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(R) APPLICATION GUIDE TO RADIAL LIP SEALS

***Foreword*—**This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

1. *Scope*

***Scope*—**This SAE Recommended Practice is intended as a guide to the use of radial lip type seals. It has been prepared from existing literature, which includes standards, specifications, and catalog data of both oil seal producers and users and includes generally accepted information and data. The main reason for the preparation of the document is to make standard information available in one document to the users of oil seals.

2. *References*

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

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

SAE J110—Seals—Testing of Radial Lip
SAE J111—Seals—Terminology of Radial Lip
SAE J1002—Seals—Evaluation of Elastohydrodynamic
SAE J1417—Fluid Sealing Handbook—Radial Lip Seals
SAE J1900—Seal Bond Test Fixture and Procedure
SAE J1901—Lip Force Measurement, Radial Lip Seals
SAE J1947—O.D. Coatings for Radial Lip-Type Shaft Seals
SAE Paper No. 740204—Spring Position Measurement

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Street, West Conshohocken, PA 19428-2959.

ASTM D 471—Test Method for Rubber Property—Effect of Liquids
ASTM D 2934—Method of Testing for Compatibility of Vulcanized Rubber Seals—Compatibility With Service Fluids
ASTM D 4289-83—Method of Testing Compatibility of Lubricating Grease With Elastomers

2.1.3 RMA PUBLICATIONS—Available from the Rubber Manufacturers Association, 1400 K Street, N.W., Suite 900, Washington, DC 20005.

RMA OS-11—Referee Measuring Guide for Rotating Shaft Fields

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3. Sealing Systems—There are two general classes of sealing systems:

a. The standard lip seal operating on a conventional mating surface.
b. Elastohydrodynamic sealing systems which incorporate supplemental sealing devices on the seal.

3.1 Standard Sealing Systems—Seal manufacturers are generally standardized on the bonded construction, single or double lip, with or without springs, and with or without inner cases. Coated or molded rubber outside diameters are a variation of each class. Figure 1 depicts the more standard seal types. Seals of an assembled construction are also used, predominantly with leather or polytetrafluoroethylene sealing elements. These lip seal designs prevent leakage in dynamic and static applications by controlling interference between the seal lip and the mating surface. Standard seals will function satisfactorily in an application only if the following conditions are met:

3.1.1 The seal lip material is chosen for its ability to function under the environmental conditions to be encountered.

3.1.2 The seal is manufactured to tolerances established herein.

3.1.3 The shaft surface is prepared as in 5.1 and the application's dynamic characteristics, that is shaft roundness and dynamic run out, shock loading, or deflection, are within limits that will establish and maintain a satisfactory oil film. Special care must be taken to insure that the shaft surface is free of lead if the standard sealing system is to function properly (refer to 5.1).

3.1.4 The seal is installed properly as outlined in 5.15.

3.1.5 Maintaining the four basic sealing requirements in production is not always economically feasible. In certain applications, a supplementary sealing device may be necessary. However, the use of these devices should not be considered a substitute for a reduction in quality of the shaft and seal.

3.2 Elastohydrodynamic Sealing Systems—These systems utilize supplemental sealing features, generally protrusions or depressions located on or adjacent to the sealing lip, which transfers lubricant in a predetermined direction.

3.2.1 UNIROTATIONAL—A seal incorporating helical ribs located on the outside surface which may or may not terminate in a static lip. Figure 2 illustrates schematics of some of the more popular designs which have reached the commercial market.

3.2.2 BIROTATIONAL—A seal incorporating configurations located on the outside lip surface which functions independent of direction of shaft rotation. Fluid transfer capability is generally lower than that of the unirotational designs, which reduces their potential to tolerate seal and shaft imperfections. Figures 3 and 4 are examples of this type of seal.

4. Factors Affecting Sealing—Environmental conditions dictate the type of material which should be used in a specific application, so seal materials can be fully evaluated only in terms of the specific operating conditions and performance requirements. Seal material-lubricant compatibility is generally the governing factor. Because of the importance of seal material-lubricant compatibility, existing data and experience of both user and supplier should be fully considered. If adequate information is not available, it is recommended that candidate seal materials be evaluated for significant changes in properties and in the actual application lubricant at normal operating temperatures. Particular importance should be given to those properties most directly affecting seal performance, such as volume swell (or shrinkage) and hardening (or softening). These evaluation tests should be of sufficient duration to establish the long-term effects. It is also recommended that consideration be given to the effect of potential temperature extremes, particularly high temperature compatibility and low temperature flexibility characteristics of both new and lubricant-aged seal materials.

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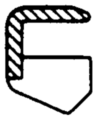
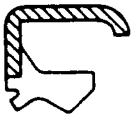
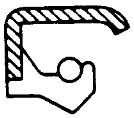
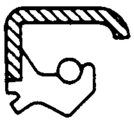
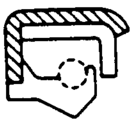
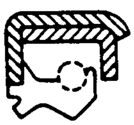
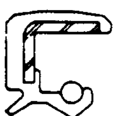
Cross Section	Type	General Application
1. 	Bonded single lip, non-spring loaded	Low cost design for viscous fluid and grease retention
2. 	Bonded double lip, non-spring loaded	Low cost design for viscous fluid or grease retention with dust, dirt, and moisture exclusion
3. 	Bonded single lip, spring loaded	Oil sealing applications and severe grease sealing applications
4. 	Bonded double lip, spring loaded	General oil sealing applications and severe grease sealing applications with dust, dirt, and moisture exclusion
5. 	Bonded single lip, with inner case	Provides all standard features plus additional inner case for greater structural rigidity
6. 	Bonded double lip, with inner case	Provides all standard features plus additional inner case for greater structural rigidity
7. 	Bonded double lip spring-loaded rubber O.D. - can also be supplied in designs 1, 2, 3, 4 and 5	Required for some aluminum and magnesium housings
8. Assembled construction	Single and multiple lip with and without springs	Special applications dependent upon the material selected

FIGURE 1—USES OF STANDARD SEAL TYPES

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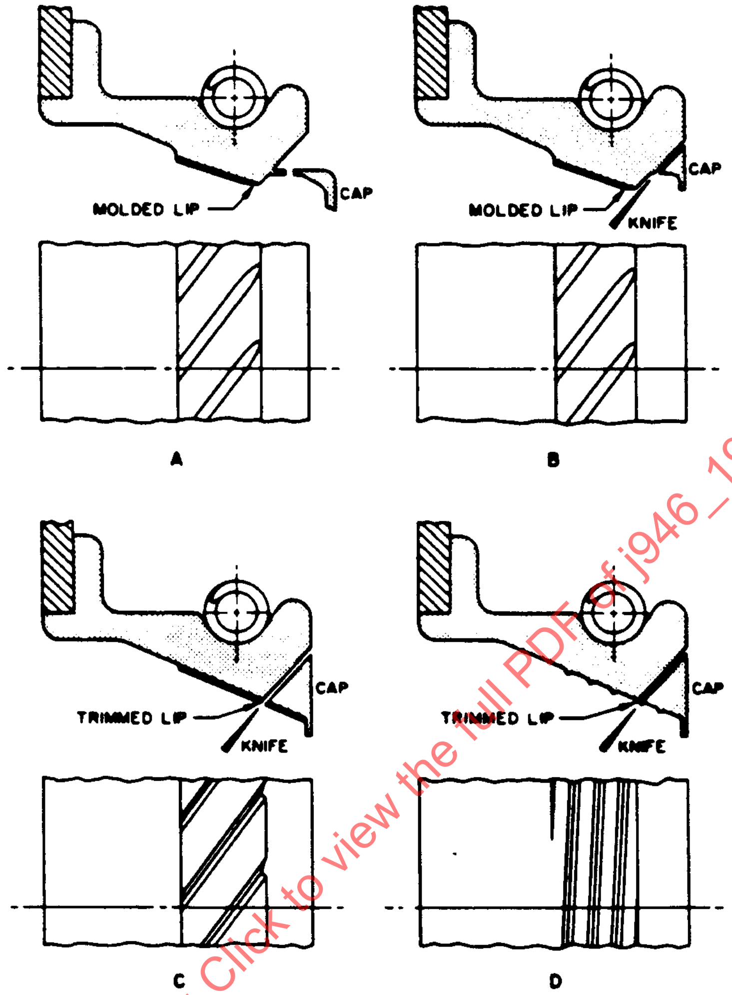

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Seals Shown in Figures 2A and 2B have a molded lip. The excess material is removed by tearing the cap from the molded part on design 2A and by a knife on design 2B. The helical ribs in both designs terminate at the contact point of the static lip.
Seals shown in Figures 2C and 2D are trimmed lip seals; that is, a knife trimming operation forms the contact lip as the excess material is removed. The helical ribs protrude at the contact point and must be compressed to prevent the seal from leaking when the shaft is not rotating prior to initial operation.

FIGURE 2—VARIOUS UNIROTATIONAL ELASTOHYDRODYNAMIC SEAL DESIGN CONCEPTS

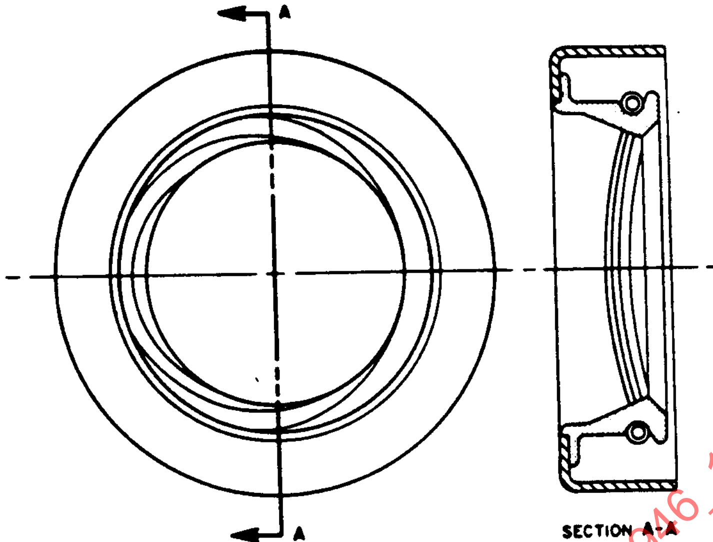

FIGURE 3—BIROTATIONAL ELASTOHYDRODYNAMIC SEAL: RIBS PROTRUDING IN OPPOSITE DIRECTIONS PRODUCE SEALING IRRESPECTIVE OF DIRECTION OF SHAFT ROTATION

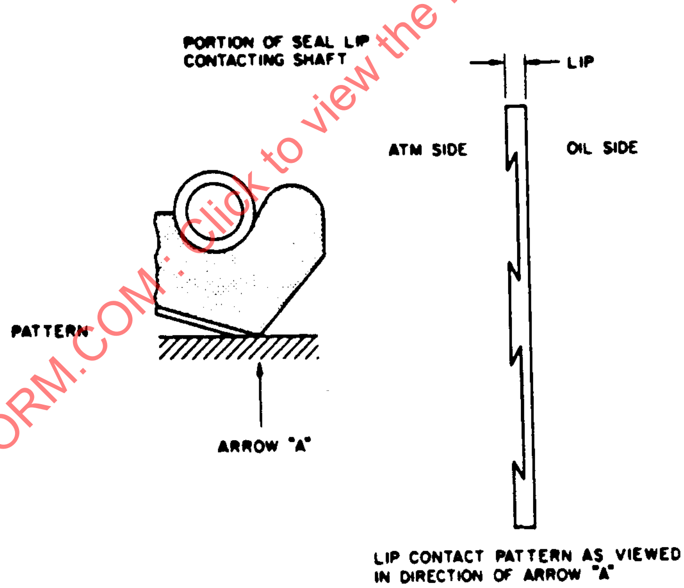

FIGURE 4—BIROTATIONAL ELASTOHYDRODYNAMIC SEAL: TRIANGULAR DEPRESSIONS OR PROTRUSIONS IN CIRCUMFERENTIAL PATTERN IN OUTSIDE LIP SURFACE PRODUCE SEALING IRRESPECTIVE OF DIRECTION OF SHAFT ROTATION

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4.1 Seal Material—The following paragraphs give general descriptions of the acceptable uses of elastomeric compounds, plastics, and leather, along with some of their advantages and disadvantages. The temperature ranges refer to normal lubricant bulk-oil operating temperatures. Acceptable upper and lower temperature limits may vary based on specific seal material and design, and are subject to substantial variations due to particular material-lubricant compatibility differences. When conditions approach extreme limits, the seal supplier should be consulted.

4.1.1 LEATHER—Leather is satisfactory for applications involving oil, grease, or foreign matter having temperatures within limits of –55 to +85 °C (–67 to +185 °F). Special leather treatments may increase the upper temperature limit to 107 °C (225 °F). The seal manufacturer must be consulted if operation temperature exceeds 85 °C (185 °F).

4.1.1.1 Advantages

a. Toughness—withstands difficult assembly
b. Accommodation of fairly rough shaft finishes
c. Good dry-running characteristics
d. Good low-temperature characteristics
e. Excellent abrasion resistance

4.1.1.2 Disadvantages

a. Poor heat resistance when combined with high shaft speed
b. Nonhomogeneous makeup can cause variations in performance

4.1.2 NITRILE COMPOUNDS (NBR)—Their operating range is –45 to +125 °C (–50 to +257 °F). When compounding a seal material for a low-temperature limit of –45 °C (–50 °F), the upper temperature limit of 125 °C (257 °F) must be lowered. Conversely, when compounding for the high temperature limit, extreme low-temperature flexibility is sacrificed. Nitrile is recommended for general use in retaining lubricants and excluding mud, dirt, water, etc. These compounds have low volume swell in low aniline point oils. The nitriles are in the low cost range of oil seal compounds.

4.1.2.1 Advantages

a. Fair dry-running characteristics
b. Good processing
c. Good low-temperature characteristics
d. Good oil resistance
e. Good abrasion resistance

4.1.2.2 Disadvantages

a. Lack of exceptional heat resistance
b. Tendency to harden during continuous high-temperature usage

4.1.3 POLYACRYLIC COMPOUNDS (ACM)—Recommended for applications where temperatures are within –18 to +150 °C (0 to +300 °F). If the shaft run out is low, some compounds may be used at temperatures as low as –40 °C. They are in the medium cost range of seal compounds.

4.1.3.1 Advantages

a. Resistant to EP-type additives
b. Good moderate-temperature performance
c. Good oil resistance

4.1.3.2 Disadvantages

a. Fair low-temperature properties with high shaft run out
b. Poor dry-running characteristics
c. Fair abrasion resistance

4.1.4 ETHYLENE ACRYLIC COMPOUNDS (AEM)—Recommended for applications where temperatures are within –40 to +165 °C (–40 to +329 °F). They are in the medium cost range of seal compounds.

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4.1.4.1 Advantages

a. Good temperature range
b. Reasonable abrasion resistance
c. Good moisture resistance

4.1.4.2 Disadvantages

a. Poor dry-running characteristics
b. High swell characteristics in some fluids

4.1.5 SILICONE COMPOUNDS (VMQ)—Recommended for applications where temperatures are within –55 to +175 °C (–67 to +345 °F). The maximum usable temperature is limited by the decomposition temperatures of the various lubricants. Silicone rubbers are in the medium cost range of seal compounds.

4.1.5.1 Advantages

a. Good temperature range
b. Excellent low-temperature properties

4.1.5.2 Disadvantages

a. High swell characteristics in some oils
b. Poor chemical resistance to oxidized oils and some EP additives
c. Poor dry-running characteristics
d. Easily damaged during assembly

4.1.6 FLUOROELASTOMER COMPOUNDS (FKM)—Recommended for applications where temperatures are within –40 to +200 °C (–40 to +392 °F). They are in the high cost range of seal compounds.

4.1.6.1 Advantages

a. Excellent fluid resistance
b. Fair dry-running characteristics
c. Excellent retention of original modulus and hardness in both dry heat and fluid service

4.1.6.2 Disadvantages

a. Use caution with low temperature service since FKM seals will leak, but not crack, under high shaft run out conditions when subjected to temperatures low enough to cause compound stiffening.
b. Special tooling is frequently required.

4.1.7 POLYTETRAFLUOROETHYLENE COMPOUNDS (PTFE)—Recommended for applications which are chemically damaging to elastomers and for extreme temperatures within –240 to +260 °C (–400 to +500 °F). Some flexibility will be maintained down to –80 °C (–110 °F). They are in the high cost range of seal compounds.

4.1.7.1 Advantages

a. Superior fluid and heat resistance
b. Excellent dry-running characteristics
c. Low coefficient of friction
d. Withstands higher pressures than shown in Tables 1A and 1B.

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4.1.7.2 Disadvantages

a. Easily damaged during assembly
b. Limited ability to follow eccentric shafts due to high stiffness
c. Some compounds are abrasive to the point that shaft wear can be a problem

TABLE 1A—OPERATING PRESSURE LIMITS—METRIC

Shaft Speed (Meters/Minute)	Maximum Pressure (kPa)
0 to 300	50
301 to 600	35
601 and up	20

TABLE 1B—OPERATING PRESSURE LIMITS—INCH/POUND

Shaft Speed (Feet/Minute)	Maximum Pressure (psi)
0 to 1000	7
1001 to 2000	5
2001 and up	3

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4.1.8 FLUOROSILICONE COMPOUNDS (FVMQ)—They are recommended for applications where temperatures are within –55 to +200 °C (–67 to +392 °F). The maximum usable temperature is limited by the decomposition temperature of the lubricant involved. They are in high cost range of seal compounds.

4.1.8.1 Advantages

a. Excellent oil and fuel resistance
b. Good temperature range

4.1.8.2 Disadvantages

a. Fair dry-running characteristics
b. Low abrasion and cut resistance

4.2 Lubricant—Lubricants vary not only in their base stock, but especially in the additives used to achieve particular lubrication characteristics. It is recommended that material-lubrication compatibility be evaluated on a number of lubricants adequately representing those that might be used in the application. Lubricant decomposition as a result of heat, combustion products, etc., should also be considered, since decomposition products may themselves significantly affect seal materials.

4.2.1 MATERIAL-LUBRICATION COMPATIBILITY TESTS—Shown in Table 2 is a listing of the property change limits intended to be used by the oil formulator, the seal material manufacturer, and the seal user as a guideline for determining material/lubrication compatibility.

TABLE 2—PROPERTY CHANGE LIMITS

	Spring Load Seals	Nonsprung Seals
Hardness (Shore A)	90 max	90 max
Elongation	–50% max	–50% max
Volume Change	–5 to +25%	–5 to +10%

4.2.1.1 The lubrication oil and/or grease formulators must be able to measure the effects of their product on standard compounds. ASTM D 2934 provides these standard formulations for most polymer systems, as well as a source for direct purchase.

4.2.1.2 The seal material formulators must be able to measure the effects of standard lubrication on their compounds. Examples of standard lubricants are ASTM Oils #1, #2, #3, and #5, Service Fluid 102, Fuel B, etc. ASTM D 471 provides pertinent data on these and other standard fluids, as well as a source for direct purchase. ASTM D 4289-83 describes methods of determining compatibility of greases with elastomers.

4.2.1.3 The seal users must be able to ascertain the compatibility of the fluid/compound combinations that will be used in particular applications. They must have some insight into the actual temperatures to be encountered and employ these temperatures in their compatibility testing. The temperature of immersion must mirror as closely as possible the actual application temperature. The time of immersion testing should be established by the part longevity required. Properties should be measured at periodic intervals, such as 70 h, 168 h, etc., to detect trends and/or extrapolate to the desired longevity. However, included in the preceding is a caution against using higher than actual service conditions as a means of shortening test duration. Oil oxidation, additive reactivity, and additive depletion are a function of temperature only. Additionally, water and air (oxygen) ingestion can markedly increase the potency of the effect of oil on seal compounds. The immersion condition should resemble the application condition as closely as possible, including the use of the actual media when possible.

4.3 Temperature—Seal material-lubricant compatibility over the normal operating temperature range is generally the governing choice factor, but adequate consideration must be given to the effects of the possible temperature extremes (low and high) on both seal material and lubricant itself. Time and temperature relationships cause irreversible changes in both seal material and lubricant, as well as the interactions between them. At low temperatures, seal materials will harden temporarily and lubricant viscosity will increase temporarily. Leakage, seal fracture, or abnormal wear may occur. This stiffening of the seal material may result in an inability of the seal lip to follow shaft deflections, thus causing low temperature leakage. The effect of shaft interference and/or pressure on the seal is heat generation at the seal-shaft interface. Higher shaft speeds and/or pressures result in higher seal lip temperatures and in a greater differential between the lip contact surface and bulk oil temperatures, thus effectively changing the viscosity of the lubricant under the seal lip. These factors should also be considered in establishing material-lubricant compatibility.

4.4 Time—Material-lubricant compatibility tests should be of sufficient duration to establish that compatibility is maintained over the required life of the seal.

5. Applications Design Data—Seal performance is greatly influenced by product design. Proper engineering of the components which affect the seal assembly is necessary for seal reliability. The following should be considered at the design stage of a new sealing application or where existing applications are being updated.

5.1 Shaft Surface Roughness—Shaft surface roughness is a prime factor in the proper functioning of a lip seal. The surface roughness should be specified as 0.25 to 0.50 µm (10 to 20 µin) with zero ±0.05 degree (±3 min). This section conforms to ISO 6194/1. (See Section 10 for the recommended shaft lead detection method.) Refer to Figure 5 for typical traces. (The recommended "cutoff" setting on the surface roughness measuring machine is 0.75 mm or 0.030 in.) The best known method for obtaining this roughness is plunge grinding. The following is the recommended manufacturing process for plunge grinding:

5.1.1 The grinding wheel-to-work piece ratio should be a low, nonwhole number ratio. (Example: 10.5:1 not 10.0:1.)

5.1.2 A crush-dress or a cluster head diamond dress should be used for wheel dressing rather than a single point diamond tool.

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5.1.3 During wheel dressing, the traverse speed should be very low (less than 3 in/min) or very high (at least 10 in/min).

5.1.4 Always "spark-out" to aid in the elimination of lead transfer even with the nonwhole number grinding wheel-to-work piece ratio.

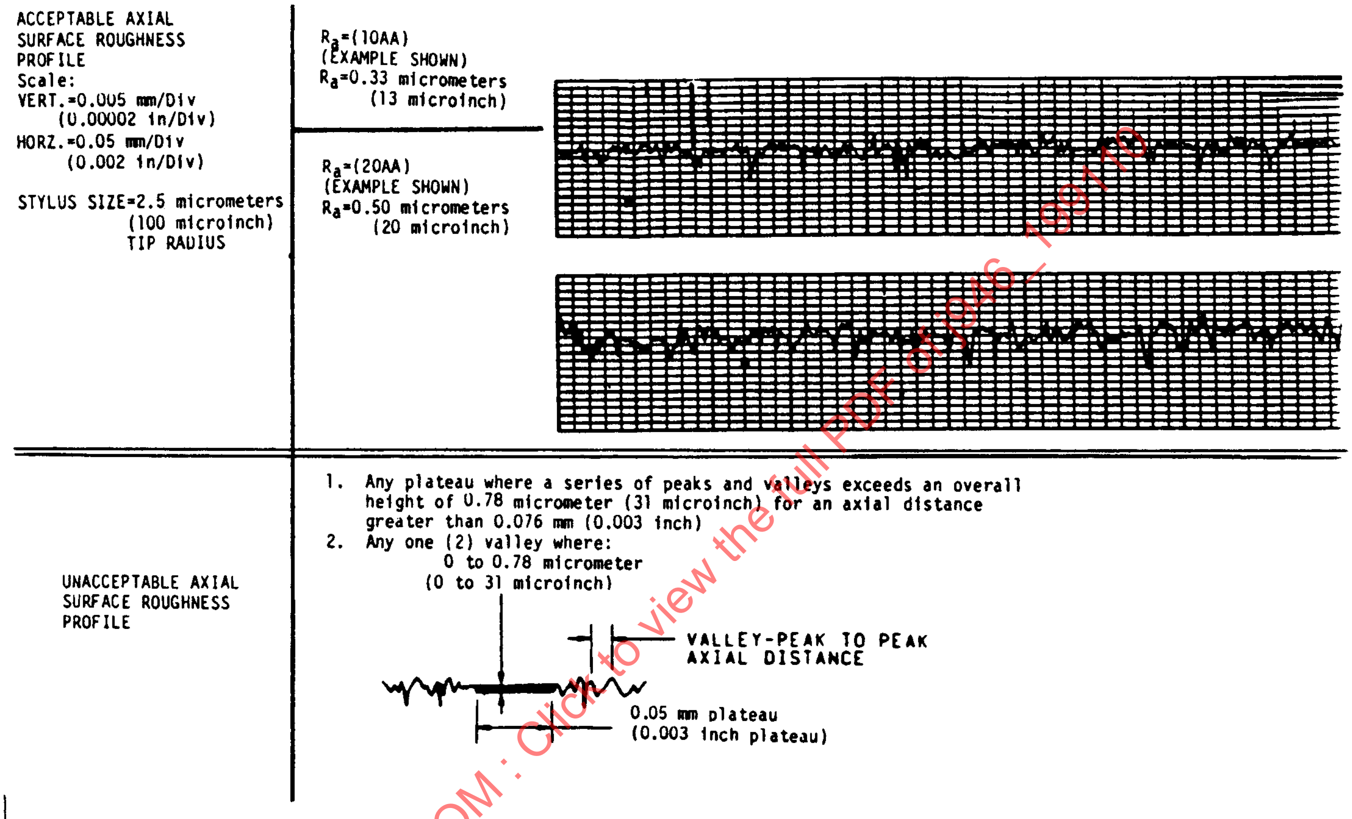

FIGURE 5—TYPICAL TRACES OF SHAFT SURFACE ROUGHNESS PROFILES

5.2 Shaft Diameter—The shaft diameter should be held within the tolerances shown in Tables 3A and 3B, although greater shaft tolerances may be used when agreed on between user and supplier.

5.3 Shaft Hardness—Under normal conditions, the portion of the shaft contacted by the seal should be hardened to Rockwell C30 minimum. There is no conclusive evidence that hardening above this will increase the wear resistance of the shaft except under extreme abrasive conditions. Where the shaft is liable to be nicked in handling previous to assembly, it is recommended that it be hardened to Rockwell C45 minimum in order to protect against being permanently damaged during assembly.

5.4 Wear Sleeves—Where the use of wear sleeves is considered, hardened shafts generally are not required. Wear sleeves, either soft or hardened, can be made from mild steel rings and pressed over a soft shaft. They are recommended for shafts made of cast iron or other soft materials, and permit the replacement of wearing surfaces coincident with oil seal changes. New wearing surfaces generally are required with the replacement oil seal.

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5.5 Offset—Offset is defined as the radial distance between the axis of the seal bore and the axis of shaft rotation. Offset is normally calculated from the tolerance stackup on the engineering drawings. Seal life can be shortened by excessive offset. Offset results in uneven wear. From a good practice standpoint, the offset should be kept under 0.25 mm (0.010 in) TIR.

5.6 Dynamic Run Out—Generally, the shaft run out should be kept below 0.25 mm (0.010 in) TIR. It must be pointed out that as shaft rpm increases it becomes more difficult to seal on a shaft with run out due to the inability of the seal to follow the shaft high-frequency camming effect.

TABLE 3A—OIL SEAL STANDARD TOLERANCES—mm
SINGLE AND DUAL LIP SPRING LOADED BONDED SEALS

Shaft Diameter	Shaft Tolerance	ID Range(1)	LOP(2) Pressure Range	RWV (3) Max	Radial Load Range
Thru 75.0	±0.08	1.0	Nominal pressure ±30% with a minimum range of 0.25 bar	0.6	Nominal load ±45%
75.01 to 150.0	±0.10	1.3	Nominal pressure ±30% with a minimum range of 0.25 bar	0.8	Nominal load ±40%
150.01 to 250.0	±0.13	1.5	Nominal pressure ±30% with a minimum range of 0.25 bar	1.0	Nominal load ±40%

1. Tentative inside diameter will be established at the time of the design of a given seal. Nominal inside diameter will be established based on the analysis of three production runs.
2. Nominal lip opening pressure will be established for a given seal based on the analysis of a minimum of three significant production runs. Preswelled silicone seals require a larger range.
3. Radial wall variation (outside diameter-inside diameter eccentricity) will be measured by the optical or shadowgraph method. It is measured with the spring removed and the sealing element allowed to relax for 24 h.

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TABLE 3B—OIL SEAL STANDARD TOLERANCES—INCHES
SINGLE AND DUAL LIP SPRING LOADED BONDED SEALS

Shaft Diameter	Shaft Tolerance	ID Range(1)	LOP(2) Pressure Range	RWV (3) Max	Radial Load Range
Thru 3.00	±0.003	0.040	Nominal Pressure ±30% with a minimum range of 4 psi	0.025	Nominal load ±45%
3.001 to 6.000	±0.004	0.050	Nominal Pressure ±30% with a minimum range of 4 psi	0.030	Nominal load ±40%
6.001 to 10.000	±0.005	0.060	Nominal Pressure ±30% with a minimum range of 4 psi	0.040	Nominal load ±40%

1. Tentative inside diameter will be established at the time of the design of a given seal. Nominal inside diameter will be established based on the analysis of three production runs.
2. Nominal lip opening pressure will be established for a given seal based on the analysis of a minimum of three significant production runs. Preswelled silicone seals require a larger range.
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5.7 Shaft Lobbing or Out-of-Round—This condition can be caused by mechanical assembly, such as bolting a flywheel onto the end of a shaft, and can cause seal leakage. Since different seal designs and materials can exhibit different performance levels related to this condition, it is recommended that the seal supplier be consulted.

5.8 Bore and Seal Tolerances—The bore and seal tolerances shown in Tables 4A and 4B apply only to ferrous materials. When a nonferrous material such as aluminum is used, the seal manufacturer should be consulted.

5.9 Bore Surface Roughness—On applications where a lubricant head is present against the seal OD and the bore surface roughness is approximately 2.54 µm Ra or smoother, bore leakage should not be a problem if no tool marks are present. This section conforms to ISO 6194/l.

If the surface is rougher than 2.54 µm Ra, a rubber OD seal (Tables 1A, 1B, 3A, 3B, 4A, 4B, and 5, and Figures 1 and 6A to 6D) or a case OD sealer should be used to ensure that no outside diameter leakage occurs. A case OD sealer is usually a resinous or rubber-like material applied by the seal manufacturer to the outside metallic diameter of the seal (SAE J1947). Most seal manufacturers can supply seals precoated with an OD sealant. User-supplied cements or sealers should be used with care to prevent contact with the sealing lip. On grease sealing applications, a bore sealer is generally not required.

5.10 Pressure—Standard design radial lip type oil seals should not be used when the operating pressure exceeds the limits shown in Tables 1A and 1B. When variable surge pressures exceeding these limits are present, a special condition exists and the seal manufacturer should be consulted. Higher operating pressures are acceptable if a customer seal design is considered. However, when a pressure seal is used, features such as the ability to accommodate offset and run out are generally sacrificed. Whenever possible, the design should be such that the system is vented to atmosphere. This will allow the lip seal to function more efficiently.

5.11 Shaft Lead Corners—To prevent damage to the seal lip and to facilitate installation, the leading edge of the shaft should have a chamfer or radius. If the chamfer is used, its dimensions should be such that the seal lip can be assembled without damage. This is especially critical if the direction of shaft entry through the lip is from the media side. (See Figure 7.)

TABLE 4A—OIL SEAL STANDARD TOLERANCES—mm
SINGLE AND DUAL LIP SPRING LOADED BONDED SEALS—CONFORMS TO ISO 6194/A

Nominal Bore Diameter	Bore Tolerance	Diameteral Tolerance(1) Metal Cased	Diametral Tolerance(1) Rubber Covered(2)(3)	Roundness Tolerance(4) Metal Cased	Roundness Tolerance(4) Rubber Covered
Up to 50	+0.039 –0.0	+0.20 +0.08	+0.30 +0.15	0.18	0.25
50 to 80	+0.046 –0.0	+0.23 +0.09	+0.35 +0.20	0.25	0.35
80 to 120	+0.054 –0.0	+0.25 +0.10	+0.35 +0.20	0.30	0.50
121 to 180	+0.063 –0.0	+0.28 +0.12	+0.45 +0.25	0.40	0.65
181 to 300	+0.075 –0.0	+0.35 +0.15	+0.45 +0.25	0.25% of out- side diameter	0.80
301 to 440	+0.089 –0.0	+0.45 +0.20	+0.55 +0.30	0.25% of out- side diameter	1.00

1. Seal Outside Diameter—The average of a minimum of three measurements to be taken at equally spaced positions.
2. Rubber covered seals having a wave profile outside surface are acceptable but will require different tolerances to be agreed between manufacturer and purchaser.
3. Rubber covered seals employing certain materials other than nitrile may require different tolerances to be agreed between manufacturer and purchaser.
4. Out of Round (OOR)—The maximum variance between any of the readings used in determining seal outside diameter. See RMA publication OS-11 for measuring methods.

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TABLE 4B—OIL SEAL STANDARD TOLERANCES—INCHES SINGLE AND DUAL LIP SPRING LOADEED BONDED SEALS

Bore Diameter	Bore Tolerance	Nominal Press Fit Metal OD	Metal OD Tolerance(1)	Metal OD OOR(2)	Nominal Press Fit Rubber OD(3)	Rubber OD Tolerance(4)	Rubber OD OOR
Up to 2.000	±0.001	0.005	±0.002	0.007	0.008	±0.003	0.010
2.001 to 3.000	±0.001	0.005	+0.003 –0.002	0.010	0.010	±0.003	0.014
3.001 to 5.000	±0.0015	0.005	+0.004 –0.002	0.012	0.010	±0.003	0.020
5.001 to 7.000	±0.0015	0.006	+0.004 –0.002	0.016	0.012	±0.004	0.026
7.001 to 12.000	±0.002	0.007	+0.005 –0.002	0.0025(5)	0.012	±0.004	0.031
12.001 to 20.000	+0.002 –0.004	0.008	+0.008 –0.002	0.0025(5)	0.015	±0.005	0.039
20.001 to 40.000	+0.002 –0.006	0.008	+0.008 –0.002	0.0025(5)	0.018	±0.006	0.045
40.001 to 60.000	+0.002 –0.010	0.008	+0.010 –0.002	0.0025(5)	0.020	±0.007	0.050

1. Seal Outside Diameter—The average of a minimum of three measurements to be taken at equally spaced positions.
2. Out of Round (OOR)—The maximum variance between any of the readings used in determining seal outside diameter. See RMA publication OS-11 for measuring methods.
3. Rubber covered seals having a wave profile outside surface are acceptable but will require different tolerances to be agreed between manufacturer and purchaser.
4. Rubber covered seals employing certain materials other than nitrile may require different tolerances to be agreed between manufacturer and purchaser.
5. Inch/inch of seal outside diameter.

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TABLE 5—GUIDE TO THE SIGNIFICANCE OF VISUAL RADIAL LIP VARIATIONS

Primary Function	Type of Application Variation	Critical	Major	Minor
Oil Retention	Blister	A	B,C,D,E	F,G
	Porosity	A	B,C	D,E,F,G
	Nonfill	A	B,C,D,E	F,G
	Mold Impression	A	B,D	C,E,F,G
	Knit Line	—	A,B,C,D,E	F,G
	Inclusion	A	B,C,D	E,F,G
	Surface Contamination	A	B,C,D,E,F	G
	Tear	A	B,C,D,E	F,G
	Nick	A	B,C,D,E	F,G
	Scratch	—	A,B,D	C,E,F,G
	Deformation	—	A,B,C,D,E	F,G
	Cut or Crack	A	B,C,D,E	F,G
	Flash	—	A,B,C,D,E	F,G
	Unbonded Flash	—	A,B,C,D,E,F	G
	Poor Bond	C	D,E	F,G
	Scoop Trim	—	A,B	—
	Incomplete Trim	—	A,B	—
	Spiral Trim	—	A,B	—
	Rough Trim	—	A,B	—
	Step Trim	—	A,B	—
Grease Retention	Blister	A	B,C,D	E,F,G
	Porosity	A	B,C	D,E,F,G
	Nonfill	A	B,C,D,E	F,G
	Mold Impression	A	B	C,D,E,F,G
	Knit Line	—	A,B,C,D	E,F,G
	Inclusion	A	B,C,D	E,F,G
	Surface Contamination	A	B,C,D,E,F	G
	Tear	A	B,C,D,E	F,G
	Nick	A	B,C,D,E	F,G
	Scratch	—	A,B,D	C,E,F,G
	Deformation	—	A,B,C,D,E	F,G
	Cut or Crack	A	B,C,D,E	F,G
	Flash	—	A,B,C,D,E	F,G
	Unbonded Flash	—	A,B,C,D,E,F	G
	Poor Bond	C	D,E	F,G
	Scoop Trim	—	A,B	—
	Incomplete Trim	—	A,B	—
	Spiral Trim	—	A,B	—
	Rough Trim	—	A,B	—
	Step Trim	—	A,B	—
Dirt Exclusion	Blister	—	A,B	C,D,E,F,G
	Porosity	—	A,B	C,D,E,F,G
	Nonfill	—	A,B,C,D	E,F,G
	Mold Impression	—	A,B	C,D,E,F,G
	Knit Line	—	A,B,C	D,E,F,G
	Inclusion	—	A,B	C,D,E,F,G

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TABLE 5—GUIDE TO THE SIGNIFICANCE OF VISUAL RADIAL LIP VARIATIONS (continued)

Primary Function	Type of Application Variation	Critical	Major	Minor
	Surface Contamination	—	A,B,C,E,F	D,G
	Tear	—	A,B,C,D,E	F,G
	Nick	—	A,B	C,D,E,F,G
	Scratch	—	A,B	C,D,E,F,G
	Deformation	—	A,B,C,D	E,F,G
	Cut or Crack	—	A,B,C	D,E,F,G
	Flash	—	A	B,C,D,E,F,G
	Unbonded Flash	—	A,B,C,D,E,F	G
	Poor Bond	C	D,E	F,G
	Scoop Trim	—	—	A,B
	Incomplete Trim		A	B
	Spiral Trim	—	—	A,B
	Rough Trim	—	A	B
	Step Trim		A	B

Letters in this table refer to areas designated in Figure 19.

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STANDARD SEAL WIDTHS

Standard Bore Sizes—Inches	.500	.625	.750	.875	1.000	1.125	1.250	1.375	1.500	1.625	1.750	1.875	2.000	2.125	2.250	2.375	2.500	2.625
.999	A																	
1.124	A	A																
1.250	A	A	A															
1.375		A	A	A														
1.499		A	A	A	A													
1.624			A	A	A	A												
1.752				A	A	A	A											
1.874					A	A	A											
2.000						A	A	B										
2.125							A	B	B									
2.250								B	B	B								
2.374								B	B	B	B							
2.502									B	B	B							
2.623										B	B	B	B					
2.750											B	B	B	C				
2.875												B	B	C				
3.000												B	B	C	C			
3.125												B	B	C	C	C		
3.251														C	C	C	C	
3.371															C	C	C	C
3.500																C	C	C
3.623																	C	C

NOTE: Where two widths are shown the smaller is standard for seals *without* innercase, whereas seals *with* innercase are available in both widths.

WIDTHS: Inch A= 5/16 B= 3/8 / 1/2 C= 7/16 / 1/2

Seal Width	Tolerance
<.400	±.015
>.400	±.020

FIGURE 6A—RMA OIL SEAL STANDARD SIZES SINGLE AND DUAL LIP SPRING LOADED BONDED SEALS CONFORMS TO ISO 6194/1

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Standard Bore Sizes-Inches	Standard Shaft Sizes-Inches																			
	2.625	2.750	2.875	3.000	3.125	3.250	3.375	3.500	3.625	3.750	3.875	4.000	4.250	4.500	4.750	5.000	5.250	5.500	5.750	6.00
3.500	C	C																		
3.625	C	C	C																	
3.751	C	C	C	C																
3.875		C	C	C																
4.003			C	C																
4.125				C	D															
4.249					D	D	D													
4.376					D	D	D	D												
4.500					D	D	D	D												
4.626						D	D	D	D	D										
4.751								D	D	D										
4.876									D	D	D									
4.999									D	D	D	D								
5.125											D	D								
5.251											D	D	D							
5.375												D	D							
5.501													D	D						
5.625													D	D						
5.751														D	E					
6.000															E	E				
6.250																E	E			
6.375																E	E			
6.500																	E	E		
6.625																	E	E		
6.750																		E	E	
6.875																		E	E	
7.000																			E	
7.125																			E	E
7.500																				E

STANDARD SEAL WIDTHS

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NOTE: Where two widths are shown the smaller is standard for seals *without* innercase, whereas seals *with* innercase are available in both widths.

WIDTHS: Inch   C = 7/16 / 1/2   D = 1/2   E = 9/16

Seal Width	Tolerance
< .400	±.015
> .400	±.020

FIGURE 6B—RMA OIL SEAL STANDARD SIZES SINGLE AND DUAL LIP SPRING LOADED BONDED SEALS

STANDARD BORE SIZES (mm)	STANDARD SHAFT SIZES (mm)																										
	6	7	8	9	10	12	15	16	18	20	22	25	28	30	32	35	38	40	42	45	50	55	60	65	70	75	80
16	7																										
22	7	7	7	7	7																						
24			7			7																					
25					7	7																					
26							7																				
30						7	7	7	7																		
35							7		7	7	7																
40										7	7	7	7														
42														7													
45															8												
47											7	7	7	7	8												
50																8											
52												7	7	7	8	8											
55																8	8	8	8								
58																	8										
62																	8	8	8	8							
65																				8							
68																					8						
72																					8	8					
80																						8	8				
85																							8	10			
90																								10	10		
95																									10	10	
100																										10	10

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Seal Width	Tolerance
<10 >10	±0.3 ±0.4

FIGURE 6C—METRIC OIL SEAL STANDARD SIZES SINGLE AND DUAL LIP SPRING LOADED BONDED SEALS

Standard Bore Sizes (mm)	Standard Shaft Sizes (mm)																								
	80	85	90	95	100	110	120	130	140	150	160	170	180	190	200	220	240	260	280	300	320	340	360	380	400
110	10	12																							
120		12	12	12																					
125					12																				
140						12																			
150							12																		
160								12																	
170									15																
180										15															
190											15														
200												15													
210													15												
220														15											
230															15										
250																15									
270																	15								
300																		20							
320																			20						
340																				20					
360																					20				
380																						20			
400																							20		
420																								20	
440																									20

STANDARD SEAL WIDTHS

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Seal Width	Tolerance
<10	±0.3
>10	±0.4

FIGURE 6D—METRIC OIL SEAL STANDARD SIZES SINGLE AND DUAL LIP SPRING LOADED BONDED SEALS CONFORMS TO ISO 6194/1

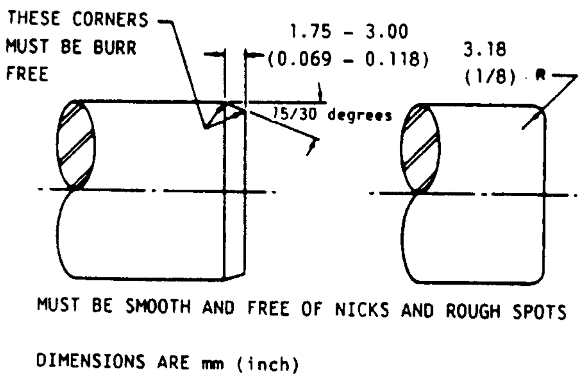

FIGURE 7—RECOMMENDED SHAFT LEAD CORNERS

5.12 Bore Lead Corners—The lead corner of the bore should be chamfered to facilitate efficient installation of the seal as shown in Figure 8. Note that, when possible, it is preferred that the chamfer be machined during the bore finishing operation rather than being cast in to maintain concentricity between the bore and the lead chamfer.

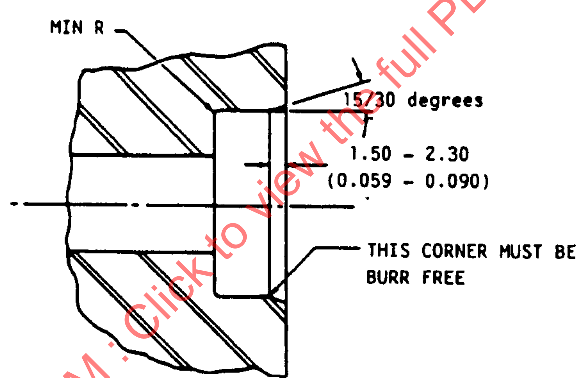

FIGURE 8—RECOMMENDED BORE LEAD CORNER

5.13 Shaft and Bore Sizes—Whenever possible, shaft and bore sizes should be selected from RMA standard size tables. See Tables 3A, 3B, 4A, and 4B and Figures 6A, 6B, 6C, and 6D.

5.14 Cocked Assembly—A factor in the proper functioning of a lip seal is the installed squareness of the outside seal face with respect to the normal shaft centerline. Keeping this value within 0.08 mm (0.003 in) for every 25 mm (1 in) of seal outside diameter with a maximum of 0.5 mm (0.020 in) is considered good general practice. A maximum of 0.25 mm (0.010 in) TIR when measured at the seal OD is considered a good general practice for automotive seal sizes. This squareness is obtained by pressing the seal flush with the front of the bore or bottoming the seal against the back of the bore. It is recommended that the seal case be designed so that a seal of maximum width is pressed approximately flush with the front of the bore. By doing this, various seal widths can be accommodated if the bore is sufficiently deep. Installation tools such as those shown in Figure 9 should be used to press the seal into place. Whether a seal is installed flush with the bore face or bottomed on the back of the bore (Figures 10 and 11), the surface it is aligned with should always be a machined surface. Unfinished surfaces should never be used for alignment purposes because of the danger of cocking the seal in the bore.

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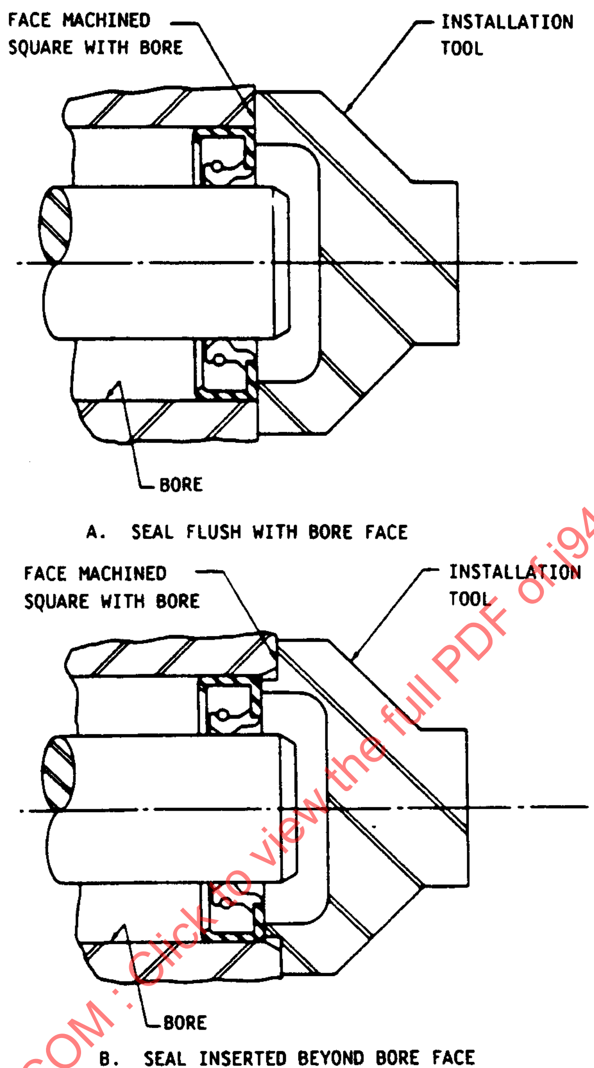

FIGURE 9—THROUGH BORE: INSTALLATION TOOL BOTTOMS ON MACHINED BORE FACE CONFORMS WITH ISO 6194/3

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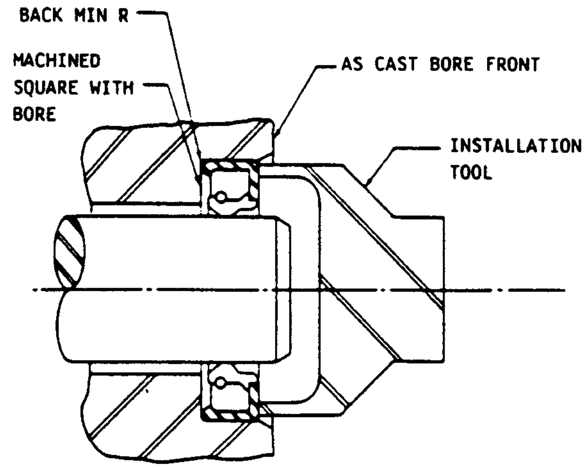

FIGURE 10—BOTTOM BORE: SEAL BOTTOMS ON MACHINE BORE SHOULDER CONFORMS WITH ISO 6194/3

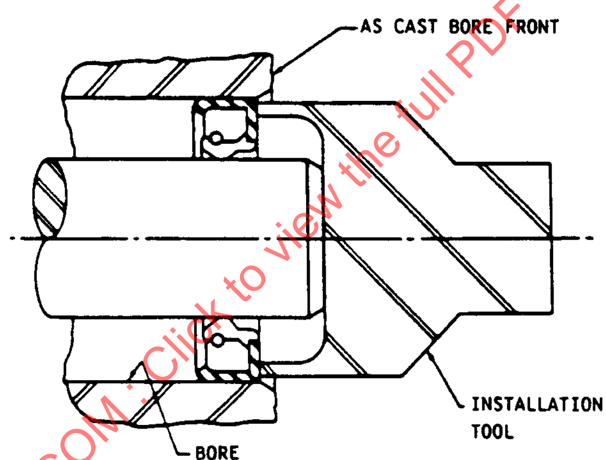

FIGURE 11—THROUGH BORE: INSTALLATION TOOL BOTTOMS ON SHAFT—CONFORMS WITH ISO 6194/3

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5.15 Seal Installation—All surfaces which the seal lip must slide over during assembly should be smooth and free from rough spots. To prevent damage to the seal lip, special installation tools should be used if the sealing element slides over splines, keyways, or holes or if the seal is assembled toe first. Assembly procedure should be carefully reviewed so that seal lips are not turned under at assembly. A light film of grease or oil applied to the shaft or seal lip prior to the assembly of elastomeric seals will decrease the probability of damage during assembly.

6. Spring—A spring is incorporated in the design of most elastomeric lip seals to provide a uniform load at the seal lip-shaft interface. There are two types of springs currently in use, the garter spring and the finger spring.

6.1 Garter Springs—The following are generally accepted terminology, design criteria, tolerances, and inspection methods for close-wound garter springs:

6.1.1 GARTER SPRING TERMINOLOGY

6.1.1.1 *Initial Tension*—The force required to cause initial separation of adjacent coils of a garter spring.

6.1.1.2 *Spring Rate*—The force, independent of initial tension, required to extend the length of a garter spring a unit distance.

6.1.1.3 *Stress Relieving*—A heat treatment of the unassembled coiled spring to relieve stresses caused by the spring coiling process. It is intended to insure that the spring force will not change in service due to exposure to heat. Stress relieving should only be specified when the spring is expected to function at temperatures exceeding 100 °C (212 °F). The temperature of stress relief must always be higher than the expected service temperature. The most common minimum stress-relief temperature is 200 °C (400 °F) for carbon steel and 260 °C (500 °F) for stainless. It must be pointed out that stress relieving reduces the maximum obtainable initial tension. Because of this, care must be taken in specifying stress-relieved springs to insure that they can be economically manufactured.

6.1.1.4 *Compressive Force*—The radial force exerted by the garter spring in its working position, expressed in units of force per unit of inner circumference.

6.1.1.5 *Spring Load*—The total load or tension at a given length which is a combination of spring rate and initial tension. Load measurements are convenient for manufacturing and quality control purposes.

6.1.1.6 *Free Length*—The unassembled length of the garter spring not including the "nib" or tapered portion, as shown in Figure 12. This calculated dimension is specified for reference only and is obtained by multiplying pi (3.14159...) by the assembled spring inner diameter plus the wire diameter.

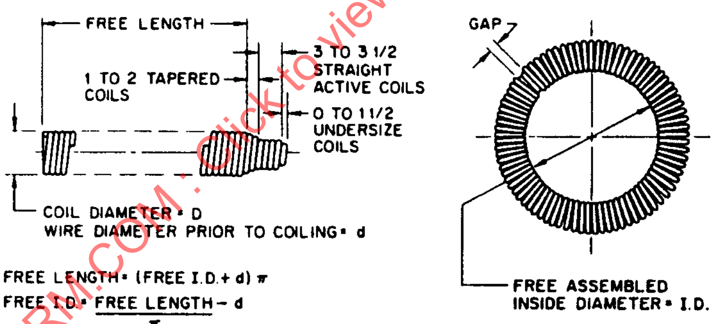

FIGURE 12—SPRING NOMENCLATURE

6.1.1.7 *Test Length*—The length to which the spring must be extended to measure the spring load. Recommended practice is to set this at the design stretch length or, optionally, at 110% of the free length.

6.1.1.8 *Passivate*—To treat (a metal) to render its surface less reactive chemically.

6.1.2 MATERIAL

6.1.2.1 *Carbon Steel Spring Wire*—Acceptable grades are SAE 1050 through 1095 (AISI C-1050 through C-1095).

6.1.2.2 *Stainless Steel Spring Wire*—Acceptable grades are SAE 30302 through 30304 (AISI Type 302 through Type 304).

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6.1.2.2.1 Coating—Stainless steel spring wire is supplied with a coating to decrease coiling die wear and to act as a lubricant during the coiling operation. The most common coatings are lime and soap, lime and oil, and copper. Unless copper coating is required for visual identification, it is best to leave the choice of coating to the spring manufacturer.

6.1.2.2.2 Passivation—Passivation changes a chemically active surface to a lesser reactive state and may be required to insure maximum corrosion resistance in stainless steel wire springs. The removal of nonmetallic coatings with alkaline cleaners is preferred prior to treatment. Passivate in a 15 to 25% solution of nitric acid at 60 to 70 °C (140 to 160 °F) for 5 min or until clean. Follow with a rinse in water. Copper coatings will also be removed. Since passivation adds to costs, it is recommended that it not be specified unless absolutely necessary.

6.1.2.3 Other Materials—Springs of other materials are available, for example, brass, or inconel, for specialized applications. These materials are considered special and it is recommended that the designer contact the spring supplier for design details.

6.1.3 TOLERANCES

6.1.3.1 Wire Diameter—It is recommended that the wire diameter be specified as a reference dimension to allow the manufacturer as much latitude as possible to meet the required tension specification. If the wire diameter must be held, ±0.03 mm (0.001 in) is the recommended tolerance. Table 6 lists the tightest acceptable tolerances and should only be specified when absolutely necessary.

When specified, the wire diameter should be such that a coil-to-wire ratio of at least 5.3:1 is maintained.

6.1.3.2 Coil Diameter—The recommended tolerance is ±0.13 mm (0.005 in). Variation in coil diameter within any one spring must not exceed 0.08 mm (0.003 in).

6.1.3.3 Assembled Inner Diameter—The internationally recommended practice is to base the inner diameter tolerance on the diameter of the wire used to manufacture the spring. This is due to the fact that, since one end of the spring screws into the other, the diameter of the wire determines how accurately ID can controlled. The recommended tolerances are as follows in Table 7.

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TABLE 6—SPRING WIRE DIAMETER TOLERANCES

Wire Diameter	Plus or Minus
0.15 – 0.25 mm (0.006 – 0.010 in)	0.008 mm (0.0003 in)
0.28 – 0.38 mm (0.011 – 0.015 in)	0.010 mm (0.0004 in)
0.41 – 0.48 mm (0.016 – 0.019 in)	0.013 mm (0.0005 in)
0.50 – 0.69 mm (0.020 – 0.027 in)	0.015 mm (0.0006 in)
0.71 – 0.86 mm (0.028 – 0.034 in)	0.018 mm (0.0007 in)

TABLE 7—TOLERANCES FOR GARTER SPRING ASSEMBLED INNER DIAMETER

Wire Diameter	ID Tolerance Plus or Minus
0.15 – 0.28 mm (0.006 – 0.011 in)	0.20 mm (0.008 in)
0.30 – 0.48 mm (0.012 – 0.019 in)	0.30 mm (0.012 in)
0.50 – 0.76 mm (0.020—0.030 in)	0.40 mm (0.015 in)
0.80 – 1.40 mm (0.031 – 0.055 in)	0.50 mm (0.020 in)

6.1.3.4 *Spring Load*—The tolerance to be applied is ±0.14 N (0.5 oz) or ±20%, whichever is greater. Note that this tolerance is to be applied to spring load specified at a given test length, not to a load at a given elongation. The reason for the distinction is that specifying a test length forces the spring manufacturer to take into account variations in spring length while specifying an extension does not. (A shorter spring must be stretched more to reach a given test length.)

6.1.4 INSPECTION

6.1.4.1 *Assembled Inner Diameter*—Inspection may be accomplished by use of a taper gage as shown in Figure 13. In no case, should a point-to-point measuring device, such as verniers, be used because the flexibility of the spring makes it impossible to obtain accurate measurements with these instruments.

6.1.4.2 *Spring Load*—Measurement of spring load requires the use of a specialized instrument capable of extending the spring to the test length with an accuracy of at least 0.02 mm (0.001 in) and measuring the resulting force within ±0.014 N (0.05 oz).

6.1.4.3 *Spring Joint (NIB)*

6.1.4.3.1 Joint Strength—Joint strength is not measured or specified as a given value but is controlled to a minimum requirement by use of an inspection gage similar to that shown in Figure 10. A spring that has acceptable joint strength will pass over the largest diameter of the gage (1.35 times the nominal ID) without disassembly. Note that this may be a destructive test.

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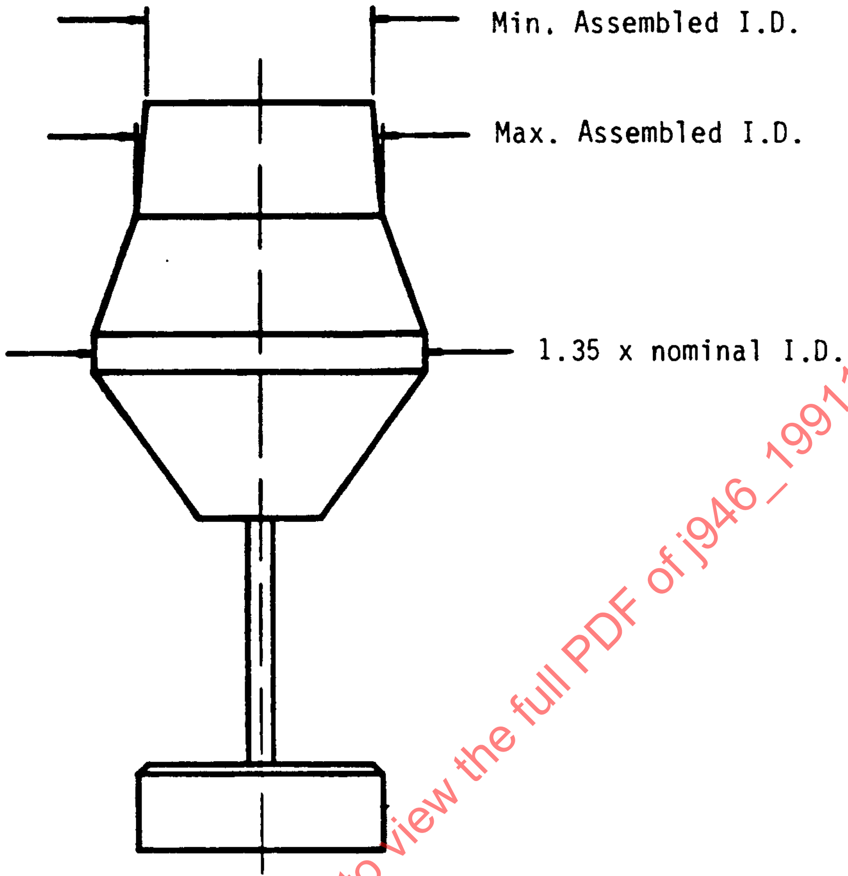

FIGURE 13—SPRING INSPECTION GAGE

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6.1.4.3.2 Allowable Gap—The maximum allowable gap is three wire diameters as shown in Figure 12.

6.1.4.4 *Spring Windup*—Spring windup is the tendency of an assembled spring to deform from a flat surface. Excessive windup results in the spring assuming a "figure eight" configuration. For acceptable springs, the figure eight must snap back to the original circular form when dropped approximately 300 mm (12 in) onto a flat, hard surface.

6.1.4.5 *Stress Relief*—When stress-relieving is specified, the recommended method of inspection is to subject an unassembled spring to the specified temperature for a minimum of 30 min and then, after cooling, measure the spring load. The spring must still meet the original load specifications.

6.2 Finger Springs—Finger springs are available from some seal manufacturers. They are generally used in assembled seals and can be subject to damage if not handled carefully.

7. Drawing Designation—In the absence of a standardized drawing format, it is recommended that the SAE standard drawing (Figure 14) be used as described in Appendix A.

8. Qualification Tests—Refer to SAE J110.

9. Inspection and Quality Control Data—This section is intended to be used as a guide and is not to be substituted for either vendor or supplier procedures.

9.1 Radial Wall Variation—Refer to Figure 15 for a diagram of radial wall dimension. Radial wall variation is checked through the use of an optical comparator. The seal outside diameter is placed on a base and the seal is rotated through 360 degrees while the maximum and minimum dimensional readings are taken. Radial wall variation is the difference between these readings. For the recommended tolerances for elastomeric seals, refer to Tables 3A and 3B.

9.2 Lip Opening Pressure—Used as a measure of the consistency of manufacture, the lip opening pressure limits for a given seal design are normally established during the first three production runs of that seal.

9.2.1 RECOMMENDED TOLERANCES—Refer to Tables 3A and 3B.

9.2.2 AIRFLOW METHOD FOR GAGING LIP OPENING PRESSURE—The lip opening pressure of the seal assembly shall be gaged by means of an airflow occurring between the seal lip and a test mandrel when air pressure is applied from the air side of the seal. Satisfactory equipment is available commercially. The procedure is as follows:

9.2.2.1 The seal case shall be mounted over the mandrel in a retainer fixture and be held concentric to the mandrel within 0.05 mm (0.002 in) TIR.

9.2.2.2 Air leakage around the seal case and around the mandrel pilot shall be prevented by means of O-rings or other suitable gaskets.

9.2.2.3 The test mandrel shall be equivalent to the mean of the shaft diameter limits specified on the seal drawing with a mandrel diameter tolerance of ±0.013 (0.0005 in).

9.2.2.4 The test mandrel shall have a surface roughness of 0.40 µm (16 µin) AA or less.

9.2.2.5 The seal shall be placed in the test fixture so that air pressure is applied to the outside face of a single-lip seal or between the lips of a double-lip seal, with care being taken to insure that an auxiliary lip does not interfere with the reading.

9.2.2.6 The seal lip opening shall be gaged at a flow of 10 000 cc/min.

9.2.2.7 To minimize material relaxation effect, the air pressure shall be increased from zero at a uniform rate such that the lip opening pressure shall be read within 3 to 6 s.

9.2.2.8 When both lip opening pressure and seal lip inside diameter measurements are to be taken consecutively, the seal lip inside diameter shall be measured first to avoid errors due to deformation of the material. Repeat measurements on the same seal shall not be taken within 16 h of a lip opening pressure measurement.

9.2.2.9 Measurements are to be taken at a room temperature above 16 °C (60 °F). The seal shall be exposed to room temperature for at least 1 h before measuring.

9.3 Radial Load—Radial load is a measurement that is useful during seal design and testing. It has not yet been generally accepted as a production quality control measurement. This measurement should be used only if equipment and procedures have been agreed on by both seal user and supplier. Some seal designs have springs to augment the force between the lip and the shaft. It is recommended that radial load measurements for spring loaded seal designs be made with the spring installed. The principle of lip force measurement and the types of radial load measuring devices are described in SAE J1901.

9.4 Inside Diameter—There are two types of inside diameters presently used in the seal industry. They are seal lip diameter and functional lip diameter.

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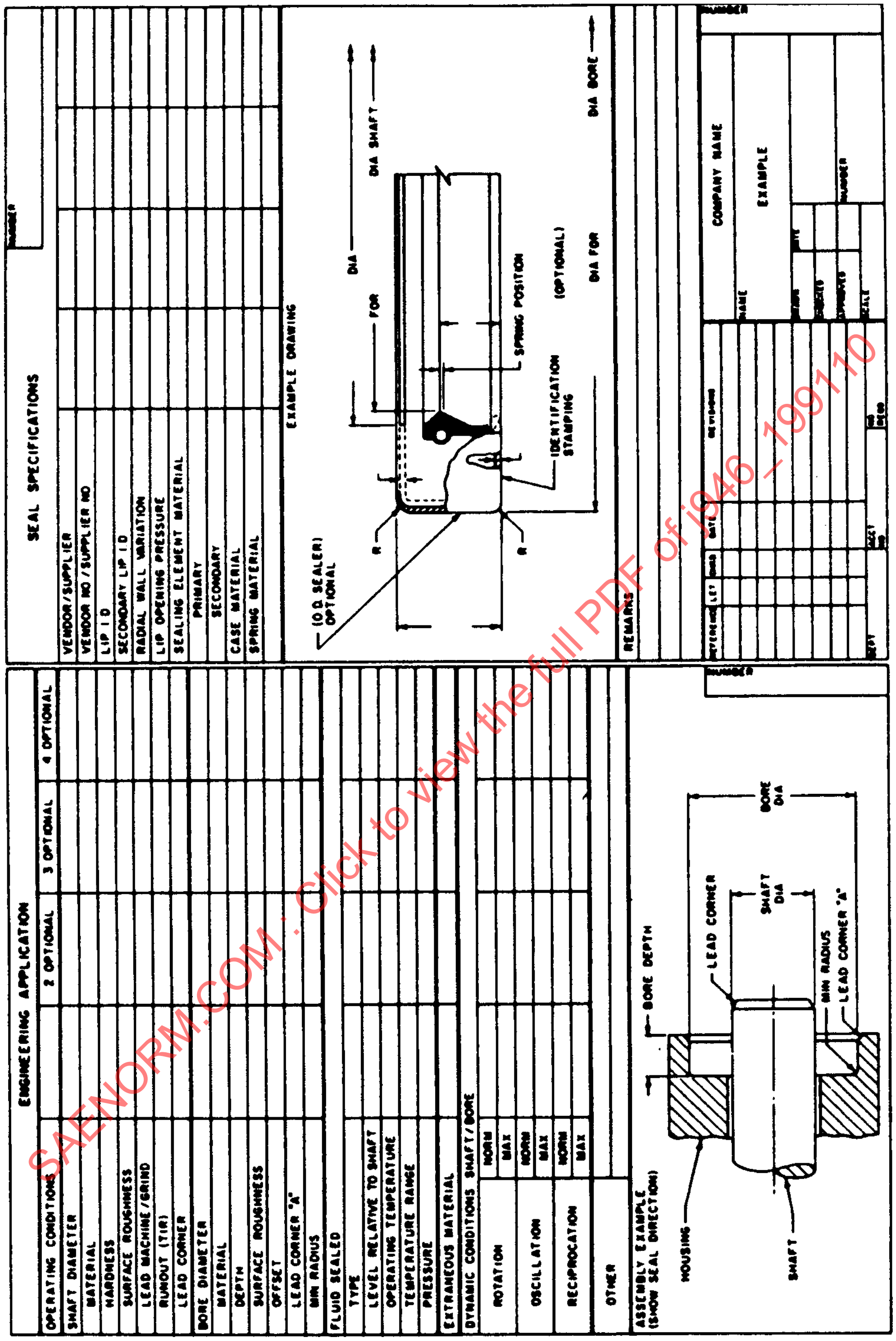

FIGURE 14—OIL SEAL DRAWING FORMAT

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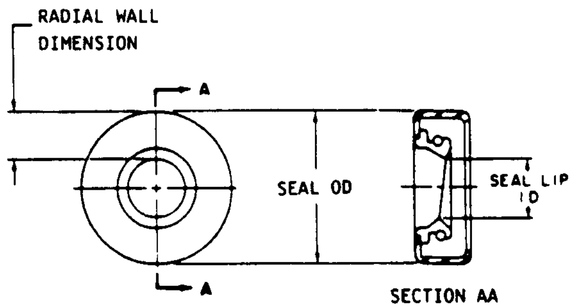

FIGURE 15—RADIAL WALL DIMENSION

9.4.1 SEAL LIP DIAMETER—Refer to Figure 15 and Tables 3A and 3B.

9.4.1.1 *Optical Comparator Method*—In one technique using an optical comparator, the seal lip diameter is measured in several positions and an average taken. The main disadvantage of this technique is lack of speed. A technique using the optical comparator which is automated and more rapid involves the determination of the average radial wall dimension. The seal lip diameter is then equal to the seal outside diameter minus twice the average radial wall dimension.

9.4.1.2 *Tapered Shaft by Light Method*—This is an acceptable method of approximating the seal lip diameter. While it does not measure diameter in the free state, it does give an acceptable approximation of the seal lip inside diameter. In this method, a shaft with a taper-to-length ratio of approximately 1:25 is used with a light source below. The seal is lowered until no light can be seen between the seal lip and the shaft. The seal lip diameter is read from markings on the shaft.

9.4.2 FUNCTIONAL LIP DIAMETER

9.4.2.1 *Airflow Method for Gaging Functional Lip Diameter*—The functional lip diameter of the seal assembly can be measured by means of an airflow between the lip and a mandrel of known size when the air is applied at a standard pressure. The procedure is as follows:

9.4.2.1.1 The seal case shall be mounted over the mandrel in a retaining fixture and be held concentric to the mandrel within 0.05 mm (0.002 in) TIR.

9.4.2.1.2 Air leakage around the seal case and around the mandrel pilot shall be prevented by means of O-rings or other suitable gaskets.

9.4.2.1.3 The test mandrel diameters shall be the same as specified for maximum and minimum lip diameters with a mandrel tolerance of ±0.013 mm (0.0005 in). The measurement using the minimum diameter mandrel shall be made first.

9.4.2.1.4 The test mandrel shall have a surface roughness of 0.40 µm (16 µin) or less.

9.4.2.1.5 The seal shall be placed in the test fixture so that air pressure is applied to the outside face.

9.4.2.1.6 An air pressure of 3.5 kPa (0.50 psi) shall be used.

9.4.2.1.7 The airflow between the seal lip and the minimum diameter test mandrel shall be equal to or less than 10 000 cc/min.

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9.4.2.1.8 When both lip opening pressure and seal lip diameter measurements are to be taken consecutively, the seal lip diameter shall be measured first to avoid errors due to deformation of the material. Repeat measurements on the same seal shall not be taken within 16 h of a lip opening pressure measurement.

9.4.2.1.9 Measurements are to be taken at a room temperature above 16 °C (60 °F). The seal shall be exposed to room temperature for at least 1 h before measuring.

9.4.2.2 Light Box Method—In this method, the seal outside diameter is held concentric to a test mandrel. High and low limit functional inside diameter mandrels are arranged with light sources underneath them. Test seals are then positioned into the fixtures, noting the light passing between the seal lip and the test mandrel. On the high limit mandrel, the seal lip must preclude all light to be acceptable (indicating that it is smaller than the mandrel); while on the low limit mandrel, the seal lip must allow light to pass. By using mandrels in increments of 0.13 mm (0.055 in), the actual seal functional lip diameter can be determined.

9.4.3 RECOMMENDED TOLERANCES—The RMA-established tolerances for elastomeric lip seal diameters are shown in Tables 3A and 3B. Functional inside diameter tolerance ranges are frequently the same as those for seal lip diameter; however, under certain conditions, the functional lip diameter tolerance ranges may be greater.

9.5 Spring Axial Position—The spring axial position is the axial distance between the projected intersection of the inside and outside lip surfaces and the centerline of the spring coil diameter (center plane of the spring) with the spring in position and the seal located on a shaft.

9.5.1 METHOD OF MEASUREMENT—The primary method to be used is designated "On Shaft Casting and Sectioning Method." An alternate, nondestructive method is described as the "Electrical Continuity Spring Location."

9.5.1.1 On Shaft Casting and Sectioning—The seal to be measured is placed in a fixture that simulates the shaft and housing bore assembly. This fixture can be constructed of various materials suitable for polishing and adhesion to a potting material. The shaft is to be concentric with the housing bore within 0.05 mm (0.002 in) TIR. The seal and fixture are then encapsulated in a potting material such as a dental casting plaster or an epoxy having a shrinkage of not more than 2%. The assembly is then cross-sectioned through its center in a vertical plane and polished. Care must be taken not to distort the seal during the sectioning operation. The spring axial position is now measured by viewing the cross section using either a reflective optical comparator or a toolmaker's microscope. This method is the most accurate but is not practical for measuring large quantities of seals.

9.5.1.2 Electrical Continuity Spring Location—The seal to be measured is placed on a device equivalent to the one described in SAE Paper No. 740204 presented at the 1974 SAE Automotive Engineering Congress and Exposition. The spring axial position is determined by adding the correction factor to the micrometer reading. This method is suitable for single case seals having sufficient clearance for a probe.

9.5.2 RECOMMENDED TOLERANCE—The recommended tolerance for spring axial position from seal to seal is 0.5 mm (0.020 in) total for molded contact line seals, and 0.6 mm (0.024 in) total for trimmed contact line seals. The recommended tolerance for spring position within one seal is 0.25 mm (0.010 in) total for molded contact line seals, and 0.40 mm (0.015 in) total for trimmed line seal. These tolerances do not apply for seals employing a variable spring axial position as a design feature. The supplier should be consulted for spring axial position tolerances for these designs. The spring axial position tolerance should not allow the centerline of the coil diameter (center plane of the spring) to shift from one side of the projected intersection of the inside and outside lip surfaces to the other.

9.6 Contact Line Height Variation—Contact line height variation is the difference between the maximum and minimum axial dimensions from the seal contact line to the outside face. See Figure 16.

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9.6.1 MEASUREMENT—The recommended method of measuring the contact line height variation is the use of a microscope and prism arranged as shown in Figure 17. In this method, the contact line height variations read directly as the seal is rotated above a fixed center. The method is easy to use and offers a good degree of repeatability. Necessary equipment is inexpensive and does not require tooling for each seal size. Since the seal contact line is viewed in its free position, handling should be minimized to avoid distortion. One method of minimizing distortion is to insert a shaft-size mandrel concentric with the seal OD prior to measuring.

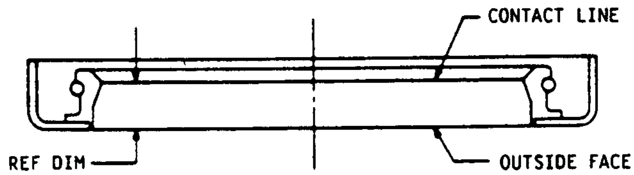

FIGURE 16—CONTACT LINE HEIGHT VARIATION

9.6.2 RECOMMENDED TOLERANCES—Recommended tolerances for limiting contact line height variation shall be within and shall not exceed the maximum allowable spring position tolerance. See 9.5.2.

9.7 Sealing Edge Roughness—Sealing edge roughness refers to the condition of the surface on the seal that forms the seal to shaft interface. See Figure 18.

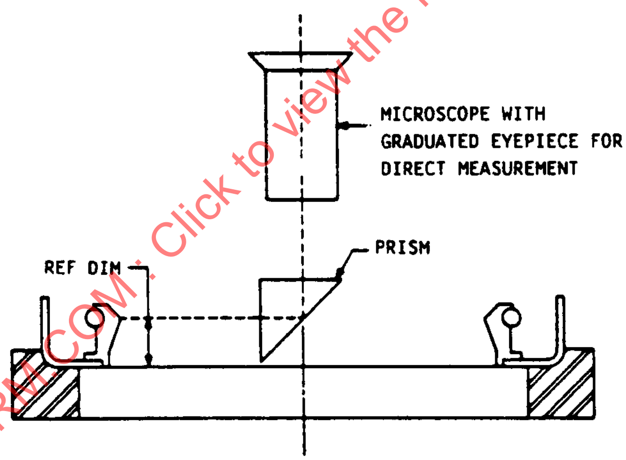

FIGURE 17—MEASUREMENT OF CONTACT LINE HEIGHT VARIATION

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9.7.1 DETERMINATION—Optical examination using magnification is recommended to determine seal edge roughness. A minimum of 7X magnification would be used. Conditions that should be noted are the following:

9.7.1.1 Average contact line roughness.

9.7.1.2 Surface characteristics immediately adjacent to the contact line, such as defects due to dirty mold surfaces, inclusions in the compound, and voids.

9.7.1.3 Angular marks on the outside lip surface adjacent to the contact line. These marks may be part of the design on elastohydrodynamic seals.