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Selection and Application of Polytetrafluoroethylene (PTFE) Backup Rings for Hydraulic and Pneumatic Fluid Power Applications

RATIONALE

This document has been revised as part of a Five-Year Review to make minor technical changes that provide clarity on figures, provide additional guidance, and a reference on installation.

FOREWORD

Backup rings were developed to protect the seal component, typically an O-ring, from being extruded out of its gland due to pressure, eccentricity, etc. Based on many types of applications, several backup ring designs have been developed over the years.

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides an overview of the various types of polytetrafluoroethylene (PTFE) backup rings for hydraulic and pneumatic fluid power applications, including their advantages and disadvantages.

1.1 Purpose

To help the user select the right backup ring, this document provides guidance in the selection of backup rings for various applications. It also identifies older designs that are no longer recommended.

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 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.

AMS3678	Polytetrafluoroethylene (PTFE) Moldings and Extrusions Unfilled, Pigmented, and Filled
AIR1186	Installation and Use of Equilateral Triangle Cross-Section Hydraulic O-Ring Seal Backup Rings (Dyna-Baks)
ARP5555	Recommendations for Installation of Seals in Standard Glands
AS4716	Gland Design, O-Ring and Other Seals
AS5781	Retainers (Backup Rings), Hydraulic and Pneumatic, Polytetrafluoroethylene Resin, Single Turn, Scarf-Cut, For Use in AS4716 Glands
AS5782	Retainers (Backup Rings), Hydraulic and Pneumatic, Polytetrafluoroethylene Resin, Solid, Un-Cut, for Use in AS4716 Glands
AS5857	Gland Design, O-Ring and Other Elastomeric Seals, Static Applications
AS5860	Retainers (Backup Rings), Hydraulic and Pneumatic, Polytetrafluoroethylene Resin, Single Turn, Scarf-Cut, For Use in AS5857 Static Glands
AS5861	Retainers, (Backup Rings), Hydraulic and Pneumatic, Polytetrafluoroethylene Resin, Solid, Un-Cut, for Use in Static Glands to AS5857
AS8791	Hydraulic and Pneumatic Retainers (Back-Up Rings), Polytetrafluoroethylene (PTFE) Resin

2.1.2 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-G-5514	Gland Design; Packing, Hydraulic, General Requirements For (Inactive for New Design)
MS27595	Retainer, Packing Backup, Continuous Ring, Polytetrafluoroethylene (Inactive for New Design)

MS28782 Retainer, Packing, Back-Up, Teflon (Inactive for New Design)

MS28783 Ring, Gasket, Back-up, PTFE (Inactive for New Design)

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 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.

AS5440 Hydraulic Systems, Military Aircraft, Design and Installation, Requirements For

AS33566 Fittings, Installation of Flareless Tube, Straight-Threaded Connectors

2.2.2 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MS21344 Fittings, Installation of Flared Tube, Straight Threaded Connectors, Design Standard for

MS28773 Retainer, Packing Back-Up, Tetrafluoroethylene, Straight Thread Tube Fitting Boss (Inactive for New Design)

MS33566 Fittings, Installation of Flareless Tube, Straight Threaded Connectors (Superseded by AS33566)

3. BACKUP RING FUNCTION AND USE

3.1 Definition of a Backup Ring

A backup ring is a rectangular cross-section ring, manufactured in a polymer material, which is installed in the seal gland next to the seal (typically an O-ring) as shown in Figure 1, to aid the extrusion resistance of the O-ring.

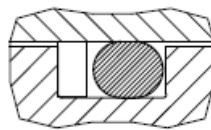


Figure 1 - Backup ring and O-ring

3.2 The Function of Backup Rings

O-rings will extrude under adverse conditions of pressure, temperature, fluid compatibility, and diametral extrusion clearance. The main function of the backup ring is to prevent the O-ring from extruding, as shown in Figure 2. This is achieved by using a backup ring made from polytetrafluoroethylene (PTFE) or other similar polymer material that deforms under pressure to maintain essentially zero extrusion clearance to provide improved support for the associated O-ring. Backup rings are effective for this purpose under both static and dynamic conditions. Backup rings made from PTFE are also effective in hostile environments, which may reduce the ability of the O-ring to resist extrusion as a result of temporary or permanent changes in the physical properties of the elastomer.

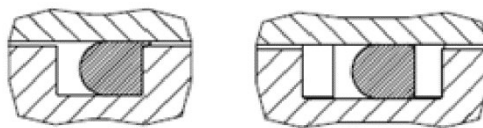


Figure 2 - O-rings may extrude (left), backup rings prevent extrusion (right)

The use of backup rings with slipper seals or spring-energized seals may protect these from extrusion and/or prolong their operational life. However, this scenario is outside the scope of this document, as these seals are not standardized. Thus, any use of backup rings should be discussed with the supplier of the seal.

3.3 Use of Backup Rings in Standard O-Ring Glands

The dimensional details of standard glands for use with O-rings and backup rings are described in AS4716 and AS5857.

3.3.1 AS4716 Glands

This standard is for dynamic and static applications, and although it does list static sizes, it is generally recommended to use AS5857 for static external applications.

3.3.2 AS5857 Glands

This standard is for static applications, and the groove sizes (depth) have been reduced to give an appropriate increased squeeze for static applications. This standard should primarily be used for static external applications where the downstream side is open to the atmosphere. If AS5857 glands are used for static sealing internally, care should be taken to avoid spiraling of the O-ring during the installation due to the high squeeze. Alternatively, AS4716 glands may be used.

3.3.3 Gland Sizes

O-ring glands are identified either as a ZERO backup ring gland, ONE backup ring gland, TWO backup ring gland, or as a male gland (for ID or rod sealing) or a female gland (for OD or piston sealing). See Figure 3. It is only possible to use backup rings in ONE or TWO backup ring gland widths. ARP5555 provides a recommendation to use TWO backup ring gland widths wherever possible except where this may compromise the design objectives for weight or space requirements. When ONE backup ring gland width is used, the backup ring must be downstream of the pressure to be effective, as shown in Figure 3(b).

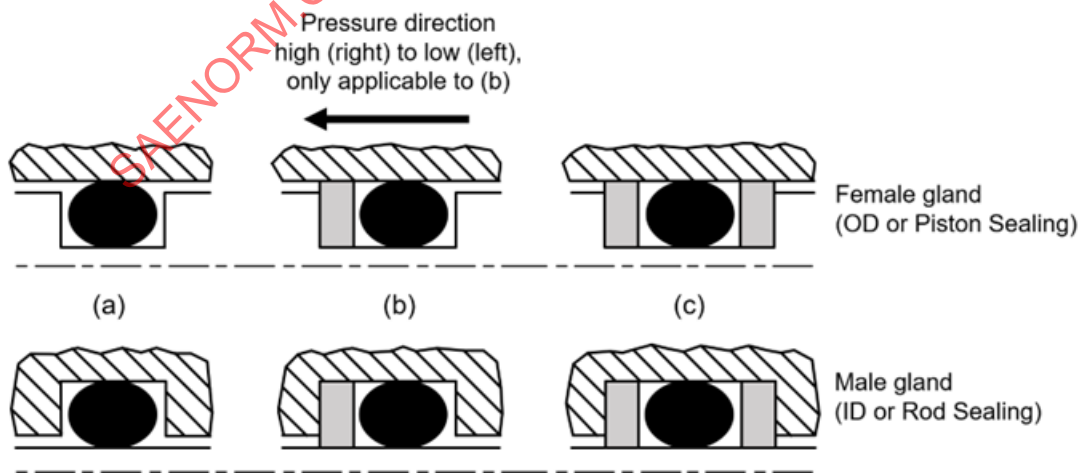


Figure 3 - Gland width for ZERO (a), ONE (b), or TWO (c) backup ring configuration

In general, a backup ring will not be required at rated operating pressures up to 1500 psi (10350 kPa). A ZERO backup ring gland configuration per AS4716 and AS5857 may be used. At rated operating pressures between 1500 psi (10350 kPa) and 3000 psi (20700 kPa), it is recommended to use the ONE or TWO backup ring gland configuration. At rated operating pressures between 3000 psi (20700 kPa) and 5000 psi (34500 kPa), it is recommended to use filled PTFE backup rings (see 8.2). Rated operating pressures above 5000 psi (34500 kPa) and/or temperatures above 275 °F (135 °C) may require diametral extrusion clearances that are less than those provided in AS4716, AS5857, and/or special backup ring configurations and materials.

ARP5555 discusses the factors that can influence the size of the diametral extrusion gap (e.g., thermal expansion, pressure expansion, side load, etc.). These factors should also be taken into account when selecting a suitable backup ring configuration and material.

3.3.4 Gland Diameters and Dash Sizes

Gland sizes, O-rings, and backup rings are identified by their diametral size (dash size).

It should be noted that, unlike MIL-G-5514, it is not recommended to use the same dash size backup rings for male and female glands of AS4716 and AS5857. The reason is that the gland depths of AS4716 and AS5857 have been reduced and the corresponding backup rings have been sized to the rod or the bore (piston), respectively. This means that if a backup ring for a rod application was used for a piston application, it would sit stretched on the groove diameter and not close the extrusion gap effectively. Figure 4 illustrates the differences in gland depth standards for rod and piston applications. Note that virgin PTFE backup rings for AS4716 and AS5857 glands are color-coded by pigmenting the PTFE material to avoid mistaken interchanges being made. Other backup rings with strengthening fillers that can fit into MIL-G-5514, AS4716, and AS5857 glands are not color-coded, and greater care should be exercised to make sure the correct part number is used in the correct gland.

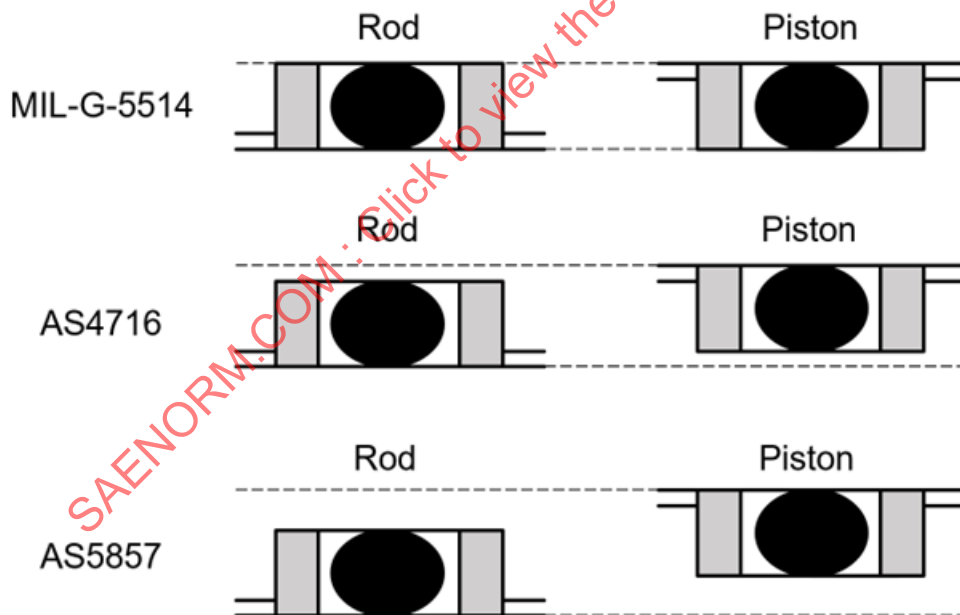


Figure 4 - Diametral differences between standards

4. BACKUP RING CONFIGURATIONS

4.1 Backup Ring Types

Backup rings can be divided into four types: continuous uncut backup rings, single-turn (scarf-cut) backup rings, spiral-cut backup rings, and special designs. Figure 5 illustrates the first three types.

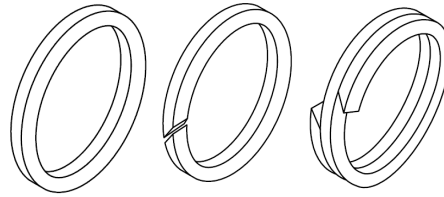


Figure 5 - Continuous uncut, single-turn (scarf-cut), and spiral-cut backup rings (from left to right)

The continuous uncut and the single-turn (scarf-cut) backup rings are commercially available in sizes to suit both older gland standards as well as AS4716 and AS5857, and the advantages and disadvantages of their use will be discussed in Sections 5, 6, and 7.

The spiral-cut backup ring is not recommended for new designs (see Section 7). For more information, it is recommended to contact the industry suppliers.

Additionally, a multitude of special or custom backup rings exist, and Figure 6 illustrates some of the most common types: right triangle, cammed, staged, and concave backup rings. These typically offer additional extrusion protection.

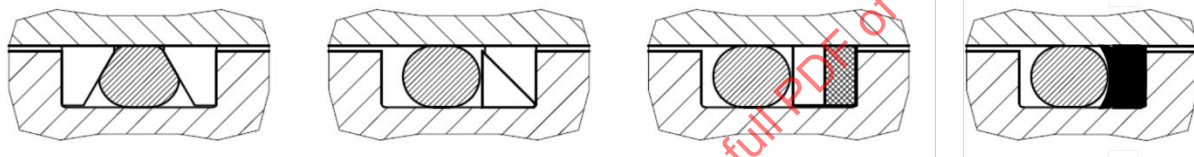


Figure 6 - Right triangle, cammed, staged, and concave backup rings (from left to right)

The cammed rings can follow the breathing of the hardware as experienced on actuators of large diameter and landing gear shock struts. Refer to ARP5555 for the definition of breathing.

The staged backup ring uses two materials, one with low modulus and one with high modulus. The lower modulus ring, typically PTFE, deforms and protects the O-ring from the nibbling action of the harder material, while the high modulus ring forms an effective barrier against extrusion. For more information, it is recommended to contact the industry suppliers.

NOTE: The use of a single backup ring (cammed, staged, or concave backup) requires the backup ring to be downstream. On these applications, the backup rings can easily be installed incorrectly.

A variant of the special backup rings is the equilateral triangle backup rings, which are available as commercial standard items as both uncut and scarf-cut backup rings. However, this backup ring type is not widely used and requires a modification to the MIL-G-5514 glands. For further information on the equilateral triangle backup ring applications, refer to AIR1186.

5. CONTINUOUS (UNCUT) BACKUP RINGS

The continuous uncut backup rings (AS5782 for use in AS4716 glands and AS5861 for use in AS5857 glands) provide the most reliable anti-extrusion protection for O-rings. Backup rings per AS5782 and AS5861 are not compatible with glands per MIL-G-5514. Backup rings per MS27595 should be used with MIL-G-5514 glands and are not interchangeable with AS5782 and AS5861 backup rings. MS27595 is not recommended for new designs.