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SURFACE VEHICLE RECOMMENDED PRACTICE

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Guide to the Application and Use of Engine Coolant Pump Face Seals

1. ***Scope***—This SAE 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 document 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 document is a compilation of present practices, as in 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 document is recommended and, through common usage, is hoped to promote uniformity in seal nomenclature.

2. *References*

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J111c—Seals—Terminology of Radial Lip
SAE J780—Engine Coolant Pump Seals
SAE Paper 660128—Fluid Performance of Factory-Installed Antifreeze Coolants in Passenger Car Service, E. Beynon, 1966
SAE Paper 760631—Engine Coolant Performance in Late Model Passenger Cars, N. E. Payerle, 1976
SAE Paper 890609—Effect of Additives in Cooling Water on Sealing Performance of Water Pump Seals of Automotive Engines, K. Kiryu et al., 1989

2.1.2 ANSI PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI B46.1

2.1.3 ASTM PUBLICATION—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 1418—Practice for Rubber and Rubber Latices—Nomenclature

2.1.4 STLE PUBLICATION

STLE Paper 88-AM-5E-1—An Investigation of Scale Deposits on the Sealing Surfaces of End Face Seals for Water Pumps, K. Kiryu et al., 1988

2.1.5 OTHER PUBLICATION

Wear Life Production in Face Seals, J. W. Abar, IRI Conference on Tribology Abstracts, January 1983

3. 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, only one basic concept is predominantly applied; the single helical spring preload concept. 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.

3.1 Single Helical Spring-Loaded Type Seal—This seal type is the most commonly utilized concept for preloading engine coolant pump mechanical face seals. The assembly generally consists of a cartridge, bellows, spring, ferrule(s), and primary seal ring (see Figure 1, SAE J780).

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 allows 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.

3.2 Unitized Type Seal—The unitized seal consists of a seal head assembly 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 (see Figure 2, SAE J780).

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

3.3 Unitized Type Seal—Positive Drive-Mating Ring—The unitized, positive drive-mating ring seal consists of a unitized seal having a special unitizer and mating ring. The unitizer is fitted with “male” tab, dents, or fingers that positively engage compatible slots, grooves, or slits provided on the mating ring. This feature removes the drive function from the secondary drive seal and it becomes only a secondary seal in function (see Figure 3, SAE J780).

3.4 Mating Ring Types—There are six widely applied mating ring types, including surfaces of pump components (see Figure 4, SAE J780) and Figure 1, Figures 1.4.1 through 1.4.6.

Mating ring types are differentiated by the method of mounting while providing a reliable means of assuring drive, secondary sealing, and the minimization of stresses and distortion during the operating cycle; they are as follows: (a) banded, with an ID mounted secondary drive seal, (b) banded, with an ID recessed mounted secondary drive seal, (c) plain (unbanded), with an ID mounted secondary drive seal, (d) bonded onto the surface or into a cavity of the pump component, e.g., rotating impeller, (e) press fitted onto the pump shaft, and (f) plain (unbanded), with an OD mounted secondary drive seal fitted into pump component.

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

4. Seal Material—Environmental conditions dictate the type of material that 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.

4.1 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.

4.1.1 RESIN BONDED GRAPHITE—Thermoset materials made from graphite with varying amounts of mineral and/or metal fillers bonded with low shrinkage resins such as epoxy, phenolic, or polyester, usually molded in the 149 to 315 °C range. Resin bonded graphites are low-cost materials.

4.1.1.1 Advantages

a. Good wear resistance at required temperatures and pressures
b. Readily molded to complex geometry and close tolerances
c. Inherent low porosity

4.1.1.2 Disadvantages

a. Poor thermal stability
b. Poor thermal conductivity
c. Poor erosion wear resistance

4.1.2 CARBON GRAPHITE—Carbon graphite is generally a manufactured product that contains some graphite, natural or synthetic, and which has a rigid, hard structure produced by firing at high temperatures usually ranging between 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.

4.1.2.1 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)

4.1.2.2 Disadvantages

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

4.1.3 SILICONIZED GRAPHITE—Siliconized graphite is generally a manufactured product produced by reacting silicon with an appropriate grade of graphite in a controlled high-temperature environment usually ranging between 1630 and 2230 °C. The manufacturing process, generally referred to as chemical vapor reaction (CVR), converts the surface of the graphite substrate to silicon carbide to a depth of 0.5 to 1.02 mm. The material has a very rigid and hard structure and is normally impregnated with a suitable resin. The material is in a very high premium cost range.

4.1.3.1 Advantages

a. Excellent wear resistance for all wear modes
b. Excellent temperature resistance and stability
c. Good thermal conductivity

4.1.3.2 Disadvantages

a. High cost
b. Very difficult to make in complex shapes and maintain close tolerances
c. Costly to lap due to its high hardness
d. Limited compatibility with mating ring materials; normally used in conjunction with solid silicon carbide mating rings or running against itself

4.1.4 BRONZE INSERTED THERMOSET—This composite material is produced by molding a powdered metal bronze insert into the primary ring configuration (see Figure 3, SAE J780). The bronze insert generally forms the outer half of the primary ring contact face; the inner half being resin bonded graphite (see 4.1.1). This material is in the premium cost range.

4.1.4.1 Advantages

a. Excellent resistance to erosion wear
b. Good resistance to adhesive and abrasive wear
c. Good thermal conductivity
d. Fair thermal stability

4.1.4.2 Disadvantages

a. Difficult to mold
b. Difficult to lap

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

4.2.1 ALUMINUM OXIDE CERAMICS—Aluminum oxide ceramics generally have an aluminum oxide (Al_2O_3) content ranging from 85 to 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 1400 and 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.

4.2.1.1 Advantages

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

4.2.1.2 Disadvantages

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

4.2.2 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.

4.2.2.1 Advantages

a. Excellent thermal shock resistance
b. Good thermal conductivity

4.2.2.2 Disadvantages

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

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

4.2.3.1 Advantages

a. Good thermal shock resistance
b. Excellent wear resistance
c. Adaptable to a large variety of sizes and shapes

4.2.3.2 Disadvantages

a. Added cost
b. Specialized processing

4.2.4 SILICON CARBIDE—Silicon carbide materials are generally manufactured by a pressureless sintering process known as "alpha sintering" and have very rigid, hard structures. They are produced by firing in a controlled atmosphere at temperatures ranging from 2260 to 2290 °C. The material is in a high premium cost range.

4.2.4.1 Advantages

a. Excellent wear resistance
b. Excellent fluid compatibility
c. Excellent dimensional stability
d. Excellent thermal stability
e. Good thermal conductivity
f. Good thermal shock resistance

4.2.4.2 Disadvantages

a. Difficult to mold in complex shapes
b. Costly to lap due to its high hardness
c. High cost
d. Poor self-lubricity, thus can withstand dry running conditions without excess torque and damaging heat generation only when mated with a low friction material

4.3 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.

4.3.1 NITRILE COMPOUNDS (NBR) (ASTM D 1418)—This material family's operating range is –40 to 121 °C. Nitrile is recommended for general use with exposure to coolants. It is in the low cost range.

4.3.1.1 Advantages

a. Good processability
b. Good oil resistance

4.3.1.2 Disadvantages

a. Limited high-temperature life
b. Poor to moderate ozone resistance

4.3.2 HYDROGENATED NITRILE COMPOUNDS (HNBR) (ASTM D 1418)—This family of materials is recommended for operating temperatures of –40 to 150 °C. HNBRs extend the high-temperature life of secondary seals while retaining many of NBR's basic properties. They are high-cost materials.

4.3.2.1 Advantages

a. Excellent heat resistance
b. Good oil resistance
c. Excellent fatigue resistance

4.3.2.2 Disadvantages

a. Increased processing costs

4.3.3 FLUOROELASTOMER COMPOUNDS (FKM) (ASTM D 1418)—These compounds are recommended for applications where operating temperatures range from –32 to 204 °C. They are in the high-cost range for seal compounds.

4.3.3.1 Advantages

a. Excellent oil resistance
b. Excellent heat resistance

4.3.3.2 Disadvantages

a. Poor processability (in terms of shape factor)
b. Poor steam resistance

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

4.4.1 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.

4.4.1.1 Advantages

a. Easily formed
b. Readily available

4.4.1.2 Disadvantages

a. Corrosion resistance dependent on surface treatment

4.4.2 STAINLESS STEEL (SAE 300 TO 400 SERIES)—Grade selection is dependent on desired level of corrosion resistance, mechanical properties, method of fabrication, and cost/availability factors.

4.4.2.1 Advantages

a. High-temperature physical property retention
b. Excellent corrosion resistance

4.4.2.2 Disadvantages

a. Limited workability
b. Availability of some grades

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

4.4.3.1 Advantages

a. Good corrosion resistance
b. Easily formed

4.4.3.2 Disadvantages

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

5. 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.

5.1 Reference Dimensions—To aid in the establishment of standard pump housing envelope dimensions, those shown in Figure 5, SAE J780, are recommended. The dimensions shown reflect specific dimensions utilized in current practice.

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

5.2.1 PRIMARY SEAL RING—Surface flatness should be in accordance with Table 1.

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

Material	Reflective Surface Roughness Average, Ra µm	Reflective Surface Flatness Light Bands	Reflective Surface Flatness Waviness µm-Ra	Nonreflective Surface Roughness Average, Ra µm	Nonreflective Surface Flatness Vacuum Test	Nonreflective Surface Flatness Waviness µm-Ra
Filled Thermoset Plastic	0.08-0.25	3-6	1.78 max	0.64 max	accept	1.78 max
Bronze Inserted Thermoset Plastic	0.08-0.25	3-6	1.78 max	—	—	—
Carbon-Graphite	0.64 max	3-6	1.78 max	0.76 max	accept	1.78 max
Siliconized-Graphite	0.64 max	2-3	0.89 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
Silicon Carbide	0.08-0.25	2-3	0.89 max	—	—	—
Ceramics	0.13-0.38	2-3	0.89 max	0.89 max	accept	0.89 max

1. See 8.4 through 8.7 for measuring test procedures.

5.2.2 MATING RINGS—Surface flatness should be in accordance with Table 1.

5.3 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.

5.4 Waviness—Waviness should be within the specifications shown in Table 1.

5.5 Squareness—Squareness of the face of the mating ring is to be within 0.13 mm FIM of shaft centerline.

5.6 Dynamic Runout—Dynamic runout is defined as twice the distance the center of the shaft is displaced from the center of rotation, expressed in FIM, and should not exceed 0.25 mm.

5.7 Offset—The radial distance between the axis of seal bore and axis of the shaft rotation. (Synonym: shaft-to-bore misalignment.) Reference SAE J111c.

5.8 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 J780). All corners should be blended smoothly.

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

***6. Drawing Designation*—**It is recommended that the standard SAE seal and housing drawing format be used. This format (Figure 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 supply only 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.

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

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

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

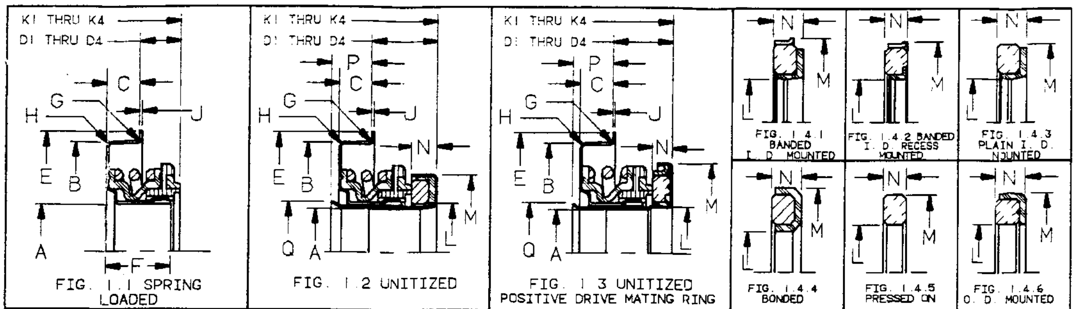
7.1.2 Complete production engine coolant pump assembly in which the seal will operate (including heater and bypass lines).

7.1.3 Drive motor capable of driving pump at 7500 rpm.

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

7.1.5 Production radiator cap (check for opening pressure).

7.1.6 Coolant recovery tank.

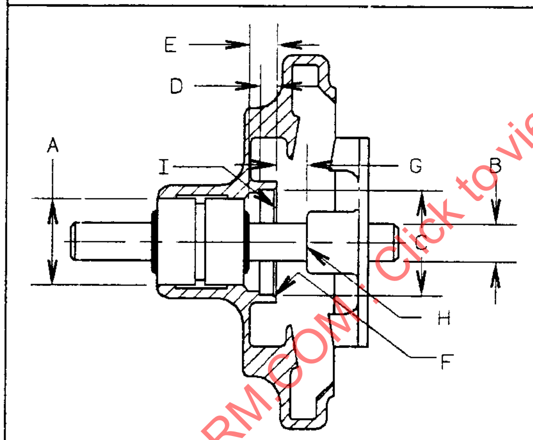


SEAL ASSEMBLY FIGURES 1.1, 1.2, AND 1.3	MATING RING FIGURES 1.4.1 THRU 1.4.6	APPLICATION PASSENGER OR NON PASS	A MIN./MAX BORE I.D.	B MIN./MAX. OUTSIDE DIA. AT GAGE POINT	C MIN./MAX LENGTH NOTE-A	D1 MAX SOLID LENGTH NOTE-C	D2 MIN. OPER'G LENGTH NOTE-B	D3 NOM OPER'G LENGTH NOTE-B	D4 MAX OPER'G LENGTH NOTE-B	A MIN./MAX. FLANGE O.D. NOTE-A	F MAX TORQUE TUBE LENGTH

G MAX. FLANGE RADIUS	H MIN. HEEL RADIUS	J NOM. FLANGE THICKNESS	K1 REF. LOAD AT D1 NOTE-C	K2 MAX LOAD AT D2 NOTE-C	K3 NOM LOAD AT D3 NOTE-C	K4 MIN. LOAD AT D4 NOTE-C	L MIN./MAX. MTG. RING ASS'Y I.D. NOTE-A	M MIN./MAX MTG. RING ASS'Y O.D. NOTE-A	N MIN./MAX. MATING RING ASS'Y THICKNESS	P MAX. PROJ. AT D2	Q MAX PROJ. DIA.

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.)	

				DRWN.		COMPANY NAME
				CHKD.		
				APVD.		SEAL EXAMPLE
SYM	DESCRIPTION	CKD.	DATE	BY	DATE	PART NO.
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FIGURE 1—STANDARD DRAWING FORMAT

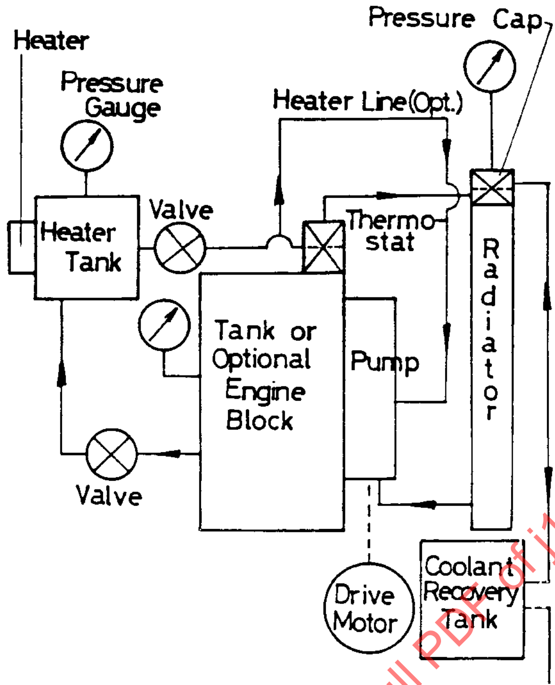

FIGURE 2—SCHEMATIC—ENGINE COOLANT PUMP SEAL DURABILITY TEST SYSTEM

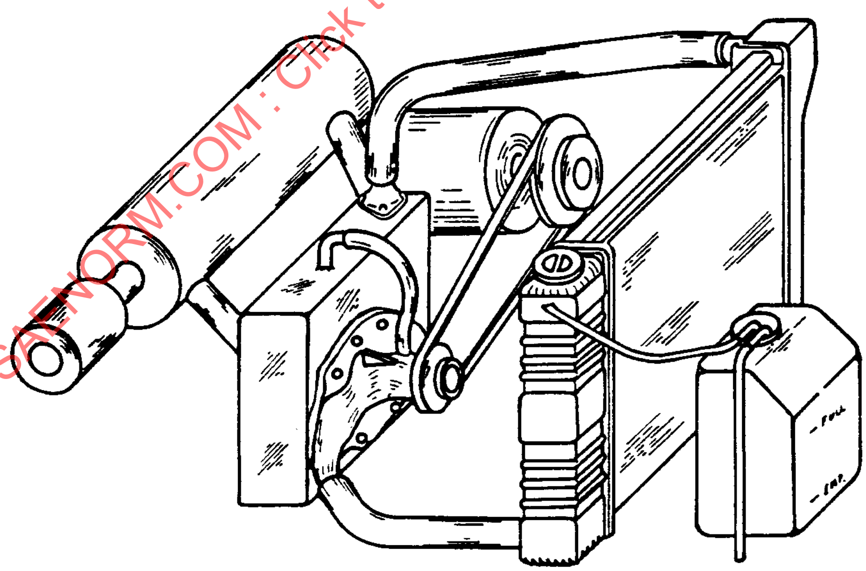

FIGURE 3—PICTORIAL ARRANGEMENT OF RECOMMENDED ENGINE COOLANT PUMP SEAL DURABILITY TEST SYSTEM

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

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

7.1.9 Pressure gauges to measure system pressures.

7.1.10 Cycle counter and running time meter.

7.1.11 Heater core (optional).

7.1.12 Automatic controls for cycling motor.

7.1.13 Heater(s) (3000 W) with controls.

7.1.14 Coolant hoses and clamps (production parts preferred).

7.2 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.

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

7.2.1.1 Coolant Temperature—Coolant temperature at the pump outlet should be maintained at 115 to 121 °C.

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

7.2.1.3 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 0 rpm to maximum rated speed in 15 s, held for 30 s, and returned to 0 rpm in 15 s. This cycle is to be repeated for the duration of the test.

7.2.1.4 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 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 (SAE Papers 760631 and 660128), will affect seal performance.

Film formations from coolant deposits at the seal faces can cause seal face separation and resultant leakage under certain operating conditions and coolant compositions (see STLE Paper 88-AM-5E-1).

Coolant chemistry can also cause "film transfer" failure. This failure is catastrophic and is the agglomeration of primary ring wear debris and transfer of same to the mating ring surface (see SAE Paper 890609 and 2.1.5).

The contaminants normally found in the system are soluble and nonsoluble in nature. The soluble elements may include constituents from the basic coolant chemistry and various commercial additives. The nonsoluble 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 nonsoluble oil contaminants may have been introduced during the normal manufacturing process or during system operation and maintenance.

If test data show nonrepeatability, 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 in Table 2.

TABLE 2—COMPOSITION OF SARASOTA CONCENTRATE

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 gal

Note—If core sand and/or other nonsoluble 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 “dropout” or erosion damage within the system, which would change the test conditions.

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

7.2.1.6 *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.

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

7.2.1.8 *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.

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

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

7.3.1.1 *Primary Seal Ring*

a. Material
b. Surface roughness
c. Surface flatness
d. Surface waviness
e. Face height

7.3.1.2 Mating Ring

a. Material
b. Surface roughness
c. Surface flatness
d. Surface waviness
e. Hardness
f. Squareness to shaft

7.3.1.3 Coolant Composition

a. Coolant identification
b. Coolant formulation

7.3.1.4 Seal and Pump Assembly

a. Seal operating length
b. Seal load at operating length
c. Test schedule and allowable leakage
d. Shaft speed

7.3.2 DURING TEST—The following data should be recorded during the test sequence:

7.3.2.1 Pump rpm

7.3.2.2 Coolant temperature at pump outlet

7.3.2.3 System pressure

7.3.2.4 Inlet pressure

7.3.2.5 Discharge pressure

7.3.2.6 Seal cavity pressure

7.3.3 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:

7.3.3.1 Primary Seal Ring

a. Wear pattern
b. Surface roughness
c. Surface flatness
d. Surface waviness
e. Face height

7.3.3.2 Mating Ring

a. Wear pattern
b. Surface roughness
c. Surface flatness
d. Surface waviness