



Technical Report Preprint

This report is scheduled to appear in the 1967 SAE Handbook.

J946

Published August 1966 by:

SOCIETY OF AUTOMOTIVE ENGINEERS, INC.,
485 Lexington Avenue, New York, New York 10017

GUIDE TO THE APPLICATION AND USE OF RADIAL LIP TYPE OIL SEALS — SAE J946

SAE Recommended Practice

Report of Nonmetallic Materials Committee approved February 1966.

1. INTRODUCTION

This manual is intended as a guide to the use of radial lip type oil seals. It has been prepared from existing literature, which includes standards, specifications, and catalog data of both oil seal producers and users. Incorporated is the work performed to date by Section XVI—Oil Seals of the SAE-ASTM Technical Committee on Automotive Rubber on qualification tests, standard drawing, nomenclature and test methods. Standard tolerances established by the Rubber Manufacturers Association (RMA) are included. One of the main reasons for the preparation of this manual is to make standard information available in one manual to the users of oil seals.

2. APPLICATION DESIGN DATA

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

2.1 Shaft Finish—Shaft finish is a prime factor in the proper functioning of a lip seal. This should be specified as 10-20 Mu in. AA with no machine lead. The best known method to date for obtaining this finish is plunge grinding.

2.2 Shaft Diameter—The shaft diameter should be held within the tolerances shown in Table 1, although greater shaft tolerances may be used when agreed upon between user and supplier.

2.3 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. 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.

2.4 Wear Sleeves—Where the use of wear sleeves is considered, hardened shafts are not required. Wear sleeves are 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 are required with the replacement oil seal.

2.5 Shaft to Bore Misalignment—This is defined as the distance the center of rotation is displaced from the center of the bore. It is normally calculated from the tolerance stackup on the engineering drawings.

Seal life can be shortened by excessive misalignment. Misalignment results in uneven wear. From a good practice standpoint the shaft to bore misalignment should be kept under 0.010 in.

2.6 Dynamic Runout—This is defined as twice the distance the center of the shaft is displaced from the center of rotation. Generally, the shaft runout should be kept below 0.010 in. TIR.

2.7 Bore and Seal Tolerances—The bore and seal tolerances apply only to ferrous materials. When a nonferrous material such as aluminum is used, the seal manufacturer should be consulted. See Table 2.

2.8 Bore Finish—On applications where a lubricant head is present against the outside diameter of the seal, if the bore finish is approximately 100 Mu in. AA or (rms) or smoother, no outside diameter leak-

age problems should be encountered, if no tool removal defects are present.

If the finish is rougher than 100 Mu in. AA or (rms) a bore sealer should be used to insure that no outside diameter leakage occurs.

A bore sealer is usually a resinous material or bonded rubber applied to the outside diameter of an oil seal by the manufacturer which upon installation acts to fill bore imperfections. Hand applied cements or sealers, if used, should be used with care.

On grease sealing application, no bore sealer is required.

2.9 Pressure—Standard design radial lip type oil seals should not be used when the operating pressure exceeds the limits shown in Table 3.

When variable surge pressures exceeding the above limits are present a special condition exists and the seal manufacturer should be consulted.

Higher operating pressures may be feasible if a custom seal design is considered. However, when a pressure seal is used, features such as the ability to take greater eccentricities are sacrificed. Whenever possible the design should be such that the system is vented. This will allow the lip seal to function more efficiently.

2.10 Lead Corners

2.10.1 Shaft—To prevent damage to the seal lip and to facilitate installation, the lead edge of the shaft should have a chamfer or radius.

TABLE 2—BORE AND SEAL RECOMMENDED TOLERANCES^a

Bore Dia	Bore Tolerance	Standard Metal OD Seals ^b	
		Nominal Press Fit	OD Tolerance
0 to 3.000	±0.001	0.004	±0.002
3.001 to 4.000	±0.0015	0.005	±0.002
4.001 to 6.000	±0.0015	0.005	+0.003 -0.002
6.001 to 8.000	±0.002	0.006	+0.003 -0.002
8.001 to 9.000	±0.002	0.007	+0.004 -0.002
9.001 to 10.000	±0.002	0.008	+0.004 -0.002
10.001 to 20.000	+0.002 -0.004	0.008	+0.006 -0.002
20.001 to 40.000	+0.002 -0.006	0.008	+0.008 -0.002
40.001 to 60.000	+0.002 -0.010	0.008	+0.010 -0.002

^a RMA recommended tolerances.

^b Seal OD: the average of a minimum of three measurements to be taken at equally spaced positions.

TABLE 1—SHAFT DIAMETER TOLERANCES, IN.

Shaft Dia	Tolerance ^a , I
Up to and including 4.000	±0.003
4.001 to 6.000	±0.004
6.001 to 10.000	±0.005

^a RMA recommended tolerances.

TABLE 3—OPERATING PRESSURE LIMITS

Shaft Speed, ft/minute	Maximum Pressure Permissible, psi
0 to 1000	7
1001 to 2000	5
2001 and up	3

If a chamfer is used, its dimensions should allow a seal lip to be assembled without damage. See Fig. 1.

2.10.2 Bore—The lead corner of the bore should be chamfered to facilitate efficient installation of the seal. See Fig. 2.

2.11 Bore and Seal Sizes—Whenever possible, shaft and bore size should be selected from the RMA standards. See Appendix.

2.12 Seal Alignment—A factor in the functioning of a lip seal is the installed squareness of the seal with respect to the normal shaft centerline. Keeping this within 0.010 in. TIR is considered a good general practice. This squareness is obtained by pressing the seal flush with the front of the bore or bottoming against the back of the bore.

It is recommended that the seal housing be designed so the seal 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 should be used to press the seal into place. See Fig. 3.

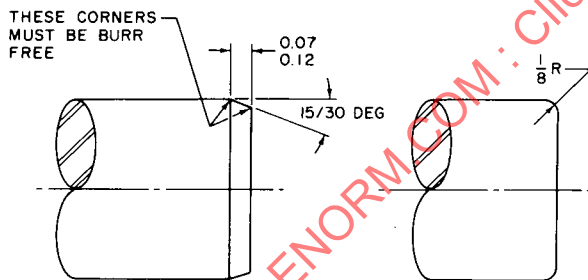
Whether a seal is installed flush to the front of the bore or bottomed on the back of the bore (Figs. 4 and 5) the surface it is aligned with should always be a machined one. Unfinished surfaces should never be used for alignment purposes because of the danger of cocking the seal in the bore.

2.13 Seal Assembly—All surfaces which the seal lip must slide over during installation 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, holes or if the seal is assembled toe first.

3. SEAL MATERIALS

Environmental conditions dictate the type of material for a specific sealing application. The normal lubricant temperature and lubricant type are generally the governing factors.

The following paragraphs give general descriptions for the intended uses of elastomeric compounds, plastics, and leather. The temperature ranges refer to normal lubricant operating temperatures. Acceptable upper and lower temperature limit may vary due to the specific seal material. The seal material-lubricant compatibility may influence the normal operating limits. For instance, 200 F may be the maximum limit with a special type of lubricant, while 225 F might be normal. The proper performance of any sealing compound is dependent on the balance of conditions it is subjected to. For example, if the extremes of speed, temperature, pressure, and eccentricity are all present simultaneously, the seal may not be satisfactory. A seal to be used in a low



Must be smooth and free of nicks and rough spots
FIG. 1—RECOMMENDED SHAFT LEAD CORNERS

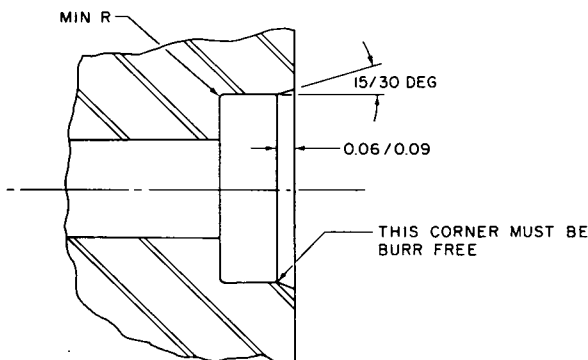


FIG. 2—RECOMMENDED BORE LEAD CORNER

temperature environment should have a minimum of eccentricity and pressure. Likewise a seal having to perform under high speeds should not have to accommodate extreme eccentricity. When conditions approach extreme limits the seal supplier should be consulted.

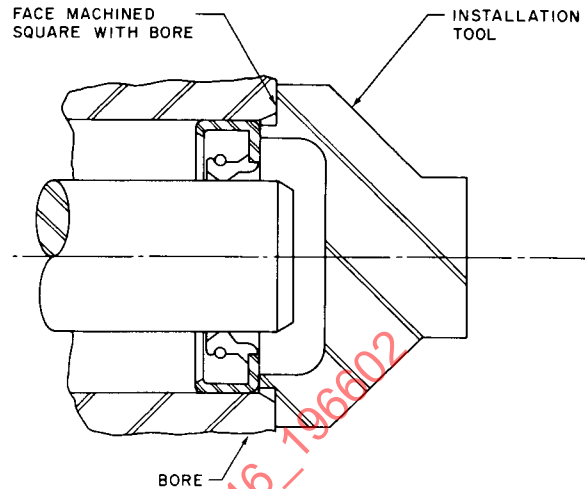


FIG. 3—THROUGH BORE: INSTALLATION TOOL BOTTOMS ON MACHINED BORE FACE

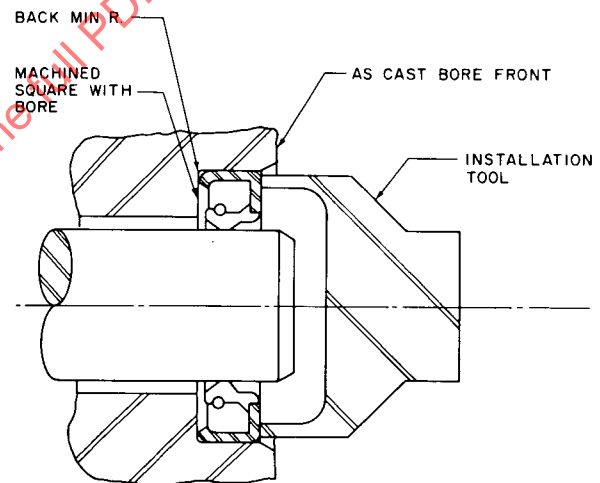


FIG. 4—BOTTOM BORE: SEAL BOTTOMS ON MACHINE BORE SHOULDER

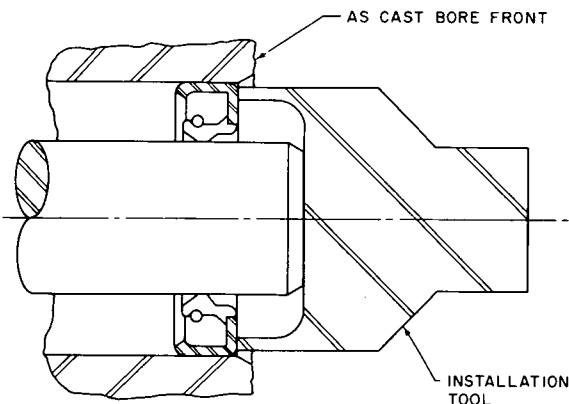


FIG. 5—THROUGH BORE: INSTALLATION TOOL BOTTOMS ON SHAFT

3.1 Leather—Leather is satisfactory for applications involving oil, grease, or foreign matter having temperatures ranging within limits of -65°F to 180°F .

3.1.1 Advantages

- (a) Toughness—it withstands difficult assembly.
- (b) It accommodates fairly rough shaft finishes.
- (c) It has good dry running characteristics.
- (d) It has good low temperature characteristics.

3.1.2 Disadvantages

- (a) It has poor heat resistance.
- (b) Its nonhomogeneous makeup makes consistent quality difficult.

3.2 Nitrile (Buna N) Compounds (NBR)¹—Nitrile (Buna N) compounds are copolymers of butadiene and acrylonitrile. Their operating range is -65°F to $+225^{\circ}\text{F}$. When compounding a seal material for a low temperature limit of -65°F the upper temperature limit of 225°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.

3.2.1 Advantages

- (a) Fair dry running characteristics.
- (b) Good processing.
- (c) Good low temperature and swell characteristics.

3.2.2 Disadvantages

- (a) Lack exceptional heat resistance.
- (b) Tendency to harden during high temperature usage.

3.3 Polyacrylic Compounds (ACM or ANM)¹—Polyacrylics are polymers of acrylic acid esters. They are recommended for applications where temperatures are within 0 to $+300^{\circ}\text{F}$. If the shaft runout is low these compounds may be used at lower temperatures. They are in the medium cost range of seal compounds.

3.3.1 Advantages

- (a) Resistant to EP type additives.

- (b) Good moderate temperature performance.

- (c) Low swell characteristics.

3.3.2 Disadvantages

- (a) Poor low temperature properties.
- (b) Poor dry running characteristics.

3.4 Silicone Compounds (V Si)¹—Silicone rubbers are semiorganic elastomers. They are recommended for applications where temperatures are within -65°F to $+350^{\circ}\text{F}$. The maximum usable temperature is limited by the decomposition temperatures of the various lubricants. Silicone rubbers are in the high cost range of seal compounds.

3.4.1 Advantages

- (a) Good heat resistance.
- (b) Excellent low temperature properties.

3.4.2 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.

3.5 Special Compounds—Compounds such as the Fluoroelastomers (FPM)¹ and Fluorocarbon plastics (PTFE) are available for applications involving extreme temperatures, special lubricants, and chemicals which can not be handled by the above three general classes. These special compounds generally cost more than any of those previously mentioned.

4. SEAL TYPES

There are a large number of seal types and designs. Seal manufacturers are generally standardizing on the bonded construction, single or double lip, with and without inner cases. Outside diameter coatings or rubber outside diameters are a variation.

Table 4 generally depicts the use of the more standard seal types.

Seals of a clamped construction are also used although generally the bonded types are preferred.

5. DRAWING DESIGNATION

It is recommended that the standard SAE oil seal drawing be used. See Appendix.

6. QUALIFICATION TESTS

Qualification tests should be performed in accordance with SAE J110. See Appendix.

7. INSPECTION AND QUALITY CONTROL DATA

7.1 Radial Wall Variation (Seal Inside-Outside Diameter Relationship)—

7.1.1 Radial Wall Dimension—The distance between the seal lip point of contact and the seal outside diameter measured in a radial direction on a finished seal in the free state. See Fig. 6.

7.1.2 Radial Wall Variation—The difference between the minimum and maximum radial wall dimension when measured around 360° deg of the seal lip.

7.1.3 Recommended Tolerances—See Table 5.

Radial wall variation is checked through the use of an optical comparator. The seal outside diameter is placed on a base and rotated through 360° deg.

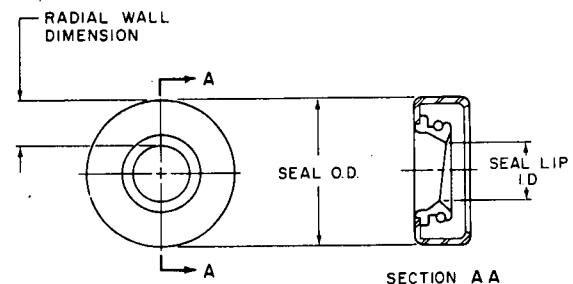


FIG. 6—RADIAL WALL DIMENSION

TABLE 4—USES OF STANDARD SEAL TYPES

Cross Section	Type	General Application
	Bonded single lip, spring loaded	For general sealing purposes. Generally most economical.
	Bonded single lip, spring loaded with inner case	Provides all standard features plus additional inner case for greater structural rigidity.
	Bonded double lip, spring loaded	Provides all single lip features plus non-spring loaded member for moderate exposure to dust, dirt, or other foreign matter.
	Bonded double lip, spring loaded with inner case	Provides all the standard features plus additional inner shell for greater structural rigidity.
	Bonded single lip, non-spring loaded	Low cost design for viscous fluid and grease retention.

TABLE 5—RECOMMENDED TOLERANCES^a FOR RADIAL WALL VARIATION, IN.

Shaft Size	RWV, Max
Up to 4.000	0.025
4.001 to 6.000	0.030
6.001 to 10.000	0.040

^a RMA recommended tolerances.

¹ASTM D 1418. Recommended Practice for Nomenclature for Synthetic Elastomers and Latexes, should be used as reference.

[illegible]