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AEROSPACE RECOMMENDED PRACTICE

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ARP 1231

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Revised

GLAND DESIGN, ELASTOMERIC O-RING SEALS, GENERAL CONSIDERATIONS

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.

2. SCOPE

This document establishes general gland design criteria for static and dynamic O-ring seal applications used in fluid systems and at fluid pressures common to the aerospace industry. Detailed discussion of design criteria and tables of recommended gland dimensions are contained in the documents listed in Table 1. S.I. unit conversions for U.S. customary units have been provided for reference purposes.

TABLE 1

TITLE	DOCUMENT NUMBER
Gland Design, Elastomeric O-Ring Seals, Static Radial	ARP 1232
Gland Design, Elastomeric O-Ring Seals, Dynamic Radial	ARP 1233*
Gland Design, Elastomeric O-Ring Seals, Static Axial, with and without backup rings	ARP 1234*
Gland Design, Elastomeric O-Ring Seals, Static Radial, with backup rings	ARP 1235*
Gland Design, Elastomeric O-Ring Seals, Dynamic Radial, with backup rings	ARP 1236*
Gland Design, Elastomeric O-Ring Seals, Dynamic Radial, with slipper seals	ARP 1237*

* To be issued at a later date

3. GENERAL REQUIREMENTS

3.1 Applicable Documents:

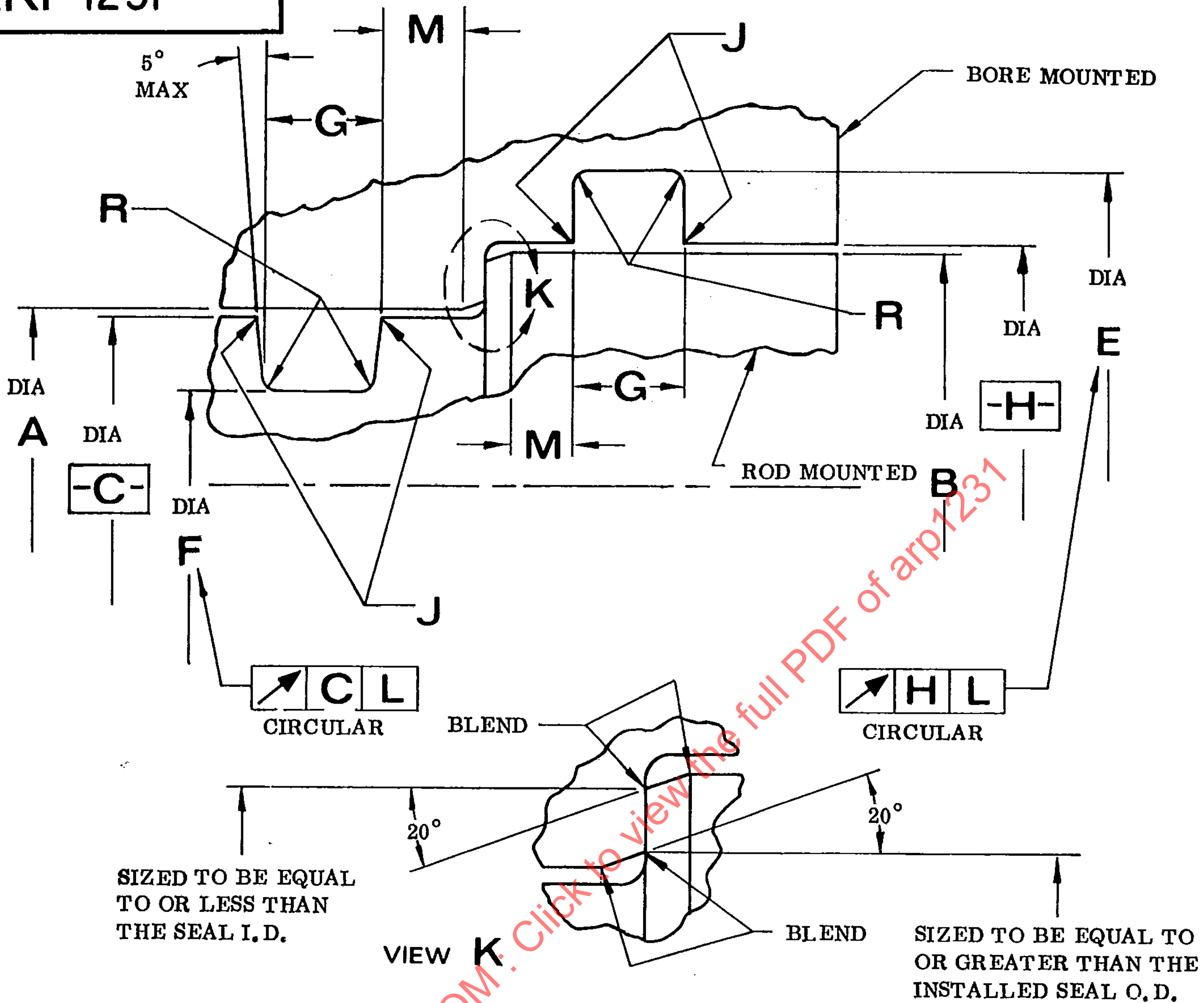
3.1.1 AIR 786 - Elastomer Compatibility Considerations Relative to O-Ring and Sealant Selection

3.1.2 AS 568 - Uniform Dash Numbering System for O-Rings

3.2 Gland Configuration

3.2.1 Radial O-ring Seal Glands: Figure 1 depicts rod-mounted and bore-mounted radial O-ring seal glands. The rod-mounted 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.

3.2.2 Axial O-Ring Seal Glands: Figure 2 illustrates an axial O-ring seal gland. In an axial gland, sealing occurs on the flat surfaces of the gland rather than on the gland diameters.



INCHES

NOM. O-RING CROSS-SECTION DIA (W) PER AS 568	EDGE BREAK J	RADIUS R	RUNOUT L	MIN M
.070	.005-.015	.010-.020	.002	.020
.103	.010-.020	.020-.030	.002	.020
.139	.010-.020	.020-.030	.003	.020
.210	.010-.020	.020-.030	.004	.020
.275	.010-.020	.020-.030	.005	.020

MILLIMETRES

NOM. O-RING CROSS-SECTION DIA (W) PER AS 568	EDGE BREAK J	RADIUS R	RUNOUT L	MIN M
1.78	.13-.38	.25-.51	.051	.51
2.62	.25-.51	.51-.76	.051	.51
3.53	.25-.51	.51-.76	.076	.51
5.33	.25-.51	.51-.76	.102	.51
6.98	.25-.51	.51-.76	.127	.51

FIGURE 1. TYPICAL RADIAL O-RING SEAL GLANDS

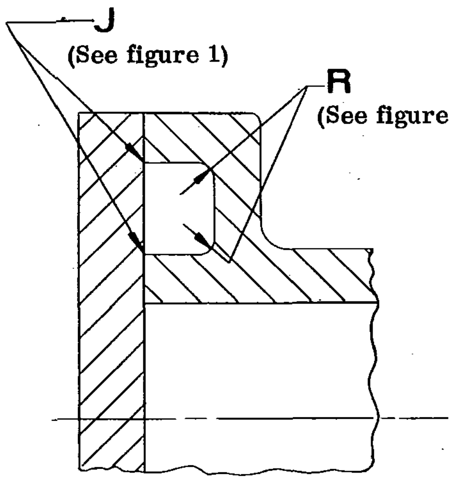


FIGURE 2

O-RING AXIAL SEAL GLAND

3.3 Gland Dimensions:

3.3.1 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 is frequently necessary to change fluids or elastomers to achieve 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.

3.3.2 Standard Gland Dimensions: Standard gland dimensions are provided in the ARP's listed in Table 1 for the O-ring seal sizes covered by AS 568. These dimensions are computed in accordance with criteria in this ARP adjusted to the needs of the specific gland classification (radial or axial, static or dynamic, etc.)

3.3.3 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.

3.3.4 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.

3.3.5 Edge Breaks: The gland edges must be broken in accordance with Figure 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.

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

4.1 Fluid Material Compatibility:

4.1.1 This document establishes gland design criteria and standards for use with nitrile (NBR), fluorocarbon (FPM), fluorosilicone (FMQ), ethylenepropylene (EPM) or silicone (VMQ) 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 see AIR 786.

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.

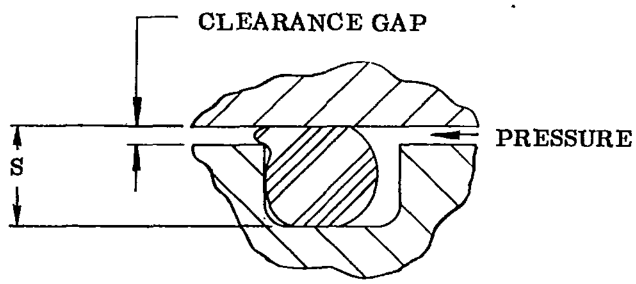


FIGURE 3

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 fluid pressure increases or seal hardness decreases, diametral clearance must be reduced to avoid O-ring seal extrusion (see Figure 4). In using Figure 4, it must 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.

4.2.3 Use of Anti-Extrusion Devices: As a general rule, systems at above 1500 psi (10 MPa) should utilize backup rings or other devices of this nature. Also, if diametral clearances are larger than desired, an anti-extrusion device may be installed in the gland to reduce the diametral clearances (see Paragraph 5.4).

4.3 Temperature Considerations:

4.3.1 Effects of Temperature on Seal Squeeze: The minimum squeezes (see Paragraph 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.

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

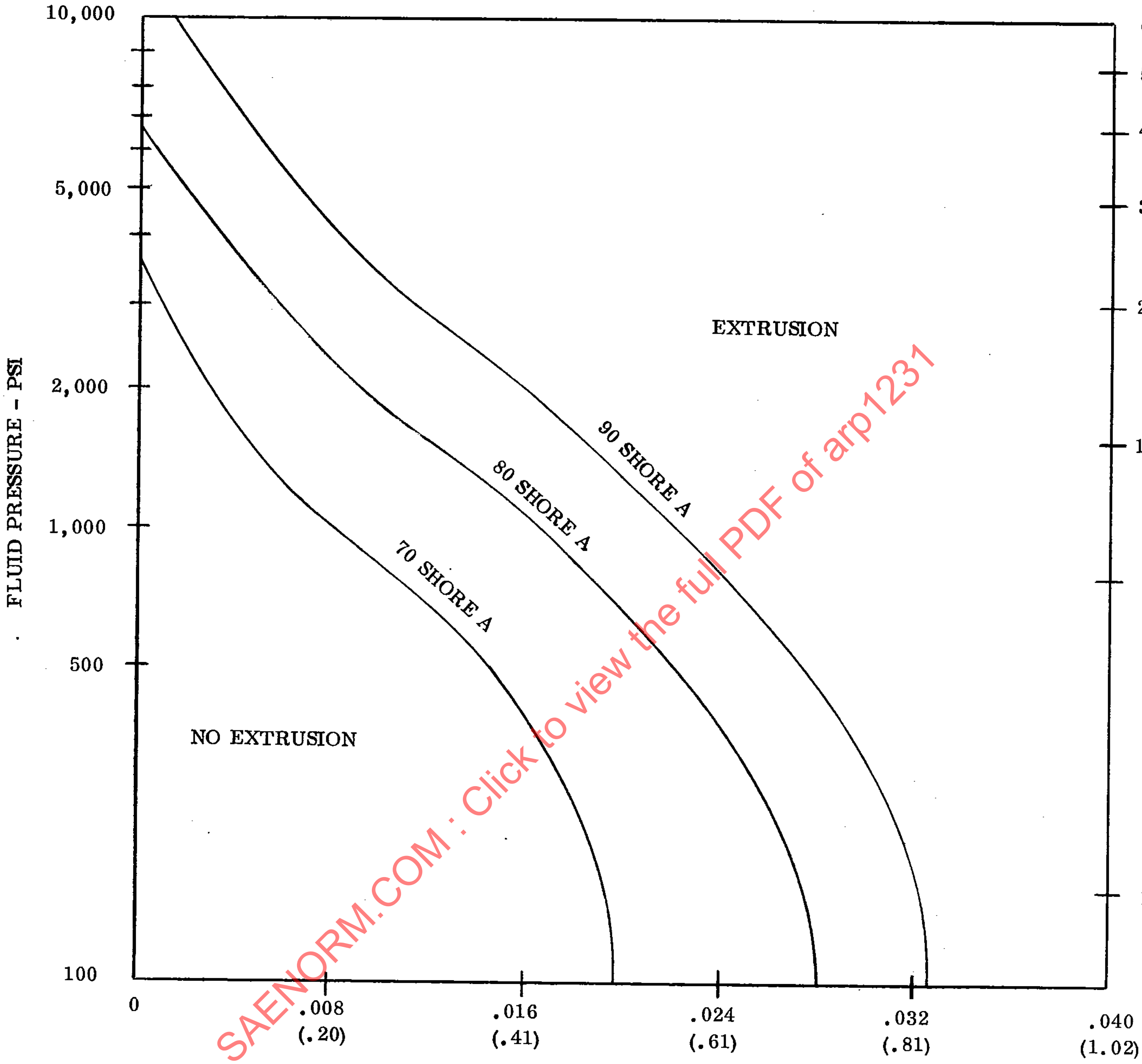
4.3.2 Effect of Temperature on O-ring Seal Materials: A significant factor in the selection of an O-ring seal material is its ability to function within the operating temperature range of a given system. Temperature limitations can be found in applicable material specifications.

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 must 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 AS 568.

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.

4.4.2.1 Specifically, the .103 in. (2.62 mm) cross-section seals in the larger ID sizes are recommended in preference to the .070 in. (1.78 mm) cross-section seals except in applications where size or weight considerations necessitate the use of .070 in.(1.78 mm) cross-section seals.



DIA CLEARANCE IN INCHES (mm)

FIGURE 4

RECOMMENDED MAXIMUM DIA CLEARANCE UNDER HIGH PRESSURE

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*. Buckling allows the seal to be pinched locally when the rod is installed in the mating bore.

* Consult ARP 1233, Gland Design, "Elastomeric O-ring Seals Dynamic Radial", 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:

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

5.1.3 Allowable Seal Stretch: For allowable seal stretch in specific applications consult the documents listed in Table 1.

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 must be considered (see paragraph 4.3.1.1).

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 must 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 rod-mounted applications

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

For bore-mounted 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 I.D. (uninstalled)