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(R) SEALS—TESTING OF RADIAL LIP

1. ***Scope***—This SAE Recommended Practice covers equipment and procedures for general performance and low temperature tests on radial lip type seals for rotating shafts. Three test sections are included: General Performance Test, Alternate General Performance Test, and Low Temperature Test.

2. ***References***—There are no referenced publications specified herein.

3. ***General Performance Test***

3.1 Introduction—This section covers equipment and procedures for high temperature tests to qualify radial lip type seals using application operating conditions.

3.2 Description of Test Apparatus

3.2.1 The test head shall consist of an externally mounted spindle and a suitable housing for retaining the test fluid and positioning the seal(s) with respect to the rotating test shaft (Figure 1).

3.2.2 The spindle shall be capable of cycling and/or maintaining constant shaft speeds within ±3%.

3.2.3 The spindle shall be rigid enough to maintain the specified test shaft runout under dynamic conditions within ±0.03 mm (±0.001 in) up to 6000 rpm. Since high frequency vibrations imposed on the driveshaft due to the drive mechanism or eccentric positioning of the tooling is detrimental to seal qualification, these conditions should be avoided or kept to a minimum.

3.2.4 The test head shall be suitably designed and constructed to maintain the preset seal bore alignment to the test shaft axis within ±0.03 mm (±0.001 in) through the operating temperature range.

3.2.4.1 The test head support shall be sufficiently rigid to insure minimum vibration.

3.2.4.2 The test head shall be suitably constructed and equipped to compensate for misalignment due to temperature gradient and to maintain pressure and test fluid level conditions required for the test.

3.2.4.3 The test head shall be equipped with a suitable arrangement for leakage determination, such as a collector and/or absorption pads.

3.2.4.4 The test head and heat transfer system shall be capable of maintaining the temperature of the test fluid within ±3 °C (±5 °F). Heat must be supplied in a manner that does not subject the test fluid to

high localized temperatures and cause fluid decomposition. Two acceptable methods would be external electrical heaters with wall temperature controllers or circulation of externally heated fluid (Figure 1).[1]

3.2.4.5 The test head shall be vented to the atmosphere. Length of pipe vent to be agreed upon by user and supplier.

3.2.5 Test shafts shall be hardened to 30 to 45 R_c and plunge ground to a surface roughness of 0.25 to 0.50 μm (10 to 20 μin R_a), with no measurable lead, unless agreed upon by user and supplier. This finish may be obtained by plunge grinding using a non-whole number wheel to work-piece speed ratio. Finishing methods other than plunge grinding to be agreed upon by user and supplier. If wear sleeves are used for the application, they should also be tested. All test shaft surfaces should be free of nicks, burrs, inclusions, or other detrimental imperfections. The specifications in this section conform to ISO 6194/4.

3.3 Test Conditions—The test should be realistic and cover the application operating conditions. The operating conditions shall be shown in the form of Figure 2.

In the event that actual application operating conditions are not known or are difficult to duplicate on test equipment, test conditions shown on Table 2 or Table 3 are recommended. In addition, it is recommended that a seal design be evaluated in the actual application following successful completion of the laboratory test.

3.4 Test Schedule—The actual application operation conditions should serve as a guide for the selection of the test schedule. It shall consist of a predetermined number of hourly and/or daily test cycles such as shown in Table 1. The test temperature shall be maintained during the shutdown period of the hourly cycle. During the shutdown period of the daily cycle, the test head temperature should be allowed to drop to ambient.

TABLE 1—TEST SCHEDULE

Cycle	Running Time	Shutdown Time
Hourly	45 min	15 min
Daily	20 h	4 h

[1] Information on machines which are commercially available and meet these specifications may be obtained from the following sources:
Balance Engineering Activity, Manufacturing Staff, General Motors Corp., 6490 East 12 Mile Rd., Warren, MI 48090.
Chicago Rawhide Manufacturing Co., 900 N. State St., Elgin, IL 60120.
Victor Products Div., Dana Corp., P.O. Box 1333, Chicago, IL 60690.

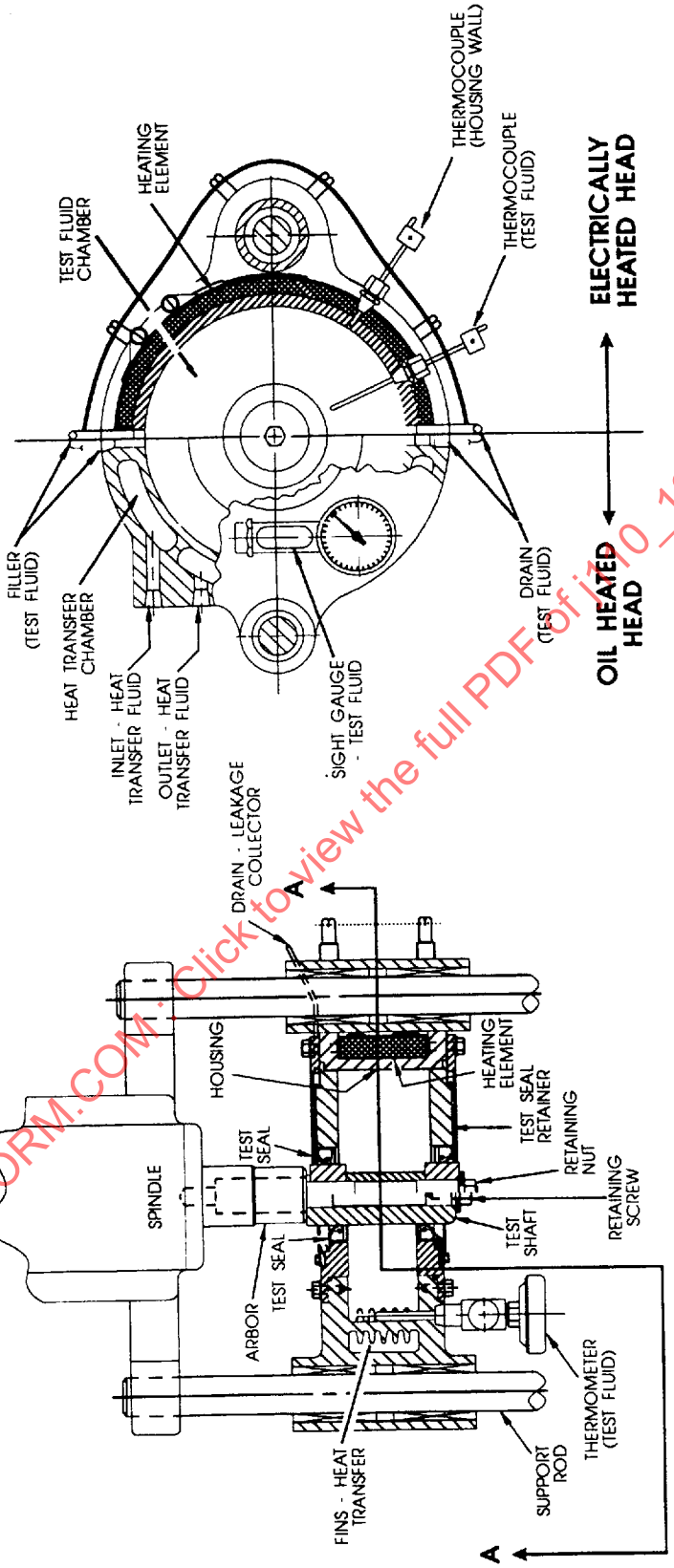

FIGURE 1—SCHEMATIC SHOWING TOP VIEW/CROSS SECTION OF STANDARD OIL OR ELECTRICALLY HEATED SEAL TEST HEAD

SHAFT: MATERIAL _____ FINISH _____ HARDNESS _____

MAX DIA _____ MIN DIA _____ LEAD RH _____ LH _____

DYNAMIC RUNOUT _____ ROTATION* RH _____ LH _____ RPM _____

RECIPROCATION (CPM) _____ LENGTH _____

BORE: MATERIAL _____ FINISH _____ HARDNESS _____

MAX DIA _____ MIN DIA _____ DEPTH _____

MISALIGNMENT TO SHAFT _____

SEAL ASSEMBLY INFORMATION _____

FLUID: MANUFACTURER _____ BRAND _____ VISCOSITY _____

PRESSURE _____ LEVEL _____

TEMP, MAX _____ TEMP, MIN _____

ADDITIONAL DATA: _____

QUALIFICATION OR QUALITY CONTROL TEST: _____

TEST SCHEDULE _____ TEST CYCLES _____

TEST TEMPERATURE(S) _____ ALLOWABLE LEAKAGE _____

* AS VIEWED FROM THE OUTSIDE FACE OF THE SEAL.

FIGURE 2—SEAL APPLICATION DATA CHART

TABLE 2A—TEST PARAMETERS[1]—AUTOMOTIVE (FRONT WHEEL DRIVE)

Application	Axle Driven Wheel	Axle Dead Axle	Engine Front	Engine Rear	Transmission Front Pump	Transmission Output Shaft	Transmission Manual Input
Shaft Runout—[TIR (Total Indicator Reading)]							
mm	0.25	0.25	0.25	0.25	0.25	0.41	0.25
in	0.010	0.010	0.010	0.010	0.010	0.016	0.010
STBM[2] Offset							
mm	0.13	0.25	0.25	0.13	0.13	0.20	0.25
in	0.005	0.010	0.010	0.005	0.005	0.008	0.010
Rotation	Either	Either	Clockwise	Counter-Clockwise	Clockwise	Either	Clockwise
Cold Test[5]							
Speed rpm[3]	100	100	300	300	300	100	300
Temperature							
°C ▪ 3°	-40	-40	-40	-40	-40	-40	-40
°F ▪ 5°	-40	-40	-40	-40	-40	-40	-40
Hot Test							
Reverse Rotation	2 min at 200 rpm	2 min at 200 rpm	None	None	None	2 min at 200 rpm	None
Speed rpm	1200	1200	5000	5000	5000[4]	1200	5000
Temperature							
°C ▪ 3°	104	82	141	141	149	Auto. 121	107
	104	82	141	141	149	Man. 107	107
°C ▪ 5°	220	180	285	285	300	Auto. 250	225
	220	180	285	285	300	Man. 225	225
Duration Hours	350	350	350	350	400	350	350

[1] To be used in the event that the actual application parameters are not used.
[2] Shaft to bore misalignment (STBM)—total indicator reading is double the value listed.
[3] Rate of acceleration to be agreed upon by user and supplier.
[4] Reciprocation at 10 strokes per min, at an amplitude of 2.5 mm (0.10 in) during shaft rotation part of cycle.
[5] For duration see 5.5, 5.6, and 5.7.

TABLE 2B—TEST PARAMETERS[1]—AUTOMOTIVE (REAR WHEEL DRIVE)

Application	Axle Pinion	Axle Wheel	Engine Front	Engine Rear	Transmission Front Pump	Transmission Rear	Transmission Manual Input
Shaft Runout—[TIR (Total Indicator Reading)]							
mm	0.25	0.25	0.25	0.25	0.25	0.25	0.25
in	0.010	0.010	0.010	0.010	0.010	0.010	0.010
STBM[2] Offset							
mm	0.13	0.25	0.25	0.13	0.13	0.25	0.25
in	0.005	0.010	0.010	0.005	0.005	0.010	0.010
Rotation	Clockwise	Either	Clockwise	Counter-Clockwise	Clockwise	Counter-Clockwise	Clockwise
Cold Test[6]							
Speed rpm[3]	300	100	300	300	300	300	300
Temperature							
°C • 3°	-40	-40	-40	-40	-40	-40	-40
°F • 5°	-40	-40	-40	-40	-40	-40	-40
Hot Test							
Reverse Rotation	2 min at 600 rpm	2 min at 200 rpm	None	None	None	2 min at 600 rpm	None
Speed rpm	3600	1200	3600	3600	3600[4]	3600[5]	3600
Temperature							
°C • 3°	99	66	121	121	149	Auto. 121	107
	99	66	121	121	149	Man. 93	107
°F • 5°	210	150	250	250	300	Auto. 250	225
	210	150	250	250	300	Man. 200	225
Duration Hours	350	350	350	350	400	350	350

[1] To be used in the event that the actual application parameters are not used.
[2] Shaft to bore misalignment (STBM)—total indicator reading is double the value listed.
[3] Rate of acceleration to be agreed upon by user and supplier.
[4] Reciprocation at 10 strokes per min, at an amplitude of 2.5 mm (0.10 in) during shaft rotation.
[5] Reciprocation at 15 strokes per min, at an amplitude of 12.7 (0.50 in) during shaft rotation.
[6] For duration see 5.5, 5.6, and 5.7.

TABLE 3—TEST PARAMETERS[1]—OFF HIGHWAY EQUIPMENT AND GENERAL

Application	Accessory Drive	Engine Front	Engine Rear	Axle Pinion	Axle Thru-Shaft Tandem Pinion	Axle Wheel	General
Shaft Runout—[TIR (Total Indicator Reading)]							
mm	0.38	0.25	0.25	0.25	0.25	0.38	0.25
in	0.015	0.010	0.010	0.010	0.010	0.015	0.010
STBM[2] Offset							
mm	0.25	0.25	0.25	0.13	0.25	0.25	0.13
in	0.010	0.010	0.010	0.005	0.010	0.010	0.005
Rotation	Either	Clockwise	Counter-Clockwise	Clockwise	Counter-Clockwise	Either	Either
Cold Test[4]							
Speed rpm[3]	300	200	200	150	150	60	200
Temperature							
°C • 3°	-40	-40	-40	-40	-40	-40	-40
°F • 5°	-40	-40	-40	-40	-40	-40	-40
Hot Test							
Reverse Rotation	None	None	None	2 min at 300 rpm	2 min at 300 rpm	2 min at 60 rpm	None
Speed rpm	3000	3000	3000	3000	3000	1000	3000
Temperature							
°C • 3°	121	135	135	93	93	82	107
°F • 5°	250	275	275	200	200	180	225
Duration Hours	350	350	350	350	350	350	350

[1] To be used in the event that the actual application parameters are not used.
[2] Shaft to bore misalignment (STBM)—total indicator reading is double the value listed.
[3] Rate of acceleration to be agreed upon by user and supplier.
[4] For duration see 5.5, 5.6, and 5.7.

3.5 Test Procedure

3.5.1 In order to analyze the test results more accurately, it is recommended that the following physical characteristic seal data be obtained before and after testing.

3.5.1.1 *Lip Diameter*

3.5.1.2 *Lip Opening Pressure*

3.5.1.3 *Outer Case Mean Diameter and Out-of-Round*

3.5.1.4 *Seal Lip to Case OD Eccentricity*

3.5.1.5 Seal lips shall be inspected at 7 to 10 diameters magnification for chipping, scratches, and ragged edges due to faulty trim, in addition to mold imperfections such as knit lines, incomplete fills, or blistering.

3.5.2 The test head must be thoroughly cleaned of all contaminants and extraneous matter.

3.5.3 The seal lip and test shaft shall be lubricated with a small quantity of the test fluid.

3.5.4 The seal must be installed in the seal retainer so that the cumulative eccentricities of the seal and the test head are known when installed. Means must be provided to insure no OD leakage when the seal is installed in the seal retainer plate.

3.5.5 The plane of the seal lip shall be perpendicular to the shaft axis unless otherwise specified.

3.5.6 The test shaft shall be placed in such a position that an unused surface is in contact with the sealing element.

3.5.7 Test fluid level shall be mid-shaft except for engine seals where the fluid level should be at the lower 1/8 of the shaft diameter. Engine seals have no static head of oil as they are splash lubricated.

3.5.8 The test shall be started and conducted in accordance with the prescribed test schedule.

3.5.9 Determine time to leakage if it occurs. If leakage is excessive, terminate the test.

3.5.10 Upon termination of the test, the seal and test shaft shall be carefully examined and their conditions evaluated and recorded.

3.5.11 A minimum of six seals is to be tested.

3.6 Criteria for Acceptance and Rejection

3.6.1 Undesirable fluid leakage rates past the seal lip, as evidenced by visual examination prior to completion of the test schedule. An accepted visual method of rating seal leakage during test is as follows in Table 4:

TABLE 4—CRITERIA FOR ACCEPTANCE AND REJECTION

Rating No.	Condition
1	No visible leakage of shaft-seal lip contact when viewed from air side.
2	A small miniscus of oil visible at shaft-seal lip contact.
3	Same as (2) but a continued wetting of seal lip (air side) and seal case.
4	Heavy wetting of seal at air side continuing down seal adapter plate.

3.6.1.1 Criteria for acceptance will vary with test duration and application requirements. Ratings of 1 or 2 would be acceptable in all instances. Allowable leakage for rating 3 or 4 should be agreed upon by user and supplier.

3.6.2 Uneven wear occurring in a small arc of the seal contact path. This condition appears as a significant increase in wear path width which occurs in an arc of 45 to 180 degrees.

3.6.3 Excessive changes in dimensional and physical properties of the seal lip after test. Typical values which can be used for rejection criteria would be:

3.6.3.1 Change in material hardness at seal contact surface in excess of ±10 points of IRHD.

3.6.3.2 Loss of seal lip interference in excess of 50% due to material tension set.

3.6.3.3 Loss of spring force in excess of 10% due to thermal stress relief.

4. Alternate General Performance Test

4.1 Introduction—This section is for spring-loaded seals only, where it is not feasible to conduct qualification and/or quality control tests under conditions that duplicate the application per the application data sheets; because the seal is used in a variety of applications, the seal is used under unknown conditions, or the seal is used under conditions that are exceptionally difficult to duplicate in the laboratory.

4.2 Description of Test Apparatus—See 2.2.

4.3 Test Conditions—These tests shall be conducted as follows:

4.3.1 Shaft offset shall be 0.25 mm (0.010 in) TIR. Dynamic runout shall be 0.25 mm (0.010 in) TIR.

4.3.2 The shaft shall rotate at the rate of 6.1 m/s (1200 ft/min) of leather seals and 10 m/s (2000 ft/min) for synthetic seals. In either case, the maximum shaft speed shall not exceed 4000 rpm.

4.3.3 The test fluid shall be SAE 10 motor oil.

4.3.4 The test fluid temperature shall be 71 °C ± 3 °C (160 °F ± 5 °F) for leather seals and 93 °C ± 3 °C (200 °F ± 5 °F) for synthetic seals.

4.3.5 The test fluid level shall be at centerline of shaft and operate at atmospheric pressure.

4.4 Test Schedule—The test shall consist of 10 daily cycles. (See Table 1.)

5. Low Temperature Test

5.1 Introduction—This section covers equipment and procedures for low temperature tests to qualify a radial lip type seal design. Three functional test methods described are: (a) Preliminary Screening Test to evaluate crack resistance, (b) Dynamic Cold Cycling Test, and (c) Optional Dynamic Functional Test to evaluate seal performance and efficiency.

5.2 Description of Test Apparatus

5.2.1 The test equipment specified in 3.2 (Figure 1) should be fitted with a cooling jacket or coils, or the entire machine may be placed in a cold room to obtain the desired low temperatures of the seal assembly.

5.2.2 The test head should be insulated with a minimum of 50 mm (2 in) of polystyrene foam (or equivalent) in order to maintain the specified temperatures.

5.3 Test Specimens

5.3.1 Two groups of seals shall be used for test samples: (a) new seals and (b) seals that have been aged in the application fluid as follows: Place seals on application size shaft and position assembly horizontally in application fluid to shaft centerline for 70 h, at the temperature selected for the application from Table 2 or 3. Recommended sample size—three seals from each group.

5.4 Pretest Measurements and Preparation

5.4.1 In order to analyze the test results more accurately, it is recommended that the following physical characteristic seal data be obtained before and after testing:

5.4.1.1 *Lip Diameter*

5.4.1.2 *Lip Opening Pressure*

5.4.1.3 *Outer Case Mean Diameter and Out-of-Round*

5.4.1.4 *Radial Wall Variation*

5.4.1.5 *Spring Load at Specified Deflected Length*

5.4.1.6 *Visual Examination of Seal Lips Under 7 to 10X Magnification*

5.4.1.7 *Shaft Diameter and Axial Surface Roughness*

5.4.2 Shafts should be examined under 20X magnification and be free of defects that would be detrimental to sealing, such as nicks, burrs, scratches, and machining lead.

5.4.3 Install the test shafts and set dynamic runout and bore misalignment, using either Table 2 or 3 as a guide.

5.4.4 Pre-lube the sealing element and/or shaft as specified for the application.

5.4.5 Install the seals in the test machine so that the minimum radial wall dimension and bore misalignment are on the same line, to provide the least possible lip interference at one point.

5.4.6 Install two thermocouples, one at approximately 13 mm (0.5 in) from the bottom of the seal lip, in the test fluid and one in the garter spring. It is recommended that a 0.13 mm (0.005 in) thick piece of shim stock, with a thermocouple bonded to it, be inserted between the garter spring coils to minimize sealing element distortion.

5.5 Preliminary Screening Test

5.5.1 This test is to serve as a screening test to quickly evaluate the capability of a seal material and design to resist cracking when flexed by the dynamic rsnout of the shaft. The application operating conditions should serve as a guide in selected test parameters. When application conditions are not available, it is recommended that the values in Table 2 or 3 be used.

5.5.2 TEST SPECIMENS—See 5.3.

5.5.3 PRETEST MEASUREMENTS AND PREPARATION—See 5.4.

5.5.4 TEST SCHEDULE—The test shall be started and conducted in accordance with the following schedule:

5.5.4.1 Without any test lubricant in the sump, lower the seal temperature to the value specified for the application.

5.5.4.2 Maintain the seal temperature for a minimum of 2 h to insure equilibrium has been obtained.

5.5.4.3 Rotate the shaft at 60 rpm ± 10% for a 10 s period.

5.5.4.4 Heat test head to room temperature and remove seals from machine.

5.5.4.5 Upon termination of the test, the seal lip(s) should be examined for failure. The lip sections should be inspected for axial cracking at the contact line and radial cracking through the flex section. Typical failures consist of cracking through the lip sections (axially and circumferentially).

5.6 Test Procedure 2—Dynamic Cold Cycling Test

5.6.1 This test should serve to evaluate the cold abrasion and leakage characteristics of a seal material and design. The actual application operating conditions should serve as a guide for the test schedule. Where it is not feasible to conduct tests under conditions that duplicate the application, it is recommended that the values in Table 2 or 3 be used.