COUGAR
DRILLING SOLUTIONS

Motor Operations Handbook

2012

Version 5.0

MISSION

Cougar Drilling Solutions strives to be the premier supplier of Vertical, Directional and Horizontal Drilling Services to the oil, gas and geothermal exploration and development industry. Cougar Drilling Solutions strives to set the standard by which all others are judged.

2012

Version 5.0

The information in this handbook is subject to change without notice.

If you have any questions or concerns, feel free to contact any of our locations.

Certified System ISO 9001

CONTENTS

CONTENTS (cont'd)

CONTENTS (cont'd)

DRILLING MOTOR SPECIFICATIONS

CONTENTS (cont'd)

DRILLING MOTOR SPECIFICATIONS (cont"d)

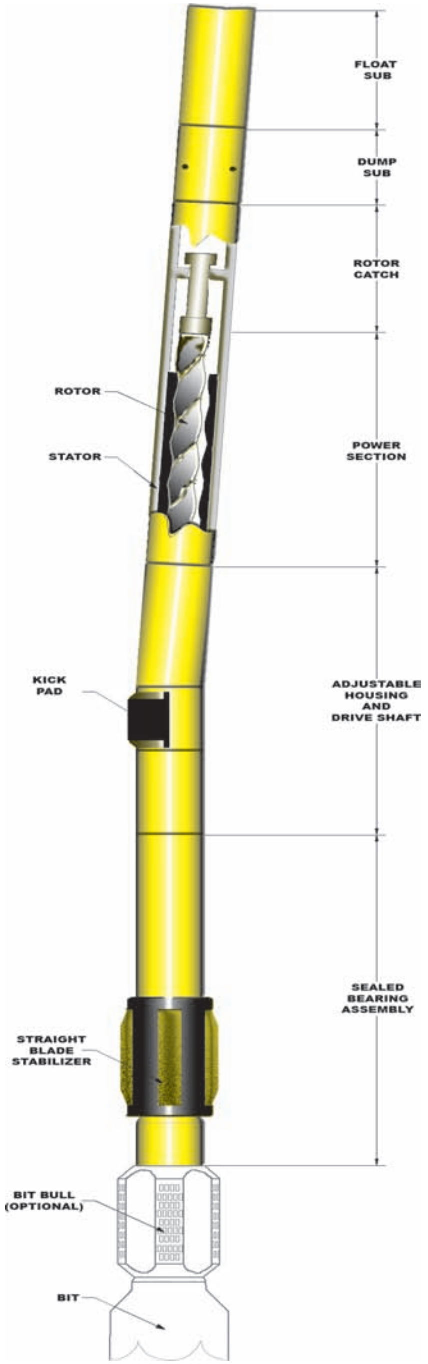
CONTENTS (cont'd)

TABLES AND CHARTS

Introduction

Cougar Drilling Solutions Inc. is pleased to present the latest release of the mud motor operations handbook. This release features more motor sizes and configurations, motor operation information and a thorough compilation of useful tables and charts.

We hope that this handbook will be a helpful tool when using the Cougar Drilling Solutions motors. If you require further information please contact us at (780) 440 2400 or by e-mail at info@cougarDS.com or consult www.cougarDS.com.


FLOAT SUB
DUMP SUB
ROTOR CATCH
ROTOR
STATOR
POWER SECTION
KICK PAD
ADJUSTABLE HOUSING AND DRIVE SHAFT
SEALED BEARING ASSEMBLY
STRAIGHT BLADE STABILIZER
BIT BULL (OPTIONAL)
BIT

BEARING ASSEMBLY

The Bearing Assembly carries all radial and thrust loading. Cougar Drilling Solutions utilizes a special rotary shaft seal designed specifically for drilling motor use that is isolated from drilling fluid at all times. The Bearing Assemblies are designed to reduce the bearing load with more radial support for side loading and with high capacity thrust bearings for on or off bottom loading.

Cougar Drilling Solutions motors are built to handle all drilling conditions from corrosive muds to high temperature holes up to 250°F for the standard configuration. If required, the motor can be outfitted with a power section and bearing assembly seals to accommodate higher operation temperatures.

Cougar Drilling Solutions Bearing Assembly is a completely oil sealed unit. The sealing system used includes a unique flow restrictor design, which delivers maximum flow to the bit. All drilling fluid is directed to the bit rather than being used to lubricate the bearings. The result is exceptional hydraulic horsepower and hole cleaning along with increased bit life and penetration rates.

The Cougar Drilling Solutions Bearing Assembly has a large bit mandrel to provide an accurate and durable drive system. It was designed with a large bore, which has been maintained throughout the motor, to minimize the pressure drop across the motor and maximize hydraulic power.

FIXED HOUSING

Where there is no need for field adjustment, Cougar Drilling Solutions can supply Fixed Housings to take place of the Adjustable Assembly. Fixed Housings are available in straight or bent orientations up to 3 degrees.

ADJUSTABLE ASSEMBLY

The Adjustable Assembly connects the stator to the housings of the Bearing Assembly and houses the Drive Shaft Assembly. The Adjustable Assembly is easily set in the field from straight to 3 degrees of bend angle.

The Cougar Drilling Solutions Adjustable Assembly has 15 settings allowing fine adjustment for refinement in build rates. The design of the Cougar Drilling Solutions Adjustable allows for greater build rates due to its short bit to bend length.

DRIVE SHAFT ASSEMBLY

The Drive Shaft Assembly connects the Power Section's rotor to the rotating components of the Bearing Assembly. The Drive Shaft converts the eccentric motion of the rotor into concentric rotation. The Drive Shaft also compensates for any angle of the Adjustable Assembly or Fixed Housing as well as the bending subjected to the motor during directional control.

Cougar Drilling Solutions' Drive Shaft Assembly uses robust, sealed and lubricated joints at both ends, mated by a massive connecting shaft. The resulting assembly can handle torques in excess of the stall torque of the Power Sections used while carrying the thrust load imposed by the pressure drop across the Power Section.

POWER SECTION

The Power Section converts hydraulic power into rotary motion. Drilling fluid pumped through the drill string drives what is essentially a reversed positive displacement pump connected to the bit.

The Power Section is composed of a rotor and stator. The rotor, the driven member, is a helical shaped steel bar that is forced to turn inside the elastomer lined stator tube. The lining of the steel stator tube is molded in a similar helical pattern, but with longer pitch lengths, to form sealed cavities as the rotor turns. Drilling fluid pumped through the stator creates a pressure drop across the cavities, causing the rotor to turn.

The number of lobes along with the length of the helix determines the performance of a Power Section. The stator profile has one more lobe than the rotor. This relationship is part of the name defining a given Power Section, ex. 7-8 Lobe. As the lobe count increases the final drive speed generally decreases. The second feature used to define a Power Section is the number of stages. One stage is one complete helical rotation, or pitch, of the stator. As the number of stages increases, the differential pressure and the torque also increase.

When circulation rates are required that are higher than that recommended for the Power Section used, the rotors can be jetted to allow excess fluid to by-pass the stator, preventing damage to the elastomer liner. Variations in fits and materials are available for Cougar Drilling Solutions power sections for operating under extreme temperatures or with specialized drilling fluids.

ROTOR CATCH

The Rotor Catch is a tool used in down-hole Drilling Motors to assure the extraction of the Rotor. On rare occasions, motors, mainly the power section, have parted below the Stator. When this occurs generally the stator comes out of the hole leaving the Rotor facing up hole and resulting in a fishing job over an uneven surface. Also, if the bit is not stuck it is hard to rotate over the Rotor to fish it, as there will be no resistance to it also turning. The Rotor catch sits at the top of the Power Section and screws directly into the Rotor. If the tool should part, the Rotor Catch will contact an internal shoulder and retrieve the Rotor.

DUMP SUB

The Dump Sub is a by-pass valve used above the motor, which allows drilling fluid to fill the bore of the drill string when tripping into the hole, and drain when tripping out of the hole, preventing a wet trip.

When there is little or no circulation, a piston in the valve is held in an open position by a coiled spring; drilling fluid flows directly to the annulus. As circulation begins to increase, the force of the fluid causes the piston to compress the spring and seal off the ports to the annulus. With the ports sealed, all drilling fluid is pumped through the power section to turn the bit. On most motor sizes, the Dump Sub can be disabled by substituting solid plugs for the ported ones threaded into the body.

Cougar Drilling Solutions Dump Subs are designed to close before the minimum recommended circulation rate of a given motor configuration is reached. The Dump Sub creates negligible pressure loss while drilling.

TOP SUB

The Top Sub is basically a Cross Over Sub, to adapt the downhole motor assembly. All Cougar Top Subs c/w a Float bore.

STABILIZATION

Cougar Drilling Solutions Bearing Assemblies come with threaded O.D. bearing housings to accommodate either a smooth thread protector or a thread on stabilizer.

The stabilizers are easily changed on the rig floor and provide added support for packed or pendulum drilling assemblies. If no stabilization is required, the bearing housing is available in a non-threaded version for slick assemblies.

MOTOR SELECTION

Cougar Drilling Solutions offers a wide range of power sections to accommodate almost any type of drilling and drilling conditions. The motors can be specified to match the torque requirements of the bit, the flow rates for cleaning, the maximum standpipe or pump pressure or even materials for high temperature applications.

Should higher flow rates than the power sections available be required, all of Cougar Drilling Solutions' motors can be configured with a bypass jet. This enables the flow rates to be considerably increased without causing the power section to be over-pumped and run inefficiently.

DRILLING

In order to drill using a motor, the standpipe pressure must be monitored. Initially, rotation must be started in the off-bottom position. The performance charts in this booklet will give the required pressure to initiate the rotation for a given motor size. Note that more pressure may be required than indicated on these charts to initiate rotation. Regions such as keyseats may cause difficulties if the motor is not oriented properly or set to a high build angle.

The off-bottom pressure, as measured on the standpipe gauge, will include the pressure differential across the motor as well as any other losses due to other tools and friction. Once the motor is rotating it may then engage the well bottom. Contacting the bottom will be directly visible on the pressure indicator, as the pressure on-bottom will increase from the pressure off-bottom.

Caution must be taken not to allow the differential pressure to exceed the maximum differential pressure for a given motor size.

The weight on bit may be increased until the desired rate of penetration (ROP), torque or maximum differential pressure is reached. As drilling commences, the weight will drill off thus lowering the torque and consequently the pressure on the indicators. It is important to re-check the off-bottom pressure periodically to ensure the motor is running optimally. As the amount of cuttings increase in the drilling fluid, some hydraulic power will go to lifting these cuttings so the pressure may need to be adjusted.

If the drilling conditions are favourable, rotation of the motor when the adjustable housing / fixed housing is set from 1.50 degrees or less is possible. This would enable the driller to steer and/or create a better environment for weight transfer to the motor. Care should be taken to not rotate the motor when it is set above 1.50 degrees or at string rotational speeds greater than 50 RPM.

PERFORMANCE DRILLING

Cougar Drilling Solutions' motors are capable of meeting the high torque or high RPMs of today's performance drilling requirements. Many modern bits such as PDCs require more torque. The high performance power sections can deliver the necessary torque; drillers will experience increased ROP and less string wear.

DIRECTIONAL DRILLING

The Cougar Drilling Solutions motor facilitates directional drilling with the use of the adjustable or fixed housings. By setting a bend between the drive and bearing assemblies, the lower portion of the motor and the bit face are oriented such as to initiate a build in the well bore. When the drill string is not rotating, the motor will build, however, when the string is rotating, the motor will drill effectively straight. The motor may be oriented to enable drilling up or down in a build.

Directional drilling has application in many fields from utility, river crossing and avoiding problematic formations and many more.

Multi-laterals have become an important addition to the many uses of a steerable assembly. This enables the creation of multiple lateral wells off of one main vertical well, greatly reducing the cost of producing a large zone.

HORIZONTAL DRILLING

The idea of directional drilling can be extended to horizontal applications. The key difference in this application is that the bend angle in the adjustable may require being set higher to create tight build rates. This eliminates the idea of rotating the assembly for steering. When the tool is set over 1.50 degrees, the motor should not be rotated.

In order to generate the build rates, the adjustable could be set under 1.50 degrees, drill until the kick-off depth is reached, trip out and re-adjust the bend angle, trip in and orient to create the build, then trip out and re-adjust once more to an angle under 1.50 degrees and complete the horizontal component of the well.

For directional or horizontal drilling, various combinations of motor bend angles and bearing assembly stabilization may be utilized to generate the desired build rates.

AIR DRILLING

When any type of compressible medium is used in the drilling fluid, the performance of the power section may change dramatically. High air, nitrogen, natural gas, etc, concentrations alter the density of the fluid thus changing how the heat is generated or dissipated, the friction on the power section elastomer and even the power generated.

The amount of gas to liquid content on a volume basis will largely determine the how different the power section will behave.

Once the fluid content exceeds 75% of the total volume, the compressibility of the total medium is low enough that it is negligible.

To maintain the correct total volume and flow rate, especially at higher temperatures, the volume of the gas and/or flow rate may have to be increased to account for the compression.

Care should be taken when running a Cougar Drilling Solutions motor in low liquid content to reduce the wear of the motor components and power section.

Lubrication should be added to reduce the friction between the rotor and stator and the internal motor component (those exposed to the drilling fluid). Lubricants should be thoroughly mixed and injected into the drilling medium at a rate of no less than 5% of the drilling medium volume. More lubricant reduces wear and cools the power section but it also changes the liquid to gas ratio.

The dump valve ports will have to be plugged in order to work with low liquid content. The pressure drop and fluid momentum present with air drilling are not sufficient to close the dump valve.

Another consideration is that air drilling does not have the damping characteristics that fluid drilling possesses. As such, applying the weight to the bit from start-up must be done more slowly. The motor must be started slowly and not allowed to spin freely.

Low amounts of fluid (Mist: Liquid is < 2.5% of total volume) causes the liquid to form droplets in the gas. This can create problems with corrosion so oxidation inhibitors may be required.

Moderate amounts of fluid (Foam: Liquid is between 2.5% to 25% of total volume) allows the liquid and gas to mix reasonably well and provides better lubrication to the power section than a mist would. Foams are typically rated as “Foam Quality” where the percentage is in gas per volume, i.e. 80% foam quality means 80% gas and 20% liquid.

Moderate to normal amounts of fluid (Aerated: liquid is between 25% to 75% of total volume) cause the gas bubbles to be suspended within the liquid.

The motor could be started with fluid to prevent over spinning the motor. The weight must be removed slowly (or allowed to drill off) as the pressure is decreased.

H_2S (SOUR) GAS

The National Association of Corrosion Engineers (NACE) has produced a specification (MR0175) that provides a range of material hardness values that are suitable for sour gas use. The Cougar Drilling Solutions motor uses materials with hardness that exceeds the NACE specification. The materials have been chosen to maximize the strength of the component. H_2S causes embrittlement, which increases the probability to initiate cracking. When running the motor in a sour gas environment, care must be taken to control the environment as much as possible.

Damage to the seals or power section is also possible from H_2S. The length of the exposure is directly proportional to the risk of damage. The average motor run is usually not long enough to cause damage. However, extended runs may cause damage to the elastomers and reduce the life of the tool.

Various regulatory or specifications are available which provide information on how to control the sour gas environment. API and NACE are two such sources.

SURFACE TESTING

Before the motor is used, it should be tested at surface level before being run-in. The Cougar Drilling Solutions motor does not require the differential pressure of the bit and therefore it can be tested at surface.

If the motor has a dump valve then it should be tested below the BOP's so the drilling fluid is kept in the system.
Make sure to remove any thread protectors if testing below the BOP without the bit.
Once the dump valve is close, rotation of the motor should start and torque should be noted in the assembly.
Once the pumps are turned off, the valve should open and the pressure should drop. If it doesn't, open the fill-line to the standpipe to relieve the pressure.

Now that the motor has been tested, connect whatever bit is desired, make any adjustments to the adjustable housing (if present) and orient the tool by whatever means are present. Then run the motor into the hole.

RUNNING IN

For the most part, a Cougar Drilling Solutions motor can be run into the hole in a similar fashion as a conventional drilling tool. Extra care is warranted if the motor is set to a high angle on the adjustable or fixed housing. The motor may become stuck in the BOP, casing shoes or liner hangers. The motor may need to be running when navigating tight regions of the bore hole. This procedure should not be used within the cased portion of the well.

If the well depth is deep, it may be worthwhile to periodically stop the run-in and circulate to prevent the bit from plugging and to pump cool fluid to the motor which will reduce the chance of the motor becoming too hot causing stator chunking problems.

During this time it may be prudent to move the motor up and down slightly so the bit rotation does not form ledges in the casing or to the well bore if in open hole.

Care should be taken to prevent backpressure on the motor. It may cause the motor to turn in reverse and increases the chance of un-screwing the internal connections.

REACTIVE TORQUE

Since the motor causes a right hand rotation, when viewed from the rig floor, the reactive torque is left-hand or counter clockwise. This reactive torque can cause the drill string connections to tighten if the torque exceeds the initial make-up torque. The reactive torque results in twisting the drill string and therefore must be considered when orienting the motor. The measurement of tool face, azimuth and inclination will likely be more accurate than calculating the angle of twist from the drill string properties. However, given the torque, length and diameters of the drilling assembly components, the angle of twist can be calculated using the following:

$$\text{Twist} = \frac{TL\,180}{JG\,\pi}$$

Where:

- T is the Torque
- J is the polar moment of Inertia
- L is the length of the segment
- G is the modulus of Rigidity for the material (steel)
- Twist is the angle in degrees

The twist is a linear quantity and can be calculated on a per section basis.

ie: The twist of the drill pipe plus the twist of the heavy weight plus the twist of the drill collars, etc.

RULE OF THUMB GUIDELINES

3 1/2” - 13.3 lb/ft Drill Pipe
    8 1/2°/100 lb-ft Torque/1000 ft
    19°/100 Nm Torque/1000 m

3 1/2” - 15.5 lb/ft Drill Pipe
    7 1/2°/100 lb-ft Torque/1000 ft
    17°/100 Nm Torque/1000 m

4 1/2” - 16.6 lb/ft Drill Pipe
    3 1/3°/100 lb-ft Torque/1000 ft
    7 1/2°/100 Nm Torque/1000 m

5 1/2” - 19.5 lb/ft Drill Pipe
    2 5/8°/100 lb-ft Torque/1000 ft
    6°/100 Nm Torque/1000 m

MOTOR STALL

Motor stall is when the bit stops rotating. This can occur either from excessive weight applied to the bit or from the bit becoming stuck. In either case the reactive torque will increase and if not properly released may cause excessive damage to motor components and possibly other tools in the assembly. Caution must be taken when releasing stored reactive torque as releasing it suddenly may cause connections to back-off. Continued circulation through a stalled motor may cause excessive wear to the elastomer in the power section. A motor stalling can be seen as a sudden pressure increase on the standpipe pressure indicators.

The following procedure should be used in order to continue drilling:

- Stop any drill string rotation immediately. Continued rotation will only increase the torque in the assembly.
- Back off completely on the pumps before lifting off the bottom.
- Release the torque. Use the break to slowly release the torque from the drill string.
- Raise the bit. By lifting the bit off bottom you will be able to increase flow once again to initiate rotation similar to the start-up procedure.

ROTATING THE MOTOR

To reduce the effects of rotating bending/cyclic fatigue, a balance must be made between the rotation speed and the motor bend angle versus the build rate. For a straight hole with a straight motor, the likelihood of bending is very low so there is minimal concern of bending fatigue. As the build rate increases the bending stresses in the motor increase.

In addition to this, as the bend angle of the motor increases, this also increases the bending stresses in the tool. The ideal rotary speed is a function of bend angle and build rate. As a rule of thumb, a rotary speed of 50 RPM and a bend angle of 1.5 or less can be used to reduce the bending fatigue in the motor.

From previous experience, 90% of the time the drilling parameters are such that this rule of thumb should work. When the bend angle and build rates are set high, then the rotary speed and the length of time the motor is rotated should be reduced to lessen the effects of rotational bending.

ROTOR BYPASS

In the event that the flow rate is not sufficient to perform adequate hole cleaning, the rotor can be fitted with a by pass jet. This enables some of the fluid to pass through the bore of the rotor while maintaining the differential pressure. This way the performance characteristics of a given power section can be maintained without over flowing or excessive pressure.

The jet size is selected such that the pressure drop around the rotor and through the rotor is equal. In order to do this, a specific pressure and flow rate must be specified and is usually at the desired drilling torque and flow. In this case, when starting the motor, the flow rates are less and there is no torque. Therefore, the pressure balance is off and may require more fluid to initiate rotation than a power section without a bypass jet.

MOTOR PRESSURE DROP

The pressure drop across the motor is a function of the flow rate. The fluid travels through the dump valve, the drive assembly and the bearing assembly creating a pressure drop due to the restriction of flow. Therefore, the pressure drop across these components is a function of flow rate and viscosity only.

Note that, the viscosity has little effect on the pressure drop of the bearing assembly and the drive assembly compared to the pressure drop across the power section.

The pressure drop across the power section is a function of the torque and increases linearly with the torque assuming a constant flow rate. Running the power section at differential pressures or flow rates higher than specified will result in premature wear to the elastomer and will degrade performance.

BIT PRESSURE DROP

The pressure drop created by the bit may be high. When the static pressure drop exceeds 1,500 PSI (10,000 kPa) the motors will require alternate sealing. Cougar Drilling Solutions should be notified when the bit pressure drop is expected to exceed 1,500 PSI for any length of time.

PLUGGING OFF

Cuttings and other debris in the well may enter the motor causing a blockage. They may enter the motor through the dump valve ports or as connections are made-up. To prevent this, the hole should be circulated to ensure that the cuttings and debris have been removed leaving the well in as clean a state as possible. If the problem persists, the filter plugs in the dump valve ports may have to be replaced with solid plugs.

PULLING OUT

When the motor is to be withdrawn from the hole, no special procedure is required when a dump valve is present. The standpipe will drain into the annulus normally. When a dump valve is not present, the fluid will have to drain through the motor. It may be worthwhile to circulate off bottom to remove any cuttings from the annulus before removing the motor. Caution should be used when retrieving a bent motor through the BOP's. Rotating while removing the motor may aid the removal process.

It is good practice, after operating the tool, to flush it. This will remove any contaminants or fluids that could freeze, and cause problems. To flush the tool, hold the Bearing Housing (first housing above the Bit Box) and rotate the Bit Box clockwise (CW). CW rotation is normal bit rotation. Caution should be taken at the start of this operation; if the Bit Box will not turn freely, discontinue. Continuing could cause an internal connection to back off. If the Bit Box does turn freely, continue rotation until flow discontinues through the Bit Box.

As the motor is being flushed or the bit box rotated, listen for any unusual noises emitting from the internal components. This will give an indication to the presence of any damage. Also, check the surface of the tool for missing oil plugs. If the tool is not rotating properly or there are oil plugs missing, return the tool for servicing.

If the motor is to be re-run, check the oil level by using the "dip" stick and check the depth of the piston. As the oil seeps from the tool the piston moves down (towards the bit). If the tool contains enough oil, it may be re-used. If not, the tool should be returned for servicing.

DRILLING FLUIDS

Many drilling fluids and additives are available. Some of the fluids and/or additives may be harmful to the elastomers used in the power section as well as the motor seals. Care should be taken when selecting the fluid for use with a Cougar Drilling Solutions motor.

Some factors to consider are:

- The pH of the fluid. The percent of hydrogen is an indication of how acidic or basic the fluid is. A drilling fluid too acidic (pH<4) or too basic (pH>10) will result in damage to the power section. Fluids close to these boundaries may be used but circulation must be maintained to reduce the damage to the elastomers. Acids may also harm plated or coated motor components. After using acid based fluids the motor should be properly flushed and serviced as soon as possible.
- The particulate content. As the particulate content increases, erosion becomes a serious problem with the elastomers and the internal motor components. Abrasive particulates should be limited to less than 1%.
- Chlorine content. When the drilling fluid contains a chlorine concentration over 30,000 PPM (parts per million) the motor must be properly flushed and serviced as soon as possible. The chloride can form acids and increase the corrosion of the motor components.

- Mud weight. In general, as the mud weight increases the erosion of internal components increases. Usually the increase in weight is largely due to increased amounts of particulates. It is possible to have more erosion with a lighter fluid with high particulates than a heavier fluid with less particulates. For this reason, it is difficult to establish a specific guideline but once the mud weight approaches 15 PPG (pounds per gallon) care must be given that the particulates are being controlled.
- Light weight, fine particle LCM (loss circulation materials). The fluid path through the motor is somewhat torturous and may result in blockage if coarse LCM materials are used. A common rule of thumb is 2 lbs per barrel or less.
- No cement. Cement should not be pumped through a motor as the cement may flash set while going through various components of the motor or the bit jets.

The operation temperature must be below the aniline point. For oil-based fluids, the aniline point gives an indication to the amount of elastomer swell that may be experienced. It is a measure of the oil's aromatic content. Oil based fluids should have an aromatic content less than 2%.

The lower the aniline point, the greater the amount of swell the elastomer may undergo. It is recommended that the power section be re-lined after being used in oil-based fluids. Diesel based fluids tend to have a more adverse effect on the elastomers than mineral or low-toxicity fluids.

A shorter motor run may be required if the guidelines stated herein are not followed.

DOWNHOLE TEMPERATURE

The elastomers used in the power section and the seals in the motor are susceptible to temperatures over 250°F (121°C). If the static operating temperature is expected to exceed 250°F then alternate materials for seals and an oversized power section may be required. The over-sized power section has more clearance between the stator and the rotor allowing for more swelling in the elastomer. If extreme temperatures warrant, alternate materials are even possible for the stator elastomer. The motors have been used in temperatures in excess of 250°F (121°C) with good performance. If temperatures exceed 250°F please contact a Cougar Drilling Solutions representative for the proper hot hole configuration.

As the temperature increases, the full load differential pressure decreases.

Performance may differ from published data when the hole temperature exceeds 140°F (60°C).

The stator may require a re-line if run for long periods in high temperatures.

TROUBLESHOOTING

DECREASE IN ROP

- Worn stator. This has the effect of reducing the available torque.
- Increase in hole drag. This could be from a stabilizer hanging up or similar events.
- Poor bit type for the type of formation.
- Worn bit.
- Formation change may require different operating parameters.
- Motor stalled.

SUDDEN PRESSURE INCREASE

- Motor stall. May be from excessive weight on bit or from hot hole swelling the elastomer in the power section.
- Internal plug. There may be a restriction in the drilling assembly. If a dump valve is present, the flow could be reduced to see if the pressure stabilizes by allowing the valve to open. This would indicate that the restriction is in the motor.
- Mud rings. This is when cuttings build around tool joints. They may cause the string to stick.

LOW PRESSURE

- Dump valve is open. All the circulated fluid is dumped into the annulus with little pressure drop. Vary the flow rates in an attempt to close the valve.
- Washout. There may be a wash out in the assembly causing fluid to flow into the annulus.
- Worn power section. The ROP would drop. An increase in the differential pressure to regain the ROP is a strong indication that the stator elastomer is worn.

ADJUSTABLE INSTRUCTIONS

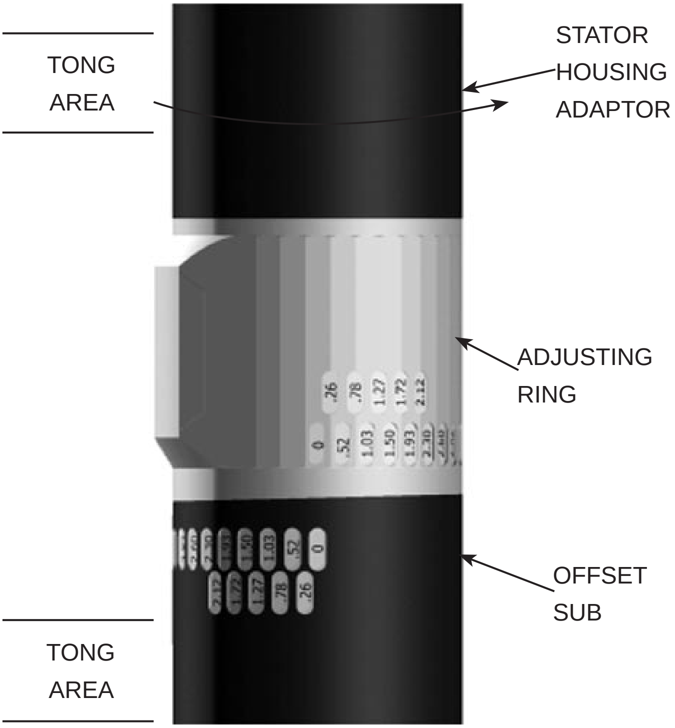


Figure 1

Break Stator Housing Adaptor from adjusting ring using tongs on the tong areas.

Ensure adjusting ring remains engaged to offset sub.

Now use chain tongs only.

Back off stator housing adaptor in 2 full turns.

ADJUSTABLE INSTRUCTIONS

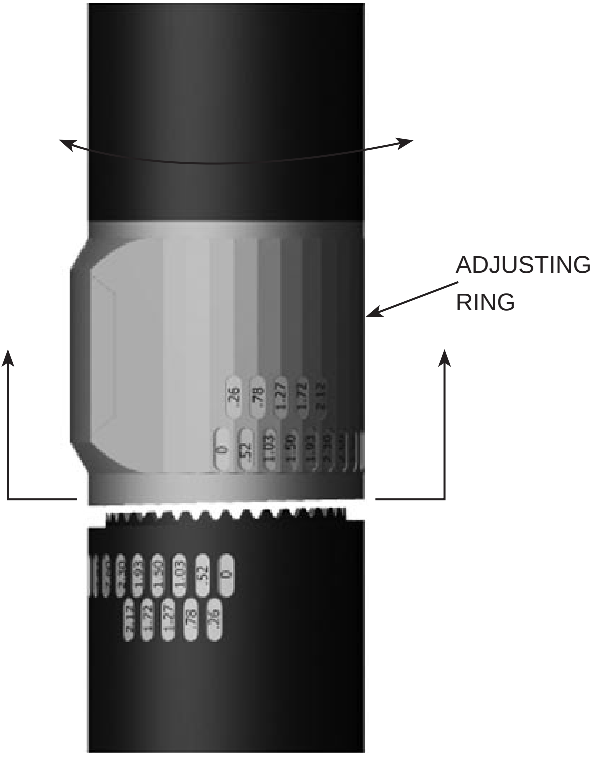


Figure 2

Place chain tongs on adjusting ring and lift up to disengage teeth.

Rotate clockwise to increase bend setting and
counter-clockwise to decrease.

Align desired bend setting values on adjusting ring with the same number on the offset sub and engage adjusting ring with offset sub.

ADJUSTABLE INSTRUCTIONS

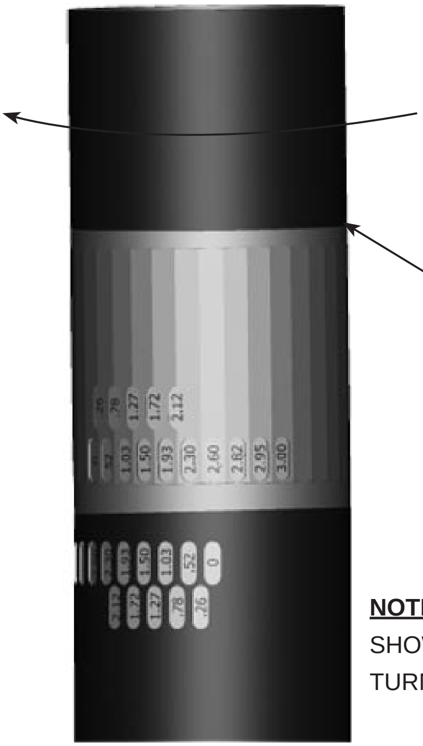


Figure 3

The aligned numbers mark the bend angle and the high side of the bend.

Dope the adjusting ring face well and torque the stator housing adaptor to specification (See Table P. 31) .

Do not allow adjusting ring to rotate CW beyond 3° setting or CCW beyond a 0° setting.

If it is not possible to make up the stator housing adaptor to the adjusting ring the adjustable assembly must be reset.

See page 31 for resetting instructions.

TORQUE SPECIFICATIONS

	ADJUSTABLE TORQUE VALUES		LOWER STABILIZER TORQUE VALUES	
MOTOR SIZE	IMPERIAL (ft-lbs)	METRIC (N-m)	IMPERIAL (ft-lbs)	METRIC (N-m)
3 1/8”	3,000	4,000	N/A	N/A
3 3/4”	5,000	6,800	N/A	N/A
4 3/4”	14,000	19,000	10,000	13,560
5”	14,000	19,000	10,000	13,560
6 1/4”	33,000	44,750	22,000	29,800
6 1/2”	33,000	44,750	22,000	29,800
6 3/4”	33,000	44,750	22,000	29,800
8”	55,000	74,600	27,000	36,600
9 5/8”	85,000	115,300	55,000	74,570

RESETTING INSTRUCTIONS

1. Back off stator housing adaptor enough to allow adjusting ring to disengage from offset sub.

2. Turn the adjusting ring CW (ie rotary right) until the bent offset mandrel (which is splined to the adjusting ring) bottoms out in the offset sub. **Adjusting ring will no longer rotate in CW direction.**

3. With the adjusting ring still disengaged, rotate CCW until a 3° bend setting is attained (ie 3.00 on the adjusting ring lines up with 3.00 on the offset sub).

4. To set to 0°, rotate CCW, until the 0.00’s line up.

5. Make up the stator housing adaptor to the adjusting ring while ensuring the adjusting ring remains engaged to the offset sub.

COUGAR
DRILLING SOLUTIONS

Mud Motor Performance Specifications

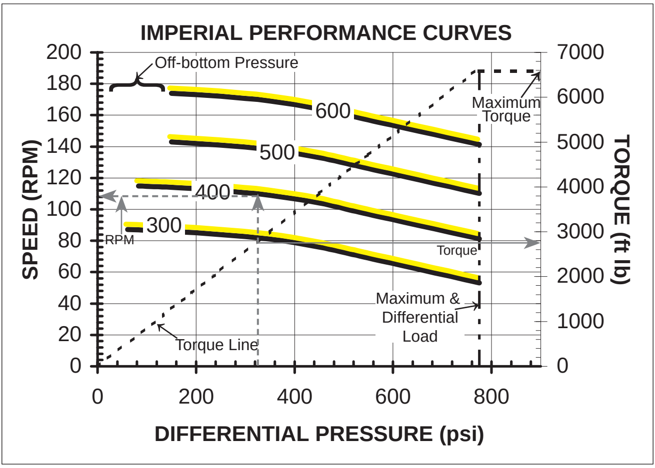
In this example the 6-3/4" (171mm) 6-7 5.0 stage motor is used. This example is to show how to get the most from the performance charts.

Maximum Pump Rate	600	gpm	2271	Lpm
Revolutions per unit volume	0.292	rev/gal	0.077	rev/L
Pressure at full Load	775	psi	5343	kPa
Torque at full load	6650	ft lb	9016	N m

This table gives a quick summary of the motor performance specifics. The maximum flow rate is the intended maximum flow the motor can receive before damage may occur.

The revolutions per unit volume is a direct indication of the RPM's you can expect at a given flow rate. The pressure at full load is the total differential pressure across the motor.

The torque at full load is the maximum torque possible when the flow and pressure specifications are met.



Drilling Fluid Flow (GPM)	300	400	500	600
Pressure Drop Across Motor with No Load (off-bottom pressure) (PSI)	61	83	112	146
Maximum Allowable Differential Pressure (on-bottom - off-bottom pressure) (PSI)	714	692	663	629

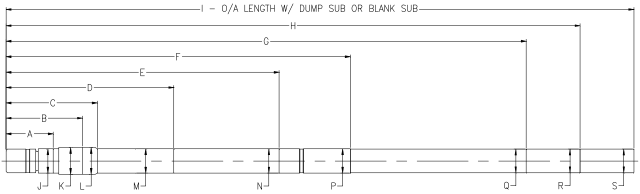
This table gives the off-bottom pressure and the maximum effective pressure for a range of flow rates.

NOTE: The off-bottom plus the maximum effective equals the total differential pressure.

Tool	Max Flow Rate		Torque at Full Load		Pressure at Full Load		Max Bit Speed
	gpm	lpm	ft.lb	N-m	psi	kPa	rpm
3 1/8" 7-8 3.0 Stage	140	530	655	888	600	4137	230
3 1/8" 7-8 4.0 Stage	110	416	425	576	750	5171	392
3 3/4" 4-5 3.5 Stage	160	606	960	1300	530	3654	250
3 3/4" 7-8 2.0 Stage	160	606	1556	2110	420	2896	80
3 3/4" 7-8 2.3 Stage	160	606	1110	1510	350	2380	122
4 3/4" 4-5 3.5 Stage	250	950	1450	1970	530	3620	260
4 3/4" 7-8 2.0 Stage	250	950	2809	3808	374	2578	74
4 3/4" 7-8 2.2 Stage	250	950	1560	2120	330	2280	140
4 3/4" 7-8 2.6 Stage ESX	300	1140	3500	4750	390	2640	79
4 3/4" 7-8 3.8 Stage	250	950	2960	4020	570	3930	140
4 3/4" 7-8 4.5 SX Stage	300	1140	3500	4745	680	4688	140
4 3/4" 7-8 4.5 SXHR Stage	300	1140	5250	7118	1010	6964	140
5" 6-7 6.0 Stage	350	1363	2736	3676	1047	7219	294
5" 6-7 7.0 Stage	360	1363	3262	4427	1225	8446	294
6 1/4" 7-8 4.8 Stage	400	1510	5740	7790	720	4960	132
6 1/2" 4-5 4.8 Stage	600	2271	2725	3695	674	4647	254
6 1/2" 6-7 3.1 Stage ERT	650	2461	8235	11165	1175	8095	240
6 1/2" 6-7 5.0 Stage	600	2270	6230	8450	750	5170	180
6 1/2" 6-7 5.0 HR Stage	600	2270	9350	12680	1130	7760	180
6 1/2" 7-8 2.9 Stage Slow	500	1893	7402	10036	560	3861	72
6 1/2" 7-8 3.0 Stage	600	2271	4190	5670	600	3103	170
6 1/2" 7-8 3.0 Stage Slow	600	2271	7200	9760	450	3100	93
6 1/2" 7-8 5.0 Stage	600	2271	6980	9460	750	5171	180
6 1/2" 7-8 5.0 HR Stage	600	2271	10460	14190	1130	7760	180
6 1/2" 7-8 5.7 Stage	600	2271	9150	12400	860	5900	150
6 1/2" 7-8 5.7 HR Stage	600	2271	13720	18600	1280	8840	150
6 1/2" 8-9 3.0 Stage	500	1893	4900	6644	584	4027	170

Tool	Max Flow Rate		Torque at Full Load		Pressure at Full Load		Max Bit Speed
	gpm	lpm	ft.lb	N-m	psi	kPa	rpm
6 3/4” 6-7 3.1 Stage ERT	650	2461	8235	11165	1175	8095	240
6 3/4” 6-7 5.0 Stage	600	2271	6230	8450	750	5170	180
6 3/4” 6-7 5.0 HR Stage	600	2271	9350	12680	1130	7760	180
6 3/4” 7-8 2.9 Stage Slow	500	1893	7402	10036	560	3861	72
6 3/4” 7-8 3.0 Stage	600	2271	4190	5681	450	3103	170
6 3/4” 7-8 5.0 Stage	600	2271	6980	9460	750	5170	180
6 3/4” 7-8 5.0 HR Stage	600	2271	10460	14190	1130	7760	180
6 3/4” 7-8 5.7 Stage	600	2271	9150	12400	860	5900	180
6 3/4” 7-8 5.7 HR Stage	600	2271	13720	18600	1280	8840	145
8” 4-5 3.6 Stage	900	3407	4294	5822	497	3427	190
8” 7-8 2.0 Stage	800	3028	7053	9563	374	2579	77
8” 7-8 3.4 ESX3 Stage	900	3410	14300	19390	510	3520	80
8” 7-8 4.0 Stage	900	3410	9950	13490	600	4140	150
8” 7-8 4.0 HR Stage	900	3410	14930	20240	900	6210	150
9 5/8” 3-4 4.5 Stage	1200	4542	6780	9192	620	4275	225
9 5/8” 3-4 6.0 Stage	1200	4542	8272	11215	765	5275	270
9 5/8” 5-6 3.0 Stage	1200	4542	10940	14833	450	3103	140
9 5/8” 5-6 5.0 Stage	1300	4920	16120	21850	750	5170	180
9 5/8” 5-6 5.0 HR Stage	1300	4920	24170	32770	1130	7760	180
9 5/8” 6-7 5.0 Stage	1200	4542	13302	18035	775	5343	156
11 1/4” 3-4 3.6 Stage	1500	5680	13390	18160	540	3720	174
11 1/4 ” 5-6 4.6 Stage	1600	6810	21800	29560	690	4760	142

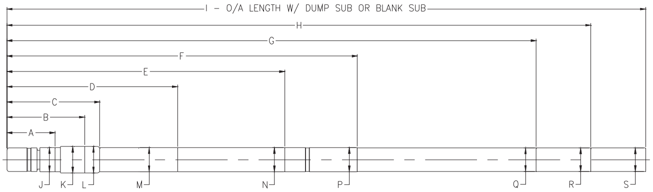
Motor Fishing Dimensions



Motor	Lobes	Stages	A	B	C	D	E	F	G	H	I
3 1/8" (79 mm)	7-8	3.0	10	n/a	16	30	48	60	166.0	177.5	194.5
		4.0							134.0	145.5	162.5
3 3/4" (95 mm)	4-5	3.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	7-8	2.0							n/a	n/a	n/a
		2.3							n/a	n/a	n/a
4 3/4" (121 mm)	4-5	3.5	11	18	21	40	64	81	203.0	217.5	244.0
	7-8	2.0							261.0	275.5	302.0
		2.2							203.0	217.5	244.0
		2.6 ESX							310.0	324.5	351.0
		3.8							268.0	282.5	309.0
		4.5 SX							289.3	303.8	330.3
		4.5 SX HR							289.3	303.8	330.3
5" (127 mm)	6-7	6.0	11	18	21	40	64	81	266.0	280.5	307.0
		7.0							293.0	307.5	334.0
6 1/4" (159 mm)	7-8	4.8	14	22	28	52	79	97	227.0	253.0	279.5
6 1/2" (165 mm) ONLY	4-5	4.8	14	22	28	52	79	97	250.5	276.5	303.0
	7-8	3.0 SLOW							301.0	327.0	353.5
	8-9	3.0							228.0	254.0	280.5
6 1/2" (165 mm) & 6 3/4" (171 mm)	6-7	3.1 ERT	14	22	28	52	79	97	224.8	250.8	277.8
		5.0							297.0	323.0	350.0
		5.0 HR							297.0	323.0	350.0
	7-8	2.9 SLOW							317.0	343.0	369.5
		3.0							228.0	254.0	280.5
		5.0							291.5	317.5	344.5
		5.0 HR							291.5	317.5	344.5
		5.7							357.0	383.0	410.0
		5.7 HR							357.0	383.0	410.0
8" (203 mm)	4-5	3.6	18	28	35	61	90	110	278.0	299.5	330.0
	7-8	2.0							278.0	299.5	330.0
		3.4 ESX3							313.2	334.7	365.2
		4.0							316.0	337.5	368.0
		4.0 HR							313.2	334.7	365.2
9 5/8" (244 mm)	3-4	4.5	17	28	36	63	95	119	297.0	318.5	349.0
		6.0							347.0	368.5	399.0
	5-6	3.0							297.0	318.5	349.0
		5.0							351.0	372.5	403.0
		5.0 HR							351.0	372.5	403.0
	6-7	5.0							327.0	348.5	379.0
11 1/4" (286 mm)	3-4	3.6	19	29	38	67	101	125	355.0	379.0	409.0
	5-6	4.6							355.0	379.0	409.0

COUGAR
DRILLING SOLUTIONS

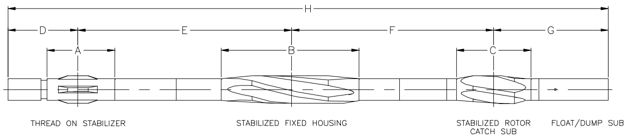
Motor Fishing Dimensions



Motor	Lobes	Stages	J	K	L	M	N	P	Q	R	S
3 1/8" (79 mm)	7-8	3.0	3.15	n/a	3.15	3.15	3.15	3.15	3.13	3.15	3.15
		4.0									
3 3/4" (95 mm)	4-5	3.5	3.75	4.20	4.20	3.75	3.75	3.75	3.75	3.75	3.75
	7-8	2.0									
		2.3									
4 3/4" (121 mm)	4-5	3.5	4.81	5.38	5.38	4.81	4.81	4.81	4.75	4.75	4.81
	7-8	2.0									
		2.2									
		2.6 ESX									
		3.8									
		4.5 SX									
		4.5 SX HR									
5" (127 mm)	6-7	6.0	4.81	5.38	5.38	4.81	4.81	4.75	4.75	4.75	4.81
		7.0									
6 1/4" (159 mm)	7-8	2.8	6.50	7.19	7.19	6.50	6.62	6.62	6.25	6.37	6.62
6 1/2" (165 mm) ONLY	4-5	4.8	6.50	7.19	7.19	6.50	6.62	6.62	6.50	6.62	6.62
	7-8	3.0 SLOW									
	8-9	3.0									
6 1/2" (165 mm) & 6 3/4" (171 mm)	6-7	3.1 ERT	6.50	7.19	7.19	6.50	6.62	6.62	6.50	6.62	6.62
		5.0									
		5.0 HR									
	7-8	2.9 SLOW									
		3.0									
		5.0									
		5.0 HR									
		5.7									
		5.7 HR									
8" (203 mm)	4-5	3.6	7.81	8.63	8.63	8.06	8.06	8.06	8.00	8.06	8.06
	7-8	2.0									
		3.4 ESX3									
		4.0									
		4.0 HR									
9 5/8" (244 mm)	3-4	4.5	9.75	10.75	10.75	9.75	9.75	9.75	9.625	9.75	9.64
		6.0									
	5-6	3.0									
		5.0									
		5.0 HR									
	6-7	5.0									
11 1/4" (286 mm)	3-4	3.6	10.80	12.00	12.00	11.25	11.25	11.25	11.25	11.25	11.25
	5-6	4.6									

Stabilizer Motor Fishing Dimensions

COUGAR
DRILLING SOLUTIONS



Motor	Lobes	Stages	A	B	C	D	E	F	G	H
3 1/8" (79 mm)	7-8	3.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
		4.0						n/a		n/a
3 3/4" (95 mm)	4-5	3.5	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	7-8	2.0						n/a		n/a
		2.3						n/a		n/a
4 3/4" (121 mm)	4-5	3.5	10.3	41.5	45.0	12.9	47.4	133.8	56.0	250.0
	7-8	2.0						191.8		308.0
		2.2						133.8		250.0
		2.6 ESX						241.1		357.3
		3.8						198.8		315.0
		4.5 SX						197.9		314.2
		4.5 SX HR						197.9		314.2
5" (127 mm)	6-7	6.0	10.3	41.5	45.0	12.9	47.4	196.8	56.0	313.0
		7.0						223.8		340.0
6 1/4" (159 mm)	7-8	4.8	12.3	45.6	42.0	15.8	59.0	149.8	55.5	280.1
6 1/2" (165 mm) ONLY	4-5	4.8	12.3	45.6	42.0	15.8	59.0	173.3	55.5	303.6
	7-8	3.0 SLOW						223.8		354.1
	8-9	3.0						150.8		281.1
6 1/2" (165 mm) & 6 3/4" (171 mm)	6-7	3.1 ERT	12.3	45.6	42.0	15.8	59.0	147.6	55.5	277.9
		5.0						219.8		350.1
		5.0 HR						176.0		306.3
	7-8	2.9 SLOW						239.8		370.1
		3.0						150.8		281.1
		5.0						279.8		410.1
		5.0 HR						213.8		344.1
		5.7						176.0		306.3
		5.7 HR						236.0		366.3
8" (203 mm)	4-5	3.6	15.5	n/a	n/a	20.1	n/a	n/a	n/a	334.3
	7-8	2.0								394.3
		3.4 ESX3								334.3
		4.0								334.3
		4.0 HR								334.2
9 5/8" (244 mm)	3-4	4.5	16.5	n/a	n/a	20.1	n/a	n/a	n/a	348.3
		6.0								398.3
	5-6	3.0								348.3
		5.0								398.0
		5.0 HR								398.0
	6-7	5.0								379.0
11 1/4" (286 mm)	3-4	3.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	409.0
	5-6	4.6								409.0