Schlumberger

PowerPak

Steerable Motor Handbook

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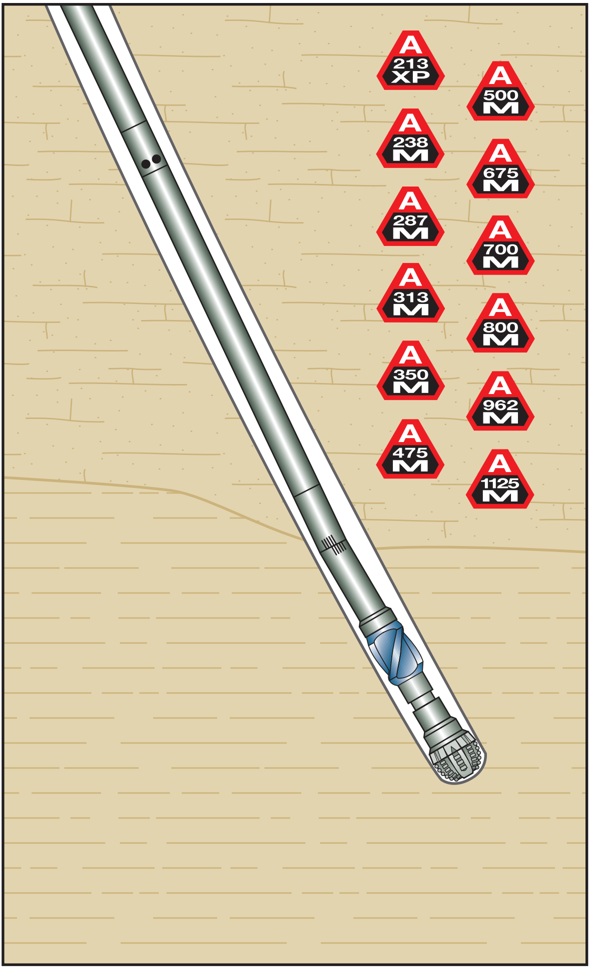
Contents

1.0 Introduction



Development of downhole drilling motors

Since the first turbodrill patent was awarded in 1873, designs and ideas for downhole motors have proliferated. Today, despite the increasing use of rotary steerable systems, positive displacement motors dominate oilfield operations and offer distinct operational and economic advantages over conventional rotary drilling in many conditions.

Downhole motors offer the option of drilling in either a traditional rotary mode or a sliding mode in which the hole is steered in the desired direction by suitable orientation of the motor's bent housing. In directional drilling applications, downhole motors permit control of the wellbore direction and, thus, more effective deviation control than conventional rotary methods.

The Schlumberger PowerPak* steerable motors (Fig. 1-1) have been designed specifically to meet the demanding criteria of directional drilling. This handbook is intended to give general advice and guidelines and sufficient technical information to enable you to use PowerPak motors to their fullest advantage.

1.1 Introduction

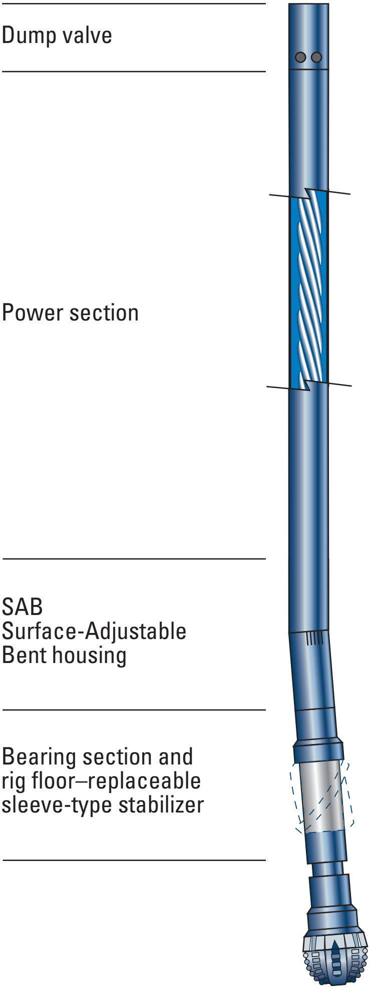


Fig. 1-1. PowerPak motor assembly.

PowerPak design and testing

PowerPak motors are designed according to directional drillers' requirements, with particular emphasis on ruggedness, simplicity and proven technology that translates to superior, dependable performance at the wellsite. Customer and operational requirements are established through liaison with drilling operators. Schlumberger engineers apply knowledge and expertise gained from more than 4 decades of involvement in directional drilling to set design criteria with a focus on reliability.

Schlumberger follows a downhole systems approach to minimize noise interference with measurements-while-drilling (MWD) telemetry and to ensure that PowerPak motors will not unnecessarily limit flow rates and other drilling procedures.

PowerPak motors

PowerPak steerable motor types:

- M-series motors have mud-lubricated bearings. A portion of the drilling fluid flow is diverted through the motor bearings for cooling and lubrication.
- S-series motors have oil-sealed bearings. The bearings are isolated from the drilling fluid and housed in a sealed oil reservoir. These are available in a limited number of sizes and should be specified for particular conditions.
- XC motors are short-radius motors with short bearing and power sections and a single articulation in order to drill short-radius curve sections.
- XF motors are used to drill ultrashort radius curve sections. They differ from XC motors because they have two articulations and an adjustable pad assembly.

1.2 Introduction

The variety of rotor/stator configurations allows PowerPak motors to be used for both low-speed/high-torque and high-speed/low-torque applications. The following are the main options available:

- SP (Standard Power) standard length power sections that are available in different lobe configurations for any motor size.
- XP (Extra Power) extended power sections that provide higher torque output (30–70% longer than SP sections).
- GT (Greater Torque) further extended power sections that maximize torque output (30% longer than XP sections).
- HS (High Speed) lengthened 2:3 lobe configuration power sections with much-increased bit speed and therefore much higher horsepower output.
- HF (High Flow) specifically designed power sections that have higher flow rate tolerance. Available on the A500 and A700 models.
- AD (Air Drilling) specifically designed motors that run slower for any flow rate.

Since the introduction of the PowerPak motor, Schlumberger has expanded the range of sizes, configurations and applications. The company continues to invest in technology improvement and to exceed design goals for reliability, performance and maintenance costs, resulting in improved efficiency and reduced drilling costs.

Features

- PowerPak steerable motors are modular in design (Fig. 1-2), which enables them to operate in a wide range of directional drilling conditions with minimal interference to MWD systems. Motor components can be selected to optimize performance for each set of drilling conditions.
- PowerPak motors feature both oil-sealed and mud-lubricated bearings for rough drilling environments.
- The variety of rotor/stator configurations allows PowerPak motors to be used for both low-speed/high-torque and high-speed/low-torque applications. Extended power sections are available in most sizes and configurations for higher torque requirements.
- The SAB* Surface-Adjustable Bent housing improves efficiency and drilling control through a wide range of settings adjustable at the wellsite.
- A forged-steel drive shaft enhances the motor's strength.
- Sealed transmission couplings extend motor life by preventing mud contamination.
- The mud-lubricated bearing section is short and compact, which places the bend closer to the bit and further enhances directional performance.
- The bearing section incorporates tungsten carbide–coated radial bearings and multiple ball races as axial bearings.
- To optimize rotary drilling performance and minimize bit wear, PowerPak bearing sections can be fitted with rig floor–replaceable, sleeve-type stabilizers or with integral blade stabilizers on the bearing housing or on an extended bit box.

1.2 Introduction

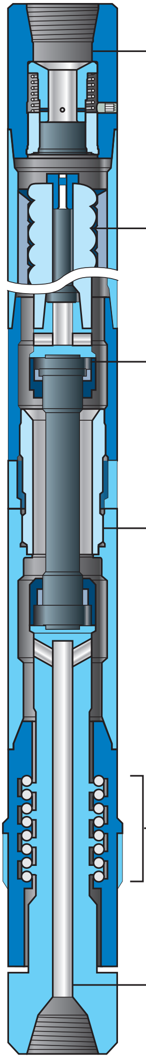


Fig. 1-2. Motor assembly cross section.

Applications

The versatility of the PowerPak motors makes them the ideal motors for both performance (straight hole) and directional drilling. They are also useful in coring, under-reaming, milling, template drilling and other operations that are not covered in this handbook. For information on these applications, call your Schlumberger service representative.

Performance drilling

In straight-hole applications, PowerPak motors function as a performance drilling tool to increase the rate of penetration (ROP) and reduce casing wear by minimizing string rotation.

Directional drilling

Compact design and high-torque capabilities make PowerPak motors ideal for both conventional directional drilling—that is, situations in which a well path is steered to follow a planned geometric course—and geosteering, in which the well or drainhole is steered to optimize its local position within a reservoir with regard to geological, fluid and structural boundaries.

For conventional directional drilling, an adjustable bent housing in the transmission section and a stabilizer on the bearing section allow the PowerPak motor to drill in either an oriented (sliding) or a rotary mode. In rotary mode, both the bit and the drillstring rotate. The rotation of the drillstring negates the effect of the bent housing, and the bit drills a straight path parallel to the axis of the drillstring above the bent housing.

2.0 PowerPak Description

2.1 Overview

In sliding mode, only the bit rotates. By orienting the bent housing in the required direction the desired well path is drilled. This method is applicable to both kickoffs and changes to the well trajectory.

The PowerPak steerable motor makes it possible to drill complete hole sections with one bottomhole assembly (BHA) and to attain various build rates for any given hole size.

In each of the applications described above, the PowerPak adjustable bent housing can be quickly set on the rig floor. Housings are available for 0° to 2° and 0° to 3° bend angle ranges. The PowerPak extra curve (XC) motor for short-radius wells has a surface-adjustable 0° to 4° bend mechanism.

The PowerPak steerable motor consists of three major subassemblies:

- power section, composed of a rotor and a stator, which converts hydraulic energy into mechanical rotary power
- transmission section, which transmits rotary drive from the power section to the bearing section and also incorporates the adjustable bent housing
- bearing section, which supports axial and radial loads during drilling and transmits the rotary drive to the bit through a drive shaft.

Top sub

The top sub of a PowerPak motor can be a crossover sub, dump valve, float sub or flex sub. Historically, PowerPak motors used a dump valve as a top sub. However, in most cases, the use of a dump valve is not necessary. Although PowerPak dump valves are reliable, running a dump valve, if not required, is not recommended. A crossover sub should be used.

Crossover sub

The crossover sub for a PowerPak motor is a sub that has a conventional box thread and a nonstandard pin thread for the PowerPak stators. A crossover sub is used as the top sub of the motor for most operations. A dump valve, float sub or flex sub is used only when necessary.

Dump valve

A dump valve can be added to the top of the power section. The dump valve prevents wet trips by allowing the drillpipe to fill with drilling fluid when tripping into the hole and to drain when pulling out. The PowerPak dump valve also acts as a crossover sub, connecting the stator's connection to a standard API-type thread.

2.2 PowerPak Description

Float sub

Float subs for PowerPak motors incorporate commercially available float valves. They also act as crossovers between conventional API-type threads and Schlumberger threads.

Flex sub

A flex sub can be run as the top sub of a PowerPak motor. The flex sub acts as a crossover sub, and it may include a float valve. Flex subs should be used in wells with high dogleg severity (DLS) (more than 12° per 100 ft), depending on tool and hole size.

Power section

The power section converts hydraulic energy from the drilling fluid into mechanical power to turn the bit. This is accomplished by reverse application of the Moineau pump principle. Drilling fluid is pumped into the motor's power section at a pressure that causes the rotor to rotate within the stator. This rotational force is then transmitted through a transmission shaft and drive shaft to the bit.

The PowerPak rotor is manufactured of corrosion-resistant stainless steel. It usually has a thin layer of chrome plating to reduce friction and abrasion. Tungsten carbide–coated rotors are also available for reduced abrasion wear and corrosion damage. Most PowerPak rotors are bored to accept bypass nozzles for high-flow applications. Note that this is not possible in very small sizes and the special-application motors.

The stator is a steel tube with an elastomer (rubber) lining molded into the bore. The lining is formulated specifically to resist abrasion and hydrocarbon-induced deterioration.

The rotor and stator have similar helical profiles, but the rotor has one fewer spiral, or lobe, than the stator (Fig. 2-1). In an assembled power section, the rotor and stator form a continuous seal at their contact points along a straight line, which produces a number of independent cavities. As fluid (water, mud or air) is forced through these progressive cavities, it causes the rotor to rotate inside the stator. This movement of the rotor inside the stator is called nutation. For each nutation cycle made by the rotor inside the stator, the rotor rotates the distance of one lobe width. The rotor must nutate for each lobe in the stator to complete one revolution of the bit box. A motor with a 7:8 rotor/stator lobe configuration and a speed of 100 revolutions per minute (rpm) at the bit box will have a nutation speed of 700 cycles per minute.

2.3 PowerPak Description

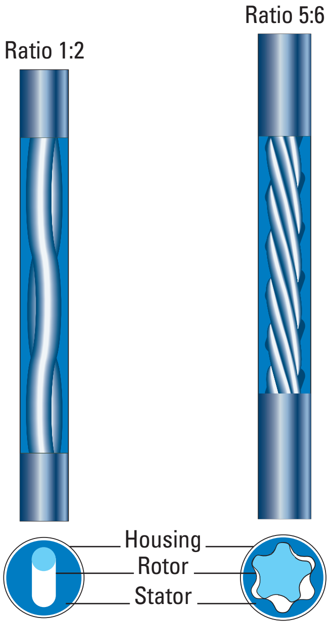


Fig. 2-1. Power section assembly.

The power section of a downhole motor is designated by its rotor/stator lobe configuration. For example, a 4:5 power section has four lobes in the rotor and five in the stator. Generally, the higher the number of lobes, the higher the torque output of the motor and the slower the speed. PowerPak motors are available in 1:2, 2:3, 3:4, 4:5, 5:6 and 7:8 lobe configurations.

Torque also depends on the number of stages (a stage is one complete spiral of the stator helix). Standard PowerPak motors provide the necessary torque output for most applications, but enhanced performance can be achieved through the longer extended power (XP) section, a greater torque (GT) section and a high-speed (HS) power section. A high flow (HF) power section can be used with the A500 and A700 models; its longer pitch on the spiral accommodates higher flow rates. Air drilling (AD) specialty power sections are similar to the HF tools. They have been designed to run slower for any given flow rate by reducing the number of stages and decreasing the pitch relative to the longitudinal axis of the motor.

Rotor/stator lobe ratio

The lobes on a rotor and stator act like a gear box. As their numbers increase for a given motor size, the motor's torque output generally increases and its output shaft speed generally decreases. Figure 2-2 shows an example of the general relationship between power section speed and torque and the power section lobe configuration. Because power is defined as speed times torque, a greater number of lobes in a motor does not necessarily produce more horsepower. Motors with more lobes are actually less efficient because the seal area between the rotor and stator increases with the number of lobes.

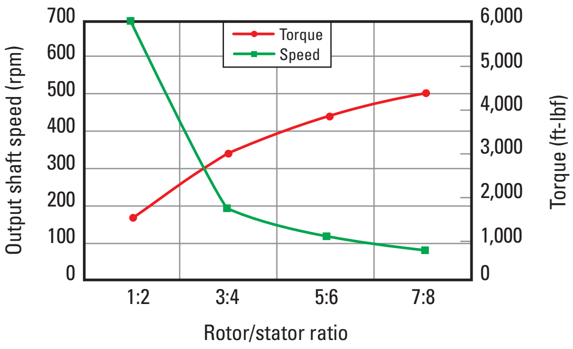


Fig. 2-2. Output shaft speed versus rotor/stator lobe ratio.

Motor mechanical power is calculated as follows:

$$HP_{mechanical} = \frac{T \times S_r}{5252} \qquad (2\text{-}1)$$

where

$HP_{mechanical}$ = motor mechanical power, hp

T = output torque, ft-lbf

S_r = drive shaft rotary speed, rpm.

Rotor/stator interference fit

The difference between the size of the rotor mean diameter (valley to lobe peak measurement) and the stator minor diameter (lobe peak to lobe peak) is defined as the rotor/stator interference fit (Fig. 2-3).

Motors are usually assembled with the rotor sized to be larger than the stator internal bore under planned downhole conditions. This produces a strong positive interference seal called a positive fit. Motors run with a rotor mean diameter more than 0.022 in. greater than the stator minor diameter at downhole conditions are very strong (capable of producing large pressure

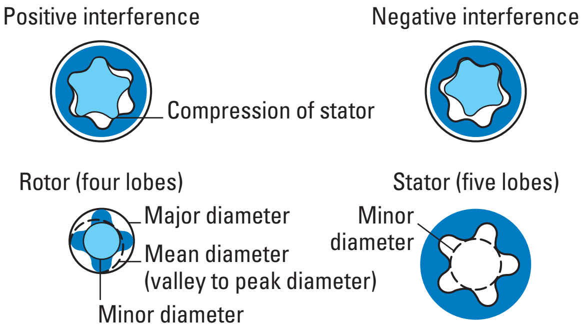


Fig. 2-3. Rotor/stator interference fit.

drops). This produces a strong positive seal called a positive interference fit. When higher downhole temperatures are anticipated, the positive fit is reduced during motor assembly to allow for the swelling of the elastomer. The mud weight and vertical depth also must be considered because they both influence the hydrostatic pressure applied on the elastomer.

A Schlumberger software utility called PowerFit is used to calculate the desired interference fit. Oversized and double-oversized stators and undersized rotors are available to accommodate high-temperature needs.

PowerPak motors are available with two different stator elastomers. The standard material is nitrile rubber (good for most applications to about 280°F). A proprietary elastomer made of highly saturated nitrile can be used for more challenging applications. It is resistant to chemical attack and has been used in temperatures to 350°F.

Spiral stage length

The stator stage length is defined as the axial length required for one lobe in the stator to rotate 360° along its helical path around the body of the stator. The stage length of a rotor, however, is not equivalent to the stage length of its corresponding stator. A rotor has a shorter stage length than its corresponding stator. The equation that describes the general relation of the rotor stages to the stator stages is

$$rotor\ stages = \frac{n+1}{n} \times stator\ stages, \qquad (2\text{-}2)$$

where

n = number of rotor lobes.

Note: For the purposes of this handbook, a stage is defined as a 360° turn of the helical spiral on the stator.

For example, for a PowerPak A675 model motor with a 4:5 lobe, 4.8-stage power section, the power section and the individual stator each have 4.8 stages. However, the rotor has more than 4.8 stages. Because

$$rotor\ stages = \frac{n+1}{n} \times stator\ stages,$$

the rotor for a 4:5 lobe, 4.8-stage power section actually has 6 full rotations of a lobe. Figure 2-4 shows the stage length of a rotor. The number of stages a stator has can also be determined by simply counting the number of rotor stages and reversing the calculation.

Stage length is dependent on the lobe pitch angle of the spiral. As the pitch angle increases, resulting in a tighter spiral and shorter stage length, the force vector perpendicular to the longitudinal axis of the rotor (torque) and the volume of the cavity within the stage decrease. This results in a reduction of torque output and an increase in the motor's speed. Conversely, a decrease in pitch angle produces a longer stage length, resulting in an increase in torque and a decrease in speed.

Long-stage motors usually produce higher torque and fewer revolutions per minute than short-stage motors. As previously mentioned, the drawback for long-stage motors is that as the seal length along the rotor/stator increases with stage length, the efficiency of the seal and the speed of the motor both decrease. The primary application for long-stage designs is air drilling.

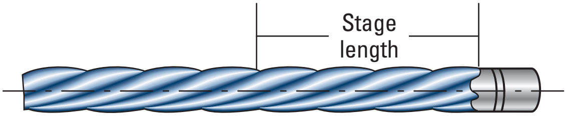


Fig. 2-4. Spiral stage length of rotor.

Number of stages

For a power section with a set lobe ratio, more stages increase the number of fluid cavities in the power section. Each cavity is capable of holding pressure, so as the number of cavities increases, the total pressure drop over the power section increases. Therefore, the total pressure drop and stall torque capability theoretically increase linearly with the number of stages.

In the same differential pressure conditions, the power section with more stages will maintain speed better. Since there will be less pressure drop per stage, there will be less leakage.

Pressure drop per stage

The maximum designed pressure drop per stage is a function of the lobe profile and the hardness of the elastomer lining. Changes in the hardness of the elastomer affect not only the pressure drop but also the resiliency and life of the elastomer.

Rotor/stator fit

The interference fit of the rotor and stator is critical to the performance and overall life of the elastomer in the stator tube. A motor with too much interference (the rotor is much bigger than the stator bore) runs with a high differential pressure but will develop premature chunking after only a few circulating hours (*i.e.*, 6–8 hr). The chunking may be uniform or follow a spiral path through the motor.

A rotor/stator interference that is too loose produces a weak motor that stalls at low differential pressure. Motor stalling is the condition in which the torque required to turn the bit is greater than the motor is capable of producing.

2.3 PowerPak Description

When a motor stalls, the rotor is pushed to one side of the stator, and mud is pumped across the seal face on the opposite side of the rotor. The lobe profile of the stator must deform for the fluid to pass across the seal face. This causes very high fluid velocity across the deformed top of the stator lobes and leads to chunking. Chunking caused by motor stalling when sliding (no surface rotation) has a straight path along one wall of the stator tube. Chunking caused by motor stalling with surface rotation can be uniform or follow a spiral path.

To prevent chunking, care must be taken to select the appropriate rotor/stator interference (or clearance) relative to downhole mud temperature.

The interference fit is predetermined using PowerFit, a Schlumberger proprietary program. Taking into account motor type and size, elastomer type and mud type, the program will calculate the "recommended interference" for the expected differential pressure, density of the drilling fluid and expected bottomhole circulating temperature.

Mud temperature

The circulating temperature is a key factor in dictating the amount of interference in assembling the rotor/stator. The higher the anticipated downhole temperature, the less compression is required between a rotor and stator. The reduction in interference during motor assembly compensates for the swell downhole of the elastomer because of temperature and mud properties. If there is too much interference between the rotor and the stator at operating conditions, then the stator will experience high shearing stresses, resulting in fatigue damage. This fatigue leads to premature chunking failure. Failure to compensate for stator swell resulting from the anticipated downhole temperature is a leading cause of motor failure.

Drilling fluids

PowerPak motors are designed to operate effectively with all types of oil- and water-base drilling fluids, as well as with oil-emulsion, high-viscosity and high-density drilling fluids, air, mist and foam. Drilling fluids can have many different additives, some of which have a detrimental effect on the stator elastomer and stainless-steel/chrome-plated rotor.

Chlorides in mud can severely corrode the chrome plating on standard rotors. In addition to the damage caused to the rotors by corrosion, the rough edges left on the rotor lobes damage the stator by cutting the top off the elastomer in the stator lobe profile. These cuts reduce the effectiveness of the rotor/stator seal and cause the motor to stall (chunking the stator) at low differential pressure.

For oil-base mud (OBM) with supersaturated water phases and for salt muds, tungsten carbide–coated rotors are recommended.

Using nonmagnetic components, for instance nonmagnetic steel stators, can improve the life of the PowerPak motor while drilling in H_2S environments. Although nonmagnetic steel is harder (stronger) than regular steel and thus helps to reduce sulfide stress cracking, focusing on the drilling fluid system is the best preventative measure.

Differential pressure: Understanding motor performance curves

The difference between on-bottom and off-bottom drilling pressure is defined as the differential pressure. This pressure difference is generated by the rotor/stator section of the motor. The larger the pressure difference, the higher the torque output of the motor and the lower the output shaft speed.

Motors that are run with differential pressures greater than recommended are more prone to premature chunking. This likelihood is severely increased if the motor is run at levels that exceed its maximum horsepower output, and chunking will occur in a manner similar to stators that have too much interference (compression) between the rotor and stator. The chunking will follow a spiral path or be uniform throughout the stator body. Running a motor at or over its rated differential pressure maximum severely reduces the life of the stator.

The PowerPak graphs in Chapter 4, "Performance Data," provide a useful guide for determining the optimum balance of differential pump pressure and flow rate. The intersection of the straight torque line with the curved motor speed line does not indicate the optimum running point.

For longest motor life, run the motor at no more than 80% of its maximum rate for any given flow rate and keep the flow rate below 90% of maximum. Under favorable drilling conditions, both may be increased to the maximum.

Lost circulation material

Lost circulation material (LCM) can cause two problems when pumped through a motor. The material can plug off inside the motor, usually at the dump valve if one is used or at the top of the output shaft or the radial bearing, and it can cause stator wear. However, LCM can be used with PowerPak motors if certain precautions are followed:

- add the LCM evenly—avoid pumping a large slug of material
- minimize the use of hard, sharp-edged materials such as nut plug, coarse mica and calcium carbonate chips because these can cause stator wear by abrasion.

- if possible, do not pump concentrations greater than 50 ppg medium nut plug or equivalent.

Although these guidelines help minimize the plugging problems associated with LCM, they cannot completely eliminate the possibility of plugging the motor or bearing section.

Nozzled rotors

Most PowerPak rotors are bored and can be fitted with a nozzle that bypasses part of the flow to extend the motor's capacity and enhance flexibility in matching motor performance to other hydraulic or downhole conditions (Fig. 2-5). The amount of fluid bypassed is determined by the nozzle, the pressure drop through the power section and the fluid density.

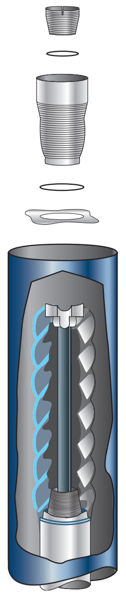


Fig. 2-5. Nozzled rotor.

2.3 PowerPak Description

For performance drilling in larger diameter hole sections, adding a rotor nozzle allows increasing the total flow to clean the hole and remove cuttings. In special applications such as spudding, under-reaming or hole opening in large-size holes, adding a rotor nozzle reduces the bit speed at high flow rates.

A simple hydraulics calculation is used to determine the size of the rotor nozzle:

$$A_N = \frac{q^2 \times W_m}{p_{d+p} \times 10{,}858} \tag{2-3}$$

where

A_N = nozzle total flow area, in.^{2}

q = amount of flow to bypass power section, gpm

W_m = mud weight, ppg

p_{d+p} = expected differential drilling pressure + friction pressure, psi.

Table 2-1 lists the total flow area of common nozzle sizes, Table 2-2 lists rotor nozzle torque values and Table 2-3 shows the amount of fluid bypassed for common mud weights at various nozzle sizes.

The amount of fluid bypassed depends greatly on the pressure drop generated by the power section. This pressure drop is only 100–150 psi when off-bottom, whereas nozzles are sized assuming a power section pressure drop of 300–500 psi.

Nozzled rotor motors should not be operated at flow rates higher than normal (non-nozzled rotor) pump limits when circulating off-bottom.

Table 2-1. PowerPak Motor Nozzle Size and Total Flow Area

Nozzle Size (in.)	Total Flow Area ($in.^2$)	Nozzle Size (in.)	Total Flow Area ($in.^2$)
6/32	0.0276	18/32	0.249
7/32	0.0376	20/32	0.307
8/32	0.0491	22/32	0.371
9/32	0.0621	24/32	0.442
10/32	0.0767	26/32	0.518
12/32	0.1100	28/32	0.601
14/32	0.1500	30/32	0.690
16/32	0.1960	30/32	0.785

Table 2-2. Rotor Nozzle Torque Values

Motor Sizes	Smith Bit Nozzle Series	Makeup Torques (ft-lbf)
A375 and smaller	65	50
A475 and larger	95	100

Table 2-3. Rotor Nozzle Bypass Flow at Different Pressure Drops

Nozzle (in.)	Mud Weight (ppg [kg/L])	Pressure Drop Across Power Section (psi [bar])							
		100 [7]	200 [14]	300 [21]	400 [28]	500 [35]	600 [42]	700 [49]	800 [56]
		Bypass Flow Rate (gpm [L/min])							
7/32	8.34 [1.00]	14 [52]	19 [73]	23 [90]	27 [103]	30 [116]	33 [127]	36 [137]	38 [146]
	10.00 [1.20]	12 [47]	18 [67]	21 [82]	25 [94]	28 [106]	30 [116]	33 [125]	35 [134]
	12.00 [1.44]	11 [43]	16 [61]	20 [75]	23 [86]	25 [96]	28 [106]	30 [114]	32 [122]
	14.00 [1.68]	10 [40]	15 [56]	18 [69]	21 [80]	23 [89]	26 [98]	28 [106]	30 [113]
9/32	8.34 [1.00]	22 [85]	32 [121]	39 [148]	45 [171]	50 [191]	55 [209]	59 [226]	63 [242]
	10.00 [1.20]	20 [78]	29 [110]	35 [135]	41 [156]	46 [174]	50 [191]	54 [206]	58 [221]
	12.00 [1.44]	19 [71]	26 [101]	32 [123]	37 [142]	42 [159]	46 [174]	49 [188]	53 [201]
	14.00 [1.68]	17 [66]	24 [93]	30 [114]	35 [132]	39 [147]	42 [162]	46 [174]	49 [187]
12/32	8.34 [1.00]	40 [152]	56 [215]	69 [263]	80 [304]	89 [340]	98 [372]	105 [402]	113 [430]
	10.00 [1.20]	36 [139]	51 [196]	63 [240]	73 [277]	81 [310]	89 [340]	96 [367]	103 [392]
	12.00 [1.44]	33 [127]	47 [179]	58 [219]	66 [253]	74 [283]	81 [310]	88 [335]	94 [358]
	14.00 [1.68]	31 [117]	43 [166]	53 [203]	62 [234]	69 [262]	75 [287]	81 [310]	87 [332]
14/32	8.34 [1.00]	54 [207]	77 [292]	94 [358]	108 [414]	121 [462]	133 [507]	144 [547]	153 [585]
	10.00 [1.20]	50 [189]	70 [267]	86 [327]	99 [378]	111 [422]	121 [462]	131 [500]	140 [534]
	12.00 [1.44]	45 [172]	64 [244]	78 [299]	90 [345]	101 [385]	111 [422]	120 [456]	128 [487]
	14.00 [1.68]	42 [160]	59 [226]	73 [276]	84 [319]	94 [357]	103 [391]	111 [422]	118 [451]
16/32	8.34 [1.00]	71 [270]	100 [382]	123 [468]	142 [540]	158 [604]	174 [662]	187 [715]	200 [764]
	10.00 [1.20]	65 [247]	91 [349]	112 [427]	129 [493]	145 [551]	158 [604]	171 [652]	183 [697]
	12.00 [1.44]	59 [225]	84 [318]	102 [390]	118 [450]	132 [503]	145 [551]	156 [596]	167 [637]
	14.00 [1.68]	55 [208]	77 [295]	95 [361]	109 [417]	122 [466]	134 [511]	145 [551]	155 [589]
18/32	8.34 [1.00]	90 [342]	127 [484]	155 [592]	179 [684]	200 [764]	220 [837]	237 [905]	254 [967]
	10.00 [1.20]	82 [312]	116 [441]	142 [541]	164 [624]	183 [698]	201 [764]	217 [826]	232 [883]
	12.00 [1.44]	75 [285]	106 [403]	129 [493]	150 [570]	167 [637]	183 [698]	198 [754]	211 [806]
	14.00 [1.68]	69 [264]	98 [373]	120 [457]	138 [528]	155 [590]	170 [646]	183 [698]	196 [746]

Rotor catchers

Most PowerPak motors can be configured to include a rotor catcher, though this is not standard. The rotor catcher is designed to help retrieve the rotor and bearing section in the event the motor parts at the stator adaptor.

Dogleg

Rotating a motor in a high-dogleg interval in a well can damage the stator. The geometry of the wellbore causes the motor to bend and flex, especially if the motor has a bent housing. Because the stator is the most flexible part of the motor, it bends the most. As the stator housing bends, the elastomer pushes on the rotor and bends it, which causes excessive compression on the stator lobes and can lead to chunking.

Transmission section

The transmission assembly, which is attached to the lower end of the rotor, transmits the rotational speed and torque generated by the power section to the bearing and drive shaft. It also compensates for the eccentric movement of the rotor's nutation and absorbs its downthrust.

Rotation is transmitted through the transmission shaft, which is fitted with a universal joint at each end to absorb the eccentric motion of the rotor (Fig. 2-6). Both universal joints are packed with grease and sealed to extend their life.

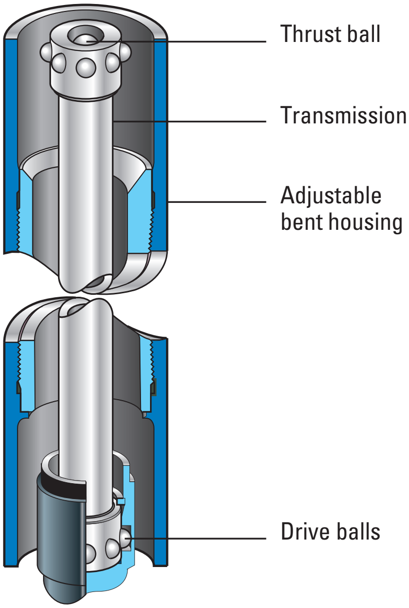


Fig. 2-6. Transmission assembly.

The PowerPak transmission section accommodates the rig floor–adjustable bent housing. The standard adjustable bent housings allow for 0–3° bends. For some of the motors, 0–2° housings are available. For short-radius motors, a 0–4° housing is available.

Straight housings are also available when motors are not used for directional purposes, such as performance drilling and other special applications.

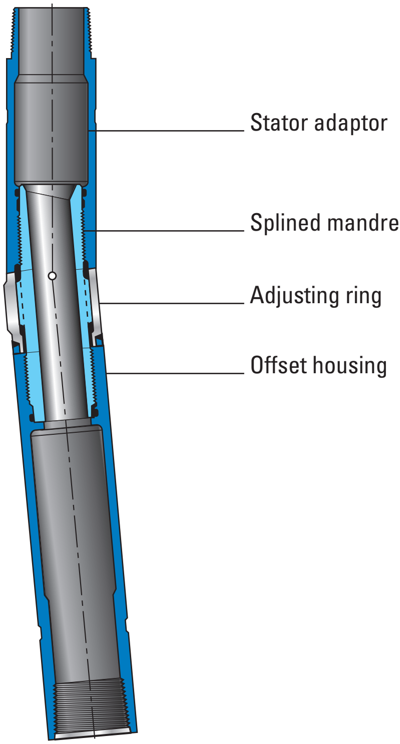


Fig. 2-7. SAB assembly.

Bearing section and drive shaft

The bearing section supports the axial and radial loads. It also transmits the torque and rotary speed from the transmission shaft to the drill bit. This section consists of a drive shaft supported by both axial and radial bearings. The drive shaft is made of forged steel for maximum strength. Depending on directional requirements, the bearing housing can be slick or fitted with either a rig floor–replaceable sleeve or an integral blade-type stabilizer. Stabilizer diameters are available to meet every application. The bearing section is either mud lubricated or oil sealed.

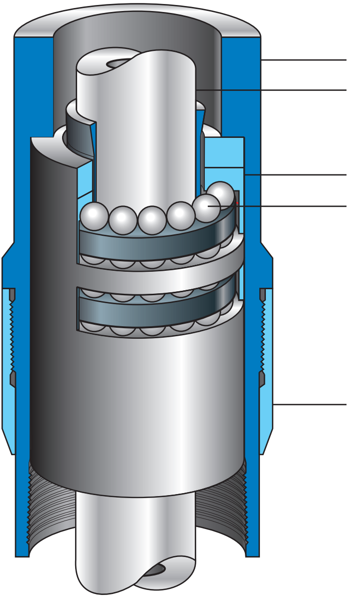


Fig. 2-8. Axial bearing assembly.

Mud-lubricated bearing assemblies

The axial bearing assemblies comprise multiple balls and races that support weight on bit (WOB) load while drilling and hydraulic downward thrust while circulating off-bottom, drilling with less than the balanced WOB or backreaming.

The tungsten carbide–coated radial journal bearings mounted above and below the axial bearings

- counteract the side force on the bit when drilling
- restrict the flow of mud through the radial bearing annulus so that only a small percentage of the total mud flow is used to lubricate the bearings.

Oil-filled sealed bearing assemblies

The oil-sealed bearing assembly functions much like the mud-lubricated assembly. Instead of ball bearings to handle the thrust loads, however, it uses roller bearings for bearing on- and off-bottom loads. The critical component in the sealed bearing assembly is the rotating seals.

If a slick assembly is run, either a slick housing or the sleeve threaded-type bearing housing must be used with the protector made up. When stabilization is used, ⅛-in. or ¼-in. undergauge size is recommended.

For most motor sizes there is a choice between three-blade-spiral or five-blade-straight stabilizer sleeves. It is generally easier to slide with a straight blade stabilizer; however, the spiral option reduces drag while rotating and provides more consistent directional performance in rotary mode.

Table 2-4. PowerPak Stabilization Options

Motor Size	Gauge Size (in.)	Type	Blades	Straight	Spiral
A475	5⅞	Integral housing	3	na	■
A475	5⅞	Integral housing	5	na	■
A475	5⅞	RNBS sleeve	3	na	■
A475	5⅞	RNBS sleeve	5	na	■
A475	5⅞	RNBS sub	5	na	■
A475	5 15⁄16	RNBS sub	5	na	■
A475	6	RNBS sub	5	na	■
A475	5¾, 5⅞	Sleeve	3	■	na
A475	5⅞, 6, 6¼, 6⅜	Sleeve	4	■	na
A475	5¾, 5 13⁄16	Sleeve	5	na	■
A475	5¾, 5⅞, 6, 6⅜, 6½, 6⅝, 7¾	Sleeve	5	■	na
A500	5¾, 5⅞, 6	Integral housing	5	na	■
A500	6⅜, 6½, 6⅝, 6¾	Sleeve	5	■	na
A625S	7¾	Sleeve	4	■	na
A625S	7¾	Sleeve	5	■	na
A675M	8¼, 8⅜	Integral housing	3	na	■
A675M	8⅜	Integral housing	5	na	■
A675M	8¼	Integral housing	5	■	na
A675M	8⅜	RNBS sleeve	5	na	■
A675M	8¼, 8⅜, 8 7⁄16, 9 7⁄16	RNBS sub	5	na	■
A675M	8⅜, 9¾	Sleeve	3	na	■
A675M	8, 8¼, 8⅜, 8½, 9¼, 9½, 9¾	Sleeve	5	■	na
A675S	8⅛, 8¼, 8⅜, 8½, 8⅝, 9⅝	Sleeve	4	■	na
A675S	8⅝	Sleeve	5	■	na

Table 2-4. PowerPak Stabilization Options (continued)

Motor Size	Gauge Size (in.)	Type	Blades	Straight	Spiral
A700	8 7/16	Integral housing	3	na	■
A700	8 3/8	Integral housing	5	na	■
A700	8 1/2, 8 5/8	Integral housing	5	■	na
A700	8 3/8, 9 3/8	RNBS sleeve	5	na	■
A700	8 1/4, 8 3/8, 8 7/16, 9 7/16	RNBS sub	5	na	■
A700	9 3/8, 9 3/4	Sleeve	5	■	na
A825	9 3/4	Integral housing	5	■	na
A825	12 1/8	RNBS sleeve	5	na	■
A825	12 1/8, 12 13/16	RNBS sub	5	na	■
A825	12 1/8, 14 5/8, 16 7/8	Sleeve	3	na	■
A825	10 1/2, 12 1/8	Sleeve	5	■	na
A962/A1125	12 1/8	Integral housing	3	na	■
A962/A1125	12 1/8	Integral housing	5	■	na
A962/A1125	12 1/8	RNBS sleeve	5	na	■
A962/A1125	14 1/2	RNBS sleeve	5	■	na
A962/A1125	12 1/8, 12 3/16, 17 1/4, 21 1/4	RNBS sub	5	na	■
A962/A1125	11 3/4, 12, 12 1/8, 12 3/16, 12 1/4, 17 1/4	Sleeve	3	na	■
A962/A1125	12 1/8, 12 3/16, 13 3/8, 13 3/4, 14, 14 1/8, 14 1/4, 14 1/2, 14 5/8, 15 3/4, 15 7/8, 16 3/4, 17 1/4, 17 3/8, 21 7/8, 22 3/4, 23 1/4, 23 3/4, 25, 25 3/4, 27 3/4, 27 15/16	Sleeve	5	■	na
A962/A1125	17 3/8	Stabilizer	5	na	■
A962/A1125	18 1/8	Stabilizer	5	na	■

na = not available.
■ = available.
RNBS = rotating near-bit stabilizer

Stabilizers

Rotating near-bit stabilizers (RNBS) are available as a replaceable sleeve on the drive shaft bit box or as a short sub run below the motor. The subs can be used with both mud-lubricated and oil-seal bearing motors. All RNBS have spiral blades to reduce drag while rotating.

RNBS help to eliminate hole spiraling and reduce drag while sliding. This increases overall ROP.

Oil-sealed bearings

Oil-sealed bearing assemblies are available in several motor sizes 6¾ in. and smaller. They should be considered for the following conditions:

- underbalanced drilling, especially with dry air, which provides poor lubrication for mud-lubed bearings
- run times less than 100 hr
- multiple short runs before returning to the base for maintenance
- very low bit pressure drop, which can cause mud-lubricated bearings to be underlubricated.

Conditions that are not favorable for oil-sealed bearings are the following:

- low-gravity solids above 8%
- mud weights 14 ppg or greater
- aggressive drilling fluids that attack elastomers and seals.

Mud-lubricated bearings

The axial bearings consist of multiple mud-lubricated ball races that support the WOB load when drilling and the hydraulic downthrust when circulating off-bottom, drilling with less than the balanced WOB or backreaming (Fig. 2-9).

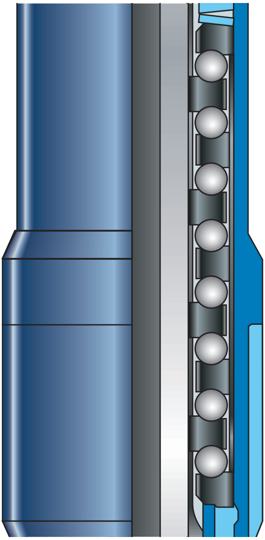


Fig. 2-9. Axial bearing loading.

The tungsten carbide radial journal bearings mounted above and below the axial bearings serve a dual purpose:

- to counteract the side force on the bit when drilling
- to restrict the flow of mud through the bearing section so that only a small percentage of the total mud flow is used to lubricate the bearings (both radial and axial).

The amount of fluid that goes through the bearing is based on the bit pressure drop developed by the bit nozzles and the clearance of the radial bearing. For proper cooling of the bearings, the bit pressure drop must be in the range of 250–1500 psi. If rig hydraulics require a bit pressure drop of less than 250 psi, the motor can be assembled with a special low-bit-pressure-drop radial journal bearing that allows more fluid to be bypassed through the bearings.

Thrust balancing

The flow of fluid through the motor and bearing assembly creates a downward axial hydraulic thrust, while WOB creates an upward thrust. To optimize the life of the motor bearings, these two forces should be balanced by matching bit and motor hydraulics with the amount of weight run on the bit.

The appropriate hydraulic thrust balance for PowerPak motors is given by the following formula:

$$t_h = W_{parts} + \left(X + p_d\right) + \left(Y + p_b\right) \qquad (2\text{-}4)$$

where

t_h = hydraulic thrust, lbf

W_{parts} = weight of rotating parts in mud, lbm

p_d = motor differential pressure, psi

p_b = bit pressure drop, psi

X = a constant related to the cross-sectional area of the rotor, in.^{2}; see Table 2-5

Y = a constant related to the cross-sectional area of the bearings, in.^{2}; see Table 2-5.

Table 2-5. PowerPak Motor Thrust Balance Constants

Motor Size	W (lbm)	X (in.^{2})	Y (in.^{2})
213	40	1.4	1.3
238	60	1.7	1.7
287	100	2.5	2.5
313	100	3.0	3.3
313S	100	3.0	3.1
350	150	3.8	3.7
350S	150	3.8	6.5
375	120	4.3	4.4
475	450	6.9	7.2
475S	450	6.9	13.7
500	650	7.7	8.7
625S	900	12.0	22.6
675	1,100	14.0	13.8
675S	1,100	14.0	24.8
700	1,600	15.0	18.3
825	2,350	20.9	21.4
962	3,050	28.4	30.9
1125	**3,200**	**38.8**	**30.9**

Optimum bearing life will be obtained if this hydraulic thrust is exactly balanced by the WOB applied while drilling.

PowerPak motor thrust bearing capacity

The dynamic load capacity of the PowerPak motor thrust bearings is given in the following table.

Table 2-6. PowerPak Motor Thrust Bearing Capacity

Motor Size	Bearing Capacity (lbm)	
	M-Series	S-Series
213	3,100	na
238	3,900	na
287	5,300	na
313XF/XC	5,100	na
313GT	na	7,500
350	5,900	12,000
375XF/XC	7,700	na
475	11,700	37,400
475XF/XC	8,800	na
500	16,000	na
625	na	47,200
675	30,000	66,000
700	31,700	na
825	45,400	na
962	48,700	na
1125	**48,700**	**na**

na = not available

The maximum WOB for any given motor can be calculated from the formula

$$Maximum\ W_{mb} = t_h + W_{bc} \qquad (2\text{-}5)$$

and the maximum overpull while circulating for any given motor can be calculated from the formula

$$O_m = W_{bc} - t_h \qquad (2\text{-}6)$$

where

O_m = maximum overpull, lbf

t_h = hydraulic thrust, lbf

W_{bc} = bearing weight capacity, lbm

W_{mb} = maximum weight on bit, lbm.

Caution: Applying forces outside of these specifications will result in damage to the thrust bearing stack.

Mud-lubricated bearing failure modes and prevention

Weight on bit

The aggressive nature of polycrystalline diamond compact (PDC) bits generally precludes very high bit weights. Tricone bits, however, are often run with high bit weights that accelerate the wear of the balls and races of the axial bearings.

The races in the mud-lubricated axial bearings are case-hardened. Their wear rate is not linear, because the amount of wear increases once they have worn past the hardened area. Just because a motor has only minor wear after a long run does not mean that the bearings are capable of repeating the same run time.

The WOB limits listed in Chapter 4, “Performance Data,” are the rated maximums for the motors and are independent of the selected power section. Motors with XP and GT power sections do not have higher bearing capacities than regular motors. The additional torque output of an XP or GT section motor increases the hydraulic downthrust of the rotor, which allows running slightly more weight on bit. However, the additional downthrust decreases the overpull capacity while backreaming. Running a PowerPak motor at or near the rated maximum WOB decreases the life of the axial bearing; a limit of 80% of the rated maximum WOB is recommended for long runs.

Bit pressure drop with mud-lubricated bearings

Bit pressure drop is the amount of force acting to push mud through the radial and axial bearings. The fluid flow passing through the bearings must be at a high enough rate to cool and lubricate them, but too much flow will wash out the bearings.

Because they are designed to restrict flow, the radial bearings allow a high bit pressure drop (1500 psi). The minimum bit pressure drop is 250 psi for standard bearings and 100 psi for low bit-pressure-drop bearings.

Problems can occur with too little pressure drop, particularly when motors are surface tested without a bit, because virtually no fluid passes through the bearing section and the radial bearings can overheat rapidly. Motors should not be surface tested for more than 1 min without the minimum 100- or 250-psi pressure drop.

Mud solids with mud-lubricated bearings

The bearing section is compatible with most mud systems. Highly abrasive mud systems can cause excessive wear on the entire bearing pack (radial and axial). Examples of highly abrasive muds include muds with more than 2% sand and systems that use hematite or similar substances for weighting material.

Housings and threads

PowerPak motors have a number of different threaded connections. The top and bottom connections are usually standard oilfield API threads. The makeup, breakout, rework (face and chase) and recut of the API connections are fairly straightforward. Most oilfield machine shops have the necessary thread gauges for this work. The Schlumberger threads on the stator connections and some other parts of the motor require special care to ensure successful operation.

Rotary speed

Normal drilling

Under normal drilling conditions (*i.e.*, where hole cleaning requirements allow), drillstring rotary speed limitations of 100 rpm or less are recommended depending on the motor model, hole size and bend angle setting. These ideal rotary speed recommendations are defined in Tables 2-7 and 2-8. These recommendations minimize the possibility of damage to motor parts (connections, bearings, stator elastomer, transmission) caused by dynamic effects like whirling, slick-slip, high lateral shocks, etc. Should well or drilling conditions dictate higher rotary speeds, absolute limits are defined in Table 2-9.

Rotating PowerPak motors with bend angles corresponding to the blank regions in the tables is not recommended.

Transitioning a steerable motor out of a build section can produce very high bending stresses because the motor must bend backwards against the adjustable bend to fit the curve. Reducing the number of rotations under these high-stress conditions will extend the life of a motor. The slower the rotation, the longer the life of the part. When using a large bend, the stresses are too high to work in a sustained rotary mode; therefore, no rotation is allowed. See Table 2-7 for details.

In the straight or tangent section, lateral vibration and the stresses placed on the bent motor by fitting it into the hole cause fatigue. Lateral vibrations can be initiated by mass imbalance of the string, misalignment and vibratory impulses generated by the bit. Once vibration is initiated, higher rotary speeds help to sustain the vibrations due to the higher energy in the system. Table 2-8 gives recommended rotary speeds to minimize this effect. If high shocks still exist, then it is recommended that these limits be reduced further to 60 rpm. However, this is again dependent on drilling conditions, and good drilling practice must take priority. Table 2-9 gives the absolute values that must not be exceeded.

Table 2-7. Recommended Maximum Drillstring Rotary Speed in Curve Sections

Motor Model	Hole Size (in.)	Rotary Speed Limit (rpm) with Bend Angle (deg) 0.00	0.39	0.78	1.15	1.5	1.83	2.12	2.38	2.6	2.77	3.0	Distance (ft)
A213XP	2⅝	100	100	100	100	90	60	40					5
A238SP	3½	100	100	100	100	90	60	40	40	40			5
A238XP	3½	100	100	100	100	90	60	40	40	40			5
A287SP	3¾	100	100	100	100	90	60						5
A287AD	3¾	100	100	100	100	90	60	40					5
A287XP	3¾	100	100	100	100	90	60	40	40				5
A313SP	3⅞	100	100	100	100	100	100						8
A350SP	4¾	100	100	100	100	90	60	40	40				8
A475SP	6	90	90	50	40	40							10
A475XP/AD	6	90	90	50	40	40	40	40					10
A475GT/HS	6	90	90	80	50	40	40	40	40				10
A500GT/HF	6	80	80	50	40	40	40						10
A625SP	7⅞	80	80	50	40	40							12
A625XP	7⅞	80	80	40	30	40	40						12
A675SP/AD	8½	80	80	50	40	40							13
A675XP	8½	80	80	50	40	40	40						13

Table 2-7. Recommended Maximum Drillstring Rotary Speed in Curve Sections (continued)

Motor Model	Hole Size (in.)	Rotary Speed Limit (rpm) with Bend Angle (deg)											Distance (ft)
		0.00	0.39	0.78	1.15	1.5	1.83	2.12	2.38	2.6	2.77	3.0	
A675HS	8½	80	80	40	40	40							15
A700GT/HF	8½	80	80	40	40	40							15
A825SP	12¼	100	100	80	70	40							15
A825XP/GT	12¼	80	80	50	40	40							15
A962SP	12¼	90	90	60	50	40							15
A962SP	17½	90	90	60	50								15
A962XP	12¼	90	90	50	40	40							15
A962XP	17½	90	90	60	50	40							15
A962GT/HS	12¼	90	90	50	40	40							15
A962GT/HS	17½	90	90	50	40								15
A1125SP	**17½**	**90**	**90**	**60**	**50**								**15**

1. These recommendations are for an ROP of 20 ft/hr. If the ROP is consistently lower, decrease the rotary speed limit proportionally.
2. The rotary speed limit is based on a tool life equivalent to a maximum of 20 full curve sections at the given bend angle.
3. These rotary speed limits are based on a static bending stress fatigue analysis. Excessive vibration can cause fatigue and failure. Decrease the speed if need be, based on local conditions.
4. These limits are for the given hole sizes. If hole sizes are smaller, the rotary speed limit will, in general, decrease. Contact Schlumberger for recommendations.
5. “Distance” refers to the distance from the end of the curve to the point after which rotary speed may be increased to tangent section values.
6. Rotating PowerPak motors with bend angles corresponding to the blank regions is not recommended.
7. For 0–2° adjustable bends, use the value of the closest bend angle listed.

Table 2-8. Recommended Maximum Drillstring Rotary Speed in Tangent or Straight Sections

Motor Model	Hole Size (in.)	Rotary Speed Limit (rpm) with Bend Angle (deg)										
		0.00	0.39	0.78	1.15	1.5	1.83	2.12	2.38	2.6	2.77	3.0
A213XP	2⅝	100	100	100	100	100	100	60				
A238SP	3½	100	100	100	100	100	100	100	100	40		
A238XP	3½	100	100	100	100	100	100	100	100	40		
A287SP	3¾	100	100	100	100	100	100					
A287AD	3¾	100	100	100	100	100	100	40				
A287XP	3¾	100	100	100	100	100	100	100	40			
A313SP	3⅞	100	100	100	100	100	100					
A350SP	4¾	100	100	100	100	100	100	100	100			
A475SP	6	100	100	100	100	100						
A475XP/AD	6	100	100	100	100	100	100	40				
A475GT/HS	6	100	100	100	100	100	100	100	40			
A500GT/HF	6	100	100	100	100	100	100					
A625SP	7⅞	100	100	100	100	60						
A625XP	7⅛	100	100	100	100	100	40					

Table 2-8. Recommended Maximum Drillstring Rotary Speed in Tangent or Straight Sections (continued)

Motor Model	Hole Size (in.)	Rotary Speed Limit (rpm) with Bend Angle (deg)										
		0.00	0.39	0.78	1.15	1.5	1.83	2.12	2.38	2.6	2.77	3.0
A675SP/AD	8½	100	100	100	100	100						
WS												
A675HS	8½	100	100	100	100	100						
A700GT/HF	8½	100	100	100	100	100						
A825XP/GT	12¼	100	100	100	100	100						
A962SP	12¼	100	100	100	100	100						
A962SP	17½	100	100	100	80							
A962XP	12¼	100	100	100	100	100						
A962XP	17½	100	100	100	100	60						
A962GT/HS	12¼	100	100	100	100	100						

Table 2-9. Absolute Maximum Drillstring Rotary Speed in Tangent or Straight Sections

Motor Model	Hole Size (in.)	Rotary Speed Limit (rpm) with Bend Angle (deg)										
		0.00	0.39	0.78	1.15	1.5	1.83	2.12	2.38	2.6	2.77	3.0
A213XP	2⅝	160	160	160	150	140	120	60				
A238SP	3½	160	160	160	150	150	140	150	120	40		
A238XP	3½	160	160	160	160	160	150	140	130	40		
A287SP	3¾	160	160	160	150	140	120					
A287AD	3¾	160	160	160	150	140	120	40				
A287XP	3¾	160	160	160	160	150	130	120	40			
A313SP	3⅞	160	160	160	150	130	100					
A350SP	4¾	160	160	160	160	150	140	130	120			
A475SP	6	160	160	160	140	120						
A475XP/AD	6	160	160	160	150	130	120	40				
A475GT/HS	6	160	160	160	150	100	130	120				
A500GT/HF	6	160	160	160	150	140	120					

Table 2-9. Absolute Maximum Drillstring Rotary Speed in Tangent or Straight Sections (continued)

Motor Model	Hole Size (in.)	Rotary Speed Limit (rpm) with Bend Angle (deg)										
		0.00	0.39	0.78	1.15	1.5	1.83	2.12	2.38	2.6	2.77	3.0
A675SP/AD	8½	160	160	150	140	120						
A675XP	8½	160	160	150	140	130	80					
A675HS	8½	160	160	160	140	120						
A700GT/HF	8½	160	160	160	140	120						
A825SP	12¼	150	150	130	120	70						
A825XP/GT	12¼	150	150	140	130	120						
A962SP	12¼	150	150	140	120	110						
A962SP	17½	140	140	120	80							
A962XP	12¼	160	160	140	130	120						
A962XP	17½	150	150	130	120	60						
A962GT/HS	12¼	160	160	140	130	120						
A962GT/HS	17½	150	150	140	120							

Recommendations when running a motor outside the recommended speed limits

If a PowerPak motor must be rotated at a faster rate than is recommended, then the following recommendations apply.

- Run as low a rotary speed as is practicable. Bear in mind that
  - in harder formations the bending stresses will be higher and the motor components will suffer greater fatigue
  - in softer formations the bending stresses may be less, but hole washout may increase the chance of vibration-induced shock
  - running a stabilizer above the motor will cause higher levels of alternating stress on the stator connections.
- Run real-time shock sensors with the motor. Usually this means the measurements will come from an MWD or logging while drilling tool above the motor.

  If rotary speed is run systematically above the recommended limit, then keep careful track of the hours accrued on the motor components, particularly the stator tube and stator adaptor.

Reaming and backreaming

The tension placed on the motor while reaming with minimal weight on bit or while backreaming reduces the shoulder compression on the connections, making them susceptible to backing off or fatigue failure. Reaming and backreaming operations have a maximum drillstring rotation of 60 rpm while backreaming and 100 rpm while reaming.

Performance drilling with a straight motor housing

Performance drilling with a straight motor housing has a recommended maximum drillstring rotation of 160 rpm. This is not applicable to motors with a bent housing section; Tables 2-7, 2-8 and 2-9 still apply.

Rotary steerable tool/PowerPak combination

A straight housing motor is preferred when running a rotary steerable tool below the motor. The recommended maximum drillstring rotation is 100 rpm to minimize the possibility of damage to the motor parts. The rotary speed tables do not apply.

Using higher than recommended rotary speed

It may be necessary to drill with greater rotary speed than recommended under special circumstances for short intervals. For these conditions, the rotary speed limits given in Table 2-7 may be used with the realization that the life of the motor will be reduced and there is added risk of fatigue failure.

Maximum bend with rotation

The bend angle at which a steerable motor can be rotated is related to the bending stress that occurs when the bent motor is rotated 180° in the curve. This produces very high bending stresses because the motor must bend backwards against the adjustable bend to fit the curve.

XC motors must be treated separately because they drill a tighter curve (higher DLS) with less bend angle. Therefore the amount of bend that can be rotated is less than with a conventional steerable motor. Refer to Table 2-10 for the maximum permissible bends that may be rotated.

Table 2-10.
Maximum Bend with Permissible Rotation (XC Motors)

Motor Size	Maximum Bend (deg)
375XC	1.04
475XC	1.04
475XH†	**1.15**

†XH is an "M" motor with a short-radius power section.

Corrosion

For the majority of applications, corrosion of the motor housing and internal components except for the rotor is usually not problematic. However, there are a few exceptions in which corrosion can cause problems, particularly in the thread roots of the stator box threads.

Severe corrosion problems have occurred in salt-saturated muds, apparently as a result of galvanic action between the dissimilar metals of the PowerPak motor, drill collars and the conductive drilling mud. Sacrificial anodes have been found to work well in the motors when this type of corrosion is a problem. Using flex pup joints above the motors also helps reduce the level of stress on the connections when drilling where corrosion is a problem.

3.1 General specifications

Tables 3-1, 3-2 and 3-3 provide the general performance characteristics of PowerPak motors. Motor-related terms are defined below.

- *OD*: Nominal outer diameter of the motor.
- *Lobes*: Rotor-stator lobe ratio for the power section.
- *Stages*: Power section stages within the stator.
- *Flow*: Normal operating flow range of the motor without a bypass nozzle. The overall flow through a PowerPak motor can be increased by fitting a nozzle in the rotor and bypassing some of the flow through the center of the motor.
- *Max flow with bypass*: Maximum flow allowed with bypass nozzle; the limit is dictated by the flow through the driveshaft.
- *Rev/unit volume*: Number of revolutions per unit of fluid pumped through the motor.
- *Speed*: Revolutions per minute for an unloaded motor operating within the normal flow rate range.
- *Operating torque*: Torque output at recommended differential pressure levels for extended motor life.
- *Differential operating pressure*: Recommended maximum differential pressure for extended motor life, which is 80% of the differential pressure at maximum motor horsepower. Should drilling conditions be favorable, the pressure differential may be allowed to reach the maximum. Good drilling practices should prevail.
- *Max power*: Maximum power that the motor is capable of delivering.

- *Length*: Nominal length of the motor, including the top sub/dump valve.
- *Bend to bit box*: Length from the shoulder of the bit box to the bend of the motor.
- *Stabilizer to bit box*: Length from the shoulder of the bit box to the center of the bearing housing stabilizer.
- *RNBS bit to bend*: Length from the shoulder of the bit box of the rotating near-bit stabilizer drive shaft to the bend of the motor.
- *RNBS bit to stabilizer*: Length from the shoulder of the bit box of the rotating near-bit stabilizer drive shaft to the stabilizer on the RNBS drive shaft.
- *Weight*: Nominal weight of the motor.
- *Working overpull*: The maximum load that can be applied to the motor, based on the strength of the bearing assembly, if the bit is stuck. Operations can continue if the bit comes free without the working overpull being exceeded.
- *Absolute overpull*: The maximum load that can be applied to the motor, based on the strength of the bearing assembly, if the bit is stuck. Exceeding the absolute overpull may cause the motor to part.

Table 3-1. PowerPak Motor Specifications, U.S. Units

Motor Model		OD† (in.)	Lobes	Stages	Bearing Section	Flow (gpm)
A213M	XP	2⅛	5:6	6.0	Mud	20–50
A238M	SP	2⅜	5:6	2.5	Mud	20–50
	SP	2⅜	5:6	3.5	Mud	20–80
	XP	2⅜	5:6	5.2	Mud	20–50
A287M	SP	2⅞	5:6	3.3	Mud	20–80
	XP	2⅞	5:6	7.0	Mud	20–80
	SP	2⅞	7:8	3.2	Mud	30–90
	SP	2⅞	7:8	3.7	Mud	40–120
	AD	2⅞	7:8	2.0	Mud	60–180
A313M	XC	3⅛	7:8	2.0	Mud	60–120
	XC	3⅛	7:8	2.9	Mud	60–120
	XF	3⅛	7:8	2.0	Mud	60–120
A313S	SP	3⅛	5:6	3.5	Oil	80–160
	GT	3⅛	5:6	5.2	Oil	80–160
A350M	SP	3½	4:5	5.0	Mud	30–110
	SP	3½	7:8	3.0	Mud	30–110
A350S	SP	3½	4:5	5.0	Oil	30–110
	SP	3½	7:8	3.0	Oil	30–110
A375M	XC	3¾	7:8	2.0	Mud	130–190
	XC	3¾	7:8	3.5	Mud	130–190
	XF	3¾	7:8	2.0	Mud	130–190
A475M	SP	4¾	1:2	3.0	Mud	100–200
	HS	4¾	2:3	10.5	Mud	100–265
	SP	4¾	4:5	3.5	Mud	100–250
	XP	4¾	4:5	6.0	Mud	100–250
	GT	4¾	5:6	8.3	Mud	100–250
	SP	4¾	7:8	2.2	Mud	100–250
	XP	4¾	7:8	3.8	Mud	100–250
	XC	4¾	7:8	2.0	Mud	100–250
	XF	4¾	7:8	2.0	Mud	100–250
	AD	4¾	7:8	2.0	Mud	300–700
A475S	SP	4¾	1:2	3.0	Oil	100–200
	HS	4¾	2:3	10.5	Oil	100–265
	SP	4¾	4:5	3.5	Oil	100–250
	XP	4¾	4:5	6.0	Oil	100–250
	GT	4¾	5:6	8.3	Oil	100–250
	SP	4¾	7:8	2.2	Oil	100–250
	XP	4¾	7:8	3.8	Oil	100–250
	AD	4¾	7:8	2.0	Oil	300–700
A500M	HS	5	2:3	10.5	Mud	100–265
	HF	5	5:6	5.2	Mud	150–400
	GT	5	5:6	8.3	Mud	100–250

Max Flow with Bypass (gpm)	Rev/Unit Volume (rpm/gal)	Speed (rpm)	Max Operating Torque (ft-lbf)	Differential‡ Operating Pressure (psi)	Max Power at Max Flow Rate (hp)	Length (ft)	Bend to Bit Box (ft)	Stabilizer to Bit Box (ft)	RNBS§ Bit to Bend (ft)	RNBS Bit to Stabilizer (ft)	Weight (lbm)	Hole OD (in.)	Working†† Overpull (lbf)	Absolute†† Overpull (lbf)
na	12.80	260–640	280	1,200	15	10.51	2.08	na	na	na	80	2⅜–2⅞	18,000	41,600
na	7.90	160–395	195	500	7	8.45	2.29	na	na	na	80	2⅞–3½	25,100	59,900
na	7.38	160–590	275	700	18	9.93	2.29	na	na	na	105	2⅞–3½	25,100	59,900
na	7.90	160–395	420	1,050	15	12.52	2.29	na	na	na	120	2⅞–3½	25,100	59,900
130	5.81	115–465	330	675	15	10.02	2.91	na	na	na	140	3⅝–4¾	37,000	80,400
130	5.81	115–465	700	1,400	35	14.62	2.91	na	na	na	195	3⅝–4¾	37,000	80,400
130	4.17	125–375	465	660	15	10.02	2.91	na	na	na	140	3⅝–4¾	37,000	80,400
na	3.54	140–425	540	760	27	11.21	2.91	na	na	na	160	3⅝–4¾	37,000	80,400
na	2.17	130–390	540	420	28	10.88	2.91	na	na	na	150	3⅝–4¾	37,000	80,400
na	3.83	230–460	280	410	10	8.85	3.32	na	na	na	135	3½–4¼	43,400	98,300
na	3.83	230–460	400	600	17	9.93	3.32	na	na	na	135	3½–4¼	43,400	98,300
na	3.83	230–460	280	410	10	8.40	1.05	na	na	na	135	3½–4¼	43,400	98,300
na	2.19	175–350	875	700	36	12.13	2.93	na	na	na	200	3½–4¼	45,600	136,800
na	2.38	195–380	1,300	1,050	53	15.60	2.93	na	na	na	250	3½–4¼	45,600	136,800
160	3.18	95–350	875	980	33	15.12	3.37	na	na	na	300	4½–6	47,500	140,800
160	1.50	45–165	960	575	18	15.12	3.37	na	na	na	310	4½–6	47,500	140,800
160	3.18	95–350	875	980	33	16.14	4.38	na	na	na	330	4½–6	42,400	146,400
160	1.50	45–165	960	575	17	16.14	4.38	na	na	na	330	4½–6	42,400	146,400
na	1.87	240–355	600	410	16	10.50	2.79	na	na	na	225	4½–4¾	69,400	152,700
na	1.87	240–355	1,050	720	35	12.94	2.79	na	na	na	225	4½–4¾	69,400	152,700
na	1.87	240–355	600	410	16	10.14	1.18	na	na	na	225	4½–4¾	69,400	152,700
na	2.18	225–435	530	400	34	18.87	4.08	1.13	5.11	0.34	630	5⅞–7	58,200	272,000
na	2.26	226–600	2,550	1,850	174	27.50	4.08	1.13	5.11	0.34	1,000	5⅞–7	58,200	272,000
350	1.04	105–260	1,900	690	51	16.62	4.08	1.13	5.11	0.34	620	5⅞–7	58,200	272,000
350	1.04	105–260	3,200	1,180	93	22.54	4.08	1.13	5.11	0.34	920	5⅞–7	58,200	272,000
350	1.04	105–260	4,600	1,650	130	27.17	4.08	1.13	5.11	0.34	1,000	5⅞–7	58,200	272,000
350	0.54	55–135	2,100	450	26	16.62	4.08	1.13	5.11	0.34	640	5⅞–7	58,200	272,000
350	0.54	55–135	3,750	780	54	22.54	4.08	1.13	5.11	0.34	900	5⅞–7	58,200	272,000
na	0.98	100–245	1,100	410	24	13.32	3.03	na	na	0.34	525	5⅞–6⅛	58,200	272,000
na	0.98	100–245	1,100	410	24	12.60	1.51	na	na	0.34	500	5⅞–6⅛	58,200	272,000
na	0.33	100–230	3,000	360	110	20.12	4.08	1.13	5.11	0.34	800	5⅞–7	58,200	272,000
na	2.20	220–440	530	440	34	18.06	5.52	1.13	na	na	610	5⅞–7	106,400	264,800
na	2.26	225–600	2,550	1,850	174	28.94	5.52	1.13	na	na	1,050	5⅞–7	106,400	264,800
350	1.04	105–260	1,900	700	51	18.06	5.52	1.13	na	na	660	5⅞–7	106,400	264,800
350	1.04	105–260	3,200	1,200	93	23.98	5.52	1.13	na	na	960	5⅞–7	106,400	264,800
350	1.04	105–260	4,600	1,650	130	28.61	5.52	1.13	na	na	1,050	5⅞–7	106,400	264,800
350	0.54	55–135	2,100	450	26	18.06	5.52	1.13	na	na	680	5⅞–7	106,400	264,800
350	0.54	55–135	3,750	780	54	23.98	5.52	1.13	na	na	960	5⅞–7	106,400	264,800
na	0.33	100–230	3,000	410	110	21.56	5.52	1.13	na	na	840	5⅞–7	106,400	264,800
na	2.26	225–600	2,550	1,850	174	26.70	4.43	1.59	5.29	0.34	1,300	5⅞–7	61,200	378,600
na	0.63	95–250	4,400	980	133	27.00	4.43	1.59	5.29	0.34	1,320	5⅞–7	61,200	378,600
na	1.04	105–260	4,500	1,650	132	26.70	4.43	1.59	5.29	0.34	1,300	5⅞–7	61,200	378,600

AD Air Drilling
GT Greater Torque
HF High Flow
HS High Speed
SP Standard Power
XC Extra Curve–Short Radius (single articulation w/ bent housing)
XF Extra Flex–Short Radius (double articulation)
XP Extra Power
na Not applicable
† Outside diameter
‡ Under normal circumstances, the recommended maximum is 80% of this number; 100% can be used if conditions allow.
§ Rotating near-bit stabilizer
†† These numbers include a 1.25, or 25%, safety factor.

Table 3-1. PowerPak Motor Specifications, U.S. Units (continued)

Motor Model		OD[†] (in.)	Lobes	Stages	Bearing Section	Flow (gpm)	Max Flow with Bypass (gpm)	Rev/Unit Volume (rpm/gal)	Speed (rpm)	Max Operating Torque (ft-lbf)	Differential[‡] Operating Pressure (psi)	Max Power at Max Flow Rate (hp)	Length (ft)	Bend to Bit Box (ft)	Stabilizer to Bit Box (ft)	RNBS[§] Bit to Bend (ft)	RNBS Bit to Stabilizer (ft)
A625S	SP	6¼	1:2	4.0	Oil	175–350	na	1.29	230–450	1,400	625	82	22.67	6.44	2.05	na	na
	SP	6¼	4:5	4.3	Oil	150–400	500	0.66	100–265	3,700	850	106	19.67	6.44	2.05	na	na
	XP	6¼	4:5	7.5	Oil	150–400	500	0.66	100–265	6,300	1,450	190	26.30	6.44	2.05	na	na
	SP	6¼	7:8	2.8	Oil	150–400	500	0.34	50–135	4,400	580	64	19.67	6.44	2.05	na	na
	XP	6¼	7:8	4.8	Oil	150–400	500	0.34	50–136	7,600	980	120	26.27	6.44	2.05	na	na
A650S	GT	6½	5:6	8.2	Oil	300–600	800	0.42	125–250	10,500	1,650	310	30.58	6.44	1.75	na	na
	AD	6½	7:8	2.0	Oil	400–800	na	0.14	60–115	6,800	380	100	22.87	6.44	1.75	na	na
A675M	SP	6¾	1:2	4.0	Mud	200–500	na	0.93	180–465	1,700	510	115	23.60	6.03	1.75	6.94	0.56
	XP	6¾	2:3	8.0	Mud	300–600	700	0.87	260–520	3,700	1,075	280	26.51	6.03	1.75	6.94	0.56
	HS	6¾	2:3	10.7	Mud	300–600	700	1.00	300–600	5,600	1,900	415	29.09	6.03	1.75	6.94	0.56
	SP	6¾	4:5	4.8	Mud	300–600	700	0.50	150–300	5,400	920	170	21.39	6.03	1.75	6.94	0.56
	XP	6¾	4:5	7.0	Mud	300–600	700	0.50	150–300	7,800	1,400	259	26.51	6.03	1.75	6.94	0.56
	SP	6¾	7:8	3.0	Mud	300–600	700	0.28	85–165	5,700	620	96	19.44	6.03	1.75	6.94	0.56
	XP	6¾	7:8	5.0	Mud	300–600	700	0.28	85–165	9,500	1,025	180	25.19	6.03	1.75	6.94	0.56
	AD[‡‡]	6¾	7:8	2.0	Mud	400–800	na	0.14	60–115	6,800	380	100	21.85	6.03	1.75	6.94	0.56
A675S	SP	6¾	1:2	4.0	Oil	200–500	na	0.93	180–465	1,700	510	115	24.62	6.44	1.75	na	na
	XP	6¾	2:3	8.0	Oil	300–600	700	0.87	260–520	3,700	1,075	280	27.53	6.44	1.75	na	na
	HS	6¾	2:3	10.7	Oil	300–600	700	1.00	300–600	5,600	1,900	415	29.09	6.44	1.75	na	na
	SP	6¾	4:5	4.8	Oil	300–600	700	0.50	150–300	5,400	920	170	22.41	6.44	1.75	na	na
	XP	6¾	4:5	7.0	Oil	300–600	700	0.50	150–300	7,800	1,400	259	27.53	6.44	1.75	na	na
	SP	6¾	7:8	3.0	Oil	300–600	700	0.28	85–165	5,700	620	96	20.46	6.44	1.75	na	na
	XP	6¾	7:8	5.0	Oil	300–600	700	0.28	85–165	9,500	1,025	180	26.21	6.44	1.75	na	na
	AD[‡‡]	6¾	7:8	2.0	Oil	400–800	na	0.14	60–115	6,800	380	100	22.87	6.44	1.75	na	na
A700M	GT	7	5:6	8.2	Mud	300–600	800	0.42	125–250	10,500	1,650	310	30.56	6.03	1.75	6.97	0.56
	HF	7	5:6	5.8	Mud	600–1,000	na	0.30	180–295	10,500	1,150	375	30.56	6.03	1.75	6.97	0.56
	GT	7	7:8	6.6	Mud	300–600	800	0.29	85–175	12,000	1,400	250	30.56	6.03	1.75	6.97	0.56
	HF	7	7:8	4.7	Mud	600–1,000	na	0.21	120–205	12,000	920	290	30.56	6.03	1.75	6.97	0.56
A775M	SP[§§]	7¾	4:5	3.6	Mud	300–900	1,100	0.25	75–225	7,500	670	178	23.60	7.06	2.01	8.25	0.67
	SP[§§]	7¾	7:8	3.0	Mud	300–900	1,100	0.16	45–145	9,900	610	132	23.60	7.06	2.01	8.25	0.67
A825M	SP	8¼	1:2	4.0	Mud	300–600	na	0.72	210–430	2,200	510	138	25.85	7.06	2.01	8.25	0.67
	SP	8¼	4:5	3.6	Mud	300–900	1,100	0.25	75–225	7,500	670	178	23.60	7.06	2.01	8.25	0.67
	XP	8¼	4:5	5.3	Mud	300–900	1,100	0.25	75–225	10,800	1,000	280	29.27	7.06	2.01	8.25	0.67
	GT	8¼	4:5	8.2	Mud	300–900	1,100	0.38	115–340	12,500	1,620	470	30.77	7.06	2.01	8.25	0.67
	SP	8¼	7:8	3.0	Mud	300–900	1,100	0.16	45–145	9,900	610	132	23.60	7.06	2.01	8.25	0.67
	XP	8¼	7:8	4.0	Mud	300–900	1,100	0.16	45–145	13,200	820	190	27.60	7.06	2.01	8.25	0.67
A962M	SP	9⅝	1:2	5.0	Mud	400–800	na	0.48	190–380	4,200	650	236	29.21	7.78	2.35	9.20	0.89
	HS	9⅝	2:3	9.2	Mud	600–1,200	1,500	0.42	250–500	12,000	1,620	709	32.02	7.78	2.35	9.20	0.89
	SP	9⅝	3:4	4.5	Mud	600–1,200	1,500	0.22	135–265	10,500	760	319	26.29	7.78	2.35	9.20	0.89
	XP	9⅝	3:4	6.0	Mud	600–1,200	1,500	0.22	135–265	14,000	1,025	435	30.48	7.78	2.35	9.20	0.89
	GT	9⅝	3:4	8.0	Mud	600–1,200	1,500	0.28	167–333	15,000	1,450	603	31.81	7.78	2.35	9.20	0.89
	SP	9⅝	5:6	3.0	Mud	600–1,200	1,500	0.11	65–135	13,000	530	201	26.29	7.78	2.35	9.20	0.89
	XP	9⅝	5:6	4.0	Mud	600–1,200	1,500	0.11	65–135	18,000	710	280	30.48	7.78	2.35	9.20	0.89
	GT	9⅝	7:8	4.8	Mud	600–1,200	1,500	0.11	65–135	24,000	1,000	342	32.02	7.78	2.35	9.20	0.89
A1125M	SP	11¼	3:4	3.6	Mud	1,000–1,500	1,700	0.11	115–170	14,900	580	318	29.02	8.29	2.35	9.20	0.89
	GT	11¼	7:8	4.8	Mud	600–1,200	1,500	0.11	65–130	24,000	1,000	342	32.02	8.29	2.35	9.20	0.89

Weight (lbm)	Hole OD (in.)	Working†† Overpull (lbf)	Absolute†† Overpull (lbf)
1,780	7⅞–8½	155,200	513,600
1,600	7⅞–8½	155,200	513,600
2,060	7⅞–8½	155,200	513,600
1,600	7⅞–8½	155,200	513,600
2,060	7⅞–8½	155,200	513,600
2,400	8⅜–9⅞	192,000	537,600
2,000	8⅜–9⅞	192,000	537,600
1,780	8⅜–9⅞	142,700	518,800
2,150	8⅜–9⅞	142,700	518,800
2,300	8⅜–9⅞	142,700	518,800
1,750	8⅜–9⅞	142,700	518,800
2,170	8⅜–9⅞	142,700	518,800
1,750	8⅜–9⅞	142,700	518,800
2,260	8⅜–9⅞	142,700	518,800
1,930	8⅜–9⅞	142,700	518,800
1,780	8⅜–9⅞	192,000	537,600
2,150	8⅜–9⅞	192,000	537,600
2,300	8⅜–9⅞	192,000	537,600
1,750	8⅜–9⅞	192,000	537,600
2,170	8⅜–9⅞	192,000	537,600
1,750	8⅜–9⅞	192,000	537,600
2,260	8⅜–9⅞	192,000	537,600
2,010	8⅜–9⅞	192,000	537,600
3,200	8½–9⅞	163,800	823,200
3,400	8½–9⅞	163,800	823,200
3,200	8½–9⅞	163,800	823,200
3,400	8½–9⅞	163,800	823,200
3,475	9⅞–14¾	219,500	754,800
3,325	9⅞–14¾	219,500	754,800
3,655	9⅞–14¾	219,500	754,800
3,650	9⅞–14¾	219,500	754,800
4,700	9⅞–14¾	219,500	754,800
4,980	9⅞–14¾	219,500	754,800
3,500	9⅞–14¾	219,500	754,800
4,020	9⅞–14¾	219,500	754,800
5,180	12¼–26	338,200	1,340,000
6,250	12¼–26	338,200	1,340,000
5,100	12¼–26	338,200	1,340,000
5,750	12¼–26	338,200	1,340,000
6,300	12¼–26	338,200	1,340,000
5,400	12¼–26	338,200	1,340,000
6,130	12¼–26	338,200	1,340,000
6,350	12¼–26	338,200	1,340,000
6,400	17½–26	338,200	1,340,000
8,500	17½–26	338,200	1,340,000

AD	Air Drilling
GT	Greater Torque
HF	High Flow
HS	High Speed
SP	Standard Power
XC	Extra Curve–Short Radius (single articulation w/ bent housing)
XF	Extra Flex–Short Radius (double articulation)
XP	Extra Power
na	Not applicable
†	Outside diameter
‡	Under normal circumstances, the recommended maximum is 80% of this number; 100% can be used if conditions allow.
§	Rotating near-bit stabilizer
††	These numbers include a 1.25, or 25%, safety factor.
‡‡	These stators have a reduced diameter of 6.5 in. for most of their length, but fit the 6.75-in. bearing section.
§§	These stators have a reduced diameter of 7.75 in, but fit the 8.25-in. bearing section.

Table 3-2. PowerPak Motor Specifications, Metric Units

Motor Model		OD† (mm)	Lobes	Stages	Bearing Section	Flow (L/min)
A213M	XP	53.98	5:6	6.0	Mud	80–190
A238M	SP	60.33	5:6	2.5	Mud	80–190
	SP	60.33	5:6	3.5	Mud	80–300
	XP	60.33	5:6	5.2	Mud	80–190
A287M	SP	73.03	5:6	3.3	Mud	80–300
	XP	73.03	5:6	7.0	Mud	80–300
	SP	73.03	7:8	3.2	Mud	110–340
	SP	73.03	7:8	3.7	Mud	150–450
	AD	73.03	7:8	2.0	Mud	230–680
A313M	XC	79.38	7:8	2.0	Mud	230–450
	XC	79.38	7:8	2.9	Mud	230–450
	XF	79.38	7:8	2.0	Mud	230–450
A313S	SP	79.38	5:6	3.5	Oil	300–610
	GT	79.38	5:6	5.2	Oil	300–610
A350M	SP	88.90	4:5	5.0	Mud	110–420
	SP	88.90	7:8	3.0	Mud	110–420
A350S	SP	88.90	4:5	5.0	Oil	110–420
	SP	88.90	7:8	3.0	Oil	110–420
A375M	XC	95.25	7:8	2.0	Mud	490–720
	XC	95.25	7:8	3.5	Mud	490–720
	XF	95.25	7:8	2.0	Mud	490–720
A475M	SP	120.65	1:2	3.0	Mud	380–760
	HS	120.65	2:3	10.5	Mud	380–1,000
	SP	120.65	4:5	3.5	Mud	380–950
	XP	120.65	4:5	6.0	Mud	380–950
	GT	120.65	5:6	8.3	Mud	380–950
	SP	120.65	7:8	2.2	Mud	380–950
	XP	120.65	7:8	3.8	Mud	380–950
	XC	120.65	7:8	2.0	Mud	380–950
	XF	120.65	7:8	2.0	Mud	380–950
	AD	120.65	7:8	2.0	Mud	1,140–2,650
A475S	SP	120.65	1:2	3.0	Oil	380–760
	HS	120.65	2:3	10.5	Oil	380–1,000
	SP	120.65	4:5	3.5	Oil	380–950
	XP	120.65	4:5	6.0	Oil	380–950
	GT	120.65	5:6	8.3	Oil	380–950
	SP	120.65	7:8	2.2	Oil	380–950
	XP	120.65	7:8	3.8	Oil	380–950
	AD	120.65	7:8	2.0	Oil	1,140–2,650
A500M	HS	127.00	2:3	10.5	Mud	380–1,000
	HF	127.00	5:6	5.2	Mud	570–1,510
	GT	127.00	5:6	8.3	Mud	380–950

Max Flow with Bypass (L/min)	Rev/Unit Volume (rpm/L)	Speed (rpm)	Max Operating Torque (N·m)	Differential‡ Operating Pressure (kPa)	Max Power at Max Flow Rate (kW)	Length (m)	Bend to Bit Box (m)	Stabilizer to Bit Box (m)	RNBS§ Bit to Bend (m)	RNBS Bit to Stabilizer (m)	Weight (kgm)	Hole OD (mm)	Working†† Overpull (N)	Absolute†† Overpull (N)
na	3.38	260–640	380	8,250	11	3.20	0.63	na	na	na	35	60.33–73.03	80,000	185,000
na	2.09	160–395	260	3,450	5	2.58	0.70	na	na	na	35	73.03–88.90	112,000	266,000
na	1.95	160–590	370	4,850	13	3.03	0.70	na	na	na	50	73.03–88.90	112,000	266,000
na	2.09	160–395	570	7,250	11	3.82	0.70	na	na	na	55	73.03–88.90	112,000	266,000
500	1.54	115–465	450	4,650	11	3.05	0.89	na	na	na	65	92.08–120.65	165,000	358,000
500	1.54	115–465	950	9,650	26	4.46	0.89	na	na	na	90	92.08–120.65	165,000	358,000
500	1.10	125–375	9,220	4,550	11	3.05	0.89	na	na	na	65	92.08–120.65	165,000	358,000
na	0.94	140–425	730	5,250	20	3.42	0.89	na	na	na	75	92.08–120.65	165,000	358,000
na	0.57	130–390	730	2,900	21	3.32	0.89	na	na	na	70	92.08–120.65	165,000	358,000
na	1.01	230–460	380	2,850	7	2.70	1.01	na	na	na	60	88.90–107.95	193,000	437,000
na	1.01	230–460	540	4,150	13	3.03	1.01	na	na	na	60	88.90–107.95	193,000	437,000
na	1.01	230–460	380	2,850	7	2.56	0.32	na	na	na	60	88.90–107.95	193,000	437,000
na	0.58	175–350	1,200	4,850	27	3.70	0.89	na	na	na	90	88.90–107.95	203,000	609,000
na	0.63	195–380	1,750	7,250	40	4.75	0.89	na	na	na	115	88.90–107.95	203,000	609,000
600	0.84	95–350	9,220	6,750	25	4.61	1.03	na	na	na	135	114.30–152.40	211,000	626,000
600	0.40	45–165	1,300	3,950	13	4.61	1.03	na	na	na	140	114.30–152.40	211,000	626,000
600	0.84	95–350	1,200	6,750	25	4.92	1.34	na	na	na	150	114.30–152.40	189,000	651,000
600	0.40	45–165	1,300	3,950	13	4.92	1.34	na	na	na	150	114.30–152.40	189,000	651,000
na	0.49	240–355	810	2,850	12	3.20	0.85	na	na	na	100	114.30–120.65	309,000	679,000
na	0.49	240–355	1,400	4,950	26	3.94	0.85	na	na	na	100	114.30–120.65	309,000	679,000
na	0.49	240–355	810	2,850	12	3.09	0.36	na	na	na	100	114.30–120.65	309,000	679,000
na	0.58	225–435	720	2,750	25	5.75	1.24	0.34	1.56	0.10	285	149.23–177.80	259,000	1,210,000
na	0.60	226–600	3,500	12,750	130	8.38	1.24	0.34	1.56	0.10	455	149.23–177.80	259,000	1,210,000
1,320	0.28	105–260	2,500	4,750	38	5.07	1.24	0.34	1.56	0.10	280	149.23–177.80	259,000	1,210,000
1,320	0.28	105–260	4,500	8,150	69	6.87	1.24	0.34	1.56	0.10	415	149.23–177.80	259,000	1,210,000
1,320	0.28	105–260	6,000	11,400	97	8.28	1.24	0.34	1.56	0.10	455	149.23–177.80	259,000	1,210,000
1,320	0.14	55–135	3,000	3,100	19	5.07	1.24	0.34	1.56	0.10	290	149.23–177.80	259,000	1,210,000
1,320	0.14	55–135	5,000	5,400	40	6.87	1.24	0.34	1.56	0.10	410	149.23–177.80	259,000	1,210,000
na	0.26	100–245	1,490	2,850	18	4.06	0.92	na	na	0.10	240	149.23–155.58	259,000	1,210,000
na	0.26	100–245	1,490	2,850	18	3.84	0.46	na	na	0.10	225	149.23–155.58	259,000	1,210,000
na	0.09	100–230	4,000	2,500	82	6.13	1.24	0.34	1.56	0.10	365	149.23–177.80	259,000	1,210,000
na	0.58	220–440	720	3,050	25	5.50	1.68	0.34	na	na	275	149.23–177.80	473,000	1,178,000
na	0.60	225–600	3,500	12,750	130	8.82	1.68	0.34	na	na	475	149.23–177.80	473,000	1,178,000
1,320	0.28	105–260	2,500	4,850	38	5.50	1.68	0.34	na	na	300	149.23–177.80	473,000	1,178,000
1,320	0.28	105–260	4,500	8,250	69	7.31	1.68	0.34	na	na	435	149.23–177.80	473,000	1,178,000
1,320	0.28	105–260	6,000	11,400	97	8.72	1.68	0.34	na	na	475	149.23–177.80	473,000	1,178,000
1,320	0.14	55–135	3,000	3,100	19	5.50	1.68	0.34	na	na	310	149.23–177.80	473,000	1,178,000
1,320	0.14	55–135	5,000	5,400	40	7.31	1.68	0.34	na	na	435	149.23–177.80	473,000	1,178,000
na	0.09	100–230	4,000	2,850	82	6.57	1.68	0.34	na	na	380	149.23–177.80	473,000	1,178,000
na	0.60	225–600	3,500	12,750	130	8.14	1.35	0.48	1.61	0.10	590	149.23–177.80	272,000	1,684,000
na	0.17	95–250	6,000	6,750	99	8.23	1.35	0.48	1.61	0.10	600	149.23–177.80	272,000	1,684,000
na	0.28	105–260	6,000	11,400	98	8.14	1.35	0.48	1.61	0.10	590	149.23–177.80	272,000	1,684,000

- AD Air Drilling
- GT Greater Torque
- HF High Flow
- HS High Speed
- SP Standard Power
- XC Extra Curve–Short Radius (single articulation w/ bent housing)
- XF Extra Flex–Short Radius (double articulation)
- XP Extra Power
- na Not applicable
- † Outside diameter
- ‡ Under normal circumstances, the recommended maximum is 80% of this number; 100% can be used if conditions allow.
- § Rotating near-bit stabilizer
- †† These numbers include a 1.25, or 25%, safety factor.

Table 3-2. PowerPak Motor Specifications, Metric Units (continued)

Motor Model		OD† (mm)	Lobes	Stages	Bearing Section	Flow (L/min)	Max Flow with Bypass (L/min)	Rev/Unit Volume (rpm/L)	Speed (rpm)	Max Operating Torque (N·m)	Differential‡ Operating Pressure (kPa)	Max Power at Max Flow Rate (kW)	Length (m)	Bend to Bit Box (m)	Stabilizer to Bit Box (m)	RNBS§ Bit to Bend (m)	RNBS Bit to Stabilizer (m)
625S	SP	158.75	1:2	4.0	Oil	660–1,320	na	0.34	230–450	2,000	4,300	61	6.91	1.96	0.62	na	na
	SP	158.75	4:5	4.3	Oil	570–1,510	1,890	0.17	100–265	5,000	5,850	79	6.00	1.96	0.62	na	na
	XP	158.75	4:5	7.5	Oil	570–1,510	1,890	0.17	100–265	8,500	10,000	142	8.02	1.96	0.62	na	na
	SP	158.75	7:8	2.8	Oil	570–1,510	1,890	0.09	50–135	6,000	4,000	48	6.00	1.96	0.62	na	na
	XP	158.75	7:8	4.8	Oil	570–1,510	1,890	0.09	50–136	10,500	6,750	90	8.01	1.96	0.62	na	na
A650S	GT	165.10	5:6	8.2	Oil	1,140–2,270	3,030	0.11	125–250	14,000	11,400	231	9.32	1.96	0.53	na	na
	AD	165.10	7:8	2.0	Oil	1,150–3,030	na	0.04	60–115	11,000	2,600	75	6.97	1.96	0.53	na	na
A675M	SP	171.45	1:2	4.0	Mud	760–1,890	na	0.25	180–465	2,500	3,500	86	7.19	1.84	0.53	2.12	0.17
	XP	171.45	2:3	8.0	Mud	1,140–2,270	2,650	0.23	260–520	5,000	7,400	209	8.08	1.84	0.53	2.12	0.17
	HS	171.45	2:3	10.7	Mud	1,140–2,270	2,650	0.26	300–600	7,500	13,100	310	8.87	1.84	0.53	2.12	0.17
	SP	171.45	4:5	4.8	Mud	1,140–2,270	2,650	0.13	150–300	7,500	6,350	127	6.52	1.84	0.53	2.12	0.17
	XP	171.45	4:5	7.0	Mud	1,140–2,270	2,650	0.13	150–300	10,500	9,650	193	8.08	1.84	0.53	2.12	0.17
	AD‡‡	171.45	7:8	2.0	Mud	1,510–3,030	na	0.04	60–115	11,000	2,600	75	6.66	1.84	0.53	2.12	0.17
	SP	171.45	7:8	3.0	Mud	1,140–2,270	2,650	0.07	85–165	7,500	4,250	72	5.93	1.84	0.53	2.12	0.17
	XP	171.45	7:8	5.0	Mud	1,140–2,270	2,650	0.07	85–165	13,000	7,050	134	7.68	1.84	0.53	2.12	0.17
A675S	SP	171.45	1:2	4.0	Oil	760–1,890	na	0.25	180–465	2,500	3,500	86	7.50	1.96	0.53	na	na
	XP	171.45	2:3	8.0	Oil	1,140–2,270	2,650	0.23	260–520	6,000	7,400	209	8.39	1.96	0.53	na	na
	HS	171.45	2:3	10.7	Oil	1,140–2,270	2,650	0.26	300–600	7,500	13,100	310	8.87	1.84	0.53	na	na
	SP	171.45	4:5	4.8	Oil	1,140–2,270	2,650	0.13	150–300	7,500	6,350	127	6.83	1.96	0.53	na	na
	XP	171.45	4:5	7.0	Oil	1,140–2,270	2,650	0.13	150–300	10,500	9,650	193	8.39	1.96	0.53	na	na
	AD‡‡	171.45	7:8	2.0	Oil	1,510–3,030	na	0.04	60–115	11,000	2,600	75	6.97	1.96	0.53	na	na
	SP	171.45	7:8	3.0	Oil	1,140–2,270	2,650	0.07	85–165	7,500	4,250	72	6.24	1.96	0.53	na	na
	XP	171.45	7:8	5.0	Oil	1,140–2,270	2,650	0.07	85–165	13,000	7,050	134	7.99	1.96	0.53	na	na
A700M	GT	177.80	5:6	8.2	Mud	1,140–2,270	3,030	0.11	125–250	14,000	11,400	231	9.31	1.84	0.53	2.12	0.17
	HF	177.80	5:6	5.8	Mud	2,270–3,790	na	0.08	180–295	14,000	7,950	280	9.31	1.84	0.53	2.12	0.17
	GT	177.80	7:8	6.6	Mud	1,140–2,270	3,030	0.08	85–175	16,500	9,650	187	9.31	1.84	0.53	2.12	0.17
	HF	177.80	7:8	4.7	Mud	2,270–3,790	na	0.06	120–205	16,500	6,350	216	9.31	1.84	0.53	2.12	0.17
A775M	SP§§	196.85	4:5	3.6	Mud	1,140–3,410	4,160	0.07	75–225	10,000	4,600	133	7.19	2.15	0.61	2.51	0.20
	SP§§	196.85	7:8	3.0	Mud	1,140–3,410	4,160	0.04	45–145	13,500	4,200	98	7.19	2.15	0.61	2.51	0.20
A825M	SP	209.55	1:2	4.0	Mud	1,140–2,270	na	0.19	210–430	3,000	3,500	103	7.88	2.15	0.61	2.51	0.20
	SP	209.55	4:5	3.6	Mud	1,140–3,410	4,160	0.07	75–225	10,000	4,600	133	7.19	2.15	0.61	2.51	0.20
	XP	209.55	4:5	5.3	Mud	1,140–3,410	4,160	0.07	75–225	14,500	6,900	209	8.92	2.15	0.61	2.51	0.20
	GT	209.55	4:5	8.2	Mud	1,140–3,410	4,160	0.10	115–340	17,000	11,150	351	9.38	2.15	0.61	2.51	0.20
	SP	209.55	7:8	3.0	Mud	1,140–3,410	4,160	0.04	45–145	13,500	4,200	98	7.19	2.15	0.61	2.51	0.20
	XP	209.55	7:8	4.0	Mud	1,140–3,410	4,160	0.04	45–145	18,000	5,650	142	8.41	2.15	0.61	2.51	0.20
A962M	SP	244.48	1:2	5.0	Mud	1,510–3,030	na	0.13	190–380	5,500	4,500	176	8.90	2.37	0.72	2.80	0.27
	HS	244.48	2:3	9.2	Mud	2,270–4,540	5,680	0.11	250–500	16,500	11,150	529	9.76	2.37	0.72	2.80	0.27
	SP	244.48	3:4	4.5	Mud	2,270–4,540	5,680	0.06	135–265	14,000	5,250	238	8.01	2.37	0.72	2.80	0.27
	XP	244.48	3:4	6.0	Mud	2,270–4,540	5,680	0.06	135–265	19,000	7,050	325	9.29	2.37	0.72	2.80	0.27
	GT	244.48	3:4	8.0	Mud	2,270–4,540	5,680	0.07	167–333	20,500	10,000	450	9.70	2.37	0.72	2.80	0.27
	SP	244.48	5:6	3.0	Mud	2,270–4,540	5,680	0.03	65–135	17,500	3,650	150	8.01	2.37	0.72	2.80	0.27
	XP	244.48	5:6	4.0	Mud	2,270–4,540	5,680	0.03	65–135	24,500	4,900	209	9.29	2.37	0.72	2.80	0.27
	GT	244.48	7:8	4.8	Mud	2,270–4,540	5,680	0.03	65–135	32,500	6,900	255	9.76	2.37	0.72	2.80	0.27
A1125M	SP	285.75	3:4	3.6	Mud	3,790–5,680	6,430	0.03	115–170	20,000	4,000	237	8.85	2.53	0.72	2.80	0.27
	GT	285.75	7:8	4.8	Mud	2,270–4,540	5,680	0.03	65–130	32,500	6,900	255	9.76	2.50	0.72	2.80	0.27

Weight (kgm)	Hole OD (mm)	Working†† Overpull (N)	Absolute†† Overpull (N)
805	200.03–215.90	690,000	2,285,000
725	200.03–215.90	690,000	2,285,000
935	200.03–215.90	690,000	2,285,000
725	200.03–215.90	690,000	2,285,000
935	200.03–215.90	690,000	2,285,000
1,090	212.73–250.83	854,000	2,391,000
905	212.73–250.83	854,000	2,391,000
805	212.73–250.83	635,000	2,308,000
975	212.73–250.83	635,000	2,308,000
1,045	212.73–250.83	635,000	2,308,000
795	212.73–250.83	635,000	2,308,000
985	212.73–250.83	635,000	2,308,000
875	212.73–250.83	635,000	2,308,000
795	212.73–250.83	635,000	2,308,000
1,025	212.73–250.83	635,000	2,308,000
805	212.73–250.83	854,000	2,391,000
975	212.73–250.83	854,000	2,391,000
1,045	212.73–250.83	854,000	2,391,000
795	212.73–250.83	854,000	2,391,000
985	212.73–250.83	854,000	2,391,000
910	212.73–250.83	854,000	2,391,000
795	212.73–250.83	854,000	2,391,000
1,025	212.73–250.83	854,000	2,391,000
1,450	215.90–250.83	729,000	3,662,000
1,540	215.90–250.83	729,000	3,662,000
1,450	215.90–250.83	729,000	3,662,000
1,540	215.90–250.83	729,000	3,662,000
1,575	250.83–374.65	976,000	3,358,000
1,510	250.83–374.65	976,000	3,358,000
1,660	250.83–374.65	976,000	3,358,000
1,655	250.83–374.65	976,000	3,358,000
2,130	250.83–374.65	976,000	3,358,000
2,260	250.83–374.65	976,000	3,358,000
1,590	250.83–374.65	976,000	3,358,000
1,825	250.83–374.65	976,000	3,358,000
2,350	311.15–660.40	1,504,000	5,961,000
2,835	311.15–660.40	1,504,000	5,961,000
2,315	311.15–660.40	1,504,000	5,961,000
2,610	311.15–660.40	1,504,000	5,961,000
2,860	311.15–660.40	1,504,000	5,961,000
2,450	311.15–660.40	1,504,000	5,961,000
2,780	311.15–660.40	1,504,000	5,961,000
2,880	311.15–660.40	1,504,000	5,961,000
2,905	444.50–660.40	1,504,000	5,961,000
3,855	444.50–660.40	1,504,000	5,961,000

AD	Air Drilling
GT	Greater Torque
HF	High Flow
HS	High Speed
SP	Standard Power
XC	Extra Curve–Short Radius (single articulation w/ bent housing)
XF	Extra Flex–Short Radius (double articulation)
XP	Extra Power
na	Not applicable
†	Outside diameter
‡	Under normal circumstances, the recommended maximum is 80% of this number; 100% can be used if conditions allow.
§	Rotating near-bit stabilizer
††	These numbers include a 1.25, or 25%, safety factor.
‡‡	These stators have a reduced diameter of 6.5 in. for most of their length, but fit the 6.75-in. bearing section.
§§	These stators have a reduced diameter of 7.75 in, but fit the 8.25-in. bearing section.

Dogleg severity limitation

Dogleg severity is a measurement of the curvature of the wellbore. Table 3-3 summarizes the maximum DLS in which PowerPak motors (excluding short-radius motors) can be safely run in the sliding mode. More dogleg severity limitation calculations are also provided as part of the PowerPlan* directional well planning program.

Table 3-3. Dogleg Severity Limitation

Motor Type	Max DLS with 3° Bend (deg/100 ft)	Max Bit Offset with 3° Bend (in.)
A213XP	50	1.51
A238M	62	1.65
A287M	51	2.03
A313S	43	2.05
A350M	36	2.32
A475M	20	3.03
A500M	18	3.25
A625S	21	4.67
A675M	19	4.42
A700M	16	4.42
A825M	17	5.07
A962M	15	5.83
A1125M	13	6.15

Job preparation

Motor selection

Hole diameter and flow rate usually dictate the tool diameter. After the diameter has been chosen, the other specifications can be selected. Ensure that all motor housings are fishable in the planned hole size.

Dump valve

The probability of plugging the dump valve can be reduced by running a float valve above the motor. If a float valve is run and plugging is still a potential problem, a crossover sub can be run instead of a dump valve.

Rotor/stator configuration

The rotor/stator configuration affects the bit speed at a given flow rate. The default standard is 4:5 (or 5:6 for PowerPak model A962M). Other configurations are also available.

Rotor nozzle

A rotor nozzle should be specified if high flow rates are anticipated.

Bent housing setting

The degree of bend depends on the anticipated maximum DLS in the hole section to be drilled. In determining this setting, use the dogleg prediction programs with caution because the calculations are based on idealized hole conditions for a limited number of BHA configurations. Local experience should be taken into consideration, even if it has been obtained using different steerable motors, because actual figures provide a guideline for the predictions obtained from the planning software.

The bend selection also depends on the diameter of any stabilizers. The bend should be set at a reasonable minimum to decrease possible stabilizer hanging. Rotating the string to hold angle rather than continuing to build angle or to ease WOB transfer may lead to premature failure of the motor bearing or housing. It is good practice to anticipate lower buildup rates at low inclination or in soft sections where hole enlargement occurs.

Stabilizer gauge

If a slick assembly is run, the sleeve threaded-type bearing housing must be used with the protector made up. When stabilization is used, ⅛- or ¼-in. undergauge size is recommended. The buildup rate is controlled by the position and gauge of the second stabilizer.

Connection

The top connection must be checked for compatibility with the BHA.

Bit selection

When selecting the bit to run with a PowerPak motor, the following factors should be taken into account:

- directional control
- expected run duration
- drilling program
- type of cutting structure required
- fluid passage design
- expected rate of penetration
- estimated rotating time
- torque output of motor.

Because of the aggressive nature of PDC bits, using medium- to low-speed motors with high torque output is recommended, *e.g.*, PowerPak XP and PowerPak GT motors.

For directional applications in which a roller cone bit is to be used, a widely accepted guideline is to select a roller cone bit with a tooth structure at least one grade harder than would be selected for rotary drilling in the same formation. A slightly harder bit design has more bottomhole coverage, which can be advantageous when higher bends are used. In vertical applications, especially with moderate rotational speeds, there is no need to select a harder bit type. Modern "directional" bit designs have features that allow the use of the softer bit designs even on high-angle bend assemblies. High bends still accelerate wear, because they increase side loads, gauge wear and bearing loading, so use caution when predicting life expectation. Additional gauge and shirttail protection for the bit should be provided, because directional drilling subjects the gauge row of teeth to lateral as well as axial loads. Fluid flow passages must have a total flow area that will not cause excessive backpressure on the PowerPak flow restrictor bearings. Hydraulics should be optimized to balance the bearings, provide desired flow rates through the motor, and give the bit at least 3 hhp/psi. If a compromise must be made, optimize for maximum flow rate when running a PDC bit and maximum hydraulic horsepower for a roller cone bit.

The use of a motor reduces the risk of stick-slip on a PDC bit. This is one of the main advantages of the product family. Motors do not reduce the risk of bit whirl, so a laterally stable bit should be used to protect the motor and other downhole tools, extend bit life and maximize penetration rates.

PDC bits with low aspect ratios and smoother torque characteristics may be preferred when building angle. In build applications, short (low-aspect) designs allow higher build rates, while more stable bits, like those with 360° gauge coverage or other torque-reducing features, are recommended.

Hydraulics calculations

Every PowerPak motor is designed to perform efficiently within a range of fluid flow rates. The flow ranges are listed in the general specifications on Tables 3-2 and 3-3 and the individual motor tables in Chapter 4, “Performance Data.”

Variation above or below recommended volumes and the related pressure drop across the bit may lead to decreased motor efficiency and life. Schlumberger uses a specialized hydraulics program to verify that the pressure drop at the bit remains within the specified range. The 250-psi minimum limit ensures proper cooling of the bearing section. The 1500-psi maximum limit prevents excessive erosion.

Drilling system pressure drop should be calculated taking into account the stalling pressure of the motor (*i.e.*, approximately 1.75 times the operating pressure). MWD pressure drop should be accounted for in the calculation.

The total pressure drop should be compared with the rig capacity, using the motor stalling pressure and the highest mud weight planned for the run.

Mud weight and plastic viscosity affect the total system pressure requirements. If the pressure required to deliver the recommended volume of fluid to the PowerPak motor is greater than the pumps can deliver, it may be necessary to reduce either the volume or pressure drop through both the tool and the bit. Pressure drop can be reduced by decreasing the number of drill collars and/or other elements that affect WOB, as well as by changing bit nozzle size or drilling fluid characteristics.

Schlumberger offers software programs for computing the optimum hydraulics for a specific situation.

Surveying considerations

Schlumberger typically uses a standard model to calculate the length of nonmagnetic material required above the motor. Where increased survey accuracy is critical, proprietary methods are used as part of the Schlumberger Geomagnetic Referencing Service.

Running PowerPak motors

Lifting and makeup procedure

A lifting sub should always be used for lifting the tool into position for makeup, both on and off the rig floor. A directional driller must be present anytime a PowerPak motor is lifted.

For applications calling for rig floor–replaceable, sleeve-type stabilizers, the stabilizer sleeve can be screwed onto the motor body while the motor is hanging in the elevators. After installation, the sleeve should be made up to the torque shown in Table 3-4 according to the OD of the motor.

If no stabilizer is run, a thread protection sleeve should be installed.

Table 3-4. Stabilizer Sleeve Makeup Torque

Motor	Torque (ft-lbf [N·m])
A475	4,000 [5,420]
A500	7,500 [10,170]
A625	10,000 [13,560]
A675	10,000 [13,560]
A700	10,000 [13,560]
A800	23,000 [31,180]
A962	37,000 [50,170]
A1125	**37,000 [50,170]**

Note: Increase torque values by 25% if a thread-locking compound is used.

Surface check prior to running

All PowerPak motors should be systematically surface-checked before running in the hole. The surface check consists of visual checks, a surface functional test and bent housing adjustment. The procedures are as follows.

Visual checks

1. Check the PowerPak motor for any transportation damage. Record the motor's serial number.
2. Perform a surface functional test before anything is added to the tool. A dog collar safety clamp should be placed just below the top sub. If the surface functional test includes an MWD system, it should ideally be tested without the motor in the drillstring. Should this be impossible, a bit must be installed before testing or testing time must be kept to an absolute minimum.
3. Before the bit is installed, check the bearing clearance or axial play of the motor by measuring the distance between the lower part of the bearing section and the top of the bit sub. Measure the distance twice, first with the motor hanging free in the elevators, then with the full weight of the motor sitting on the rotary table (Fig. 3-1). The difference between the two distances is the amount of axial bearing clearance. Record the two measurements and compare them with the figures shown in the documentation supplied with the motor. Repeat this check after the motor has been run to determine the amount of bearing wear that occurred during the run. The maximum allowable clearance for both the preinstallation check and after running is shown in Table 3-5.

3.4 Operations

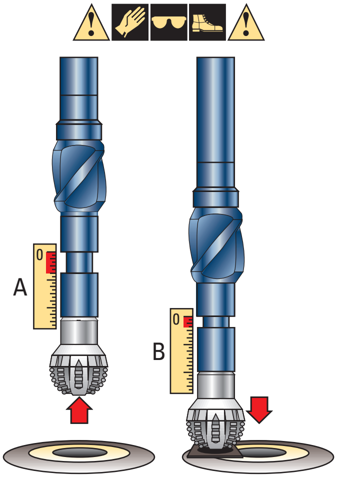


Fig. 3-1. Determining axial bearing clearance.

Table 3-5. Maximum Allowable Axial Bearing Clearance

Motor	M-Series (in. [mm])	S-Series (in. [mm])
A213	0.12 [3]	na
A238	0.12 [3]	na
A287	0.16 [4]	na
A313	0.16 [4]	0.06 [1.5]
A350	0.16 [4]	0.06 [1.5]
A375	0.20 [5]	na
A475	0.20 [5]	0.06 [1.5]
A500	0.24 [6]	na
A625	na	0.06 [1.5]
A675	0.24 [6]	0.06 [1.5]
A700	0.24 [6]	na
A825	0.32 [8]	na
A962	0.32 [8]	na
A1125	**0.32 [8]**	**na**

na = not applicable

Functional test

1. Lift the PowerPak motor with the appropriate lifting sub, set it in the rotary slips and secure it by placing a dog collar safety clamp just below the top sub.
2. Install a crossover sub, if necessary, between the PowerPak motor and the kelly/topdrive. Next, make up the kelly to the PowerPak motor, remove the safety clamp, and lift the motor from the slips.
3. Open the blowout preventer (BOP) rams, and lower the PowerPak motor below the rotary table. If a dump valve is used, ensure that the valve ports are below the bell nipple, yet still visible. Use the rig tongs to secure the motor and the kelly.
4. The pumps can now be turned on and the stroke speed slowly increased. If mud is used, it should squirt out of the ports on the dump valve until the volume is sufficient to force the piston down and close off the ports. When the ports close, pull up the motor with the pumps on until the drive shaft is visible. If a bit is in place, record the flow rate when the dump valve closes.
5. Check the area at the bottom of the bearing housing and the drive shaft to confirm mud flow from the radial bearing. This discharge is designed to lubricate and cool the bearing pack, and it should be about 3% to 10% of the total mud flow rate. Depending on the mud properties and whether the test is performed before making up the bit to the motor, mud flow may be insignificant or nonexistent because of insufficient backpressure across the motor. In this case, the duration of the test should be as short as possible to avoid damaging the bearing. If no bit or a dummy bit is used to provide bit pressure drop, the test should not exceed 1 min in duration.

6. Lower the motor back through the rotary table with the pumps still running. (If the pumps are turned off while the motor is above the table, the dump valve can open and squirt mud on the rig floor.)
7. With the dump valve below the rotary table, turn the pumps off. If the valve does not open, bleed off the mud from the standpipe.
8. If the functional test is performed before installing the stabilizer sleeve or drill bit, these should now be made up at the correct torque, according to Table 3-4. The bit can be screwed onto the drive shaft bit box and torqued to specifications with a rig makeup tong.

Bent housing adjustment

Schlumberger recommends hanging the motor in the elevator to make an adjustment in the bend. If slips are used, they are set on the offset housing, and the driller should slack off until the adjusting ring turns easily.

Observe the following procedure for adjusting the bent housing angle (Fig. 3-2).

1. Place a breakout tong on the stator adapter and a makeup tong on the offset housing and break the connection.
2. Unscrew the connection with two full turns. The gap that appears above the adjusting ring allows lifting up the sleeve and turning it to the required setting.
3. Lift up the adjustment ring to disengage the alignment teeth.
4. Place a backup tong on the offset housing. While holding the adjusting ring in the upper position, turn it until just before the upper and lower machine slots are aligned (*i.e.*, the required degree marks are opposite one another). Then, lower the adjusting ring so it gently rests on the top of the alignment

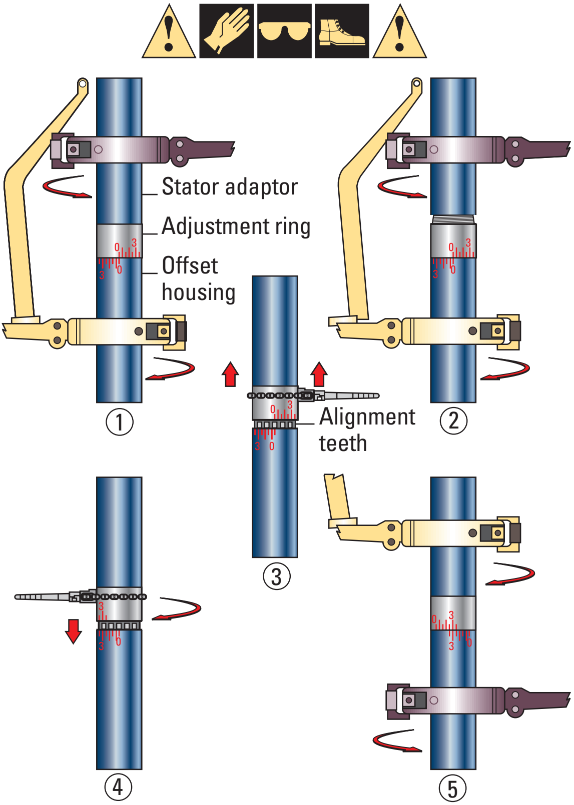


Fig. 3-2. Adjusting the bent housing angle.

teeth, and slowly resume turning until the adjusting ring falls in the required position. The adjusting ring should normally be rotated with chain tongs, although rig tongs may be necessary for large-diameter motors. Properly aligning the setting marks achieves the required bend. The toolface or scribe line for alignment with MWD equipment is through the middle of the two slots that have just been aligned.

5. The tongs can now be reversed and the joint tightened to the correct torque. Once the joint is torqued according to Table 3-6, check the setting to make sure it did not jump a slot while being tightened.

Table 3-6. Bent Housing Adjustment Makeup Torque

Motor Size	Makeup Torque (ft-lbf [N·m])
A213	650 [875]
A238	890 [1,200]
A287	1,650 [2,240]
A313	17,000 [2,300]
A350	3,500 [4,750]
A375	4,500 [6,100]
A475	10,000 [13,560]
A500	11,500 [15,600]
A625/A675	25,000 [33,900]
A700	28,000 [37,970]
A825	35,000 [47,450]
A962	60,000 [81,350]
A1125	**85,000 [115,240]**

Running in hole

Caution is urged when tripping assemblies with large bent housing angles. Special care should be exercised when running through the BOP and wellhead equipment, marine risers, stage cementing collars, casing packers, liner hangers, etc.

When running a PowerPak motor in a deep or high-temperature well or in mud systems that may be contaminated with cement or steel cuttings (*i.e.*, after milling a casing window), the trip should include stops to fill the drillpipe and circulate for a few minutes.

Drilling

- When bottom is reached, the motor should be held a few feet off-bottom to circulate briefly until the planned flow rate is reached. Motor speeds and circulation rates above or below the specified general ranges in Tables 3-1 and 3-2 should be avoided, because they may result in increased wear on motor components.
- The off-bottom standpipe pressure and pump strokes should be recorded. While lowering the assembly, drilling is indicated by an increase in standpipe pressure corresponding directly to the differential pressure created across the rotor/stator as bit torque increases.
- Weight must be applied slowly at first, with any pump pressure changes noted. The driller should proceed carefully while acquiring a feel for the formation and gently break in the bit until a pattern has been cut.
- Drilling with the PowerPak motor is controlled by the amount of WOB required and the differential pressure (*i.e.*, the difference between drilling and off-bottom circulating pressure) developed by the motor section. The value of this differential pressure is a direct indication of bit torque. It increases as WOB is added and decreases as drill-off occurs.
- When the optimum drilling rate is reached, constant standpipe pressure should be maintained to give steady torque at the bit.
- Many drillers make small incremental adjustments to WOB to optimize the rate of penetration. However, the application of WOB must be carefully controlled so that the differential pressure does not exceed the recommended operating values. Otherwise, motor stalling may occur.

- When motor stalling occurs, the driller must immediately cut back or shut off the pumps to avoid damaging the stator and other tool components. The torque trapped in the drillstring must then be released slowly by using the rotary table brake or clutch to allow the kelly/rotary to turn to the left and pick up off bottom. Releasing the trapped torque slowly reduces the risk of downhole backoff. Drilling can then be resumed as described above. If a motor stalls frequently under normal drilling conditions, its operating pressure may have to be modified.
- Paying careful attention to mud pressure variations provides early warning of many common downhole problems. See Table 3-7, “Troubleshooting,” for information to help identify and correct problems before they lead to costly trips.
- The rugged design of PowerPak motors makes it possible to exert high overpull in the event of a stuck bit.

Pulling out of hole and surface check after drilling

There are no special procedures required when pulling out of hole (POOH).

- If the rig is equipped with a top-drive system, the driller will probably backream out of any tight spots while carefully maintaining circulation and avoiding sidetracking if the drillstring is rerun through the backreamed section.
- PowerPak transmission rotational free play can be verified at the surface by holding the bit and examining the free play between the drive shaft and rotor.

- The axial bearing clearance should be measured and checked against the last measurement to determine bearing wear.
- Before the PowerPak motor is laid down, it should be flushed with water. When a hose is used, the body is held with a breakout tong, and the bit is rotated in the bit breaker. When clean water drips out of the lower radial bearing, the bit can be broken off.
- If the SAB housing was set to a high angle, the housing joint should be broken.

Environmental constraints

There is no Material Safety Data Sheet (MSDS) risk for the PowerPak system; no specific environmental protection procedures need be applied when operating the motors. However, any mud remaining in motors returning from jobs must be safely collected for later recycling or disposal. Schlumberger bases are equipped with zero-discharge systems to handle the disposal of all drilling fluids.

Troubleshooting

By paying careful attention to variations in mud-flow pressure, it is possible to detect many common downhole problems that may occur while drilling and take corrective action before a costly trip becomes necessary. Information to identify and correct problems is given in Table 3-7.

Table 3-7. Troubleshooting PowerPak Motor Operations

Observation	Secondary Observation	Possible Explanation	Remedial Action
ROP drops Pressure surges	Unchanged flow rate Torque increases	Motor stalling	Stop rotation immediately. Pull off-bottom; shut down pumps. Release torque from string and re-establish circulation. Resume drilling carefully. Apply WOB gradually.
ROP drops Constant pressure	Flow rate drops	Motor stalling	Same as above; pump stroke forced down by motor stalling.
ROP decreases Pressure fluctuates	Normal WOB Torque decreases	Bit balling	Pull off-bottom; reciprocate string; eventually increase flow rate.
	Normal WOB Torque increases	Stabilizers hanging or reaming	Proceed with care. When stabilizer hanging occurs while sliding, drill a few feet in rotation. Eventually POOH to reduce bend in SAB housing.

Table 3-7. Troubleshooting PowerPak Motor Operations (continued)

Observation	Secondary Observation	Possible Explanation	Remedial Action
ROP decreases Irregular pressure	Normal WOB Irregular rotary torque	Junk in hole Cone locking	Proceed carefully to wash junk away and/or POOH.
ROP decreases Pressure decreases	Normal WOB Normal torque	Washout or dump valve failure	Pull off-bottom. Look for trends on charts. POOH.
	Normal WOB	Formation change	Adapt parameters.
ROP normal Pressure surges	Normal WOB, torque Flow rate unchanged	String ID obstructed	Recycle pumps with various flow rates. Reciprocate string.
ROP normal Pressure decreases	Normal WOB, torque Flow rate unchanged	Washout	Look for trends on charts. POOH.
	Abnormal mud return and pit levels	Mud losses	Follow lost circulation procedure.
ROP increases		Formation change	Adapt parameters.

Air drilling

PowerPak motors can be run on air or foam. Special long-stage power sections are available for these applications. However, the standard multilobe PowerPak motor has proved highly reliable when air or foam is used as the circulating medium.

The design of long-stage power sections provides two key features when using air. Because the long stage length produces higher torque than the standard power section for the same pressure and volume of air pumped at surface, less surface pressure is required. The long-stage power section also produces a bigger cavity between the rotor and stator, which reduces the motor's speed and helps prevent "runaway" when pulling off bottom.

Both the standard and long-stage power sections require adding some form of lubricant to the dry air. A minimum of 2% surfactant (soap) in the air stream is recommended. Increasing this amount enhances motor performance.

The air volume requirements for a PowerPak motor vary depending on system pressure. In general, the maximum allowable volume of surface air (ft^3/min) is equal to

$$\frac{q_m \times p_{standpipe}}{110} \quad (3\text{-}1)$$

where

q_m = max flow rate, gpm

$p_{standpipe}$ = standpipe pressure, psi.

As the surface pressure decreases, so does the maximum volume of air.

Motor stalls when air is used do not produce the sudden increase in standpipe pressure that occurs with water- or oil-base mud. The compressibility of air and the volume of the drillpipe result in a gradual increase in air pressure when the motor stalls. This effect increases with measured depth and drillpipe size. The sudden decrease in ROP is a better indicator of a stalled motor when drilling with air.

Do not run a nozzle in the rotor when using a compressible fluid. Available torque will be reduced significantly.

Air drilling operational procedures

1. Pick up motor and nonmagnetic drill collars.
2. Lubricate motor by pouring 1 gal of oil or surfactant into the nonmagnetic drill collars.
3. Continue trip in hole and pour in 1 gal of oil or surfactant every 20 stands.
4. When 30 ft off bottom, establish slow circulating rate and start mist pump at 5 to 8 gal/hr.
5. Mist pump should be on the discharge side of the air compressors with a check valve between the mist pump and the discharge line of the compressors.
6. Tag bottom and increase circulating rate to drilling parameter.
7. At this point, note standpipe pressure and log on report.
8. Keep logs of the flow rate being pumped and the mist amount being pumped on report.
9. Keep log of hole temperature and note on report.
10. Drill ahead with slow rotary speed (max of 45 rpm) to help reduce shock.

11. Keep constant check on mist amount and flow-rate being pumped.
12. A constant mist is necessary to extend the life of the motor.
13. Drill using penetration rate, because a stall takes a long time to show as a pressure increase on the standpipe.
14. When kelly is down, blow hole clean.
15. Reduce circulating rate before picking the motor up off bottom to prevent overspeeding the motor.
16. Pick up to connection point and kill or bypass compressors and mist pump.
17. Close off annulus and blow down pipe for connection.
18. Make connection and follow same steps as above.

Short-radius drilling

Short-radius curves are used in reentry and multilateral drilling where it is desirable to kick off below a problem formation, external casing shoe or internal completion component. A short-radius well requires less total drilling and minimizes the need for an isolation packer or liner by keeping both the curve and the lateral within the desired portion of the reservoir.

PowerPak XF motor

The PowerPak extra flex motor has articulations above and below a shortened power section and is used for drilling curves down to a 40-ft radius. With the XF motors, the three points of contact that define the drilled curve are established by the bit, near-bit stabilizer and the lower rear pad. These three points are less than 4 ft apart, which enables the motor to achieve very high build rates with very little bit offset. The build mechanism includes the bit, a rotating stabilizer, a bent housing and a pair of shimmable pads that act like an offset field-adjustable stabilizer. A significant innovation is the stabilizer geometry of the bit drive sub (Fig. 3-3). As this second point of contact rotates, it smoothes out steps or ledges created by bit offset and allows easier sliding of the BHA. The stabilizers and pads (Fig. 3-4) are easily configured on the rig floor to achieve build rates as high as 145°/100 ft.

Above the bearing section, motor flexibility is

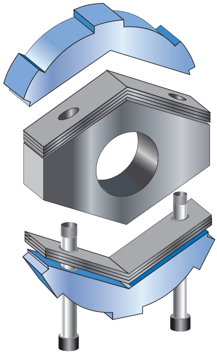


Fig. 3-3. XF short-radius motor near-bit stabilizer and bit.

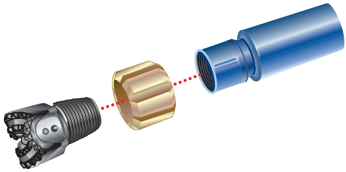


Fig. 3-4. XF short-radius motor adjustable pads.

achieved with articulations above and below the power section (Fig. 3-5). These pressure-sealed ball-and-socket mechanisms act much like the universal joints on an automobile drivetrain, transmitting torque yet bending in any plane. This allows the system to rotate while drilling and also negotiate severe doglegs without regard to orientation when tripping in and out of the hole. If greater drilling horsepower is required, the system has the capability to combine a second power section joined by another articulation. Both

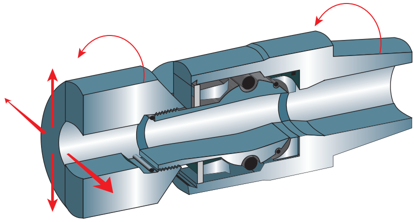


Fig. 3-5. Articulation mechanism.

rollercone and PDC bits can be used, depending on the formation. It is generally recommended that a roller cone bit be used for drilling the curve to reduce reactive fluctuations in motor torque and improve control of the toolface.

PowerPak XC motor

The PowerPak extra curve (XC) motor is capable of drilling curves down to a 65- to 70-ft radius. The three points of contact for the build are at the bit, the pad at the bend and the top end of the power section. Although the bit offset is much greater than that of the XF motor, the flexibility of the components allows the XC motor to bend, compensating for the higher bit offset and allowing a safer trip in and out of the hole. The surface-adjustable 0°–4° bend mechanism is similar to that of conventional PowerPak motors and is easily configured on the rig floor. The ability to kick off and turn in difficult situations such as soft cement plugs or whipstock faces makes the XC motor popular in the field.

Fishing

In the event that it becomes necessary to fish a PowerPak motor, a Schlumberger representative should be consulted on the types and sizes of overshot or extension tools that should be used. Fishing for a PowerPak motor does not normally present any additional problems. If circulation is necessary, it is important to remember that reactive torque and vibration tend to unscrew the fish from the overshot.

Tables 3-8 through 3-11 summarize the fishing dimensions for the various PowerPak motors.

Failure modes and prevention

The elastomer lining in the stator tube is usually the element that fails first in the power section. The causes of rubber failure in a stator are chunking, debond and junk damage.

- Chunking (or chunked out) describes a stator in which the rubber across the top of the lobes has apparently ripped away. Chunking occurs when the strength of the friction force between the rotor lobe and the stator lobe exceeds the strength of the rubber in the stator.

  The magnitude of the friction force between the rotor and the stator is affected by the lubricity of the mud, interference fit between the rotor and stator, nutation speed and pressure drop.

  Most stator failures result from chunking for various reasons.

- Two bonding agents are used in stators. One agent bonds to the steel tube, the other agent bonds to the stator elastomer, and both agents bond to one another. Debond is defined as the failure of any one, two or all three bonds in the stator.
  - steel tube to bonding agent
  - bonding agent to bonding agent
  - bonding agent to elastomer.
- Stators failing from debond typically have large sheets of loose elastomer. These sheets of rubber usually have a smooth back surface where the stator was molded against the steel tube. PowerPak stator failures resulting from debond are extremely rare.
- Junk damage is caused by pumping "junk" through the motor. The stator will have sharp cuts along a spiral path, and the rotor may also have damage along the same path.

It is difficult to prevent debond failures, which fortunately are rare. Measures can be taken to prevent chunking failures and junk damage. The most obvious prevention technique is to ensure that no junk can get into the mud system or drillstring. If the mud is kept free of junk pieces or particles, then there should be no damage to the motor. Chunking prevention is a combination of techniques involving the rotor/stator fit, bottomhole temperature, drilling mud selection, proper operation (performance curves), lost circulation material, nozzled rotors, dogleg severity and stator age tracking.

3.7 Operations

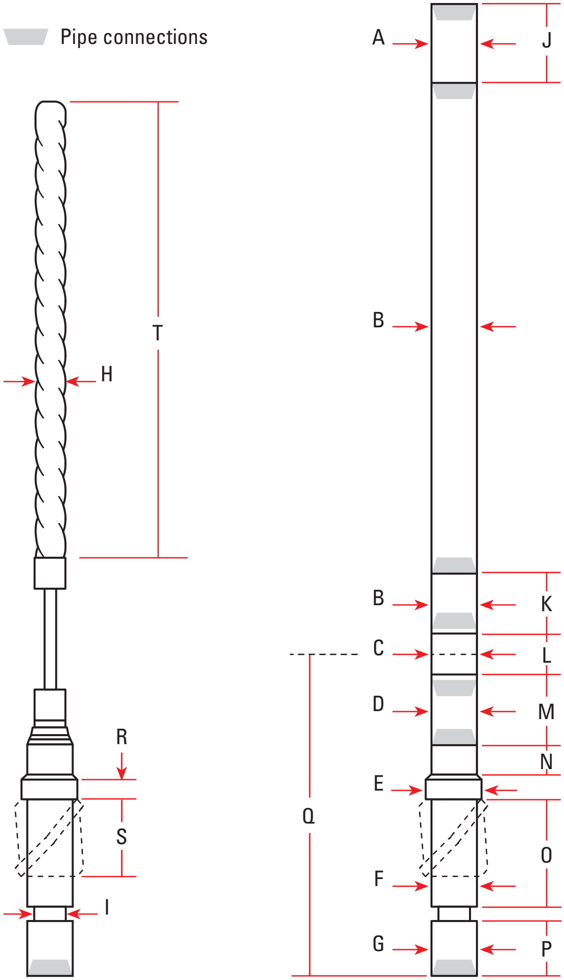


Fig. 3-6. PowerPak motor fishing diagram.

Table 3-8. Fishing Dimensions, U.S. Units

Reference	Description	Motor Sizes (in.)												
		A213	A238	A287	A313	A350	A475	A500	A625	A675	A700	A825	A962	A1125
A	Dump valve/top sub OD	2.13	2.38	3.06	3.13	3.50	4.75	5.00	6.25	6.75	7.00	8.00	9.63	11.25
B	Stator/stator adaptor OD	2.13	2.38	1.88	3.12	3.50	4.75	5.00	6.25	6.75	7.00	8.25	9.63	11.25
C	Adjusting ring OD (kick pad)	2.25	2.47	2.99	3.26	3.59	5.03	5.28	6.88	7.00	7.25	8.38	9.82	11.63
D	Offset housing OD	2.13	2.38	2.90	3.12	3.50	4.75	5.00	6.38	6.75	7.00	8.25	9.63	11.25
E	Stabilizer body maximum OD	na	na	na	na	na	5.38	5.63	7.12	7.50	8.25	9.25	11.00	13.38
F	Bearing housing/nut OD	2.13	2.38	2.87	3.12	3.50	5.38	5.00	6.38	6.75	7.25	8.25	8.25	11.00
G	Bit box OD	2.25	2.38	3.06	3.20	3.75	4.75	4.75	6.25	6.70	6.70	8.18	14.62	9.63
I	Drive shaft OD	1.18	1.60	1.88	2.00	2.28	3.00	4.25	4.63	4.60	5.75	5.25	6.25	6.25
J	Dump valve/top sub length	4.50	5.91	9.62	6.00	9.00	17.50	14.50	16.12	16.00	16.00	16.50	18.50	15.72
K	Stator adaptor length	7.44	8.40	14.88	4.40	12.48	14.28	14.25	17.28	16.80	16.75	19.68	22.56	27.48
L	Adjusting ring length	2.40	2.28	3.00	2.96	3.60	5.40	5.56	6.06	6.12	6.50	6.36	6.36	8.52
M	Offset housing length	11.88	12.60	16.56	14.16	19.56	22.08	22.10	21.68	30.48	30.62	32.6	38.40	43.80
N	Bearing housing fishing neck	6.84	7.44	9.48	1.88	10.56	3.60	4.00	17.94	8.76	8.90	13.56	10.56	14.28
O	Bearing housing bottom neck	na	na	na	na	na	11.04	12.00	18.20	11.40	17.00	11.04	14.52	14.52
P	Drive shaft visible length	3.96	3.96	4.92	4.63	6.00	5.64	6.21	7.25	8.28	7.43	10.08	10.44	10.4
Q	Bend to bit box length	24.96	27.48	34.92	35.15	40.40	48.96	52.98	77.30	72.36	72.98	84.72	93.36	99.48
R	Stabilizer upset length	na	na	na	na	na	0.48	2.26	1.16	1.56	2.37	2.76	3.12	na
S	Sleeve length	na	na	na	na	na	12.00	12.00	14.00	14.00	13.25	16.00	18.00	18.00
A	Dump valve/top sub ID	0.75	0.75	1.38	2.75	1.75	2.00	2.00	2.50	3.00	3.00	3.00	3.00	4.50
B	Stator/stator adaptor ID	1.50	1.62	1.93	2.63	2.25	3.38	3.75	4.50	5.00	4.69	5.88	7.00	8.50
C	Adjusting ring ID	1.56	1.87	2.20	2.36	2.70	3.70	3.89	4.86	5.14	5.39	6.18	7.31	8.53
D	Offset housing ID	1.09	1.31	1.88	2.06	2.12	2.88	3.13	3.50	4.00	4.38	5.00	6.00	7.75
E	Bearing housing/nut ID	1.33	1.50	1.79	1.94	2.15	3.06	3.37	4.12	4.44	5.47	5.13	6.19	6.19
F	**Drive shaft ID**	**0.50**	**0.50**	**0.75**	**0.82**	**0.82**	**1.13**	**1.25**	**1.50**	**1.50**	**1.88**	**2.00**	**2.38**	**2.38**

na = not applicable

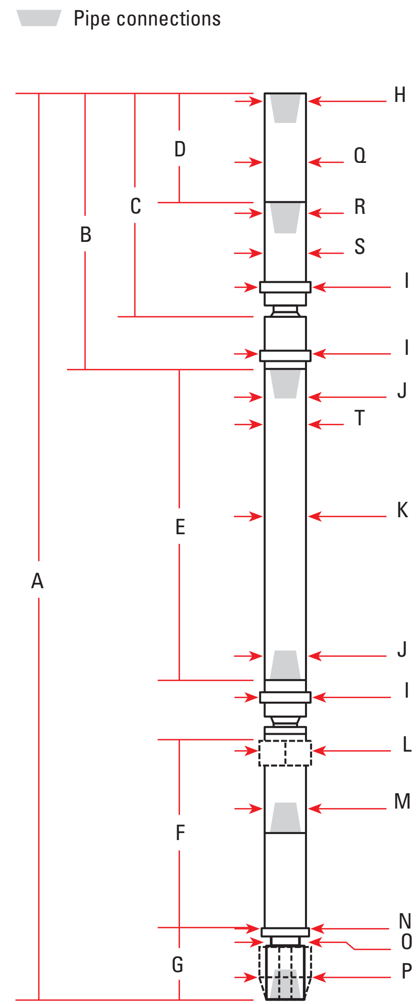


Fig. 3-7. PowerPak XF motor fishing diagram.

Table 3-9. Fishing Dimensions, Metric Units

		Motor Sizes (mm)												
Reference	**Description**	**A213**	**A238**	**A287**	**A313**	**A350**	**A475**	**A500**	**A625**	**A675**	**A700**	**A825**	**A962**	**A1125**
A	Dump valve/top sub OD	54.1	60.5	77.7	95.3	95.3	127.0	127.0	158.8	171.5	177.8	203.2	244.6	285.8
B	Stator/stator adaptor OD	54.1	60.5	47.8	79.5	88.9	127.0	127.0	158.8	171.5	177.8	209.6	244.6	285.8
C	Adjusting ring OD (kick pad)	57.2	62.7	75.9	82.8	91.2	127.8	134.1	174.8	177.8	184.2	212.9	249.4	295.4
D	Offset housing OD	54.1	60.5	73.7	79.2	88.9	120.7	127.0	162.1	171.5	177.8	209.6	244.6	285.8
E	Stabilizer body maximum OD	na	na	na	na	na	136.7	143.0	180.8	190.7	209.6	235.0	279.4	339.9
F	Bearing housing/nut OD	54.1	60.5	72.9	79.2	88.9	136.7	127.0	162.1	171.5	184.2	209.6	209.6	279.4
G	Bit box OD	57.2	60.5	77.7	81.3	95.3	120.7	120.7	158.8	170.2	170.2	207.8	371.3	244.6
I	Drive shaft OD	30.0	40.1	47.8	50.8	57.9	76.2	108.0	117.6	101.6	146.1	133.4	158.8	158.8
J	Dump valve/top sub length	115.8	150.1	244.3	152.4	228.6	445.4	368.3	409.4	406.4	406.4	419.1	470.0	399.3
K	Stator adaptor length	189.0	253.0	378.0	111.8	317.0	362.7	362.0	438.9	426.7	425.5	499.9	573.0	698.0
L	Adjusting ring length	61.0	57.9	76.2	75.2	94.5	137.2	141.2	153.9	155.4	165.1	161.5	161.5	216.4
M	Offset housing length	301.8	320.0	420.6	359.7	496.8	560.8	561.3	550.7	774.2	777.7	829.1	975.4	1,112.5
N	Bearing housing fishing neck	173.7	189.0	240.8	47.8	268.2	91.4	101.6	455.7	222.5	226.1	344.4	268.2	362.7
O	Bearing housing bottom neck	na	na	na	na	na	1,280.4	304.8	462.3	289.6	431.8	289.6	368.8	368.8
P	Drive shaft visible length	100.6	100.6	125.0	117.6	152.4	143.3	157.7	184.2	210.3	188.7	256.0	265.2	265.2
Q	Bend to bit box length	634.0	698.0	887.0	892.8	1,018.0	1,243.6	1,345.7	1,963.4	1,837.9	1,853.7	2,151.9	2,371.3	2,526.8
R	Stabilizer upset length	na	na	na	na	na	12.2	57.4	29.5	39.6	60.2	70.1	79.2	na
S	Sleeve length	na	na	na	na	na	304.8	304.8	355.6	355.6	336.6	406.4	457.2	457.2
A	Dump valve/top sub ID	19.1	19.1	35.1	69.9	44.5	50.8	50.8	63.5	76.2	76.2	76.2	76.2	114.3
B	Stator/stator adaptor ID	38.1	41.1	49.0	66.8	57.2	85.9	95.3	114.3	127.0	119.1	149.4	177.8	215.9
C	Adjusting ring ID	39.6	47.5	55.9	59.9	68.6	94.0	98.8	123.4	130.6	136.9	157.0	185.7	216.7
D	Offset housing ID	27.7	33.3	47.8	52.3	54.1	73.2	79.5	88.9	101.6	111.3	127.0	152.4	196.9
E	Bearing housing/nut ID	33.8	38.1	45.5	49.3	54.6	77.7	85.6	104.6	112.8	138.9	130.3	157.2	157.2
F	Drive shaft ID	12.7	12.7	19.1	20.8	20.8	28.7	31.8	38.1	38.1	47.8	50.8	60.5	60.5

na = not applicable

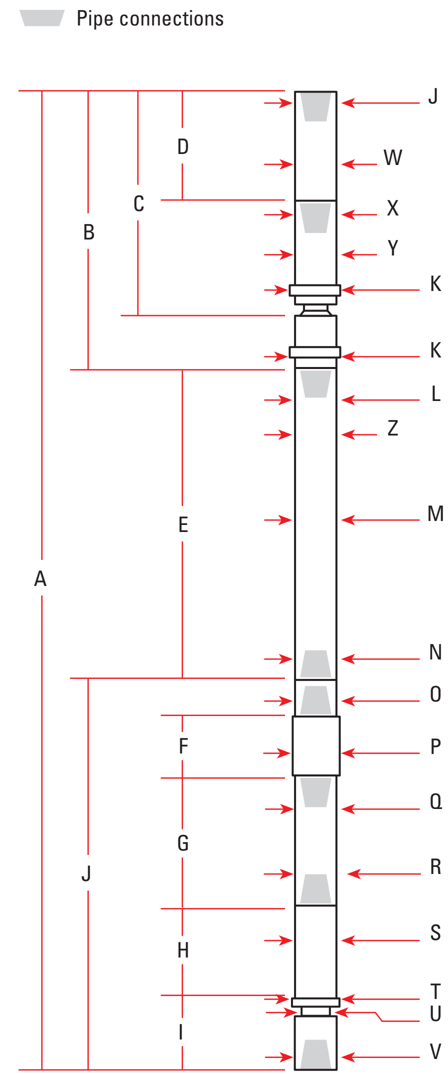


Fig. 3-8. PowerPak XC motor fishing diagram.

Table 3-10. Rotor Dimensions, U.S. Units

Motor		Lobes	Stages	Reference T Rotor Contour Length (in.)	Reference H Standard Rotor Major Diameter (in.)
A213	XP	5:6	6.0	83.0	1.24
A238	SP	5:6	2.5	51.5	1.33
	SP	5:6	3.5	73.4	1.33
	XP	5:6	5.2	100.0	1.33
A287	SP	5:6	3.3	55.0	1.66
	XP	5:6	7.0	110.0	1.66
	SP	7:8	3.2	55.0	1.82
	SP	7:8	3.7	73.0	1.80
	AD	7:8	2.0	69.0	1.81
A313	XC	7:8	2.0	2.9	2.02
	XC	7:8	2.9	4.2	2.02
	XF	7:8	2.0	2.9	2.02
	SP	5:6	3.5	8.2	2.09
	GT	5:6	5.2	121.5	2.09
A350	SP	4:5	5.0	111.0	1.92
	SP	7:8	3.0	111.0	1.97
A375	XC	7:8	2.0	38.4	2.51
	XC	7:8	3.5	66.4	2.51
	XF	7:8	2.0	38.4	2.51
A475	SP	1:2	3.0	134.0	2.43
	HS	2:3	10.5	223.5	2.67
	SP	4:5	3.5	107.0	2.91
	XP	4:5	6.0	178.0	2.91
	GT	5:6	8.3	225.5	2.92
	SP	7:8	2.2	107.0	2.94
	XP	7:8	3.8	172.0	2.95
	XC	7:8	2.0	47.5	3.07
	XF	7:8	2.0	47.5	3.07
	AD	7:8	2.0	143.0	3.02
A500	HS	2:3	10.5	223.5	2.67
	HF	5:6	5.2	228.5	2.95
	GT	5:6	8.3	225.5	2.92
A625	SP	1:2	4.0	145.0	3.42
	SP	4:5	4.3	110.0	3.87
	XP	4:5	7.5	189.5	3.87
	SP	7:8	2.8	110.0	3.98
	XP	7:8	4.8	188.2	3.98

Table 3-10. Rotor Dimensions, U.S. Units (continued)

Motor		Lobes	Stages	Reference T Rotor Contour Length (in.)	Reference H Standard Rotor Major Diameter (in.)
A650	GT	5:6	8.2	226.0	4.37
	AD	7:8	2.0	140.0	4.50
A675	SP	1:2	4.0	160.4	3.82
	XP	2:3	8.0	196.1	4.02
	HS	2:3	10.7	227.0	4.02
	SP	4:5	4.8	134.3	4.22
	XP	4:5	7.0	195.5	4.22
	SP	7:8	3.0	111.3	4.52
	XP	7:8	5.0	181.0	4.52
	AD	7:8	2.0	140.0	4.50
A700	GT	5:6	8.2	226.0	4.37
	HF	5:6	5.8	226.0	4.37
	GT	7:8	6.6	227.0	4.54
	HF	7:8	4.6	227.0	4.54
A775	SP	4:5	3.6	145.0	4.94
	SP	7:8	3.0	145.1	5.19
A825	SP	1:2	4.0	172.5	4.36
	SP	4:5	3.6	145.0	4.94
	XP	4:5	5.3	213.0	4.94
	GT	4:5	8.2	232.0	4.94
	SP	7:8	3.0	145.1	5.19
	XP	7:8	4.0	188.2	5.19
A962	SP	1:2	5.0	194.0	5.46
	HS	2:3	9.2	218.0	5.85
	SP	3:4	4.5	158.6	5.98
	XP	3:4	6.0	210.6	5.98
	GT	3:4	8.0	227.5	5.93
	SP	5:6	3.0	158.6	6.24
	XP	5:6	4.0	211.0	6.24
	GT	7:8	4.8	226.5	6.37
A1125	SP	3:4	0.2	182.6	6.97
	GT	7:8	4.8	226.5	6.37

Table 3-11. Rotor Dimensions, Metric Units

Motor		Lobes	Stages	Reference T Rotor Contour Length (m)	Reference H Standard Rotor Major Diameter (mm)
A213	XP	5:6	6.0	2.11	31.5
A238	SP	5:6	2.5	1.31	33.8
	SP	5:6	3.5	1.86	33.8
	XP	5:6	5.2	2.54	33.8
A287	SP	5:6	3.3	1.40	42.2
	XP	5:6	7.0	2.79	42.2
	SP	7:8	3.2	1.40	46.2
	SP	7:8	3.7	1.85	45.7
	AD	7:8	2.0	1.75	46.0
A313	XC	7:8	2.0	0.07	51.3
	XC	7:8	2.9	0.11	51.3
	XF	7:8	2.0	0.07	51.3
	SP	5:6	3.5	0.21	53.1
	GT	5:6	5.2	3.09	53.1
A350	SP	4:5	5.0	2.82	48.8
	SP	7:8	3.0	2.82	50.0
A375	XC	7:8	2.0	0.98	63.8
	XC	7:8	3.5	1.69	63.8
	XF	7:8	2.0	0.98	63.8
A475	SP	1:2	3.0	3.40	61.7
	HS	2:3	10.5	5.68	67.8
	SP	4:5	3.5	2.72	73.9
	XP	4:5	6.0	4.52	73.9
	GT	5:6	8.3	5.73	74.2
	SP	7:8	2.2	2.72	74.7
	XP	7:8	3.8	4.37	74.9
	XC	7:8	2.0	1.21	78.0
	XF	7:8	2.0	1.21	78.0
	AD	7:8	2.0	3.63	76.7
A500	HS	2:3	10.5	5.68	67.8
	HF	5:6	5.2	5.80	74.9
	GT	5:6	8.3	5.73	74.2
A625	SP	1:2	4.0	3.68	86.9
	SP	4:5	4.3	2.79	98.3
	XP	4:5	7.5	4.81	98.3
	SP	7:8	2.8	2.79	101.1
	XP	7:8	4.8	4.78	101.1

Table 3-11. Rotor Dimensions, Metric Units (continued)

Motor		Lobes	Stages	Reference T Rotor Contour Length (m)	Reference H Standard Rotor Major Diameter (mm)
A650	GT	5:6	8.2	5.74	111.0
	AD	7:8	2.0	3.56	114.3
A675	SP	1:2	4.0	4.07	97.0
	XP	2:3	8.0	4.98	102.1
	HS	2:3	10.7	5.77	102.1
	SP	4:5	4.8	3.41	107.2
	XP	4:5	7.0	4.97	107.2
	SP	7:8	3.0	2.83	114.8
	XP	7:8	5.0	4.60	114.8
	AD	7:8	2.0	3.56	114.3
A700	GT	5:6	8.2	5.74	111.0
	HF	5:6	5.8	5.74	111.0
	GT	7:8	6.6	5.77	115.3
	HF	7:8	4.6	5.77	115.3
A775	SP	4:5	3.6	3.68	125.5
	SP	7:8	3.0	3.69	131.8
A825	SP	1:2	4.0	4.38	110.7
	SP	4:5	3.6	3.68	125.5
	XP	4:5	5.3	5.41	125.5
	GT	4:5	8.2	5.89	125.5
	SP	7:8	3.0	3.69	131.8
	XP	7:8	4.0	4.78	131.8
A962	SP	1:2	5.0	4.93	138.7
	HS	2:3	9.2	5.54	148.6
	SP	3:4	4.5	4.03	151.9
	XP	3:4	6.0	5.35	151.9
	GT	3:4	8.0	5.78	150.6
	SP	5:6	3.0	4.03	158.5
	XP	5:6	4.0	5.36	158.5
	GT	7:8	4.8	5.75	161.8
A1125	SP	3:4	0.2	4.64	177.0
	GT	7:8	4.8	5.75	161.8

4.1 Motor power curves

In this section, data are given for mud-lubricated bearing systems. For oil-lubricated systems, please refer to Tables 3-1 and 3-2.

Power curves in this handbook show output rotary speed, torque and horsepower versus differential pressure. Torque and speed values are shown as bands to indicate the expected range. This range is used to illustrate the variations in motor performance caused when there is leakage across the rubber-to-steel seals created between the rotor and stator. The amount of leakage increases with differential pressure and is also affected by rotor/stator interference fits, elastomer properties, operating temperature, chemical exposure and wear. However, this leakage can be controlled using results from the PowerFit spreadsheet and local field experience. The PowerFit spreadsheet recommends the most suitable elastomer and interference fit for a given drilling application, taking into consideration operating temperature and mud type.

For PowerPak power section fitting information, please consult your local Schlumberger representative. The operation will use the InTouch online support and knowledge management system. Resources include the PowerFit, PowerPak Off-Bottom Pressure Drop and PowerPredicter spreadsheets.

The maximum predicted power is obtained with equation 2-1,

$$HP_{mechanical} = \frac{T \times S_r}{5252},$$

where

$HP_{mechanical}$ = motor mechanical power, hp

T = output torque, ft-lbf

S_r = drive shaft rotary speed, rpm.

The power curves are not exact multiples of the maximum torque output and maximum speed output but are more representative of typical results.

Differential pressure is defined as the difference between on-bottom and off-bottom drilling pump pressure. The local representative can use the PowerPak Off-Bottom Pressure Drop program to estimate free running pressure losses, including losses caused by friction and by the flow passages within the motor.

As the torque output increases and the bit speed decreases, the rotor/stator section of the motor generates a larger differential pressure value. It is recommended that a differential operating pressure of 80% of the maximum be used in normal drilling conditions, the maximum being the differential pressure value corresponding to the maximum horsepower as shown on the curve graphs. The flow rates shown are generally the lowest, middle and highest flow rate ranges specified for the power section. Note that if the desired flow rate is not plotted, a linear approximation must be made from the known values.

The power curves are generated at room temperature. The full differential pressure may not be achievable under certain downhole conditions, for example, at high temperature or when using oil-base or other drilling fluids that soften the stator elastomer. The local Schlumberger representative will use the PowerPredicter equations to estimate the motor performance under downhole conditions. Use the PowerFit spreadsheet to configure the best power section for the job.

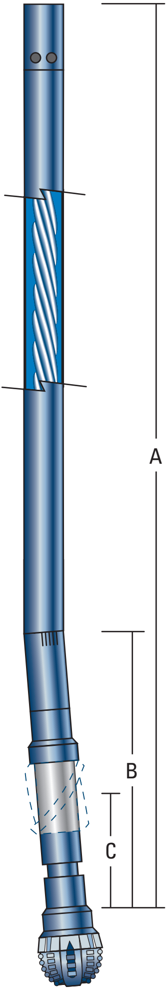
The following information can be obtained from the performance curves.

- Off-bottom rotary speed: Locate the speed value for the desired flow rate at zero differential pressure.
- Recommended operating pressure: Locate the maximum power output (peak of the horsepower curve) for a given flow rate and draw a vertical line

downward to the differential pressure axis. For extended life under normal drilling conditions, do not exceed 80% of this value. Should drilling conditions be favorable, you may use up to 100% of the value. Good drilling practices should prevail.

- Operating torque: Locate the intersection of the torque line and a vertical line from the appropriate point on the differential pressure axis. Draw a horizontal line to the right and record the value at which it crosses the torque axis.
- Operating speed: Locate the intersection of the curve for the desired flow rate and a vertical line from the appropriate point on the differential pressure axis. Draw a horizontal line to the left and record the value at which it crosses the speed axis.
- Operating power: Locate the intersection of the power curve for the desired flow rate and a vertical line from the appropriate point on the differential pressure axis. Draw a horizontal line to the left and record the value at which it crosses the power axis.
- Maximum power: Estimate the highest point of the power curve at the desired flow rate. Draw a horizontal line to the left and record the value at which it crosses the power axis. Differential pressure, speed and torque at maximum horsepower can be determined as above.

The rotary speed limits given in this handbook are fatigue limits based on an acceptable life for the motor components. Fatigue life estimations are based on a calculation of alternating stresses created by the reverse bending of the motor components when the motor is rotated within the hole, which will vary depending on hole curvature. It is important to recognize that the rotary speed limit given is a guideline. Local experience and knowledge of particular formations may permit increasing this limit after consultation with the client and district office.



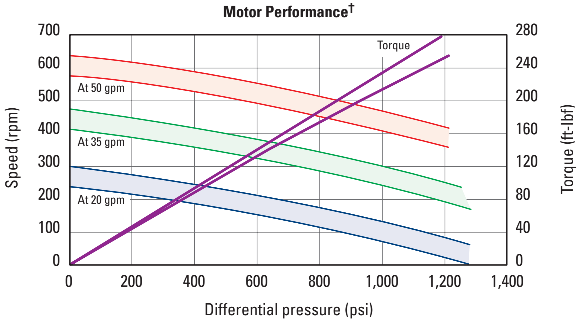
PowerPak A213 2⅛-in. OD		
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Bent housing adjustment makeup torque	650 ft-lbf [875 N·m]	
Bit size	2⅜–2⅞ in.	
Bit connection	1¼ REG or AW rod	
Top connection	1¼ REG or AW rod	
Working overpull (no motor damage)	18,000 lbf [80 kN]	
Max WOB with flow (no motor damage)	3,200 lbf [14 kN]	
Max WOB without flow (no motor damage)	15,000 lbf [67 kN]	
Absolute overpull (motor damage will occur)	41,600 lbf [185 kN]	

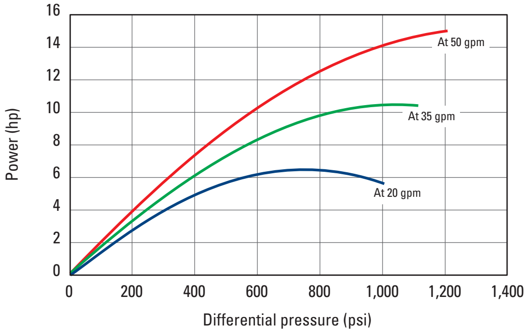
Note: These limits apply only when bit is stuck.

PowerPak A213XP, 2⅛-in. OD, 5:6 Lobes, 6.0 Stages

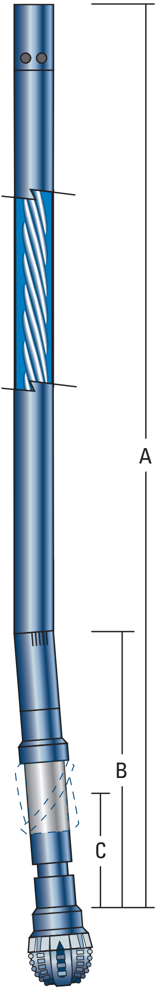
Tool Data	
Weight	80 lbm [35 kgm]
Nominal length (A)	10.51 ft [3.20 m]
Bit box to bend (B)	2.08 ft [0.63 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	20–50 gpm [80–190 L/min]
Nozzle flow rate	na
Bit speed (free running)	260–640 rpm
Revolutions per unit volume	12.80/gal [3.38/L]
Max power	15 hp [11 kW]

na = not applicable





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.



PowerPak A238 2⅜-in. OD		
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Bent housing adjustment makeup torque	890 ft-lbf [1200 N·m]	
Bit size	2⅞–3½ in.	
Bit connection	1¼ REG	
Top connection	1¼ REG	
Working overpull (no motor damage)	25,100 lbf [112 kN]	
Max WOB with flow (no motor damage)	5,000 lbf [22 kN]	
Max WOB without flow (no motor damage)	22,000 lbf [98 kN]	
Absolute overpull (motor damage will occur)	59,900 lbf [266 kN]	

Note: These limits apply only when bit is stuck.

PowerPak A238SP, 2⅜-in. OD, 5:6 Lobes, 2.5 Stages

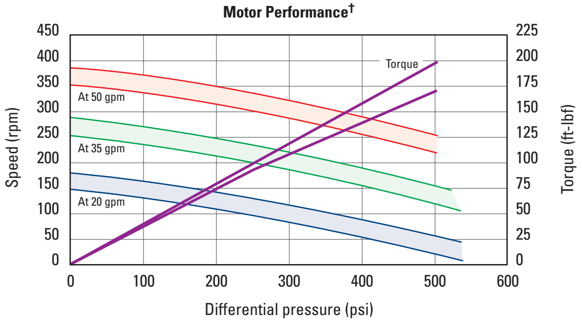
Tool Data

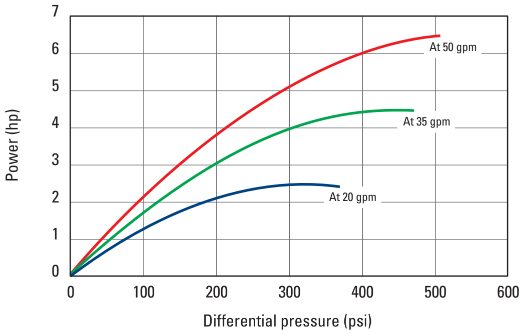
Weight	80 lbm [35 kgm]
Nominal length (A)	8.45 ft [2.58 m]
Bit box to bend (B)	2.29 ft [0.70 m]
Bit box to center of stabilizer (C)	na

Performance Data

Standard flow rate	20–50 gpm [80–190 L/min]
Nozzle flow rate	na
Bit speed (free running)	160–395 rpm
Revolutions per unit volume	7.90/gal [2.09/L]
Max power	7 hp [5 kW]

na = not applicable





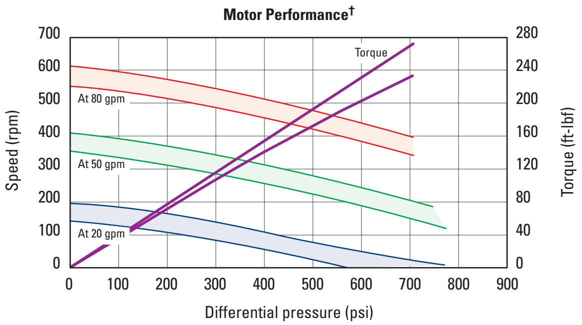
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

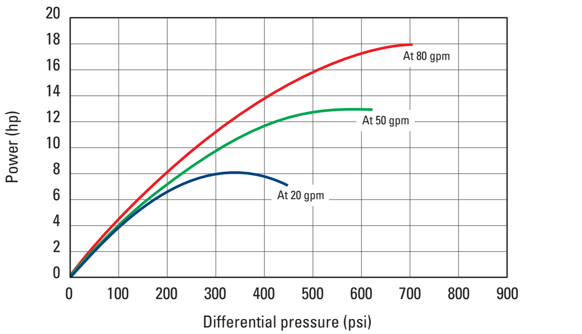
4.1 Performance Data

PowerPak A238SP, 2⅜-in. OD, 5:6 Lobes, 3.5 Stages

Tool Data	
Weight	105 lbm [50 kgm]
Nominal length (A)	9.93 ft [3.03 m]
Bit box to bend (B)	2.29 ft [0.70 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	20–80 gpm [80–300 L/min]
Nozzle flow rate	na
Bit speed (free running)	160–590 rpm
Revolutions per unit volume	7.38/gal [1.95/L]
Max power	18 hp [13 kW]

na = not applicable





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

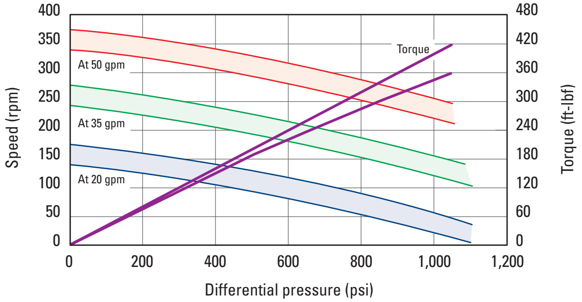
Schlumberger

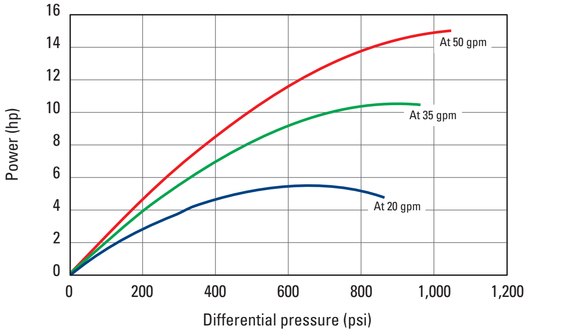
PowerPak A238XP, 2⅜-in. OD, 5:6 Lobes, 5.2 Stages

Tool Data	
Weight	120 lbm [55 kgm]
Nominal length (A)	12.52 ft [3.82 m]
Bit box to bend (B)	2.29 ft [0.70 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	20–50 gpm [80–190 L/min]
Nozzle flow rate	na
Bit speed (free running)	160–395 rpm
Revolutions per unit volume	7.90/gal [2.09/L]
Max power	15 hp [11 kW]

na = not applicable

Motor Performance†

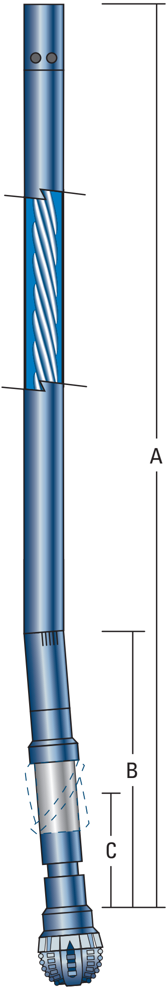




†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

4.1 Performance Data

287

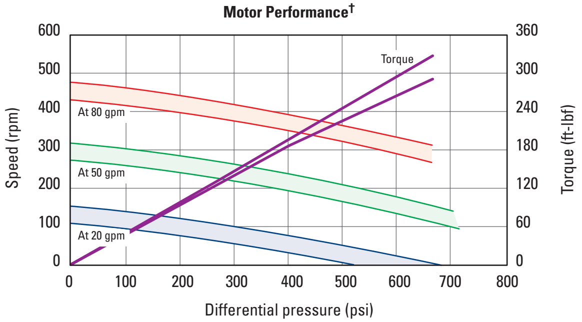


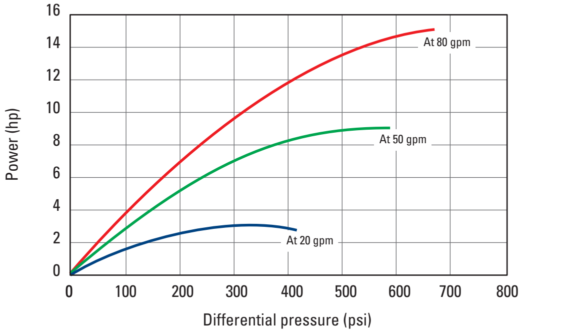
PowerPak A287 2⅞-in. OD		
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Bent housing adjustment makeup torque	1,650 ft-lbf [2,240 N·m]	
Bit size	3⅝–4¾ in.	
Bit connection	2⅜ REG	
Top connection	2⅜ REG	
Working overpull (no motor damage)	37,000 lbf [165 kN]	
Max WOB with flow (no motor damage)	6,500 lbf [29 kN]	
Max WOB without flow (no motor damage)	24,000 lbf [107 kN]	
Absolute overpull (motor damage will occur)	80,400 lbf [358 kN]	

Note: These limits apply only when bit is stuck.

PowerPak A287SP, 2⅞-in. OD, 5:6 Lobes, 3.3 Stages	
Tool Data	
Weight	140 lbm [65 kgm]
Nominal length (A)	10.02 ft [3.05 m]
Bit box to bend (B)	2.91 ft [0.89 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	20–80 gpm [80–300 L/min]
Nozzle flow rate	20–130 gpm [80–500 L/min]
Bit speed (free running)	115–465 rpm
Revolutions per unit volume	5.81/gal [1.54/L]
Max power	15 hp [11 kW]

na = not applicable





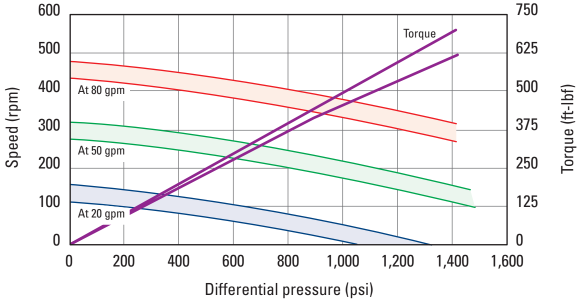
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

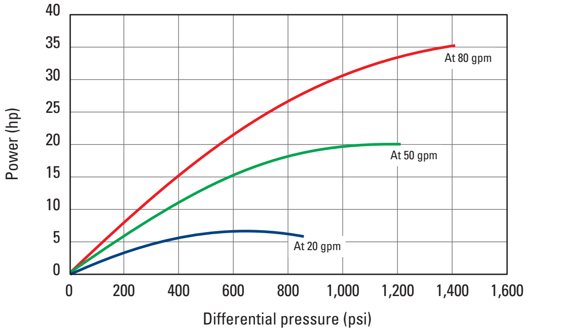
4.1 Performance Data

PowerPak A287XP, 2⅞-in. OD, 5:6 Lobes, 7.0 Stages	
Tool Data	
Weight	195 lbm [90 kgm]
Nominal length (A)	14.62 ft [4.46 m]
Bit box to bend (B)	2.91 ft [0.89 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	20–80 gpm [80–300 L/min]
Nozzle flow rate	20–130 gpm [80–500 L/min]
Bit speed (free running)	115–465 rpm
Revolutions per unit volume	5.81/gal [1.54/L]
Max power	35 hp [26 kW]

na = not applicable

Motor Performance†

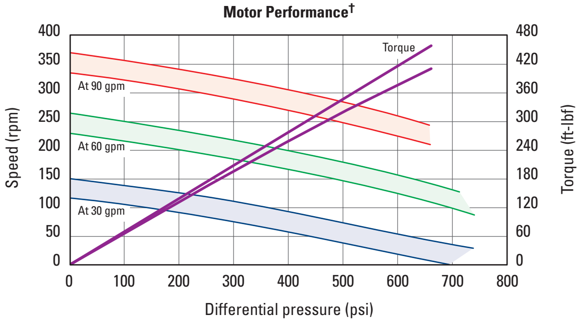


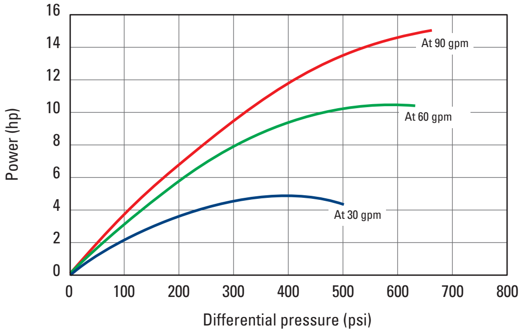


†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

PowerPak A287SP, 2⅞-in. OD, 7:8 Lobes, 3.2 Stages	
Tool Data	
Weight	140 lbm [65 kgm]
Nominal length (A)	10.02 ft [3.05 m]
Bit box to bend (B)	2.91 ft [0.89 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	30–90 gpm [110–340 L/min]
Nozzle flow rate	30–130 gpm [110–500 L/min]
Bit speed (free running)	125–375 rpm
Revolutions per unit volume	4.17/gal [1.10/L]
Max power	15 hp [11 kW]

na = not applicable



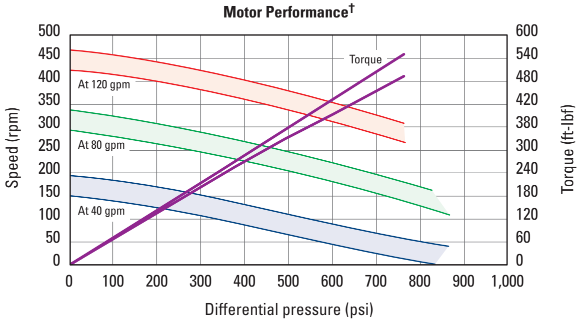


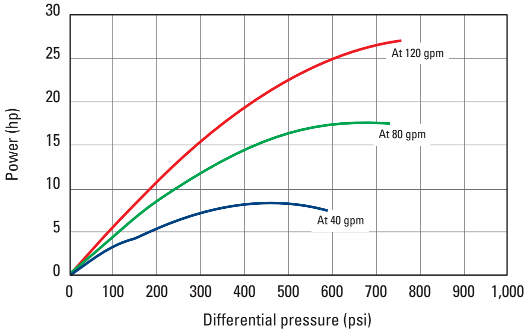
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

4.1 Performance Data

PowerPak A287SP, 2⅞-in. OD, 7:8 Lobes, 3.7 Stages	
Tool Data	
Weight	160 lbm [75 kgm]
Nominal length (A)	11.21 ft [3.42 m]
Bit box to bend (B)	2.91 ft [0.89 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	40–120 gpm [150–454 L/min]
Nozzle flow rate	na
Bit speed (free running)	140–425 rpm
Revolutions per unit volume	3.54/gal [0.94/L]
Max power	27 hp [20 kW]

na = not applicable





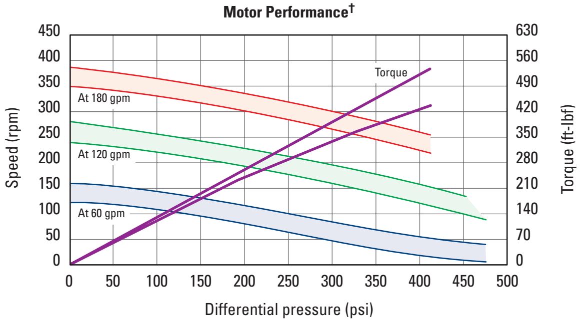
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

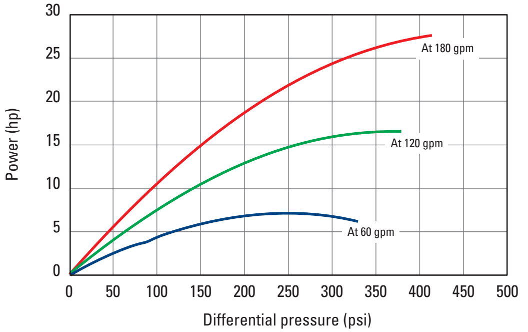
Schlumberger

PowerPak A287AD, 2⅞-in. OD, 7:8 Lobes, 2.0 Stages

Tool Data	
Weight	150 lbm [70 kgm]
Nominal length (A)	10.88 ft [3.32 m]
Bit box to bend (B)	2.91 ft [0.89 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	60–180 gpm [230–680 L/min]
Nozzle flow rate	na
Bit speed (free running)	130–390 rpm
Revolutions per unit volume	2.17/gal [0.57/L]
Max power	**28 hp [21 kW]**

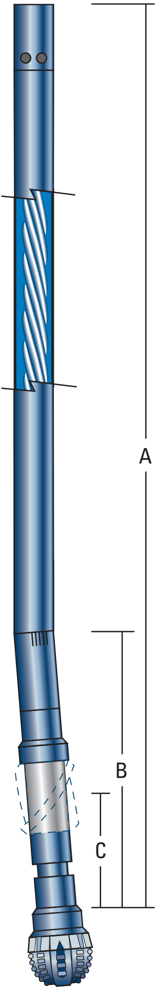
na = not applicable





†Performance based on 160°F air mist at 320 psi.
Flow rate (gpm) = 109.75 × ft³/min/pump pressure (psi).

4.1 Performance Data



PowerPak A313 3⅛-in. OD		
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.28°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Bent housing adjustment makeup torque	1,700 ft-lbf [2,430 N·m]	
Bit size	3⅓–4¼ in.	
Bit connection	2⅜ API REG	
Top connection	2⅜ API REG	
Working overpull (no motor damage)	45,600 lbf [203 kN]	
Max WOB with flow (no motor damage)	7,500 lbf [33 kN]	
Max WOB without flow (no motor damage)	22,000 lbf [98 kN]	
Absolute overpull (motor damage will occur)	136,800 lbf [609 kN]	

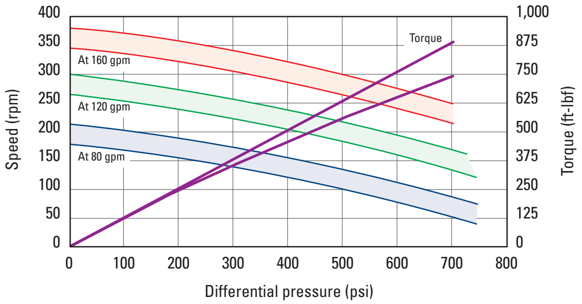
Note: These limits apply only when bit is stuck.

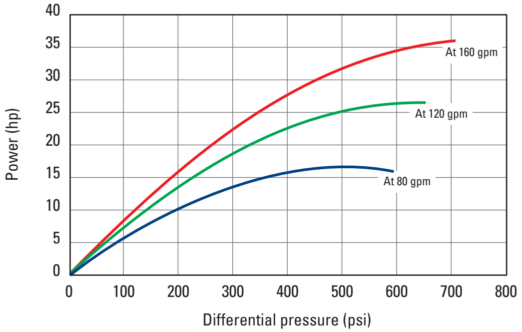
PowerPak A313SP, 3⅛-in. OD, 5:6 Lobes, 3.5 Stages

Tool Data	
Weight	200 lbm [90 kgm]
Nominal length (A)	12.13 ft [3.70 m]
Bit box to bend (B)	2.93 ft [0.89 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	80–160 gpm [300–610 L/min]
Nozzle flow rate	na
Bit speed (free running)	175–350 rpm
Revolutions per unit volume	2.19/gal [0.58/L]
Max power	36 hp [27 kW]

na = not applicable

Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

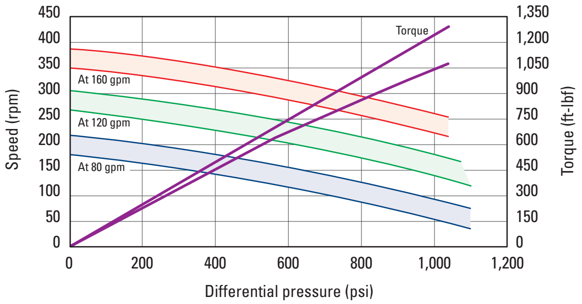
4.1 Performance Data

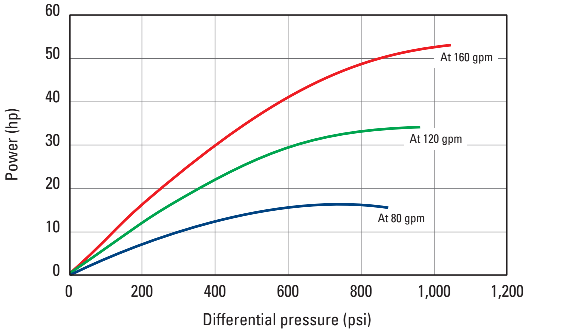
PowerPak A313GT, 3⅛-in. OD, 5:6 Lobes, 5.2 Stages	
Tool Data	
Weight	250 lbm [115 kgm]
Nominal length (A)	15.60 ft [4.75 m]
Bit box to bend (B)	2.93 ft [0.89 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	80–160 gpm [300–610 L/min]
Nozzle flow rate	na
Bit speed (free running)	195–380 rpm
Revolutions per unit volume	2.38/gal [0.63/L]
Max power	**53 hp [40 kW]**

na = not applicable

313

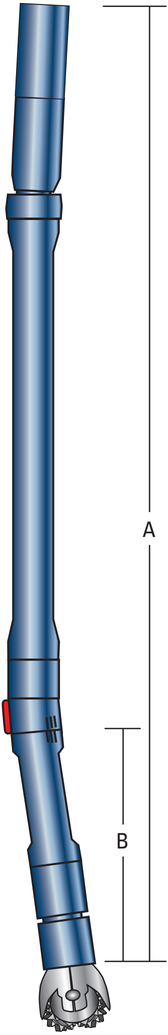
Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

Schlumberger



PowerPak A313XC 3⅛-in. OD		
Adjustable bent housing settings (0°–4°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Bent housing adjustment makeup torque	1,800 ft-lbf [2,430 N·m]	
Bit size	3½–4¼ in.	
Bit connection	2⅜ REG	
Top connection	2.590–6 V055	
Working overpull (no motor damage)	43,400 lbf [193 kN]	
Max WOB with flow (no motor damage)	7,500 lbf [33 kN]	
Max WOB without flow (no motor damage)	22,000 lbf [98 kN]	
Absolute overpull (motor damage will occur)	98,300 lbf [437 kN]	

Note: These limits apply only when bit is stuck.

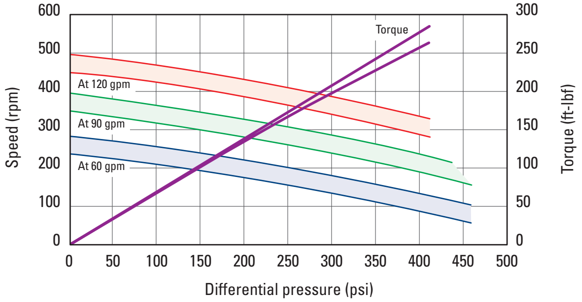
4.1 Performance Data

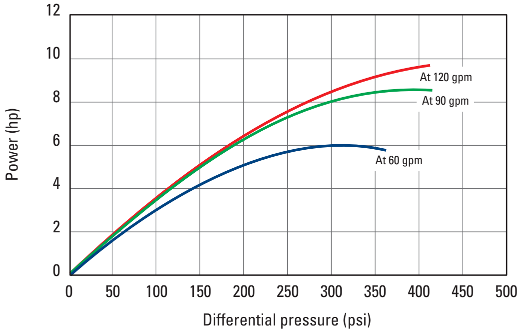
PowerPak A313XC, 3⅛-in. OD, 7:8 Lobes, 2.0 Stages	
Tool Data	
Weight	135 lbm [60 kgm]
Nominal length (A)	8.85 ft [2.70 m]
Bit box to bend (B)	3.32 ft [1.01 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	60–120 gpm [230–450 L/min]
Nozzle flow rate	na
Bit speed (free running)	230–460 rpm
Revolutions per unit volume	3.83/gal [1.01/L]
Max power	10 hp [7 kW]

na = not applicable

313

Motor Performance†



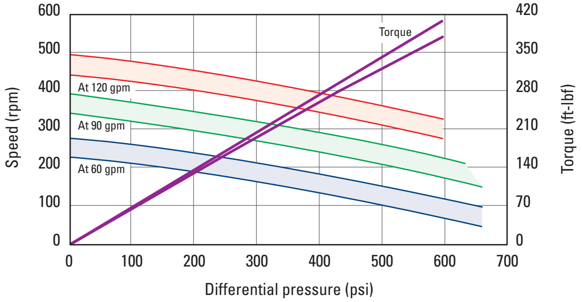


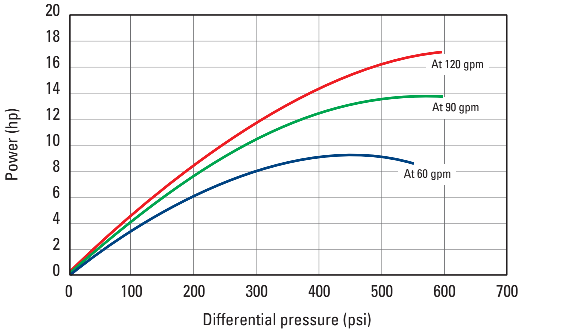
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

PowerPak A313XC, 3⅛-in. OD, 7:8 Lobes, 2.9 Stages	
Tool Data	
Weight	135 lbm [60 kgm]
Nominal length (A)	9.93 ft [3.03 m]
Bit box to bend (B)	3.32 ft [1.01 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	60–120 gpm [230–450 L/min]
Nozzle flow rate	na
Bit speed (free running)	230–460 rpm
Revolutions per unit volume	3.83/gal [1.01/L]
Max power	17 hp [13 kW]

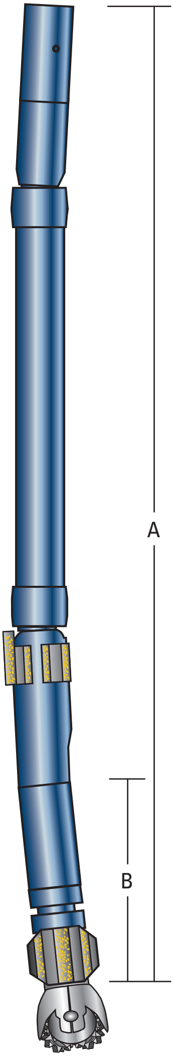
na = not applicable

Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

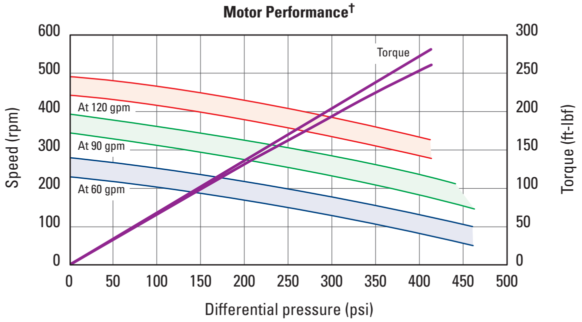


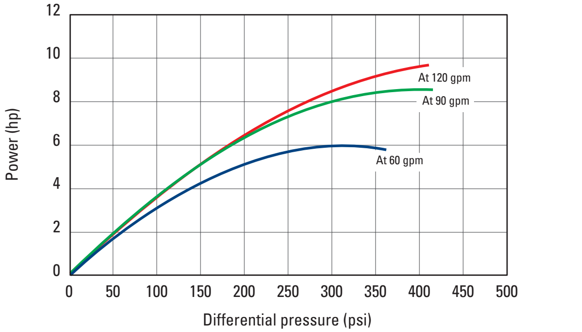
PowerPak A313XF 3⅛-in. OD	
Adjustable pad settings	Shimmed to allow from 20°/100 ft to 145°/100 ft in 5°/100 ft increments
Bent housing adjustment makeup torque	1,800 ft-lbf [2,430 N·m]
Bit size	3½–4¼ in.
Bit connection	2⅜ REG
Top connection	2.590–6 V055
Working overpull (no motor damage)	43,400 lbf [193 kN]
Max WOB with flow (no motor damage)	7,500 lbf [33 kN]
Max WOB without flow (no motor damage)	22,000 lbf [98 kN]
Absolute overpull (motor damage will occur)	98,300 lbf [437 kN]

Note: These limits apply only when bit is stuck.

PowerPak A313XF, 3⅛-in. OD, 7:8 Lobes, 2.0 Stages	
Tool Data	
Weight	135 lbm [60 kgm]
Nominal length (A)	8.40 ft [2.56 m]
Bit box to bend (B)	1.05 ft [0.32 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	60–120 gpm [230–450 L/min]
Nozzle flow rate	na
Bit speed (free running)	230–460 rpm
Revolutions per unit volume	3.83/gal [1.01/L]
Max power	10 hp [7 kW]

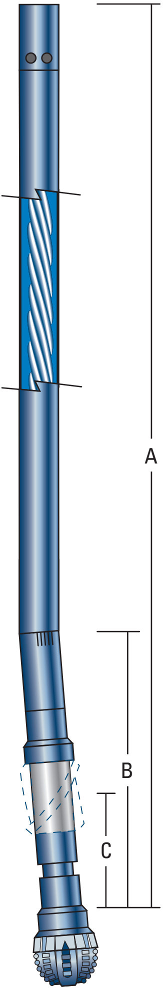
na = not applicable





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

4.1 Performance Data

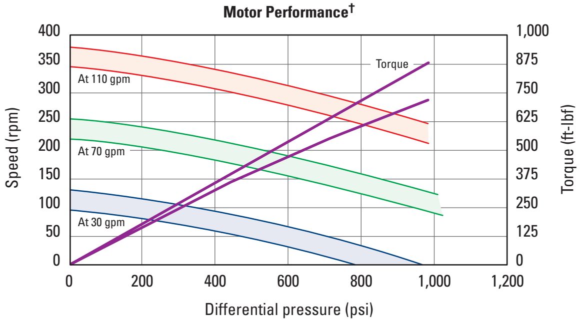


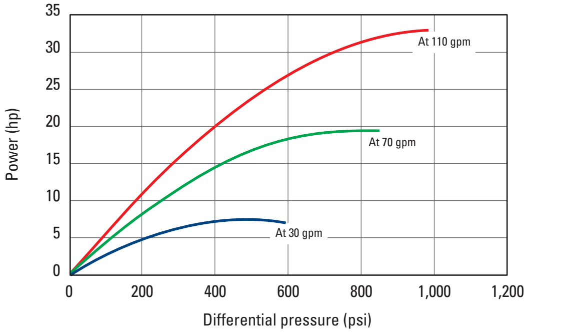
PowerPak A350 3½-in. OD		
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Bent housing adjustment makeup torque	3,500 ft-lbf [4,750 N·m]	
Bit size	4½–6 in.	
Bit connection	2⅞ REG	
Top connection	2⅞ REG	
Working overpull (no motor damage)	47,500 lbf [211 kN]	
Max WOB with flow (no motor damage)	8,000 lbf [36 kN]	
Max WOB without flow (no motor damage)	30,000 lbf [133 kN]	
Absolute overpull (motor damage will occur)	140,800 lbf [626 kN]	

Note: These limits apply only when bit is stuck.

PowerPak A350SP, 3½-in. OD, 4:5 Lobes, 5.0 Stages	
Tool Data	
Weight	300 lbm [135 kgm]
Nominal length (A)	15.12 ft [4.61 m]
Bit box to bend (B)	3.37 ft [1.03 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	30–110 gpm [110–420 L/min]
Nozzle flow rate	30–160 gpm [110–600 L/min]
Bit speed (free running)	95–350 rpm
Revolutions per unit volume	3.18/gal [0.84/L]
Max power	33 hp [25 kW]

na = not applicable





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

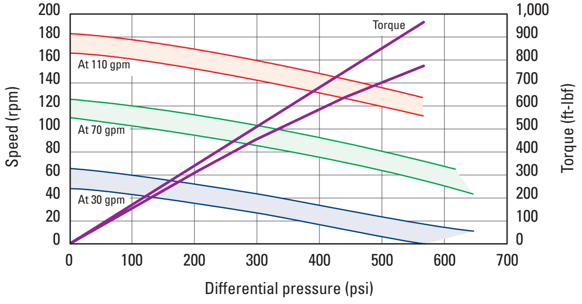
4.1 Performance Data

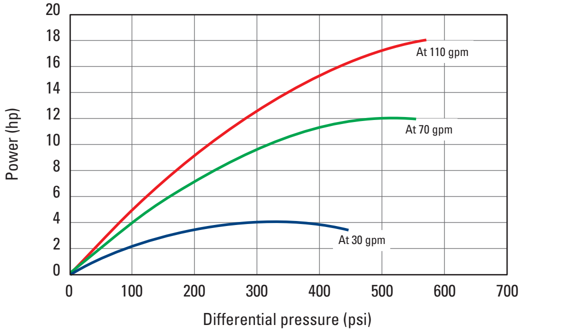
PowerPak A350SP, 3½-in. OD, 7:8 Lobes, 3.0 Stages	
Tool Data	
Weight	310 lbm [140 kgm]
Nominal length (A)	15.12 ft [4.61 m]
Bit box to bend (B)	3.37 ft [1.03 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	30–110 gpm [110–420 L/min]
Nozzle flow rate	30–160 gpm [110–600 L/min]
Bit speed (free running)	45–165 rpm
Revolutions per unit volume	1.50/gal [0.40/L]
Max power	18 hp [13 kW]

na = not applicable

350

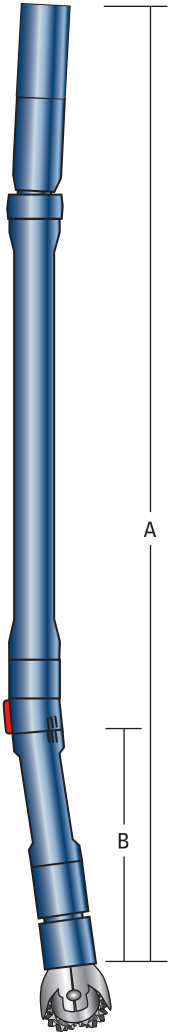
Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

Schlumberger



PowerPak A375XC 3¾-in. OD		
Adjustable bent housing settings (0°–4°)	0.00°	0.35°
	0.69°	1.04°
	1.37°	1.69°
	2.00°	2.29°
	2.57°	2.83°
	3.06°	3.28°
	3.46°	3.63°
	3.76°	3.86°
	3.94°	3.98°
	4.00°	
Bent housing adjustment makeup torque	4,500 ft-lbf [6,100 N·m]	
Bit size	4½–4¾ in.	
Bit connection	2⅞ REG	
Top connection	2.812–6 V055	
Working overpull (no motor damage)	69,400 lbf [309 kN]	
Max WOB with flow (no motor damage)	22,000 lbf [98 kN]	
Max WOB without flow (no motor damage)	45,000 lbf [200 kN]	
Absolute overpull (motor damage will occur)	152,700 lbf [679 kN]	

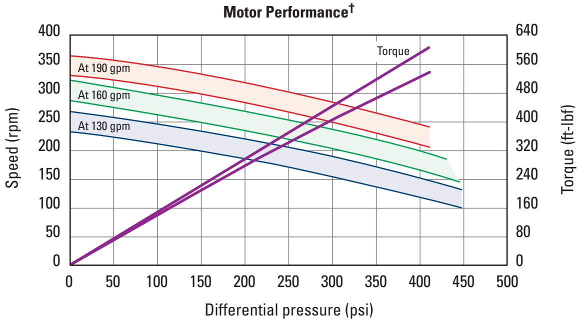
Note: These limits apply only when bit is stuck.

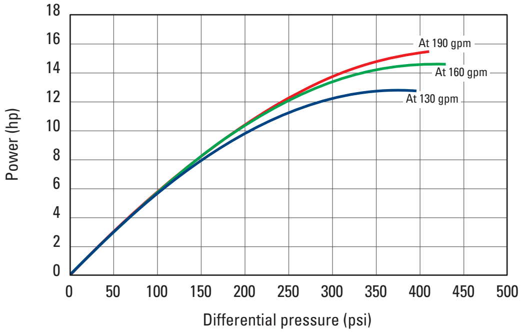
4.1 Performance Data

PowerPak A375XC, 3¾-in. OD, 7:8 Lobes, 2.0 Stages	
Tool Data	
Weight	225 lbm [100 kgm]
Nominal length (A)	10.50 ft [3.20 m]
Bit box to bend (B)	2.79 ft [0.85 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	130–190 gpm [490–720 L/min]
Nozzle flow rate	na
Bit speed (free running)	240–355 rpm
Revolutions per unit volume	1.87/gal [0.49/L]
Max power	16 hp [12 kW]

na = not applicable

375





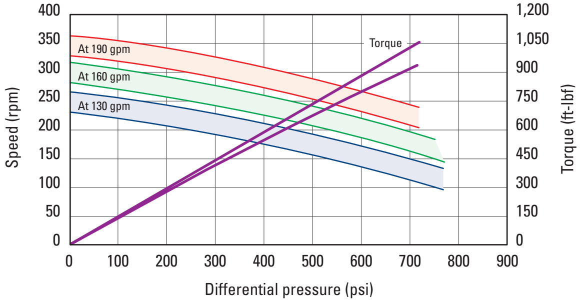
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

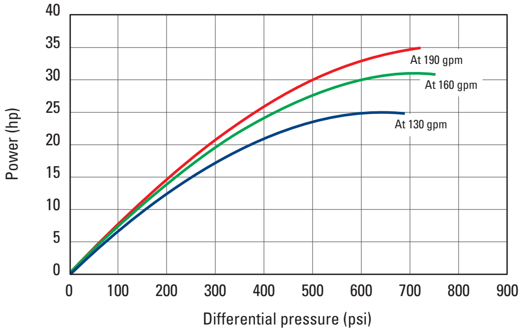
Schlumberger

PowerPak A375XC, 3¾-in. OD, 7:8 Lobes, 3.5 Stages	
Tool Data	
Weight	225 lbm [100 kgm]
Nominal length (A)	12.94 ft [3.94 m]
Bit box to bend (B)	2.79 ft [0.85 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	130–190 gpm [490–720 L/min]
Nozzle flow rate	na
Bit speed (free running)	240–355 rpm
Revolutions per unit volume	1.87/gal [0.49/L]
Max power	35 hp [26 kW]

na = not applicable

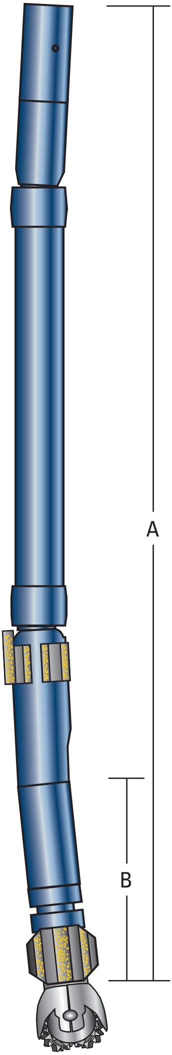
Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

4.1 Performance Data



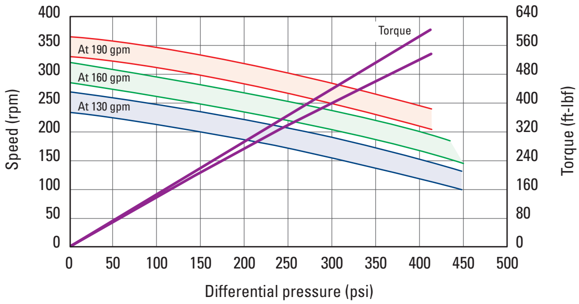
PowerPak A375XF 3¾-in. OD	
Adjustable pad settings	Shimmed to allow from 20°/100 ft to 145°/100 ft in 5°/100 ft increments
Stabilizer sleeve makeup torque	na
Bit size	4½–4¾ in.
Bit connection	2⅞ REG
Top connection	2.812–6 V055
Working overpull (no motor damage)	69,400 lbf [309 kN]
Max WOB with flow (no motor damage)	22,000 lbf [98 kN]
Max WOB without flow (no motor damage)	45,000 lbf [200 kN]
Absolute overpull (motor damage will occur)	152,700 lbf [679 kN]

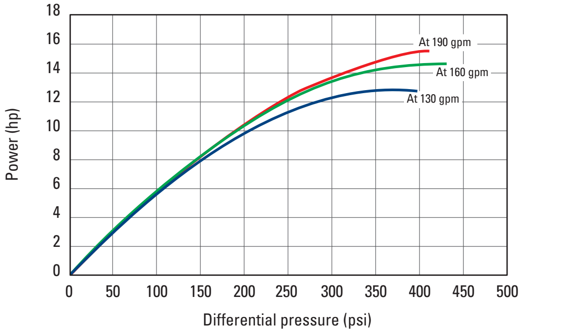
Note: These limits apply only when bit is stuck.

PowerPak A375XF, 3¾-in. OD, 7:8 Lobes, 2.0 Stages	
Tool Data	
Weight	225 lbm [100 kgm]
Nominal length (A)	10.14 ft [3.09 m]
Bit box to bend (B)	1.18 ft [0.36 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	130–190 gpm [490–720 L/min]
Nozzle flow rate	na
Bit speed (free running)	240–355 rpm
Revolutions per unit volume	1.87/gal [0.49/L]
Max power	16 hp [12 kW]

na = not applicable

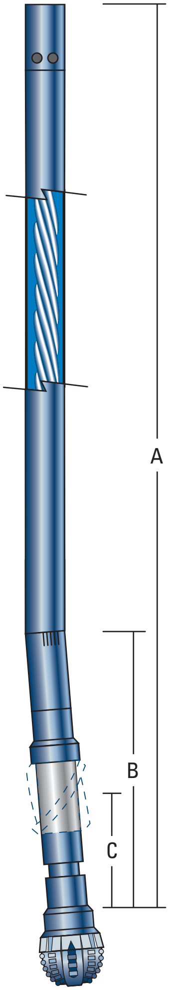
Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

4.1 Performance Data



475

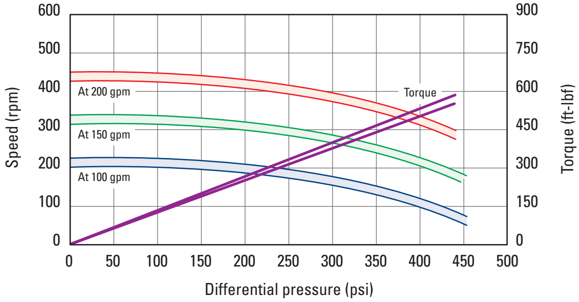
PowerPak A475 4¾-in. OD		
Adjustable bent housing settings (0°–2°)	0.00°	0.26°
	0.52°	0.77°
	1.00°	1.22°
	1.41°	1.59°
	1.73°	1.85°
	1.93°	1.98°
	2.00°	
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Stabilizer sleeve makeup torque	4,000 ft-lbf [5,420 N·m]	
Bent housing adjustment makeup torque	10,000 ft-lbf [13,560 N·m]	
Bit size	5⅞–7 in.	
Bit connection	3½ REG	
Top connection	3½ IF or 3½ REG	
Working overpull (no motor damage)	58,200 lbf [259 kN]	
Max WOB with flow (no motor damage)	25,000 lbf [111 kN	
Max WOB without flow (no motor damage)	50,000 lbf [222 kN]	
Absolute overpull (motor damage will occur)	272,000 lbf [1,210 kN]	

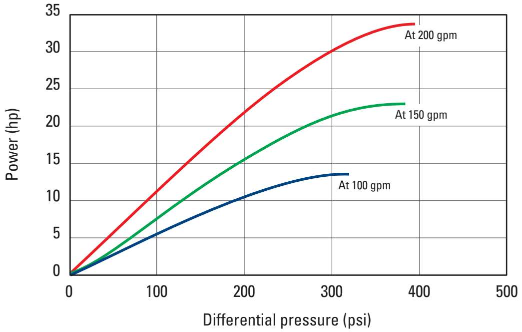
Note: These limits apply only when bit is stuck.

Schlumberger

PowerPak A475SP, 4¾-in. OD, 1:2 Lobes, 3.0 Stages	
Tool Data	
Weight	630 lbm [285 kgm]
Nominal length (A)	18.87 ft [5.75 m]
Bit box to bend (B)	4.08 ft [1.24 m]
Bit box to center of stabilizer (C)	1.13 ft [0.34 m]
Performance Data	
Standard flow rate	100–200 gpm [380–760 L/min]
Nozzle flow rate	na
Bit speed (free running)	225–435 rpm
Revolutions per unit volume	2.18/gal [0.58/L]
Max power	34 hp [25 kW]

na = not applicable





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

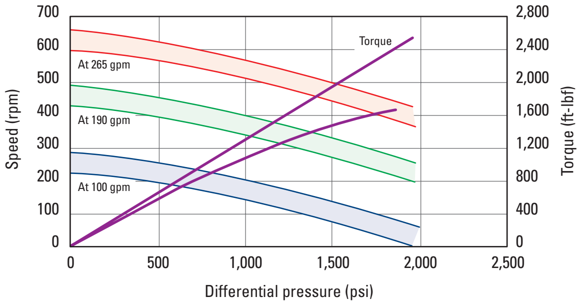
4.1 Performance Data

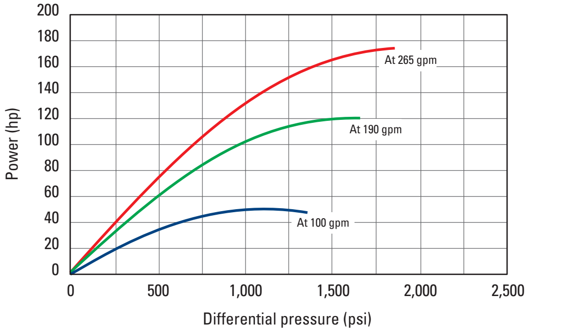
PowerPak A475HS, 4¾-in. OD, 2:3 Lobes, 10.5 Stages	
Tool Data	
Weight	1,000 lbm [455 kgm]
Nominal length (A)	27.50 ft [8.38 m]
Bit box to bend (B)	4.08 ft [1.24 m]
Bit box to center of stabilizer (C)	1.13 ft [0.34 m]
Performance Data	
Standard flow rate	100–265 gpm [380–1,000 L/min]
Nozzle flow rate	na
Bit speed (free running)	226–600 rpm
Revolutions per unit volume	2.26/gal [0.60/L]
Max power	174 hp [130 kW]

na = not applicable

475

Motor Performance†



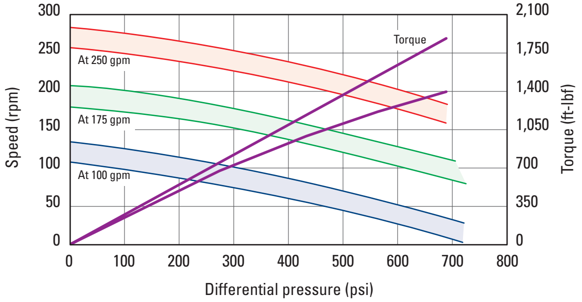


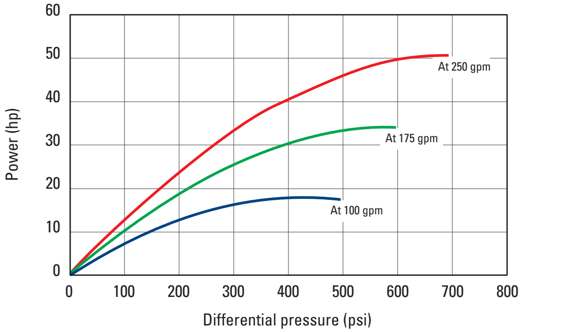
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

Schlumberger

PowerPak A475SP, 4¾-in. OD, 4:5 Lobes, 3.5 Stages	
Tool Data	
Weight	620 lbm [280 kgm]
Nominal length (A)	16.62 ft [5.07 m]
Bit box to bend (B)	4.08 ft [1.24 m]
Bit box to center of stabilizer (C)	1.13 ft [0.34 m]
Performance Data	
Standard flow rate	100–250 gpm [380–950 L/min]
Standard flow rate	100–350 gpm [380–1,320 L/min]
Bit speed (free running)	105–260 rpm
Revolutions per unit volume	1.04/gal [0.27/L]
Max power	51 hp [38 kW]

Motor Performance†





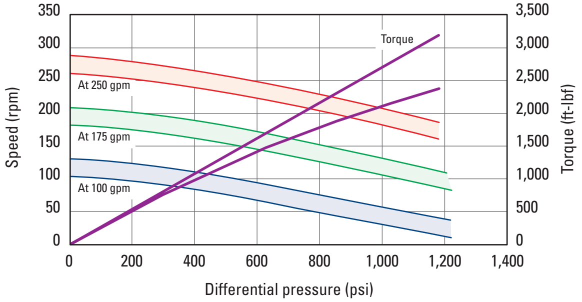
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

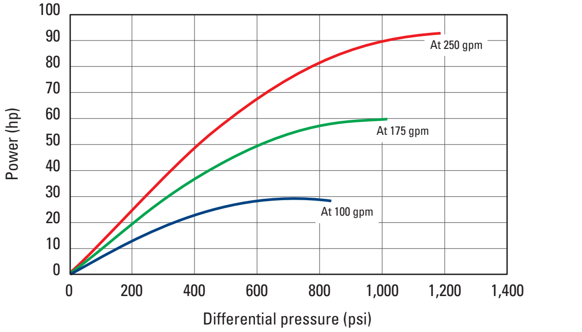
4.1 Performance Data

PowerPak A475XP, 4¾-in. OD, 4:5 Lobes, 6.0 Stages	
Tool Data	
Weight	920 lbm [415 kgm]
Nominal length (A)	22.54 ft [6.87 m]
Bit box to bend (B)	4.08 ft [1.24 m]
Bit box to center of stabilizer (C)	1.13 ft [0.34 m]
Performance Data	
Standard flow rate	100–250 gpm [380–950 L/min]
Standard flow rate	100–350 gpm [380–1,320 L/min]
Bit speed (free running)	105–260 rpm
Revolutions per unit volume	1.04/gal [0.27/L]
Max power	93 hp [69 kW]

475

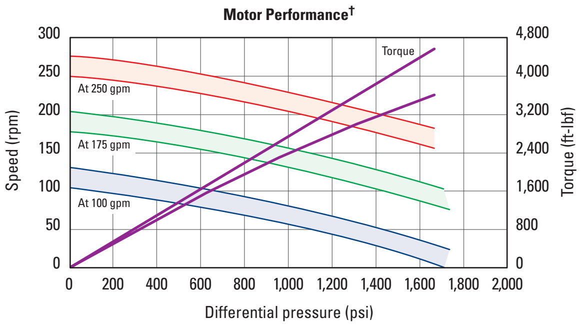
Motor Performance†

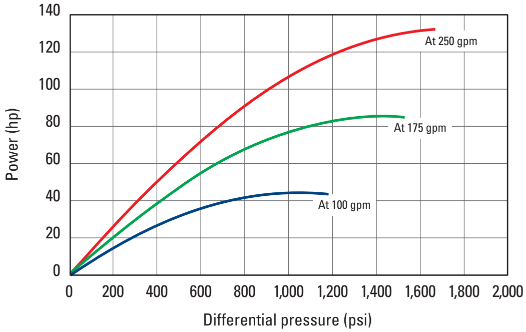




†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

PowerPak A475GT, 4¾-in. OD, 5:6 Lobes, 8.3 Stages	
Tool Data	
Weight	1,000 lbm [455 kgm]
Nominal length (A)	27.17 ft [8.28 m]
Bit box to bend (B)	4.08 ft [1.24 m]
Bit box to center of stabilizer (C)	1.13 ft [0.34 m]
Performance Data	
Standard flow rate	100–250 gpm [380–950 L/min]
Standard flow rate	100–350 gpm [380–1,320 L/min]
Bit speed (free running)	105–260 rpm
Revolutions per unit volume	1.04/gal [0.27/L]
Max power	130 hp [97 kW]





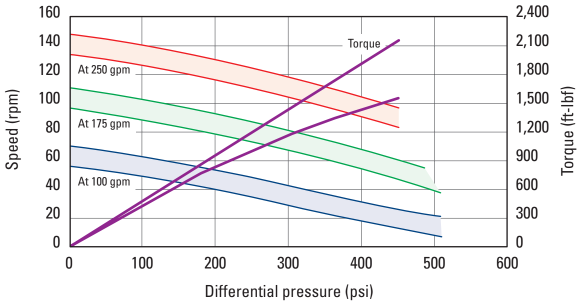
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

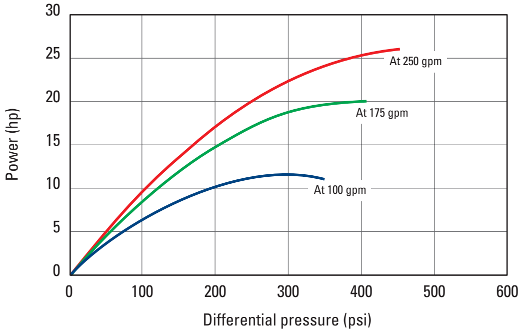
4.1 Performance Data

PowerPak A475SP, 4¾-in. OD, 7:8 Lobes, 2.2 Stages	
Tool Data	
Weight	640 lbm [290 kgm]
Nominal length (A)	16.62 ft [5.07 m]
Bit box to bend (B)	4.08 ft [1.24 m]
Bit box to center of stabilizer (C)	1.13 ft [0.34 m]
Performance Data	
Standard flow rate	100–250 gpm [380–950 L/min]
Standard flow rate	100–350 gpm [380–1,320 L/min]
Bit speed (free running)	55–135 rpm
Revolutions per unit volume	0.54/gal [0.14/L]
Max power	26 hp [19 kW]

475

Motor Performance†

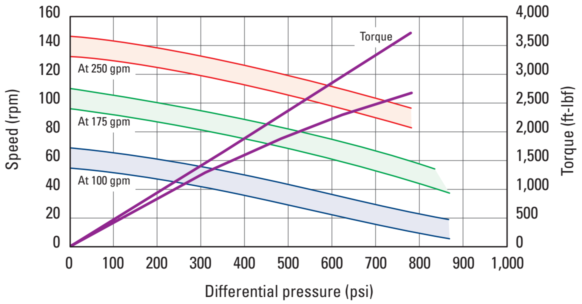


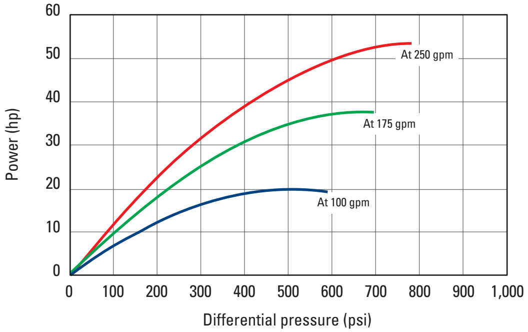


†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

PowerPak A475XP, 4¾-in. OD, 7:8 Lobes, 3.8 Stages	
Tool Data	
Weight	900 lbm [410 kgm]
Nominal length (A)	22.54 ft [6.87 m]
Bit box to bend (B)	4.08 ft [1.24 m]
Bit box to center of stabilizer (C)	1.13 ft [0.34 m]
Performance Data	
Standard flow rate	100–250 gpm [380–950 L/min]
Standard flow rate	100–350 gpm [380–1,320 L/min]
Bit speed (free running)	55–135 rpm
Revolutions per unit volume	0.54/gal [0.14/L]
Max power	54 hp [40 kW]

Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

PowerPak A475AD, 4¾-in. OD, 7:8 Lobes, 2.0 Stages

Tool Data

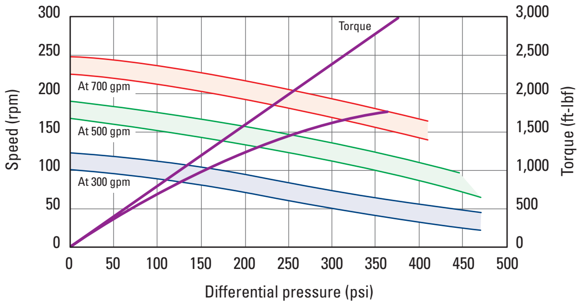
Weight	800 lbm [365 kgm]
Nominal length (A)	20.12 ft [6.13 m]
Bit box to bend (B)	4.08 ft [1.24 m]
Bit box to center of stabilizer (C)	1.13 ft [0.34 m]

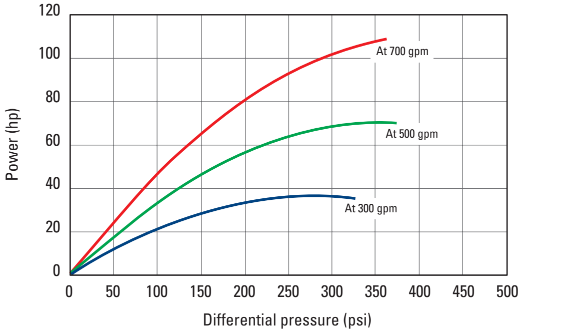
Performance Data

Nozzle flow rate	300–700 gpm [1,140–2,650 L/min]
Nozzle flow rate	na
Bit speed (free running)	100–230 rpm
Revolutions per unit volume	0.33/gal [0.09/L]
Max power	110 hp [82 kW]

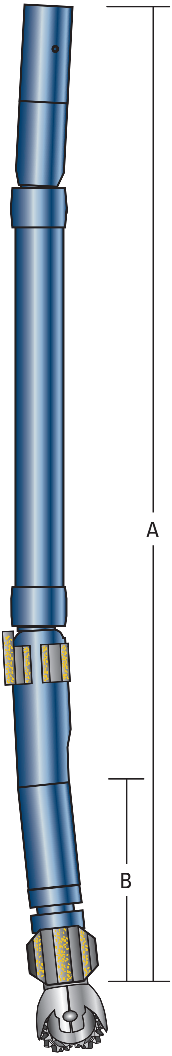
na = not applicable

Motor Performance†





†Performance based on 160°F air mist at 320 psi.
Flow rate (gpm) = 109.75 × ft³/min/pump pressure (psi).



PowerPak A475XF 4¾-in. OD	
Adjustable pad settings	Shimmed to allow from 20°/100 ft to 145°/100 ft in 5°/100 ft increments
Bit size	5⅞–6⅛ in.
Bit connection	3½ REG
Top connection	3½ IF or 3½ REG
Working overpull (no motor damage)	58,200 lbf [259 kN]
Max WOB with flow (no motor damage)	25,000 lbf [111 kN]
Max WOB without flow (no motor damage)	50,000 lbf [222 kN]
Absolute overpull (motor damage will occur)	272,000 lbf [1,210 kN]

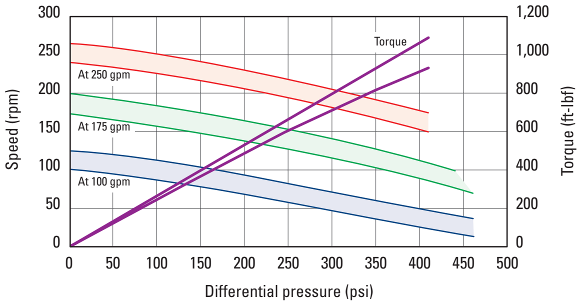
Note: These limits apply only when bit is stuck.

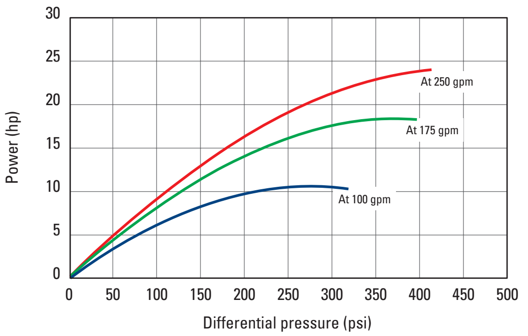
4.1 Performance Data

PowerPak A475XF, 4¾-in. OD, 7:8 Lobes, 2.0 Stages	
Tool Data	
Weight	670 lbm [225 kgm]
Nominal length (A)	12.60 ft [3.84 m]
Bit box to bend (B)	1.51 ft [0.46 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	100–250 gpm [380–950 L/min]
Nozzle flow rate	na
Bit speed (free running)	100–245 rpm
Revolutions per unit volume	0.98/gal [0.26/L]
Max power	24 hp [18 kW]

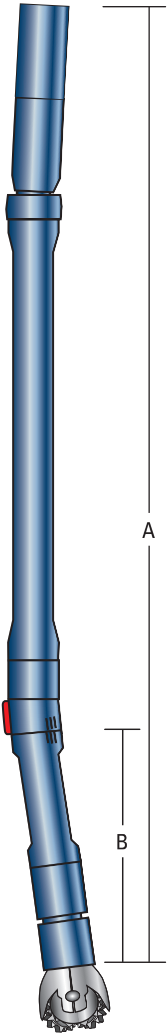
na = not applicable

475





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.



PowerPak A475XC 4¾-in. OD		
Adjustable bent housing settings (0°–4°)	0.00°	0.35°
	0.69°	1.04°
	1.37°	1.69°
	2.00°	2.29°
	2.57°	2.83°
	3.06°	3.28°
	3.46°	3.63°
	3.76°	3.86°
	3.94°	3.98°
	4.00°	
Bent housing adjustment makeup torque	9,000 ft-lbf [12,300 N·m]	
Bit size	5⅞–6⅛ in.	
Bit connection	3½ REG	
Top connection	3½ IF 3½ REG	
Working overpull (no motor damage)	58,200 lbf [259 kN]	
Max WOB with flow (no motor damage)	25,000 lbf [111 kN]	
Max WOB without flow (no motor damage)	50,000 lbf [222 kN]	
Absolute overpull (motor damage will occur)	**272,000 lbf [1,210 kN]**	

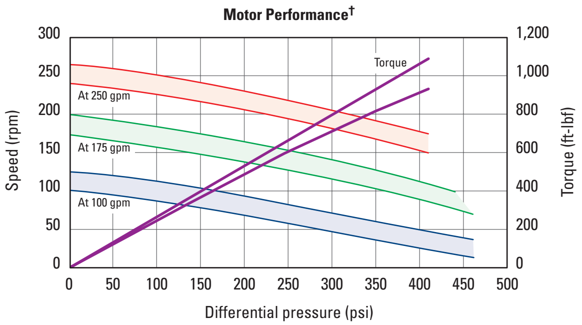
Note: These limits apply only when bit is stuck.

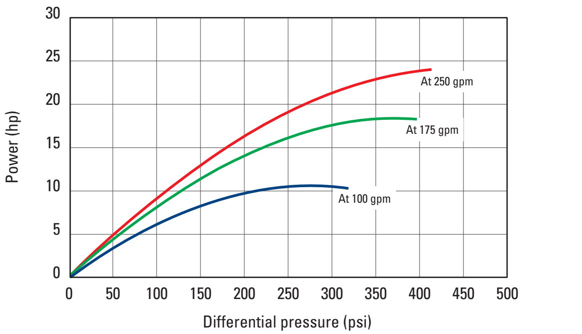
4.1 Performance Data

PowerPak A475XC, 4¾-in. OD, 7:8 Lobes, 2.0 Stages	
Tool Data	
Weight	670 lbm [240 kgm]
Nominal length (A)	13.32 ft [4.06 m]
Bit box to bend (B)	3.03 ft [0.92 m]
Bit box to center of stabilizer (C)	na
Performance Data	
Standard flow rate	100–250 gpm [380–950 L/min]
Nozzle flow rate	na
Bit speed (free running)	100–245 rpm
Revolutions per unit volume	0.98/gal [0.26/L]
Max power	24 hp [18 kW]

na = not applicable

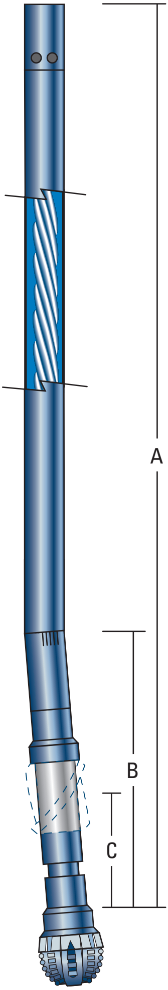
475





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

Schlumberger



PowerPak A500 5-in. OD		
Adjustable bent housing settings (0°–2°)	0.00°	0.26°
	0.52°	0.77°
	1.00°	1.22°
	1.41°	1.59°
	1.73°	1.85°
	1.93°	1.98°
	2.00°	
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Stabilizer sleeve makeup torque	na	
Bent housing adjustment makeup torque	11,500 ft-lbf [15,590 N·m]	
Bit size	5⅞–7 in.	
Bit connection	3½ REG	
Top connection	3½ REG or 3½ NC 38	
Working overpull (no motor damage)	61,200 lbf [272 kN]	
Max WOB with flow (no motor damage)	30,000 lbf [133 kN]	
Max WOB without flow (no motor damage)	55,000 lbf [244 kN]	
Absolute overpull (motor damage will occur)	378,600 lbf [1,684 kN]	

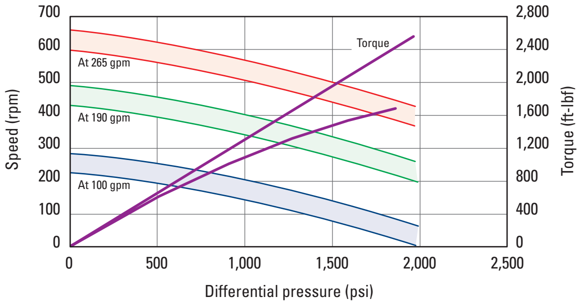
Note: These limits apply only when bit is stuck.

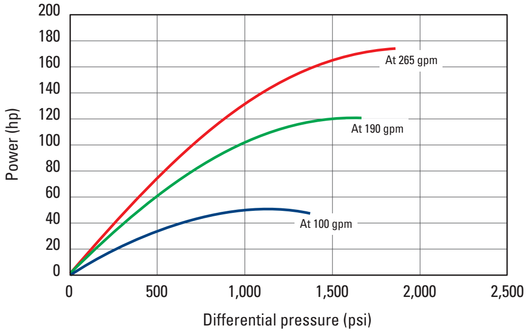
PowerPak A500HS, 5-in. OD, 2:3 Lobes, 10.5 Stages

Tool Data	
Weight	1,300 lbm [590 kgm]
Nominal length (A)	26.70 ft [8.14 m]
Bit box to bend (B)	4.43 ft [1.35 m]
Bit box to center of stabilizer (C)	**1.59 ft [0.48 m]**
Performance Data	
Standard flow rate	150–265 gpm [380–1,000 L/min]
Nozzle flow rate	na
Bit speed (free running)	225–600 rpm
Revolutions per unit volume	2.26/gal [0.60/L]
Max power	**174 hp [130 kW]**

na = not applicable

Motor Performance†

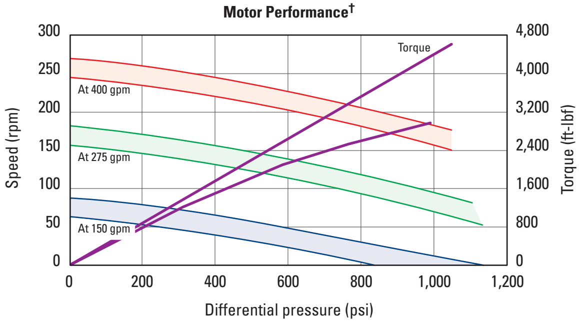


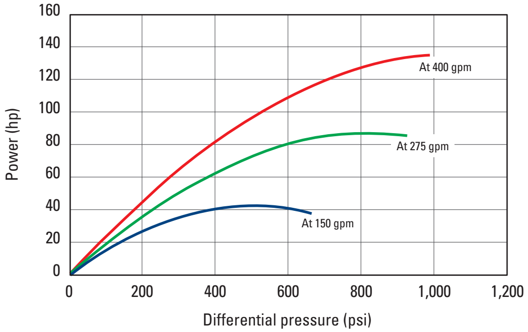


†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

PowerPak A500HF, 5-in. OD, 5:6 Lobes, 5.2 Stages	
Tool Data	
Weight	1,320 lbm [600 kgm]
Nominal length (A)	27.0 ft [8.23 m]
Bit box to bend (B)	4.43 ft [1.35 m]
Bit box to center of stabilizer (C)	1.59 ft [0.48 m]
Performance Data	
Standard flow rate	150–400 gpm [570–1,510 L/min]
Nozzle flow rate	na
Bit speed (free running)	95–250 rpm
Revolutions per unit volume	0.63/gal [0.17/L]
Max power	133 hp [99 kW]

na = not applicable





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

500

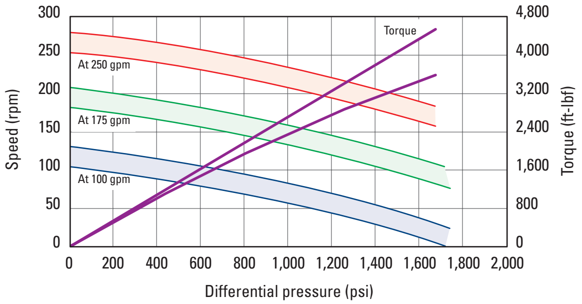
4.1 Performance Data

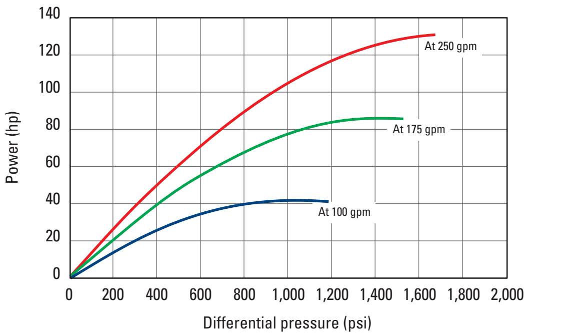
PowerPak A500GT, 5-in. OD, 5:6 Lobes, 8.3 Stages	
Tool Data	
Weight	1,300 lbm [590 kgm]
Nominal length (A)	26.70 ft [8.14 m]
Bit box to bend (B)	4.43 ft [1.35 m]
Bit box to center of stabilizer (C)	1.59 ft [0.48 m]
Performance Data	
Standard flow rate	150–250 gpm [380–950 L/min]
Nozzle flow rate	na
Bit speed (free running)	105–260 rpm
Revolutions per unit volume	1.04/gal [0.27/L]
Max power	132 hp [98 kW]

na = not applicable

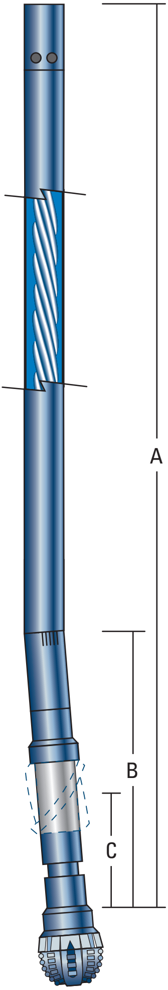
500

Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.



PowerPak A625 6¼-in. OD		
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.28°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Stabilizer sleeve makeup torque	10,000 ft-lbf [13,560 N·m]	
Bent housing adjustment makeup torque	25,000 ft-lbf [33,900 N·m]	
Bit size	7⅞–8½ in.	
Bit connection	4½ API REG	
Top connection	4½ API REG, 4½ H-90, or 4½ XH (4 IF)	
Working overpull (no motor damage)	155,200 lbf [690 kN]	
Max WOB with flow (no motor damage)	50,000 lbf [222 kN]	
Max WOB without flow (no motor damage)	75,000 lbf [334 kN]	
Absolute overpull (motor damage will occur)	513,600 lbf [2,285 kN]	

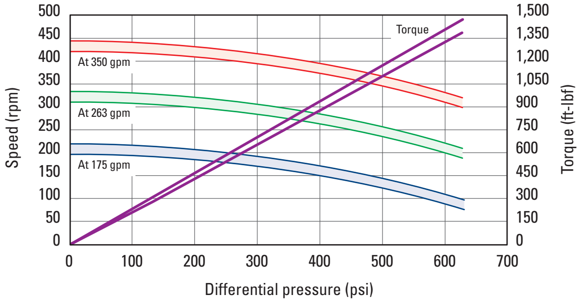
Note: These limits apply only when bit is stuck.

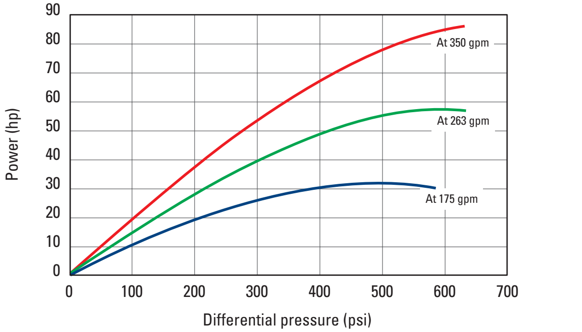
4.1 Performance Data

PowerPak A625SP, 6¼-in. OD, 1:2 Lobes, 4.0 Stages	
Tool Data	
Weight	1,780 lbm [805 kgm]
Nominal length (A)	22.67 ft [6.91 m]
Bit box to bend (B)	6.44 ft [1.96 m]
Bit box to center of stabilizer (C)	2.05 ft [0.62 m]
Performance Data	
Standard flow rate	175–350 gpm [660–1,320 L/min]
Nozzle flow rate	na
Bit speed (free running)	230–450 rpm
Revolutions per unit volume	1.29/gal [0.34/L]
Max power	82 hp [61 kW]

na = not applicable

Motor Performance†



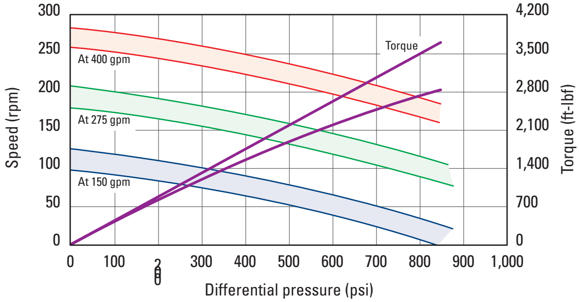


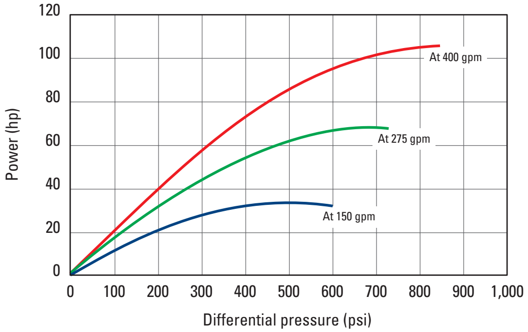
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

625

PowerPak A625SP, 6¼-in. OD, 4:5 Lobes, 4.3 Stages	
Tool Data	
Weight	1,600 lbm [725 kgm]
Nominal length (A)	19.67 ft [6.00 m]
Bit box to bend (B)	6.44 ft [1.96 m]
Bit box to center of stabilizer (C)	2.05 ft [0.62 m]
Performance Data	
Standard flow rate	150–400 gpm [570–1,510 L/min]
Nozzle flow rate	150–500 gpm [570–1,890 L/min]
Bit speed (free running)	100–265 rpm
Revolutions per unit volume	0.66/gal [0.17/L]
Max power	106 hp [79 kW]

Motor Performance†



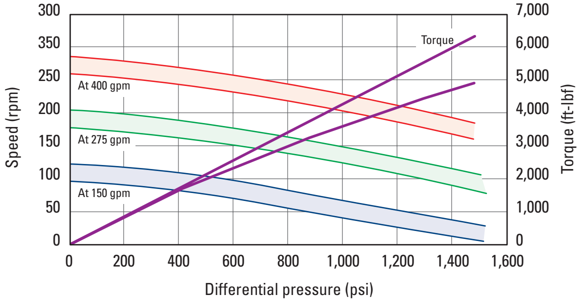


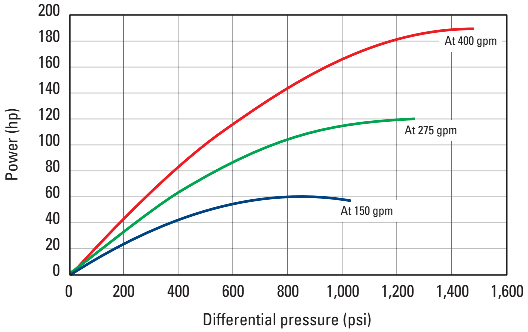
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

4.1 Performance Data

PowerPak A625XP, 6¼-in. OD, 4:5 Lobes, 7.5 Stages	
Tool Data	
Weight	2,060 lbm [935 kgm]
Nominal length (A)	26.3 ft [8.02 m]
Bit box to bend (B)	6.44 ft [1.96 m]
Bit box to center of stabilizer (C)	2.05 ft [0.62 m]
Performance Data	
Standard flow rate	150–400 gpm [570–1,510 L/min]
Nozzle flow rate	150–500 gpm [570–1,890 L/min]
Bit speed (free running)	100–265 rpm
Revolutions per unit volume	0.66/gal [0.17/L]
Max power	190 hp [142 kW]

Motor Performance†

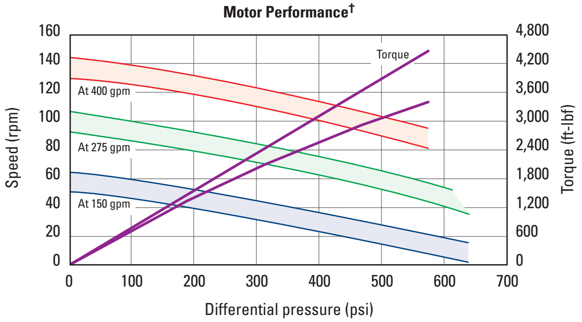


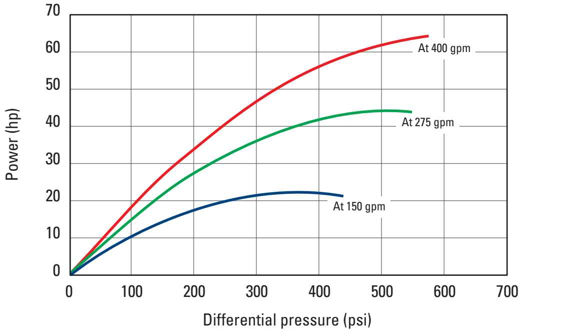


†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

Schlumberger

PowerPak A625SP, 6¼-in. OD, 7:8 Lobes, 2.8 Stages	
Tool Data	
Weight	1,600 lbm [725 kgm]
Nominal length (A)	19.67 ft [6.00 m]
Bit box to bend (B)	6.44 ft [1.96 m]
Bit box to center of stabilizer (C)	2.05 ft [0.62 m]
Performance Data	
Standard flow rate	150–400 gpm [570–1,510 L/min]
Nozzle flow rate	150–500 gpm [570–1,890 L/min]
Bit speed (free running)	50–135 rpm
Revolutions per unit volume	0.34/gal [0.09/L]
Max power	64 hp [48 kW]





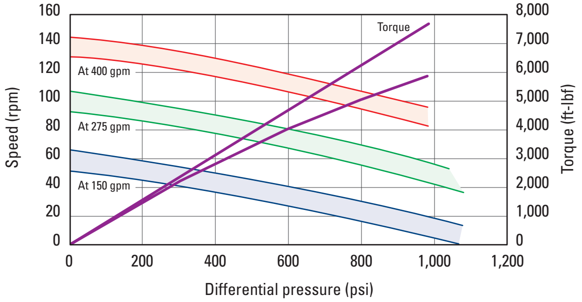
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

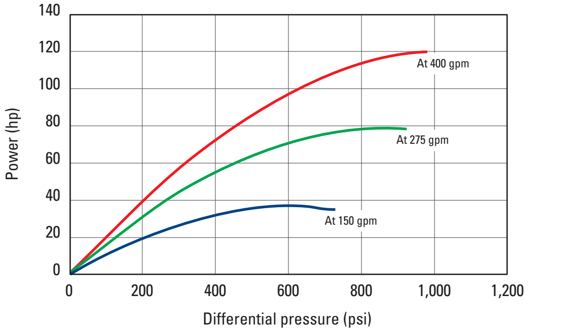
625

4.1 Performance Data

PowerPak A625XP, 6¼-in. OD, 7:8 Lobes, 4.8 Stages	
Tool Data	
Weight	2,060 lbm [935 kgm]
Nominal length (A)	26.27 ft [8.01 m]
Bit box to bend (B)	6.44 ft [1.96 m]
Bit box to center of stabilizer (C)	2.05 ft [0.62 m]
Performance Data	
Standard flow rate	150–400 gpm [570–1,510 L/min]
Nozzle flow rate	150–500 gpm [570–1,890 L/min]
Bit speed (free running)	50–136 rpm
Revolutions per unit volume	0.34/gal [0.09/L]
Max power	120 hp [90 kW]

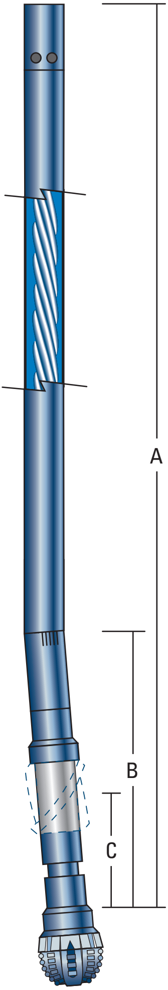
Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

625



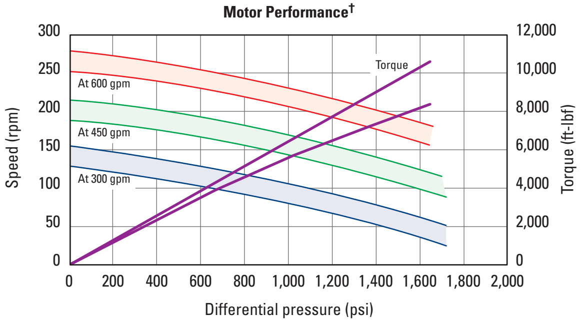
PowerPak A650 6½-in. OD		
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.28°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Stabilizer sleeve makeup torque	10,000 ft-lbf [13,560 N·m]	
Bent housing adjustment makeup torque	25,000 ft-lbf [33,900 N·m]	
Bit size	7⅞–9⅞ in.	
Bit connection	4½ API REG	
Top connection	4½ API REG, 4½ H-90, 4½ XH (4 IF) or 4½ IF	
Working overpull (no motor damage)	192,000 lbf [854 kN]	
Max WOB with flow (no motor damage)	50,000 lbf [222 kN]	
Max WOB without flow (no motor damage)	75,000 lbf [334 kN]	
Absolute overpull (motor damage will occur)	537,600 lbf [2,391 kN]	

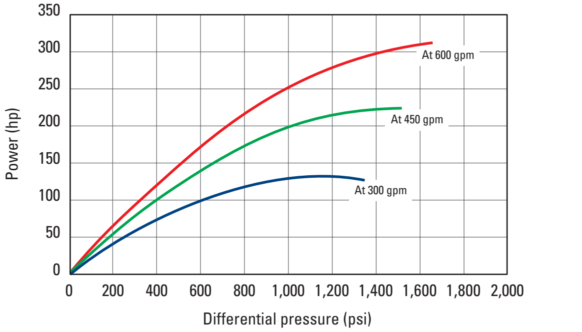
Note: These limits apply only when bit is stuck.

4.1 Performance Data

PowerPak A650GT, 6½-in. OD, 5:6 Lobes, 8.2 Stages	
Tool Data	
Weight	2,400 lbm [1,090 kgm]
Nominal length (A)	30.58 ft [9.32 m]
Bit box to bend (B)	6.44 ft [1.96 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	300–600 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–700 gpm [1,140–3,030 L/min]
Bit speed (free running)	125–250 rpm
Revolutions per unit volume	0.42/gal [0.11/L]
Max power	310 hp [231 kW]

650





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

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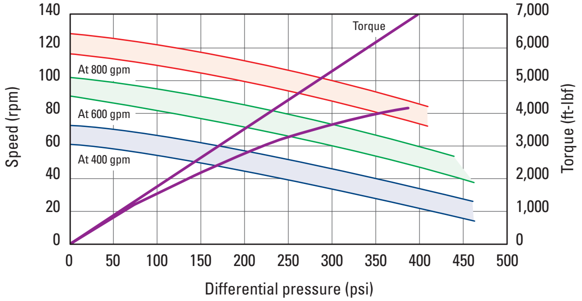
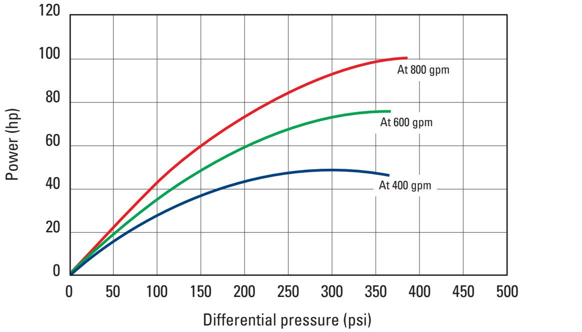
PowerPak A650AD, 6½-in. OD, 7:8 Lobes, 2.0 Stages

Tool Data	
Weight	2,000 lbm [905 kgm]
Nominal length (A)	22.87 ft [6.97 m]
Bit box to bend (B)	6.44 ft [1.96 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	400–800 gpm [1,150–3,030 L/min]
Nozzle flow rate	na
Bit speed (free running)	60–115 rpm
Revolutions per unit volume	0.14/gal [0.04/L]
Max power	100 hp [75 kW]

na = not applicable

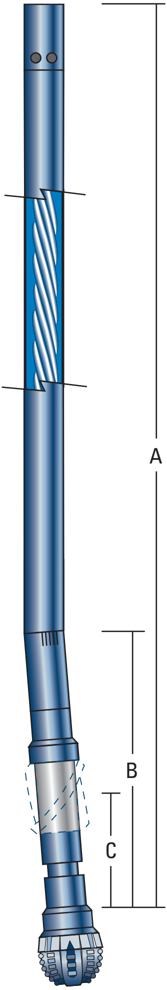
Motor Performance†





†Performance based on 160°F air mist at 320 psi.
Flow rate (gpm) = 109.75 × ft³/min/pump pressure (psi).

650

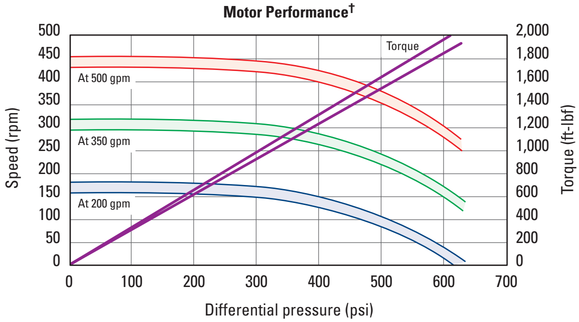


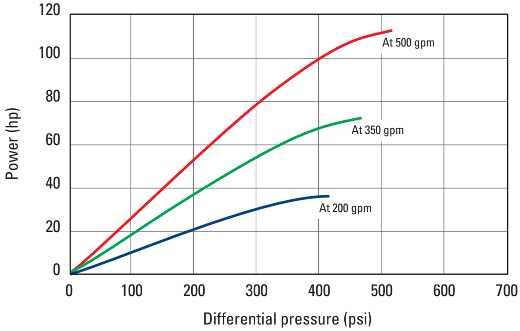
PowerPak A675 6¾-in. OD		
Adjustable bent housing settings (0°–2°)	0.00°	0.26°
	0.52°	0.77°
	1.00°	1.22°
	1.41°	1.59°
	1.73°	1.85°
	1.93°	1.98°
	2.00°	
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Stabilizer sleeve makeup torque	10,000 ft-lbf [13,560 N·m]	
Bent housing adjustment makeup torque	25,000 ft-lbf [33,900 N·m]	
Bit size	8⅜–9⅞ in.	
Bit connection	4½ REG	
Top connection	4½ REG or 4½ IF	
Working overpull (no motor damage)	142,700 lbf [635 kN]	
Max WOB with flow (no motor damage)	50,000 lbf [222 kN]	
Max WOB without flow (no motor damage)	75,000 lbf [334 kN]	
Absolute overpull (motor damage will occur)	518,800 lbf [2,391 kN]	

Note: These limits apply only when bit is stuck.

PowerPak A675SP, 6¾-in. OD, 1:2 Lobes, 4.0 Stages	
Tool Data	
Weight	1,780 lbm [805 kgm]
Nominal length (A)	23.60 ft [7.19 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	200–500 gpm [760–1,890 L/min]
Nozzle flow rate	na
Bit speed (free running)	180–465 rpm
Revolutions per unit volume	0.93/gal [0.25/L]
Max power	115 hp [86 kW]

na = not applicable



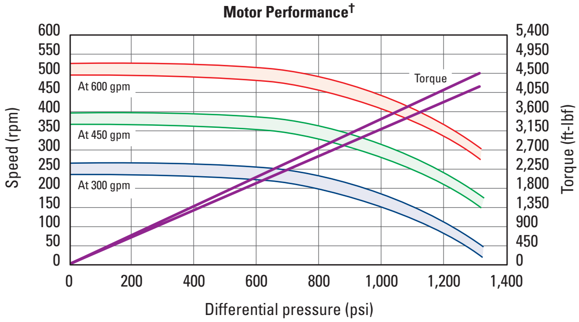


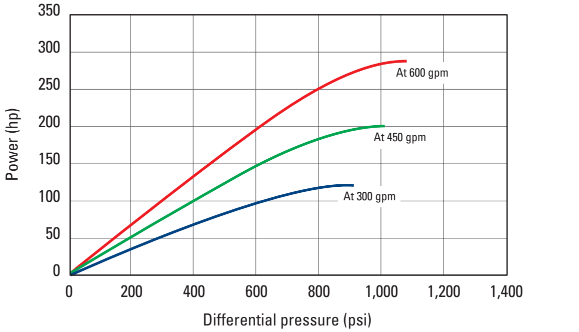
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

675

4.1 Performance Data

PowerPak A675XP, 6¾-in. OD, 2:3 Lobes, 8.0 Stages	
Tool Data	
Weight	2,150 lbm [975 kgm]
Nominal length (A)	26.51 ft [8.08 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	300–600 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–700 gpm [1,140–2,650 L/min]
Bit speed (free running)	260–520 rpm
Revolutions per unit volume	0.87/gal [0.23/L]
Max power	280 hp [209 kW]





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

675

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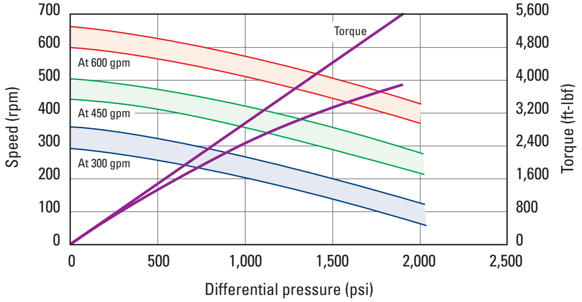
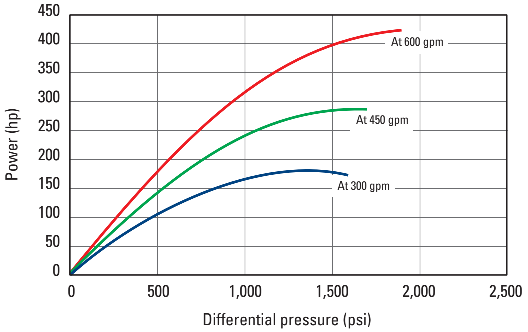
PowerPak A675HS, 6¾-in. OD, 2:3 Lobes, 10.7 Stages	
Tool Data	
Weight	2,300 lbm [1,045 kgm]
Nominal length (A)	29.09 ft [8.87 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	300–600 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–700 gpm [1,140–2,650 L/min]
Bit speed (free running)	300–600 rpm
Revolutions per unit volume	1.00/gal [0.26/L]
Max power	415 hp [310 kW]

Motor Performance†





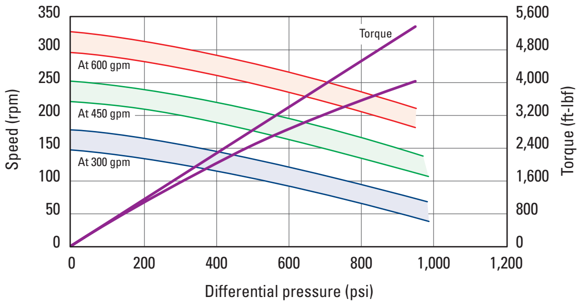
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

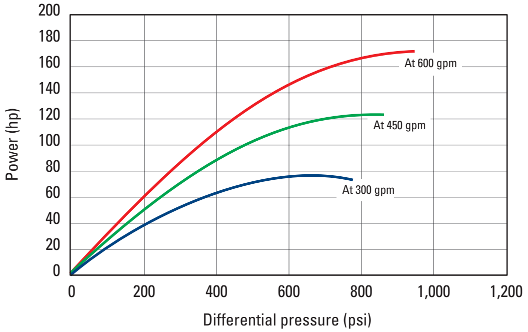
675

4.1 Performance Data

PowerPak A675SP, 6¾-in. OD, 4:5 Lobes, 4.8 Stages	
Tool Data	
Weight	1,750 lbm [795 kgm]
Nominal length (A)	21.39 ft [6.52 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	300–600 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–700 gpm [1,140–2,650 L/min]
Bit speed (free running)	150–300 rpm
Revolutions per unit volume	0.5/gal [0.13/L]
Max power	170 hp [127 kW]

Motor Performance†





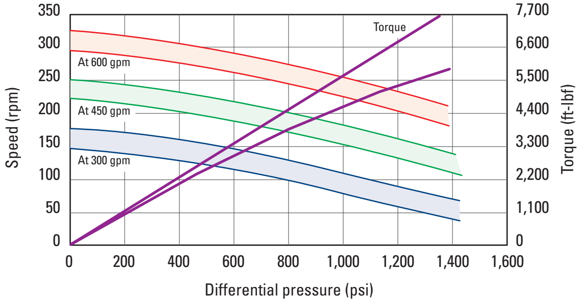
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

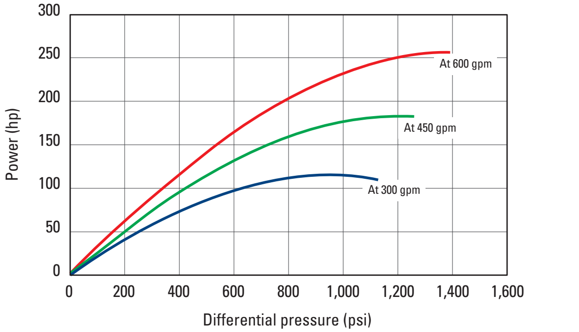
675

Schlumberger

PowerPak A675XP, 6¾-in. OD, 4:5 Lobes, 7.0 Stages	
Tool Data	
Weight	2,170 lbm [985 kgm]
Nominal length (A)	26.51 ft [8.08 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	300–600 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–700 gpm [1,140–2,650 L/min]
Bit speed (free running)	150–300 rpm
Revolutions per unit volume	0.5/gal [0.13/L]
Max power	259 hp [193 kW]

Motor Performance†



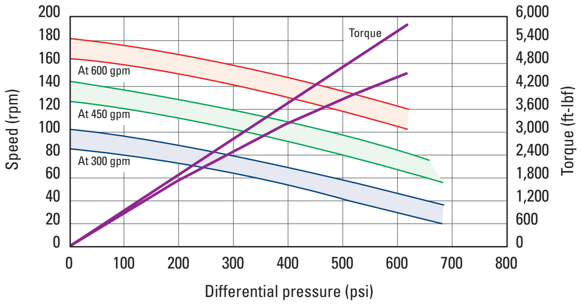


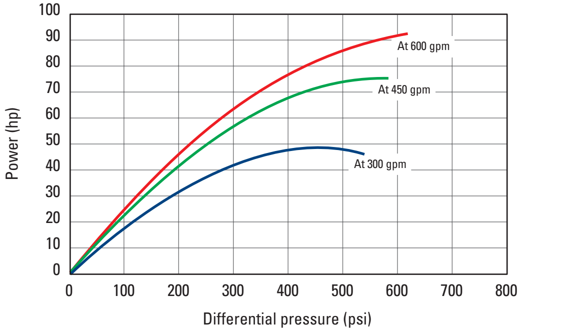
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

4.1 Performance Data

PowerPak A675SP, 6¾-in. OD, 7:8 Lobes, 3.0 Stages	
Tool Data	
Weight	1,750 lbm [794 kgm]
Nominal length (A)	19.44 ft [5.93 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	300–600 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–700 gpm [1,140–2,650 L/min]
Bit speed (free running)	85–165 rpm
Revolutions per unit volume	0.28/gal [0.07/L]
Max power	96 hp [72 kW]

Motor Performance†





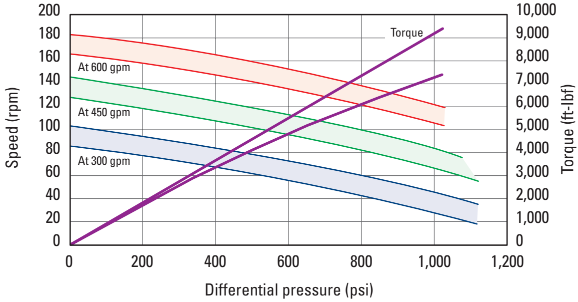
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

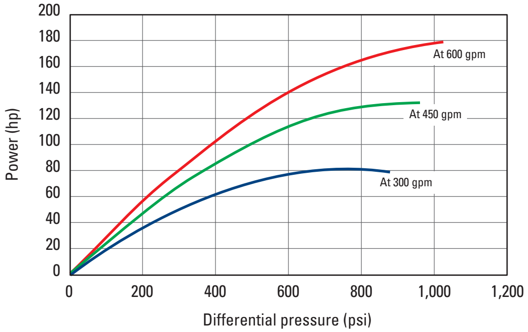
675

Schlumberger

PowerPak A675XP, 6¾-in. OD, 7:8 Lobes, 5.0 Stages	
Tool Data	
Weight	2,260 lbm [1,025 kgm]
Nominal length (A)	25.19 ft [7.68 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	300–600 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–700 gpm [1,140–2,650 L/min]
Bit speed (free running)	85–165 rpm
Revolutions per unit volume	0.28/gal [0.07/L]
Max power	180 hp [134 kW]

Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

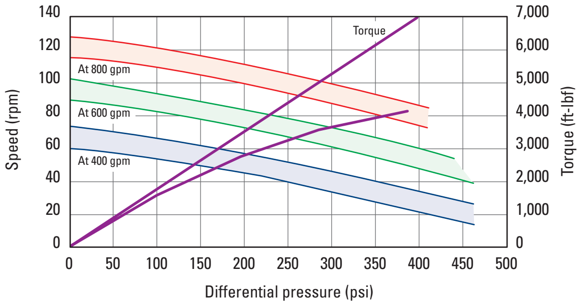
675

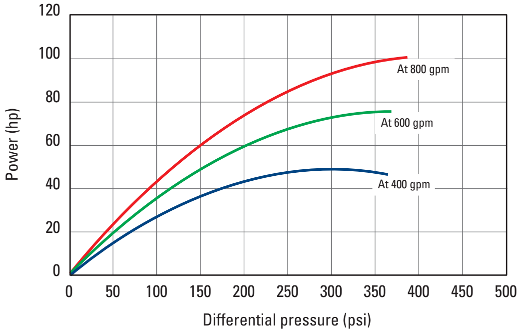
4.1 Performance Data

PowerPak A675AD, 6¾-in. OD, 7:8 Lobes, 2.0 Stages	
Tool Data	
Weight	1,930 lbm [875 kgm]
Nominal length (A)	21.85 ft [6.66 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	400–800 gpm [1,150–3,030 L/min]
Nozzle flow rate	na
Bit speed (free running)	60–115 rpm
Revolutions per unit volume	0.14/gal [0.04/L]
Max power	100 hp [93 kW]

na = not applicable

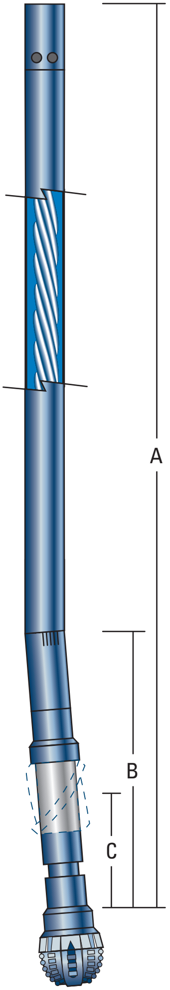
Motor Performance†





†Performance based on 160°F air mist at 320 psi.
Flow rate (gpm) = 109.75 × ft^3/min/pump pressure (psi).

Schlumberger



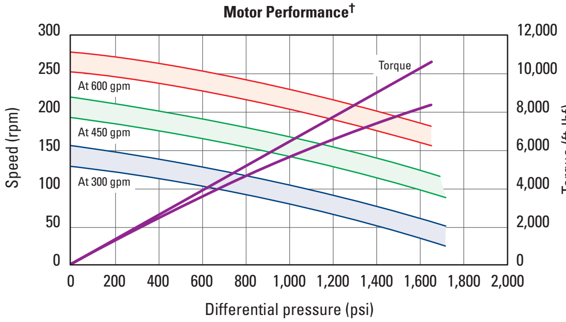
PowerPak A700 7-in. OD

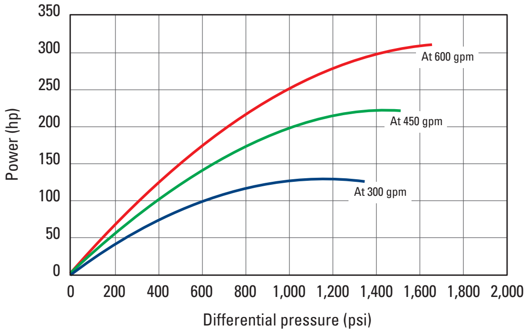
Adjustable bent housing settings (0°–2°)	0.00° 0.52° 1.00° 1.41° 1.73° 1.93° 2.00°	0.26° 0.77° 1.22° 1.59° 1.85° 1.98°
Adjustable bent housing settings (0°–3°)	0.00° 0.78° 1.50° 2.12° 2.60° 2.90° 3.00°	0.39° 1.15° 1.83° 2.38° 2.77° 2.97°
Stabilizer sleeve makeup torque	10,000 ft-lbf [13,560 N·m]	
Bent housing adjustment makeup torque	28,000 ft-lbf [37,960 N·m]	
Bit size	8½–9⅞ in.	
Bit connection	4½ REG	
Top connection	4½ REG or 4½ IF [4½ Hughes H-90 or 4½ X-hole (4 IF)]	
Working overpull (no motor damage)	163,800 lbf [729 kN]	
Max WOB with flow (no motor damage)	55,000 lbf [244 kN]	
Max WOB without flow (no motor damage)	100,000 lbf [445 kN]	
Absolute overpull (motor damage will occur)	823,200 lbf [3,662 kN]	

Note: These limits apply only when bit is stuck.

4.1 Performance Data

PowerPak A700GT, 7-in. OD, 5:6 Lobes, 8.2 Stages	
Tool Data	
Weight	3,200 lbm [1,450 kgm]
Nominal length (A)	30.56 ft [9.31 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	300–600 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–800 gpm [1,140–3,030 L/min]
Bit speed (free running)	120–250 rpm
Revolutions per unit volume	0.42/gal [0.11/L]
Max power	310 hp [231 kW]





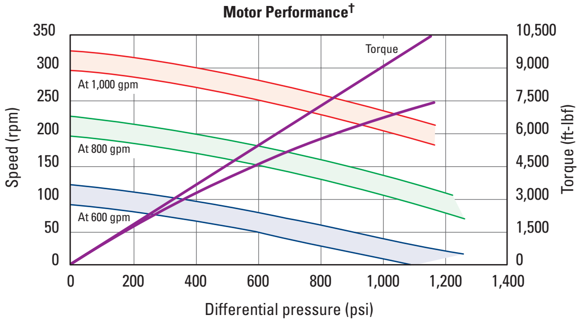
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

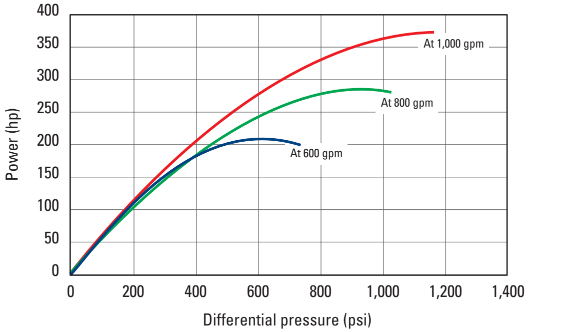
700

Schlumberger

PowerPak A700HF, 7-in. OD, 5:6 Lobes, 5.8 Stages	
Tool Data	
Weight	3,400 lbm [1,540 kgm]
Nominal length (A)	30.56 ft [9.31 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C) 1.75 ft [0.53 m]	
Performance Data	
Standard flow rate	600–1,000 gpm [2,270–3,790 L/min]
Nozzle flow rate	na
Bit speed (free running)	180–295 rpm
Revolutions per unit volume	0.30/gal [0.08/L]
Max power	375 hp [280 kW]

na = not applicable



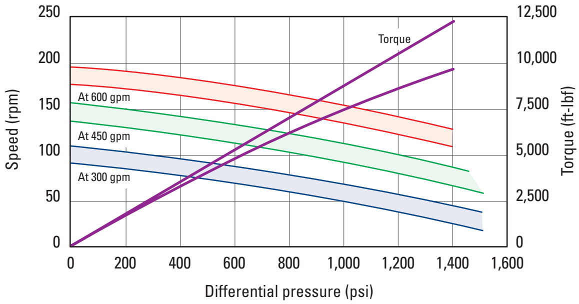


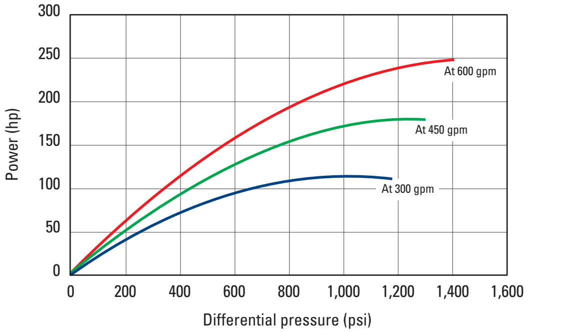
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

4.1 Performance Data

PowerPak A700GT, 7-in. OD, 7:8 Lobes, 6.6 Stages	
Tool Data	
Weight	3,200 lbm [1,450 kgm]
Nominal length (A)	30.56 ft [9.31 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	300–600 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–800 gpm [1,140–3,030 L/min]
Bit speed (free running)	85–175 rpm
Revolutions per unit volume	0.29/gal [0.08/L]
Max power	250 hp [187 kW]

Motor Performance†



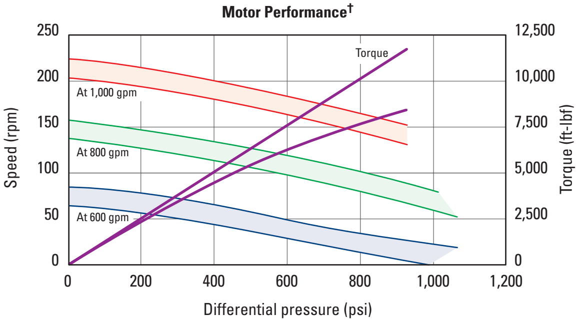


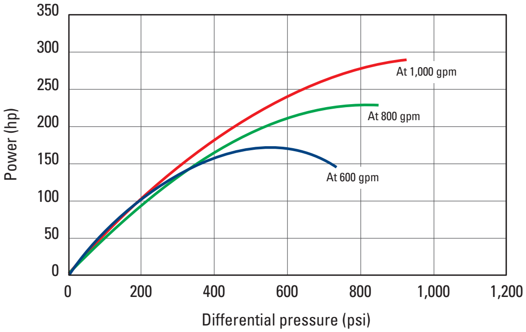
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

700

PowerPak A700HF, 7-in. OD, 7:8 Lobes, 4.7 Stages	
Tool Data	
Weight	3,400 lbm [1,540 kgm]
Nominal length (A)	30.56 ft [9.31 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	600–1,000 gpm [2,270–3,790 L/min]
Nozzle flow rate	na
Bit speed (free running)	120–205 rpm
Revolutions per unit volume	0.21/gal [0.06/L]
Max power	290 hp [216 kW]

na = not applicable

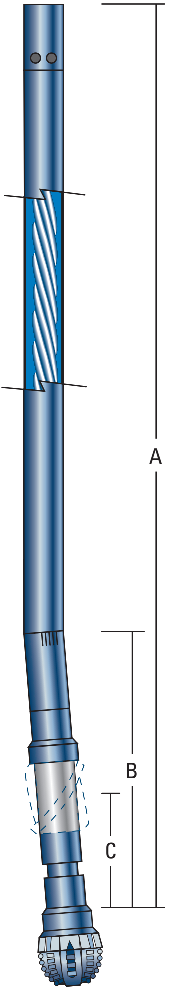




†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

700

4.1 Performance Data

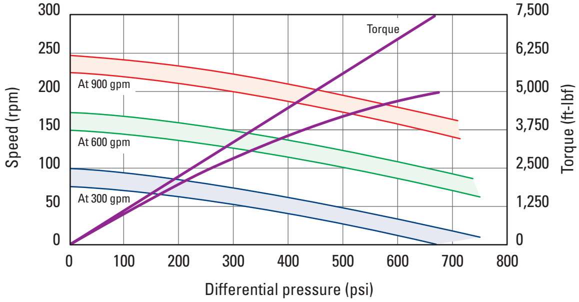


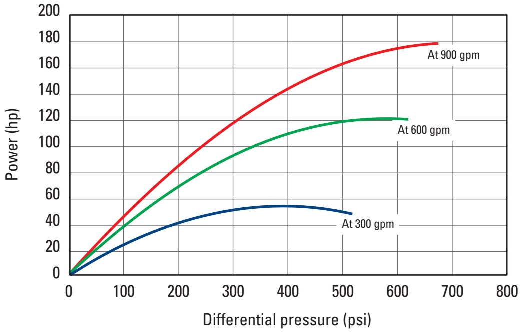
PowerPak A775 7¾-in. OD		
Adjustable bent housing settings (0°–2°)	0.00°	0.26°
	0.52°	0.77°
	1.00°	1.22°
	1.41°	1.59°
	1.73°	1.85°
	1.93°	1.98°
	2.00°	
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
		3.00°
Stabilizer sleeve makeup torque	23,000 ft-lbf [31,180 N·m]	
Bent housing adjustment makeup torque	35,000 ft-lbf [47,450 N·m]	
Bit size	9⅞–14¾ in.	
Bit connection	6⅝ REG	
Top connection	6⅝ REG or 5½ IF	
Working overpull (no motor damage)	219,500 lbf [976 kN]	
Max WOB with flow (no motor damage)	50,000 lbf [222 kN]	
Max WOB without flow (no motor damage)	125,000 lbf [556 kN]	
Absolute overpull (motor damage will occur)	754,800 lbf [3,358 kN]	

Note: These limits apply only when bit is stuck.

PowerPak A775SP, 7¾-in. OD, 4:5 Lobes, 3.6 Stages	
Tool Data	
Weight	3,200 lbm [1,575 kgm]
Nominal length (A)	23.60 ft [7.19 m]
Bit box to bend (B)	7.06 ft [2.15 m]
Bit box to center of stabilizer (C) 2.01 ft [0.61 m]	
Performance Data	
Standard flow rate	300–900 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–1,100 gpm [1,140–3,030 L/min]
Bit speed (free running)	75–225 rpm
Revolutions per unit volume	0.25/gal [0.08/L]
Max power	178 hp [186 kW]

Motor Performance†





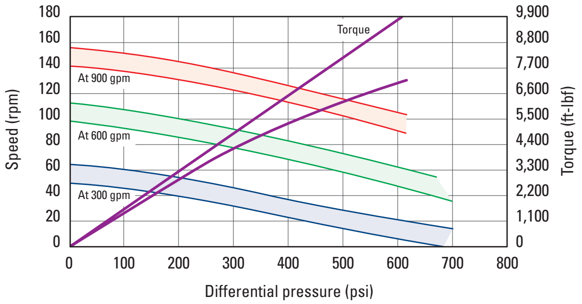
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

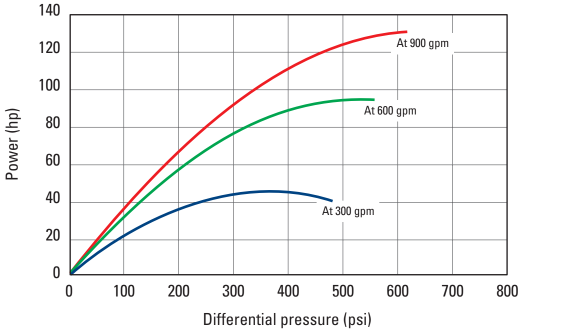
4.1 Performance Data

PowerPak A775SP, 7¾-in. OD, 7:8 Lobes, 3.0 Stages	
Tool Data	
Weight	3,400 lbm [1,542 kgm]
Nominal length (A)	23.60 ft [7.19 m]
Bit box to bend (B)	6.03 ft [1.84 m]
Bit box to center of stabilizer (C)	1.75 ft [0.53 m]
Performance Data	
Standard flow rate	300–900 gpm [1,140–2,270 L/min]
Nozzle flow rate	300–1,100 gpm [1,140–3,030 L/min]
Bit speed (free running)	45–145 rpm
Revolutions per unit volume	0.16/gal [0.06/L]
Max power	132 hp [216 kW]

na = not applicable

Motor Performance†

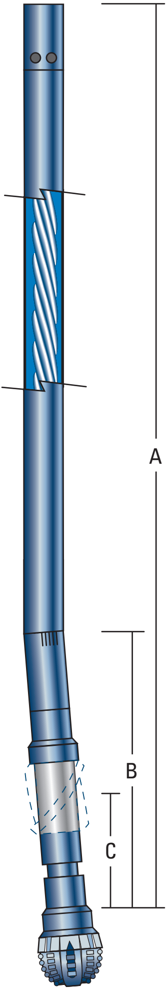




†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

775

Schlumberger



PowerPak A825 8¼-in. OD		
Adjustable bent housing settings (0°–2°)	0.00°	0.26°
	0.52°	0.77°
	1.00°	1.22°
	1.41°	1.59°
	1.73°	1.85°
	1.93°	1.98°
	2.00°	
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
		3.00°
Stabilizer sleeve makeup torque	23,000 ft-lbf [31,180 N·m]	
Bent housing adjustment makeup torque	35,000 ft-lbf [47,450 N·m]	
Bit size	9⅞–14¾ in.	
Bit connection	6⅝ REG	
Top connection	6⅝ REG or 5½ IF	
Working overpull (no motor damage)	219,500 lbf [976 kN]	
Max WOB with flow (no motor damage)	50,000 lbf [222 kN]	
Max WOB without flow (no motor damage)	125,000 lbf [556 kN]	
Absolute overpull (motor damage will occur)	754,800 lbf [3,358 kN]	

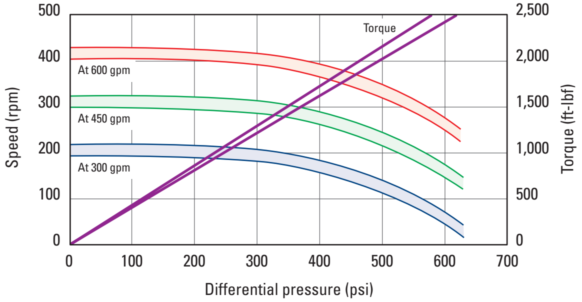
Note: These limits apply only when bit is stuck.

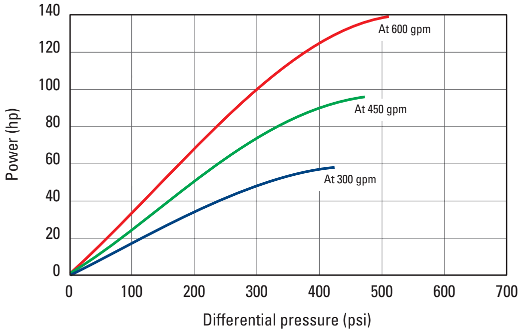
4.1 Performance Data

PowerPak A825SP, 8¼-in. OD, 1:2 Lobes, 4.0 Stages	
Tool Data	
Weight	3,655 lbm [1,660 kgm]
Nominal length (A)	25.85 ft [7.88 m]
Bit box to bend (B)	7.06 ft [2.15 m]
Bit box to center of stabilizer (C)	2.01 ft [0.61 m]
Performance Data	
Standard flow rate	300–600 gpm [1,140–2,270 L/min]
Nozzle flow rate	na
Bit speed (free running)	210–430 rpm
Revolutions per unit volume	0.72/gal [0.19/L]
Max power	138 hp [103 kW]

na = not applicable

Motor Performance†



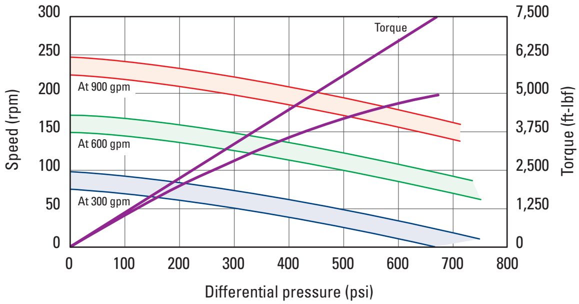


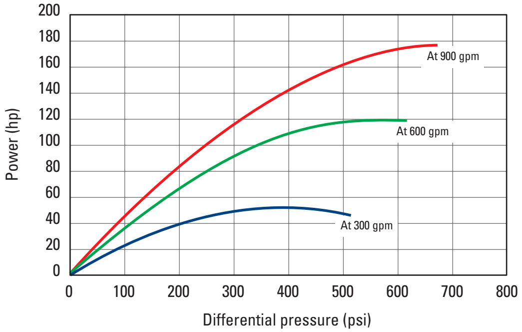
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

825

PowerPak A825SP, 8¼-in. OD, 4:5 Lobes, 3.6 Stages	
Tool Data	
Weight	3,650 lbm [1,655 kgm]
Nominal length (A)	23.60 ft [7.19 m]
Bit box to bend (B)	7.06 ft [2.15 m]
Bit box to center of stabilizer (C)	2.01 ft [0.61 m]
Performance Data	
Standard flow rate	300–900 gpm [1,140–3,410 L/min]
Nozzle flow rate	300–1,100 gpm [1,140–3,030 L/min]
Bit speed (free running)	75–225 rpm
Revolutions per unit volume	0.25/gal [0.07/L]
Max power	178 hp [133 kW]

Motor Performance†



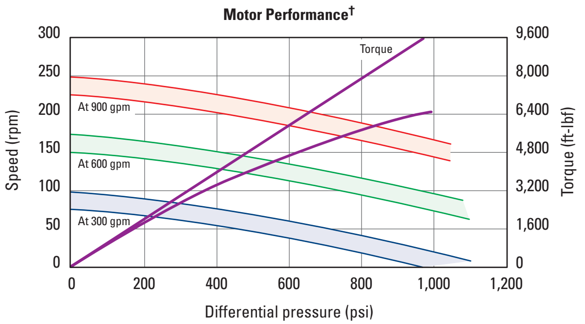


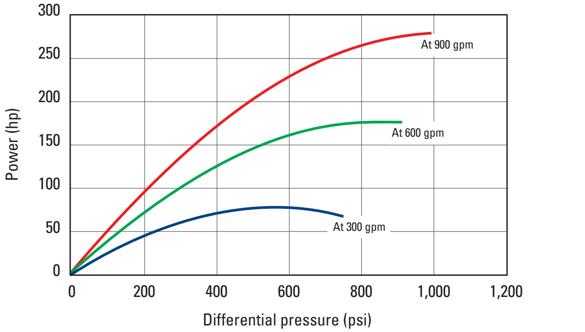
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

825

4.1 Performance Data

PowerPak A825XP, 8¼-in. OD, 4:5 Lobes, 5.3 Stages	
Tool Data	
Weight	4,700 lbm [2,130 kgm]
Nominal length (A)	29.27 ft [8.92 m]
Bit box to bend (B)	7.06 ft [2.15 m]
Bit box to center of stabilizer (C)	2.01 ft [0.61 m]
Performance Data	
Standard flow rate	300–900 gpm [1,140–3,410 L/min]
Nozzle flow rate	300–1,100 gpm [1,140–3,030 L/min]
Bit speed (free running)	75–225 rpm
Revolutions per unit volume	0.25/gal [0.07/L]
Max power	280 hp [209 kW]



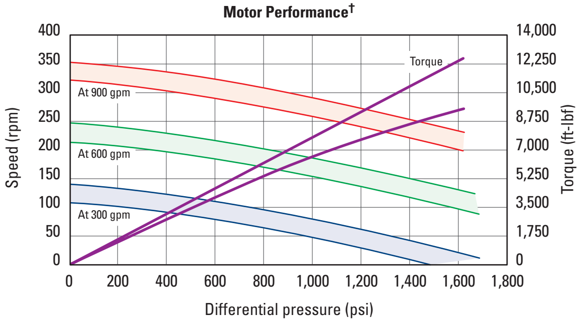


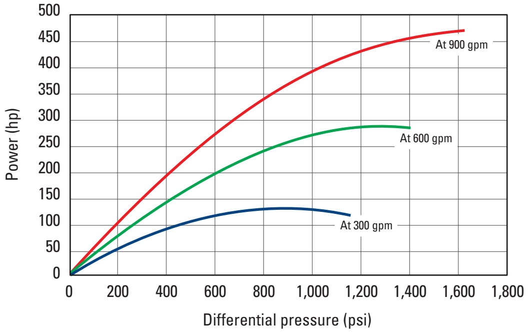
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

825

Schlumberger

PowerPak A825GT, 8¼-in. OD, 4:5 Lobes, 8.2 Stages	
Tool Data	
Weight	4,980 lbm [2,260 kgm]
Nominal length (A)	30.77 ft [9.38 m]
Bit box to bend (B)	7.06 ft [2.15 m]
Bit box to center of stabilizer (C)	2.01 ft [0.61 m]
Performance Data	
Standard flow rate	300–900 gpm [1,140–3,410 L/min]
Nozzle flow rate	300–1,100 gpm [1,140–3,030 L/min]
Bit speed (free running)	115–340 rpm
Revolutions per unit volume	0.38/gal [0.10/L]
Max power	470 hp [351 kW]



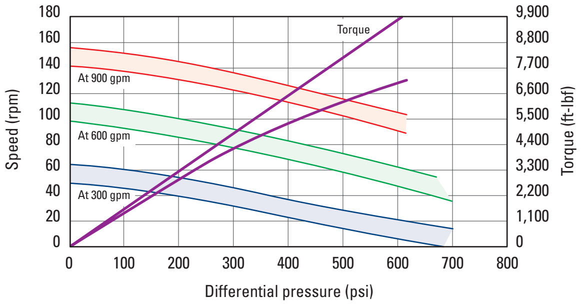


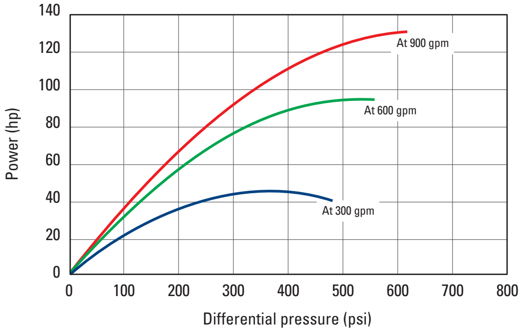
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

4.1 Performance Data

PowerPak A825SP, 8¼-in. OD, 7:8 Lobes, 3.0 Stages	
Tool Data	
Weight	3,500 lbm [1,590 kgm]
Nominal length (A)	23.60 ft [7.19 m]
Bit box to bend (B)	7.06 ft [2.15 m]
Bit box to center of stabilizer (C)	2.01 ft [0.61 m]
Performance Data	
Standard flow rate	300–900 gpm [1,140–3,410 L/min]
Nozzle flow rate	300–1,100 gpm [1,140–3,030 L/min]
Bit speed (free running)	45–145 rpm
Revolutions per unit volume	0.16/gal [0.04/L]
Max power	132 hp [99 kW]

Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

PowerPak A825XP, 8¼-in. OD, 7:8 Lobes, 4.0 Stages

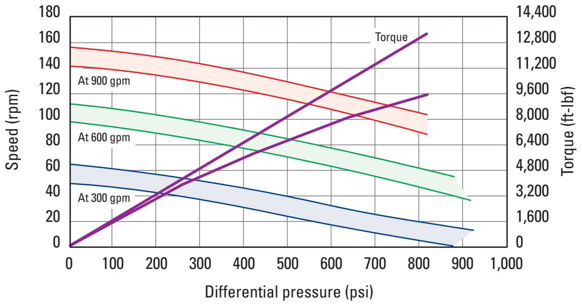
Tool Data

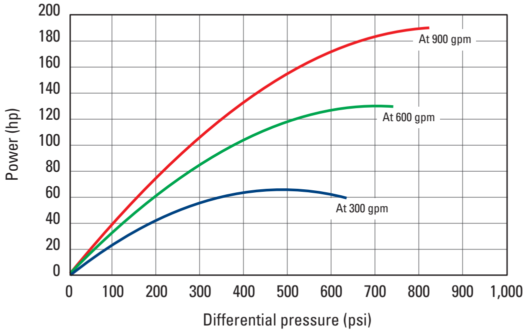
Weight	4,020 lbm [1,825 kgm]
Nominal length (A)	27.60 ft [8.41 m]
Bit box to bend (B)	7.06 ft [2.15 m]
Bit box to center of stabilizer (C)	2.01 ft [0.61 m]

Performance Data

Standard flow rate	300–900 gpm [1,140–3,410 L/min]
Nozzle flow rate	300–1,100 gpm [1,140–3,030 L/min]
Bit speed (free running)	45–145 rpm
Revolutions per unit volume	0.16/gal [0.04/L]
Max power	190 hp [142 kW]

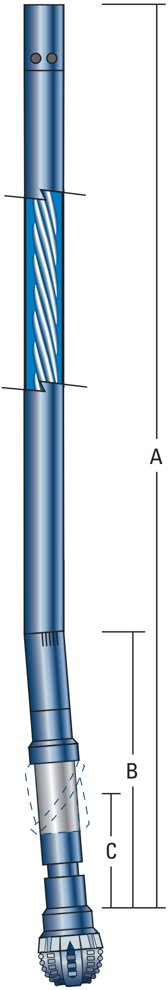
Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

825

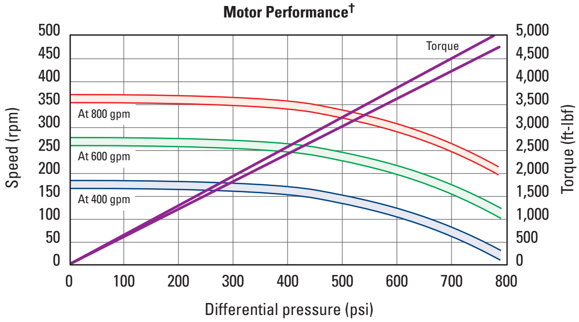


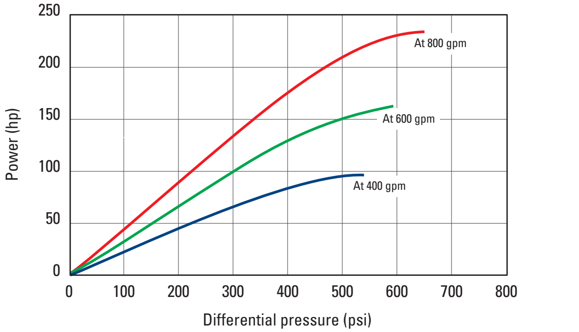
PowerPak A962 9⅝-in. OD		
Adjustable bent housing settings (0°–2°)	0.00°	0.26°
	0.52°	0.77°
	1.00°	1.22°
	1.41°	1.59°
	1.73°	1.85°
	1.93°	1.98°
	2.00°	
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Stabilizer sleeve makeup torque	37,000 ft-lbf [50,170 N·m]	
Bent housing adjustment makeup torque	60,000 ft-lbf [81,350 N·m]	
Bit size	12¼–26 in.	
Bit connection	6⅝ or 7⅝ REG or 8⅝ REG	
Top connection	6⅝ or 7⅝ REG or 8⅝ REG	
Working overpull (no motor damage)	338,200 lbf [1,504 kN]	
Max WOB with flow (no motor damage)	75,000 lbf [334 kN]	
Max WOB without flow (no motor damage)	225,000 lbf [1,000 kN]	
Absolute overpull (motor damage will occur)	1,340,000 lbf [5,961 kN]	

Note: These limits apply only when bit is stuck.

PowerPak A962SP, 9⅝-in. OD, 1:2 Lobes, 5.0 Stages	
Tool Data	
Weight	5,180 lbm [2,350 kgm]
Nominal length (A)	29.21 ft [8.90 m]
Bit box to bend (B)	7.78 ft [2.37 m]
Bit box to center of stabilizer (C) 2.35 ft [0.72 m]	
Performance Data	
Standard flow rate	400–800 gpm [1,510–3,030 L/min]
Nozzle flow rate	na
Bit speed (free running)	190–380 rpm
Revolutions per unit volume	0.48/gal [0.13/L]
Max power	236 hp [176 kW]

na = not applicable





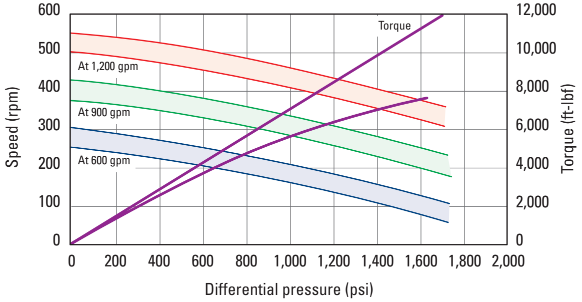
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

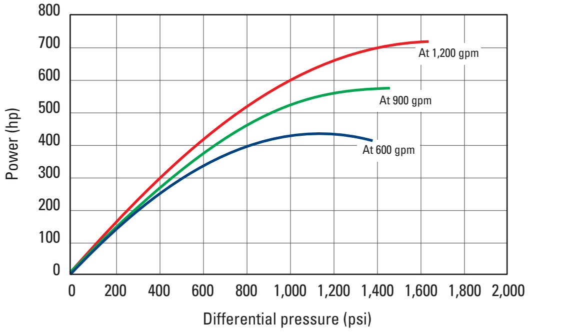
962

4.1 Performance Data

PowerPak A962HS, 9⅝-in. OD, 2:3 Lobes, 9.2 Stages	
Tool Data	
Weight	6,250 lbm [2,835 kgm]
Nominal length (A)	32.02 ft [9.76 m]
Bit box to bend (B)	7.78 ft [2.37 m]
Bit box to center of stabilizer (C)	2.35 ft [0.72 m]
Performance Data	
Standard flow rate	600–1,200 gpm [2,270–4,540 L/min]
Nozzle flow rate	600–1,500 gpm [2,270–5,680 L/min]
Bit speed (free running)	250–500 rpm
Revolutions per unit volume	0.42/gal [0.11/L]
Max power	709 hp [560 kW]

Motor Performance†



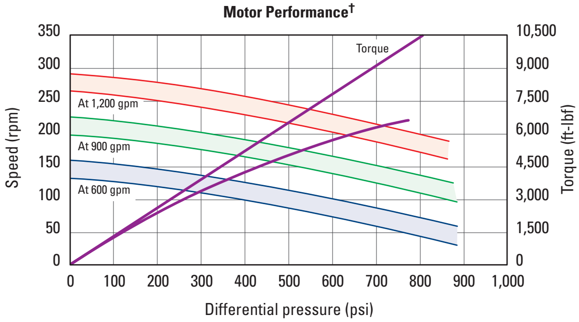


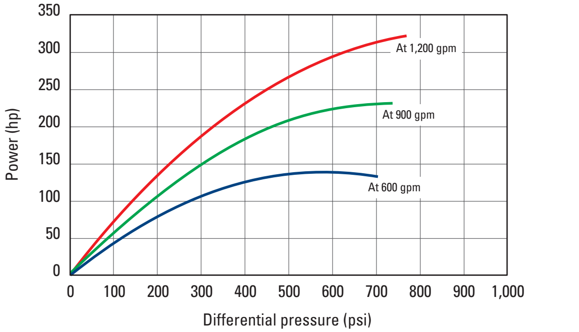
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

962

Schlumberger

PowerPak A962SP, 9⅝-in. OD, 3:4 Lobes, 4.5 Stages	
Tool Data	
Weight	5,100 lbm [2,315 kgm]
Nominal length (A)	26.29 ft [8.01 m]
Bit box to bend (B)	7.78 ft [2.37 m]
Bit box to center of stabilizer (C)	2.35 ft [0.72 m]
Performance Data	
Standard flow rate	600–1,200 gpm [2,270–4,540 L/min]
Nozzle flow rate	600–1,500 gpm [2,270–5,680 L/min]
Bit speed (free running)	135–265 rpm
Revolutions per unit volume	0.22/gal [0.06/L]
Max power	319 hp [238 kW]

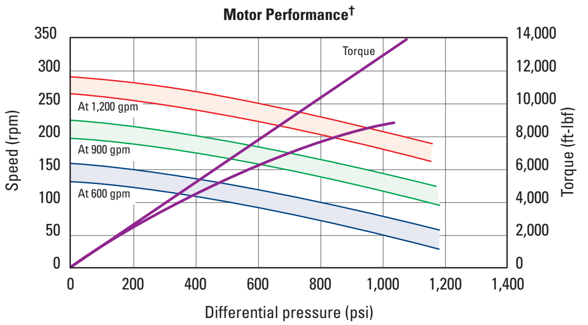


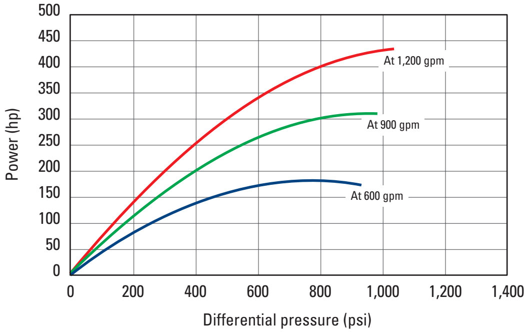


†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

4.1 Performance Data

PowerPak A962XP, 9⅝-in. OD, 3:4 Lobes, 6.0 Stages	
Tool Data	
Weight	5,750 lbm [2,610 kgm]
Nominal length (A)	30.48 ft [9.29 m]
Bit box to bend (B)	7.78 ft [2.37 m]
Bit box to center of stabilizer (C)	2.35 ft [0.72 m]
Performance Data	
Standard flow rate	600–1,200 gpm [2,270–4,540 L/min]
Nozzle flow rate	600–1,500 gpm [2,270–5,680 L/min]
Bit speed (free running)	135–265 rpm
Revolutions per unit volume	0.22/gal [0.06/L]
Max power	435 hp [325 kW]



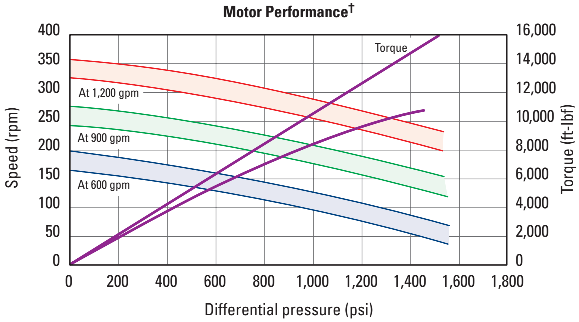


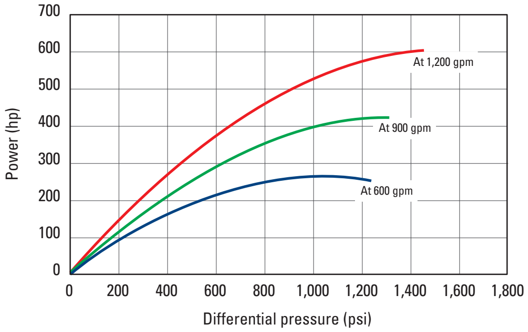
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

962

Schlumberger

PowerPak A962GT, 9⅝-in. OD, 3:4 Lobes, 8.0 Stages	
Tool Data	
Weight	6,300 lbm [2,860 kgm]
Nominal length (A)	31.81 ft [9.70 m]
Bit box to bend (B)	7.78 ft [2.37 m]
Bit box to center of stabilizer (C)	2.35 ft [0.72 m]
Performance Data	
Standard flow rate	600–1,200 gpm [2,270–4,540 L/min]
Nozzle flow rate	600–1,500 gpm [2,270–5,680 L/min]
Bit speed (free running)	167–333 rpm
Revolutions per unit volume	0.28/gal [0.07/L]
Max power	603 hp [450 kW]

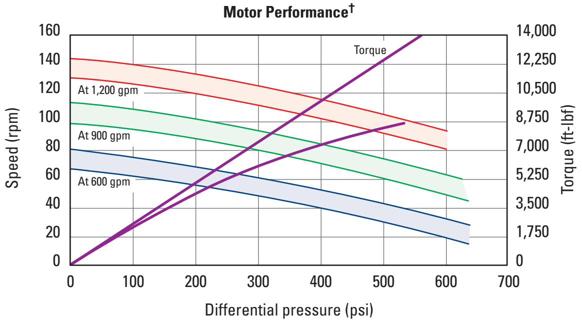


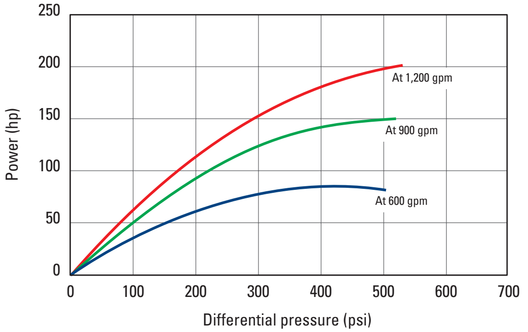


†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

962

PowerPak A962SP, 9⅝-in. OD, 5:6 Lobes, 3.0 Stages	
Tool Data	
Weight	5,400 lbm [2,450 kgm]
Nominal length (A)	26.29 ft [8.01 m]
Bit box to bend (B)	7.78 ft [2.37 m]
Bit box to center of stabilizer (C)	2.35 ft [0.72 m]
Performance Data	
Standard flow rate	600–1,200 gpm [2,270–4,540 L/min]
Nozzle flow rate	600–1,500 gpm [2,270–5,680 L/min]
Bit speed (free running)	65–135 rpm
Revolutions per unit volume	0.11/gal [0.03/L]
Max power	201 hp [150 kW]





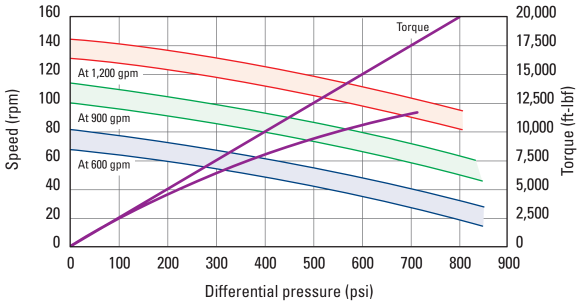
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

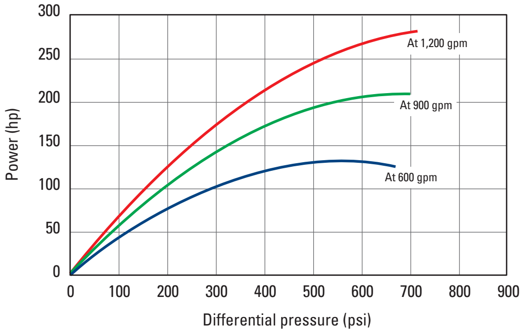
962

Schlumberger

PowerPak A962XP, 9⅝-in. OD, 5:6 Lobes, 4.0 Stages	
Tool Data	
Weight	6,130 lbm [2,780 kgm]
Nominal length (A)	30.48 ft [9.29 m]
Bit box to bend (B)	7.78 ft [2.37 m]
Bit box to center of stabilizer (C)	2.35 ft [0.72 m]
Performance Data	
Standard flow rate	600–1,200 gpm [2,270–4,540 L/min]
Nozzle flow rate	600–1,500 gpm [2,270–5,680 L/min]
Bit speed (free running)	65–135 rpm
Revolutions per unit volume	0.11/gal [0.03/L]
Max horsepower	280 hp [209 kW]

Motor Performance†





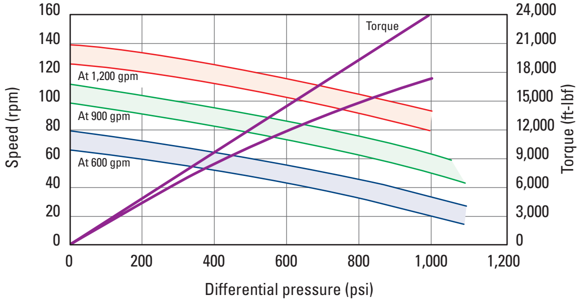
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

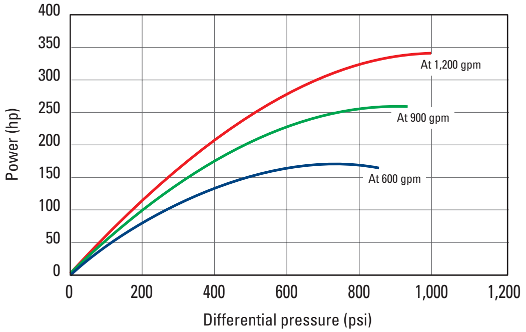
962

4.1 Performance Data

PowerPak A962GT, 9⅝-in. OD, 7:8 Lobes, 4.8 Stages	
Tool Data	
Weight	6,350 lbm [2,880 kgm]
Nominal length (A)	32.02 ft [9.76 m]
Bit box to bend (B)	7.78 ft [2.37 m]
Bit box to center of stabilizer (C)	2.35 ft [0.72 m]
Performance Data	
Standard flow rate	600–1,200 gpm [2,270–4,540 L/min]
Nozzle flow rate	600–1,500 gpm [2,270–5,680 L/min]
Bit speed (free running)	65–130 rpm
Revolutions per unit volume	0.11/gal [0.03/L]
Max horsepower	342 hp [255 kW]

Motor Performance†

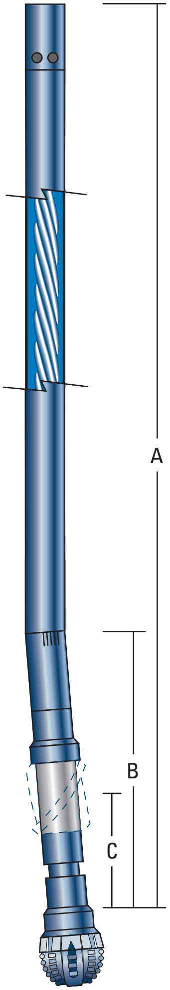




†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

962

Schlumberger

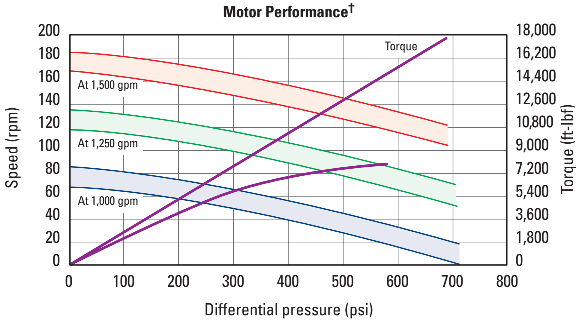


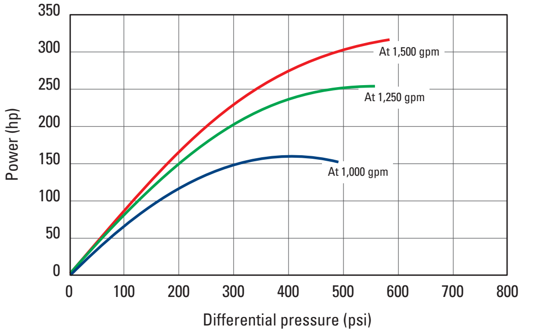
PowerPak A1125 11¼-in. OD		
Adjustable bent housing settings (0°–2°)	0.00°	0.26°
	0.52°	0.77°
	1.00°	1.22°
	1.41°	1.59°
	1.73°	1.85°
	1.93°	1.98°
	2.00°	
Adjustable bent housing settings (0°–3°)	0.00°	0.39°
	0.78°	1.15°
	1.50°	1.83°
	2.12°	2.38°
	2.60°	2.77°
	2.90°	2.97°
	3.00°	
Stabilizer sleeve makeup torque	37,000 ft-lbf [50,170 N·m]	
Bent housing adjustment makeup torque	85,000 ft-lbf [115,240 N·m]	
Bit size	17½–26 in.	
Bit connection	7⅝ REG or 8⅝ REG	
Top connection	7⅝ REG or 8⅝ REG	
Working overpull (no motor damage)	338,200 lbf [1,504 kN]	
Max WOB with flow (no motor damage)	75,000 lbf [334 kN]	
Max WOB without flow (no motor damage)	225,000 lbf [1,000 kN]	
Absolute overpull (motor damage will occur)	1,340,000 lbf [5,961 kN]	

Note: These limits apply only when bit is stuck.

4.1 Performance Data

PowerPak A1125SP, 11¼-in. OD, 3:4 Lobes, 3.6 Stages	
Tool Data	
Weight	6,400 lbm [2,905 kgm]
Nominal length (A)	29.02 ft [8.85 m]
Bit box to bend (B)	8.29 ft [2.53 m]
Bit box to center of stabilizer (C)	2.35 ft [0.72 m]
Performance Data	
Standard flow rate	1,000–1,500 gpm [3,790–5,680 L/min]
Nozzle flow rate	1,000–1,700 gpm [3,790–6,430 L/min]
Bit speed (free running)	115–170 rpm
Revolutions per unit volume	0.11/gal [0.03/L]
Max power	318 hp [237 kW]





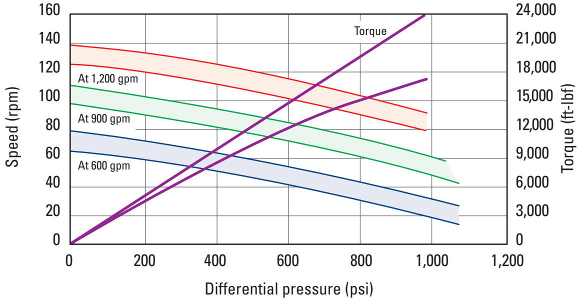
†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

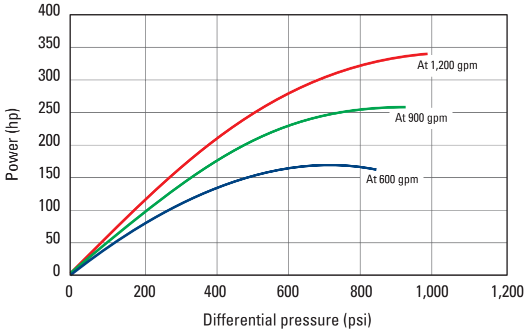
PowerPak A1125GT, 11¼-in. OD, 7:8 Lobes, 4.8 Stages

Tool Data	
Weight	8,500 lbm [3,855 kgm]
Nominal length (A)	32.02 ft [9.76 m]
Bit box to bend (B)	8.29 ft [2.53 m]
Bit box to center of stabilizer (C) 2.35 ft [0.72 m]	
Performance Data	
Standard flow rate	600–1,200 gpm [2,270–4,540 L/min]
Nozzle flow rate	600–1,500 gpm [2,270–5,680 L/min]
Bit speed (free running)	65–130 rpm
Revolutions per unit volume	0.11/gal [0.03/L]
Max power	342 hp [255 kW]

na = not applicable

Motor Performance†





†Output curves based on nominal rotor-stator fit tested at room temperature with water as the drilling fluid.

Table 5-1. Total Flow Area—Comparison of Values

Size (in.)	Flow Area (in.²) with Number of Jets								
	1	2	3	4	5	6	7	8	9
7/32	0.038	0.075	0.113	0.150	0.188	0.225	0.263	0.301	0.338
8/32	0.049	0.098	0.147	0.196	0.245	0.295	0.344	0.393	0.442
9/32	0.062	0.124	0.186	0.249	0.311	0.373	0.435	0.497	0.559
10/32	0.077	0.153	0.230	0.307	0.383	0.460	0.537	0.614	0.690
11/32	0.093	0.186	0.278	0.371	0.464	0.557	0.650	0.742	0.835
12/32	0.110	0.221	0.331	0.442	0.552	0.663	0.773	0.884	0.994
13/32	0.130	0.259	0.389	0.518	0.648	0.778	0.907	1.037	1.167
14/32	0.150	0.301	0.451	0.601	0.752	0.902	1.052	1.203	1.353
15/32	0.173	0.345	0.518	0.690	0.863	1.035	1.208	1.381	1.553
16/32	0.196	0.393	0.589	0.785	0.982	1.178	1.374	1.571	1.767
17/32	0.222	0.443	0.665	0.887	1.108	1.330	1.552	1.773	1.995
18/32	0.249	0.497	0.746	0.994	1.243	1.491	1.740	1.988	2.237
19/32	0.277	0.554	0.831	1.108	1.384	1.661	1.938	2.215	2.492
20/32	0.307	0.614	0.920	1.227	1.534	1.841	2.148	2.454	2.761
22/32	**0.371**	**0.742**	**1.114**	**1.485**	**1.856**	**2.227**	**2.599**	**2.970**	**3.341**

Table 5-2. Buoyancy and Drilling Fluid Density[†]

Drilling Fluid Density (ppg)	Buoyancy Factor
8.5	0.871
9.0	0.863
9.5	0.855
10.0	0.847
10.5	0.840
11.0	0.832
11.5	0.825
12.0	0.817
12.5	0.810
13.0	0.802
13.5	0.794
14.0	0.786
14.5	0.779
15.0	0.771
15.5	0.764
16.0	0.756
16.5	0.749
17.0	0.741
17.5	0.733
18.0	**0.725**

[†]Figures for steel only

Table 5-3. Drilling Fluid Density

Drilling Fluid Density		Specific Gravity	Gradient Depth
(ppg)	(lbm/ft³)		(psi/ft)
8.3	62.38	1.00	0.433
8.4	62.83	1.01	0.436
8.5	63.58	1.02	0.441
8.6	64.33	1.03	0.447
8.7	65.08	1.04	0.452
8.8	65.92	1.06	0.457
8.9	66.57	1.07	0.462
9.0	67.32	1.08	0.467
9.1	68.07	1.09	0.472
9.2	68.82	1.10	0.478
9.3	69.56	1.12	0.483
9.4	70.31	1.13	0.488
9.5	71.06	1.14	0.493
9.6	71.81	1.15	0.498
9.7	72.56	1.16	0.504
9.8	73.30	1.18	0.509
9.9	74.05	1.19	0.514
10.0	74.80	1.20	0.519
10.1	75.55	1.21	0.524
10.2	76.30	1.22	0.530
10.3	77.04	1.24	0.535
10.4	77.79	1.25	0.540
10.5	78.54	1.26	0.545
10.6	79.29	1.27	0.550
10.7	80.04	1.28	0.556
10.8	80.78	1.30	0.561
10.9	81.53	1.31	0.566
11.0	82.28	1.32	0.571
11.1	83.03	1.33	0.576
11.2	83.78	1.34	0.581
11.3	84.52	1.36	0.587
11.4	85.27	1.37	0.592
11.5	86.02	1.38	0.597
11.6	86.77	1.39	0.602
11.7	87.52	1.40	0.607
11.8	88.26	1.42	0.613
11.9	89.01	1.43	0.618
12.0	89.76	1.44	0.623
12.1	90.51	1.45	0.628
12.2	91.26	1.46	0.633
12.3	92.00	1.48	0.639
12.4	92.75	1.49	0.644
12.5	93.50	1.50	0.649
12.6	94.25	1.51	0.654

Table 5-3. Drilling Fluid Density (continued)

Drilling Fluid Density (ppg)	Drilling Fluid Density (lbm/ft³)	Specific Gravity	Gradient Depth (psi/ft)
12.7	95.00	1.52	0.659
12.8	95.74	1.54	0.664
12.9	96.49	1.55	0.670
13.0	97.24	1.56	0.675
13.1	97.99	1.57	0.680
13.2	98.74	1.58	0.685
13.3	99.48	1.60	0.690
13.4	100.23	1.61	0.696
13.5	100.98	1.62	0.701
13.6	101.73	1.63	0.706
13.7	102.48	1.64	0.711
13.8	103.22	1.66	0.717
13.9	103.97	1.67	0.722
14.0	104.72	1.68	0.727
14.1	105.47	1.69	0.732
14.2	106.22	1.70	0.737
14.3	106.96	1.72	0.742
14.4	107.71	1.73	0.748
14.5	108.46	1.74	0.753
14.6	109.21	1.75	0.758
14.7	109.96	1.76	0.763
14.8	110.70	1.78	0.768
14.9	111.45	1.79	0.774
15.0	112.20	1.80	0.779
15.1	112.95	1.81	0.784
15.2	113.70	1.82	0.789
15.3	114.44	1.84	0.794
15.4	115.19	1.85	0.800
15.5	115.94	1.86	0.805
15.6	116.69	1.87	0.810
15.7	117.44	1.88	0.815
15.8	118.18	1.90	0.821
15.9	118.93	1.91	0.825
16.0	119.68	1.92	0.831
16.1	120.43	1.93	0.836
16.2	121.18	1.94	0.841
16.3	121.92	1.96	0.846
16.4	122.67	1.97	0.851
16.5	123.42	1.98	0.857
16.6	124.17	1.99	0.862
16.7	124.92	2.00	0.867
16.8	125.66	2.02	0.872
16.9	126.41	2.03	0.877
17.0	127.16	2.04	0.883

Table 5-4. Drill Collar Weight

Drill Collar OD (in.)	Weight (lbm-ft) with Bore of Collar (in.)												
	1	1¼	1½	1¾	2	2¼	2½	2¹³⁄₁₆	3	3¼	3½	3¾	4
2⅞	19	18	16										
3	21	20	18										
3⅛	22	22	20										
3¼	26	24	22										
3½	30	29	27										
3¾	35	33	32										
4	40	39	37	35	32	29							
4⅛	43	41	39	37	35	32							
4¼	46	44	42	40	38	35							
4½	51	50	48	46	43	41							
4¾			54	52	50	47	44						
5			61	59	56	53	50						
5¼			68	65	63	60	57						
5½			75	73	70	67	64	60					
5¾			82	80	78	75	72	67	64	60			

Source: API Publication 7G, “Drill Stem Design and Operating Limits,” 15th ed. (January 1, 1995). Reprinted courtesy of the American Petroleum Institute.

Table 5-4. Drill Collar Weight (continued)

Drill Collar OD (in.)	Weight (lbm-ft) with Bore of Collar (in.)											
	1	1¼	1½	1¾	2	2¼	2½	2¹³⁄₁₆	3	3¼	3½	3¾	4
6			90	88	85	83	79	75	72	68			
6¼			98	96	94	91	88	83	80	76	72		
6½			107	105	102	99	96	91	89	85	80		
6¾			116	114	111	108	105	100	98	93	89		
7			125	123	120	117	114	110	107	103	98	93	84
7¼			134	132	130	127	124	119	116	112	108	103	93
7½			144	142	139	137	133	129	126	122	117	113	102
7¾			154	152	150	147	144	139	136	132	128	123	112
8			165	163	160	157	154	150	147	143	138	133	122
8¼			176	174	171	168	165	160	158	154	149	144	133
8½			187	185	182	179	176	172	169	165	160	155	150
9			210	208	206	203	200	195	192	188	184	179	174
9½			234	232	230	227	224	220	216	212	209	206	198
9¾			248	245	243	240	237	232	229	225	221	216	211
10			261	259	257	254	251	246	243	239	235	230	225
11			317	315	313	310	307	302	299	295	291	286	281
12			379	377	374	371	368	364	361	357	352	347	342

Source: API Publication 7G, "Drill Stem Design and Operating Limits," 15th ed. (January 1, 1995). Reprinted courtesy of the American Petroleum Institute.

Table 5-5. Heavy-Weight Drillpipe Properties

Nominal Size (in.)	Pipe ID (in.)	Nominal Weight (lbm/ft)	Tool Joint Connection
Standard			
3½	2.063	25.3	3½ IF NC 38
4	2.563	29.7	4 FH NC 40
4½	2.750	41.0	4 IF NC 46
5	3.000	48.5	4½ IF NC 50
5½	3.313	58.1	5½ FH
6⅝	4.500	70.5	6⅝ FH
Spiral-Wate®			
3½	2.063	25.3	3½ IF NC 38
4	2.563	29.7	4 FH NC 40
4½	2.750	41.0	4 IF NC 46
5	3.000	49.3	4½ IF NC 50
5½	3.313	58.1	5½ FH —
6⅝	4.500	70.5	6⅝ FH —

Table 5-6. Drillpipe Properties

OD (in.)	Nominal Weight Threads/ Couplings (lbm/ft)	Plain End Weight† (lbm/ft)	Wall Thickness (in.)	ID (in.)	Section Area Body of Pipe‡ ($in.^2$)
2⅜	4.85§	4.43	0.190	1.995	1.3042
	6.65	6.26	0.280	1.815	1.8429
2⅞	6.85§	6.16	0.217	2.441	1.8120
	10.40	9.72	0.362	2.151	2.8579
3½	9.50	8.81	0.254	2.992	2.5902
	13.30	12.31	0.368	2.764	3.6209
	15.50	14.63	0.449	2.602	4.3037
4	11.85§	10.46	0.262	3.476	3.0767
	14.00	12.93	0.330	3.340	3.8048
	15.70§	14.69	0.380	3.240	4.3216
4½	13.75	12.24	0.271	3.958	3.6004
	16.60	14.98	0.337	3.826	4.4074
	20.00	18.69	0.430	3.640	5.4981
5	16.25§	14.87	0.296	4.408	4.3743
	19.50	17.93	0.362	4.276	5.2746
	25.60	24.03	0.500	4.000	7.0686
5½	19.20§	16.87	0.304	4.892	4.9624
	21.90	19.81	0.361	4.778	5.8282
	24.70	22.54	0.415	4.670	6.6296
6⅝	25.20	22.19	0.330	5.965	6.5262

†lbm/ft = 3.3996 × section area body of pipe

‡Section area body of pipe = 0.7854 × ($OD^2 - ID^2$)

§These sizes and weights are non-API and are not included in API Specification 5A or 5AX.

Table 5-7. Rotary-Shouldered Connection Interchange List

Common Name (Style)	Size	Same as or Interchanges With
Internal flush (IF)	2⅜ in.	2⅞-in. slimhole NC 26
	2⅞ in.	3½-in. slimhole NC 31
	3½ in.	4½-in. slimhole NC 38
	4 in.	4½-in. extra hole NC 46
	4½ in.	5-in. extra hole NC 50
	4½ in.	5½-in. double streamline
Full hole (FH)	4 in.	4½-in. double streamline NC 40
Extra hole (XH) (EH)	2⅞ in.	3½-in. double streamline
	3½ in.	4-in. slim hole
	3½ in.	4½-in. external flush
	4½ in.	4-in. internal flush NC 46
	5 in.	4½-in. internal flush NC 50
	5 in.	5½-in. double streamline
Slim hole (SH)	2⅞ in	2⅜-in. internal flush NC 26
	3½ in.	2⅞-in. internal flush NC 31
	4 in.	3½-in. extra hole
	4 in.	4½-in. external flush
	4½ in.	3½-in. internal flush NC 38
Double streamline (DSL)	3½ in.	2⅞-in. extra hole
	4½ in.	4-in. full hole NC 40
	5½ in.	4½-in. internal flush
	5½ in.	5-in. extra hole NC 50
Numbered connections (NC)	26	2⅜-in. internal flush
	26	2⅞-in. slim hole
	31	2⅞-in. internal flush
	31	3½-in. slim hole
	38	3½-in. internal flush
	38	4½-in. slim hole
	40	4-in. full hole
	40	4½-in. double streamline
	46	4-in. internal flush
	46	4½-in. extra hole
	50	4½-in. internal flush
	50	5-in. extra hole
	50	5½-in. double streamline
External flush (EF)	4½ in.	4-in. slim hole
	4½ in.	3½-in. extra hole

Source: API Publication 7G, "Drill Stem Design and Operating Limits," 15th ed. (January 1, 1995). Reprinted courtesy of the American Petroleum Institute.

Engineering formulas

Mechanical power

Mechanical power is calculated in standard units with

$$HP_{mechanical} = \frac{T \times S_r}{5252}$$

and in metric units with

$$HP_{mechanical} = \frac{2\pi \times T \times S_r}{60}.$$

Hydraulic power

Hydraulic power is calculated in standard units with

$$HP_{hydraulic} = \frac{q_m \times p_d}{1714}$$

and in metric units with

$$HP_{hydraulic} = \frac{100 \times q_m \times p_d}{60}.$$

Motor efficiency

Motor effeciency is calculated in standard units with

$$E = \frac{32.64 \times T \times S_r}{q_m \times p_d}$$

and in metric units with

$$E = \frac{2\pi \times T \times S_r}{q_m \times p_d}.$$

For nomenclature and units, please see page 203.

6.0 Reference Equations and Nomenclature

Engineering formulas

Fluid velocity

Fluid velocity is calculated in standard units with

$$v_f = \frac{0.3208 \times q_m}{A_N}$$

and in metric units with

$$v_f = \frac{q_m}{A_N}.$$

Hydrostatic pressure

Hydrostatic pressure is calculated in standard units with

$$p_{hydrostatic} = 0.052 \times D \times W_m$$

and in metric units with

$$p_{hydrostatic} = 9.81 \times D \times W_m.$$

Bit pressure drop

Bit pressure drop is calculated in standard units with

$$p_b = \frac{q_m{}^2 \times W_m}{10,858 \times A_N{}^2}.$$

and in metric units with

$$p_b = \frac{q_m{}^2 \times W_m}{6.496 \times A_N{}^2}.$$

For nomenclature and units, please see page 203.

6.0 Reference Equations and Nomenclature

Nomenclature

A_N = nozzle total flow area, in.^{2} [mm^2]

D = depth, ft [m]

E = efficiency, percent

$HP_{mechanical}$ = motor mechanical power, hp [watt]

$HP_{hydraulic}$ = hydraulic power, hhp [watt]

n = number of rotor lobes

O_m = maximum overpull, lbf [N]

p_b = bit pressure drop, psi [pascals]

p_d = motor differential pressure, psi [bar]

p_{d+f} = Expected differential drilling pressure + friction pressure, psi [bar]

$p_{hydrostatic}$ = hydrostatic pressure, psi [kP]

$p_{standpipe}$ = standpipe pressure, psi [bar]

q = flow rate to bypass power section, gpm [L/min]

q_m = mud flow rate, gpm [L/min]

$q_{maximum}$ = maximum flow rate, gpm [L/min]

S_r = drive shaft rotary speed, rpm

T = output torque, ft-lbf [N·m]

t_h = hydraulic thrust, lbf

v_f = fluid velocity, ft/s [m/s]

W_{bc} = bearing weight capacity, lbm [kgm]

W_m = mud weight, ppg [sg]

W_{mb} = maximum weight on bit, lbm [kgm]

W_{parts} = weight of rotating parts in mud, lbm [kgm]

X = a constant related to the cross-sectional area of the rotor. See Table 2-5.

Y = a constant related to the cross-sectional area of the bearings. See Table 2-5.