



METRIC AEROSPACE RECOMMENDED PRACTICE

MAP3440™

REV. A

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Superseding MAP3440

(R) O-Ring Groove Design for Metric O-Ring Seals
Used in Static Radial Compression Applications
Specifically for Engine and Engine Control Systems

RATIONALE

This standard has been reformatted for ease of use with no technical changes.

NOTE: This standard was transferred from the E25 General Standards for Aerospace and Propulsion Systems Committee to A-6C2 Seals Committee.

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Documents

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1. SCOPE

This SAE Recommended Practice provides the design criteria for static elastomeric O-ring seals used specifically in engine and engine control systems. It provides radial compression groove dimensions for aerospace metric O-ring sizes specified in MA2010. The conditions considered to formulate the design criteria are also described, e.g., seal stretch, cross-section reduction, seal squeeze, and swell.

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 a 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 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.

ARP1231	Gland Design, Elastomeric O-Ring Seals, General Considerations
ARP1232	Gland Design Criteria and Dimensions for Static Radial O-Ring Seal Applications without Anti-Extrusion Devices Specifically for Engine and Engine Control Systems
MA2010	Packing, Preformed - O-Ring Seal, Standard Sizes and Size Codes, Metric

2.1.2 ANSI Accredited Publications

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

ANSI B4.2-1978	Preferred Metric Limits and Fits
ANSI/ASME B46.1-1985	Surface Texture (Surface Roughness, Waviness, and Lay)
ANSI Y14.36-1978	Surface Texture Symbols

2.2 Symbols

Letter symbols used in this standard are as follows:

d ₁	O-ring inside diameter
d ₂	O-ring cross-section diameter
d ₃	O-ring groove diameter, piston mounted
d ₄	Bore inside diameter
d ₅	Rod outside diameter
d ₆	O-ring groove diameter, housing mounted
b	O-ring groove width
t	O-ring gland radial depth

nom	Nominal
max	Maximum
min	Minimum
r_1	Corner radius, bottom of the groove
r_2	Edge radius, top of the groove
z	Length of lead-in chamfer
g	Radial clearance between rod and bore
v_o	Volume of O-ring (unsoaked)
v_g	Volume of O-ring gland
X	Percent stretch of O-ring inside diameter, d_1
Y	Percent reduction of O-ring cross-section, d_2 , due to stretching d_1

3. TECHNICAL REQUIREMENTS

3.1 General

The following static, radial squeeze, O-ring groove categories have been incorporated in this standard:

- a. Piston mounted O-ring groove/gland
- b. Housing mounted O-ring groove/gland

The O-ring groove design is based on 2% minimum stretch and the following nominal percentage squeeze which is based on the mean gland depth (t nom) and the mean O-ring cross-section diameter (d_2 nom). This is shown in Table 1 using the formula in Equation 1. This criterion is similar to ARP1232.

Table 1 - Mean O-ring cross-section and corresponding nominal percentage squeeze

d_2 nom mm	nom squeeze % of d_2 nom
1.80	21
2.65	19
3.55	18
5.30	16
7.00	15

$$\text{Percentage squeeze, nom} = ((d_2 \text{ nom} - t \text{ nom}) / d_2 \text{ nom}) \times 100 \quad (\text{Eq. 1})$$

3.2 O-Rings

Figure 1 illustrates an O-ring; the inside diameters, cross-section diameters, and size codes are per MA2010.

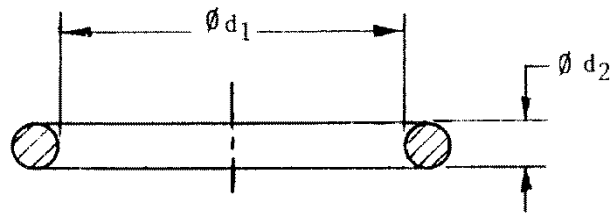


Figure 1 - O-ring dimensions

3.3 Typical Radial Compression Sealing

Figure 2 illustrates typical radial compression O-ring sealing applications without anti-extrusion devices (back-up rings).

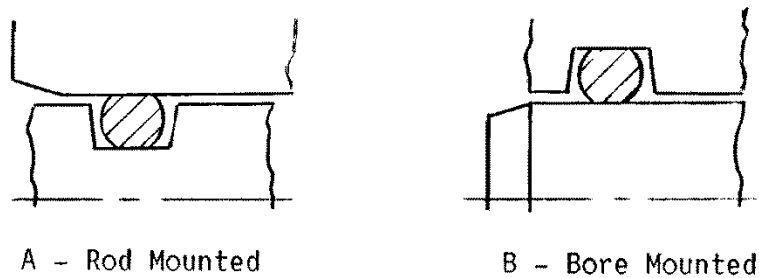


Figure 2 - O-ring radial compression sealing applications

3.4 Radial O-Ring Grooves

Figure 3 specifies the letter symbol dimensions for radial O-ring groove, piston mounted. Figure 4 specifies the letter symbol dimensions for radial O-ring groove, housing mounted.

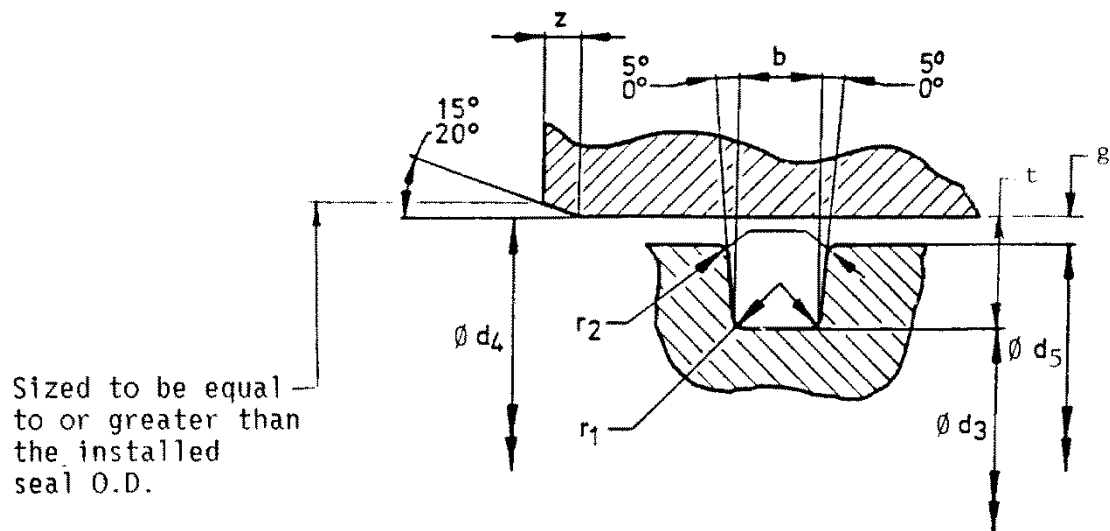


Figure 3 - Radial O-ring groove, piston mounted

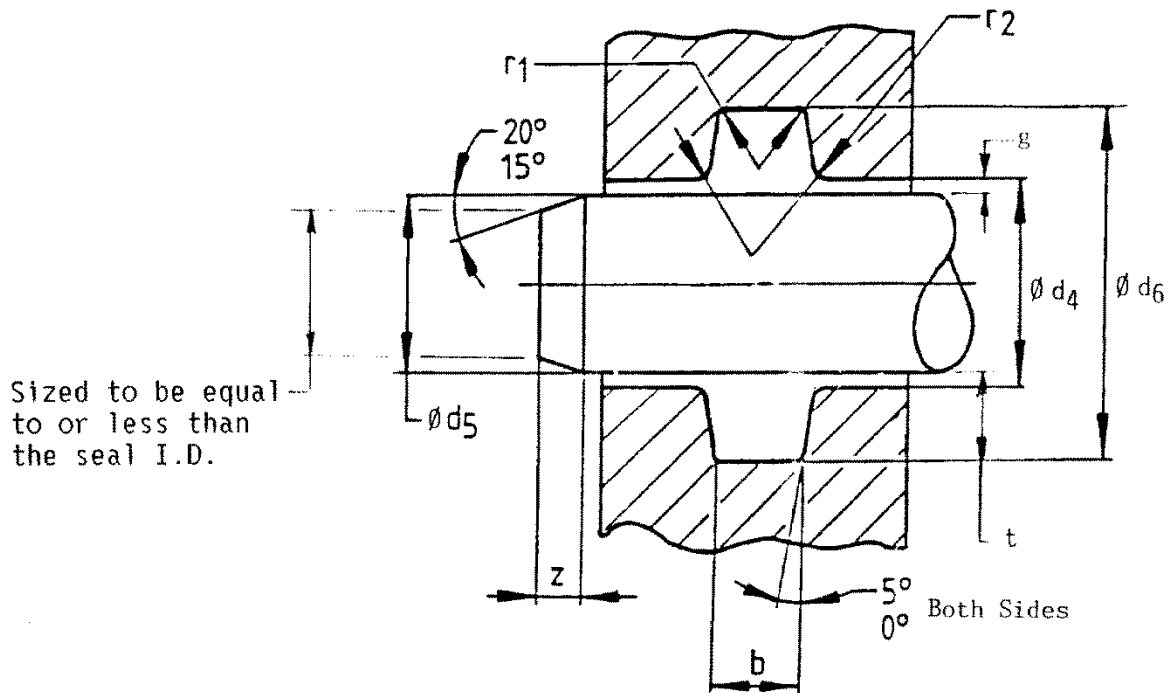


Figure 4 - Radial O-ring groove, housing mounted

3.5 Fluid Pressure

The recommended maximum fluid pressure is 10000 kPa that may be applied to the glands specified herein, using 70 durometer hardness O-rings. As a general rule, fluid systems above 10000 kPa pressure should design the gland for use of back-up rings to avoid O-ring extrusion into the gland clearance gap.

3.6 Surface Roughness

The surface roughness should be 1.6 μm Ra on the groove sides and bottom surfaces, also on the mating surface (rod or bore) in contact with the O-ring seal.

3.7 Corner and Edge Radii

The corner radius (r_1) and edge radius (r_2) of the O-ring groove shall be as specified in Table 2.

Table 2 - Groove corner and edge radii

d_2 nom	r_1 (corner)	r_2 (edge)
1.80	0.3-0.5	0.1-0.3
2.65	0.3-0.5	0.1-0.3
3.55	0.4-0.8	0.1-0.3
5.30	0.4-0.8	0.1-0.3
7.00	0.8-1.2	0.1-0.3

NOTE: Dimensions are in millimeters.

3.8 Lead-in Chamfers

A lead-in chamfer angle of 15 to 20 degrees is used to prevent damage to the O-ring seal on assembly by the bore for piston mounted applications or by the rod for housing mounted applications. Provide for the length of lead-in chamfer (z) as specified in Table 3. Chamfer edges to be rounded 0.1 to 0.3.

Table 3 - Lead-in chamfer length

d ₂ nom	1.80	2.65	3.55	5.30	7.00
z min	1.1	1.5	1.8	2.7	3.6

NOTE: Dimensions are in millimeters

3.9 Groove Runout Tolerance

The groove runout tolerance of d₃ relative to d₅ and d₆ relative to d₄ shall be 0.025 up to 50 mm groove diameter, and 0.050 over 50 mm groove diameter.

3.10 Groove Diameter Tolerances

The groove diameter tolerances are as shown in Table 4.

Table 4 - Groove diameter tolerances

d ₂ nom		1.80	2.65	3.55	5.30	7.00
Groove Diameter		Tolerances				
Groove, Piston Mounted	d ₃	0.04	0.05	0.06	0.07	0.09
Bore, ID	d ₄	0.06	0.07	0.08	0.09	0.11
Rod, OD	d ₅	f7	f7	f7	f7	f7
Groove, Housing Mounted	d ₆	0.06	0.07	0.08	0.09	0.11

NOTE: Dimensions are in millimeters.

3.11 Groove Depths, t

The maximum groove depths, t, are specified in Table 5 and are based on 2% stretch of d₁ max and 1.73% reduction of d₂ min. The resulting minimum percentage squeeze is also given in Table 5. The minimum depth results from the tolerances in Table 4.

Table 5 - Maximum groove depths, t

d ₂ nom	1.80	2.65	3.55	5.30	7.00
T max	1.44	2.17	2.94	4.48	6.01
% Squeeze, min	14.8	13.7	13.3	11.8	10.7

NOTE: Dimensions are in millimeters.

3.12 Groove Widths, b

The groove widths, b, are specified in Table 6. Tolerance is 0 to +0.25. The values were calculated and averaged to provide a groove volume not less than 120% of the max O-ring volume, and for most groove sizes the volume is 130% or more, to allow for O-ring swell.

Table 6 - Minimum groove widths, b

d ₂ nom	1.80	2.65	3.55	5.30	7.00
b min	2.65	3.68	4.80	6.86	8.82

NOTE: Dimensions are in millimeters.

3.13 Derivation of Groove Dimensions

The groove dimensions in this section are based on 2% minimum stretch and a minimum squeeze as given in Table 5. Percent seal stretch is calculated as follows:

$$\text{Percentage Stretch} = ((\text{Installed seal ID} - \text{free seal ID}) / \text{free seal ID}) \times 100 \quad (\text{Eq. 2})$$

3.13.1 Piston Mounted Groove Diameter, d₃

$$d_3 \text{ min} = 1.02(d_1 \text{ max}) \quad (\text{Eq. 3A})$$

$$d_3 \text{ max} = d_3 \text{ min} + \text{tol in Table 3} \quad (\text{Eq. 3B})$$

3.13.2 Housing Mounted Groove Diameter, d₄

$$d_4 \text{ max} = d_3 \text{ min} + 2t \text{ max} \quad (\text{Eq. 4A})$$

$$d_4 \text{ min} = d_4 \text{ max} - \text{tol in Table 3} \quad (\text{Eq. 4B})$$

3.13.3 Piston Mounted, Rod Outside Diameter, d₅

$$d_5 \text{ max} = d_4 \text{ min} - 2g \text{ min} \quad (\text{Eq. 5A})$$

where:

2g min = fundamental deviation f from ANSI B4.2

$$d_5 \text{ min} = d_5 \text{ max} - \text{tol grade IT7 from ANSI B4.2} \quad (\text{Eq. 5B})$$

3.13.4 Reduction in O-Ring Cross Section Diameter, d₂, Due to Stretch

When an O-ring is stretched, its cross section is reduced and flattened. In the stretched condition, an O-ring cross section is no longer circular. The following empirical formulas were developed by the Research Laboratories of General Motors Corp. based on actual measurements of a large number of O-rings:

$$0 \text{ to } 3\% \text{ inside diameter stretch: } Y = 0.01 + 1.06X - 0.1(X)^2 \quad (\text{Eq. 6A})$$

$$3 \text{ to } 25\% \text{ inside diameter stretch: } Y = 0.56 + 0.59X - 0.0046(X)^2 \quad (\text{Eq. 6B})$$

where:

Y = percent reduction in cross-section diameter, d₂

X = percent stretch of inside diameter, d₁ (i.e., for 2% stretch, X = 2)

For 2% stretch, $Y = 0.01 + 1.06(2) - 0.1(2)^2 = 1.73\%$ reduction on d_2 . Minimum cross section of 2% stretched O-ring is:

$$d_2^* \text{ min} = d_2 \text{ min} - 0.0173(d_2 \text{ min}) = 0.9827(d_2 \text{ min}) \quad (\text{Eq. 7})$$

where:

d_2^* = min cross section of the 2% stretched O-ring

3.13.5 Maximum Groove Depth, t: Piston Mounted and Housing Mounted

$$t \text{ max} = d_2^* \text{ min} - (\text{percent squeeze min}/100)d_2^* \text{ min} \quad (\text{Eq. 8})$$

where:

percent squeeze min is given in Table 5

The percent squeeze min was derived from ARP1232 by comparing comparable dimensions for max gland depth, $t \text{ max}$, that is, $(\varnothing A \text{ max} - \varnothing F \text{ min}) 0.5$ for piston mounted and for housing mounted $(\varnothing E \text{ max} - \varnothing B \text{ min}) 0.5$, and the $d_2^* \text{ min}$ for the 2% stretched inch O-ring. The percent squeeze min in Table 4 is based on a $t \text{ max}$ depth of gland and an O-ring at $d_1 \text{ max}$ and $d_2 \text{ min}$ in a free state, which, when mounted, is stretched to 2% with $d_2^* \text{ min}$ in a stretched condition.

3.13.6 Groove Width, b: Piston Mounted

$$v_o \text{ max} = 2.4674(d_2 \text{ max})^2(d_1 \text{ max} + d_2 \text{ max}) \quad (\text{Eq. 9})$$

$$v_g \text{ min} = [0.5(d_4 \text{ min} - d_3 \text{ max})b - 0.4292(r_1)^2]0.5(d_4 \text{ min} + d_3 \text{ max})\pi \quad (\text{Eq. 10A})$$

$$v_g \text{ min} = 1.3(v_o \text{ max}) \quad (\text{Eq. 10B})$$

$$b \text{ min} = \frac{1.3(v_o \text{ max})}{0.25\pi[(d_4 \text{ min})^2 - (d_3 \text{ max})^2]} + \frac{0.4292(r_1 \text{ max})^2}{0.5(d_4 \text{ min} - d_3 \text{ max})} \quad (\text{Eq. 11})$$

3.13.7 Groove Width, b: Housing Mounted

$$b \text{ min} = \frac{1.3(v_o \text{ max})}{0.25\pi[(d_6 \text{ min})^2 - (d_4 \text{ max})^2]} + \frac{0.4292(r_1 \text{ max})^2}{0.5(d_6 \text{ min} - d_4 \text{ max})} \quad (\text{Eq. 12})$$

3.13.8 Housing Mounted, Rod Outside Diameter, d_5

$$\begin{aligned} d_5 \text{ min} &= 1.02(d_1 \text{ max}) \\ d_5 \text{ max} &= d_5 \text{ min} + \text{tol grade IT7 from ANSI B4.2} \end{aligned} \quad (\text{Eq. 13})$$

3.13.9 Housing Mounted Groove Diameter, d_6

$$\begin{aligned} d_6 \text{ max} &= d_5 \text{ min} + 2t \text{ max} \text{ (see 3.11.5 for derivation of } t \text{ max)} \\ d_6 \text{ min} &= d_6 \text{ max} - \text{tol in Table 4} \end{aligned} \quad (\text{Eq. 14})$$

3.13.10 Housing Mounted, Bore Inside Diameter, d_4

$$\begin{aligned} d_4 \text{ min} &= d_5 \text{ max} + 2g \text{ min} = \text{fundamental deviation } f \text{ from ANSI B4.2} \\ d_4 \text{ max} &= d_4 \text{ min} + \text{tol in Table 4} \end{aligned} \quad (\text{Eq. 15})$$