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Radial Lip Seal Torque: Measurement Methods and Results

SAE Recommended Practice
Issued June 1989

Submitted for Recognition as
an American National Standard

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HIGHWAY VEHICLE PRACTICE

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RADIAL LIP SEAL TORQUE: MEASUREMENT METHODS AND RESULTS

1. RADIAL LIP OIL SEAL FRICTIONAL TORQUE:

The radial lip oil seal is designed to retain lubricants and exclude contaminants. Retaining lubricants depends upon maintaining an interference fit between the shaft and the sealing lip throughout the life of the seal (Fig. 1). The interference fit between the shaft and the sealing lip results in radial forces that create the sealing force. These forces also generate frictional torque when the shaft rotates. This frictional torque consumes power and reduces the efficiency of operating equipment. Frictional torque also generates heat that can be detrimental to the sealing element, the lubricant, and the bearings contained within the mechanical device. It is, thus, important to define consistent methods of measuring seal torque. The methods described and data generated in this report pertain to a radial lip oil seal operating with oil only as the lubricant. Seals with grease as a lubricant may require different test procedures. The torque trend of seals operating in grease may not parallel the trends discussed in this report.

2. TEST EQUIPMENT AND PROCEDURE:

2.1 Torque Measurement with a Torque Wrench: A crude measurement of seal torque can be obtained with a fixture to hold the seal and a torque wrench. The recommended procedure is as follows:

2.1.1 A fixture similar to the one shown in Fig. 2 shall be used. Zero shaft-to-bore misalignment (STBM) is desired, but readings of 0.08 mm (0.003 in) or less shall be acceptable.

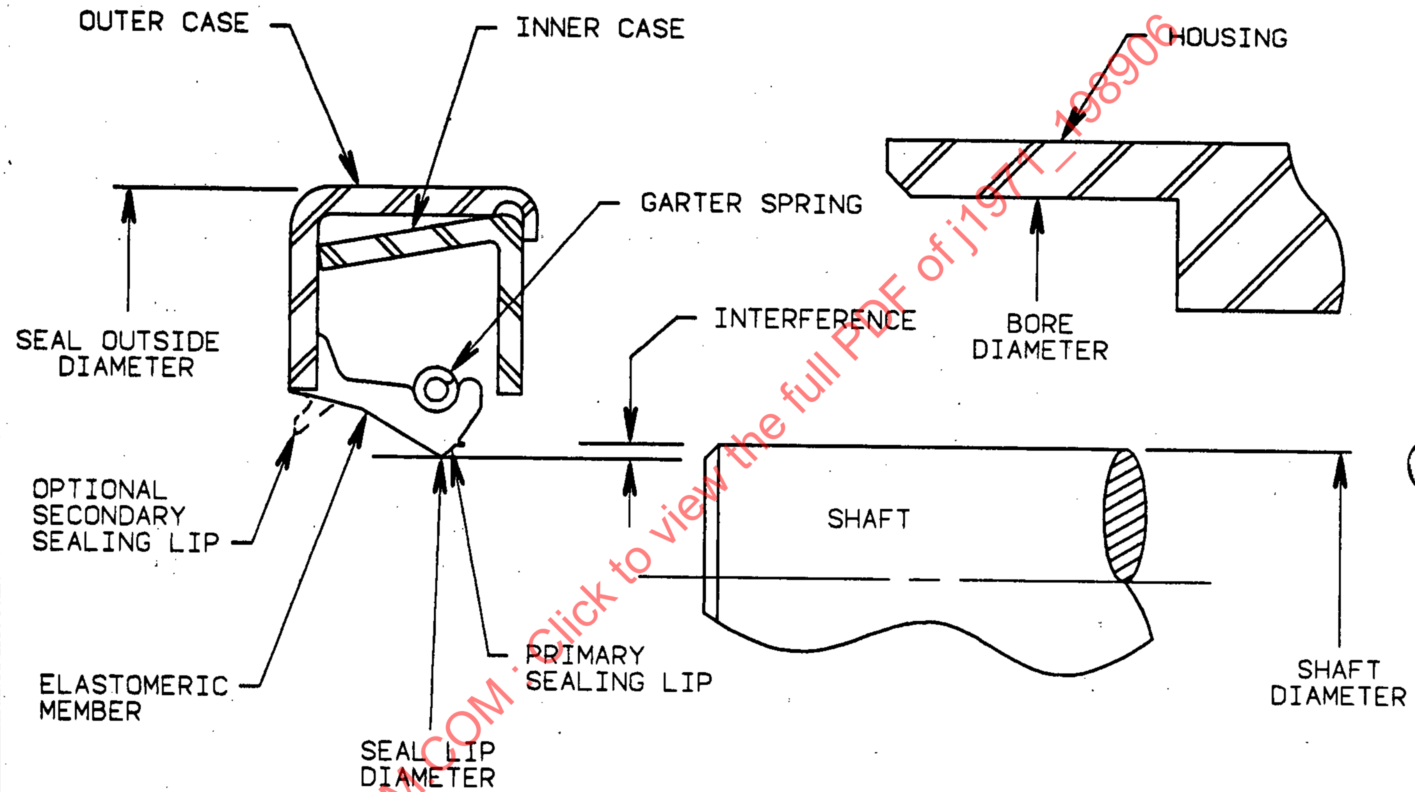

FIGURE 1 - Typical Radial Lip Oil Seal

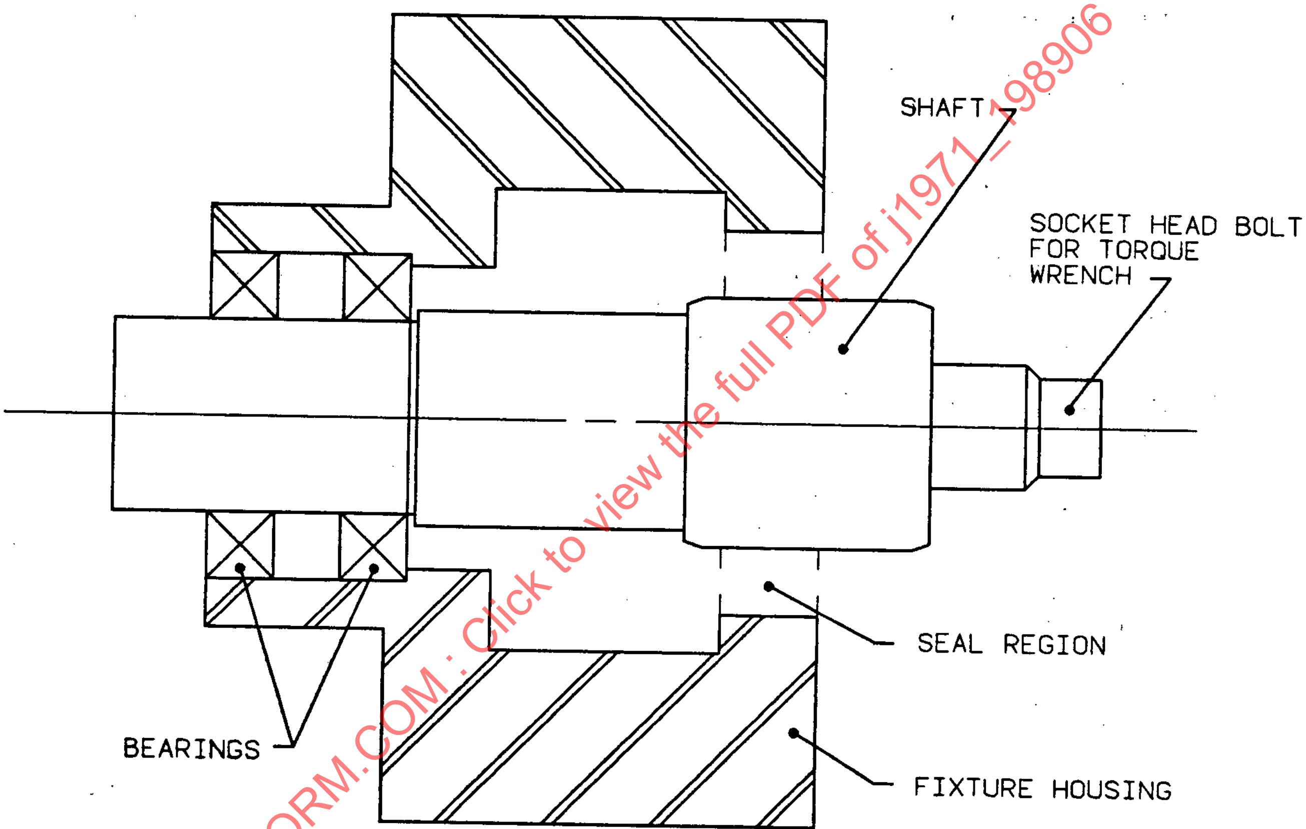

FIGURE 2 - Fixture to Measure Seal Torque With Torque Wrench

2.1.2 The shaft size shall be recorded and must conform to SAE standards shown in Table 1 (Reference 1).

TABLE 1 - Shaft Diameter Tolerances

Millimeter (mm)		Inches	
Shaft Diameter	Tolerance	Shaft Diameter	Tolerance
through 75.0	±0.08	through 3.000	±0.003
75.01 to 150.0	±0.10	3.001 to 6.000	±0.004
150.01 to 250.0	±0.13	6.001 to 10.000	±0.005

2.1.3 The shaft must conform to SAE standards with a surface roughness of 0.25 to 0.50 µm (10 to 20 µin) Ra, a machine lead angle of 0 ± 3 min and a hardness of Rockwell C30 minimum (Reference 1,2).

2.1.4 The dynamic runout of the shaft shall be measured with a dial indicator and should be less than 0.08 mm (0.003 in) TIR.

2.1.5 The seal lip ID and radial force (Reference 3,4) shall be measured and recorded.

2.1.6 The test shall normally be conducted at room temperature. If values at elevated temperatures are desired, then the test fixture shown in Fig. 2 should be equipped with heaters and controlled within ±3°C (±5°F). It is recommended that the fixture head be filled with a fluid to promote heat transfer and prevent hot spots.

2.1.7 The seal lip should be lubricated lightly with oil (SAE 30 engine oil is recommended).

2.1.8 The seal shall be installed in the fixture.

2.1.9 A torque wrench divided into 0.01 N·m (1.43 oz-in) increments or smaller is placed on the end of the shaft and turned slowly (about 60 rpm). The torque required to move the shaft is recorded. This procedure will provide relative information for guidance only. It will not predict the torque of a seal operating under actual application conditions.

2.2 Torque Measurement with an Electronic Device: An electronic transducer can be placed between a drive motor and a test head (Fig. 3) to provide accurate torque readings at a variety of application conditions (shaft speed, sump temperature, pressure, etc.). The test head must meet the standard SAE requirements (Reference 5). It is recommended that air bearings be used to reduce system friction. The intrinsic friction of the spindle assembly should be held to less than 1% of the seal torque to be measured. This can be verified by measuring the spindle torque without a seal installed. The recommended test procedure is:

2.2.1 The shaft size shall be recorded and must conform to the SAE standards of Table 1 (Reference 1).

2.2.2 The shaft must conform to SAE standards with a surface roughness of 0.25 to 0.50 µm (10 to 20 µin) Ra, a machine lead angle of 0 ± 3 min and a hardness of Rockwell C30 minimum (Reference 1,2).

2.2.3 The dynamic runout of the shaft shall be measured with a dial indicator and recorded.

2.2.4 The seal lip ID and radial load (Reference 3, 4) shall be measured and recorded.

2.2.5 The seal shall be installed in a suitable end plate and assembled onto the housing.

2.2.6 The shaft shall be inserted into the seal. It is important that the depth of insertion be standardized since fluid drag on the shaft can influence torque readings. It is also important to standardize the sump volume when constructing more than one test machine.

2.2.7 The shaft-to-bore misalignment shall be measured and recorded.

2.2.8 The sump shall be filled to the desired level with the test lubricant. It is important to fill the sump to the same level when comparing different seal designs and/or materials since the amount of fluid in the sump can affect torque readings.

2.2.9 The fluid shall be heated to the desired temperature and the shaft shall be rotated at a surface speed of 8.65 m/s (1700 ft/min) for 20 h to break-in a new seal (Note: if data is generated at different sump temperatures then a chart of lubricant viscosity vs. temperature will be useful).

2.2.10 The torque of the seal shall be measured at 500 rpm after the torque has stabilized to less than 1% change within any 10 min period.

2.2.11 The shaft speed shall be increased in 500 rpm increments until the maximum desired surface speed is reached. The torque is recorded at each speed after the torque value has stabilized to less than a 1% variation within a 10 min period.

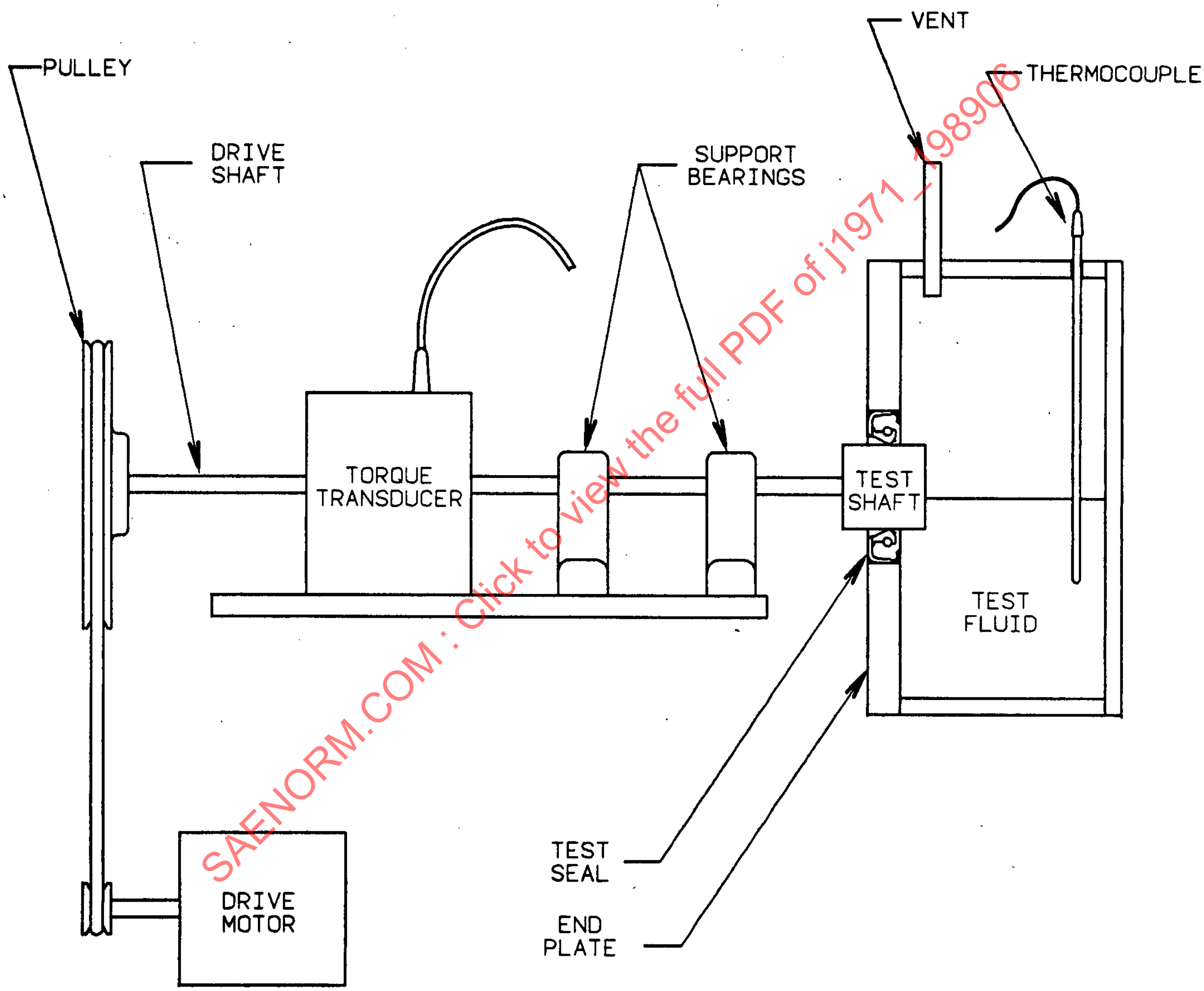

FIGURE 3 - Electronic Torque Measuring Machine

2.2.12 A curve of seal torque vs. shaft speed shall be generated (Note: even if the sump temperature is maintained constant, seal underlip temperature will increase with speed and affect the viscosity of the fluid in the immediate vicinity of the seal lip. This will have a diminishing effect on true seal torque and must be considered when analyzing torque vs. speed results).

2.2.13 Torque data should always be qualified by specifying the following conditions:

a. Speed

b. Sump temperature

c. Fill level and volume

d. Oil type and viscosity

e. Set-up geometry [Shaft-to-Bore Misalignment (STBM), Dynamic Run-Out (DRO), and Angular Misalignment or Seal Cock]

f. Direction of shaft rotation

3. <u>CALCULATION OF POWER CONSUMPTION</u>:

The power (Pkw or Php) consumed by the oil seal is the product of torque (T) and shaft speed(s). Torque is usually measured in Newton meters or ounce inches and the shaft speed is measured in revolutions per minute (rpm). The following equations are used to calculate power:

$Php = 9.917 \times 10^{-7}$ (Toi S) horsepower
$Php = 1.404 \times 10^{-4}$ (Tnm S) horsepower
$Pkw = 7.395 \times 10^{-7}$ (Toi S) kilowatts
$Pkw = 1.046 \times 10^{-4}$ (Tnm S) kilowatts
$Tnm = 7.063 \times 10^{-3}$ Toi
Toi = 141.6 Tnm
Pkw = 0.7457 Php
Php = 1.341 Pkw

Where: "Toi" is torque in ounce inch
"Tnm" is torque in Newton meters
"S" is shaft speed in rpm
"Php" is power in horsepower
"Pkw" is power in kilowatts

4. EFFECTS OF OPERATING CONDITIONS ON OIL SEAL TORQUE MEASUREMENTS:

Oil seal torque depends upon many variables which include seal design, material, and operating parameters. Actual test data is presented to define how variations in operating parameters affect seal torque and power consumption. This data is meant to be used as a guide only and the absolute values obtained are valid only for the seal design and material tested. The trends shown in the curves will apply to other seal designs and material. Absolute torque values for other seal designs and materials must be measured with electronic equipment similar to that described in 2.2.

4.1 Oil Seal Torque and Power Consumption vs. Shaft Speed: At a constant temperature with a full sump, seal torque dips slightly from the breakaway value at low speeds and then increases approximately linearly with speed (Fig. 4). Seal power consumption increases as speed increases (Fig. 5).

4.2 Oil Seal Torque and Power Consumption vs. Sump Temperature: Increasing sump temperature reduces fluid viscosity (Fig. 6), softens elastomeric materials and causes the seal lip ID to change. The net short term result is a reduction in torque (Fig. 7) and power consumption (Fig. 8) as sump temperatures increase. Increasing the sump temperature to reduce torque and power consumption is not recommended since excessive heat could degrade seal lip materials and lubricants, thus causing early failures (References 6,7).

4.3 Seal Torque and Power Consumption vs. Sump Fill Level: The sump fill level affects seal torque (Fig. 9) and power consumption (Fig. 10). At low speeds, seal torque and power consumption are relatively independent of sump fill level. At high speeds, the effect is more dramatic. The torque values and power consumption decrease as fluid level is lowered. Fluid drag on the rotating shaft is also reduced. It is not recommended that oil sump levels be lowered in actual applications to reduce torque and power consumption since low lubricant levels may result in bearing and/or seal failure.

4.4 Seal Torque and Power Consumption vs. Fluid Viscosity: Fluids with high viscosities generate higher torque and greater power consumption than fluids with low viscosity. At 5000 rpm, seals run in SAE 50 oil have torque values about 40% higher than the same seals run in SAE 10W oil (Fig. 11). The power consumption in SAE 50 oil is also about 40% higher than the power consumption in SAE 10W oil at 5000 rpm (Fig. 12). Lubricants with viscosities recommended by the equipment manufacturer should be used in the application. Attempts to reduce torque and power consumption by using low viscosity fluids can result in catastrophic equipment failure.

4.5 Seal Torque and Power Consumption vs. Shaft-to-Bore Misalignment (STBM) and Dynamic Run-Out (DRO): Tests show that varying the STBM and DRO from 0.000 to 0.5 mm (0.000 to 0.020 in) had no effect on seal torque and power consumption.

SEAL MATERIAL	FLUOROELASTOMER
SHAFT SIZE	76.2 mm (3.000 in)
BORE SIZE	101.6 mm (4.000 in)
WIDTH	12.7 mm (0.500 in)
TEST FLUID	MOBIL 1
STBM	0.0
D.R.O.	LESS THAN 0.08 mm (0.003 in)
DIRECTION OF SHAFT ROTATION	CW
BREAK IN PROCEDURE	20 HOUR BREAK IN AT 2000 RPM AND 149°C (300°F)
SUMP LEVEL	FULL
SUMP TEMPERATURE	149°C (300°F)

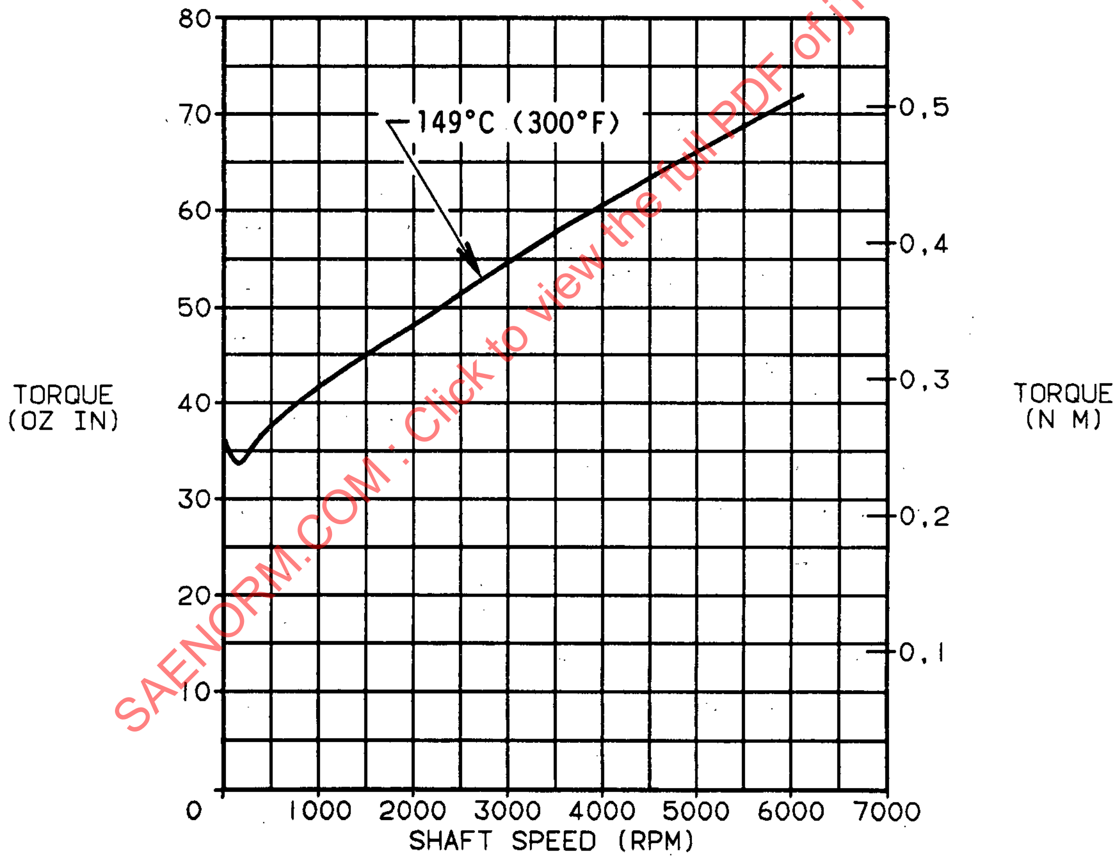

FIGURE 4 - Seal Torque vs. Shaft Speed

SEAL MATERIAL ----------------	FLUOROELASTOMER
SHAFT SIZE -------------------	76.2 mm (3.000 in)
BORE SIZE --------------------	101.6 mm (4.000 in)
WIDTH ------------------------	12.7 mm (0.500 in)
TEST FLUID -------------------	MOBIL 1
STBM -------------------------	0.0
D.R.O. -----------------------	LESS THAN 0.08 mm (0.003 in)
DIRECTION OF SHAFT ROTATION ---	CW.
BREAK IN PROCEDURE -----------	20 HOUR BREAK IN AT 2000 RPM AND 149°C (300°F)
SUMP LEVEL -------------------	FULL
SUMP TEMPERATURE -------------	149°C (300°F)

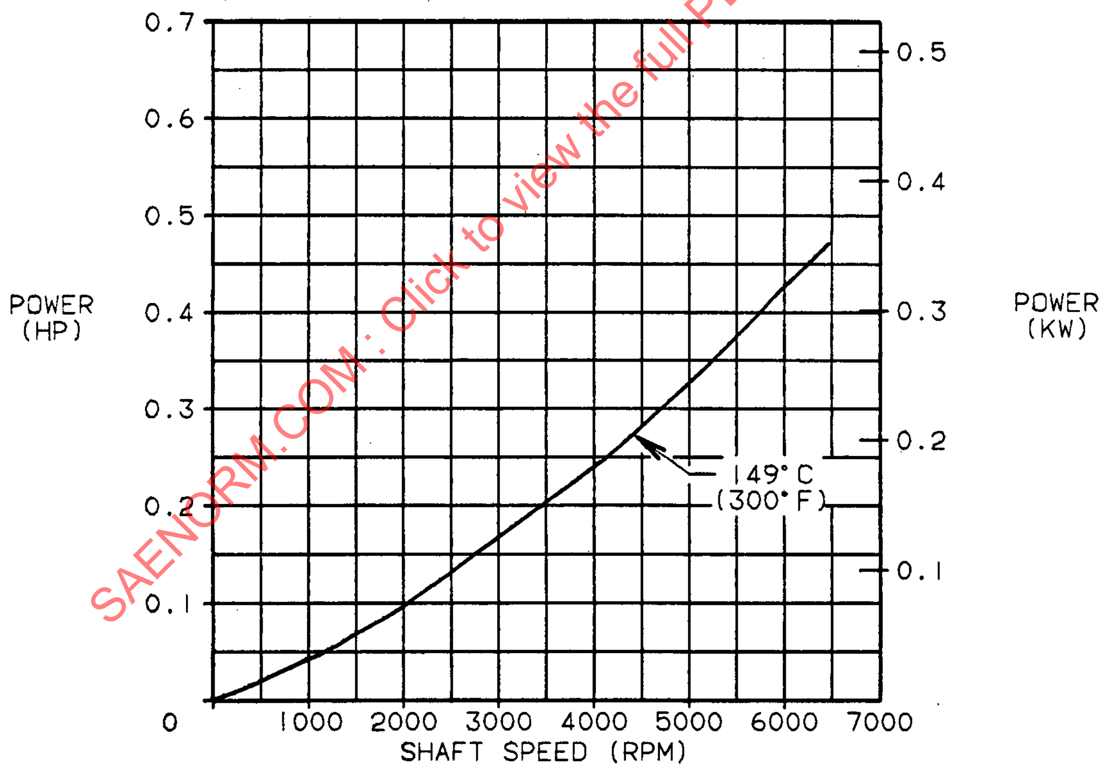

FIGURE 5 - Power vs. Shaft Speed

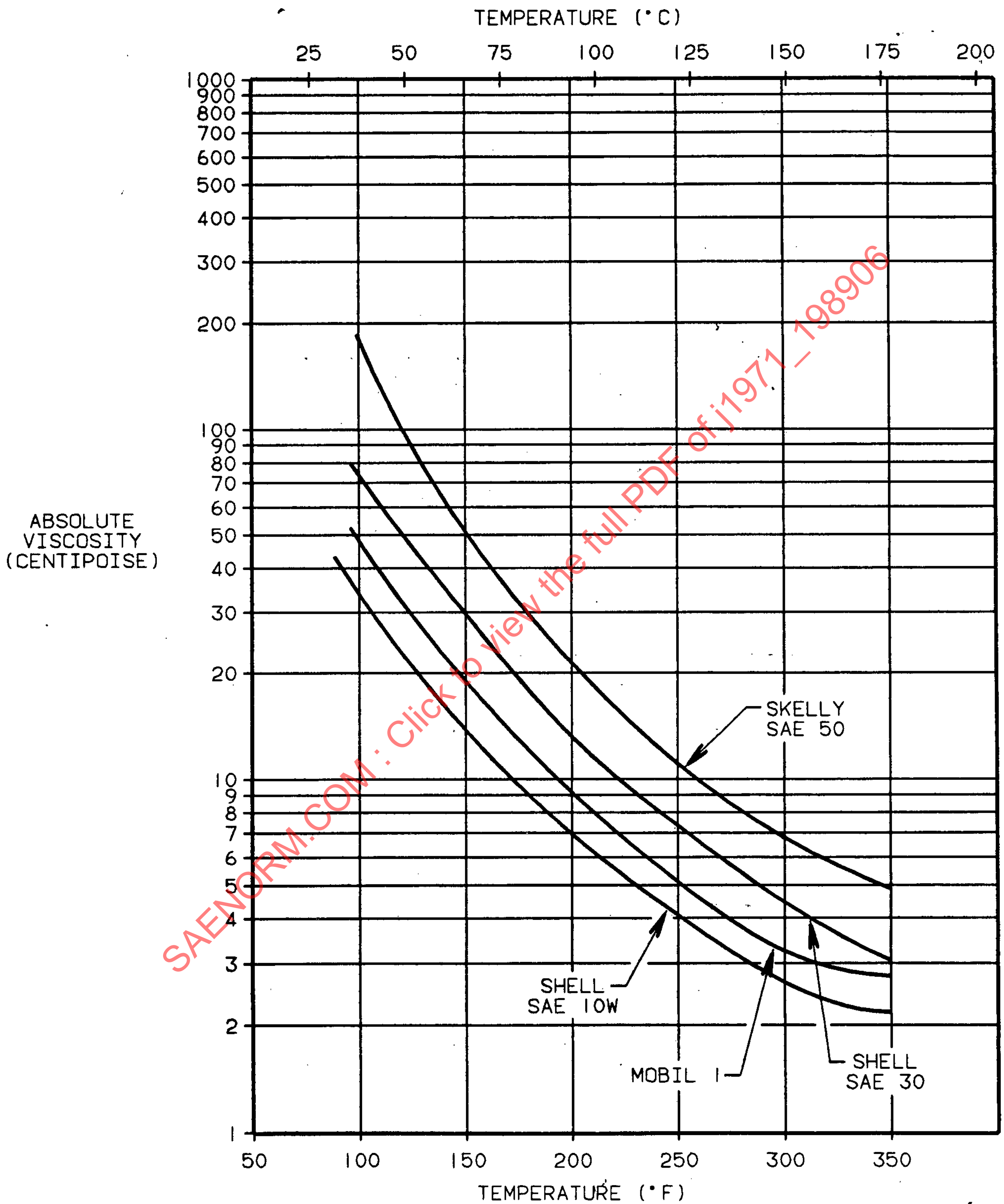

FIGURE 6 - Absolute Oil Viscosity vs. Temperature

SEAL MATERIAL	FLUOROELASTOMER
SHAFT SIZE	76,2 mm (3.000 in)
BORE SIZE	101,6 mm (4.000 in)
WIDTH	12,7 mm (0.500 in)
TEST FLUID	MOBIL 1
STBM	0.0
D.R.O.	LESS THAN 0.003 INCH (0,076 mm)
DIRECTION OF SHAFT ROTATION	CW
BREAK IN PROCEDURE	20 HOUR BREAK IN AT 2000 RPM AND 149°C (300°F)
SUMP LEVEL	FULL

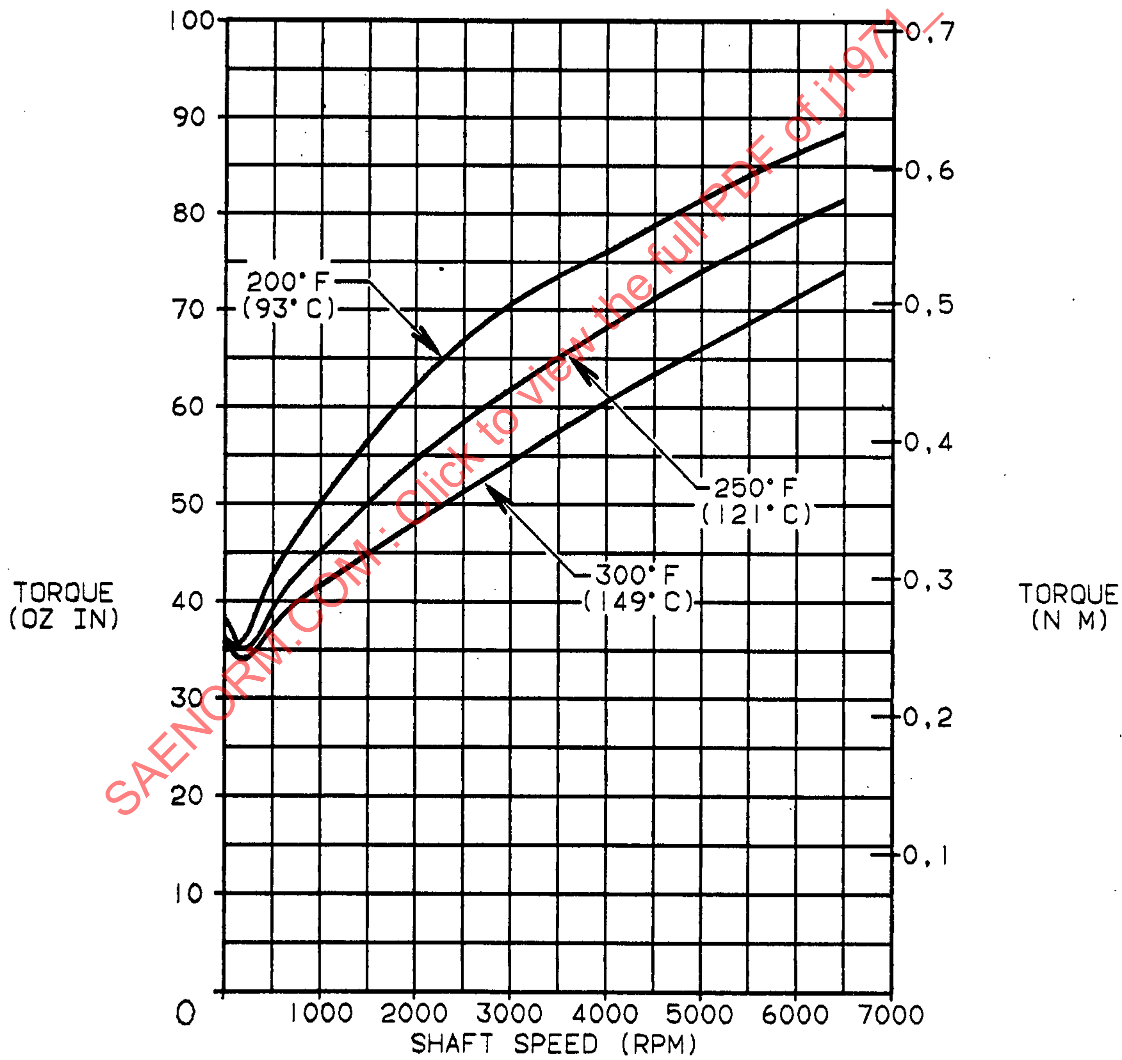

FIGURE 7 - Effect of Sump Temperature on Seal Torque

SEAL MATERIAL	FLUOROELASTOMER
SHAFT SIZE	76.2 mm (3.000 in)
BORE SIZE	101.6 mm (4.000 in)
WIDTH	12.7 mm (0.500 in)
TEST FLUID	MOBIL 1
STBM	0.0
D.R.O.	LESS THAN 0.08 mm (0.003 in)
DIRECTION OF SHAFT ROTATION	CW
BREAK-IN PROCEDURE	20 HOUR BREAK-IN AT 2000 RPM AND 149°C (300°F)
SUMP LEVEL	FULL

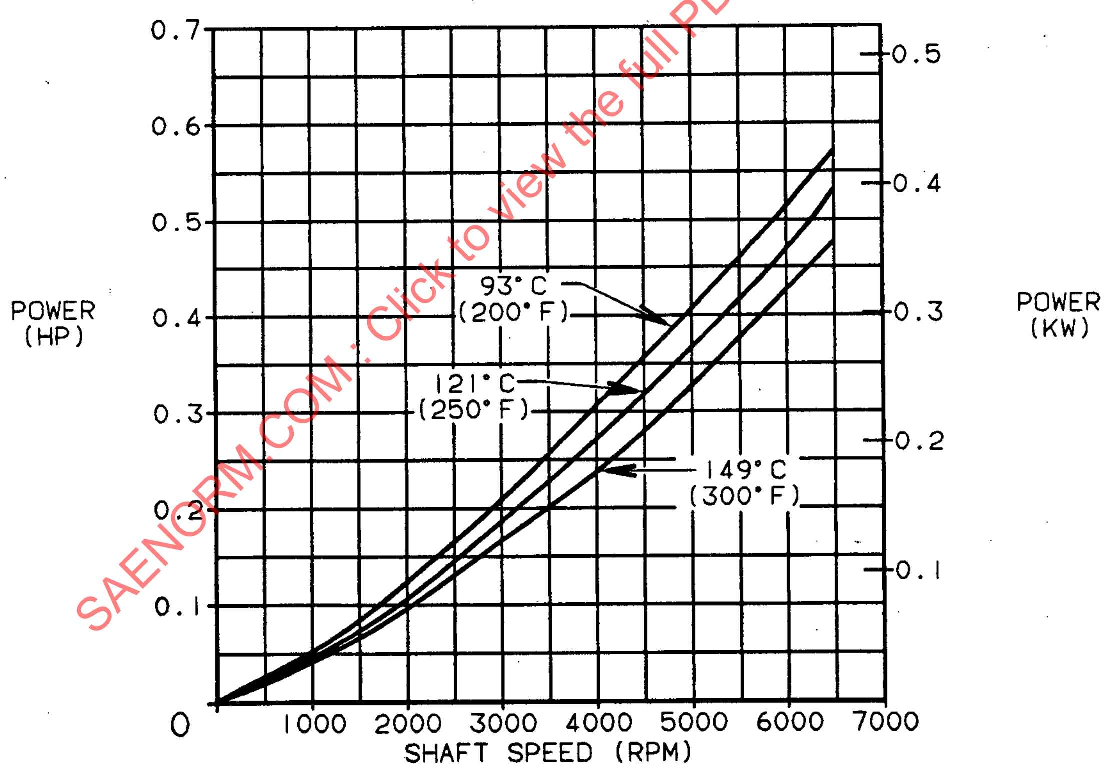

FIGURE 8 - Effect of Sump Temperature on Seal Power Consumption

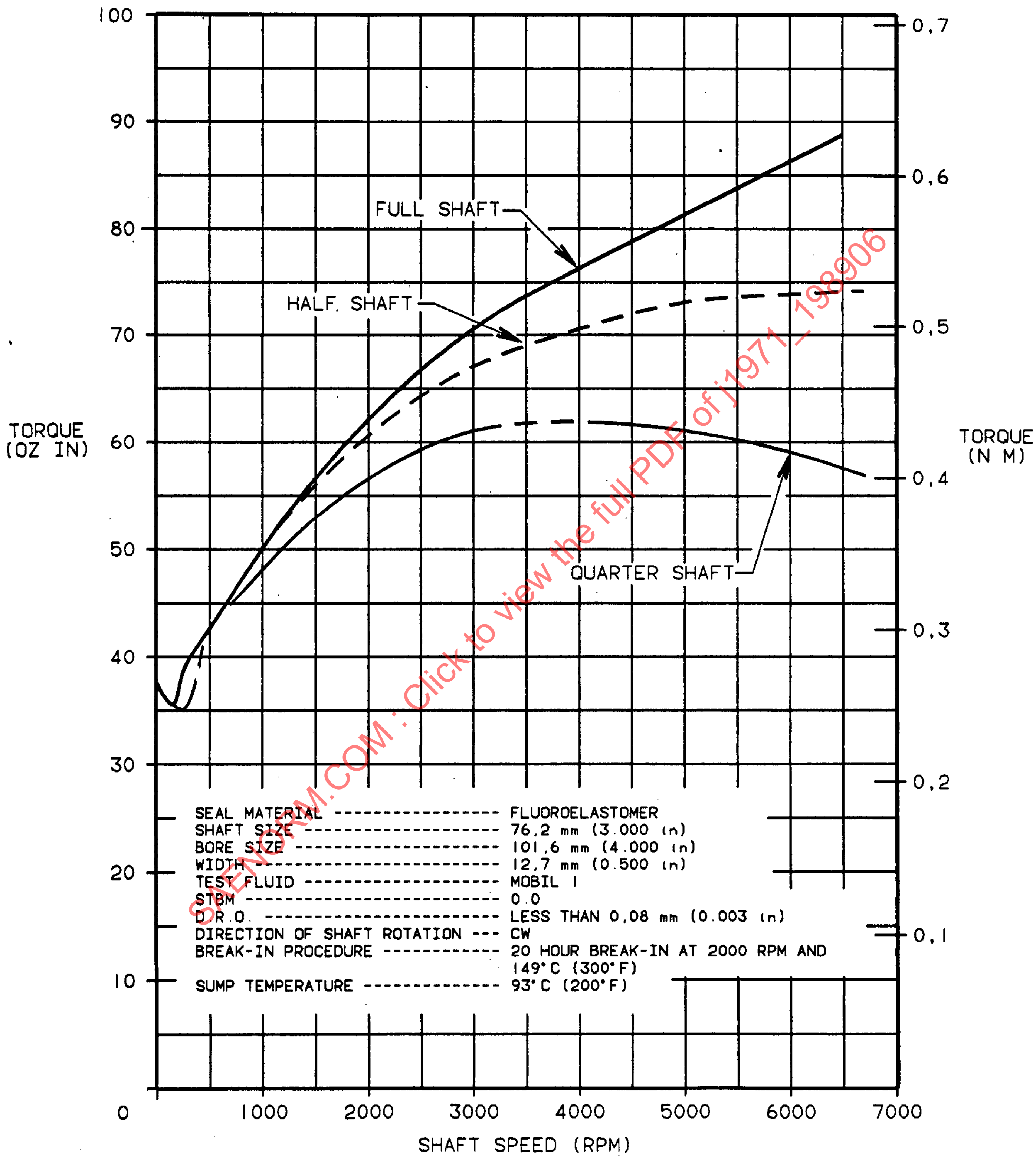

FIGURE 9 - Effect of Sump Fill Level on Seal Torque

SEAL MATERIAL	FLUOROELASTOMER
SHAFT SIZE	76,2 mm (3.000 in)
BORE SIZE	101,6 mm (4.000 in)
WIDTH	12,7 mm (0.500 in)
TEST FLUID	MOBIL 1
STBM	0.0
D.R.O.	LESS THAN 0,08 mm (0.003 in)
DIRECTION OF SHAFT ROTATION	CW
BREAK-IN PROCEDURE	20 HOUR BREAK-IN AT 2000 RPM AND 149°C (300°F)
SUMP TEMPERATURE	93°C (200°F)

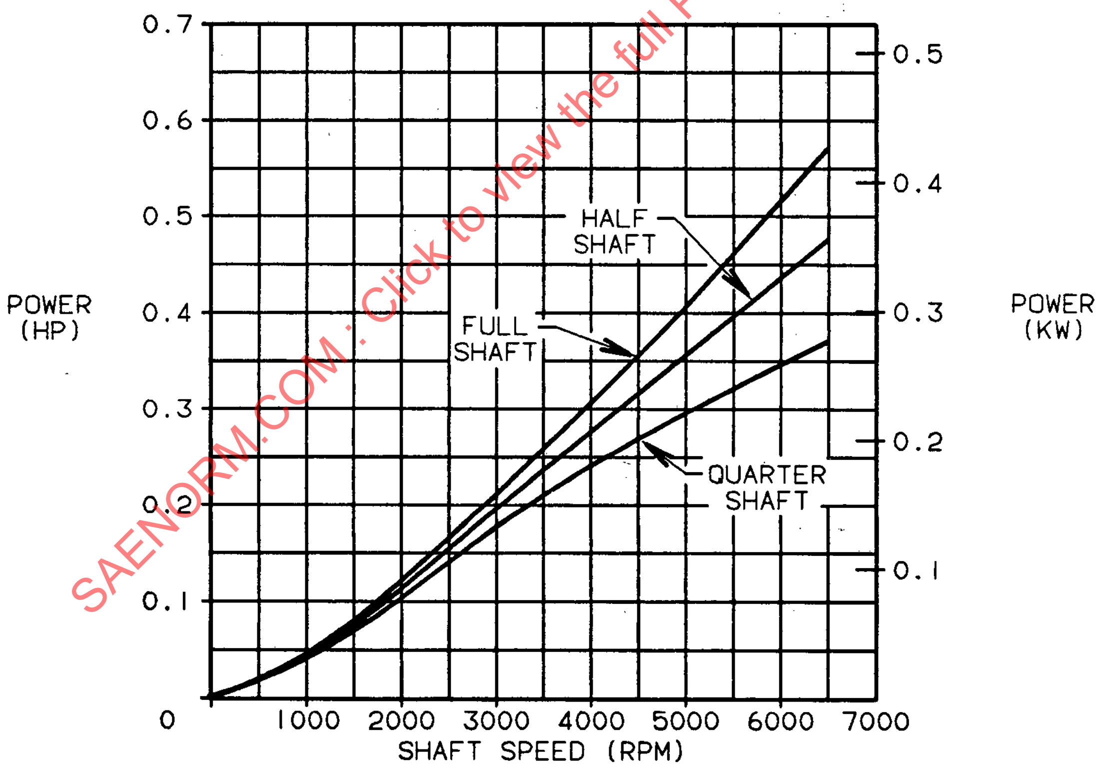

FIGURE 10 - Effect of Sump Fill Level on Seal Power Consumption

SEAL MATERIAL	NITRILE
SHAFT SIZE	76,2 mm (3.000 in)
BREAK-IN PROCEDURE	20 HOUR BREAK-IN AT 2150 RPM
SUMP TEMPERATURE	93°C (200°F)
D.R.O.	0,13 mm (0.005 in) TIR
STBM	0,13 mm (0.005 in)
SUMP LEVEL	FULL

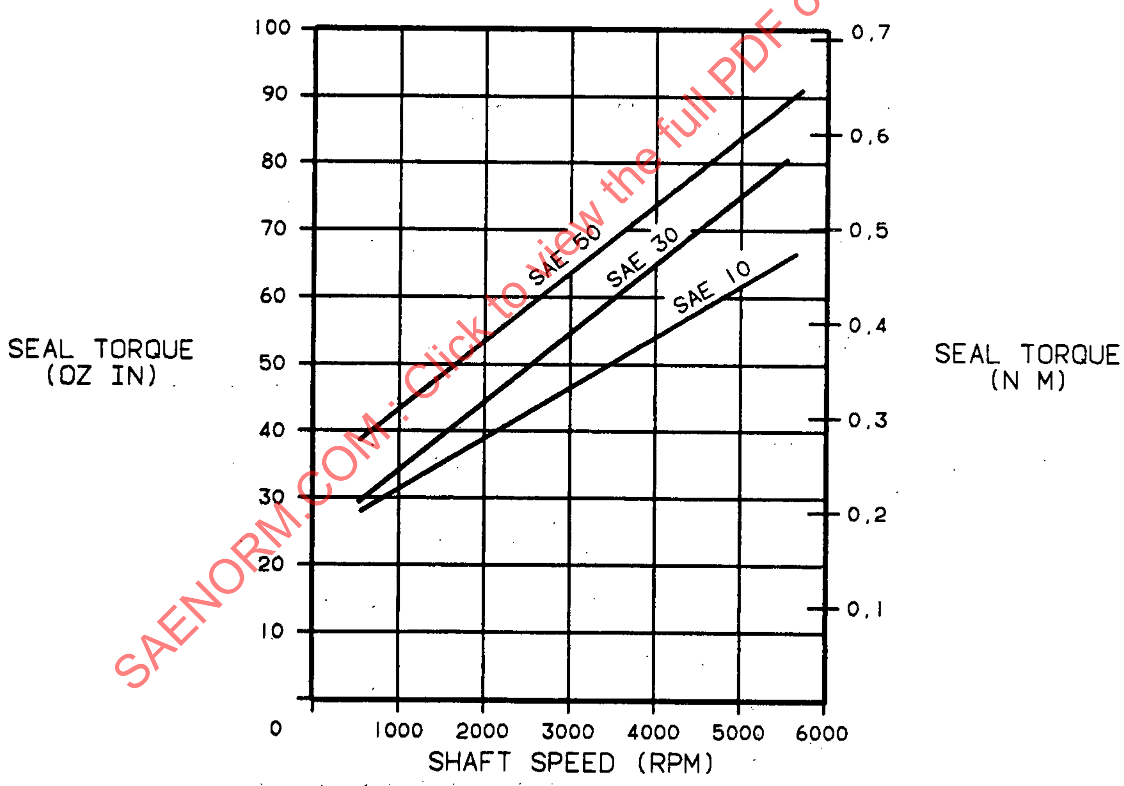

FIGURE 11 - Seal Torque vs. Shaft Speed for Various Fluid Viscosities

SEAL MATERIAL	NITRILE
SHAFT SIZE	76,2 mm (3.000 in)
BREAK-IN PROCEDURE	20 HOUR BREAK-IN AT 2150 RPM
SUMP TEMPERATURE	93°C (200°F)
D.R.O.	0,13 mm (0.005 in) TIR
STBM	0,13 mm (0.005 in)
SUMP LEVEL	FULL

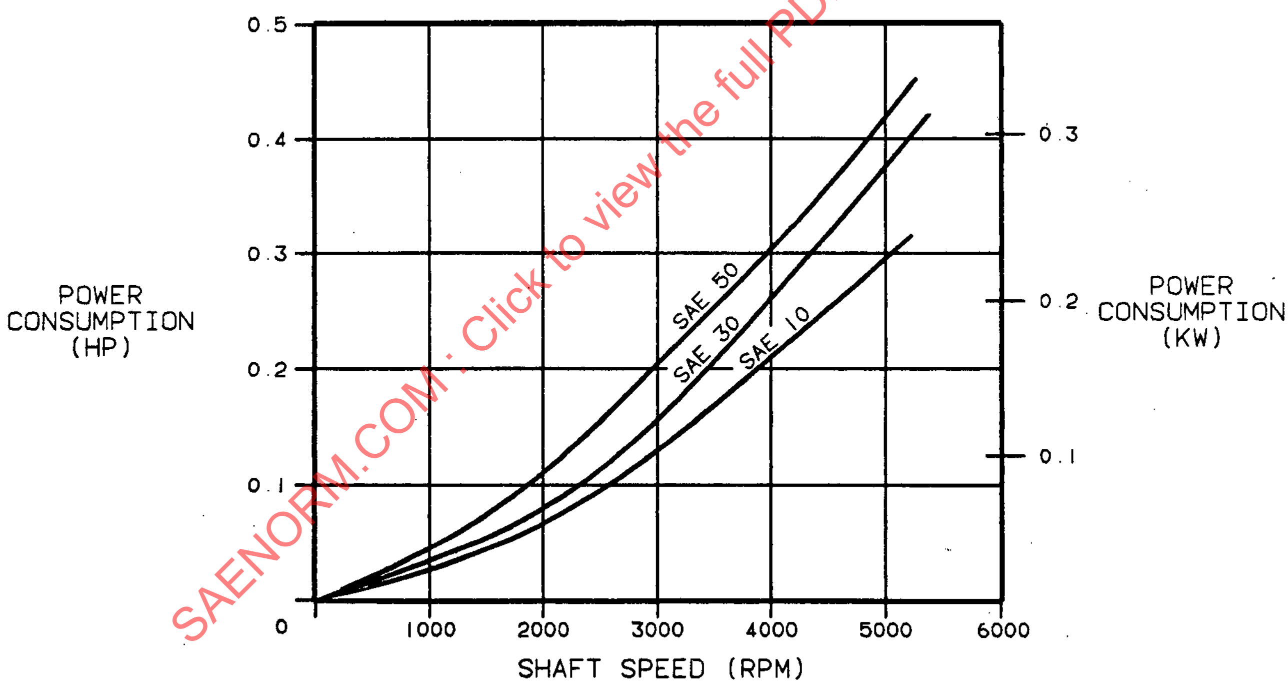

FIGURE 12 - Power Consumption vs. Shaft Speed for Various Fluid Viscosities

4.6 Effect of Angular Misalignment Upon Seal Performance: Seals are sometimes installed without the back face being perpendicular to the centerline axis of the shaft. This condition is known as angular misalignment or seal cock. Seal friction torque and power consumption increase as seal cocking increases. At 5000 rpm, torque changes from 0.42 N·m (60 oz-in) to 0.56 N·m (80 oz-in) as cocking increases from zero to 0.5 mm (0.20 in) (Fig. 13). The power consumption increases by approximately 0.075 Kw (0.1 hp) (Fig. 14). The increase in frictional torque will increase underlip temperature. Since seals with high underlip temperatures have shorter lives than seals with low underlip temperatures, it is essential to develop installation procedures that minimize cocking.

4.7 Seal Torque and Power Consumption as a Function of Shaft Diameter: Seal torque and power consumption increase as shaft size increases (Figs. 15 and 16). At constant speed, the power consumption and frictional torque are approximately in direct proportion to the square of the shaft diameter. At 3000 rpm, the torque is approximately 0.21 N·m (30 oz-in) and the power consumption is about 0.075 Kw (0.1 hp) for a 50 mm (1.968 in) shaft size. Doubling the shaft size to 100 mm (3.937 in) increases the torque to 0.85 N·m (120 oz-in) and quadruples the power consumption to 0.30 Kw (0.4 hp).

5. REFERENCES:

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6. OS-6, RMA Handbook - "Radial Lip Type Shaft Seals - Radial Force Measurement", Rubber Manufacturers Association, Washington, DC.
7. OS-9, RMA Technical Bulletin - "The Effect of Test Variables Upon Shaft Lip Seal Performance", Rubber Manufacturers Association, Washington, DC.
8. OS-15, RMA Technical Bulletin - "Measuring Radial Lip Seal Torque and Power Consumption", Rubber Manufacturers Association, Washington, DC.

SEAL MATERIAL ------------------ NITRILE
SHAFT SIZE --------------------- 76,2 mm (3.000 in)
BREAK-IN PROCEDURE-------------- 20 HOUR BREAK-IN AT 2150 RPM
SUMP TEMPERATURE --------------- (93°C) (200°F)
LUBE --------------------------- SAE 30 AT ℄ FILL
D.R.O. ------------------------- 0,13 mm (0.005 in) TIR
STBM --------------------------- 0.13 mm (0.005 in)

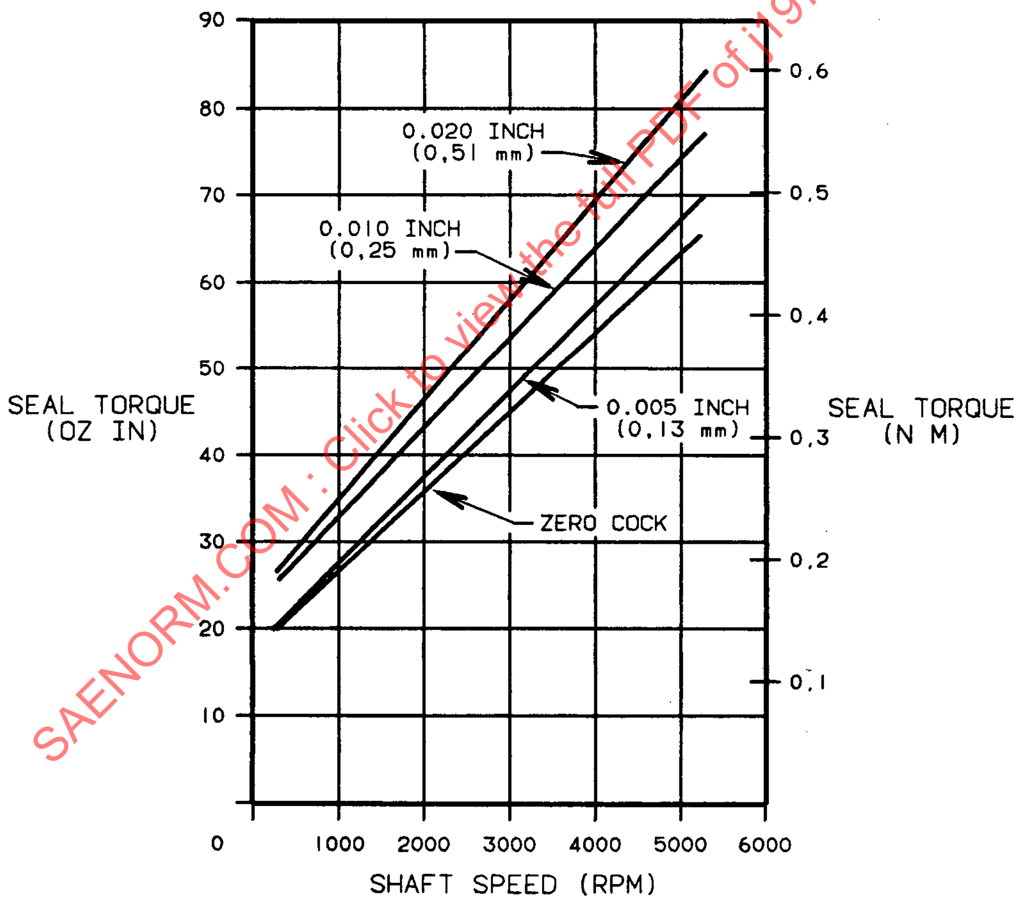

FIGURE 13 - Seal Torque vs. Shaft Speed for Various Values of Seal Angular Misalignment