STABIL DRILL

Rival Motor Handbook

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This handbook is intended to be an aid to the operator and is solely provided for information and illustration purposes.

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The technical data and text in this handbook are subject to change without notice.

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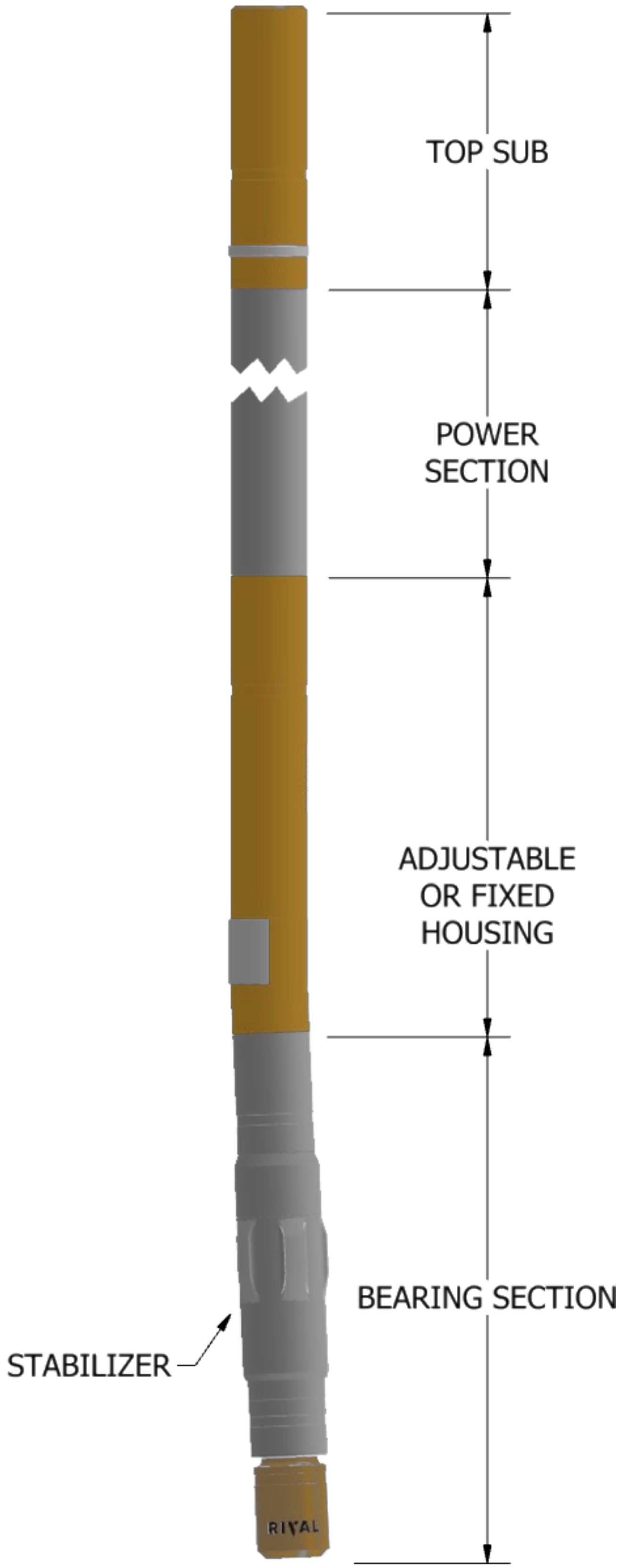

Figure 1 Motor Sections

Top Sub & Rotor Catch

At the top end of the motor is the top sub, which is a crossover housing between the power section and the rest of the BHA. Most top subs accommodate API float valves. The top sub also provides a seat for the rotor catch system.

The rotor catch is a retaining device which minimizes the possibility of losing motor components downhole in the unlikely event that an external connection breaks or backs-off. The rotor catch is attached to the top of the rotor by a threaded connection. Stabil Drill designs the catch system for maximum overpull capability.

Power Section

The power section is a positive displacement motor comprised of a rotor and a stator. The rotor is a long, spiral shaft with several external, curved lobes. The stator has a similar spiral profile formed internally by the stator elastomer but is designed to have one more lobe than the rotor.

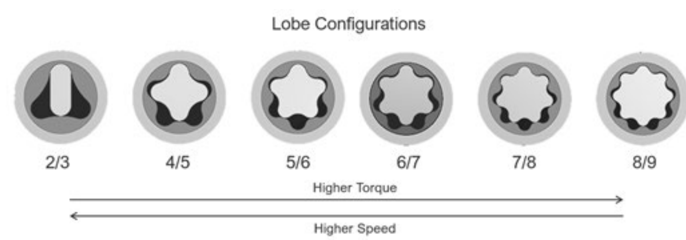

Figure 2 Power Section Lobes

The design results in a cavity for fluid to flow into. As pressure increases, the cavity progresses down the rotor by forcing the rotor to rotate and progress around the spiral profile. This action converters hydraulic horsepower into mechanical horsepower delivered to the drill bit.

The desired lobe configuration will vary depending on the application. In general, a power section with fewer lobes generates a lower torque and higher speed, and a power section with more lobes generates a higher torque and lower speed.

Since the power section is a positive displacement motor, speed and torque are determined independently from each other during operation.

The rotational speed is proportional to the fluid flow rate through the power section. The higher the flow rate, the higher the output speed.

The torque generated is proportional to the differential pressure across the power section. Differential pressure is created by applying a load to the bit, thus the more weight applied to the bit, the higher the differential pressure across the power section.

For each power section configuration, there is a limit to how much differential pressure the power section can handle. If the differential pressure increases beyond the elastomer limitations, the power section will no longer keep the fluid cavities travelling down the rotor separate from each other causing the rotor, and thus the bit, to stop rotating. This is commonly known as a stalled motor and can cause damage to the stator elastomer, motor, and other BHA components.

Adjustable Bend Housing

The adjustable bend housing connects the stator to the bearing section assembly. The angle setting is field adjustable, producing a wide range of build rates. Contact Stabil Drill personnel for the field adjustment procedure.

Fixed Bend Housing

Fixed, non-adjustable housings are available in a wide range of settings, including straight.

Transmission Assembly

The transmission assembly converts the eccentric rotational motion of the rotor to the concentric rotational motion of the bearing mandrel. It also accommodates any angle set on a fixed bend or adjustable bend housing.

Stabil Drill utilizes different transmission types per application based on the requirements of the motor. This includes the use of dual articulating transmissions (sealed and unsealed), single articulating hybrid transmissions, and flexshafts (conventional, radial flex, and titanium). Transmission designs each have relative benefits and selecting the right transmission for the application is key to maximizing reliability and performance.

Figure 3 Dual Articulating Sealed

Figure 4 Dual Articulating Unsealed

Figure 5 Single Articulating Hybrid

Figure 6 Conventional Flex Shaft

Figure 7 Radial Flex Shaft

Bearing Section

The bearing section is comprised of necessary components to transmit drilling forces to the bit. The main components include a bearing mandrel, radial bearings and thrust bearings. The thrust and radial bearings are mud-lubricated, eliminating the need for oil and seals, and providing a simple to operate and service design. Due to the mud-lubricated system, a percentage of drilling fluid is expected to flow through the bearings and directly to the annulus, bypassing the drill bit. Adjustments can be made to fluid bypass through optimized gap design.

The bearing mandrel transmits all the power (torque and rpm) to the bit. The bearing mandrel is center bored to provide drilling fluid directly to the bit. Included on the mandrel is a safety catch mechanism. In the unlikely event of a bearing mandrel break, the catch minimizes the possibility of leaving the drill bit or BHA in the hole.

The thrust bearings are designed to sustain the applied weight of the BHA to the bit during drilling operations. The thrust bearings are also capable of sustaining the forces required for off-bottom circulation and back-reaming. Care should be taken to minimize the time thrust bearings are kept in a neutral position (no load).

The radial bearings keep the bearing mandrel centralized by providing a smooth and wear-resistant surface. The radial bearings resist the side-load forces seen in directional drilling operations.

Stabilizers

Stabilizers are available as removable or integral stabilizers. The removable stabilizers are threaded on to the bearing housing, whereas the integral stabilizers are directly integrated into the bearing housing. Contact Stabil Drill personnel for the removable stabilizer procedure. Threaded Kickpad stabilization is also available.

A stabilizer can assist in acquiring and maintaining a particular hole angle and increase the yield of the motor. Calculated build rates for stabilized motors are based on stabilizers that are 1/8” smaller than the hole size.

If no stabilizer is desired, slick bearing housings and slick thread protectors are available.

Operation

Bearing Lubrication & Pressure Drop

Mud-lubricated motors require back pressure to divert sufficient fluid through the bearing stack to cool the radial and thrust bearings. 200 psi minimum of back pressure is required to ensure proper lubrication and cooling.

Bearings can overheat and fail with too little pressure drop, particularly when motors are surface tested at flow rates or pressure drops below running parameters. Motors tests should be performed with a minimum of 200 psi pressure drop and be limited to less than one minute.

When performing motor dynos, Stabil Drill recommends installing a choke below the motor to create 200 psi of back pressure and simulate the bit. Performing a dyno with little back pressure will damage the radial bearings. Power section fits are selected based on downhole operating temperatures and dyno results with mud at temperatures below operating may show lower performance.

BHA Pressure Drop

When drilling with a Rotary Steerable System, the total system pressure below the motor should be limited to 1,500 PSI. Fluid Bypass through the bearings can vary significantly in Rotary Steerable applications due to the pressure requirements. Contact Stabil Drill personnel for guidance on fluid bypass.

Motor Stalling

Motor stalling occurs when the torque demand from the drill bit exceeds maximum output of the motor. All stalling should be avoided as it reduces reliable performance of the Bottom Hole Assembly.

As the motor goes into a stall the motor differential pressure builds and exceeds its maximum operating specification. The excessive pressure and resulting torque can cause power section damage, wear, chunking, reduced power output (which increases risk of further stalls), and increased risk of connection related incidents & damage to the rest of the BHA.

Once the motor has stalled, the rotor has stopped rotating and the motor is under maximum load. When the stall energy is released catastrophic damage to the motor and drill bit will occur unless sufficient precaution is taken to relieve differential pressure before picking up off bottom.

Note: In interbedded formations and at formation transitions, drilling near maximum recommended differential pressures limits will increase the risk of major stalling events. When approaching such zones parameters should be reduced to avoid stalling. Bits with aggressive or damaged cutting structures will increase the likelihood of a stall.

While micro stalls and stick-slip commonly occur in field operations, they nonetheless have negative impacts on motor reliability & performance. As such, efforts should be made to optimize parameters for the motor and cutting structure selected to mitigate micro-stalling and stick-slip.

Stabil Drill's Friction Reduction Tools can further assist in reducing stick-slip and micro-stalls while increasing sliding & rotating ROP.

Over Running the Bit

Over-running the drill bit occurs while rotating the drill string while the motor is in a stalled condition. This can cause significant damage to the stator liner and connection related incidents.

Rotary Drilling

Rotary drilling with bent motors enables increased performance and hole cleaning. Rotary speeds should be kept below 50 RPM and with a maximum bend of 2.25 to reduce risk of damage to the motor but damage can occur even within these limits depending on or formation, hole curvature, run length, BHA design, and operating parameters. Contact Stabil Drill personnel for further guidance on these limits.

Highly deviated sections (12º/100 ft or more) will also increase load on external and internal motor components. This includes going to bottom or coming out with BHAs through previously drilled, highly deviated sections. Rotating straight or bent motors through such sections may cause significant damage to motors. Using high WOB can reduce the life of thrust bearings and add unnecessary side loading to radial bearings.

Back Reaming

Back-reaming should be avoided. If back-reaming is unavoidable it should only be performed at less than 40 rpm, and caution should be taken when changing directions.

Vibration

Although component fatigue can occur over an extended period, field data has confirmed that motor fractures can occur as the result of vibration induced fatigue over a single run. As such, it is important to mitigate vibration to avoid related motor incidents. Vibrations can considerably reduce drilling performance and in extreme cases, can cause significant damage to BHA tools.

Drilling Fluids

The motor uses drilling fluid for lubrication and to generate mechanical horsepower. Good mud control and power section fit planning is essential to reliable motor performance.

Abrasive Fluids

While the bearing section is compatible with a wide range of fluids, abrasive elements in mud systems will cause excessive wear and reduce motor life. Damage can be seen within a few hours when abrasive solids are present. Corrected or Total Solids should be limited to 18%.

Low gravity solids (LGS) must be limited to 5% of total solids. Low gravity solids increase erosion within the motor negatively impacting power section and bearing life. Low gravity solids can also block the fluid bypass pathways to the bearings, starving them of lubrication, which will cause accelerated damage and lead to premature failure.

Sand must be limited to 0.25% as determined by an API sand test to maximize reliable motor performance. Increased sand concentrations lead to reduce performance and reduced motor life. Sand content beyond 1% will greatly increase risk of erratic performance and unplanned trips due to damage.

Other recognized sources of highly abrasive material in mud systems can be damaging and should be mitigated such as metallic particles in the mud resulting from casing wear, hard band wear, and pipe scale or corrosion particles from rusted pipe interiors. Such abrasives are known to cause damage rapidly at the start of operations when high concentrations are pumped through the motor.

Additives & LCM

Drilling motors are designed to provide reliable performance when drilling operations require the intermittent use of fluid additives or LCM, provided, they are well incorporated into the drilling fluid. Pumping large concentrations of the additives or LCM through the motor may result in reduced service life and increased risk of pack-off or bearing starvation.

Never pump cement through a drilling motor.

Mud Chlorides

Chlorides above 30,000 ppm reduce the service life of rotor chrome and carbide coatings. While carbide can be used to prolong service life as compared to chrome in environments with chlorides between 30,000 and 65,000. Beyond 65,000 ppm chlorides both carbide and chrome coatings will have reduced service life.

Field experience shows motors still operate in high chlorides applications, but it results in reduce service life and increased repairs post run. Motors should be flushed with freshwater post run.

Power Section Fit

Power section fit must be optimized to compensate for temperature changes and mud types. Stabil Drill determines best motor fit by calculating predicted downhole compression. Compression is the percentage the elastomer is compressed by the rotor to create a hydraulic seal in the downhole environment. Stabil Drill uses OEM recommended downhole compression ranges, swell rates, expected hole temperature, and field experience to determine optimal fit for every run. The below chart illustrates a good rule of thumb for downhole compression.

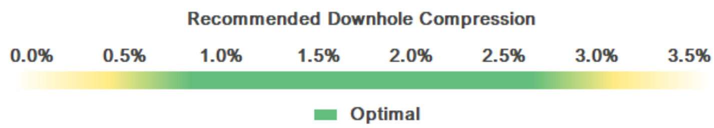

Figure 8 Recommended Downhole Compression Range

Note: The above figure does not apply to air drilling. Please contact Stabil Drill for further guidance when air of foam drilling.

Derating for Downhole Temperature

Stator life is reduced at higher operational temperatures. To maintain a stable balance between stator life and performance it is required to reduce differential pressure at elevated temperatures. The graph below illustrates the maximum allowable differential pressure at different temperature intervals. The green bars represent differential pressure for maximum life while the yellow bars represent differential pressure for maximum output.

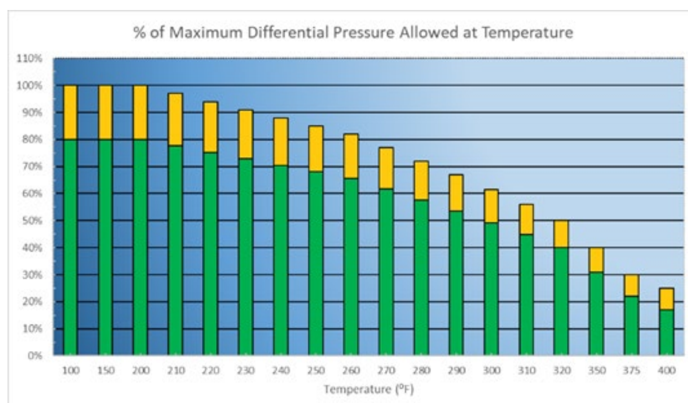

Figure 9 Temperature Derating Chart

Stators that have been exposed to elevated power output for extended drilling times can develop damage. With increased temperatures, the thermal breakdown process is accelerated and significantly shortens the life of the lining.

Air Drilling

When using mud lubricated motors in Air Drilling applications, caution must be used to provide adequate cooling to the bearing section as air does not cool as well as liquid. Mist, foam, or lubrication must be added every stand to increase service life of the motor. Contact Stabil Drill for guidance on fluid requirements and build requests.