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# Application Guide to Radial Lip

SAE Recommended Practice
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Submitted for Recognition as an American National Standard

SAE The Engineering Society For Advancing Mobility Land Sea Air and Space®
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HIGHWAY VEHICLE PRACTICE

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# SEALS: APPLICATION GUIDE TO RADIAL LIP



## 1. INTRODUCTION:

This 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 recommended practice is to make standard information available in one document to the users of oil seals.

## 2. 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.

2.1 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. Table 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:

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

2.1.2 The seal is manufactured to tolerances established herein.

2.1.3 The shaft surface is prepared as in paragraph 4.1 and the applications dynamic characteristics, that is shaft roundness and dynamic runout, 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 paragraph 4.1).

2.1.4 The seal is installed properly as outlined in paragraph 4.15.

2.1.5 Maintaining the above 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.

2.2 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.

2.2.1 Unirotational: A seal incorporating helical ribs located on the outside surface which may or may not terminate in a static lip. Fig. 1 illustrates schematics of some of the more popular designs which have reached the commercial market.

2.2.2 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. Figs. 2 and 3 are examples of this type of seal.

## 3. 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.

3.1 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.

3.1.1 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).

3.1.1.1 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.

3.1.1.2 Disadvantages:

(a) Poor heat resistance when combined with high shaft speed.

(b) Nonhomogenous makeup can cause variations in performance.

3.1.2 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.

3.1.2.1 Advantages:

(a) Fair-dry running characteristics.

(b) Good processing.

(c) Good low-temperature characteristics.

(d) Good oil resistance.

(e) Good abrasion resistance.

3.1.2.2 Disadvantages:

(a) Lack of exceptional heat resistance.

(b) Tendency to harden during continuous high-temperature usage.

3.1.3 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.

3.1.3.1 Advantages:

(a) Resistant to EP type additives.

(b) Good moderate-temperature performance.

(c) Good oil resistance.

3.1.3.2 Disadvantages:

(a) Fair low-temperature properties with high shaft runout.

(b) Poor dry-running characteristics.

(c) Fair abrasion resistance.

3.1.4 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.

3.1.4.1 Advantages:

(a) Good temperature range.

(b) Reasonable abrasion resistance.

(c) Good moisture resistance.

3.1.4.2 Disadvantages:

(a) Poor dry-running characteristics.

(b) High swell characteristics in some fluids.

3.1.5 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.

3.1.5.1 Advantages:

(a) Good temperature range.

(b) Excellent low-temperature properties.

3.1.5.2 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.

3.1.6 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.

3.1.6.1 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.

3.1.6.2 Disadvantages:

(a) Use caution with low-temperature service since FKM seals will leak, but not crack, under high shaft runout conditions when subjected to temperatures low enough to cause compound stiffening.

(b) Special tooling is frequently required.

3.1.7 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.

3.1.7.1 Advantages:

(a) Superior fluid and heat resistance.

(b) Excellent dry-running characteristics.

(c) Low coefficient of friction.

(d) Withstands higher pressures than shown in Table 2.

3.1.7.2 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.

3.1.8 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.

3.1.8.1 Advantages:

(a) Excellent oil and fuel resistance.

(b) Good temperature range.

3.1.8.2 Disadvantages:

(a) Fair dry-running characteristics.

(b) Low abrasion and cut resistance.

3.2 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 adequatly 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.

3.2.1 Material-Lubrication Compatibility Tests: Shown below 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.



PROPERTY CHANGE LIMITS

| | Spring Loaded Seals | Non-sprung Seals |
|---|---|---|
| Hardness (Shore A) | 90 Max | 90 Max |
| Elongation | -50% Max | -50% Max |
| Volume Change | -5 to +25% | -5 to +10% |

3.2.1.1 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.

3.2.1.2 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.

3.2.1.3 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.

3.3 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.

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

## 4. 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.

4.1 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 0.25-0.50 micrometers (10-20 microinches) with no machine lead. (See Section 9 for the recommended shaft lead detection method.) Refer to Fig. 4 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:

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

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

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

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

4.2 Shaft Diameter: The shaft diameter should be held within the tolerances shown in Table 3, although greater shaft tolerances may be used when agreed upon between user and supplier.

4.3 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.

4.4 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.

4.5 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.

4.6 Dynamic Runout: Generally, the shaft runout 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 runout due to the inability of the seal to follow the shaft high-frequency camming effect.

4.7 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.

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

4.9 Bore Surface Roughness: On applications where a lubricant head is present against the outside diameter of the seal, if the bore surface roughness is approximately 2.54 micrometers (100 microinches) AA or smoother, no outside diameter leakage problems should be encountered provided no tool marks are present. If the surface is rougher than 2.54 micrometers (100 microinches) AA, a case OD sealer should be used to insure 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 diameter of the seal. 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 generally is not required.

4.10 Pressure: Standard design radial lip type oil seals should not be used when the operating pressure exceeds the limits shown in Table 2. 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 runout 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.

4.11 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 Fig. 5).

4.12 Bore Lead Corners: The lead corner of the bore should be chamfered to facilitate efficient installation of the seal as shown in Fig. 6. 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.

4.13 Shaft and Bore Sizes: Whenever possible, shaft and bore sizes should be selected from RMA standard size tables. See Tables 3, 4 and 5.

4.14 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 Fig. 7 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 (Figs. 8 and 9), 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.

4.15 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.

5. 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.

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

5.1.1 Garter Spring Terminology:

5.1.1.1 Initial Tension: The force required to cause initial separation of adjacent coils of a garter spring.

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

5.1.1.3 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.

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

5.1.1.5 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.

5.1.1.6 Free Length: The unassembled length of the garter spring not including the "nib" or tapered portion, as shown in Fig. 10. 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.

5.1.1.7 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.

5.1.1.8 Passivate: To treat (a metal) to render its surface less reactive chemically.

5.1.2 Material:

5.1.2.1 Carbon Steel Spring Wire: Acceptable grades are SAE 1050 through 1095 (AISI C-1050 through C-1095).

5.1.2.2 Stainless Steel Spring Wire: Acceptable grades are SAE 30302 through 30304 (AISI Type 302 through Type 304).

5.1.2.2.1 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.

5.1.2.2.2 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 five minutes 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.

5.1.2.3 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.

5.1.3 Tolerances:

5.1.3.1 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. The following are the tightest acceptable tolerances and should only be specified when absolutely necessary:

| WIRE DIAMETER | PLUS OR MINUS |
|---|---|
| 0.15 - 0.25 mm | 0.008 mm |
| (0.006 - 0.010 in) | (0.0003 in) |
| 0.28 - 0.38 mm | 0.010 mm |
| (0.011 - 0.015 in) | (0.0004 in) |
| 0.41 - 0.48 mm | 0.013 mm |
| (0.016 - 0.019 in) | (0.0005 in) |
| 0.50 - 0.69 mm | 0.015 mm |
| (0.020 - 0.027 in) | (0.0006 in) |
| 0.71 - 0.86 mm | 0.18 mm |
| (0.028 - 0.034 in) | (0.0007 in) |

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

5.1.3.2 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).

5.1.3.3 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 the I.D. can be controlled. The recommended tolerances are as follows:

5.1.3.3 (Continued):

| WIRE DIAMETER | I.D. TOLERANCE PLUS OR MINUS |
|---|---|
| 0.15 - 0.28 mm | 0.20 mm |
| (0.006 - 0.011 in) | (0.008 in) |
| 0.30 - 0.48 mm | 0.30 mm |
| (0.012 - 0.019 in) | (0.012 in) |
| 0.50 - 0.76 mm | 0.40 mm |
| (0.020 - 0.030 in) | (0.015 in) |
| 0.80 - 1.40 mm | 0.50 mm |
| (0.031 - 0.055 in) | (0.020 in) |

5.1.3.4 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.)



5.1.4 Inspection:

5.1.4.1 Assembled Inner Diameter: Inspection may be accomplished by use of a taper gauge as shown in Fig. 11. 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.

5.1.4.2 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).

5.1.4.3 Spring Joint (NIB):

5.1.4.3.1 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 gauge similar to that shown in Fig. 11. A spring that has acceptable joint strength will pass over the largest diameter of the gauge (1.35 times the nominal I.D.) without disassembly. Note that this may be a destructive test.

5.1.4.3.2 Allowable Gap: The maximum allowable gap is three wire diameters as shown in Fig. 10.

5.1.4.4 Spring Wind-up: Spring wind-up is the tendency of an assembled spring to deform from a flat surface. Excessive wind-up 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.

5.1.4.5 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.

5.2 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.

6. DRAWING DESIGNATION:

In the absence of a standardized drawing format, it is recommended that the SAE standard drawing (Fig. 12) be used as described in Section 10.2.

7. QUALIFICATION TESTS:

Refer to SAE J110.

8. 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.

8.1 Radial Wall Variation: Refer to Fig. 13 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 deg 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 Table 3.

8.2 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.

8.2.1 Recommended Tolerances: Refer to Table 3.

8.2.2 Air Flow 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:

8.2.2.1 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.

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

8.2.2.3 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).

8.2.2.4 The test mandrel shall have a surface roughness of 0.40 micrometers (16 microinches) AA or less.

8.2.2.5 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.

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

8.2.2.7 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 - 6 seconds.

8.2.2.8 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.

8.2.2.9 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.

8.3 Ø <u>Radial Load</u>: 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 upon 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.

8.4 <u>Inside Diameter</u>: There are two types of inside diameter presently used in the seal industry. They are seal lip diameter and functional lip diameter.

8.4.1 <u>Seal Lip Diameter</u>: Refer to Fig. 13 and Table 3.

8.4.1.1 <u>Optical Comparator Method</u>: 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.

8.4.1.2 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.

8.4.2 Functional Lip Diameter:

8.4.2.1 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:

8.4.2.1.1 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.

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

8.4.2.1.3 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.

8.4.2.1.4 The test mandrel shall have a surface roughness of 0.40 micrometers (16 microinches) or less.

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

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

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

8.4.2.1.8 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.

8.4.2.1.9 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.

8.4.2.2 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.

8.4.3 Recommended Tolerances: The RMA-established tolerances for elastomeric lip seal diameters are shown in Table 3. 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.

8.5 Spring Axial Position: The spring axial position is the axial distance between the projected intersection of the inside and outside lip surface 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.

8.5.1 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".

8.5.1.1 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 or 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.

8.5.1.2 Electrical Continuity Spring Location: The seal to be measured is placed on a device equivalent to the one described in SAE Paper No. 740204, "Spring Position Measurement", 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.

8.5.2 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.

8.6 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 Fig. 14.

8.6.1 Measurement: The recommended method of measuring contact line height variation is the use of a microscope and prism arranged as shown in Fig. 15. 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 O.D. prior to measuring.

8.6.2 Recommended Tolerances: Recommended tolerances for limiting contact line height variation shall be within and shall not exceed the maximum allowable spring position tolerance. See paragraph 8.5.2.

8.7 Sealing Edge Roughness: Sealing edge roughness refers to the condition of the surface on the seal that forms the seal to shaft interface. See Fig. 16.

8.7.1 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:

8.7.1.1 Average contact line roughness.

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

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

8.7.1.4 Any deviation that exists in a small increment of seal contact line length (approximately 6 mm or 1/4 in). This differentiates between "contact line height variation" and "contact line roughness". See Fig. 16.

8.7.2 Production Measurement: The method above will not lend itself to volume seal examination. If volume examination is required, it may be accomplished by the use of a suitable mechanical measuring device with a reasonable degree of confidence. When using these devices, they should be periodically referenced against some optical method.

8.8 Visual Radial Lip Variations:

8.8.1 Identification of Visual Radial Lip Variations: The variations described and shown in this section are the result of manufacturing and handling variations and in no way are intended to describe variations as a result of service. Typical visual variations for elastomeric radial lip type seals are shown in Fig. 17. These variations are shown in the areas where they normally occur. They may occur at other places on the seal and on other seal types. Reference radial seal nomenclature and glossary SAE J111 for definition of terms.

8.8.2 Location of Visual Elastomeric Variations: The location of an elastomeric variation is very significant. Figure 17 shows the surface area on a single-lip and a dual-lip seal by letter. Each area is defined.

8.8.2.1 Area A - Primary Lip Contact Area: The lip of any single-lip seal is the primary lip. If a multiple-lip seal is used for fluid retention, the fluid-retaining lip is the primary lip and contaminant-excluding lips are secondary lips. If a multiple-lip seal is not used to retain a fluid, the primary lip would be the most critical lip. A seal could have two primary lips if two fluids are separated by a multiple-lip seal. The maximum wear anticipated on the primary lip established the boundaries of Area A.

8.8.2.2 Area B - Seconday Lip Contact Area: The secondary lip or lips are intended for dirt, dust, or other contaminant exclusion. The maximum wear anticipated on the secondary lip or lips establishes the boundaries of Area B.

8.8.2.3 Area C - Flex Sections and Other Critical Areas: The flex section, the remainder of the primary and secondary lips not included in Areas A and B, and any other flexing and critical areas constitute Area C.

8.8.2.4 Area D - Seal O.D.: The seal outer diameter where contact is provided with the mating bore constitutes Area D.

8.8.2.5 Area E - Seal Endface: The endface of the seal which serves to locate the seal axial in the mating bore constitutes Area E. On some applications, Area E and G could be reversed from that shown in Fig. 17.

8.8.2.6 Area F - Interior Areas: All nonfunctional interior areas constitute Area F.

8.8.2.7 Area G - Exterior Areas: All nonfunctional exterior areas constitute Area G. On some applications, Areas E and G could be reversed from that shown in Fig. 17.

8.8.3 Primary Function of Seal: The primary function of a seal is determined by the purpose of its primary lip. The primary functions are defined.

8.8.3.1 Fluid Retention: The primary function of the seal is considered to be fluid retention if the primary lip is used to retain fluid.

8.8.3.2 Grease or Other Semifluid Retention: The primary function of the seal is considered to be grease retention if the primary lip is used to retain grease or some other semifluid material.

8.8.3.3 Dirt or Other Contaminant Exclusion: The primary function of the seal is considered to be dirt exclusion if the primary lip is used to exclude dirt or some other nonliquid contaminant.

8.8.4 Significance of Visual Elastomer Variations: Visual variations can have significance depending upon:

1. The primary function of the seal.
2. Their location on the seal.
3. The magnitude of the variation.

Table 6 provides a list of all variations shown in Fig. 17. The list is divided into three sections with one section provided for each type of primary seal function. Figure 17 is used in conjunction with Table 6 to determine the significance of the variation. The steps required are outlined below:

a. Identify variations using Fig. 17.

b. Determine variation location using Fig. 17.

c. Determine primary function of seal using paragraph 8.8.3.

d. Determine significance of variation using Table 6.

This procedure will establish the variation as critical, major, or minor.

The significance of these terms is as follows:

8.8.4.1 Critical: The designation "critical" means that the variation is detrimental to fluid or grease retention and/or contaminant exclusion. Usage of seals with critical variations is not recommended.

8.8.4.2 Major: The designation "major" means that the variation may or may not be detrimental to the primary function of the seal. Usage of seals with major variations must be determined by a careful review of:

1. Service requirements.

2. Magnitude of variation.

3. Consequences of seal failure.

All designations in Table 6 listed as "major" should be reviewed prior to initiation of inspection standards. Those areas designated "major" which are detrimental to the specific application under consideration should be redesignated as "critical." The decision as to the detrimental nature of each variation should be predetermined by testing and not left to the judgment of the inspector.

8.8.4.3 Minor: The designation "minor" means the variation is not detrimental to the primary function of the seal. Usage of seals with minor variations is permissible.

8.8.5 Optical Magnification: It is not the intent of this section to encourage or discourage the use of optical magnification to view the variations depicted in Fig. 17. The variations shown are intended to be identifiable with the naked eye. Optical magnification, however, can be a valuable tool in evaluating the type and significance of variations observed.

8.8.6 Customer Supplier Relationship: Special care should be taken before a variation in area A is classified "critical" on a specific seal design. As stated above, visual variations can have a varied significance. The only positive way of determining if a variation is critical is to subject the seal to operating conditions. Several types of pneumatic devices now in use attempt to define whether or not a variation in Area A is critical. The use of these or other inspection devices to replace or supplement visual inspection is determined by agreement between supplier and customer.

8.9 Ø Bond Test: Bond, as it relates to elastomeric seals, is defined as "The adhesion, established by vulcanization, between two cured elastomeric surfaces, or between one cured elastomer surface and one non-elastomer surface." Good bond is essential to the function of elastomeric radial lip seals and other precision bonded parts. Bond tests should be performed with the fixture and procedure outlined in SAE J1900.

## 9. SHAFT LEAD DETECTION METHOD:

9.1 Shaft Lead: Spiral grooves can be generated on a shaft surface by the relative axial movement of the finishing tool during the finishing operation. This condition, known as shaft lead, can have an effect on the sealing properties of a mating radial lip type oil seal. Lead may be detected and quantified by placing a thread (220 to 240 deg wrap angle) and a suspended weight (28 g (1 oz)) around a leveled shaft and slowly (60 rpm) rotating the shaft. If the thread transverses back and forth as the direction of rotation is reversed, shaft lead is present.

9.2 Equipment Required to Detect Shaft Lead: The shaft can be checked for lead by chucking it in a lathe that can be reversed. Special test machines can also be constructed with small reversible variable speed electric motors to drive the test piece. In some cases, the unit has been mounted on a comparator. The surface of the shaft and the thread are magnified on the screen of the comparator. This magnified view is helpful in measuring the rate of thread advance when the shaft is rotated.

9.3 Procedure to Detect Shaft Lead:

9.3.1 Mount shaft or sleeve in holding chuck, then check and adjust to insure shaft is level. For consistent repeatable results, shafts must be level.

9.3.2 Lightly coat the shaft or sleeve with a 5 to 10 cst viscosity silicone oil.

9.3.3 A thread [1](Belding, Lily - Article #3288, 100% extra strong quilting thread 0.23 mm (0.009 in) diameter is recommended) is draped over the surface of the shaft and a 28 g (1 oz) weight is attached at a distance below the shaft to create a string-to-shaft contact arc of 220 to 240 deg.

9.3.4 Adjust rotational speed to 60 $\pm$ 5 rpm.

9.3.5 Observe the axial movement of the thread while the shaft rotates. Reverse the direction of shaft rotation. Place the thread both at the center and edges of the shaft to observe for movement.

9.4 Interpretation of Results:

9.4.1 CW or Right Hand Lead (Fig. 18a): The tread will advance from the fixed or arbor end of the shaft towards the free end when the shaft is rotating clockwise (CW). The thread will move from the free end of the shaft towards the fixed end for counterclockwise (CCW) rotation.

9.4.2 CCW or Left Hand Lead (Fig. 18b): The thread will advance from the fixed or arbor end of the shaft towards the free end when the shaft is rotating counter clockwise (CCW). The thread will move from the free end of the shaft towards the fixed end for clockwise (CW) rotation.

9.4.3 No Lead: Thread remains stationary at the center and ends of the shaft for both directions of shaft rotation.

[1]Unwaxed dental floss or a monofilament line of approximately 0.13 mm (0.005 in) may be substituted for quilting thread.

9.4.4 Tapered Shaft (Fig. 18c): Thread moves across the surface in the same direction for both directions of shaft rotation. Remounting the shaft end-for-end reverses the direction in which the thread moves across the shaft.

9.4.5 Non Level Shaft: Thread moves across the surface in the same direction for both directions of shaft rotation. Remounting the shaft end-for-end does not reverse the direction in which the thread moves across the shaft.

9.4.6 Crowned Shaft (Fig. 18d): Thread moves away from the center for both directions of shaft rotation.

9.4.7 Cupped Shaft (Fig. 18e): Thread moves toward the center for both directions of shaft rotation.

9.5 Definition of Lead Angle: The lead of a shaft can be compared with other shafts of different diameters by calculating a lead angle. The lead angle is the angle whose tangent is found by dividing the string advance (in) by the product of the shaft circumference (in) and the number of revolutions required to advance the string the measured amount.

$$\text{Lead angle} = \text{Arctan}\,\frac{\text{String Advance}}{(\text{Shaft Diameter})\ (\text{Number of Revolutions})}$$

For example, it is found that a string will advance 8.0 mm (0.315 in) in 30 s on a 100 mm (3.937 in) diameter shaft rotating at 60 rpm.

$$\text{Lead angle} = \text{Arctan}\,\frac{8.0}{(100)\ (30)} = 0.049\ \text{deg} = 2\ \text{min}\ 56\ \text{s}$$

A 50 mm (1.968 in) diameter shaft with the same advance (8.0 mm (0.315 in) in 30 s at 60 rpm) will have a lead angle of 0.0970 = 5 min 49 s

9.6 Lead Specification: It is recommended that the lead angle of the shaft be zero with a tolerance of $\pm$0.05 deg ($\pm$3 min).

10. APPENDIX:

10.1 RMA Standards: These standards embody current optimum design practice and should be utilized to the fullest extent possible on new radial lip seal applications. Availability of parts conforming to all listed combinations of envelope dimensions is not presently guaranteed by members of the Oil Seal Division of RMA. It is their intention, however, to be governed by these standards in the continuing expansion of their individual product lines as more widespread acceptance of standard bonded radial lip seals justifies expenditures for necessary tooling. See Tables 2, 3, and 5.

10.2 Standard SAE Drawing Form: This SAE recommended oil seal drawing format (Fig. 12) is a composite of all the engineering applications and seal specification data that might be required to assure functional compatibility of an elastomeric radial lip seal with a specific application. This format is intended only as an example 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, material specifications, etc. In those cases, it is recommended that the format and/or sketches be suitably altered to meet the user's requirements.

The seals specification data shall be furnished by the seal supplier in conjunction with the user. This data and information must be such that they are compatible with the engineering application data as supplied by the user.

10.3 Seals - Testing of Radial Lip: See SAE J110.

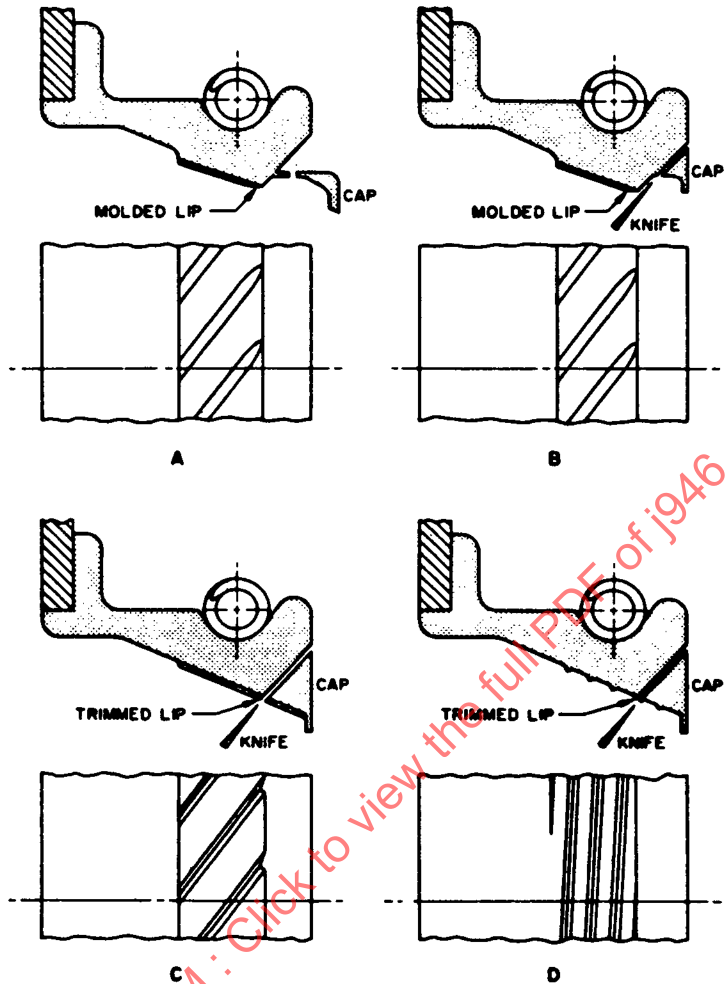
10.4 Seals - Terminology of Radial Lip: See SAE J111.

10.5 Seals - Evaluation of Elastohydrodynamic: See SAE J1002.

10.6 Fluid Sealing Handbook - Radial Lip Seals: See SAE J1417.



The phi (Ø) 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.




SEALS SHOWN IN FIGS. 1A AND 1B HAVE A MOLDED LIP. THE EXCESS MATERIAL IS REMOVED BY TEARING THE CAP FROM THE MOLDED PART ON DESIGN 1A AND BY A KNIFE ON DESIGN 1B. THE HELICAL RIBS IN BOTH DESIGNS TERMINATE AT THE CONTACT POINT OF THE STATIC LIP.

SEALS SHOWN IN FIGS. 1C AND 1D 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 1 - Various Unirotational Elastohydrodynamic Seal Design Concepts

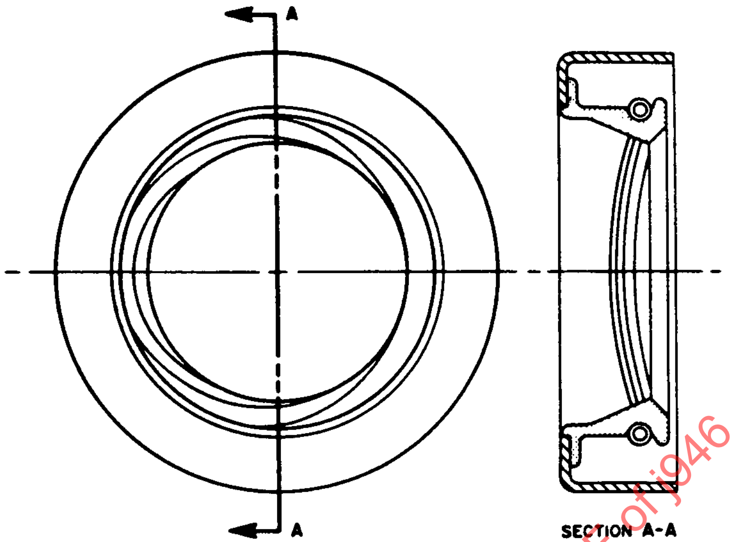



FIGURE 2 - Birotational Elastohydrodynamic Seal: Ribs Protruding in Opposite Directions Produce Sealing Irrespective of Direction of Shaft Rotation

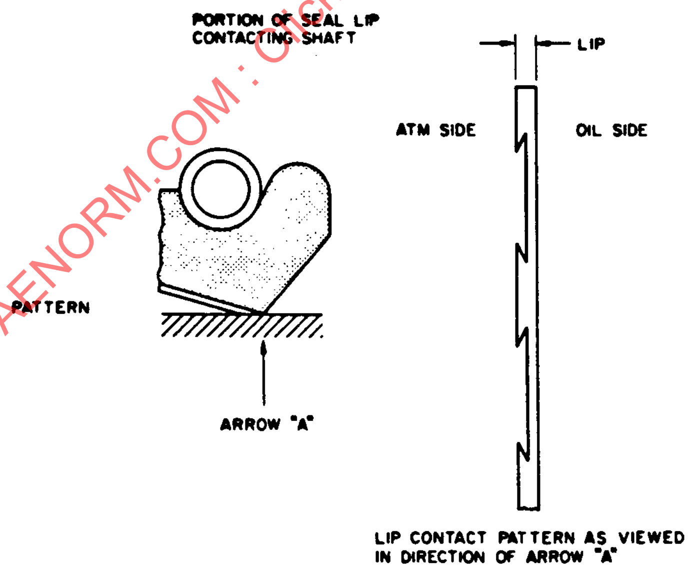


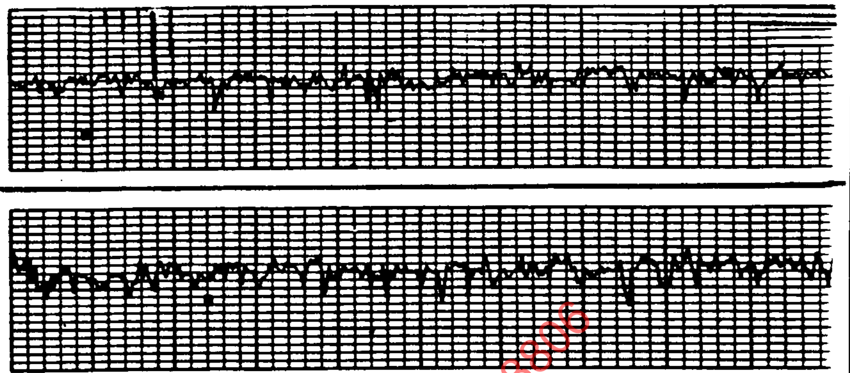

FIGURE 3 - Birotational Elastohydrodynamic Seal: Triangular Depressions or Protrusions in Circumferential Pattern in Outside Lip Surface Produce Sealing Irrespective of Direction of Shaft Rotation

ACCEPTABLE AXIAL SURFACE ROUGHNESS PROFILE
Scale:
VERT.=0.005 mm/Div (0.00002 in/Div)
HORZ.=0.05 mm/Div (0.002 in/Div)

STYLUS SIZE=2.5 micrometers (100 microinch) TIP RADIUS

$R_a$=(10AA) (EXAMPLE SHOWN)
$R_a$=0.33 micrometers (13 microinch)

$R_a$=(20AA) (EXAMPLE SHOWN)
$R_a$=0.50 micrometers (20 microinch)



UNACCEPTABLE AXIAL SURFACE ROUGHNESS PROFILE

1. Any plateau where a series of peaks and valleys exceeds an overall height of 0.78 micrometer (31 microinch) for an axial distance greater than 0.076 mm (0.003 inch)
2. Any one (2) valley where:
   0 to 0.78 micrometer
   (0 to 31 microinch)

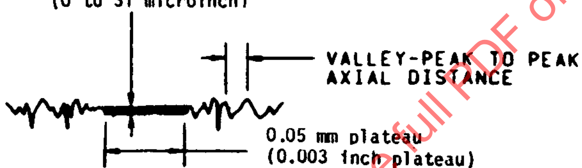
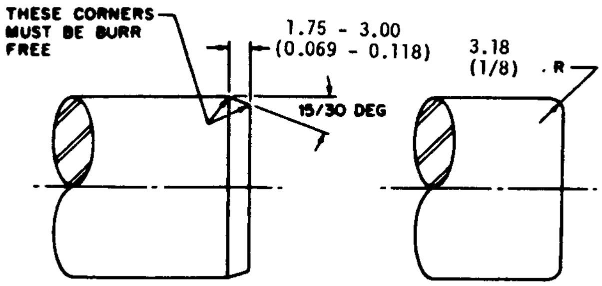



FIGURE 4 - Typical Traces of Shaft Surface Roughness Profiles






MUST BE SMOOTH AND FREE OF NICKS AND ROUGH SPOTS
DIMENSIONS ARE mm (inch)

FIGURE 5 - Recommended Shaft Lead Corners

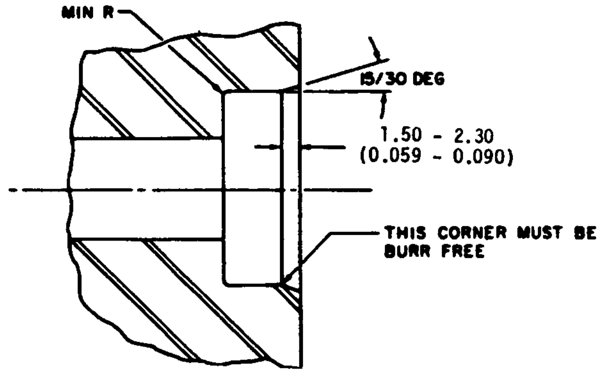
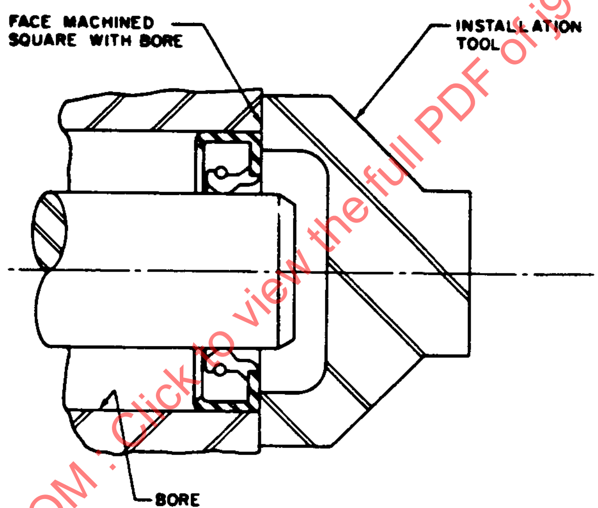
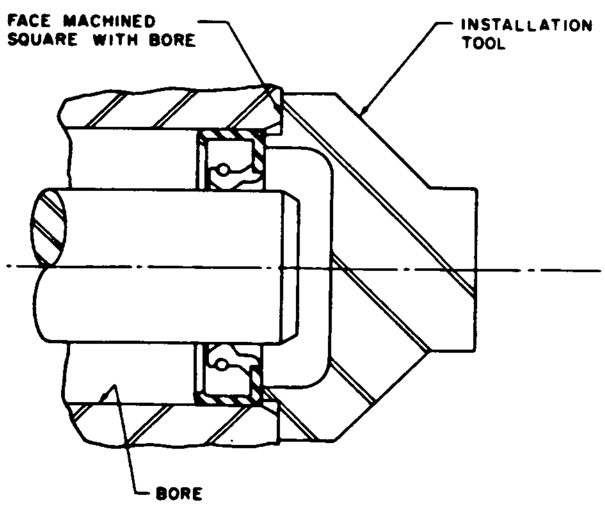



FIGURE 6 - Recommended Bore Lead Corner




A. SEAL FLUSH WITH BORE FACE




B. SEAL INSERTED BEYOND BORE FACE

FIGURE 7 - Through Bore: Installation Tool Bottoms on Machined Bore Face

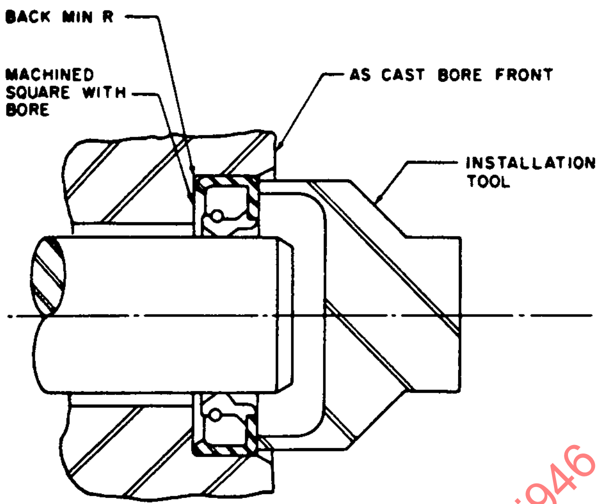



FIGURE 8 - Bottom Bore: Seal Bottoms on Machine Bore Shoulder

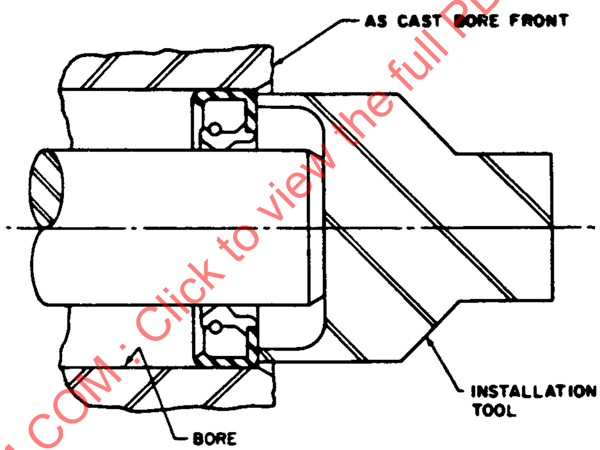



FIGURE 9 - Through Bore: Installation Tool Bottoms on Shaft



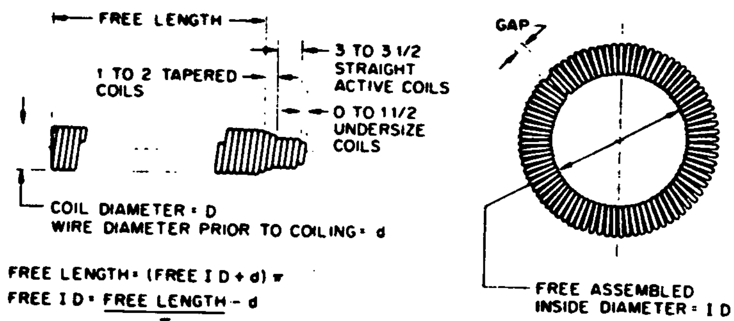



FIGURE 10 - Spring Nomenclature

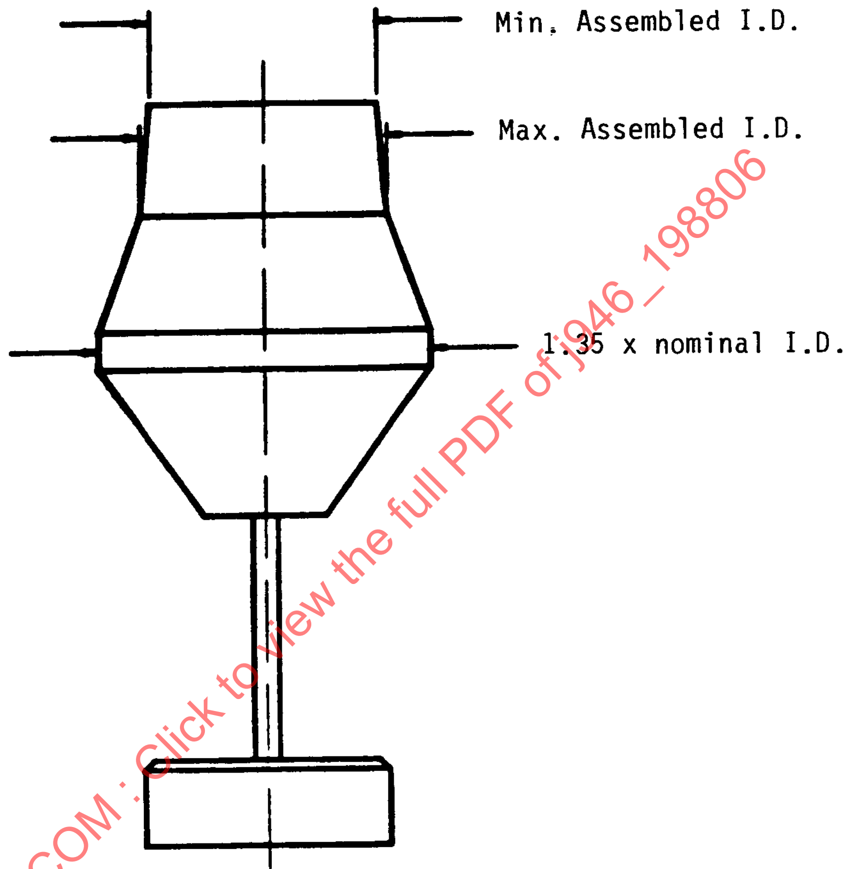



FIGURE 11 - Spring Inspection Gauge

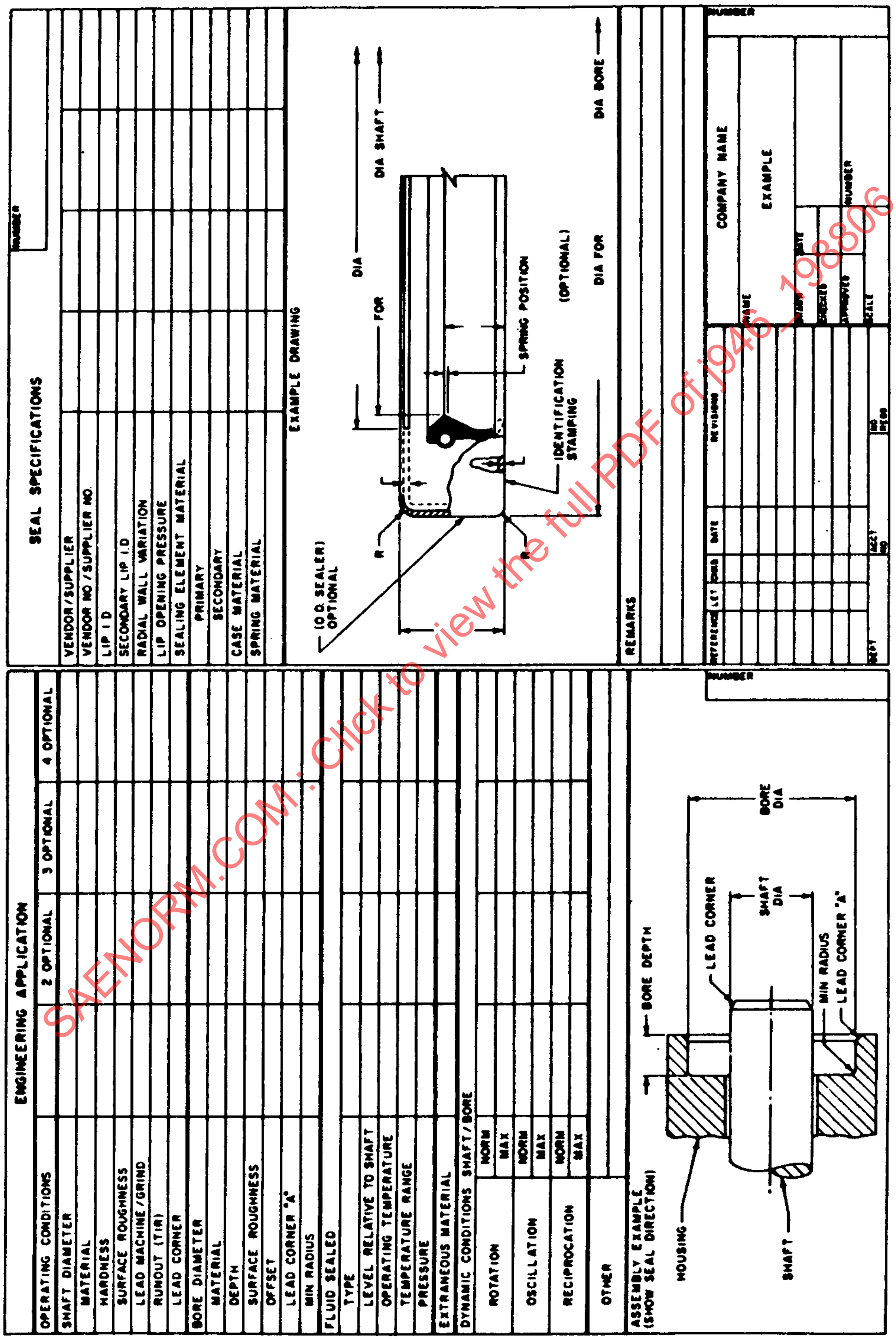



FIGURE 12 - Oil Seal Drawing Format

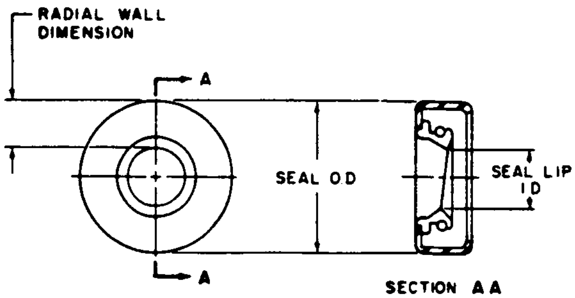



FIGURE 13 - Radial Wall Dimension

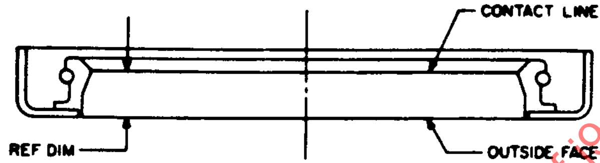



FIGURE 14 - Contact Line Height Variation

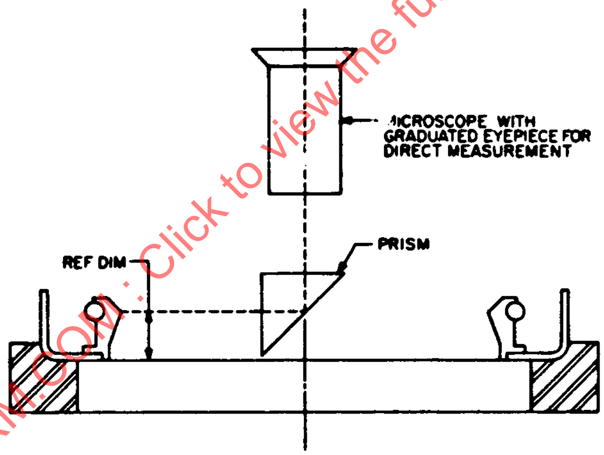



FIGURE 15 - Measurement of Contact Line Height Variation

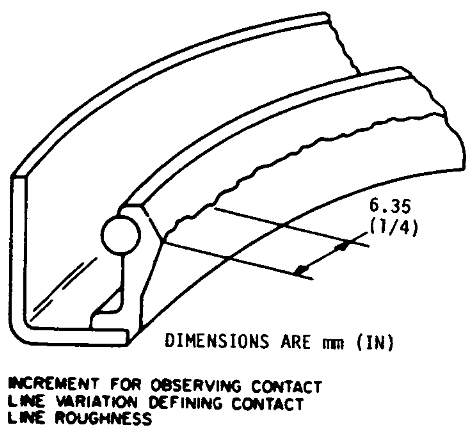



FIGURE 16 - Sealing Edge Roughness

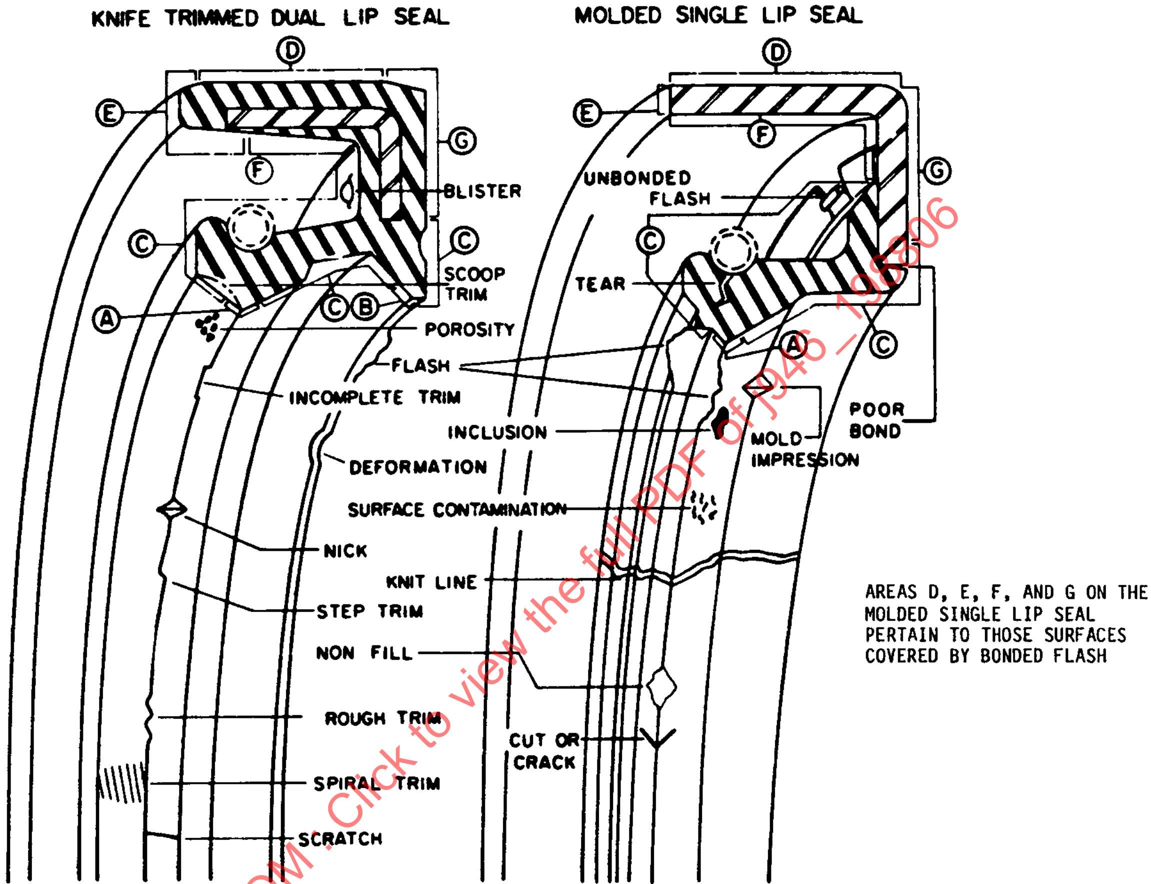



FIGURE 17 - Visual Elastomer Variations

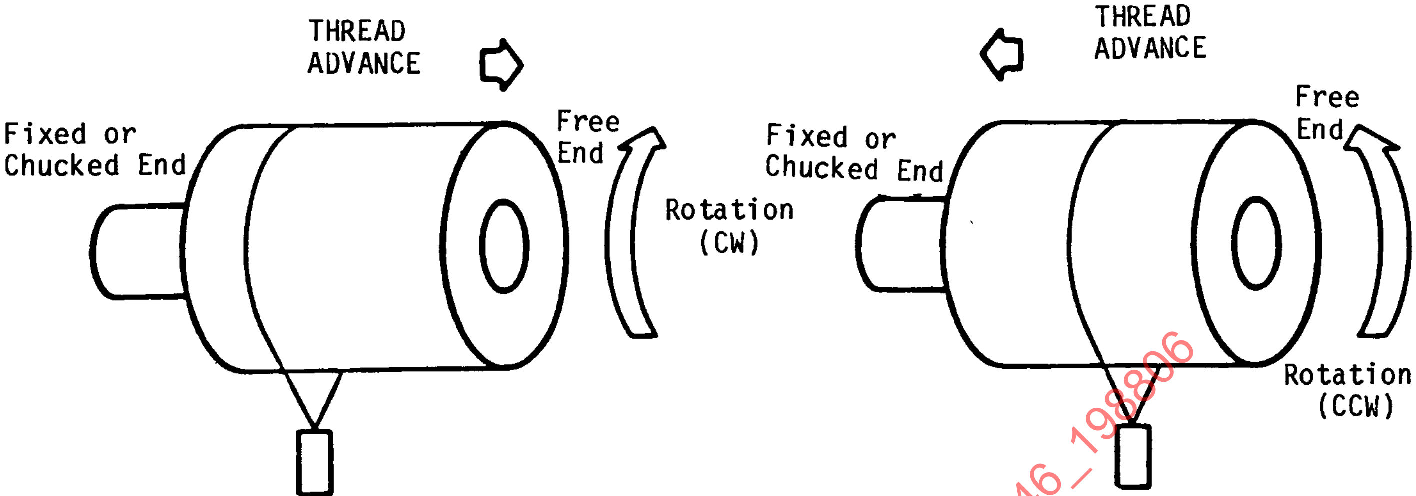



FIGURE 18a - CW or Right Hand Lead

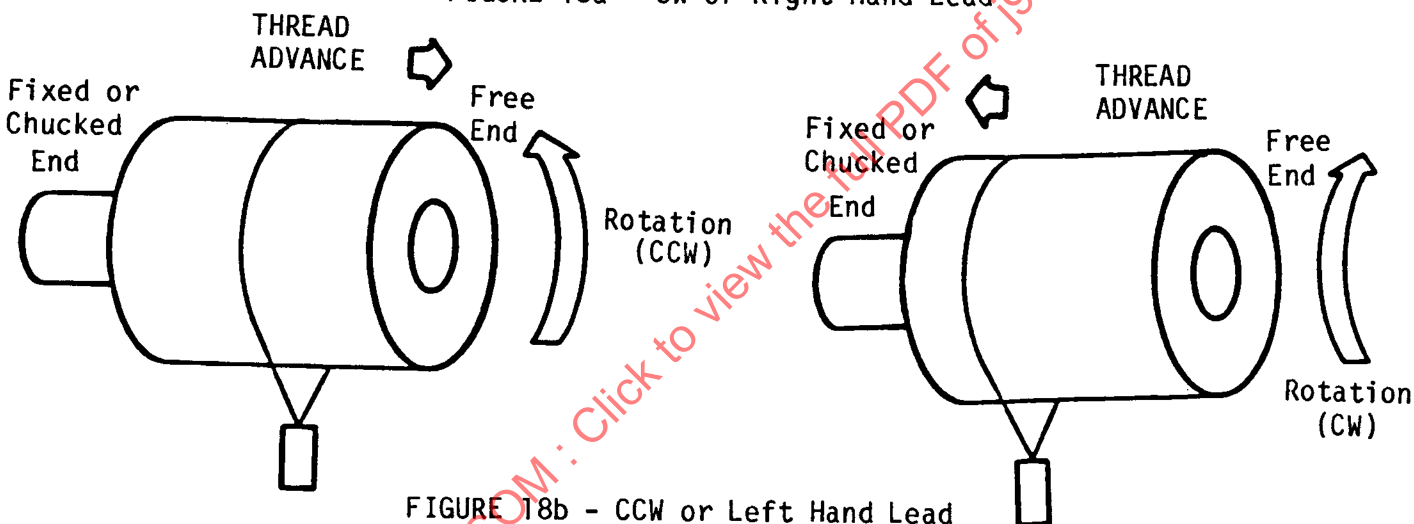



FIGURE 18b - CCW or Left Hand Lead

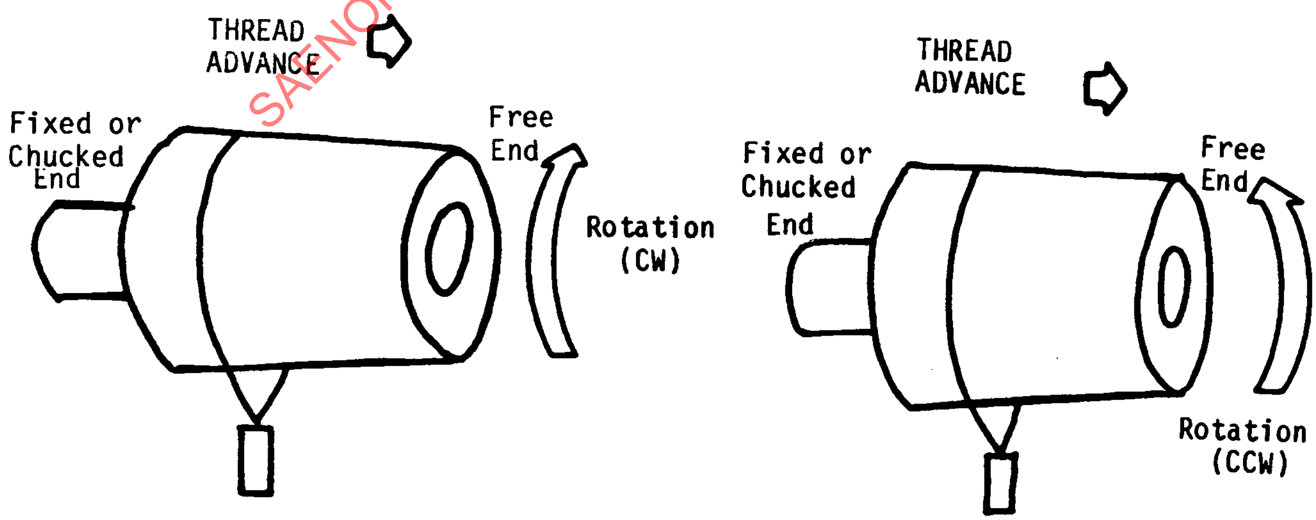



FIGURE 18c - Tapered Shaft

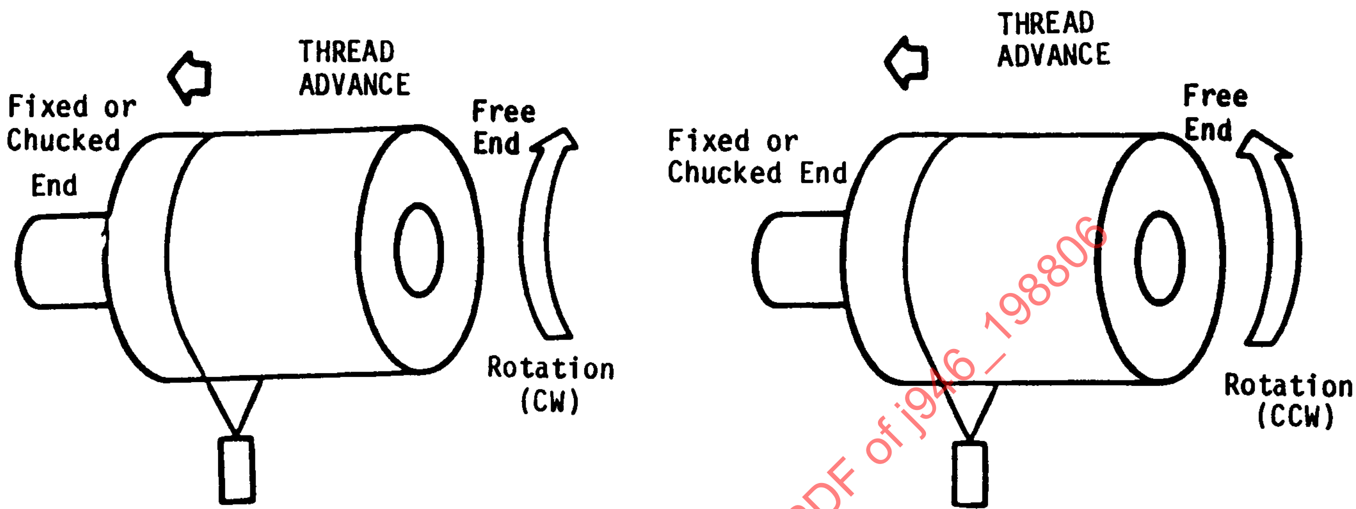



FIGURE 18d - Crowned Shaft

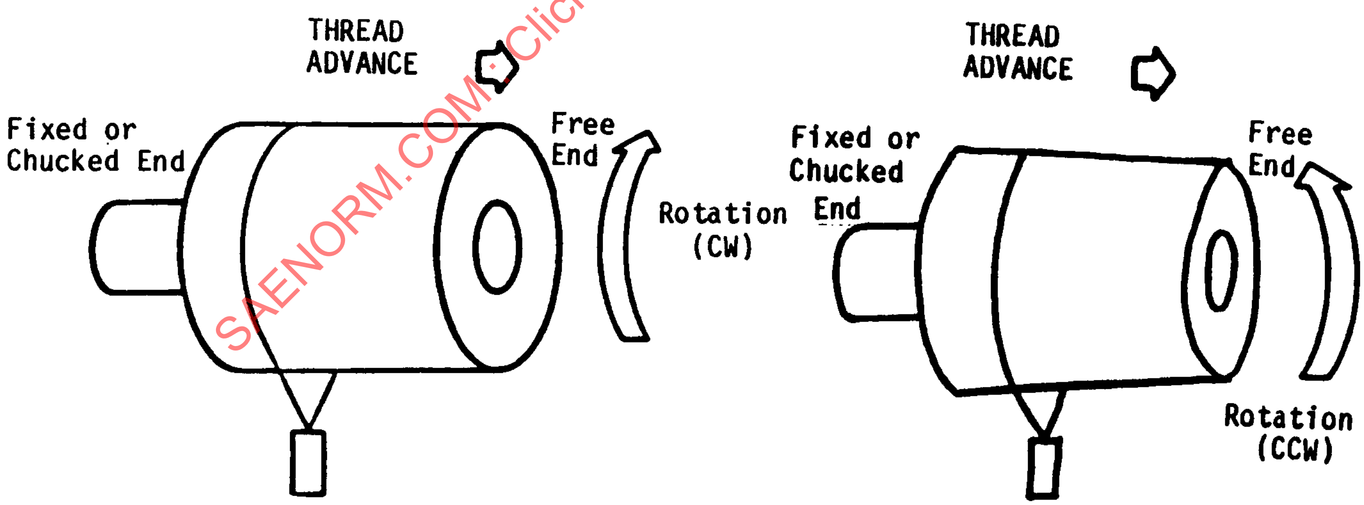



FIGURE 18e - Cupped Shaft

TABLE 1 - Uses of Standard Seal Types

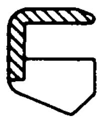
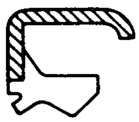
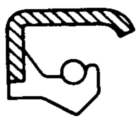
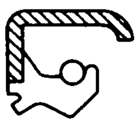
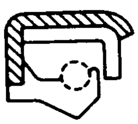
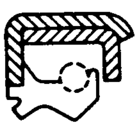
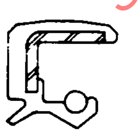
| Cross Section | Type | General Application |
|---|---|---|
| 1.  | Bonded single lip, non-spring loaded | Low cost design for viscous fluid and grease retention |
| 2.  | Bonded double lip, non-spring loaded | Low cost design for viscous fluid or grease retention with dust, dirt, and moisture exclusion |
| 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 |

TABLE 2 - Operating Pressure Limits

TABLE 2a

| SHAFT SPEED | MAXIMUM PRESSURE |
|---|---|
| FEET/MINUTE | P.S.I. |
| 0 TO 1000 | 7 |
| 1001 TO 2000 | 5 |
| 2001 AND UP | 3 |

TABLE 2b

| SHAFT SPEED | MAXIMUM PRESSURE |
|---|---|
| METERS/MINUTE | kPa |
| 0 TO 300 | 50 |
| 301 TO 600 | 35 |
| 601 AND UP | 20 |

TABLE 3a - Oil Seal Standard Tolerances - Inches
Single and Dual Lip Spring Loaded Bonded Seals

| Shaft Diameter | Shaft Tolerance | I.D. Range[1] | LOP[2] Pressure Range | RWV[3] Max | Radial Load Range |
|---|---|---|---|---|---|
| Thru 3.000 | ±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 | | 0.030 | Nominal Load ±40% |
| 6.001 to 10.000 | ±0.005 | 0.060 | | 0.040 | Nominal Load ±40% |



1. Tentative I.D. will be established at the time of the design of a given seal. Nominal I.D. will be established based upon the analysis of three production runs.
2. Nominal lip opening pressure will be established for a given seal based upon the analysis of a minimum of three (3) significant production runs. Preswelled silicone seals require a larger range.
3. Radial wall variation (O.D.-I.D. 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.

TABLE 3b - Oil Seal Standard Tolerances - mm
Single and Dual Lip Spring Loaded Bonded Seals

| Shaft Diameter | Shaft Tolerance | I.D. 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 Bars | 0.6 | Nominal Load ±45% |
| 75.01 to 150.0 | ±0.10 | 1.3 | | 0.8 | Nominal Load ±40% |
| 150.01 to 250.0 | ±0.13 | 1.5 | | 1.0 | Nominal Load ±40% |

1. Tentative I.D. will be established at the time of the design of a given seal. Nominal I.D. will be established based upon the analysis of three production runs.
2. Nominal lip opening pressure will be established for a given seal based upon the analysis of a minimum of three (3) significant production runs. Preswelled silicone seals require a larger range.
3. Radial wall variation (O.D.-I.D. 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 hours.