



AEROSPACE RECOMMENDED PRACTICE	ARP1231™	REV. C
	Issued 1973-04 Reaffirmed 2012-10 Revised 2022-01	
Superseding ARP1231B		
(R) General Gland Design Criteria for Static and Dynamic O-Ring Seal Applications Specifically for Engines and Engine Control Systems		

RATIONALE

This standard has been updated to include technical and editorial changes.

NOTE: This standard was transferred from the E25 General Standards for Aerospace and Propulsion Systems Committee to A6C Seals Committee.

1. SCOPE

This document recommends general gland design criteria for static and dynamic O-ring seal applications specifically for engines and engine control systems.

1.1 Purpose

The purpose of this document is to provide the aerospace industry with basic information pertinent to the design and selection of elastomeric O-ring seal glands for use specifically in engine and engine control applications.

2. 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 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

- AIR786 Elastomer Compatibility Considerations Relative to Elastomeric Sealant Selection
- ARP1232 Gland Design Criteria and Dimensions for Static Radial O-Ring Seal Applications without Anti-Extrusion Devices Specifically for Engine and Engine Control Systems
- ARP1233 Gland Design Criteria and Dimensions for Dynamic Radial O-Ring Seal Applications Specifically for Engine and Engine Control Systems Operating at 1500 psi Max

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ARP1234 Static Axial O-Ring Seal Applications without Anti-Extrusion Devices for Engine Control Systems

AS568 Aerospace Size Standard for O-rings

3. GENERAL REQUIREMENTS

3.1 Gland Configuration

3.1.1 Radial O-Ring Seal Glands

Figure 1 depicts piston and rod radial O-ring seal glands. The piston configuration is preferred. Fabrication costs are lower, assembly is easier, and there is less likelihood of the seal buckling or twisting and being pinched as the rod is installed.

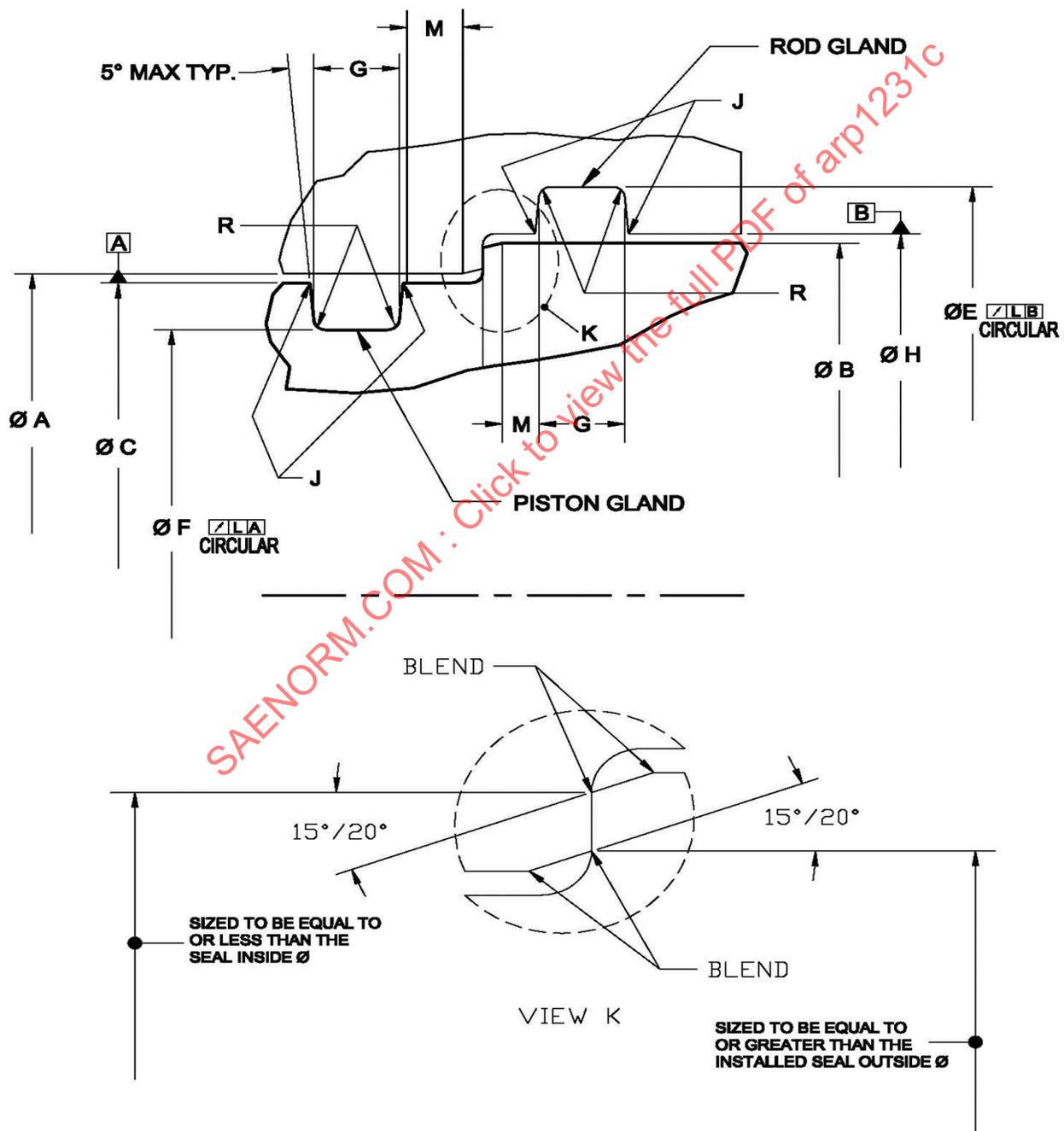


Figure 1 - Typical radial O-ring seal glands

3.1.2 O-Ring Face Seal Glands

Figure 2 illustrates an O-ring face seal gland. In a face seal gland, sealing occurs on the flat surfaces of the gland rather than on the gland diameters.

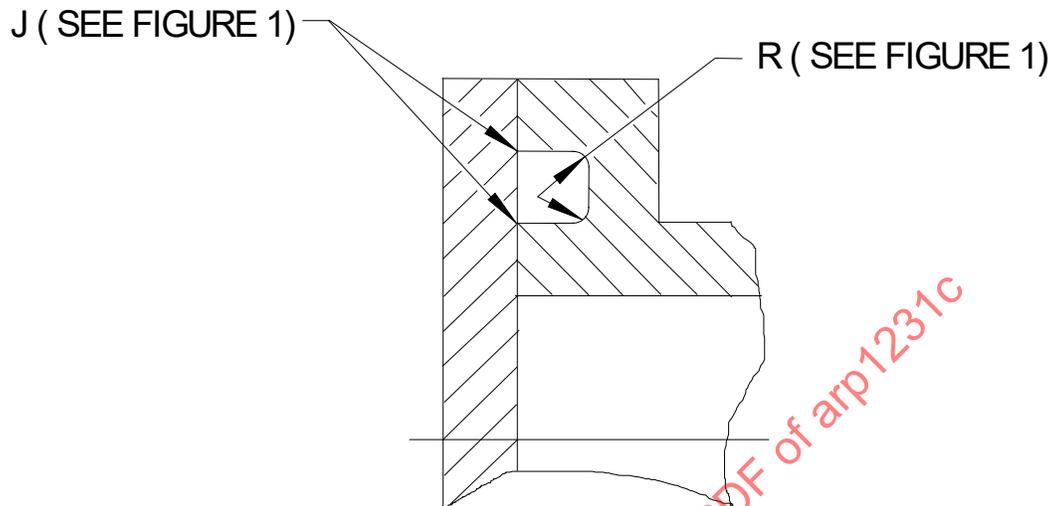


Figure 2 - O-ring face seal gland

3.2 Gland Dimensions

3.2.1 General

The best dimensions for a particular gland are functions of the fluids, elastomers, pressures, and temperatures employed in the system. However, the use of the best gland in each application is not always desirable or necessary. Within a given aerospace system, it may be necessary to change fluids or elastomers to achieve the desired fluid system performance. When such a change is required, O-ring seal gland dimensions should not be changed. Therefore, it is preferable to design O-ring seal glands which will operate satisfactorily with a number of different fluids and materials in varying environmental conditions.

3.2.2 Standard Gland Dimensions

Standard gland dimensions are provided in ARP1232, ARP1233, and ARP1234 for the O-ring seal sizes covered by AS568. These dimensions are computed in accordance with criteria in the above ARPs and are adjusted to the needs of the specific gland classification (radial or axial, static or dynamic, etc.).

3.2.3 Modified Gland Dimensions

The standard gland dimensions may be modified in a given application to achieve the best sealing configuration. In computing special gland configurations, the design criteria in Section 5 should be reviewed.

3.2.4 Lead-In Ramps

Radial seal applications require lead-in ramps to prevent seal damage as the rod is assembled into the bore. View K in Figure 1 depicts the preferred external and internal ramps. The entering diameters of the ramps should be sized such that the seals first contact the ramp slope.

3.2.5 Edge Breaks

The gland edges should be broken in accordance with Figures 1 and 2 and Table 1 to avoid damaging seals during assembly and disassembly. The edge break should be carefully blended to avoid any condition that will cut the mating seal. If desired by the design activity, a radius may be substituted for the edge break.

Table 1 - Edge breaks

Nominal O-Ring Cross-Section Ø (w) per AS568	Edge Break J	Radius R	L	Min M
Inches				
0.070	0.005-0.015	0.010-0.020	0.002	0.020
0.103	0.010-0.020	0.020-0.030	0.002	0.020
0.139	0.010-0.020	0.020-0.030	0.003	0.020
0.210	0.010-0.020	0.020-0.030	0.004	0.020
0.275	0.010-0.020	0.020-0.030	0.005	0.020
Millimeters				
1.78	0.13- 0.38	0.25- 0.51	0.05	0.51
2.62	0.25- 0.51	0.51- 0.76	0.05	0.51
3.53	0.25- 0.51	0.51- 0.76	0.08	0.51
5.33	0.25- 0.51	0.51- 0.76	0.10	0.51
6.98	0.25- 0.51	0.51- 0.76	0.13	0.51

4. EFFECT OF O-RING SEAL SELECTION ON GLAND DESIGN

4.1 Fluid Material Compatibility

This document establishes gland design criteria and standards for use with nitrile (NBR), fluorocarbon (FKM), and fluorosilicone (FVQM), ethylenepropylene diene (EPDM), or silicone (Q) elastomers in systems containing hydrocarbon fuels, petroleum oils, ester base synthetic oils, phosphate ester hydraulic fluids, silicate ester fluids, or air. The realization that differences in compatibility exist between various fluid/seal material combinations is essential to good design. The selection of the fluid/seal combination is the task of the designer. For more specific information on compatibilities, refer to AIR786.

4.2 Effects of Fluid Pressure on Seal Wear

4.2.1 Extrusion

Figure 3 shows the tendency of a pressurized O-ring seal to extrude into the clearance gap. This leads to increased seal wear and premature seal failure.

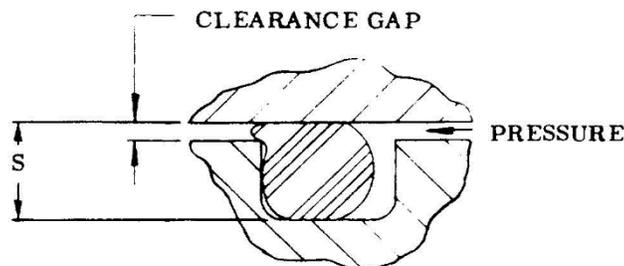


Figure 3 - O-ring seal extrusion

4.2.2 Control of Extrusion

Seal extrusion is a function of the O-ring seal hardness, the fluid system pressure and the bore/rod diametral clearance. Diametral clearance is defined as the numerical difference between the bore and piston diameters (per Figure 1: Dia A-Dia C or Dia H-Dia B). As the fluid pressure increases or the seal hardness decreases, the diametral clearance should be reduced to avoid any O-ring seal extrusion (see Figure 4).

When using Figure 4, it should be taken into account that elastomer hardness will decrease at elevated temperature and under fluid immersion. The elastomer used to derive Figure 4 displayed average modulus values at the indicated hardness levels. For engines and engine control systems, the maximum pressure would be 1500 psi (10345 kPa).

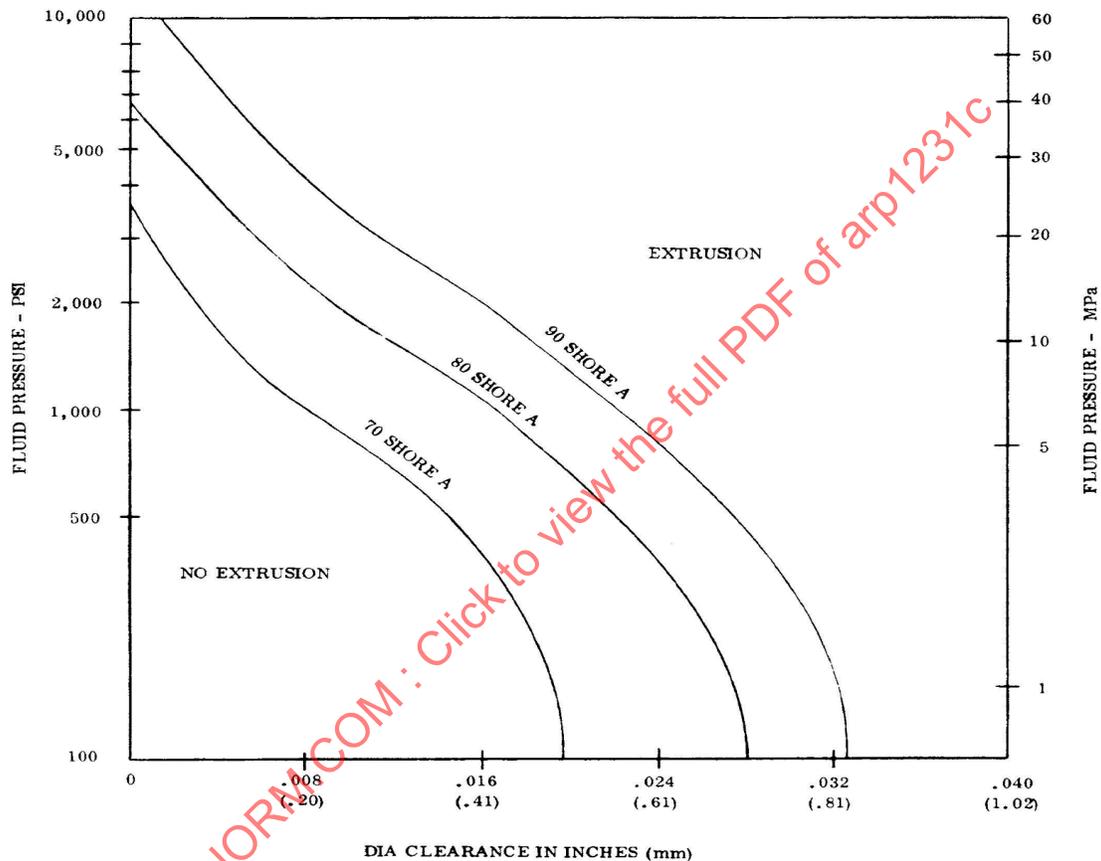


Figure 4 - Recommended maximum diametral clearance under high pressure

NOTE: The normal value in metric units should be kPa, but for the sake of clarity and neatness, Figure 4 shows values in MPa (1 MPa = 1000 kPa).

4.2.3 Use of Anti-Extrusion Devices

As a general rule, systems at above 1500 psi (10345 kPa) should utilize backup rings or other devices of this nature. Also, if the diametral clearances are larger than desired, an anti-extrusion device may be installed in the gland to reduce the diametral clearances (see 5.4).

4.3 Temperature Considerations

4.3.1 Effects of Temperature on Seal Squeeze

The minimum squeezes (see 5.2) used in developing standard gland dimensions are designed to be effective across the full range of temperatures which the seal materials are capable of withstanding.

A better seal can be obtained by reducing the gland volume if the operation is to be only at low temperatures because elastomers contract faster than metals. Conversely, an increase in gland volume will generally improve a seal where the seal operates primarily in the higher temperature range.

4.3.2 Effect of Temperature on O-Ring Seal Materials

A significant factor in the selection of an O-ring seal material is its ability to function within the operating temperature range of a given system. Temperature limitations can be found in applicable material specifications.

4.4 Seal Size Selection

4.4.1 Standard O-Ring Seal Sizes

The O-ring seal size is a function of the system performance requirements and should be compatible with the mating rod and bore sizing. Sizes should be selected from standard O-ring seal drawings which meet the dimensional requirements of AS568.

4.4.2 Cross-Section Diameters

The durability of the O-ring seal and its ability to seal are proportional to its cross section. The larger cross-section rings are less likely to twist during installation and operation although they may generate higher friction levels. Also, larger cross-section seals should be used where low temperature sealing problems are expected.

Specifically, the 0.103 inch (2.62 mm) cross-section seals in the larger ID sizes are recommended in preference to the 0.070 inch (1.78 mm) cross-section seals, except in applications where size or weight considerations necessitate the use of 0.070 inch (1.78 mm) cross-section seals.

5. DESIGN CRITERIA

5.1 Seal Stretch

5.1.1 Designing for Seal Stretch

Glands should be designed to assure that the O-ring seal is stretched when installed in order to avoid buckling of the seal. This is particularly important in the cases of rod-mounted static and low relative motion dynamic seals (see note). Buckling allows the seal to be pinched locally when the rod is installed in the mating bore.

NOTE: Consult ARP1233 for factors defining seal stretch requirements in other dynamic seal applications.

5.1.2 Computing Seal Stretch

Seal stretch is measured as a percentage increase in diameter and is calculated as follows:

$$\text{Percent Stretch} = \frac{\text{installed seal ID} - \text{free seal ID}}{\text{free seal ID}} \times 100$$

5.1.3 Allowable Seal Stretch

Consult ARP1232, ARP1233, and ARP1234 for the allowable seal stretch in specific applications.

5.2 O-Ring Seal Squeeze

5.2.1 Importance of Squeeze

Proper sealing depends on the amount of squeeze (compression) imposed on the seal cross section.

5.2.2 Factors Affecting Squeeze

The amount of squeeze selected for a given application is a compromise of the following factors:

5.2.2.1 Friction

Increased squeezes tend to improve sealing, but the force required to install a seal or to move a dynamic seal is increased substantially as the amount of squeeze increases.

5.2.2.2 Seal Hardness

Seal hardness affects squeeze. Soft seals perform better with increased squeeze because of the greater elastomer to metal contact. Soft seals can tolerate more squeeze than hard seals and still assemble well.

5.2.2.3 Compression Set/Stress Relaxation

Elastomers are subject to compression set or stress relaxation which causes a reduction in the amount of sealing force during service. The amount varies with temperature and with each elastomer.

5.2.2.4 Thermal Expansion

The thermal expansion rates of the elastomer and the metallic gland components differ. Often the rod and bore are made of different materials. The effect of these varying thermal expansion rates should be considered.

5.2.2.5 Gland Breathing

Expansion of the gland due to system pressure, known as gland breathing, affects squeeze and diametral clearances. Sufficient structural rigidity should be designed into the gland to confine such breathing to acceptable limits.

5.2.2.6 Seal Stretch

The seal cross-section is reduced whenever the seal is stretched. The following formulas have been established empirically for many seal materials and provide a suitable method of adjusting the seal cross-section for the effects of stretch:

For piston applications:

$$\text{Reduction in cross section diameter} = \frac{W}{10} \sqrt{6 \frac{F - K}{K}}$$

For rod applications:

$$\text{Reduction in cross section diameter} = \frac{W}{10} \sqrt{6 \frac{B - K}{K}}$$

where:

W = seal cross-section diameter (uninstalled)

F = gland diameter (see Figure 1)

B = rod diameter (see Figure 1)

K = seal ID (uninstalled)

5.2.2.7 Nominal Squeeze

Squeeze is normally expressed as a percentage of seal cross-section and is computed by the following formula:

$$\text{Percentage Squeeze (Nominal)} = \frac{W - S}{W} \times 100$$

where:

W = free cross-section diameter of seal

S = gland height (see Figure 3)

5.3 O-Ring Seal Swell

5.3.1 Fluid Absorption Rates of Elastomers

Some O-ring seal materials absorb fluid when installed in a fluid application. The amount of absorption depends on the elastomer and the fluid. The recommended maximum limit for swell is 18%. In some cases, the fluid can extract materials from the elastomer and effectively shrink the elastomer, shrinkage should not be allowed so it is important to confirm the behavior of the elastomer in the operating fluid.

5.3.2 Designing for Seal Swell

The volume of the O-ring seal gland should be large enough to accommodate a fully soaked seal in its intended application. This volume is controlled by the selection of an appropriate gland width. Formulas for computing gland width are as follows:

Piston applications:

$$G_{\min} = \frac{XV + N_R}{.7854 (A^2 \min - F^2 \max)} \quad (\text{Eq. 5})$$

Rod applications:

$$G_{\min} = \frac{XV + N_B}{.7854 (E^2 \min - B^2 \max)} \quad (\text{Eq. 6})$$

All applications

$$G_{\max} = G_{\min} + \text{desired tolerance}$$

where:

A, B, E, F, G, and R = gland dimensions per Figure 1

V = maximum un-soaked seal volume = $2.4674 (K_{\max} + W_{\max}) (W_{\max}^2)$

K = seal inside diameter

W = seal cross-section diameter

X = The factor used to increase the seal volume to the expected value after installation and soaking (for example, X = 1.3 is a reasonable factor for use in arriving at a gland width for general purpose use)

N_R = approximate gland volume lost by gland corner radii (rod-mounted) = $1.3484 F_{\max} R_{\max}^2$

N_B = approximate gland volume lost by gland corner radii (bore-mounted) = $1.3484 E_{\min} R_{\max}^2$