AEROSPACE INFORMATION REPORT	AIR1244™	REV. B
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(R) Aerospace, Slipper Seals, Selection for Fluid Power Applications

RATIONALE

This document has been completely revised to reflect the current design practices.

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides basic information on the use of slipper seal sealing devices when used as piston (OD) and rod (ID) seals in aerospace fluid power components such as actuators, valves, and swivel joints, including:

- The definition of a slipper seal and the description of the basic types in use.
- Guidelines for selecting the type of slipper seal for a given design requirement are provided in terms of friction, leakage, service life, installation characteristics, and interchangeability.

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 the 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 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 Components

AIR1243 Anti-Blow-By Design Practice for Cap Seals

ARP4386 Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies

ARP4727 Gland Design, Computation of Seal Squeeze and Gland Volume

ARP4752 Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems

ARP4925 Aerospace Design and Installation of Commercial Transport Helicopter Hydraulic Systems

ARP5555 Recommendations for Installation of Seals in Standard Glands

ARP6175 Recommended Practice Regarding Commercial Aircraft Hydraulic System External Leakage

AS568 Aerospace Size Standard for O-Rings

AS4716 Gland Design, O-Ring and Other Seals

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

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

2.2 U.S. Government Publications

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

MIL-G-5514 Gland Design; Packings, Hydraulic, General Requirements for (inactive for new design)

3. INTRODUCTION

3.1 Definition of a Slipper Seal

A slipper seal is a separate circumferential band typically made of polytetrafluoroethylene (PTFE) fitted to the inside diameter (ID), outside diameter (OD), or face of an elastomer O-ring or other shape of a molded elastomeric sealing element which also acts an energizer. The cross-section of the slipper seal configuration can be a variety of symmetrical or asymmetrical shapes. Typical examples are shown in Figure 1.

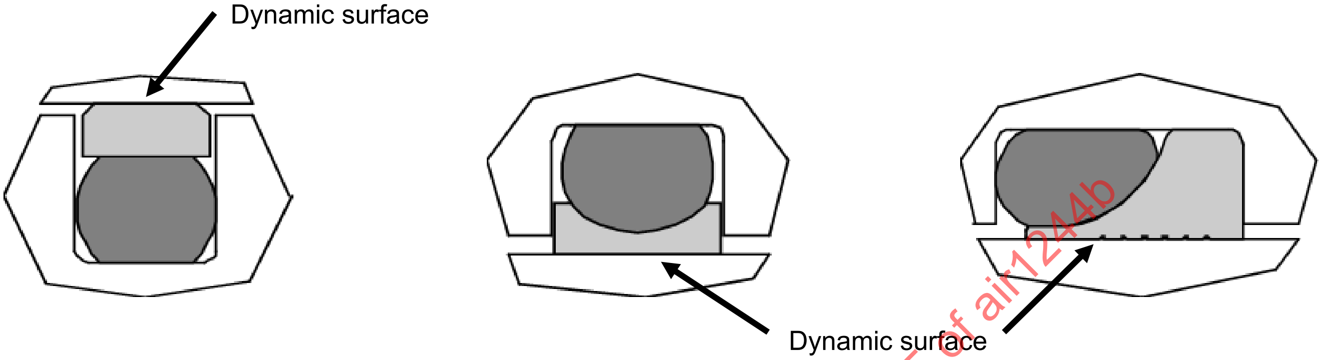


Figure 1 - Typical slipper seals

The combination of a slipper seal and a molded elastomeric sealing element, when fitted in a gland and squeezed, acts to control fluid leakage. When in a static condition, the slipper seal prevents extrusion of the elastomer but will not be as effective in terms of leakage control when compared to a full elastomer contact seal. When in a dynamic condition, the slipper seal generally—but not always—reduces breakout and running friction and protects the elastomer from extrusion and wear.

The slipper seal concept became practical with the availability of PTFE compounds. It is estimated that PTFE slipper seals were first used successfully around 1950. PTFE is a chemically inert, temperature-resistant (450 to 500 °F) (232 to 260 °C), low-friction, thermoplastic fluorocarbon plastic, compatible with all industrial and military fuels and hydraulic fluids in military and commercial use. Most PTFE slipper seals are manufactured from filled PTFE compounds. Care should be taken to ensure the filler material is compatible with the fluid and the material of the dynamic surface(s) in the hardware.

Although PTFE is not elastic in the same sense as an elastomer material, it is deformable for good sealing and can be stretched and folded for ease in installation. Because PTFE is a plastic, sealing surfaces must be protected from scratches and nicks during handling and installation. Installation tools for both OD and ID slipper seals can be used to advantage where one-piece glands are involved but are not always necessary.

Most slipper seal commercial standards are designed for use in commercial (ARP4752 and ARP4925) and military (AS5440) hydraulic systems. They are normally designed to fit glands per AS4716 and are energized with either an O-ring dimensionally per AS568 or a proprietary elastomer geometry. Slipper seals may be designed for use in hydraulic systems with operating conditions exceeding these requirements provided additional extrusion resistance is provided by reduced clearances and/or the addition of high-modulus thermoplastic backup rings. Other types of commercial standards are also available. No military standard (MS) or other industry part standards have been issued for slipper seals.

4. OPERATION AND USE OF SLIPPER SEALS

An O-ring in a static or dynamic application is installed with a diametral squeeze and may be pressure-energized in service. O-rings used in a dynamic application are exposed to extrusion, spiral failure, and wear, and will have a relatively short life compared to O-rings used as static seals in a similar environment.

When an O-ring is used with a backup ring, such as AS5781 or AS5782, it is protected against extrusion, but it is still vulnerable to the effects of friction that cause spiral failure and wear. An O-ring used with a slipper seal in a dynamic environment becomes a static seal and is protected from the effects of friction as well as extrusion.

Figure 2 illustrates the slipper seal principle, where A is the cylinder bore and P is the system pressure. Without pressure, the O-ring provides the sealing force and as system pressure rises it enters the seal groove and activates the O-ring, thus providing increasing sealing force with increasing system pressure.

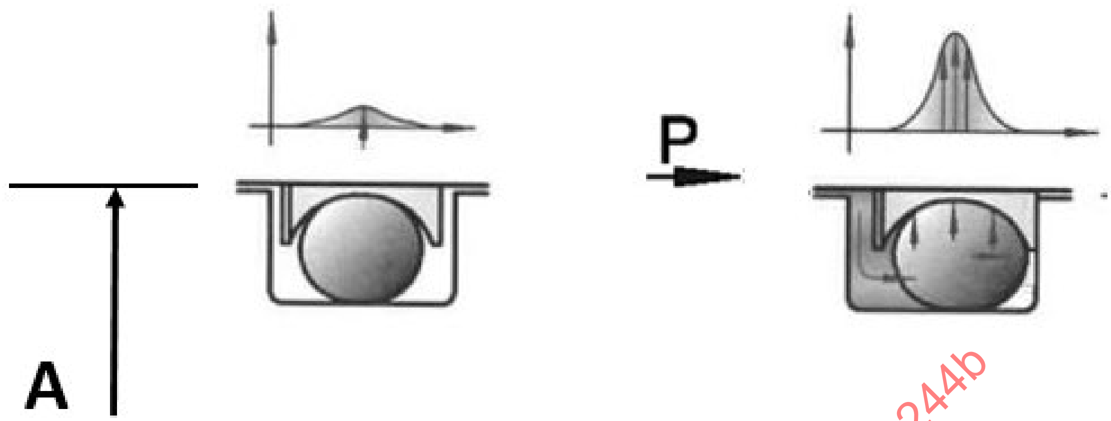


Figure 2 - Slipper seal principle (piston type shown)

Referring to Figure 2 and assuming static conditions, there are three possible leak paths:

1. Between the slipper seal and the cylinder bore.

2. Between the slipper seal and the O-ring.

3. Between the O-ring and the bottom of the groove.

Similar leak path principles also apply to rod-type slipper seals. The rate of leakage is a function of the fluid pressure, fluid viscosity as a result of temperature, and the quality of surface conditions at each leakage path. Under dynamic conditions, the film thickness passing by the slipper seal is an additional potential leakage path.

If the quality of the surface conditions at each leakage path is substandard, that is, rough, nicked, scratched, or contaminated with foreign particles, minute flow paths exist that permit leakage. Assuming constant viscosity, leakage through a tiny orifice is proportional to the square root of the pressure drop across the orifice. If the surfaces of potential leakage paths—such as those present in a typical slipper seal configuration—could be matched perfectly, leakage would be zero regardless of the pressure, since no passage would exist.

There are practical limits to the achievement of this ideal sealing condition. It can be approached very closely, however, by selecting seal materials that are deformable under stress, such as an elastomer or PTFE. Although PTFE is deformable under compressive load, it has a higher compressive modulus than rubber and is, therefore, less forgiving of surface imperfections and contamination. This is particularly true at low fluid pressure when deformation due to compressive stress is low.

When imperfections on the PTFE surface cause greater than allowable leakage, a brief running-in or application of high pressure will often result in improved surface-to-surface conformity and, therefore, reduced leakage.

Fillers (see 8.1) are added to PTFE to improve wear resistance and to further decrease deformation under load. These can have an adverse effect on leakage if they are not considered in the design concept, detail, and workmanship.

For consistent sealing performance, a slipper seal must have a diametral interference fit on the bore or rod. A good rule of thumb for minimum interference is 0.001 in/in (0.001 mm/mm) of diameter or 0.002 inch (0.051 mm), whichever is greater. Greater diametral interference is often used effectively. Consult the slipper seal supplier for recommendations.

Slipper seal performance may be influenced by elastomer squeeze. Optimum squeeze will vary with the slipper seal and elastomer configuration and the friction, leakage, and service life requirements of the application. Consult the slipper seal supplier for recommendations. ARP4727 provides computer programs that can be used to compute seal squeeze and gland occupancy when O-rings are used in combination with slipper seals.

4.1 Use of Slipper Seals

Slipper seals are specified in hydraulic, pneumatic, and other fluid power components as adjuncts to O-rings, alternatives to piston rings, and other types of packings to provide:

- Higher working pressure/temperature capability.
- Reduced seal breakout and running friction.
- Longer seal service life.
- Reduced space and weight of the hardware.
- Reduced risk of elastomer damage in blind assembly situations.

While slipper seals are primarily intended for use in dynamic applications that typically have periods of static conditions, there is also a wide usage of simple slipper seals (e.g., rectangular section PTFE caps with O-ring energizers) in purely static applications. As noted above, this is mostly to aid with blind assembly and save length on long sleeves in hydraulic equipment (e.g., spool valves). These installations are generally sealing between internal cavities of the equipment where slight leakage is considered acceptable and not noticed.

4.2 Pressure Trapping

In dual un-vented dynamic rod seal applications, care should be taken to choose design combinations that discourage pressure trapping between seals. As shown in Figure 3, the primary seal should preferably be of a unidirectional design that will allow pressure between the seals to vent back toward the upstream side when system pressure is reduced. This will reduce or eliminate the pressure trap between primary and secondary seals that would otherwise result in high seal friction and high seal wear.

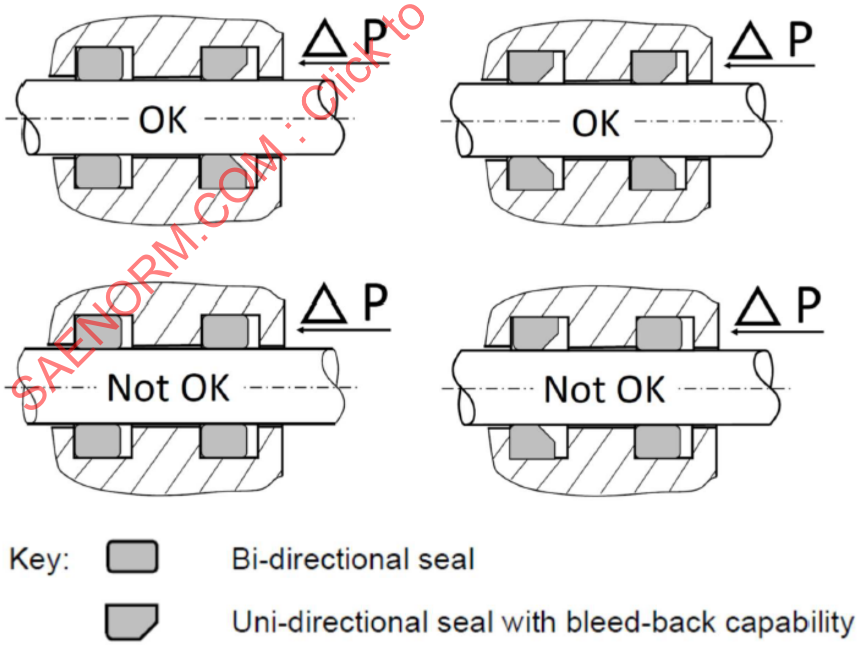


Figure 3 - Acceptable and unacceptable practice for dual unvented dynamic rod seal arrangements

5. TYPES OF SLIPPER SEALS

There are many commercial sources for PTFE and filled PTFE slipper seals. Usually, the trade names used for slipper seals are proprietary. Many of the commercial standards in use are interchangeable concerning gland fit but vary in design detail. Some designs are proprietary and available from only one source.

Most commercial slipper seal standards, except for some proprietary designs, are classified for size with the same dash number as their matching O-rings for the applicable nominal rod or bore size.

Slipper seals are further identified as ID (rod) seals or OD (piston) seals. An additional description for groove width may be necessary if the design is for use with a no backup-width, one backup-width, or two backup-width glands per AS4716 or AS5857.

The recommended specification for dynamic O-ring glands is AS4716. Slipper seal designs for glands according to this specification are interchangeable with most slipper seals designed for the previous standard, MIL-G-5514F. MIL-G-5514F is classified as inactive for new designs. Slipper seal designs for glands to MIL-G-5514F are interchangeable with some slipper seals designed for earlier versions of this specification. (Note that MIL-G-5514 was preceded by MIL-P-5514.)

Slipper seals designed for MIL-P-5514 (revisions C, D, E, and F) glands are interchangeable with each other and with some designs for other revisions. Slipper seals designed for MIL-P-5514A and B are interchangeable with each other and with some designs for later revisions of the specification. The slipper seal supplier is the best source of information on the interchangeability of products.

AS5857 is a gland especially designed for static seals. The gland depth is smaller than AS4716 to achieve a higher squeeze. It is necessary to check if slipper seals designed for use in AS4716 can be used without over occupying the groove. It is recommended to seek the advice of the slipper seal supplier. Also, note that some groove widths to AS5857 are different from those of AS4716 and MIL-G-5514.

As in the case of O-rings, up to three cross-sectional sizes of slipper seals are available for some diameters. In general, dynamic dash sizes, as defined in AS4716, are recommended. This is recommended for the same advantages afforded by using a larger O-ring cross-section. The additional space required can be offset by reduced hardware weight, improved installation characteristics, and reduced friction. All distinct advantages in favor of reduced cross-section (static) dash sizes. Another important consideration is that O-rings are in a static environment and are therefore not exposed to torsional forces, thus eliminating one of the advantages of larger cross-sections. The choice between a large or a small cross-section is largely a case of judgment since environments vary widely. Overall, reliable performance can best be assured by using dynamic dash sizes.

5.1 Slipper Seals for No Backup-Width Glands according to AS4716

These types of slipper seals provide extrusion protection for the O-ring without requiring the extra groove width necessary to accommodate backup rings. Typical preferred uses include spool-valve sleeves and swivel glands as well as rod and piston seals for actuators.

5.1.1 Description and Rating

Table 1 describes different types of slipper seals for no backup-width glands according to AS4716 and provides a review of the advantages/disadvantages of each slipper seal configuration.

Table 1 - Review of different slipper seals for no backup-width glands according to AS4716

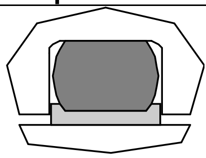
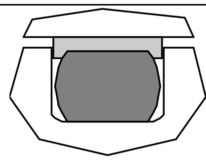
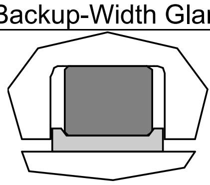
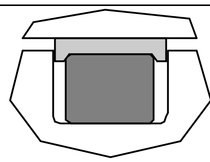
	Description - O-Ring Energized Cap Seal - No Backup-Width Gland - Bi-Directional	**Rating**
	  Rod Seal Piston Seal	Friction advantage versus O-ring Static .... Good Dynamic .... Fair
 (a) (b) (c)	Use on Rod and Piston May not stay in place during assembly May tip in the groove during use Gland dimensions impose high occupancy which increases the unit loading on the slipper seal and reduces the friction advantage of the PTFE	Service life versus other slipper seals .... Fair Sealing characteristics .... Good Recommended for new designs .... No
	Description - Square Ring Energized Cap Seal - No Backup-Width Gland - Bi-Directional	Rating
	  Rod Seal Piston Seal	Friction advantage versus O-ring Static .... Fair Dynamic .... Poor
 (a) (b) (c)	Use on Rod and Piston May not stay in place during assembly Reduced tendency to tip in the groove during use Gland dimensions impose high occupancy which increases the unit loading on the slipper seal and reduces the friction advantage of the PTFE	Service life versus other slipper seals .... Fair Sealing characteristics .... Good Recommended for new designs .... No

Table 1 - Review of different slipper seals for no backup-width glands according to AS4716 (continued)

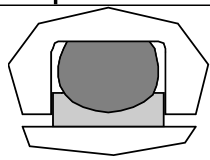
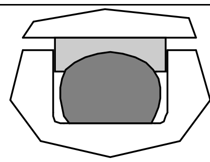
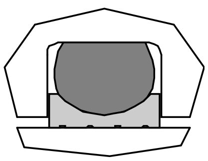
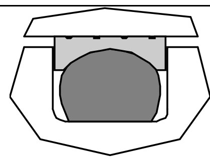
Description - O-Ring Energized Channel Seal - No Backup-Width Gland - Bi-Directional	**Rating**
 Rod Seal  Piston Seal Use on Rod and Piston (a) Will stay in place during assembly (b) Will not tip in the groove during use (c) Gland dimensions impose high occupancy which increases the unit loading on the slipper seal and reduces the friction advantage of the PTFE	Friction advantage versus O-ring Static .... Fair Dynamic .... Fair Service life versus other slipper seals .... Good Sealing characteristics .... Good Recommended for new designs .... Yes
NOTES: 1. The groove depth may be increased by the same amount as the web thickness dimension to reduce the occupancy and/or the squeeze level. 2. Consult the seal supplier(s) for recommendations of the optimum solution.	
Description - O-Ring Energized Grooved Cap Seal - No Backup-Width Gland - Bi-Directional	**Rating**
 Rod Seal  Piston Seal Use on Rod and Piston (a) Will stay in place during assembly (b) Will not tip in the groove during use (c) Gland dimensions impose high occupancy which increases the unit loading on the slipper seal and reduces the friction advantage of the PTFE (d) Miniature grooves on dynamic surfaces improve low-pressure leakage control; reduce friction	Friction advantage versus O-ring Static .... Excellent Dynamic .... Excellent Service life versus other slipper seals .... Excellent Sealing characteristics .... Good Recommended for new designs .... Yes

Table 1 - Review of different slipper seals for zero backup-width glands according to AS4716 (continued)

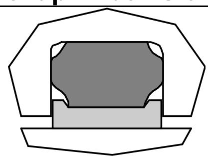
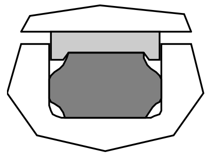
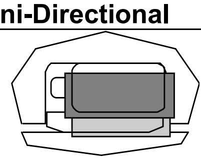
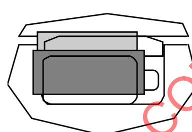
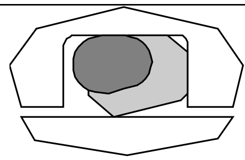
Description - Cruciform Ring Energized Cap Seal - Zero Backup-Width Gland - Bi-Directional	**Rating**
  Rod Seal Piston Seal Use on Rod and Piston (a) Will stay in place during assembly (b) Will not tip in the groove during use (c) A thick web improves service life (d) Reduced volumetric occupancy in groove reduces friction (e) Elastomer geometry reduces the tendency of elastomer to shuttle across a groove during pressure reversals (f) A special elastomeric energizer required	Friction advantage versus O-ring Static ………..……………........................ Excellent Dynamic ……………..…...……………... Excellent Service life versus other slipper seals .. Excellent Sealing characteristics …………………. Good Recommended for new designs ……… Yes
NOTES: 1. The groove depth may be increased by the same amount as the web thickness dimension to reduce the occupancy and/or the squeeze level. 2. Consult the seal supplier(s) for recommendations of the optimum solution.	
Description - Proprietary Seal - Zero Backup-Width Gland - Uni-Directional	**Rating**
High Pressure  Low Pressure Rod Seal Low Pressure  High Pressure Piston Seal Use on Rod and Piston (a) Use as a primary buffer seal in dual unvented glands (b) Uni-directional sealing (c) Stays in place during assembly (d) Thick web improves wear life (e) High modulus materials for improved extrusion resistance (f) Special elastomeric energizer required	Friction advantage versus O-ring Static ………..……….……................ Good Dynamic ………………...………………. Good Service life versus other slipper seals .. Excellent Sealing characteristics ………………..…. Fair Recommended for new designs …..…. No

Table 1 - Review of different slipper seals for zero backup-width glands according to AS4716 (continued)

Description - O-Ring Energized Proprietary Seal - Zero Backup-Width Gland - Uni-Directional		**Rating**	
	High Pressure  Low Pressure	Friction advantage versus O-ring	
		Static ………………………………………	Good
		Dynamic ………………………………………	Good
	Use on Rod only	Service life versus other slipper seals …	Excellent
(a)	Use as a heavy duty high pressure seal	Sealing characteristics ………………………	Good
(b)	Uni-directional sealing	Recommended for new designs …………	Yes
(c)	Stays in place during assembly		
(d)	Thick seal web improves wear life		
(e)	High modulus materials for improved extrusion resistance		
(f)	Full groove depth of slipper seal heel may lead to installation difficulties on small rod sizes		

5.2 Slipper Seals for One Backup-Width Glands according to AS4716

When specifying slipper seals for a one backup-width gland, the choice of basic configurations is limited. Space is a consideration over the two backup-width gland. Description and Rating

Table 2 describes different types of slipper seals for one backup-width glands according to AS4716 and provides a review of the advantages/disadvantages of each slipper seal configuration.

Table 2 - Review of different slipper seals for one backup-width glands according to AS4716

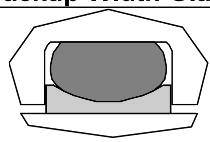
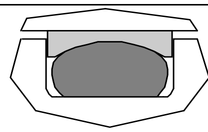
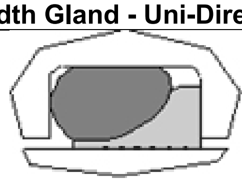
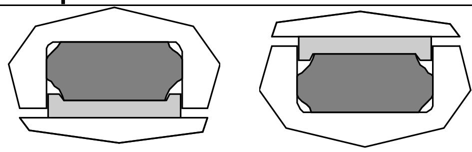
Description - O-Ring Energized Channel Seal - One Backup Width Gland - Bi-Directional	**Rating**
  Rod Seal Piston Seal Use on Rod and Piston (a) Use on linear actuators (b) Gland dimensions are favorable for limiting the effect of occupancy on friction	Friction advantage versus O-ring Static ……………….............................. Good Dynamic ……..……………………..…....... Good Service life versus other slipper seals ...... Excellent Sealing characteristics …………….…....... Good Recommended for new designs ………... Yes
NOTES: 1. The groove depth may be increased by the same amount as the web thickness dimension to reduce the occupancy and/or the squeeze level. 2. Consult the seal supplier(s) for recommendations of the optimum solution.	
Description - O-Ring Energized Cap Seal (Footseal) - One Backup-Width Gland - Uni-Directional	**Rating**
High Pressure  Low Pressure Use on Rod (a) Primarily for rod applications on linear actuators (b) Seals in one direction only (c) Gland dimensions impose high occupancy which increases the unit loading on the slipper seal and reduces the friction advantage of the PTFE (d) Seal contour improves leakage characteristics but tends to increase friction out of proportion with an increase in fluid pressure (e) Full groove depth of slipper heel may lead to installation difficulties on small rod sizes and small piston sizes where one-piece glands are used.	Friction advantage versus O-ring Static ……..……..……..................... Good Dynamic ………………..…...………….... Fair Service life versus other slipper seals ...... Excellent Sealing characteristics ……………….…... Good Recommended for new designs ………... Yes

Table 2 - Review of different slipper seals for one backup-width glands according to AS4716 (continued)

	Description - Cruciform Ring Energized Cap Seal - One Backup-Width Gland - Bi-Directional	Rating	
	 Rod Seal Piston Seal	Friction advantage versus O-ring	
		Static ……….…………….........................	Excellent
		Dynamic ……………...…...………...........	Excellent
	Use on Rod and Piston	Service life versus other slipper seals	Excellent
(a)	Will stay in place during assembly	Sealing characteristics …….…………….....	Good
(b)	Will not tip in the groove during use	Recommended for new designs ………..	Yes
(c)	A thick web improves service life		
(d)	Reduced volumetric occupancy in groove reduces friction		
(e)	Elastomer geometry reduces the tendency of elastomer to shuttle across a groove during pressure reversals		
(f)	A special elastomeric energizer required		

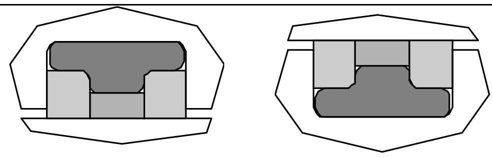
	Description - Proprietary Seal Assembly - One Backup-Width Gland - Bi-Directional	Rating	
	 Rod Seal Piston Seal	Friction advantage versus O-ring	
		Static ……….…………….........................	Excellent
		Dynamic ……………...…...………...........	Excellent
	Use on Rod and Piston	Service life versusother slipper seals	Excellent
(a)	Use as a heavy-duty, high-pressure piston or rod seal	Sealing characteristics …….…………….....	Good
(b)	Will stay in place during assembly	Recommended for new designs ………..	Yes
(c)	Thick web improves service life		
(d)	Special elastomeric energizer required		
(e)	Positive actuation of scarf-cut backup reduces incidence of cap extrusion and prevents pressure trapping		

Table 2 - Review of different slipper seals for one backup-width glands according to AS4716 (continued)

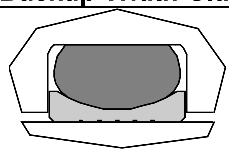
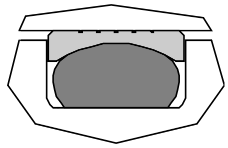
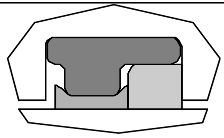
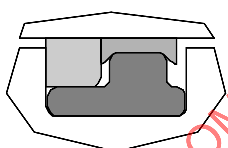
Description - O-Ring Energized Grooved Cap Seal - One Backup-Width Gland - Bi-Directional		Rating	
	 Rod Seal  Piston Seal	Friction advantage versus O-ring	
		Static ……….…………….........................	Excellent
		Dynamic ……………...…...………..........	Excellent
	Use on Rod and Piston	Service life versus other slipper seals ..	Excellent
(a)	Use as a heavy-duty, high-pressure piston seal	Sealing characteristics ……..…………..	Good
(b)	Will stay in place during assembly	Recommended for new designs ……...	Yes
(c)	A thick web improves service life		
(d)	Miniature grooves improve low-pressure leakage control and reduce friction		
NOTES: 1. The groove depth may be increased by the same amount as the web thickness dimension to reduce the occupancy and/or the squeeze level. 2. Consult the seal supplier(s) for recommendations of the optimum solution.			
Description - Proprietary Seal Assembly - One Backup-Width Gland - Uni-Directional		**Rating**	
	High Pressure  Low Pressure Rod Seal Low Pressure  High Pressure Piston Seal	Friction advantage versus O-ring	
		Static ……….…………….........................	Excellent
		Dynamic ……………...…...………..........	Excellent
	Use on Rod and Piston	Service life versusother slipper seals ...	Excellent
(a)	Use as heavy duty, high pressure seal	Sealing characteristics ………………..	Good
(b)	Seals in both directions, but resists high pressure in one direction only	Recommended for new designs ……...	Yes
(c)	Will stay in place during assembly		
(d)	Thick web improves service life		
(e)	Special elastomeric energizer required		
(f)	Positive actuation of scarf-cut backup ring reduces incidence of cap extrusion		

Table 2 - Review of different slipper seals for one backup-width glands according to AS4716 (continued)

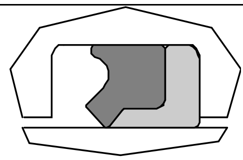
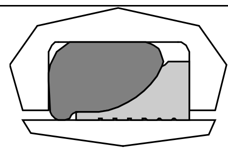
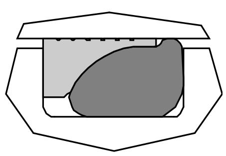
	Description - Proprietary Seal Assembly - One Backup-Width Gland - Uni-Directional	Rating	
	High Pressure  Low Pressure	Friction advantage versus O-ring Static ………...……………................. Dynamic ………………...….………….........	 Excellent Excellent
	Use on Rod	Service life versusother slipper seals ... Sealing characteristics.. ……………....... Recommended for new designs ……...	Good Excellent Yes
(a)	Primarily for rod applications on linear actuators		
(b)	Uni-directional sealing		
(c)	Uses proprietary elastomer		
(d)	Unique design limits elastomer contact and controls friction		
(e)	May be used as low pressure seal, for example, secondary seal in dual vented application		
(f)	Full groove depth of slipper heel may lead to installation difficulties on small rod sizes		
	Description - O-Ring Energized Proprietary Seal - One Backup-Width Gland - Uni-Directional	**Rating**	
	High Pressure  Low Pressure Rod Seal Low Pressure  High Pressure Piston Seal	Friction advantage versus O-ring Static ……………….............................. Dynamic ……..……………………..……..	 Good Good
	Use on Rod and Piston	Service life versusother slipper seals ... Sealing characteristics.. ……………....... Recommended for new designs ……….	Excellent Excellent Yes
(a)	Use primarily as a rod seal		
(b)	Uni-directional sealing		
(c)	O-ring contact improves leakage characteristics		
(d)	Optional miniature grooves improve low pressure leakage control and reduce friction		
(e)	Full groove depth of slipper heel may lead to installation difficulties on small rod sizes		

Table 2 - Review of different slipper seals for one backup-width glands according to AS4716 (continued)

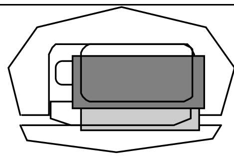
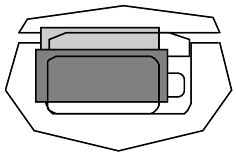
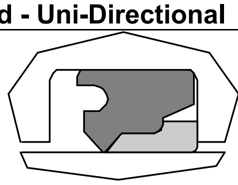
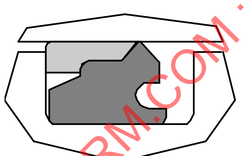
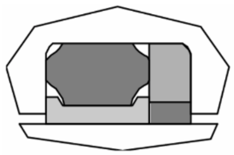
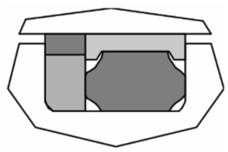
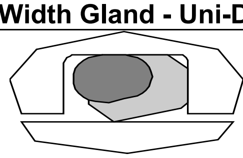
Description - Proprietary Seal Assembly - One Backup-Width Gland - Uni-Directional	Rating
High Pressure  Low Pressure Rod Seal Low Pressure  High Pressure Piston Seal Use on Rod and Piston (a) Use as primary buffer seal in dual unvented glands (b) Unidirectional sealing (c) Will stay in place during assembly (d) Thick web improves service life (e) Special elastomeric energizer required (f) High modulus materials for improved extrusion resistance	Friction advantage versus O-ring Static …………….......................... Good Dynamic ……..…………………..…... Good Service life vs other slipper seals .... Excellent Sealing characteristics ……………..….. Fair Recommended for new designs …...... No
Description - Proprietary Seal Assembly - One Backup-Width Gland - Uni-Directional	**Rating**
High Pressure  Low Pressure Rod Seal Low Pressure  High Pressure Piston Seal Use on Rod and Piston (a) Primarily for rod applications on linear actuators (b) Unidirectional sealing (c) Unique design limits elastomeric contact and controls friction (d) High modulus materials for improved extrusion resistance (e) Special elastomeric energizer required	Friction advantage versus O-ring Static …………….......................... Good Dynamic ……..……………..……...... Excellent Service life vs other slipper seals ……. Good Sealing characteristics ……...…….…... Excellent Recommended for new designs …...... Yes

Table 2 - Review of different slipper seals for one backup-width glands according to AS4716 (continued)

	Description - Cruciform Ring Energized Cap Seal - One Backup-Width Gland - Uni-Directional	**Rating**
	High Pressure  Low Pressure Rod Seal Low Pressure  High Pressure Piston Seal	Friction advantage versus O-ring Static ………..……………....................... Excellent Dynamic ……………...…...……….......... Excellent
	Use on Rod and Piston	Service life versus other slipper seals .. Excellent
(a)	Use as a heavy-duty high-pressure seal	Sealing characteristics ………………….. Good
(b)	Bi-directional sealing, but backup provides high-pressure extrusion resistance in one direction only	Recommended for new designs ……... Yes
(c)	Stays in place during assembly	
(d)	A thick web improves service life	
(e)	The high modulus dynamic backup ring component prevents extrusion of the PTFE cap and the static PTFE backup ring prevents abrasion to the elastomeric energizer	
(f)	A special elastomeric energizer required	
	Description - O-Ring Energized Proprietary Seal Assembly - One Backup-Width Gland - Uni-Directional	**Rating**
	High Pressure  Low Pressure	Friction advantage versus O-ring Static ………..……………....................... Excellent Dynamic ……………...…...……….......... Excellent
	Use on Rod only	Service life versus other slipper seals .. Excellent
(a)	Use as a heavy-duty high-pressure seal	Sealing characteristics ………………….. Good
(b)	Uni-directional sealing	Recommended for new designs ……... Yes
(c)	Stays in place during assembly	
(d)	A thick web improves service life	
(e)	High modulus backup rings may be incorporated to prevent extrusion	
(f)	Full groove depth of slipper heel may lead to installation difficulties on small rod sizes	

5.3 Slipper Seals for Two Backup-Width Glands according to AS4716

There are several slipper seal configurations for two backup-width glands. Some types are for general-purpose applications and others are intended for special purposes.

5.3.1 Description and Rating

Table 3 describes different types of slipper seals for two backup-width glands according to AS4716 and provides a review of the advantages/disadvantages of each slipper seal configuration.

Table 3 - Review of different slipper seals for two backup-width glands according to AS4716

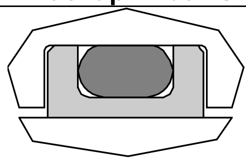
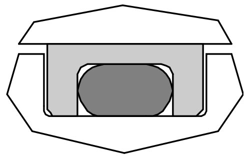
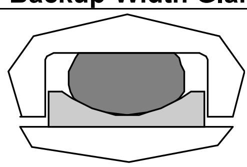
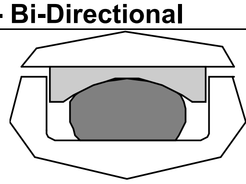
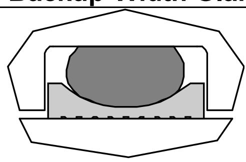
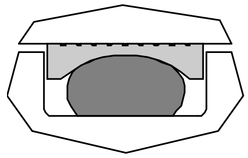
Description - O-Ring Energized Channel Seal - Two Backup-Width Gland - Bi-Directional	**Rating**
  Rod Seal Piston Seal Use on Rod or Piston (a) Possible web cracking during folding of rod seals. (b) Stretching of piston seals may shorten the life (c) O-ring may be damaged adjacent to the bottom of the leg (d) Gland dimensions are favorable for limiting the effect of occupancy on friction (e) Difficult to install in small sizes due to legs being full groove depth	Friction advantage versus O-ring Static .... Good Dynamic .... Good Service life versus other slipper seals .... Poor Sealing characteristics .... Good Recommended for new designs .... No
Description - O-Ring Energized Cap Seal - Two Backup-Width Gland - Bi-Directional	**Rating**
  Rod Seal Piston Seal Use on Rod and Piston (a) Will stay in place during assembly (b) Will not tip in the groove during use (c) A thick web improves service life (d) Reduced volumetric occupancy in groove reduces friction	Friction advantage versus O-ring Static .... Good Dynamic .... Good Service life versusother slipper seals .... Excellent Sealing characteristics .... Good Recommended for new designs .... No
NOTES: 1. The groove depth may be increased by the same amount as the web thickness dimension to reduce the occupancy and/or the squeeze level. 2. Consult the seal supplier(s) for recommendations of the optimum solution.	

Table 3 - Review of different slipper seals for two backup-width glands according to AS4716 (continued)

Description - O-Ring Energized Grooved Cap Seal - Two Backup-Width Gland - Bi-Directional	**Rating**
  Rod Seal Piston Seal Use on Rod and Piston (a) Will stay in place during assembly (b) Will not tip in the groove during use (c) A thick web improves service life (d) Reduced volumetric occupancy in groove reduces friction (e) Miniature grooves improve low-pressure leakage control; reduce friction, improve wear life	Friction advantage versus O-ring Static .... Excellent Dynamic .... Excellent Service life versus other slipper seals .. Excellent Sealing characteristics .... Good Recommended for new designs .... No
NOTES: 1. The groove depth may be increased by the same amount as the web thickness dimension to reduce the occupancy and/or the squeeze level. 2. Consult the seal supplier(s) for recommendations of the optimum solution.	

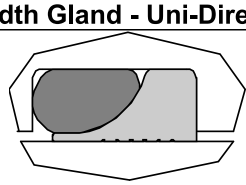
Description - O-Ring Energized Cap Seal (Footseal) - Two Backup-Width Gland - Uni-Directional	**Rating**
High Pressure  Low Pressure Use on Rod (a) Use primarily as a rod seal (b) Unidirectional sealing (c) Gland dimensions are favorable for limiting the effect of occupancy on friction (d) Full groove depth of slipper heel may lead to installation difficulties on small rod sizes	Friction advantage versus O-ring Static .... Good Dynamic .... Fair Service life versusother slipper seals ... Excellent Sealing characteristics .... Good Recommended for new designs .... Yes

Table 3 - Review of different slipper seals for two backup-width glands according to AS4716 (continued)

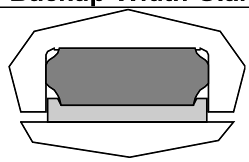
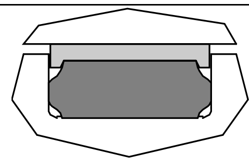
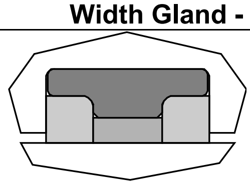
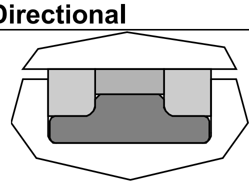
	Description - Cruciform Ring Energized Cap Seal - Two Backup-Width Gland - Bi-Directional	Rating
	 	Friction advantage versus O-ring Static ……………….............................. Excellent Dynamic ……..……………………............ Excellent
	Rod Seal Piston Seal	
	Use on Rod and Piston	Service life versus other slipper seals ..... Excellent Sealing characteristics ………………...... Good Recommended for new designs ….…..... Yes
(a)	Will stay in place during assembly	
(b)	Will not tip in the groove during use	
(c)	A thick web improves service life	
(d)	Reduced volumetric occupancy in groove reduces friction	
(e)	Elastomer geometry reduces the tendency of elastomer to shuttle across the groove during pressure reversals	
(f)	A special elastomer energizer required	
	Description - Proprietary Seal Assembly - Two Backup-Width Gland - Bi-Directional	**Rating**
	 	Friction advantage versus O-ring Static ……………….............................. Excellent Dynamic ……..……………………............ Excellent
	Rod Seal Piston Seal	
	Use on Rod and Piston	Service life versus other slipper seals ..... Excellent Sealing characteristics ………………...... Good Recommended for new designs ……...... Yes
(a)	Use as heavy-duty, high-pressure piston and rod seal	
(b)	Will stay in place during assembly	
(c)	Thick web improves service life	
(d)	Special elastomeric energizer required	
(e)	Positive actuation of scarf-cut backup reduces the incidence of cap extrusion and prevents pressure trapping	

Table 3 - Review of different slipper seals for two backup-width glands according to AS4716 (continued)

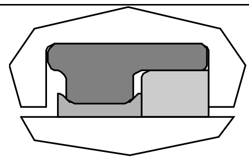
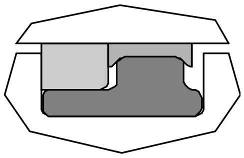
	Description - Proprietary Seal Assembly - Two Backup-Width Gland - Uni-Directional	**Rating**	
	High Pressure  Low Pressure Rod Seal Low Pressure  High Pressure Piston Seal	Friction advantage versus O-ring Static ………………............................. Dynamic ……..……………………..........	 Excellent Excellent
	Use on Rod and Piston	Service life versus other slipper seals ...	Excellent
(a)	Use mainly as heavy-duty, high pressure rod seal	Sealing characteristics …………………..	Good
(b)	Seals in both directions, but resists high pressure in one direction only	Recommended for new designs ……...	Yes
(c)	Excellent as second stage seal in dual seal application		
(d)	Will stay in place during assembly		
(e)	Thick web improves service life		
(f)	Special elastomeric energizer required		
(g)	Positive actuation of scarf-cut backup reduces incidence of cap extrusion and prevents pressure trapping		

Table 3 - Review of different slipper seals for two backup-width glands according to AS4716 (continued)

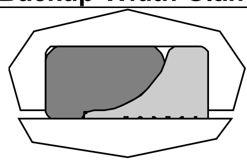
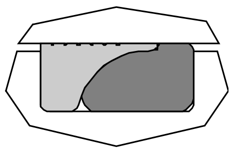
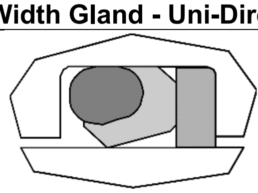
Description - O-Ring Energized Proprietary Seal Assembly - Two Backup-Width Gland	**Rating**
 Rod Seal  Piston Seal	Friction advantage versus O-ring Static ………………………………..….. Good Dynamic ……..…………..…………….. Good
Use on Rod and Piston (a) Use primarily as a rod seal (b) Uni-directional sealing (c) O-ring contact improves leakage characteristics (d) Optional miniature grooves improve low pressure leakage control; reduce friction (e) Full groove depth of slipper heel may lead to installation difficulties on small rod sizes	Service life versusother slipper seals ... Excellent Sealing characteristics ………………... Good Recommended for new designs ……... Yes
Description - O-Ring Energized Proprietary Seal Assembly - Two Backup-Width Gland - Uni-Directional	**Rating**
 	Friction advantage versus O-ring Static ……………….........................…. Good Dynamic ……..…………………….……... Good
Use on Rod only (a) Use as heavy duty high pressure seal (b) Uni-directional sealing (c) Will stay in place during assembly (d) Thick web improves service life (e) High modulus materials for extrusion resistance (f) Full groove depth of slipper heel may lead to installation difficulties on small rod sizes	Service life versusother slipper seals ... Excellent Sealing characteristics ………………... Good Recommended for new designs ……... Yes

Table 3 - Review of different slipper seals for two backup-width glands according to AS4716 (continued)

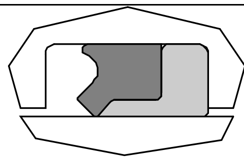
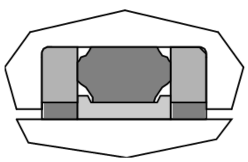
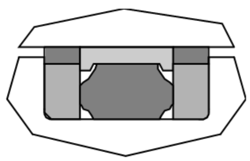
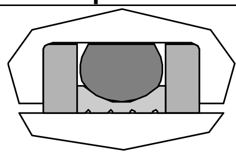
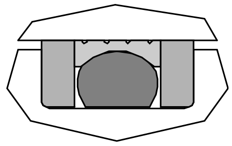
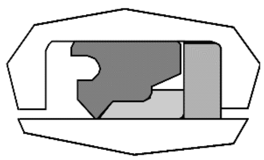
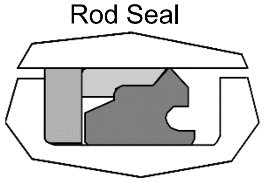
	Description - O-Ring Energized Proprietary Seal Assembly - Two Backup-Width Gland - Uni-Directional	**Rating**
	High Pressure  Low Pressure	Friction advantage versus O-ring Static ………………............................... Excellent Dynamic ……..………………….……......... Excellent
	Use on Rod	Service life versus other slipper seals .. Excellent Sealing characteristics ………………….... Good Recommended for new designs ……... Yes
(a)	Primarily for rod applications on linear actuators	
(b)	Unidirectional sealing	
(c)	Uses proprietary elastomer	
(d)	Unique design limits elastomer contact and controls friction	
(e)	May be used as low pressure seal, for example, secondary seal in dual vented application	
(f)	Full groove depth of slipper heel may lead to installation difficulties on small rod sizes	
	Description - Cruciform Ring Energized Cap Seal - Two Backup-Width Gland - Bi-Directional	**Rating**
	  Rod Seal Piston Seal	Friction advantage versus O-ring Static ………………............................... Excellent Dynamic ……..………………….……......... Excellent
	Use on Rod and Piston	Service life versus other slipper seals .. Excellent Sealing characteristics ………………….... Good Recommended for new designs ……... Yes
(a)	Use as heavy-duty, high-pressure rod and piston seal	
(b)	Will stay in place during assembly	
(c)	A thick web improves service life	
(d)	A high modulus dynamic backup ring component prevents extrusion, static PTFE backup ring prevents abrasion to the elastomeric energizer	
(e)	A special elastomeric energizer required	
(f)	Elastomer geometry reduces the tendency of elastomer to shuttle across the groove during pressure reversals	

Table 3 - Review of different slipper seals for two backup-width glands according to AS4716 (continued)

	Description - O-Ring Energized Grooved Cap Seal - Two Backup-Width Gland - Bi-Directional	Rating	
	  Rod Seal Piston Seal	Friction advantage versus O-ring Static ………………... Dynamic ……..……………………..........	 Excellent Excellent
	Use on Rod and Piston	Service life versus other slipper seals .	Excellent
(a)	Use as heavy-duty, high-pressure rod and piston seal	Sealing characteristics ………………..	Good
(b)	Miniature grooves help to lower friction	Recommended for new designs ……...	Yes
(c)	Grooved sealing surface provides greater leakage control		
(d)	Filled PTFE backup rings prevent high pressure extrusion		
(e)	Standard elastomeric O-ring energizer		
	Description - Proprietary Seal Assembly - Two Backup-Width Gland - Uni-Directional	**Rating**	
	High Pressure  Low Pressure Rod Seal Low Pressure  High Pressure Piston Seal	Friction advantage versus O-ring Static ………………... Dynamic ……..……………………..........	 Good Excellent
	Use on Rod and Piston	Service life versusother slipper seals ..	Good
(a)	Primarily for rod applications on linear actuators and as secondary seals	Sealing characteristics ………………......	Excellent
(b)	Uni-directional sealing	Recommended for new designs ……...	Yes
(c)	High modulus materials for extrusion resistance		
(d)	Unique design limits elastomeric contact and controls friction		
(e)	A special elastomeric energizer required		

5.4 Slipper Seals Requiring Special Glands

Some slipper seal designs have features that prevent the fitting of the seal to a standard AS4716 gland.

5.4.1 Description and Rating

Table 4 describes different types of slipper seal designs that have features that excludes fitting the seal to a standard AS4716 O-ring gland and provides a review of the advantages/disadvantage of each slipper seal configuration.