# High-Power Drilling Motor Field Tests

**by**

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## INTRODUCTION

High drilling costs are a major constraint on the development of marginal oil and gas reserves in the USA. Hole-making drilling costs constitute approximately 50 percent of the total well costs, so increasing drilling rate can have a major impact on drilling costs.

Doubling drilling rates in oil and gas wells could save hundreds of million of dollars in the USA and significantly improve the economics of producing marginal oil and gas reservoirs.

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## OBJECTIVE

The objective of this project is to double the power output of downhole positive-displacement motors (PDMs) so that they will drill twice as fast. Doubling the drilling rate will reduce drilling costs by up to 25 percent since approximately 50 percent of well costs are spent in making the hole, which is directly related to drilling rate.

## APPROACH

A PDM motor utilizes a steel rotor and a rubber stator to convert hydraulic power to mechanical power to rotate the drill bit. PDM stators contains one more lobe than the rotors, as shown in **Figures 1** and **2**.

For a given rotor/stator design, motor speed is proportional to flow rate and motor torque is proportional to pressure drop across the motor. Multilobe motors have larger volumetric displacement than single-lobe motors and therefore deliver higher torque and run at lower speeds.

The pressure drop, p, across a motor equals:

$$p = np_s \tag{1}$$

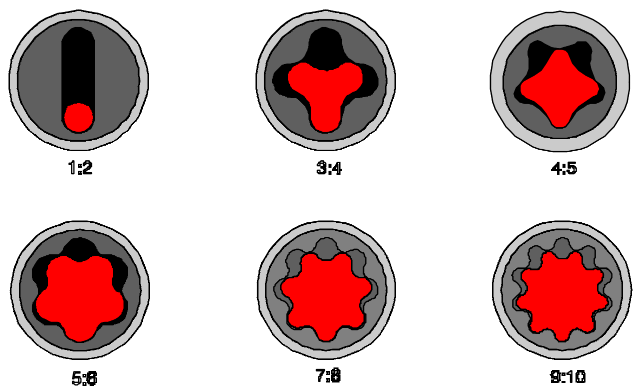


Fig. 1. PDM Multilobe Stator Combinations

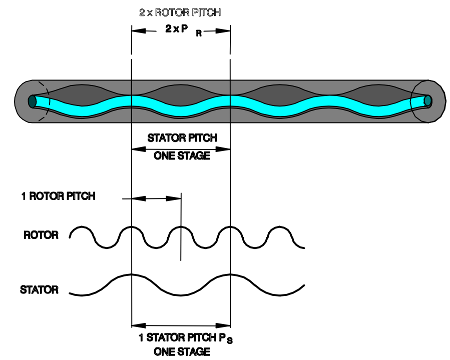


Fig. 2. PDM Rotor/ Stator Pitches

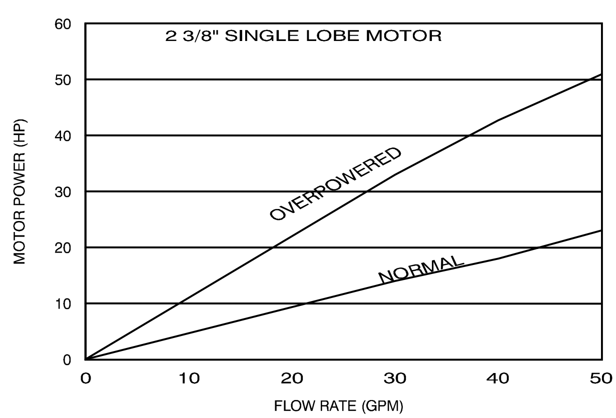


Fig. 3. Motor Power vs. Flow Rate

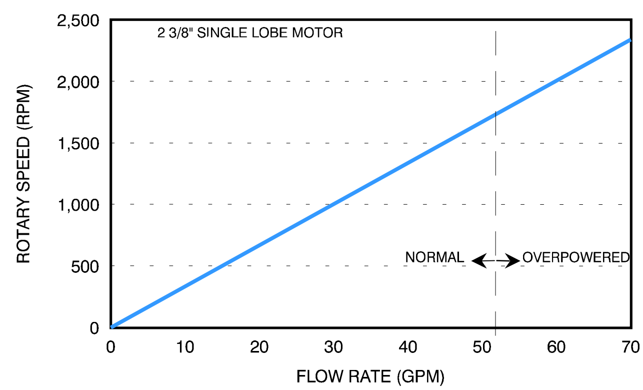


Fig. 4. Rotary Speed vs. Flow Rate

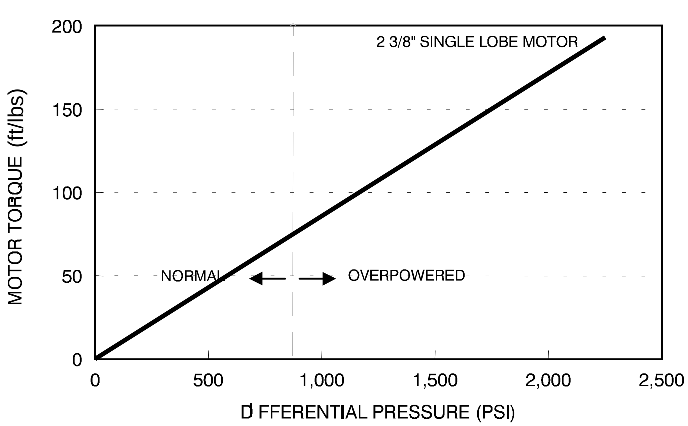


Fig. 5. Motor Torque vs. Pressure

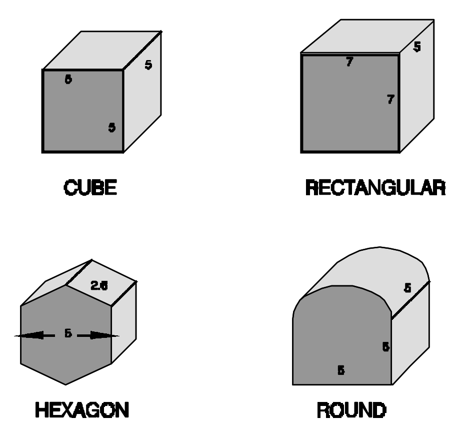


Fig. 6. Large TSP Cutters

where

$p$ = motor pressure drop
$p_s$ = pressure drop per stage
$n$ = number of stages

Eq. 1 shows that the motor pressure drop (i.e., power output) can be increased by increasing the number of stages (i.e., increasing motor length) or by increasing the pressure drop per stage (e.g., tighter interference between the rotor and stator). Increasing pressure increases torque, but does not change rotary speed.

The approach taken on this project is to double the number of stages in the motor (which doubles the power output) and to increase the rotor/stator interference to increase the pressure drop per stage, thus increasing motor output by over 150 percent.

## PROJECT DESCRIPTION

A 2⅜-in. (60-mm) high-power motor was developed that delivers up to 50 HP compared to 23 HP for a conventional motor of the same size (**Figure 3**). The 2⅜-in. motor, which normally operates at a rotary speed of 1,670 rpm with 50 GPM, was operated at 2,340 rpm with 70 GPM flow (**Figure 4**).

Motor torque is proportional to motor pressure drop as shown in **Figure 5**. The 2⅜-in. high-power motor delivered a maximum of 195 ft-lbs compared to 73 ft-lbs for a conventional motor.

Special high-power thermally stable diamond (TSP) bits were developed for use with these high-power motors because conventional bits cannot operate reliably at these high power levels. Large TSP cutters of different shapes were tested in these bits (**Figure 6**).

Laboratory drilling tests were conducted at the Drilling Research Center (DRC) in Houston, Texas, with the high-power motor and these TSP drill bits. The overpowered 2⅜-in. high-power motor (2,060 rpm) drilled Batesville marble at rates up to 540 ft/hr with 3-in. large-cutter TSP bits compared to 190 ft/hr for a conventional motor and 60 ft/hr for rotary drilling (**Figure 7**).

Following these tests, a 3⅜-in. high-power multi-lobe motor was developed that utilizes a 4:5 rotor/stator design, with the number of stages increased from 5 to 10 and the interference between the rotor/stator increased to allow higher pressure drop per stage (**Figure 8**). A bearing pack with stronger bearings, a stronger shaft, and a stronger flex coupling were used on this motor.

Dynamometer tests were conducted at the DRC (**Figure 9**). The high-power 3⅜-in. motor delivered up to 75 HP compared to 30 HP for a conventional motor (**Figure 10**). In laboratory tests, the 3⅜-in. motor drilled a 4¾-in. hole in Carthage marble at 50 ft/hr compared to 25 ft/hr with a conventional motor (**Figure 11**).

Following these laboratory drilling tests, the 3⅜-in. high-power motor was field tested at AMOCO’s Catoosa test site near Tulsa, Oklahoma in a dolomite formation at depths of 1,600 to 1,900 feet (**Figure 12**).

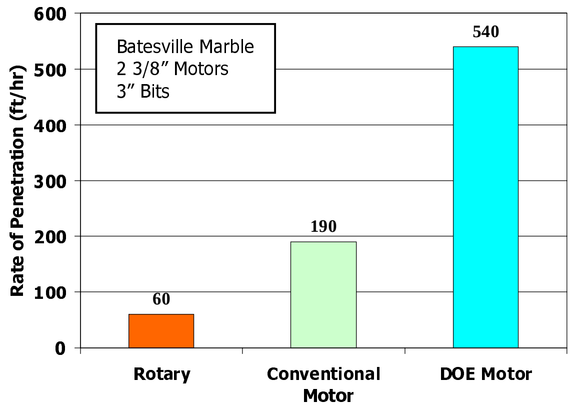


Fig. 7. Drilling Rate Comparison

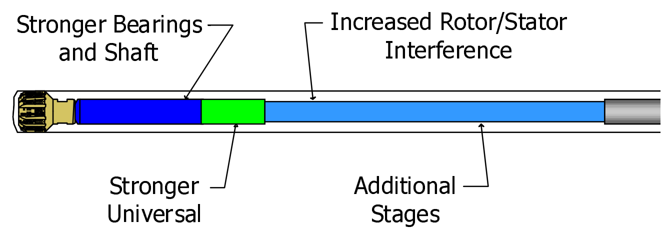


Fig. 8. DOE High-Power Motor Design

Fig. 9. DOE Motor In Dynameter

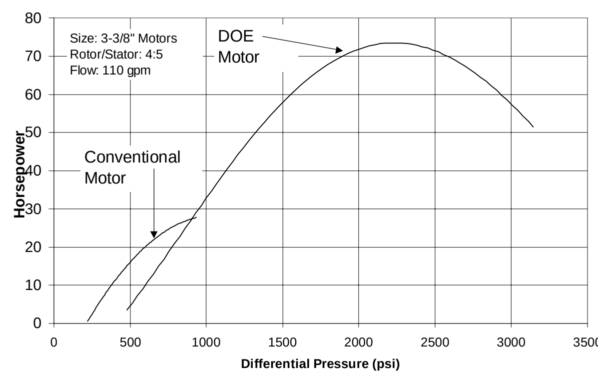


Fig. 10. Motor Performance Comparison

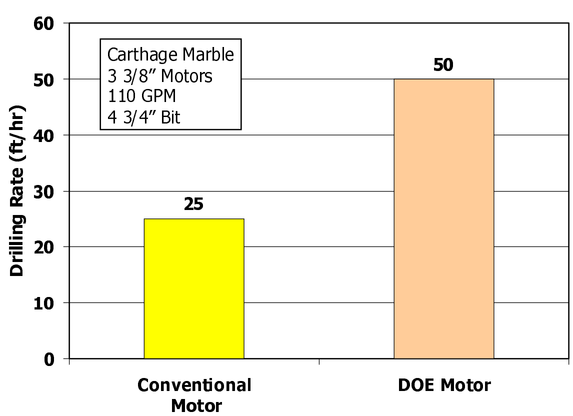


Fig. 11. Laboratory Drilling Rates

Fig. 12. Catoosa Drilling Rig

The lithology at the Catoosa test site is well documented, allowing good comparative test drilling with different motors. The Arbuckle Dolomite, a hard dolomite formation that extends from 1,621 ft to 2,920 ft, was selected for the tests. The motors were run sequentially with the conventional motor being run between the two high-power motors to allow direct comparison between the motors.

**Figure 13** shows the two 3⅜-in. DOE high-power motors and the 3⅜-in. conventional motor used in these tests. The DOE motors are longer due to the longer rotors and stators used in these high-power motors.

New hybrid bits were developed for use with the DOE high-power motor (**Figure 14**). The PDC cutters on these bits drill at high rates in softer formations, while TSP cutters located behind the PDC cutters protect the PDC cutters in hard streaks. These bits performed well during the field tests. The first bit was damaged when it drilled through a 1-ft thick chert stringer in one hour at the end of the first run. However, the bit was able to successfully drill through the chert stringer, showing the strength of the hybrid bit.

**Figure 15** shows the DOE high-power motor in the derrick and **Figure 16** shows the rig crew attaching the hybrid bit to the DOE motor.

Due to large casing (13⅜-inch) in the upper section of the well, the annular velocities would have been inadequate to clean the hole effectively with the low flow rates used with the 3⅜-in. motor. A Halliburton pump (**Figure 17**) was used on a parasite string to increase the annular flow rate to effectively clean the cuttings from the well.

The hybrid bit on the first DOE motor run was damaged in a chert stringer so a drilling rate comparison could not be made. The second DOE motor drilled at 48 ft/hr compared to 23 ft/hr for the conventional motor, demonstrating the high drilling rate capabilities of the high-power DOE motor (**Figure 18**).

The high-power output allowed the DOE high-power motors to be run at bit weights of 8,000 to 10,000 lbs compared to maximum bit weights of 3,000 to 7,000 lbs with the conventional motors.

The drillers found the DOE motors much easier to operate than conventional motors because they tended to stall less due to their higher torque capability. The DOE motors could be restarted by reducing the bit weight, whereas the conventional motor had to be raised off bottom to be restarted.

Dynamometer tests conducted at the DRC following the field tests showed that the DOE motors were in excellent condition and could have drilled further during the tests. These field tests were very successful, demonstrating the high potential of the DOE high-power motors.

## APPLICATIONS AND BENEFITS

The DOE high-power motor has potential application in directional and horizontal drilling since motors are required in these wells. Directional drilling is usually much more expensive than straighthole drilling because of the added costs of the motors, MWD tools and other directional drilling equipment. Doubling the drilling rate in these wells could save the industry hundreds of millions of dollars per year.

Fig. 13. DOE and Conventional Motors

Fig. 14. DOE Hybrid TSP/PDC Bit

Fig. 15. DOE Motor In Derrick

Fig. 16. Attaching Hybrid Bit to DOE Motor

Fig. 17. Parasite String Pump

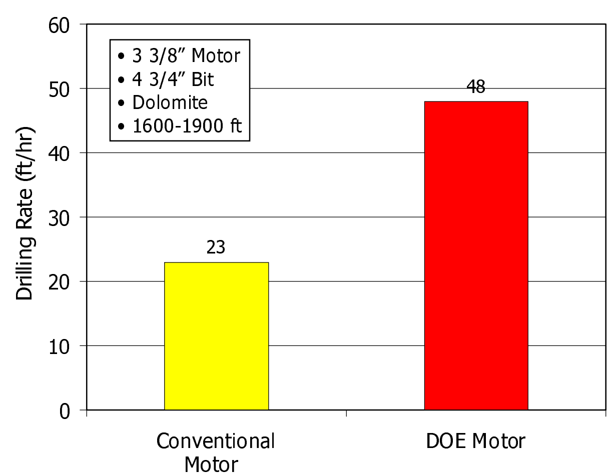


Fig. 18. Field Drilling Rates

These high-power motors also have application with coiled tubing (CT) drilling because drilling motors must be used with CT since the CT cannot be rotated in wells. CT rigs are more expensive than conventional drilling rigs, so increased drilling rates could produce significant cost savings with these rigs.

The high-power motors drill up to 2 to 4 times faster than rotary rigs, so they also have potential application in straighthole drilling.

## FUTURE ACTIVITIES

Additional field tests need to be conducted in oil and gas wells to demonstrate the economic benefits and reliability of these motors to service companies and operators and to accelerate implementation and commercialization of these high-power motors.

## ACKNOWLEDGMENTS

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