Guide to the Application and Use of Engine Coolant Pump Face Seals —SAE J1245 JUN82

SAE Recommended Practice
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PREPRINT

The ϕ symbol is for the convenience of the user in locating areas where technical revisions have been made to the previous issue of the report. If the symbol is next to the report title, it indicates a complete revision of the report.

GUIDE TO THE APPLICATION AND USE OF ENGINE COOLANT PUMP FACE SEALS—SAE J1245 JUN82

SAE Recommended Practice

Report of the Transmission and Drivetrain Committee, approved November 1978, revised by the Seals Committee June 1982.

1. Introduction—This recommended practice is intended as a guide in the usage of mechanical face seals for the engine coolant pump application. The main purpose of the guide, is to fill the void caused by the lack of a ready source of practical information on the design and use of the engine coolant pump face seal. Included in the report is a compilation of present practices, viz.; a description of the various types of seals, material combinations, design data, tolerances, drawing format, qualification and inspection information, and quality control data. The terminology used throughout the guide is recommended, and through common usage it is hoped to promote uniformity in seal nomenclature.

2. Seal and Mating Ring Types—The mechanical face seal assemblies utilized in automotive and other heavy duty vehicle engine coolant pumps consist of a seal head assembly and a mating ring. Although many variations of face seal designs exist, two basic concepts are predominantly applied; they are based on the single helical and elastomeric spring preload concepts. Preload is defined as the force applied to the primary seal ring, when located in its normal operating position, to prevent separation of the sealing interfaces during the anticipated duty cycle.

2.1 Single Helical Spring-Loaded Type Seal—This seal type is the most commonly utilized concept for preloading mechanical face seals. The seal head assembly generally consists of a cartridge, bellows, spring, ferrule(s), and primary seal ring (Ref. Fig. 1, SAE J780a (November, 1978)).

Force is applied to the primary seal ring by the compression of a single helical coil spring between the cartridge and primary seal ring during installation of the seal head assembly to its proper operating length. The bellows allow the primary seal ring to move axially, thus compensating for wear without loss of its sealing ability. Ferrules may be used to provide a contact surface for the spring and secondary sealing functions. Under normal operating conditions and with proper materials selection, this design is generally resistant to corrosion, abrasion, time-temperature, and coolant exposure effects.

2.2 Elastomeric Spring Loaded Type Seal—The seal head assembly consists of a primary seal ring and bellows (Ref. Fig. 2, SAE J780a (November, 1978)).

Preload force is applied to the primary seal ring by the axial and/or radial deformation of the elastomeric bellows member. This design is resistant to corrosion and abrasion, but its load characteristics are dependent on elastomeric material properties to resist time-temperature and coolant exposure effects.

2.3 Unitized Type Seal—The unitized seal consists of a seal head assembly of either helical or elastomeric spring preload concept and the mating ring, constructed so as to be handled as a single piece. The unitized seal generally consists of a cartridge, bellows, spring, ferrule(s), primary seal ring, secondary drive seal, mating ring, and unitizer (Ref. Fig. 3, SAE J780a (November, 1978)).

The unitizer is press fitted onto the shaft, thus the unit is not dependent on impeller position to establish operating length.

2.4 Mating Ring Types—There are six widely applied mating ring types, including surfaces of pump components (Ref. Fig. 4, SAE J780a (November, 1978)).

Mating ring types are differentiated by the method of mounting while providing a reliable means of assuring drive, secondary sealing, and to minimize stresses and distortion during the operating cycle; they are as follows: (1) banded, I.D. mounted with a secondary drive seal; (2) plain (unbanded), I.D. mounted with a secondary drive seal; (3) bonded onto the surface or into a cavity of the pump component, e.g., rotating impeller; (4) the surface of the pump component is machined and lapped to provide a mating ring surface; (5) mating ring is press fitted onto the pump shaft; and (6) the mating ring is mounted into the pump component with a secondary drive seal.

NOTE: Type 5 mating ring would result in the most distortion of the mating ring face.

3. Seal Material—Environmental conditions dictate the type of material which should be used in a specific application. Seal materials can be fully evaluated only in terms of specific operating conditions and performance requirements. The following paragraphs give general descriptions of primary seal rings and their mating ring materials, elastomeric compounds, and hardware, also outlining some advantages and disadvantages. It should be recognized that batch to batch variations due to material inconsistencies can occur in all materials listed. Such inconsistencies can alter the performance data given.

3.1 Primary Seal Ring—The primary seal ring is allowed axial motion to permit the sealing face to remain in contact despite shaft endplay, runout, and face wear.

3.1.1 THERMOSET PLASTIC MATERIALS—Thermoset plastic materials with varying amounts of mineral and/or metal fillers are low shrinkage resin materials such as epoxy, phenolic, or polyester, usually molded in the 400–600°F (205–315°C) range. Thermoset plastics are low cost materials.

3.1.1.1 *Advantages:*

(a) Good wear resistance at required temperatures and pressures.
(b) Readily molded to complex geometry and close tolerances.

3.1.1.2 *Disadvantages:*

(a) Poor thermal stability.
(b) Poor thermal conductivity.

3.1.2 CARBON GRAPHITE—Carbon graphite is generally a manufactured product which contains some graphite, natural or synthetic, and which has a rigid, hard structure produced by firing at high temperatures usually ranging between 1650 and 3630°F (900 and 2000°C).

The material can be impregnated with various materials, including metals, to impart a particular carbon mix identity. The material is in the premium cost range.

3.1.2.1 *Advantages:*

(a) Excellent temperature resistance and stability.
(b) Low absorption of coolant and consequent lack of degradation.
(c) Some degree of self-lubricity, thus able to withstand dry runs without galling.
(d) Excellent wear resistance.
(e) Good thermal conductivity (via impregnation).

3.1.2.2 *Disadvantages:*

(a) Difficult to mold relatively complex shapes and maintain close tolerances.
(b) Poor handling characteristics (damages easily).
(c) Possible chemical attack on impregnants.

3.2 Mating Rings—Mating rings are usually of a dissimilar material which is harder than the primary seal ring. The material choice depends upon operating conditions, configuration, costs, and performance requirements.

3.2.1 ALUMINUM OXIDE CERAMICS—Aluminum oxide ceramics generally have an aluminum oxide (Al_2O_3) content ranging from 85–99.9% by weight. The parts are formed by compacting finely ground oxide powders with fluxing agents and inhibitors at high pressures. The formed part is then fired at high temperatures usually ranging between 2550 and 3250°F (1400–1800°C). After firing, the ceramic is a strong, hard, dense material, composed mostly of pure alumina crystals of controlled size. Cost is moderate to premium.

3.2.1.1 *Advantages:*

(a) Excellent wear resistance.
(b) Excellent dimensional stability.
(c) Excellent fluid compatibility.

3.2.1.2 *Disadvantages:*

(a) Mechanical and thermal shock susceptibility.
(b) Difficult to mold complex shapes and maintain tolerances.

3.2.2 POWDERED AND CAST METAL MATERIALS—Metal powders, such as iron, are placed in a die and compressed. The parts are then sintered in a controlled atmosphere, whereas cast metal is poured or injected in its molten state into a mold. These can be supplied in a diversity of alloys for high volume low cost applications.

3.2.2.1 *Advantages:*

(a) Excellent thermal shock resistance.
(b) Good thermal conductivity.

3.2.2.2 *Disadvantages:*

(a) Poor corrosion resistance (compatibility verified).
(b) Moderate wear resistance.

3.2.3 SPRAYED COATINGS—Sprayed coatings can combine various qualities of materials to improve performance and obtain certain economic advantages.

3.2.3.1 *Advantages:*

(a) Good thermal shock resistance.

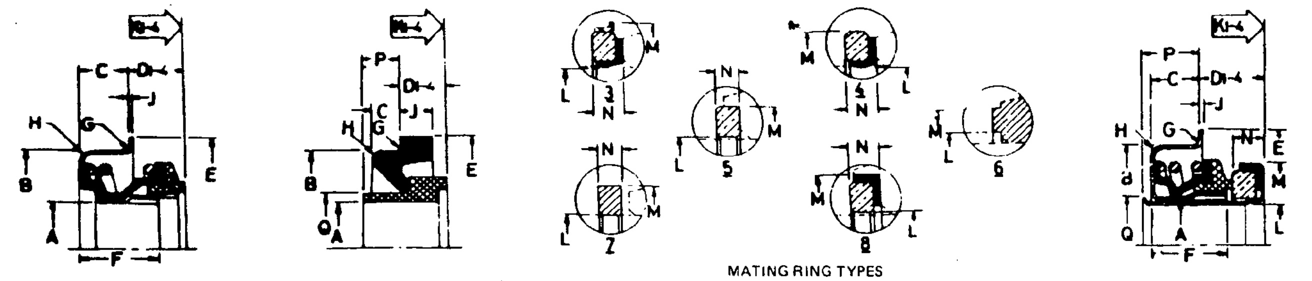


FIG. 1A—SPRING LOADED

FIG. 1B—ELASTOMER LOADED

FIG. 1C—BANDED, I.D. MOUNTED
FIG. 1D—BONDED
FIG. 1E—PRESSED ON

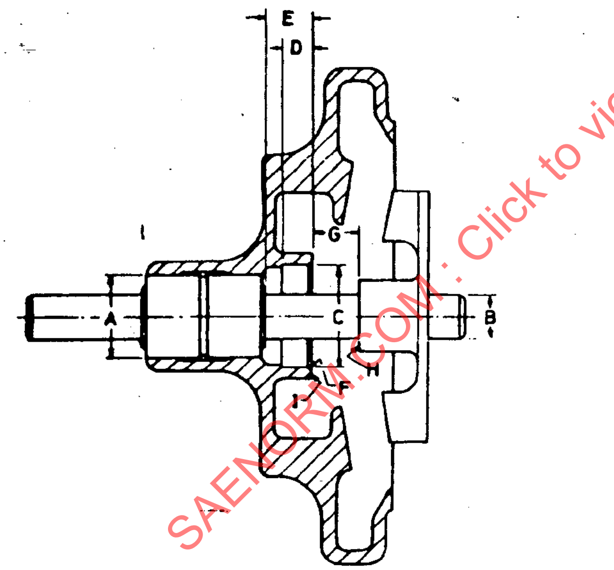
FIG. 1F—PLAIN I.D. MOUNTED
FIG. 1G—LAPPED PUMP COMPONENTS
FIG. 1H—O.D. MOUNTED

FIG. 1I—UNITIZED

ASS'Y TYPE FIGS. 1A, 1B, 1I	MATING RING TYPE FIGS. 1C–1H	APPLICATION (PASSENGER OR NON-PASS)	A BORE I.D. MIN.	B OUTSIDE DIA MIN/MAX (AT HEEL)	C LENGTH MIN/MAX NOTE a	D1 MAX "SOLID" LENGTH NOTE c	D2 MIN OPERATING LENGTH NOTE b	D3 NOM OPERATING LENGTH NOTE b	D4 MAX OPERATING LENGTH NOTE b	E FLANGE O.D. MIN/MAX NOTE a	F TORQUE TUBE LENGTH MAX

G FLANGE RADIUS MAX	H HEEL RADIUS MIN	J FLANGE THICKNESS NOM	K1 REF. LOAD AT D1 lb. oz (kg) NOTE c	K2 MAX LOAD AT D2 lb. oz (kg) NOTE c	K3 LOAD RANGE AT D3 lb. oz (kg) NOTE c	K4 MIN LOAD AT D4 lb. oz (kg) NOTE c	L MATING RING ASS'Y I.D. MIN/MAX NOTE a	M MATING RING ASS'Y O.D. MIN/MAX NOTE a	N MATING RING ASS'Y THICKNESS MIN/MAX	P PROJECTION AT D2 MAX	Q PROJECTION DIA MAX

NOTES:
[a]DIMENSION BEFORE INSTALLATION.
[b]DIMENSION TAKEN FROM BACK SIDE OF FLANGE.
[c]REFER TO SECTION FOR LOAD DETERMINATION.



SEAL ASSEMBLY OPERATING CONDITIONS

FLUID COMPOSITION:

RPM ________ MIN ________ MAX
TEMPERATURE ________ MIN ________ MAX
PRESSURE ________ MIN ________ MAX
REMARKS:

NOTES:

A BEARING BORE DIA	B SHAFT DIA	C SEAL HOUSING BORE DIA	D SEAL HOUSING BORE DEPTH	E AXIAL CLEARANCE	F SEAL BORE LEAD-IN CHAMFER

G PUMP HOUSING TO IMPELLER	SURFACE ROUGHNESS		CONCENTRICITY BETWEEN A & C (F.I.M.)	
	B	C	CONCENTRICITY BETWEEN B & C (F.I.M.)	
			SQUARENESS BETWEEN B & H (F.I.M.)	
SHAFT END PLAY			SQUARENESS BETWEEN B & I (F.I.M.)	

SYM	DESCRIPTION	CKD	DATE	DRAWN CHKD APPVD	BY	DATE	COMPANY NAME SEAL EXAMPLE
REVISIONS				SCALE			PART NO.

FIG. 1—STANDARD DRAWING FORMAT

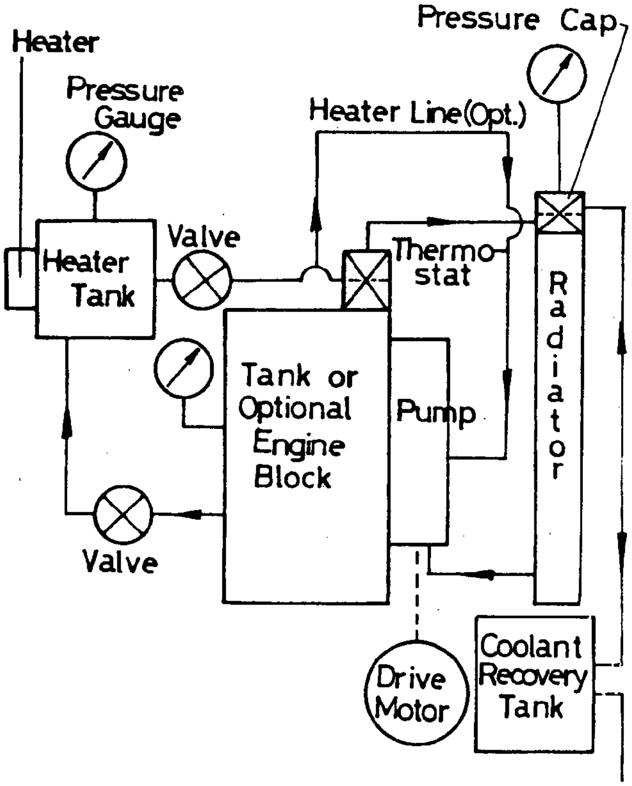


FIG. 2—SCHEMATIC—ENGINE COOLANT PUMP SEAL DURABILITY TEST SYSTEM

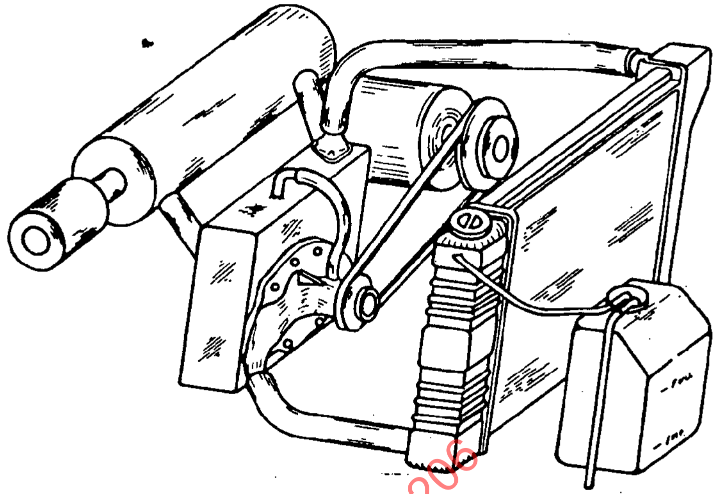


FIG. 3—PICTORIAL ARRANGEMENT OF RECOMMENDED ENGINE COOLANT PUMP SEAL DURABILITY TEST SYSTEM

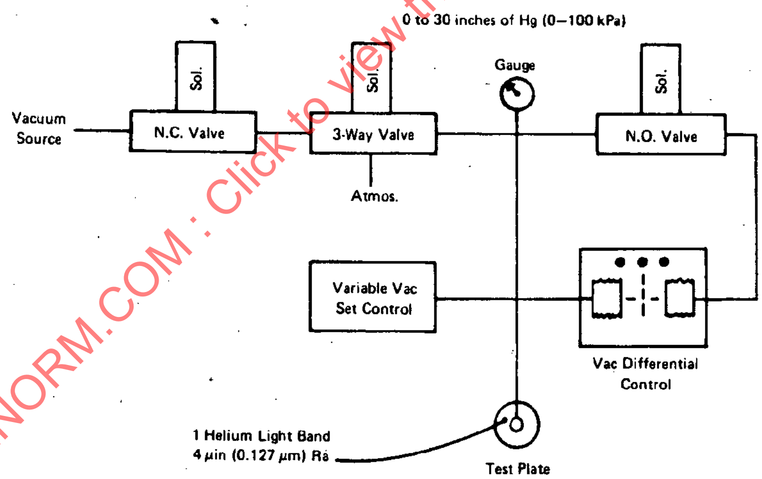


FIG. 4—SCHEMATIC—TYPICAL VACUUM TEST ARRANGEMENT

(b) Excellent wear resistance.
(c) Adaptable to a large variety of sizes and shapes.

3.2.3.2 *Disadvantages:*
(a) Added cost.
(b) Specialized processing.

3.3 Secondary Seals—Secondary seals are generally elastomers that can be categorized as not-oil or not-solvent resistant, oil or solvent resistant, and heat resistant.

3.3.1 NITRILE COMPOUNDS (NBR)[1]—This material family's operating range is −65–275°F (−54–135°C). Nitrile is recommended for general use with exposure to coolants. It is in the low cost range.

3.3.1.1 *Advantages:*
(a) Good processability.
(b) Good oil resistance.

3.3.1.2 *Disadvantages:*
(a) Limited high temperature life.
(b) Poor to moderate ozone resistance.

3.3.2 SILICONE COMPOUNDS (V Si)[1]—Silicone compounds are recommended for applications where temperatures are within −65–350°F (−54–177°C). The maximum useable temperature is limited by the decomposition temperatures of the various coolants. Silicone rubbers are in the high cost range of seal compounds.

3.3.2.1 *Advantages:*
(a) Excellent heat resistance.
(b) Excellent low-temperature properties.

3.3.2.2 *Disadvantages:*
(a) Poor compatibility in some coolants.
(b) Moderate abrasion resistance.

[1] ASTM D 1418, Recommended Practice for Nomenclature for Synthetic Elastomers and Lattices, 1976 Edition, should be used as reference.

3.3.3 Fluoroplastic Compounds (PTFE)[2]—These compounds are recommended for applications which are chemically damaging to elastomers and for extreme temperatures within −400–500°F (−240–260°C). They are in the high cost range of seal compounds.

3.3.3.1 *Advantages:*

(a) Excellent coolant resistance.
(b) Excellent heat resistance.

3.3.3.2 *Disadvantages:*

(a) Easily damaged during assembly.
(b) High plastic deformation.

3.4 Hardware—This hardware consists of cartridges, ferrules, springs, unitizers, and other miscellaneous stampings.

3.4.1 Plated mild steel—Hardware fabricated from low carbon steel can be typically plated with cadmium or zinc, with or without chromates. These parts are in the low cost range.

3.4.1.1 *Advantages:*

(a) Easily formed.
(b) Readily available.

3.4.1.2 *Disadvantages:*

(a) Corrosion resistance dependent upon surface treatment.

3.4.2 Stainless Steel (SAE 300–400 Series)—Grade selection is dependent on desired level of corrosion resistance, mechanical properties, method of fabrication, and cost/availability factors.

3.4.2.1 *Advantages:*

(a) High temperature physical property retention.
(b) Excellent corrosion resistance.

3.4.2.2 *Disadvantages:*

(a) Limited workability.
(b) Availability of some grades.

3.4.3 Brass—Generally, annealed 70/30 brass (SAE alloy No. CA 260) is utilized.

3.4.3.1 *Advantages:*

(a) Good corrosion resistance.
(b) Easily formed.

3.4.3.2 *Disadvantages:*

(a) Season (stress corrosion) cracking.
(b) Easily deformed.

*4. **Application Design Data***—The following section is presented to provide guidelines as to specific dimensions and conditions that may functionally affect the applied seal within the engine coolant pump envelope.

4.1 Reference Dimensions—To aid in the establishment of standard pump housing envelope dimensions, those shown in Table 1, SAE J780a (November, 1978), are recommended. The dimensions shown reflect specific dimensions utilized in current practice.

4.2 Flatness—Overall flatness for sealing surfaces is critical to maintain a liquid or gas tight seal.

4.2.1 Primary Seal Ring—Surface flatness should be in accordance with Table 1.

4.2.2 Mating Rings—Surface flatness should be in accordance with Table 1.

4.3 Surface Roughness—Surface roughness is a function of base material, grain size, structure, and method of finishing. Surface roughness is to be evaluated on the part of the supplier and user for specific combinations of materials and for specific applications. See Table 1.

4.4 Waviness—Waviness should be within the specifications shown on Table 1.

4.5 Squareness—Squareness of the face of the mating ring is to be within 0.005 in (0.13 mm) F.I.M. of shaft center line.

4.6 Dynamic Runout—Dynamic runout is defined as twice the distance the center of the shaft is displaced from the center of rotation, expressed in F.I.M., and should not exceed 0.010 in (0.25 mm).

4.7 Eccentricity—Eccentricity is defined as the radial distance the geometric center of a shaft is displaced from the axis of rotation and should be held within 0.005 in (0.13 mm) F.I.M.

4.8 Lead-In Chamfer—A lead-in chamfer is required at the pump housing bore and the bearing shaft end for ease of seal installation and prevention of damage to the secondary seals (see Table 1, SAE J780a (November, 1978)). All corners should be blended smoothly.

4.9 Clearances—All clearances must be large enough to provide sufficient coolant circulation for proper seal functioning.

*5. **Drawing Designation***—It is recommended that the standard SAE seal and housing drawing format be used. This format (Fig. 1) is a composite of the engineering application, seal, and pump housing dimensional data that is required to assure functional compatibility of the seal in a specific application. The format is intended as a guide and it is not required that it be followed precisely as shown. It is understood that standard engineering practices, as employed by some users, will not require that this amount of detailed information be shown on the print since it may be recorded elsewhere in their engineering standards. In those cases, it is recommended that the format and/or sketches be suitably altered to meet the user's requirements.

The seal user should only supply that portion of the engineering application and dimensional data that is necessary for the particular product requirements. The seal specification data should be furnished by the seal supplier in conjunction with the user. This data and information must be such that it is compatible with the engineering application data as supplied by the user.

*6. **Qualification Test***—This test is conducted to determine the durability characteristics of an engine coolant pump seal in a functional engine coolant pump assembly.

6.1 Description of Equipment and Installation—The following equipment and system orientation is recommended (see Figs. 2 and 3).

6.1.1 Tank and heater capacity and pressure drop equivalent to engine cylinder block (engine block equipped with heaters—optional).

6.1.2 Complete production engine coolant pump assembly in which the seal will operate (including heater and bypass lines).

6.1.3 Drive motor capable of driving pump at 6000 rpm.

6.1.4 Production radiator (preferred) or tank with equivalent restriction.

6.1.5 Production radiator cap (check for opening pressure).

6.1.6 Coolant recovery tank.

6.1.7 Production thermostat and housing (checked for opening temperature).

6.1.8 Valves for setting restrictions equivalent to that in production cooling systems.

6.1.9 Pressure gauges to measure system pressures.

TABLE 1—RECOMMENDED SURFACE ROUGHNESS AND FLATNESS FOR PRIMARY AND MATING SEAL RINGS (ENGLISH UNITS)[a]

Material	Reflective Surface			Non-Reflective Surface		
	Roughness Average, Ra μin	Flatness: Light Bands	Flatness: Waviness μin-Ra	Roughness Average, Ra μin	Flatness: Vacuum Test	Flatness: Waviness μin-Ra
Filled Thermoset Plastic	3–10	3–6	70 max	25 max	accept	70 max
Carbon Graphite	25 max	3–6	70 max	30 max	accept	70 max
Cast Iron	3–10	2–3	35 max	20 max	accept	35 max
Sintered Metals	5–15	2–3	35 max	35 max	accept	35 max
Ceramics (Al_2O_3)	5–15	2–3	35 max	35 max	accept	35 max

[a] See paragraphs 7.4 through 7.7 for measuring test procedures.
Note: See Table 1A for SI Units.

TABLE 1A—RECOMMENDED SURFACE ROUGHNESS AND FLATNESS FOR PRIMARY AND MATING SEAL RINGS (SI UNITS)[a]

Material	Reflective Surface			Non-Reflective Surface		
	Roughness Average, Ra μm	Flatness: Light Bands	Flatness: Waviness μm-Ra	Roughness Average, Ra μm	Flatness: Vacuum Test	Flatness: Waviness μm-Ra
Filled Thermoset Plastic	0.08–0.25	3–6	1.78 max	0.64 max	accept	1.78 max
Carbon-Graphite	0.64 max	3–6	1.78 max	0.76 max	accept	1.78 max
Cast Iron	0.08–0.25	2–3	0.89 max	0.51 max	accept	0.89 max
Sintered Metals	0.13–0.38	2–3	0.89 max	0.89 max	accept	0.89 max
Ceramics	0.13–0.38	2–3	0.89 max	0.89 max	accept	0.89 max

[a] See paragraphs 7.4 through 7.7 for measuring test procedures.

[2] ASTM D 1600, Tentative Abbreviations of Terms Relating to Plastics, 1975 Edition, should be used as reference.

6.1.10 Cycle counter and running time meter.
6.1.11 Heater core (optional).
6.1.12 Automatic controls for cycling motor.
6.1.13 Heater(s) (3000 W) with controls.
6.1.14 Coolant hoses and clamps (production parts preferred).

6.2 Procedure—The following procedural outline is provided as a guide; obviously, this procedure should be modified to be compatible with the user's established standard engineering practice.

6.2.1 TEST DURATION AND CONDITIONS—The engine coolant pump assembly should be run under the following conditions commensurate with the user's standards.

6.2.1.1 *Coolant Temperature*—Coolant temperature, at the pump outlet should be maintained at 240–250°F (115–121°C).

6.2.1.2 *System Pressure*—The system pressure should be maintained, at the pump outlet, at a level equivalent to that of a standard production system.

6.2.1.3 *Pump Rotational Speed*—The engine coolant pump rotational speed should be maintained at maximum rated speed. Maximum rated speed is the pump speed attained at the maximum rated engine speed. **Optional: Engine coolant pump speed should be cycled from zero rpm** to maximum rated speed in 15 s, held for 30 s, and returned to zero rpm in 15 s. This cycle is to be repeated for the duration of the test.

ϕ 6.2.1.4 *Coolant Concentration*—The coolant concentration should be maintained in accordance with engine manufacturer's factory specification. However, the coolant boiling point, at test pressure, should be 10°F (5.5°C) greater than test temperature. It should be emphasized here that contaminants in the coolant system, either present originally or developed after a period of operation (Reference #1, #2), will affect seal performance.

The contaminants normally found in the system are soluble and non-soluble in nature. The soluble elements may include constituents from the basic coolant chemistry and various commercial additives. The non-soluble elements may include precipitates from the basic coolant and additives, core sand, and oxides of aluminum, iron and other metallic elements in the coolant system. Soluble and non-soluble oil contaminants may have been introduced during the normal manufacturing process or during system operation and maintenance.

If test data shows non-repeatability, and coolant variations are determined to be the principal contributor, then a standard fluid, such as ASTM 3585-77 can be utilized for test stand qualification.

It is recommended that long term durability and contamination effects be determined by vehicle testing. If it is desirable to establish a contaminated test system fluid, typical fluid composition is as follows:

Fill the cooling system with a mixture of 88% factory fill coolant and 12% Sarasota water (by volume). Sarasota water is made with 82% distilled water and 18% Sarasota Concentrate (by volume). The composition of Sarasota Concentrate is as follows:

Ingredients	Grams/Gallon
Sodium Metasilicate	2.39
Sodium Chloride	5.50
Potassium Chloride	0.64
Sodium Bicarbonate	2.20
Sodium Sulphate	25.40
Distilled Water	Remainder to complete 1 gallon

NOTE: If core sand and/or other non-soluble contaminants are to be purposely added, modifications (such as removal of heater cores, radiators, etc.) to the test system may be necessary to minimize contaminant "drop out" or erosion damage within the system which would change the test conditions.

6.2.1.5 *Heater and Bypass Lines*—All bypass and heater return lines to the engine coolant pump should be connected and operable.

6.2.1.6 *System Pressure Drop*—When an engine block and radiator are not employed, valves on the inlet and discharge sides of the engine coolant pump are to be used to set a restriction equivalent to that found in the production cooling system.

6.2.1.7 *Belt Tension*—Initial engine coolant pump drive belt tension should be set to manufacturer's specifications.

6.2.1.8 *Thermostat*—If an engine is used, a thermostat valve disc position should be mechanically maintained at an opening equal to that achieved at the test temperature.

6.3 Data to be Recorded—To provide meaningful test data, the following minimum data should be recorded:

6.3.1 BEFORE TEST—The following data should be obtained and recorded prior to pump assembly and testing.

6.3.1.1 *Primary Seal Ring*
(a) Material.
(b) Surface roughness.
(c) Surface flatness.
(d) Surface waviness.
(e) Face height.

6.3.1.2 *Mating Ring*
(a) Material.
(b) Surface roughness.
(c) Surface flatness.
(d) Surface waviness.
(e) Hardness.
(f) Squareness to shaft.

6.3.1.3 *Coolant Composition*
(a) Coolant identification.
(b) Coolant formulation.

6.3.1.4 *Seal and Pump Assembly*
(a) Seal operating length.
(b) Seal load at operating length.
(c) Test schedule and allowable leakage.
(d) Shaft speed.

6.3.2 DURING TEST—The following data should be recorded during the test sequence.
6.3.2.1 Pump rpm.
6.3.2.2 Coolant temperature at pump outlet.
6.3.2.3 System pressure.
6.3.2.4 Inlet pressure.
6.3.2.5 Discharge pressure.
6.3.2.6 Seal cavity pressure.

6.3.3 AFTER TEST—The following data or observations should be noted and recorded after completion of the test sequence and the seal has been removed from the pump assembly:

6.3.3.1 *Primary Seal Ring*
(a) Wear pattern.
(b) Surface roughness.
(c) Surface flatness.
(d) Surface waviness.
(e) Face height.

6.3.3.2 *Mating Ring*
(a) Wear pattern.
(b) Surface roughness.
(c) Surface flatness.
(d) Surface waviness.

6.3.3.3 *Bellow Condition*
(a) Time-temperature effect.
(b) Glue joints.
(c) Abrasion.

6.3.3.4 *Spring*
(a) Corrosion.
(b) Fatigue.

6.3.3.5 *Cartridge*
(a) Corrosion.
(b) Pressfit pattern.

7. Inspection and Quality Control Data—The following is presented as an inspection guide and outlines broad general quality control equipment and procedures. These guidelines should be reviewed and modified to be commensurate with the supplier's and user's standard inspection and quality control procedures.

7.1 Concentricity and Squareness Relationships—Concentricity and squareness relationships are defined in accordance with referenced dimensions given in Table 1, SAE J780a (November, 1978), and are:
(a) Concentricity between Bore A and Bore C (F.I.M.).
(b) Concentricity between Shaft B and Bore C (F.I.M.).
(c) Squareness between Shaft B and Surface H (F.I.M.).
(d) Squareness between Shaft B and Surface I (F.I.M.).
(e) Shaft endplay.

Measurement of these relationships shall be made with dial indicators having accuracy within ±0.0001 in (2.5 μm). The use of precision collets and/or expanding mandrels will greatly facilitate measurement of these relationships.

Measurement of concentricity between B and C and squareness between B and I shall be made with bearing and shaft assembly installed in the pump housing. Measurement of squareness between B and H may be made independent of other pump components. See SAE J780a (November, 1978) for recommended limits of concentricity and squareness.

7.2 Operating Length Variation—Operating length variation is defined as dimension (D_4-D_2) given in the standard drawing format Fig. 1,