time and consequently cost.

Schlumberger drilled first well CC14 for Agip gas, 12 ¼ hole section was drilled in 4.7 days where the plan was 9 days, Agip gas saved around 4.3 days of rig time, and saving 650 K on the AFE cost for this well.

![Diagram](image)

**Days**

**Drilling 8 ½ Hole with RSS**

Since the introduction of 6 ¾ rotary steerable technology in 2000 the envelope has been pushed further still. Wells have now been drilled to measured depths in access of 30,000 feet with 8-½ drain length of over 25,000 feet. The rotary steerable system brings improved positional control and increased penetration rates with new records. As such rotary steerable drilling is able to meet the challenges:

- Placing the well in the optimum part of reservoir.
- Drilling the longest drain section possible within the reservoir.
- Maintaining optimum spatial distribution wells.
- Being cost effective.

The use of rotary steerable system in 8 ½ hole first time in Libya is used to drill soft formation from Cherahil B to the top of Metolaoui group as mixture of Shale and limestone, packstone and mudstone, providing improved directional control and significantly improved penetration rates.

To hold 60-70 deg to 7 casing setting depth using a steerable motor would normally take a minimum of 6 bit runs with an average penetration rate in the region of 30 feet per hour. This formation sequence is perhaps a classic for responding to benefits of a rotary BHA.

High penetration rates are achieved through maximizing drilling parameters. Using an eight blade PDC bit with 13 mm cutters, such as an RSX130, on a fully rotating system such PowerDrive 675 requires weight on bit to be kept to the top end of the range suitable for the bit: 4.5-20 KLBS. Rotary speed should be as high as possible to limit stick slip vibration between 120-145 RPM. These parameters are very difficult to achieve using a steerable motor explaining why the rotary steerable systems drill the section so much faster. The shale ROP has been seen to double purely based on bit hydraulics and with best performance to date of 50 feet per hour average.

The first well in Libya drilled using a rotary steerable system (PowerDrive675) to make a significant reduction in drilling time and consequently cost.

Schlumberger drilled first well CC14 for Agip gas, 8 ½ hole section was drilled in 6.5 days where the plan was 10 days, Agip gas saved
around 3.5 days of rig time, and saving 525 K on the AFE cost for this well.

Problems Encountered

PD 900:
When you consider the amount of footage these tools have performed I find it encouraging that when we had to POOH it was due to a down linking problem and caused minimum hole problems it had only been in the hole 17 hrs. After the Telemetry was dumped we found the commands had been taken. The other problems we had involved SHT failures twice where the flow came from only one Pad time lost was around ½ hr each

PD 675:
The only time we had to pull this tool was when the commands did not respond, I do not consider this to be a failure I would put this under hole conditions causing the POOH. The well had started to show losses as usual in the formation drilled so at the client’s request the flow rate was lowered to try and combat this problem. This caused the problem as the flow rate was to low causing the tool response to fail. The telemetry was dumped and commands were seen but they seemed to be partial not complete. The last setting of OTF 100% and the test setting in the casing were inside

Embargo Difficulties:
- Drilling Engineering Center support was not available.
- Drilling Office Software cannot be used in Libya
- Limited capability of (DSP-One) Software –Well planning, BHA, T&D, Hydraulics, Close Approach
- Technical Support: when we started this project was difficult to access the technical websites: intouchsupport, D&M Hub &Network
- RSS Maintenance facility was not available, PowerDrive Tools brought from another location.

In spite of the developments in the drilling technology since the first phase of Bouri development (which was drilled with M1 MWD, Eastman motors and bent subs), Libya has been under US embargo for a number of years, and consequently, most of the benefits of recent technology were unavailable for this particular operation.

Equipment
- The project had to be executed with extremely limited selection of equipment. The technology available was outdated, and limited in both quantity and quality. Besides the obvious restriction these conditions placed on the operation, a less obvious drawback was the difficulty of providing efficient technical support, as supplies of parts and replacement were restricted due to the trade and technical embargo imposed on Libya, as well as the cessation of manufacturing and support for a lot of the tools used. Basically, each phase before had to be drilled with two PDMs, and two M1 MWD tools with M3 modulators. The surface MWD system consisted of the ADVISOR v5.4C and SPM v.4.0 for the MWD, and MacDD (subsequently replaced by a PC based DSP-1 software) system for the Directional Drilling. In the 6” hole, SLIM-1+Gamma Ray was used instead of the M1/M3 hybrid.

Operational
- Executive: A lot of external factors were involved in decision making on the project. Only limited executive power was given to the client representative on the rig. This did not help us to provide a solution rather than a service.
- A lot of operational limits were imposed by the status of the rig equipment. Very frequent stops for repair and maintenance reflected on overall performance.

Personnel
- It is quite difficult to get personnel to work in Libya both due to the involved legal process required for each new expatriate in Libya, as well as the awkwardness of travel arrangements. Direct flights to Libya became available only last year, from a limited number of cities, and before that personnel had to travel to neighboring countries, and then cross to Libya either by land or by sea.
- The equipment used has been obsolete for a long time, and no company training schools are available for the MWD technology in use, both surface and downhole. Also the customer requirement of experienced personnel only made it impossible to utilize local engineers.

Logistics
- Turnaround of equipment from the rig for maintenance was taking a minimum of three weeks, possibly more if parts or personnel were not readily available. The reason was that the equipment could only be transported between the rig and town by supply vessels, which sailed once a week. Also, the Anadrill base was 1000km away from Tripoli. Add to that extensive paperwork and customs’ clearances for each trip, and even three weeks sometimes were out of the question.
- The above problem combined with a severe shortage of equipment placed unforgiving restrictions on forward planning for the project. It was quite impractical to compensate for the possible delays in equipment delivery by maintaining an extra set of tools on the rig.
## Capability of the available Software (DSP-One)

### BUGS

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<thead>
<tr>
<th>Module</th>
<th>Description of bug</th>
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<td>Hydraulics</td>
<td>Choosing a certain model of flow in the output will give another model in the output report</td>
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<tr>
<td>BHA</td>
<td>Different output tools spec in the drawing than the input data</td>
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### Suggestions/Improvements

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<tr>
<th>Application</th>
<th>Description of Suggestion</th>
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<tr>
<td>Plan</td>
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<td>Plan</td>
<td>Declination data to inter automatics.</td>
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<td>Plan</td>
<td>To be able having soft copy of the output drawing not by print screen.</td>
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<td>Need more option in the trajectory design to have more flexibility to build the profile</td>
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<tr>
<td>Hydraulics</td>
<td>Need to have graphics output to reflect the data in numbers also to be able to have soft copy of the final clients report</td>
</tr>
<tr>
<td>Torque &amp; Drag</td>
<td>Need to be able to have soft copy of the final clients report.</td>
</tr>
<tr>
<td>Backup</td>
<td>Need to improve the back up process to be more easier and more global not by parts. And to be easy to sent to the field and to merge in the old data.</td>
</tr>
</tbody>
</table>

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### Conclusion:

I consider the fact that we introduced the RSS system to this operation possibly the biggest success story of the project. This is due the fact, that the main concern on this rig was the hole cleaning due to the amount of sliding and also as mentioned before the low surface RPM used due to the bend in the motor was a maximum of 90. Which combined with the time the pipe is stationary in sliding mode made excessive cuttings beds. The client is very happy as now the surface RPM is between 150 and 165 therefore the hole cleaning capabilities are nearly doubled and because of continuous rotation the cuttings bed are continually agitated. The one thing everyone onboard agree is that with out it we would not have been in the advanced position we are in now, well ahead of schedule. Another advantage is that due to the fact we are able to alter the direction down hole the well can be followed as per the planned line, which is Agip gas preference, therefore avoiding any undue doglegs correcting as before with the motor. On this project we found the BHA to be stable using a slightly under gauge stab on top. The client wanted a full gauge stab 60ft above this to aid hole cleaning. This in my mind is not necessary and also can create more problems than it solves, due to the fact if for any reason the downlink commands are not taken you automatically create a dropping assembly. This will cause the BHA to be pulled even if close to the target. This was proved in one well where the BHA held stable as a rotary assembly and the section was completed without the need to POOH to replace the unit when the commands failed. Also if a Full gauge stab has to be used then the trailing edge of the blades should be hard faced to help in the case of back reaming through limestone as apparent here in NC 41. The only thing I personally think needs to be changed if used in a tangent section contract similar to this is that the 81-point map has to be changed by taking out the 10% positions and replacing them with 30% settings. The reason behind this is on the last 3 wells in both sections we found 10% to drop 20% hold and 40% to build slightly to much in a tangent section therefore the ideal setting is 30%. Obviously areas dictate the map but on the next contract I think we should start with this set up, as realistically a 10% change should be covered in stabilization. The fact that the maintenance facility in Tripoli is up and running can only benefit our operation concerning battery life and routine service matters. As in all wells, the proof of success is the running of casing and this has caused no problem since the introduction of PowerDrive. The company men here in Libya are all complete PowerDrive converts whereas 8 months ago they were sceptical.
Values Added

- Improved hole cleaning
- Increased ROP
- Reduced number of failures
- Reduced Run Numbers
- Improved directional Control

The using of rotary steerable system will represent a significant cost for any drilling operation cost analysis of obvious importance when assessing the value a rotary steerable system can bring. Tangible timesavings can be estimated, but is equally important to review the intangible benefits such as improved casing accessibly through reduced tortuosity and improved LWD log quality through continuous rotation and improved wellbore geometry.

Key performance indicators for rotary steerable systems should focus on total time for the hole section, the tortuosity of the profile as well as the ease of tripping, logging and running casing.

Offshore Libya. Drilling 8418 ft by PowerDrive for well CC-14 saved 8 days for Agip gas, 42% of total saving by PowerDrive, Agip gas saved 1.2 M USD. Also PowerDrive drilled 7760 ft and saved 10 days in well CC-05 for Agip gas, 50% of total saving by PowerDrive, Fig6, drilling until now another 7 wells completed for Agip gas by PowerDrive.

Results

- New Tech tools have been introduced successfully First time in Libya.
- Service Quality improved for Agip gas
- DEC has been supported RSS successfully with full Drilling Engineering Solution after set up from Zero.
- RSS Business start to expand in Libya
- Potential to use PowerDrive in 2004 by Agip Oil Offshore, Agip Oil onshore, TOTAL on/offshore.

Acknowledgments

The authors would like to thanks Agip Gas and Schlumberger for permission to publish the material contained in this paper. We would also like to acknowledge the commitments of Agip gas and associated partners who supported the introduction of PowerDrive throughout Libya.
Footage drilled is low

Footage drilled increased

BHA Runs is high

BHA runs decreased

**Footage/Run Analysis**

- **Footage**
- **Improvement Ratio**