Extreme Equipment Sales & Rentals
PowerDrive High Risk Operations
Revision 1.0

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Applicability: PowerDrive
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BACKGROUND INFORMATION

Land operations typically utilize motor-assisted rotary steerable BHA's. These systems rely on long sections of the BHA (including the RSS) to be placed below the motor and rotated at relatively high speeds. This increases the kinetic energy and flexibility below the motor dramatically with respect to conventional assemblies. Awareness and management of these risky operations is key to avoiding costly damages and tool failures.

What is presented here is to promote awareness and suggestions for management of these environments with typical RSS systems.

GENERAL BEST PRACTICES

MWD and PowerDrive vibration measurements (if real-time information is available) can be used to monitor and manage high risk environments. Please contact Extreme for additional information about interpretation of PowerDrive data points.

Be aware that downhole vibration measurements can vary dramatically as measured at different points in the string, mechanical mounting, filtering, etc. Torsional measurements can be affected by their reliance on magnetometers when run in casing.

CASING DRILL OUT

Plugs, Float Collars, Cement and Shoe Tracks are very different materials than the formation. Non-formation drilling increases the risk to the Bias Unit (excess wear/impact damage) and Control Unit (shock/recirculated debris). The bit is not designed to drill this material, especially when drilling in a soft rock environment where bits with low blade count and big cutters (aggressive design) are used. Bit and BHA whirl are common problems during these periods.

The following guidelines for drilling out of the casing shoe and rathole are recommended:

- The tool should be in neutral mode or a low proportion setting to minimize steering actuations in any one direction. IH or HIA modes must not be used while drilling out the shoe tracks.
- Flow rate should be at a reduced rate from the planned drilling flow (+/- 5% above the minimum drilling flow rate noted on the OST sheet). This reduces the pressure drop across the BU and limits the contact between the pads and casing.
- Rotary speed should be limited to 60 RPM or less while inside casing to minimize shock and vibration.
- When drilling shoe track and larger diameter rathole, the BHA is unconstrained and susceptible to high shocks which can lead to catastrophic hardware failures. Monitor shock & vibrations closely and adjust parameters accordingly. Slow down whenever a material change is expected. Watch shakers for pieces coming up. Always use float equipment with a locking feature to assist in drill out.
- Increase the rotary speed only when the uppermost stabilizer is out of the shoe and into new formation.

REAMING / BACKREAMING

During reaming operations, the drill string has greater freedom of motion as it is not constrained by WOB. With this greater freedom of motion comes a greater potential for vibration.

Reaming at low rpm reduces the energy in the system, decreasing the amplitude and the number of shocks to the tool. It is recommended to rotate as slow as is practicable to achieve the necessary hole cleaning effects of reaming.

Never rotate the string without circulation. This could result in several problems such as packing off the drill string, premature bearing failure in the motor or overheating tools with sensitive electronics.

Reaming in the hole:

In certain formations, it is often necessary to ream small sections while running in the hole. For longer sections of reaming such as a curve that was drilled with a slick BHA, suggest a separate, stabilized reaming run prior to picking up PowerDrive.

If a short period of reaming is necessary while running in the hole:

- Reduce flow to 5% above the minimum drilling flow rate of the Control Unit, which is noted on the OST sheet. This will reduce pad pressure significantly, but still allow for adequate cleaning of the torquers to prevent jamming.
- Be sure to ream at a high penetration rate (usually 2-4x prior drilling ROP) to avoid forming a ledge and inadvertently sidetracking.
- Set the PowerDrive (TF/%) as if you were drilling this section to prevent an accidental sidetrack.
    - If reaming a curve with DLS greater than 8 deg/100 ft, set the tool in 0/100%.
    - If reaming a lateral, set the tool in 0/25%.
    - For all other scenarios, select the setting that would achieve the DLS of the section being reamed.

Back-reaming out of the hole:

Ordinarily, back-reaming should not be planned into the drilling program. On occasion, offset well experience may show that plastic formations flow or swell and constrict the wellbore over time. In these cases, regular wiper trips and back-reaming may be unavoidable. In many other cases, back-reaming is not effective and can consume rig time and damage the wellbore and/or BHA components.

If back-reaming becomes unavoidable:

- Drill the stand down, pick up off bottom, and reduce the rpm to approximately 40 to 60 rpm.
- Reduce flow to 5% above the minimum drilling flow rate of the Control Unit, which is noted on the OST sheet. This will reduce pad pressure significantly, but still allow for adequate cleaning of the torquers to prevent jamming.
- Monitor real-time shock and vibration levels from the BHA and monitor the annular pressure readings if available.
- Slowly (usually 1-2x prior drilling ROP) start back-reaming while continuously monitoring real-time data.

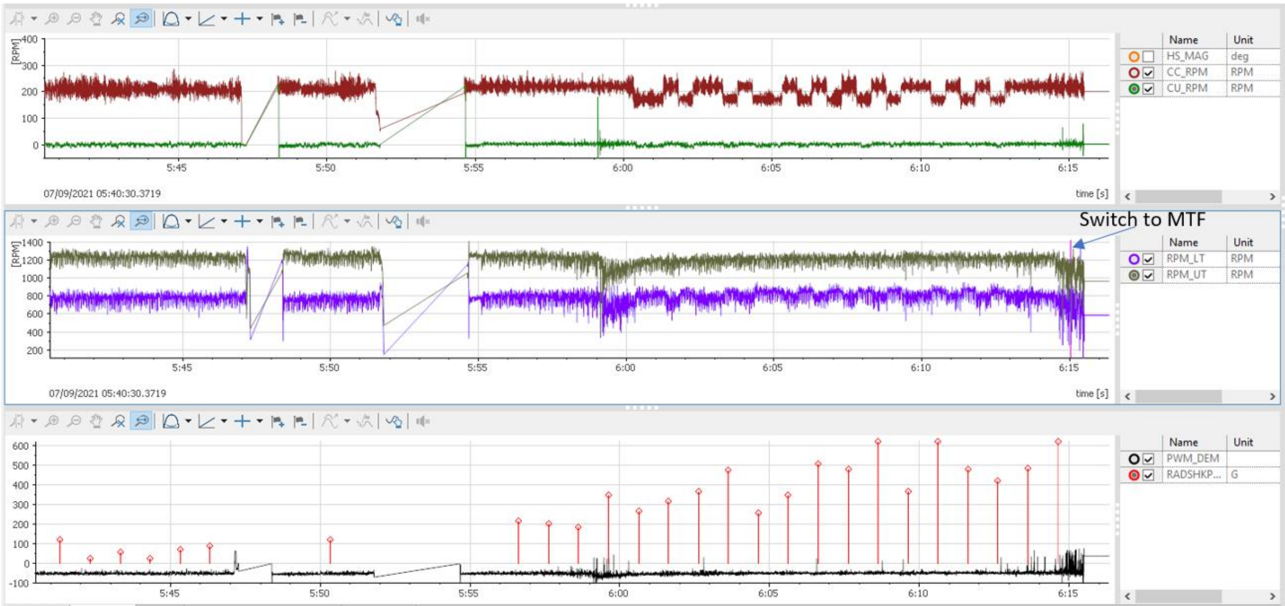
Downlinking Off Bottom In Low Angle Sections

Higher levels of lateral and torsional vibration occur at inclinations less than 15° when forces (due to gravity) acting to resist the movement of the BHA within the borehole are low. These vibrational events are usually worse off-bottom than on-bottom. When drilling ahead, the bit on bottom acts as a kind of anchor to help restrain/dampen the movement of the BHA.

The following guidelines for downlinking in low angle sections are recommended:

- **Downlinking while on-bottom is preferred.** This will reduce shocks, prolong the life of the tools, and reduce NPT due to time spent off-bottom downlinking.
- If have directional concerns, control drill at a reduced ROP. Determine a minimum WOB allowable to keep the BHA stable with regards to shocks. If needed, reduce surface RPM to gain WOB allowance.
- There are many downlinking options depending on whether using flow/rpm with the available bit periods. Evaluate which option work best in these sections and capture as a best practice.
- Certain critical downlinks may need to be done off-bottom but be aware of the risks in low angle situations.
- Post-run analysis of the PD dump data can be done to help evaluate the risks/rewards of on-bottom vs off-bottom downlinking.

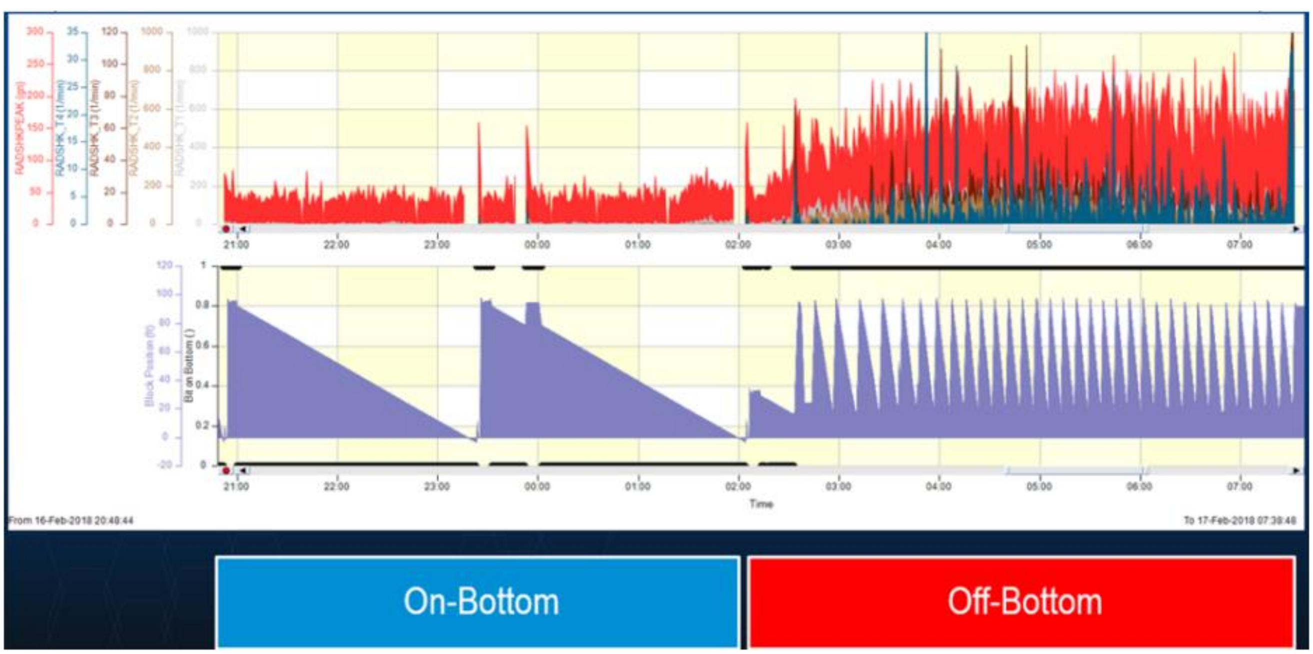
The following zoomed figure shows a downlink being performed off-bottom with collar RPM in a near vertical section. The tool recorded severe shock and vibrations, saturating the radial shock sensor at 624G. Shortly thereafter the tool had a failed PSPD (power supply and phase drive) due to the shocks causing the tool to no longer have any steering response.



OFF BOTTOM CLEAN-UP CYCLES

Upon reaching TD it is normal for a client to perform a cleanup cycle to ensure the cutting are adequately removed from the hole. During these clean up cycles, where the BHA is rotated off-bottom for hours at a time, is where a majority of PowerDrive damages and BHA twist offs occur. The damage is even higher when BHA components are rotating faster below a motor assist.

The following figure shows the difference in shock and vibration on-bottom vs off-bottom. The left side of the figure shows the last 2 stands drilled with minimal shocks and on the right side of the figure the client is performing an off-bottom clean-up cycle and devastating shocks are recorded.



The figure below displays an example of external Bias unit damage which occurs during an extended off-bottom cleanup cycle.

In situations where the shock and vibrations to the BHA are much higher off-bottom, K&M suggests that control drilling with the bit on-bottom can be an effective alternative to circulating off-bottom. Determining what a slow enough ROP for this method to be effective will vary depending on hole size, BHA clearance and hole stability. Drilling the last couple of stands at 5-15 ft/hr can be slow enough, but field experience is required to determine the optimal ROP needed to allow tripping without experiencing overpull. K&M states that this approach has been shown to be effective at cleaning the hole while reducing the shocks & damage to the BHA. It is offered as a solution where off-bottom shocks are not manageable by altering parameters.

It is vital to discuss the cleanup cycle with the client prior to starting the operation. The PowerDrive logs generated after a run are an excellent source of historical data to determine if shocks in the clean-up cycle are a major contributing factor to tool failures/damages on prior runs. In these cases, it is strongly recommended to perform on-bottom clean up cycles. The following procedure is a best practice that has dramatically reduced this vibration mode and associated damages.

For the last stand before TD:

- Control the ROP to 5-15'/hour, depending on the # of bottoms up needed
- Use the same drilling flow rate & 100-120 surface RPM
- Consider doing procedure on more than 1 stand, if more circulation is needed
- Watch the surface parameters & shocks closely and adjust drilling parameters if needed
- One bottoms-up circulation after reaching TD, then Pooh

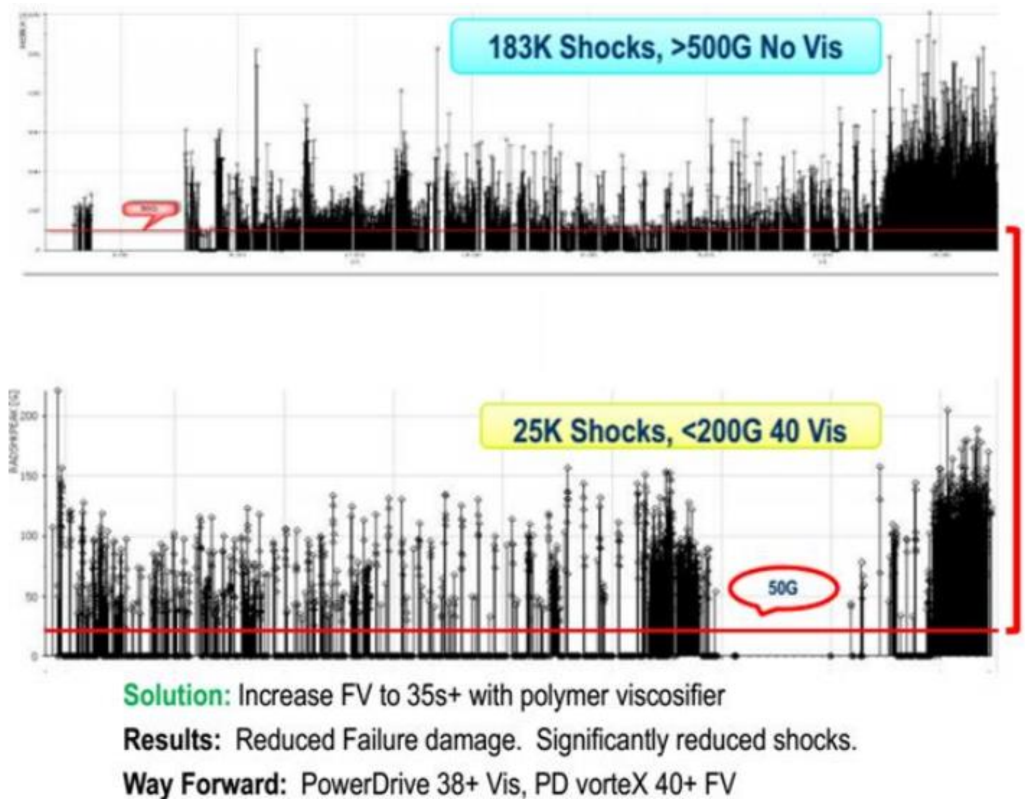
Low Viscosity Fresh Water Or Brine Muds

Low viscosity drilling fluid (<40 sec funnel viscosity) is known to increase the risk of lateral vibration in RSS BHA's. Multiple factors increase this risk with lower viscosity fluid:

- Flow of turbulent fluid around the BHA can cause chaotic vibration of the string.
- Less fluid damping exists with lower viscosity. Impacts between string and borehole can become much more violent.
- Lower viscosity fluid can have poorer lubrication properties between formation and BHA, increasing the risk of whirl.

The funnel viscosity measurement is qualitative and experimentally proven as a rule of thumb. NAL has no recommendation for Fann or other mud rheology numbers, other than that viscosity should be achieved with a polymeric viscosifier that cause minimal increase in PV, vs, salt gel or clay-based rheology additives that elevate PV without improving hole-cleaning properties. The mud provider should be consulted to achieve a rheology that meets hole cleaning objectives while targeting a funnel viscosity test result of 40 seconds.

The figure below shows a comparison between brine water (top) and viscosified water-based mud (bottom) reducing shock count and amplitude.



The following figures display Control Unit damage (failed/ burnt electronics, cracked chasis) and Bias Unit damage (kicker wear, plate sleeve, lug bushing, plate contact area) observed in a recent run on a well using water-based mud with a low funnel viscosity.