



AEROSPACE INFORMATION REPORT

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Guidelines for Rotary Lip Seal Selection, Application, and Installation Procedures

RATIONALE

Rotary lip seals are widely used sealing devices in aerospace applications, but their application, functionality, and operation may not be fully understood. Therefore, there is a need for a document that provides information on the various types of rotary lip seals and their application. This document fulfills that need.

FOREWORD

There are many configurations and permutations of rotary lip seal designs for applications depending on operating conditions, allowable leakage, friction limitations, service life requirements, and possibly many other factors by each application. The final design decision would be a joint effort between the sealing manufacturer and the customer.

Lip seals for sealing rotary shafts are comprised of two basic types concerning the lip element material, which are:

- Elastomer
- Polytetrafluoroethylene (PTFE)

Both types usually utilize a metal outer component (there are exceptions for special circumstances), which is pressed into the housing and may or may not require a retaining plate, depending on the pressure differential across the seal.

This document addresses the basic types of elastomer and PTFE lip types. There are also many alternate designs of both types, and these are illustrated in Appendix A.

This document describes the following factors that should be considered by the user in approaching hardware design and the type of rotary lip seal to be used:

- Those factors affecting the sealing performance, inclusive of leakage
- Those factors influencing the friction performance
- Those factors influencing the service life

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides information and guidelines on the selection and use of rotary lip seals for their expected duty cycle. Information on seal installation procedures is also included.

NOTE: This document does not address mechanical or magnetic face seals.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 ASME Publications

Available from ASME, P.O. Box 2900, 22 Law Drive, Fairfield, NJ 07007-2900, Tel: 800-843-2763 (U.S./Canada), 001-800-843-2763 (Mexico), 973-882-1170 (outside North America), www.asme.org.

ASME B46.1 Surface Texture (Surface Roughness, Waviness, and Lay)

2.1.2 ISO Publications

Copies of these documents are available online at <https://webstore.ansi.org/>.

ISO 4287-1 Geometrical Product Specifications (GPS) - Surface Texture: Profile Method - Terms, Definitions and Surface Texture Parameters

2.1.3 Other Publications

Bhushan, Bharat (2000). *Modern Tribology Handbook, Two Volume Set*. CRC Press.

2.2 Definitions

See Figures 1 and 2 for the overall definition of the elements that comprise a rotary seal.

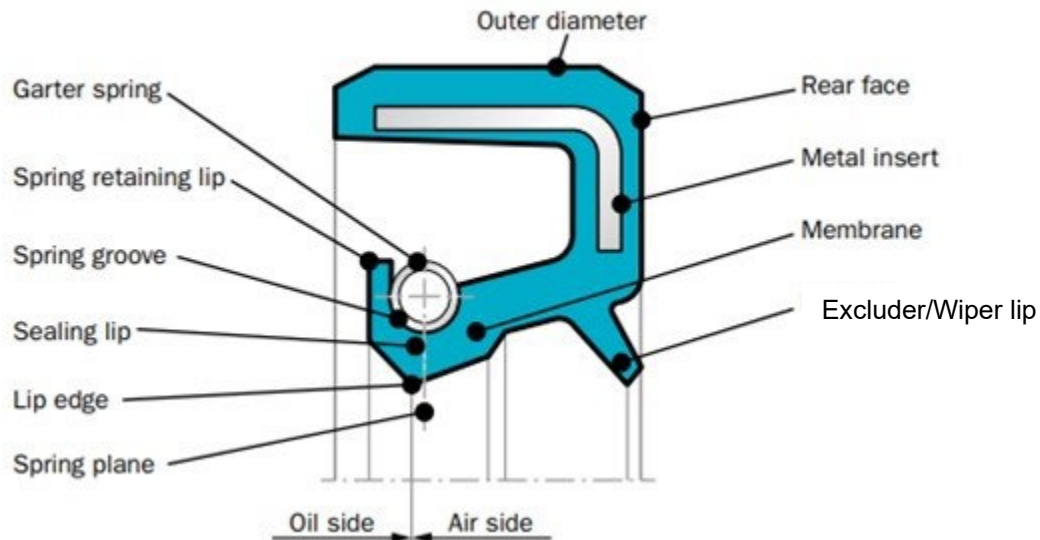


Figure 1 - Elastomer rotary lip seal definitions

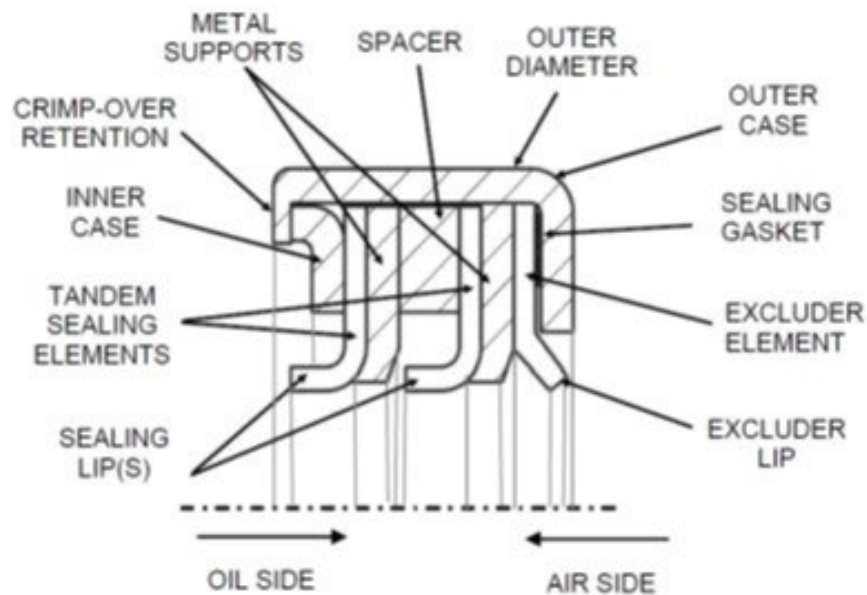


Figure 2 - PTFE rotary lip seal definitions

GARTER SPRING: This is a spring wound from coiled round wire.

LIP: This is the sealing element of a rotary lip seal that contacts the rotary shaft.

METAL CASE: This is a metal component with an L shape in cross section that is used to form the outer profile of the seal assembly or the seal support.

WIPER LIP: This is a secondary lip on the outer extremity of the lip seal assembly used to exclude foreign particles or fluids from degrading the primary lip.

2.3 Acronyms

HVOF high-velocity oxygen fuel

ID inside diameter

OD outside diameter

OEM original equipment manufacturer

PV pressure times velocity

3. TYPES OF ROTARY LIP SEALS

3.1 Rotary Lip Seals with Elastomer Lip Element(s)

3.1.1 Construction and Methods of Production

Rotary lip seals using an elastomer sealing and/or wiper element(s) have the element(s) molded onto a metal case. The elastomer, depending on the service required, may or may not have a layer of the elastomer molded to the front (atmosphere) side and/or the OD of the case. See Figure 3 (metal case encased with rubber) and Figure 4 (metal case not encased).



Figure 3 - Elastomer rotary lip seal, case molded over



Figure 4 - Elastomer rotary lip seal, case not molded over

In both Figure 3 and Figure 4, the case is pressed from sheet metal, inserted into a mold, and the elastomer is molded onto it. It should be noted that there are areas on either the inner surface of the case or the front outer surface of the case, or both, where the elastomer will not be molded on and bare metal can be seen. This is because there is a requirement for the case to be rigidly and dimensionally located within the mold tool during the molding process; see Figure 5.



Figure 5 - Elastomer rotary lip seal areas exposed after molding



Where a sharp corner is molded, any impurities and/or minor porosity tend to permeate toward sharp corners, and one of these areas typically is the sealing lip. To achieve a sharp, clean sealing edge, in most cases, the lips are molded oversize compared to the finished dimension, and this excess rubber is machined off usually with a knife tool, which removes any contamination at the lip area and provides a very sharp, clean edge for good sealing capability.

3.1.1.1 Materials

The metal case, elastomer, and garter spring materials should be selected to be compatible with environmental conditions (fluid exposure, temperature limits, etc.) and the dynamic shaft and housing materials.

Where the case OD is encased with molded elastomer (see Figure 3), the material used for the metal case is not particularly important for thermal compatibility with the application housing since the elastomer on the OD will cater to any minor differences in thermal expansion or contraction.

However, where the case is not over-molded with elastomer (see Figure 4), consideration should be given to ensure that the thermal expansion of the case with that of the application housing ensures compatibility and the case and housing materials are electrochemically compatible.

3.1.2 How Elastomer Rotary Lip Seals Function

The elastomer lip(s) are manufactured with an interference fit onto the rotary shaft, thereby providing a sealing load. Elastomer sealing lips usually have the sealing efficiency enhanced by the inclusion of a garter spring (see Figures 3 and 4).

The spring shown in Figure 6 is a coil that is wound from a suitable round wire. One end has a wound-in taper (or reduced outer diameter) to enable it to be inserted into the opposite end of the spring, thereby forming a ring. The ring is made undersize in diameter so it will be stretched by a predetermined amount to provide a radially inward force on the seal lip when the shaft is installed, thereby enhancing the sealing efficiency.



Figure 6 - Garter spring construction

Where a garter spring is incorporated, the mating outer surface of the lip has a groove molded in to retain the spring during assembly and in service.

However, on applications where low friction is required, this feature may not be included.

Static sealing against the housing is accomplished by an interference fit, and the seal is pressed into the housing bore.

3.1.2.1 Elastomer OD

The elastomer molded onto the OD produces a sealing interface with the housing groove. The elastomer profile may be flat without any contours (see Figure 3) or may comprise concentric ridges to provide a labyrinth effect as shown in Figure 7.



Figure 7 - Elastomer rotary lip seal with ribbed OD

In both cases, there is usually a lead-in chamfer on the leading edge of the OD where it is pressed into the housing.

3.1.2.2 Metal OD

Where the elastomer is not molded to the OD as shown in Figure 4, the OD is usually coated with a sealant compatible with the application fluid to aid sealing to the housing.

3.1.3 Lip Configurations

Elastomer element rotary lip seals usually have only one sealing lip; however, it is strongly recommended that a wiper lip is included to eliminate the ingress of particle contaminants that would otherwise be detrimental to the performance of the sealing lip (see Figure 1).

3.1.4 Pump-Back Features

Several other features may be included in the lip dynamic surface, such as a spiral feature (return pumping feature) to return any leaked fluid to the system during rotation. This feature returns fluid even against the pressure differential as shown in Figure 8. It is advisable not to use this feature on external sealing applications unless precautionary actions (wiper lip) are taken to avoid damage to the seal due to the ingress of dirt or dust into the pumping feature.

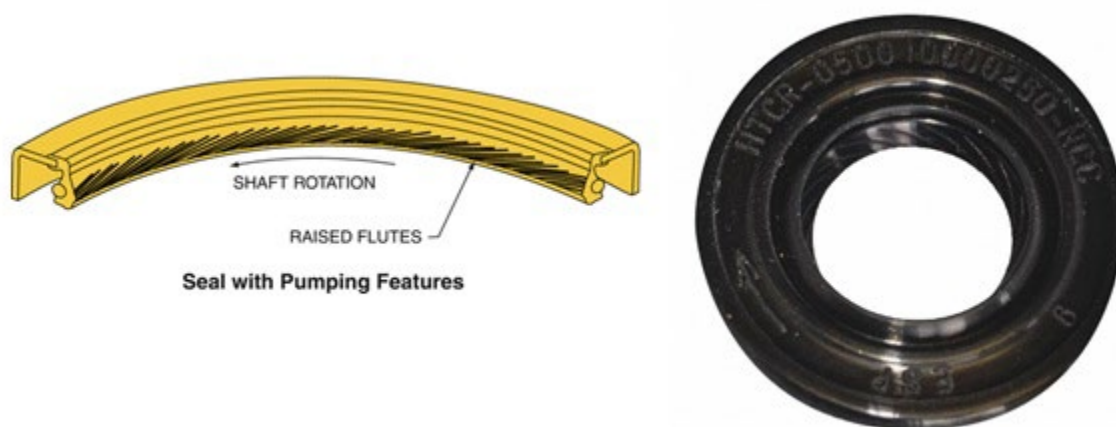


Figure 8 - Fluid return pumping feature

The spiral direction of the return feature is dependent on the direction of shaft rotation, although some return pumping features are bidirectional. Elastomeric seals typically cannot be used bidirectionally.

3.2 Rotary Lip Seals with PTFE Lip Element(s)

3.2.1 Construction and Method of Production

Generally, the construction of the PTFE element rotary lip seals consists of two metal cases, one fitting inside the other, whereby a suitable flat washer-shaped sealing gasket is used to seal the PTFE element(s) to the metal cases. During the assembly process, usually in a press, an axial load is applied against the inner case to provide a sealing effect. During this process, the outer case's open end is pressed over the inner case, thereby retaining the sealing load. Figures 9 and 10 describe this process.

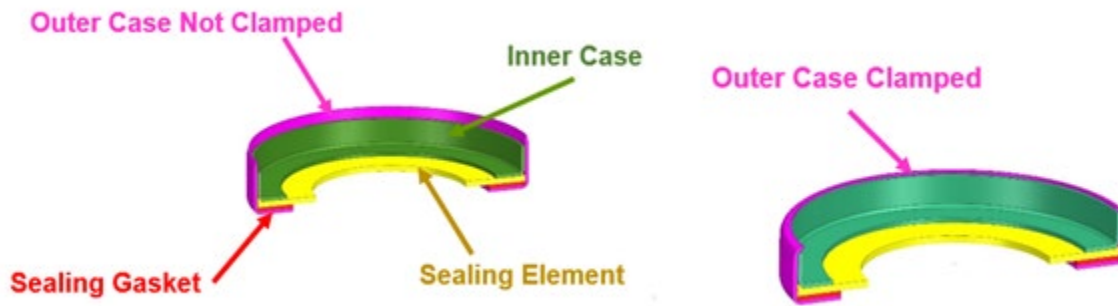


Figure 9 - PTFE rotary lip construction and assembly process

The PTFE sealing element is generally machined as a flat washer from molded and sintered PTFE tube or rod stock.

After assembly (see Figure 9), the PTFE lip element(s) are deformed into the sealing configuration (see Figure 10), and the part is usually shipped with a plain tubular sleeve or an assembly sleeve of an appropriate OD (i.e., very close to the application shaft diameter) to retain the lip(s) in the desired geometry during shipping and storage (see Figure 11). The shipping sleeve may not be suitable for installation procedures, and an additional installation sleeve may be required.

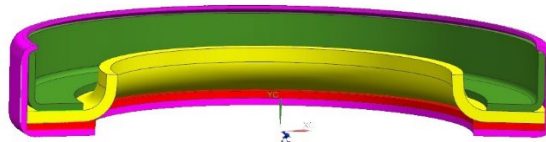


Figure 10 - PTFE seal with lip after profiling

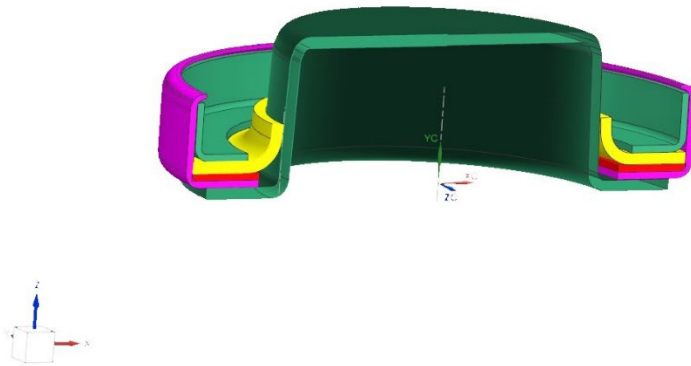


Figure 11 - PTFE lip seal with shipping sleeve

3.2.1.1 Materials

The metal case materials, PTFE element material(s), and gasket material should be selected to be compatible with environmental conditions (fluid exposure, temperature limits, etc.), and the housing materials should be compatible with housing thermal expansion and/or contraction.

Where the case OD is encased with molded elastomer, the material used for the metal case is not particularly important for thermal compatibility with the application housing since the elastomer on the OD will cater to any minor differences in thermal expansion or contraction.

However, where the case is not over-molded with elastomer, consideration should be given to ensure that the thermal expansion of the case with that of the application housing ensures compatibility and the case and housing materials are electrochemically compatible.

3.2.2 How PTFE Rotary Lip Seals Function

As stated previously, the PTFE sealing element is machined as a thin washer, and after installing it in the metal case assembly, it is deformed into a “J” shape in cross section (see Figure 10). Naturally, this shape will try to return to its original shape, thereby providing a sealing load at the lip contact area with the rotary shaft. As the temperature falls from ambient, the PTFE material will attempt to shrink, thereby increasing the sealing load and increasing sealing efficiency against a presumably higher viscosity fluid. In contrast, as temperature increases from ambient, the PTFE lip material will expand, and it may be expected to decrease sealing efficiency. However, PTFE has a memory property whereby as temperature increases, it attempts to return to its original as-sintered shape before any deformation. Therefore, this mechanism, as temperature increases during running (usually due to friction), maintains the sealing efficiency at the sealing lip.

3.2.2.1 Metal OD

Static sealing against the housing is accomplished by an interference fit when the seal is pressed into the housing bore, and this is usually enhanced by a suitably compatible painted-on sealant.

3.2.2.2 Elastomer OD

The elastomer molded onto the OD produces a sealing interface with the housing groove. The elastomer profile may be flat without any contours or may be comprised of concentric ridges to provide a labyrinth effect (see Figure 7). In both cases, there is usually a lead-in chamfer on the leading edge of the OD where it is pressed into the housing.