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SECOND REVISION

NAVAL SHIPS' TECHNICAL MANUAL

CHAPTER 078

VOLUME 1 – SEALS

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CHAPTER 078
VOLUME 1.
SEALS

SECTION 1.
GENERAL

078–1.1 INTRODUCTION

078–1.1.1 Seals are devices which prevent or control the escape of fluids or gases and prevent entry of foreign materials. There are hundreds of sealing devices and it is impossible to cover each one in this volume. This volume describes a number of the sealing devices used aboard Navy ships. Emphasis is placed on devices which are covered by military specifications or are interchangeable with devices used in standard configuration glands. Packings and gaskets are covered in Volume 2.

078–1.2 DEFINITIONS

078–1.2.1 GASKETS, PACKINGS, AND SEALS. In common usage, gaskets, packings, and seals are terms which are often used interchangeably. The seals covered in this volume include those preformed sealing devices that are manufactured to a specific size for a specific application along with any associated glands, rings, springs, and other auxiliary devices. Gaskets and packings, as defined below (paragraphs 078–1.2.1.1 and 078–1.2.1.2), are not covered in this volume.

078–1.2.1.1 Gasket. This term is applied to material used to provide a static seal between two mechanical joints, in which the sealing material is dependent on mechanical compression to form the seal. A gasket is often used to seal mating surfaces without a gland, where low differential pressure exists across the seal boundary. Gaskets are usually punched or cut from a sheet of thin, somewhat resilient material (see Volume 2).

078–1.2.1.2 Packing. This term is applied to material used to provide a seal in a mechanical coupling where some form of movement between the surfaces to be sealed is intended or anticipated. Packing material usually consists of bulk deformable materials which are shaped by manually adjusted compression to obtain and maintain effectiveness (see Volume 2).

078–1.2.1.3 Sealing Device (Seal). A seal is a device which prevents the escape of a fluid or gas or entry of a foreign material.

078–1.2.2 GENERAL TERMS. The terms defined in paragraphs 078–1.2.2.1 through 078–1.2.2.4 are frequently used in describing a sealing device.

078–1.2.2.1 Durometer Hardness. Durometer hardness is an indication of the hardness of the sealing material as determined by an indentor (see paragraph 078–2.2.5).

078–1.2.2.2 Squeeze. Squeeze is the amount by which a seal is compressed (distorted from its molded shape) when installed in the gland.

078–1.2.2.3 Dynamic Seal. A dynamic seal is a sealing device used between parts that have relative motion, such as piston or shaft seals.

078–1.2.2.4 Static Seal. A static seal is a type of seal where there is no relative motion between the seal and any parts in contact with the seal. Limited freedom may be provided to permit the seal to change its shape within the gland under pressure.

078–1.2.3 TYPES OF SEALING DEVICES. Sealing devices are often described by their shape or what they seal. some of the more commonly used types are listed in paragraphs 078–1.2.3.1 through 078–1.2.3.22.

078–1.2.3.1 O–Ring. An O–ring is a ring (seal) which has a round cross section.

078–1.2.3.2 Piston Ring. A piston sealing ring is usually one of a series and is often split to facilitate expansion or contraction.

078–1.2.3.3 Scraper Ring. A scraper ring is a ring which removes material by a scraping action.

078–1.2.3.4 T–Ring. A T–ring is a ring which has a T–shaped cross section.

078–1.2.3.5 U–Ring. A U–ring is a ring which has a U–shaped cross section.

078–1.2.3.6 V–Ring. A V–ring is a ring with a V–shaped cross section.

078–1.2.3.7 Wiper Ring. A wiper ring is a ring which removes material by a wiping action.

078–1.2.3.8 Cup Seal. A cup seal is a sealing device with a radial base integral with an axial cylindrical projection at its outer diameter.

078–1.2.3.9 Diaphragm Seal (Flat Diaphragm). A diaphragm seal is a relatively thin, flat or molded sealing device fastened and sealed at its periphery with its inner portion free to move.

078–1.2.3.10 Dished Diaphragm Seal. A dished diaphragm seal is a diaphragm in which the central area is depressed in a free state permitting longer travel than a comparable flat diaphragm.

078–1.2.3.11 Flange (Hat) Seal. A flange (hat) seal is a sealing device with a radial base integral with an axial projection at its inner diameter.

078–1.2.3.12 Lip Seal. A lip seal is a sealing device which has a flexible sealing projection.

078–1.2.3.13 Mechanical Seal. A mechanical seal is a sealing device in which sealing action is aided by mechanical force.

078–1.2.3.14 Oil Seal. An oil seal is a sealing device which retains oil.

078–1.2.3.15 O–Ring Seal. An O–ring seal is a sealing device which has a round cross section.

078–1.2.3.16 Piston Seal. A piston seal is a sealing device installed on a piston to maintain a sealing fit with a cylinder bore.

078–1.2.3.17 Pressure–Actuated Seal. A pressure–actuated seal is a sealing device in which sealing action is aided by fluid pressure.

078–1.2.3.18 Radial Seal. A radial seal is a sealing device which seals by radial contact pressure.

078–1.2.3.19 Rod Seal (Shaft or Stem). A rod seal is a sealing device which seals the periphery of a piston rod.

078–1.2.3.20 Sliding Seal. A sliding seal is a sealing device used between parts that have relative reciprocating motion.

078–1.2.3.21 Static Seal (Gasket). A static seal is a sealing device used between parts that have no relative motion (see paragraph 078–1.2.2.4).

078–1.2.3.22 Wiper Seal. A wiper seal is a sealing device which operates by a wiping action.

078–1.2.4 AUXILIARY DEVICES. Auxiliary devices include parts which hold or assist the sealing device in forming an effective seal. Various types of auxiliary devices are described in paragraphs 078–1.2.4.1 through 078–1.2.4.13.

078–1.2.4.1 Adapter (Support Ring). An adapter (support ring) is a seal support shaped to conform with the contour of the seal and the mating element.

078–1.2.4.2 Female Adapter. A female adapter is an adapter with a concave seal support. For V–ring sets, the female adapter is the last ring of the set and is flat on one side and V–shaped on the other to support the adjacent V–ring.

078–1.2.4.3 Male Adapter. A male adapter is an adapter with a convex seal support. For V–ring sets, the male adapter is the first ring (pressure end) of the set and is flat on one side and wedge shaped on the other to fit into the V of the adjacent V–ring.

078–1.2.4.4 Backup (Anti–Extrusion) Ring. A backup ring is a ring which bridges a clearance to minimize seal extrusion.

078–1.2.4.5 Filler Ring. A filler ring is a ring which fills the recess of a V–type or U–type seal.

078–1.2.4.6 Gland. A gland is the cavity of a stuffing box; the cavity which surrounds and supports the sealing device.

078–1.2.4.7 Gland Follower. A gland follower is the closure for a stuffing box.

078–1.2.4.8 Lantern Ring (Seal Cage). A lantern ring is a ring in line with a part in a gland to introduce a lubricant or a coolant to the packing and stuffing box.

078–1.2.4.9 Expander Spring. An expander spring is a spring which produces outward radial force.

078–1.2.4.10 Garter Spring. A garter spring is a compression or tension ring formed from helical wire spring with connected ends to produce force.

078–1.2.4.11 Spreader Spring. A spreader spring is a spring which produces sealing force against both lips of U or V seals.

078–1.2.4.12 Wave (Marcel) Spring. A wave spring is a compression spring of waved configuration which produces force.

078–1.2.4.13 Stuffing Box. A stuffing box is a cavity and a closure for a sealing device.

078–1.3 SEAL SELECTION

078–1.3.1 SEALS FOR NEW APPLICATIONS. For new applications of seals the designer has a choice of many standard and proprietary seals. Often the designer's selection is limited by shipbuilding specifications to seals covered by military specifications and standards unless specific approval is obtained. For difficult sealing situations the use of nonstandard or proprietary seals reflecting the advancing state of the art may be necessary. Although the information in this chapter may assist in selection of seals for new applications, the chapter does not cover all types of seals available and does not provide comparative performance data on various seal configurations. For this type of data the Naval Sea Systems Command (NAVSEA) and seal manufacturers should be consulted.

078–1.3.2 SUBSTITUTION OF SEALS IN EXISTING APPLICATIONS. Several circumstances may result in the need to consider use of a substitute seal. Unavailability of the required seal may necessitate the use of a substitute. If a seal is not performing properly (as in the case of short service life) a substitute seal may appear attractive. Seal substitution has the potential for causing serious problems and a number of factors must be considered before making any substitutions. Because of the number of shipboard seal applications and operating situations it is difficult to develop applicable criteria. Some guidelines which should apply to most situations are provided in paragraphs 078–1.3.2.1 through 078–1.3.2.3.

078–1.3.2.1 Emergency Substitutions. In emergency situations, such as at sea operations, a seal substitute may be necessary because the proper seal is not available. If the seal fits a standard gland, such as an O–ring gland, it may be possible to substitute a seal of a different material or a different configuration. In the case of an O–ring, it may be possible to make a replacement ring from cord stock or a larger ring. The splicing procedures for O–rings described in paragraphs 078–3.9 through 078–3.9.4 may also apply to other configuration rings of similar material. Section 2 provides information on compatibility of the substitute seal material with the application. Seals installed as emergency substitutions should be replaced at the first opportunity and do not require approval by NAVSEA.

078–1.3.2.2 Interim or Temporary Substitutions. The interim or temporary installation of a seal not listed on a component drawing or component Allowance Part List (APL) may be accomplished without NAVSEA approval under specific conditions:

a. On submarines the seal is not used for piping or components within the **Submarine Safety Certifications** Boundary.

b. The substitute seal is used in an application where it is required to seal pressure from only one direction and where rotary motion is 360 degrees or less.

c. The installed seal does not provide a satisfactory seal, has an unsatisfactory operating life, or is not readily available from stock.

d. The existing seal gland requires no modification to make the substitute seal fit properly other than the addition or removal of shims.

e. The substitute seal material has been determined to be compatible with the system fluid or gas and is suitable for the temperature and pressure of the application.

f. The seal is used in an application where an increase in seal friction cannot affect system or component performance.

NOTE

Interim or temporary installations that do not meet the above criteria should be referred to NAVSEA for technical approval.

078–1.3.2.3 Permanent Substitutions. Approval for permanent installation of substitute seals shall be requested from NAVSEA. The need for the change can then be considered both on an individual ship basis and on a classwide basis, and supporting documentation can be revised as necessary to ensure logistic support. Permanent substitution should be requested when it has been determined that the existing seal design is inadequate or that periodic maintenance is excessive. Each request for a permanent substitution must offer justification, including the following specific information:

a. Equipment or component identification.

b. APL number.

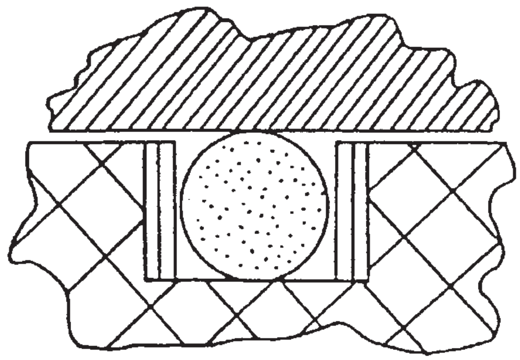
c. Technical manual number (if applicable).

d. Identification of the existing seal (NSN, part, or drawing number).

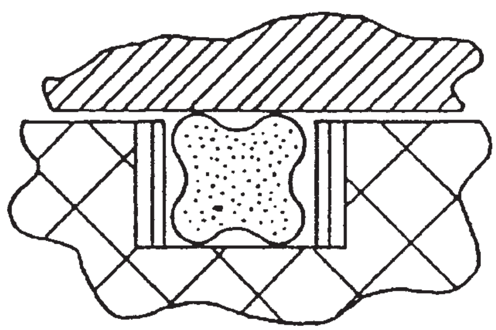
e. Reason(s) a substitute seal is needed.

f. Description of any experience with a substitute seal that had been installed on an interim or temporary basis.

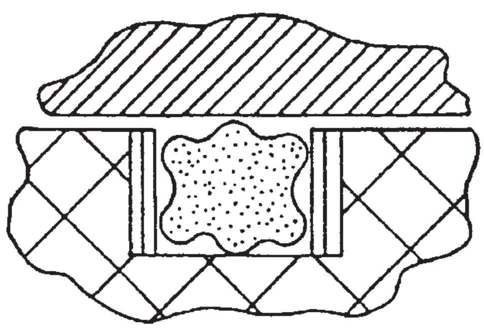
078–1.3.3 CROSS–SECTIONAL ILLUSTRATIONS OF PREFORMED SEALS AND PACKINGS. Illustrations of some of the preformed seals and packings used in Navy ship applications are shown in Figure 078–1–1, along with references to sections of this chapter that provide additional information on seal configurations. Although proprietary trade names may be given in some cases, no endorsement of a particular manufacturer's product is intended and similar packings manufactured by other companies may be equally suitable.



1. O-RING (SEE SECTION 3.)

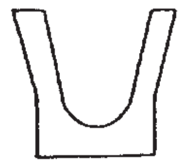


2. QUAD RINGS (SEE SECTION 6.)

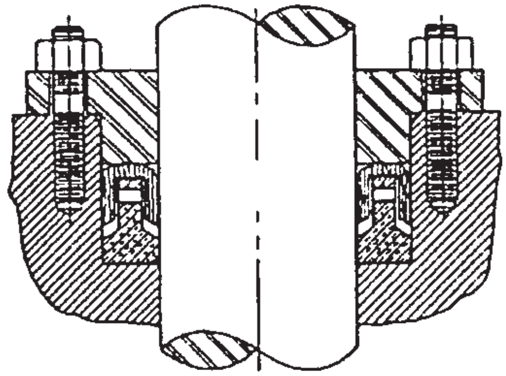


3. QUAD-O-DYN SEAL (SEE SECTION 6.)

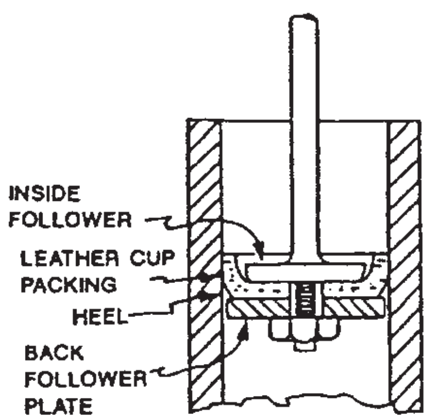
Figure 078–1–1. Preformed Packings (Sheet 1 of 5)



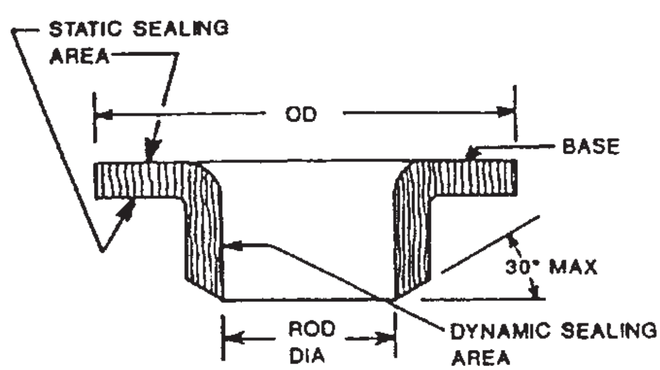
4. U-CUP (SEE SECTION 6.)



5. U-PACKING (SEE SECTION 6.)



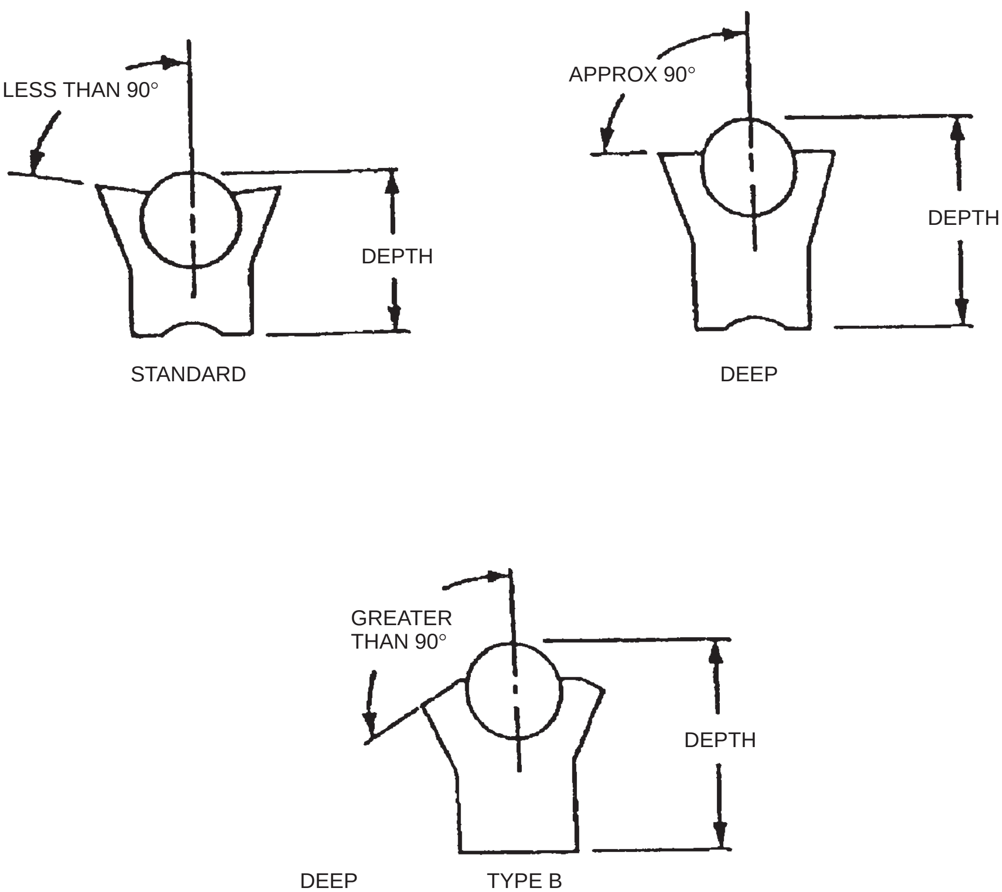
6. CUP PACKING (SEE SECTION 6.)



7. FLANGE PACKING (SEE SECTION 6.)

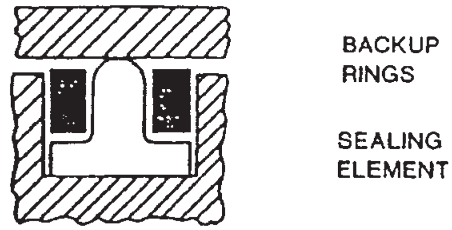
Figure 078–1–1. Preformed Packings (Sheet 2 of 5)

8. V-RINGS (SEE SECTION 4.)

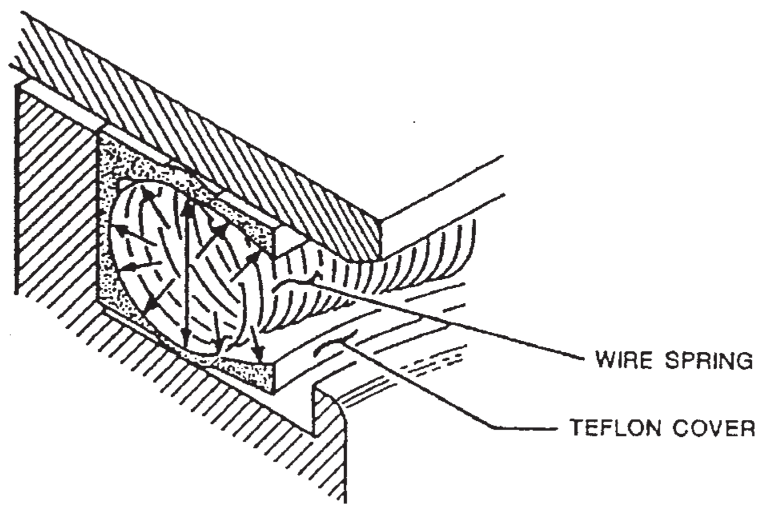


9. COMPRESSION LIP SEAL (POLYPAK, SEAL, PAC, POLY SEAL) (SEE SECTION 5.)

Figure 078–1–1. Preformed Packings (Sheet 3 of 5)

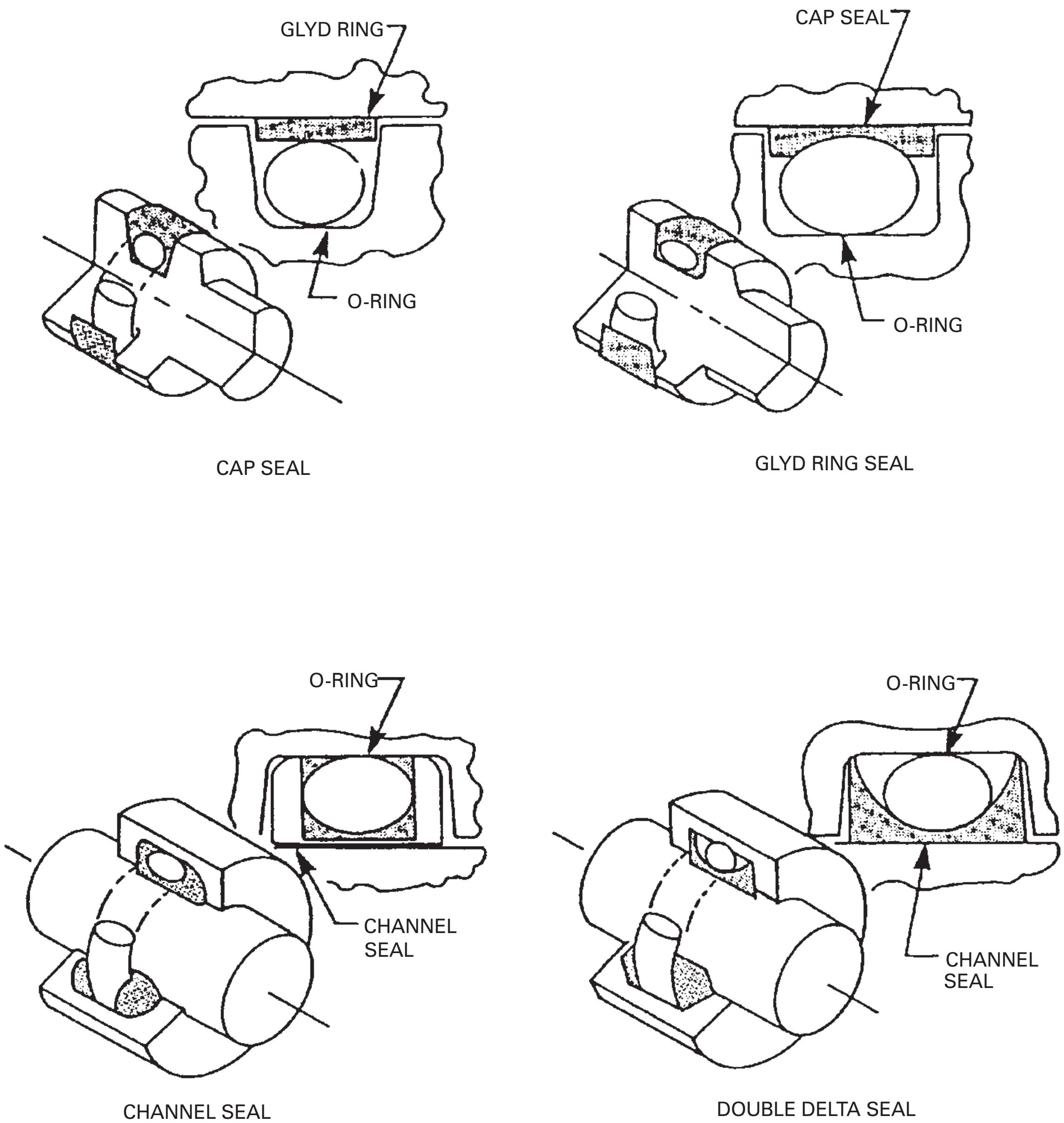


10. T-SEAL (SEE SECTION 6.)



11. TYPICAL OMNISEAL CROSS SECTION (SEE SECTION 6.)

Figure 078–1–1. Preformed Packings (Sheet 4 of 5)



12. SHAMBAM SEALS (SEE SECTION 3)

Figure 078–1–1. Preformed Packings (Sheet 5 of 5)

SECTION 2.
RUBBER MATERIALS FOR SEALS AND PACKINGS

078–2.1 GENERAL CHARACTERISTICS OF RUBBER SEAL MATERIALS

078–2.1.1 Some general characteristics of rubber materials most commonly used in seals are described in paragraphs 078–2.1.2 through 078–2.1.10.1. More detailed technical information and design data can be found in **Rubber and Rubber–Like Materials,** MIL–HDBK–149.

078–2.1.2 NITRILE (OR BUNA N) RUBBER. Nitrile (or Buna N) is the work horse of the industrial seal elastomers. Nitrile's value lies in its inherent resistance to most petroleum products and to its useful working temperature range which extends from at least –40 to 93.3°C (–40 to 200°F) for most nitrile compounds. Some military specifications for aircraft applications require a temperature capability of –53.9°C (–65°F).

078–2.1.2.1 All elastomers change gradually with age, but nitrile changes more rapidly than most of the other seal compounds. Tests made on nitrile after 13 years of storage in a cool place away from ozone, circulating air, and ultraviolet light showed that nitrile O–rings still have excellent, though somewhat changed, physical properties. If exposed to air and sunlight nitrile rubber may deteriorate in a few months or weeks. MIL–HDBK–695 allows a shelf life of 10 years for most nitrile seals, provided the compounds are stored out of contact with ozone, ultraviolet light, and circulating air, and are not exposed to high temperatures.

078–2.1.3 SBR, GRS, OR BUNA S RUBBER. Styrene butadiene (SBR) has poor resistance to petroleum fluids. When properly compounded, the abrasive resistance is excellent. SBR also has good resistance to nonpetroleum fluids used in automotive brake and power steering systems. SBR's resistance to aging is similar to that of the nitrile rubbers. SBR often is used as a seal for weathertight hatches on ships.

078–2.1.4 BUTYL RUBBER. Butyl has certain properties which make this compound important in a few applications. Butyl has a very low permeability rate, which means that gases will escape at a slower rate through butyl than through almost any other elastomer. This low permeability rate, together with fair compression set characteristics and a good temperature range make butyl a preferred rubber for sealing gases. Temperature range is –53.9 to 107°C (–65 to 225°F). Butyl rubber has good resistance to water, steam, aging, and to the phosphate ester hydraulic fluids **(Skydrol, Fyrquel,** MIL–H–19457). Butyl has poor resistance to petroleum fluids.

078–2.1.5 CHLOROPRENE OR NEOPRENE RUBBER. Neoprene R (also called polychloroprene) was one of the first of the synthetic rubbers. The resistance of neoprene to petroleum fluid is much better than that of natural rubber. The early neoprenes (like natural rubber) exhibited an interesting property, called crystallization, which caused the neoprenes to lose their resilience and develop compression set after long or repeated exposure to low temperatures. This tendency has been overcome in the newer neoprene materials and one of the major present uses for neoprene seals is for refrigerants.

078–2.1.6 ETHYLENE PROPYLENE RUBBER. Ethylene propylene (EP) rubber seals are used as replacements for butyl seals in commercial aircraft hydraulic systems using primarily phosphate ester fluids. EP rubber seals tolerate higher temperatures than butyl seals. In addition to the excellent resistance to phosphate esters required for aircraft hydraulic systems, EP has superior resistance to hot water and steam. EP also has good resistance to ultraviolet light, oxygen, ozone, and both acid and basic fluids. EP's useful temperature range extends down to –53.9°C (–65°F), and this compound has high tensile strength and wear resistance, making EP a good material for many dynamic seals. EP, like butyl, has poor resistance to petroleum fluids.

078–2.1.7 FLUOROCARBON RUBBER. Fluorocarbon rubber is well known under the trade name **Viton** (DuPont) and **Fluorel** (Minnesota Mining and Manufacturing). Fluorocarbon rubber has good resistance to a wide range of fluids, including petroleum fluids; the compound is tough and wear–resistant and can be used at temperatures up to 204°C (400°F) for long periods. Fluorocarbon rubber has good resistance to ozone and aging, but sealing with fluorocarbon rubber is difficult at temperatures below –20°C (–4°F).

078–2.1.7.1 Fluorocarbon rubber is relatively expensive; a 1–inch fluorocarbon O–ring costs about three times as much as an industrial nitrile ring. MIL–HDBK–695 allows a shelf life of 20 years for applicable fluorocarbon seals.

078–2.1.8 NATURAL RUBBER. The use of natural rubber for industrial packing has almost ceased. Although natural rubber has low compression set, it has very poor resistance to petroleum fluids. In addition, natural rubber ages quite rapidly, especially when exposed to oxygen or ozone, so that even if the fluid is compatible with natural rubber, a synthetic rubber will usually do the job as well or better.

078–2.1.9 SILICONE RUBBER. Silicone rubber is well known because of its suitability over a wide temperature range. Some silicone compounds remain flexible below –101°C (–150°F) and some will resist temperatures up to 371°C (700°F) for short periods of time. Silicone compounds also have excellent resistance to the effects of aging and ozone and generally have outstanding compression set properties. A number of inherent characteristics keep the silicones from being the long–sought universal packing compound. Silicones have poor resistance to most petroleum fluids, although they can be used with high aniline point oils. In addition, the tensile strength and abrasive resistance of silicones are inferior to those of most other elastomers.

078–2.1.10 POLYURETHANE RUBBER. Polyurethane is noted for high tensile strength, outstanding wear and abrasive resistance, and for excellent resistance to extrusion. Polyurethane also holds up very well in petroleum fluids. Limitations of polyurethane rubber are primarily:

a. Loss of strength at higher temperatures; this compound is seldom recommended for service above 93.3 to 107°C (200 to 225°F) .

b. Swelling and softening in steam or hot water above 87.8°C (190°F).

078–2.1.10.1 Because Polyurethane rubber has poorer compression set resistance than other compounds, polyurethane packings are often designed to be pressure–assisted, or to be activated by a more resilient member.

078–2.2 IMPORTANT PHYSICAL PROPERTIES FOR SEAL MATERIALS

078–2.2.1 GENERAL. In the selection of a seal material, important considerations are that the material have physical properties suitable to the application as well as compatibility with the fluid which is being sealed. Frictional and wear characteristics, along with the hardness of the material and the ability of the seal material to operate over the temperature range of a particular application must be considered. The various physical properties of some rubber seal materials are compared in Table 078–2–1.

078–2.2.2 FLUID COMPATIBILITY. Fluid compatibility of various rubber and rubber–like materials is briefly included in paragraphs 078–2.1 through 078–2.1.10.1. Table 078–2–1 indicates the compatibility with hydraulic fluids commonly used in shipboard hydraulic systems. For compatibility with other fluids, see MIL–HDBK–149 or consult the seal manufacturer's catalog. Because of variations in rubber and fluid formulations by manufacturers, the fluid compatibility can vary significantly in some cases. For example, Buna N formulations compatible with MIL–H–5606 petroleum base hydraulic fluid may be subject to significant degradation when used in systems containing MIL–L–17672 and MIL–L–17331 petroleum base fluids.

078–2.2.3 FRICTION. Friction is present in dynamic seal operations. Increasing the sealing element contact pressure to minimize leakage increases the friction. Hardness of the packing material also influences friction. In general, harder materials have a lower coefficient of friction; that is, the friction force (drag) is a lower percentage of the contact force between the packing and the packing mating surface. In formed packings such as O–rings an increase in hardness also increases the contact load for a given size in a given gland, so a harder material may actually produce a higher friction load. Fluid pressure also affects friction load. Fluid pressure is transmitted more or less uniformly through the packing material (that is, equally in all directions), so increasing fluid pressure will increase the contact load between the packing and the packing mating surface, and friction load increases accordingly. Friction is also proportional to contact area, so increasing fluid pressure can produce a double effect. As fluid pressure rises, the packing increases its area of contact with the gland and increases the contact load at

Table 078–2–1. COMPARISON OF PHYSICAL PROPERTIES FOR SOME HYDRAULIC FLUID SEAL MATERIALS

Application	Seal Materials								
	Nitrile (Buna N)[3]	Styrene Butadiene (SBR, Buna S)	Butyl Rubber	Chloroprene (Neoprene)	Ethylene Propylene Rubber	Fluoro-carbon Rubber[2]	Natural Rubber	Silicone	TFE (Plastic)[4]
Alkyl Aryl Phosphate (Skydrol 500)	P	P	F	P	E	P	P	F	G
Tri Aryl Phosphate (MIL-H-19457)	P	P	E	P	E	E	P	PF	E
Petroleum Oil[1]	G	P	P	FG	P	E	P	PG	E
Synthetic Hydrocarbon (MIL-H-83282)	E	P	P	F	P	E	P	PG	E
Impermeability	G	F	E	G	G	G	F	P	G
Cold Resistance	G	F	G	G	GE	F	G	E	E
Tear Resistance	FG	PF	FG	FG	GE	F	GE	PF	E
Abrasion Resistance	G	G	FG	GE	GE	G	E	PF	E
Set Resistance	GE	F	FG	F	GE	GE	G	GE	P
Dynamic Properties	GE	G	F	F	GE	GE	G	P	P
Tensile Strength	GE	GE	G	G	GE	GE	E	P	E
Water/Steam Resistance	FG	FG	G	F	E	FG	FG	F	E
Heat Resistance	G	F	GE	F	E	E	F	E	E

LEGEND: E-Excellent; G-Good; F-Fair, P-Poor

NOTES:

1. Includes MIL-L-17672, MIL-L-17331, and MIL-H-5606. Compatibility with specific petroleum fluid should be checked (see paragraph 078-2.2.2).
2. The material is supplied under various trade names such as VITON (Du Pont) or FLUOREL (Minnesota Mining and Manufacturing Co) MIL-R-83248, and MIL-R-83485 apply.
3. Includes MIL-P-5516, MIL-P-25732, and MIL-P-5510.
4. Polytetrafluoroethylene, commonly identified as TEFLON (Du Pont Trade name).

the same time. A formed packing with a long, easily deformed lip will have more friction at high pressure but usually less at low pressure than another packing with a short stiff lip. Some seal materials contain graphite, molybdenum disulfide, or tetrafluoroethylene powder to reduce friction. Regardless of seal material, dynamic seals will have a much longer life if lubricated by some type of grease or oil. Often, the fluid medium will have ample lubricity, but in pneumatic and vacuum systems, supplementary lubrication is often needed.

078–2.2.3.1 Excessive static gland pressure should not be applied to lip type packings because excessive gland pressure destroys freedom of the lips to flex or breathe. Excessive gland pressure applied to a set of V–rings, for example, can change a long wearing lip packing to a high friction, rapid–wearing compression packing. Lip packings seal because the force of the liquid pressure expands the packing; as a result, the friction produced by the packing is in proportion to the pressure on the pressure stroke. If the liquid pressure is relieved on the return stroke the friction will be negligible. With a compression packing, the seal relies on mechanical pressure and the friction force produced by the compression packing is practically the same on the return stroke as on the pressure stroke.

078–2.2.4 WEAR. Designing seal materials for maximum wear resistance means designing for minimum friction. Minimum friction is ensured by adequate lubrication, minimum packing load, proper gland surface finish, a packing shape compatible with the pressure, and the right packing material. No specific material properties are indicative of good wear resistance. Packing materials for wear–resistant seals are selected primarily on the basis of prior experience. Abrasive metal particles or other foreign matter may cling to or become embedded in the gland surface, and with each stroke, will produce wear in packings or wiper rings. Filtration can remove most foreign particles from the circulating fluid, but additional precautions, such as use of wiper rings and scrapers, are needed to keep the particles from entering the system.

078–2.2.5 HARDNESS. A packing is intended to seal a fluid under pressure. The capacity of the packing to do so depends on the hardness of the seal. In general, the higher the hardness of the packing, the higher the pressure the packing can seal. It must be recognized that high hardness makes assembly of the gland difficult in some cases and tends to increase abrasive loss in dynamic service. High hardness may also be accompanied by a greater–than–normal tendency toward compression set and stress relaxation in service. The most commonly used elastomers have a hardness between 65 and 75 on the Shore A Durometer (3–second reading). Some elastomers have a hardness between 75 and 85, and a few are even harder than 85 or softer than 65. Satisfactory hardness measurements cannot be made on an O–ring with a Shore durometer; therefore durometer measurements of O–ring compounds are made on 1/4 inch thick slabs of the compound having the same cure as the O–ring.

078–2.2.6 EXPLOSIVE DECOMPRESSION. Explosive decompression, or gas expansion rupture is caused by high–pressure gas trapped inside the seal. Rapid decrease in system pressure causes the gas trapped in the seal to expand to match the outside pressure and this expansion causes blisters and ruptures on the seal surface. If the volume of trapped gas is small the blisters may recede as the pressure is equalized with little effect on seal integrity. Small pits or blisters on the O–ring surface are an indication of explosive decompression. In severe cases, splits and fissures may be present which result in complete loss of seal integrity.

078–2.2.6.1 Seal Selection for Rapid Decompression Applications. Systems should be designed so that decompression time is sufficient to allow trapped gas to work out of the seal material. In addition, seal materials should be selected which have good resistance to explosive decompression. Generally, higher durometer, less permeable materials have greater resistance to explosive decompression. With the MIL–R–83248 fluorocarbon O–rings used in many Navy applications, the 90 durometer material has better resistance to explosive decompression than the 75 durometer material. Ethylene propylene (EPR) usually has a high resistance to explosive decompression as do some high durometer nitrile materials. If seals are failing due to explosive decompression, contact NAVSEA for recommendations as to more resistant materials. In designing components subject to rapid decompression, use seals with a small cross section to minimize problems.

078–2.2.7 TEMPERATURE. Temperatures higher than normal or lower than normal have a detrimental effect on elastomer performance. Heating an elastomer to a high temperature immediately reduces the strength and hardness of the elastomer and sometimes temporarily improves sealing ability by thermal expansion. Swell at high temperature causes compression set, stress relaxation, and further loss of strength. Most rubber compounds are gradually hardened by continued exposure; a few are softened. The best elastomers for high temperature service;

that is, above 149°C (300°F), are the silicones, fluorosilicones, and fluorocarbons. Low temperature immediately increases the strength and hardness of some elastomers, and reduces their sealing ability to some extent because of thermal contraction. Dwell at low temperatures causes some packings (such as neoprene O–rings) to lose all sealing ability because of crystallization of the rubber. Packing made of some silicone rubber compounds give good service at temperatures down to and below –51.1°C (–60°F).

078–2.3 IDENTIFICATION AND STORAGE

078–2.3.1 PACKAGING. Packages for O–ring seals manufactured to a government specification are marked to the requirements specified in MIL–P–4861. MIL–STD–129 identifies the required marking for each package as follows:

a. National Stock Number (NSN)

b. Nomenclature

c. Military Part Number

d. Material Specification

e. Manufacturer's Name

f. Manufacturer's Compound Number

g. Manufacturer's Batch Number

h. Contract Number Cure Date.

For items described by a commercial part number, use standard package marking in accordance with MIL–STD–129. Normally, unit and intermediate packs are also marked with the commercial part number.

078–2.3.1.1 Report receipt of O–ring packages which are not marked as described above to Defense Industrial Supply Center on Standard Form 364 (ROD), Attn: DISC–QP, for appropriate action.

078–2.3.2 STORAGE. Proper storage practices shall be observed to prevent deformation and deterioration of preformed packings. Most preformed packings are not damaged by several years of storage under ideal conditions. However, most synthetic rubbers deteriorate when exposed to heat, light, oil, grease, fuels, solvents, thinners, moisture, strong drafts, or ozone (form of oxygen formed by an electrical discharge). Damage by such exposure is magnified when rubber is under tension, compression, or stress. Conditions to be avoided include the following:

a. Deformation as a result of improper stacking of parts and storage containers

b. Creasing caused by force applied to corners and edges and squeezing between boxes and storage containers

c. Compression and flattening, as a result of storage under heavy parts

d. Punctures caused by staples used to attach identification

e. Deformation and contamination due to hanging the preformed packings from nails or pegs (paragraph 078–2.3.2.1)

f. Contamination caused by adhesive tapes applied directly to preformed packing surfaces (paragraph 078–2.3.2.1)

g. Contamination by fluids leaking from parts stored above and adjacent to preformed packing surface

h. Retention of overage parts as a result of improper storage arrangement or illegible identification (paragraph 078–2.3.2.1)

i. Exposure to adverse environments (paragraph 078–2.3.2.1).

078–2.3.2.1 Keep preformed packings in their original envelopes which provide preservation, protection, identification, and cure date. Secure a torn package with a pressure–sensitive, moisture–proof tape, but don't allow the tape to contact the preformed packing surfaces. **Arrange preformed packings so that older seals are used first**. Store rubber packing in an area protected from sunlight and drafts. Storage temperatures, also applicable to those components in which these packings are installed, should normally range from 15.6°C (60°F) to 38°C (100°F), and shall not exceed 52°C (125°F).

078–2.3.3 SHELF–LIFE. The shelf–life for seals, packings and gaskets is the period of time during which a properly packaged and stored item should be suitable for unrestricted use. Shelf–life requirements do not apply once the elastomer is installed.

078–2.3.3.1 Shelf–Life Managed Items. Shelf–life managed seals with a definite non–extendable period of shelf–life may be identified by an **Expiration Date** on the seal package. Some items carry an additional marking such as **Type I Shelf–Life Item**. These seals are managed in accordance with policies and procedures of the **Shelf–Life Management Manual, DoD 4140.27M**, and should be removed from the supply system when they reach their expiration dates. This manual covers items with a definite non–extendable period of shelf–life (Type I) and those items which may be extended after inspection, test or restorative action (Type II). Shelf–life managed seals are almost always non–extendable items since testing to determine if shelf–life could be extended is more costly than buying new seals. Most seals and packings with an expected shelf–life greater than 5 years are not under the shelf–life management program. Exceptions include items designated by the manual as Type I, Code X items having Individual Repair Part Ordering Data (IRPOD). Some seals used in Navy nuclear reactor plants with shelf–lives greater than 5 years are in this category.

078–2.3.3.2 Non–Managed Items. Most seals and packings with an expected (or suggested) shelf–life exceeding 5 years are not subject to shelf–life management program. This means that the supply system does not remove items from supply when they exceed their suggested shelf–life. Non–managed items do not carry an expiration date. However, they may carry a **Cure Date** (see paragraph 078–2.3.4.1) and some carry a **Use Before** date (see paragraph 078–2.3.5.2). Elastomeric materials are subject to deterioration with time, particularly if not properly stored. Accordingly, personnel installing seals have a responsibility to verify that the material to be installed is suitable for service. In the absence of specific shelf–life requirements for seals and packings, the suggested shelf–lives of rubber compounds listed in MIL–HDBK–695 should be used as guidance in determining the age suitability. (See paragraph 078–2.4.4).

078–2.3.3.3 MIL–HDBK–695 Shelf–Life Requirements. This handbook provides information on the suggested shelf–life of elastomeric products described by common and trade names, Military, Federal and recognized industry specifications and standards. This handbook is intended as a guide only. Overage items should be carefully evaluated for possible use as originally intended before being discarded on the basis of the suggested shelf–life of this handbook. NAVSEA recommends that the expected shelf–life suggestions of MIL–HDBK–695 be used as a guidance in determining whether an item should be used. See paragraph 078–2.5 for guidance regarding use of materials exceeding the suggested shelf–life of MIL–HDBK–695.

078–2.3.4 MARKING OF SEAL PACKAGES FOR SHELF–LIFE. Seal packages are marked with data to identify the age of the seal and aid in shelf–life management. These markings are explained in the following paragraphs.

078–2.3.4.1 Cure Date. Cure date is the date of manufacture. The cure date is the basis of determining the age of an elastomeric material. The cure date should be marked on the package for most seals and packings. Consider packings manufactured during any given month or quarter to be 1 month or one quarter old at the end of the following month or quarter. There are two methods used to designate cure date:

a. When the shelf–life of an item is a maximum of 3 years, cure date is expressed in terms of the month of the calendar and the year, i.e., 10–88.

b. When the expected shelf–life of the item is in excess of 3 years, cure date is expressed in terms of the quarter of the calendar year and the year, i.e., 4Q–88, where the calendar year is divided into quarters as follows:

First Quarter:	January, February, March
Second Quarter:	April, May, June
Third Quarter:	July, August, September
Fourth Quarter:	October, November, December

078–2.3.5 EXPIRATION DATE. Only packages with a non–extendable shelf–life (Type I) carry an expiration date. This is the date beyond which non–extendable items (Type I) should be discarded as no longer suitable for issue or use. If an item does not carry an **Expiration Date**, it is not a Type I shelf–life managed item. A typical package marking will be **Cure Date 1Q82** followed by **Exp Date 1Q87**.

078–2.3.5.1 Inspection or Test Date. The date by which extendable items (Type II) should be subjected to inspection, test, or restoration. Type II items will have the inspection or test date marked on the package. (Low cost seals are not usually Type II items.)

078–2.3.5.2 USE BEFORE Date. A **Use Before** or **Use By** date is often marked on items not subject to shelf–life management to indicate when the material will reach its suggested shelf–life. This date is usually based on the guidance in MIL–HDBK–695 for various materials. For applications on Navy ships, the **Use Before** date should be considered the final date for unrestricted use. See paragraph 078–2.5 for restrictions regarding use of seal materials after the **Use Before** date. (This marking is being implemented for seals to military specifications which are not shelf–life managed.)

078–2.4 SEAL MATERIAL AND CONDITION VERIFICATION

078–2.4.1 PREINSTALLATION VERIFICATION. Prior to installing a seal, packing or gasket, it is necessary to verify that the correct material is being used and that the condition and age of the material is satisfactory. Seal condition verification is necessary even when the elastomer has not exceeded its suggested shelf–life. Guidance for seal material, condition and age verification is provided in the following paragraphs.

078–2.4.2 SEAL MATERIAL VERIFICATION. When installing a seal, verification of proper material is of primary importance since seals of different materials often look exactly alike. Seals (packings) should be stored in their original packages so that the identification data and cure date are available. Compare the identification data on the seal package with the Allowance Part List (APL), or other (technical manual, drawing) requirements. APL's are more likely to reflect current requirements than technical manuals. See paragraph 078–3.4.5 for guidance as to the identification of replacement O–rings for ship piping systems and components.

078–2.4.3 SEAL CONDITION VERIFICATION. More important than the age of an elastomer is its actual condition. Therefore, a visual and tactile examination of all seals should be conducted before their installation. This examination is to verify that the elastomer is pliable and shows no evidence of nicks, cuts, cracking, discoloration, flaking, tackiness, brittleness, permanent deformation or surface contaminants. Specific guidance cannot be provided for the tactile examination and pliability of each type of seals. However, for O–rings and similar seals it is recommended that the seals be stretched slightly before or during examination.

078–2.4.4 SEAL AGE VERIFICATION. Age is a factor to be considered when determining whether a seal is suitable for use since rubber products can deteriorate with age. Seal age verification is required for the conditions identified in paragraph 078–2.4.4.1. The procedures to be followed in seal age verification are identified in paragraphs 078–2.4.4.2 through 078–2.4.4.6 and depend upon how the seal package is marked.

078–2.4.4.1 Conditions Requiring Seal Age Verification. Seal age verification is required under the following conditions:

a. When the seal age exceeds the **Expiration Date** for shelf–life managed items or the **Use Before** date for non–managed items.

b. When no **Expiration** or **Use Before** date is indicated on the package and the age of the elastomer exceeds 8 years based on the cure date.

c. When no **Expiration Date** or **Use Before** date is indicated on the package and the cure date is unknown.

078–2.4.4.2 Items With Expired Shelf–Life. Type I items (see paragraph 078–2.3.3.1) should normally be discarded and not installed when the shelf–life is exceeded. Type I items are identifiable by the marking of the **Expiration Date** on the package. There are some exceptions under which use of these items is acceptable. The first case is when the shelf–life of the item has been extended by logistic managers and a revised expiration date is on the package. Another exception is for materials which were at one time shelf–life controlled but for which the recommended shelf–life in MIL–HDBK–695 was subsequently increased. As a result, many nitrile seals were changed from shelf–life managed items to non–managed items. Unfortunately, many packages in the supply system were not re–marked to indicate this change. Table 078–2–2 identifies some of the nitrile seals which are suitable for unrestricted use if less than 10 years old. Other seals which exceed the expiration date may be used only if they are within the recommended shelf–life identified in the latest revision of MIL–HDBK–695.

078–2.4.4.3 Non–Managed Items Under 8 Years of Age. For packages not marked with an **Expiration Date**, the seals are not shelf–life managed items and have an expected shelf–life of at least 8 years. The suggested shelf–life in MIL–HDBK–695 for rubber products not subject to shelf–life management is 8 years or longer. Therefore, seals without an **Expiration Date** or **Use Before** date may be used without any further age verification if determined by the cure date to be less than 8 years old.

078–2.4.4.4 Non–Managed Items Over 8 Years of Age. Seals, packings and gaskets over 8 years old based on the cure date but without an **Expiration** or **Use Before** date on the package should be verified in the following manner:

a. For commonly used seal materials see Table 078–2–2 to determine the expected shelf–life. For other rubber materials see MIL–HDBK–695.

b. If seal age exceeds the expected shelf–life, use of the seal is subject to the guidance in paragraph 078–2.5.

078–2.4.4.5 Items Exceeding Use Before Dates. Items marked with **Use Before** or **Use By** dates should be used prior to this date. After the date is exceeded, use is subject to the guidance of paragraph 078–2.5.

078–2.4.4.6 Items of Unknown Age. Proprietary, non–military specification parts are often not identified with a cure date, **Use Before** date or sufficient material identification to determine their suitability for use on the basis of age. Sometimes it is possible to determine the approximate age of the seal based on the date in the contract number identified on the package. When the age of the seal is suspected to be greater than 8 years and the material is unknown, use of the seal is subject to the guidance of paragraph 078–2.5 with one addition. The additional requirement, whether or not the seal is installed, is reporting the improper marking to the Inventory Control Point. For most seals, the Inventory Control Point is the Defense Industrial Supply Center. The reporting procedure is identified in paragraph 078–2.3.1.1.

Table 078–2–2. SUGGESTED SHELF-LIFE OF COMMONLY USED SEAL MATERIALS

Seal Specification (Standard)	Material	Suggested Shelf-life (Years)
*MIL–P–5315 (MS29512 & MS29513) *MIL–P–5510 (AN6290) *MIL–P–5516 (AN6227 & AN6230) *MIL–P–25732 (MS28775 & MS28778) *MIL–P–83461 Mare Island Compound P-52-2	Nitrile or Buna N	10
MIL–G–22050 NAS 1611, 1612 & 1613	Ethylene- Propylene Rubber	10
MIL–G–23652 MIL–R–25987 MIL–R–83248 MIL–R–83485	Fluorocarbon Rubber (Viton Fluorel)	20
*Note: These items are no longer shelf-life managed, however items may be received from the supply system with expired shelf-life dates based on older requirements when the shelf-life was 5 years. If under 10 years of age, these seals may be used without age restrictions despite the shelf-life expiration date. If over 10 years of age, see the guidance in paragraph 078−2.5.		

078–2.5 USING OVER–AGE SEALS NOT SUBJECT TO SHELF–LIFE MANAGEMENT

078–2.5.1 GENERAL GUIDANCE. Activities should use older seals first so that the seals do not exceed the suggested shelf–life of MIL–HDBK–695. The suggested shelf–lives in MIL–HDBK–695 are for guidance and not hard requirements. Per MIL–HDBK–695, non–managed items should be considered for possible use before being discarded. The suggested shelf–lives in MIL–HDBK–695 may be conservative in some cases. For example, one seal manufacturer has indicated that they have tested properly packaged nitrile O–rings with a suggested shelf–life of 10 years and found them to be satisfactory for use after 25 years although the hardness may have increased slightly. If multiple seals from the same batch are available, it is possible to run tests to determine if the seals comply with some of the more important specification requirements such as tensile strength, elongation, and hardness. However, testing is relatively expensive and not usually a cost effective solution. Testing should be limited to very critical applications where maximum confidence in seal reliability is necessary.

078–2.5.1.1 Factors For Consideration In Use of Over–Age Seals. The following factors should be considered before an over–age seal is used:

a. Can a seal which has not exceeded its suggested shelf–life be easily obtained?

b. Can the seal (packing) be replaced without significant effort and can the replacement be accomplished at sea? (Assurance of seal quality is more important in an application which requires significant installation effort and time as compared to one which requires only a few minutes.)

c. Will failure of the seal (packing) pose a significant hazard to personnel, equipment, or mission? (For most seals the failure mode is slight leakage, which will not pose a significant hazard.)

078–2.5.2 RESTRICTIONS FOR USE OF SEALS EXCEEDING THE SUGGESTED SHELF–LIFE. Non–managed seals which exceed the suggested shelf–life of MIL–HDBK–695 may be used if ship or component delivery schedules do not make installing a within–shelf–life seal cost effective and provided the following conditions apply:

a. Seal is properly stored in its original package.

b. The condition of the seal is verified to be satisfactory in accordance with paragraph 078–2.4.3.

c. The component or system in which the seal is installed is operationally tested after seal installation to verify satisfactory performance. (If feasible, operational test should be at low pressure as well as nominal operating pressure as many seals have more difficulty sealing at low pressure.)

d. System or equipment technical manuals do not prohibit installation of seals beyond their suggested shelf–life.

e. Seals which exceed their suggested shelf–life are not to be used in Navy nuclear reactor plant applications.

SECTION 3.
O–RINGS AND ANTI–EXTRUSION RINGS FOR O–RING APPLICATIONS

078–3.1 GENERAL

078–3.1.1 HOW O–RINGS SEAL. An O–ring is a torus, that is, it is doughnut shaped. Usually molded from rubber compounds, O–rings also can be molded or machined from plastic materials. An O–ring seal consists of an O–ring mounted in a groove or cavity (usually called a gland) in such a manner that the O–ring cross section is compressed (squeezed) when the gland is assembled. When installed, the compression of the O–ring cross section enables it to seal low fluid pressures. The method of sealing is illustrated in position A in Figure 078–3–1.

078–3.1.1.1 The greater the compression the greater is the fluid pressure that can be sealed by the O–ring, as shown in position A. The degree of compression is limited by the difficulty of assembling glands where the O–ring is greatly compressed, and by the possibility of encountering excessive abrasion of the highly compressed O–ring if one of the walls of the gland moves in an axial or circumferential direction relative to the other wall.

078–3.1.1.2 As the fluid pressure rises, the O–ring is pushed until it presses firmly against the downstream shoulder of the gland. The greater the pressure the more closely the O–ring conforms to the space into which it is forced. The pressure of the O–ring against the walls of the gland assembly equals the pressure caused by the recovery force of the compressed O–ring plus the fluid pressure. This pressure against the walls, and the stiffness of the O–ring in shear, prevent fluid from leaking past the O–ring. If the downstream clearance is large, the O–ring extrudes into this clearance, as shown in position B of Figure 078–3–1. The stiffness of the O–ring material in shear prevents the O–ring from completely extruding through the downstream clearance unless that clearance is abnormally large or the pressure is excessive.

078–3.1.2 ANTI–EXTRUSION (BACKUP) RINGS. Backup rings, also referred to as retainer rings, anti–extrusion devices, and non–extrusion rings, are washer–like devices which are installed on the low pressure side of a packing to prevent extrusion of the O–ring material. Backup rings, when used with O–rings in dynamic sealing application minimize erosion of the packing materials and subsequent failure of the seal. At lower pressure backup rings will prolong the normal wear life of the O–ring. At higher pressures backup rings permit greater clearances between the moving parts. Normally, backup rings are required for operating pressure over 1500 lb/in^2 (see paragraphs 078–3.10 through 078–3.10.3).

078–3.1.3 WHY O–RINGS ARE USED. An O–ring sealing system is often one of the first sealing systems considered when a fluid closure is designed because of the advantages of such a system:

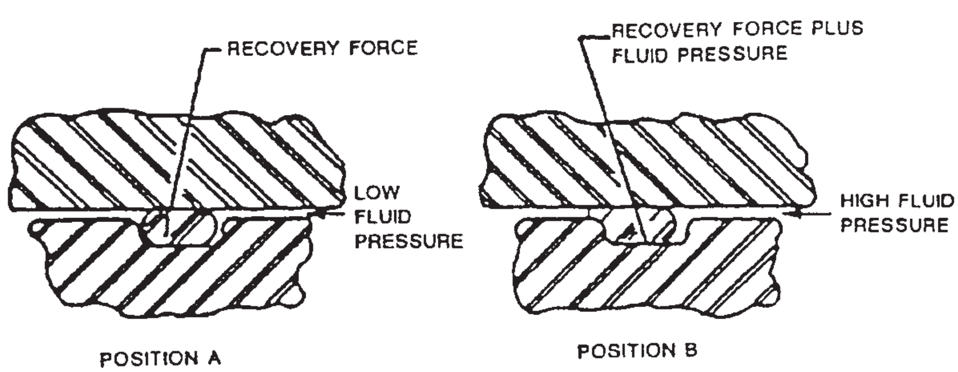


Figure 078–3–1. O–Ring Seal Operation

a. Simplicity

b. Ruggedness

c. Low cost

d. Ease of installation

e. Ease of maintenance

f. No adjustment required

g. No critical torque in clamping

h. Low distortion of structure

i. Small space requirement

j. Reliability

k. Effectiveness over wide pressure and temperature ranges

078–3.1.3.1 Sealing results from deformation of the O–ring material within a confined space. For the seal to function it is necessary only that the confined space around the O–ring be controlled. O–rings properly selected and installed can and do provide excellent service.

078–3.2 TYPES OF O–RING APPLICATIONS

078–3.2.1 STATIC SEAL APPLICATIONS. A static seal is one in which the metal parts normally do not move in relation to each other except for a slight expansion or separation caused by fluid pressure; for example, a seal under a bolt head, rivet, cover plate, plug, or in a similar arrangement. Fluids, temperatures, pressure, and geometry permitting, an O–ring will almost always prove the most satisfactory choice of seals. Because of its round cross section, it can be squeezed quite readily to establish the sealing line, and the load required to establish the seal line is generally light, between 15 and 70 lb/linear inch in most cases.

078–3.2.2 AXIAL SQUEEZE (FACE) SEAL. In the axial squeeze seal (commonly called a face seal), the squeeze occurs along the axis of the O–ring; that is, the squeeze is on the face of the O–ring. The gland is a groove in a flat surface, plus the mating flat surface which covers the gland when assembled.

078–3.2.2.1 A face seal is designed to seal either internal or external pressure and usually uses a rectangular cross–section packing gland. The face seal is often used in pressure containers, as shown in Figure 078–3–2. A similar application is in standard union connections. In pressure containers or standard union connections, if the pressure is outward, the outside diameter of the O–ring should hug the groove wall even at zero pressure. When pressure is applied, the ring cannot slide farther outward in the groove. The ring will flow slightly into corner voids of the groove without sliding or significant stretching. If the O–ring has room to move outward when pressure is applied, the elasticity of the ring will return it when pressure is removed, and the resulting cyclic motion will cause gradual wear. This cyclic motion can result in leakage because a small amount of confined fluid (liquid or gas) can be carried past the seal with each pressure pulse. The use of static face seals should be avoided if a breathing problem exists or a radial squeeze seal design is feasible.

078–3.2.3 RADIAL SQUEEZE SEAL. In the radial squeeze seal, the squeeze occurs between the internal and external diameters of the packing. As illustrated in Figure 078–3–3, examples of radial squeeze seals are the cap seal, the internal plug seal, and the external plug seal. In the gland for an internal seal, the groove is made in the outside diameter of a round surface like the groove in a piston. Conversely, in an external seal, the groove which receives the seal is located in the bore. For static applications, the O–ring is the most common and the best overall

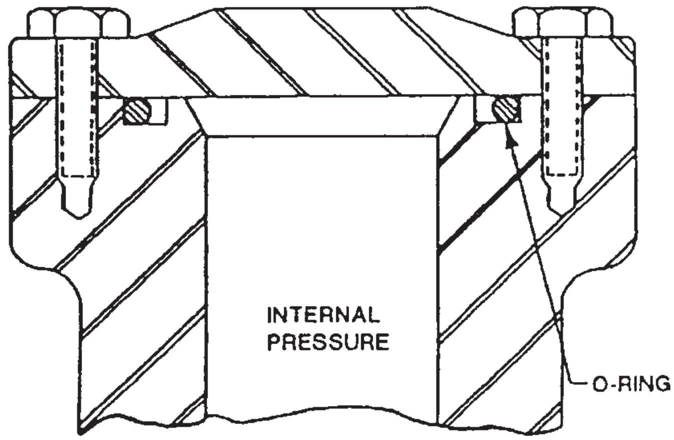


Figure 078–3–2. Typical Face Seal

packing. In special situations where an O–ring might not perform satisfactorily, a compression–type packing of another configuration may be suitable. Greater squeeze is applied across the packing (O–ring) cross section in static seals than in dynamic seals, but a maximum squeeze limit exist, which if exceeded, may cause the packing to be pinched or nicked when the mating parts are forced together. For assembly, some radial clearance is necessary. This clearance, together with the hardness and strength characteristics of the packing compound, determines the maximum pressure that can be sealed. Backup rings may be used to increase pressure limits. If backup rings are used, a wider gland groove will be needed. Extrusion, (the most common cause of radial squeeze seal failure), may be controlled by reducing the diametrical clearance between mating parts. Detailed guidance for the selection and use of O–rings for static seals is provided in MIL–G–5514.

078–3.3 DYNAMIC SEAL APPLICATIONS

078–3.3.1 ROTARY SEALS. Standard O–ring packings are not specifically designed to be used as rotary seals. When infrequent rotary motion or low peripheral velocity is required, standard O–ring packings may be used, provided consistent surface finishes over the entire gland are used and eccentricities are accurately controlled. In addition, the use of low–friction nonextrusion devices is helpful in prolonging life and improving performance. O–rings perform satisfactorily in two application areas:

a. In low speed applications where the surface speed of the shaft does not exceed 200 ft/ min

b. In high speed moderate pressure applications, between 50 and 800 lb/in^2 .

078–3.3.1.1 Application Size. For use as a rotary seal an O–ring with the smallest cross–sectional diameter available for the inside diameter required is best. An O–ring with a maximum cross–sectional dimension of 0.103–inch is recommended for use at speeds over 600 ft/min. O–rings cannot compensate for out–of–round or eccentrically rotating shafts. Shafts should remain concentric within 0.0005–inch total indicator reading. Industrial gland standards may take precedence over MIL–G–5514 for rotary seal applications. In a high speed application when the rotary surface speed exceeds 200 ft/min, the normal 8 to 25 percent cross section squeeze provided by MIL–G–5514 glands will cause heating due to friction.

078–3.3.1.2 Gow–Joule Effect. The Gow–Joule Effect is exhibited by elastomers. An elastomer heated while under tension tends to contract. In the unstressed condition an elastomer will expand when heated, like most other materials. If an O–ring is stretched appreciably over the shaft, the heating effect is intensified due to the Gow–Joule Effect, and the ring will quickly overheat and be destroyed.

078–3.3.1.3 Minimizing Gow–Joule Effect. In rotary O–ring seal design, the Gow–Joule Effects from heating are minimized in several ways:

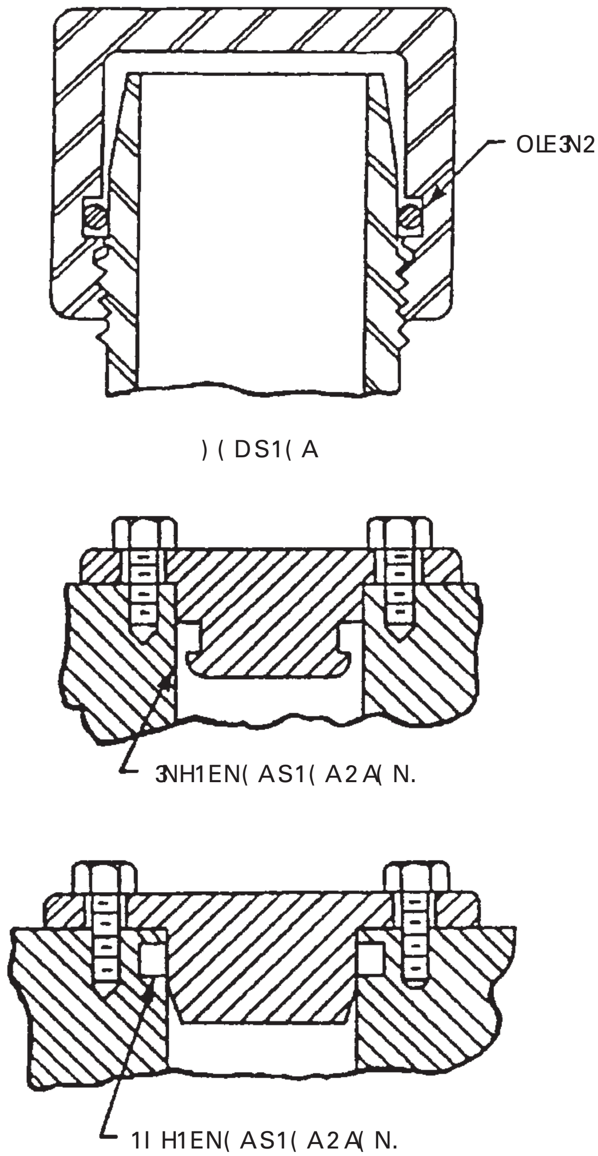


Figure 078–3–3. Examples of Radial Squeeze Seals

a. The O–ring is stretched only slightly over the shaft, or not stretched at all.

b. Only a very light squeeze is applied on the O–ring cross section,

c. A generous clearance is provided adjacent to the seal gland to avoid the possibility of extra heating caused by the shaft rubbing in the housing bore. A clearance of 0.008–inch between the rotating shaft and the O–ring housing is recommended.

d. Bearings are located far enough from the O–ring so their heat of operation will not add appreciably to the heat on the O–ring. Bearing length should be at least 10 times the cross–sectional diameter of the O–ring.

078–3.3.1.4 Fluid Pressure. Since O–rings in rotary seal glands have little squeeze, there must be some fluid pressure to activate the ring. This is particularly important at low temperatures. Fluid pressure is not recommended at temperatures below 0°C (32°F) because, as the temperature drops, the rubber material shrinks more than surrounding metal members shrink. The basic rotary O–ring seal design will leak if the pressure differential across the O–ring drops too low. In high speed rotary designs, the O–rings are located in grooves in the stationary housing. If the shaft were grooved to receive the O–ring, centrifugal force would tend to throw the ring outward, increasing the rubbing force between the ring and the bore, adding friction and reducing the life of the seal. When surface speed is low (usually less than 50 ft/min) heating effects are much less severe. At low surface speeds it is feasible to apply appreciable squeeze on the O–ring cross section and the inside diameter may even be stretched slightly. For the lower speeds, gland designs similar to those used for reciprocating applications are acceptable (see paragraph 078–3.3.2). In addition, the O–ring may be applied in either internal or external glands.

078–3.3.2 RECIPROCATING SEALS. O–rings are often used as reciprocating seals in hydraulic and pneumatic systems. While best suited for short–stroke, relatively small diameter applications, O–rings have been used successfully in long stroke, large diameter applications. Glands for O–rings used as reciprocating seals are usually designed in accordance with MIL–G–5514 to provide a squeeze which varies from 8 to 10 percent minimum and 13.5 to 16 percent maximum. A squeeze of 20 percent is allowed on O–rings with a cross section of 0.070–inch or less. Some dynamic pneumatic applications utilize zero squeeze where some leakage is acceptable. In some reciprocating pneumatic applications, a floating O–ring design may simultaneously reduce friction and wear by maintaining no squeeze by the gland on the O–ring. When air pressure enters the cylinder, the air pressure flattens the O–ring, causing sufficient squeeze to seal during the stroke. If the return stroke does not use pneumatic power, the O–ring returns to its round cross section, minimizing drag and wear on the return stroke.

078–3.4 O–RING SIZES AND SPECIFICATIONS

078–3.4.1 AS568 UNIVERSAL DASH NUMBERS. A standardized dash number system for O–ring sizes is contained in Aerospace Standard AS568 published by the Society of Automotive Engineers. AS568 (which has the same dash numbers as superseded document ARP 568) is the basis for the dash numbers used in many military and industrial specifications. For non–gasket type O–rings, the dash numbers are divided into groups of one hundred. Each hundred group identifies the cross section size of the O–rings within the group, as listed in Table 078–3–1.

Table 078–3–1. O–RING DASH NUMBERS VERSUS CROSS SECTION SIZES

Dash Number	Cross Section (inches)
–001 thru –099	0.070 and smaller
–100 thru –199	0.103
–200 thru –299	0.139
–300 thru –399	0.210
–400 thru –499	0.275

078–3.4.1.1 The gasket section of AS568, using the 900 series dash numbers, lists all the presently standardized straight thread tube fitting boss gaskets. With the exception of –901, the last two digits of the dash number designate the tube size in 16ths of an inch. For example, the –904 size is for a 1/4 inch tube and the –916 size is for a 1 inch tube. For O–ring dimensions corresponding to the AS568 dash numbers refer to Table 078–3–2 for standard O–rings and to Table 078–3–3 for O–ring gaskets. For dimensional tolerances refer to AS568 or applicable military specifications and standards.

078–3.4.2 METRIC O–RING STANDARDS. Standard sizes and size codes are listed in SAE Metric Aerospace Standard MA2010. SAE Metric Aerospace Standard MA3352 has been developed for fluorocarbon rubber, 70 to 80 Shore A durometer, O–rings. SAE MA3352 metric O–rings are suitable for use in piping systems serviceable by MIL–R–83248/l as identified in Table 078–3–4. SAE MA3445 O–rings are MIL–R–83485, Type I, 75 durometer, fluorocarbon rubber in accordance with SAE MA2010 dimensional standards. Dimensional standards

Table 078−3−2. STANDARD O−RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 1 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–001	– – –	1/32	3/32	1/32	0.029	0.040±0.003	01–010–3367	
–002	– – –	3/64	9/64	3/64	0.042	0.050±0.003	01–010–3368	
–003	– – –	1/16	3/16	1/16	0.056	0.060±0.003	01–006–3930	
–004	– – –	5/64	13/64	1/16	0.070	0.070±0.003	00–166–0959	
–005	– – –	3/32	7/32	1/16	0.101	0.070±0.003	00–240–3392	
–006	AN6227–1	1/8	1/4	1/16	0.114	0.070±0.003	00–166–0963	01–132–1925
–007	AN6227–2	5/32	9/32	1/16	0.145	0.070±0.003	00–166–0966	00–425–0649
–008	AN6227–3	3/16	5/16	1/16	0.176	0.070±0.003	00–166–0967	00–166–1078
–009	AN6227–4	7/32	11/32	1/16	0.208	0.070±0.003	00–166–0968	
–010	AN6227–5	1/4	3/8	1/16	0.239	0.070±0.003	00–166–0969	00–166–1079
–011	AN6227–6	5/16	7/16	1/16	0.301	0.070±0.003	00–166–0975	00–166–1081
–012	AN6227–7	3/8	1/2	1/16	0.364	0.070±0.003	00–166–0980	00–166–1084
–013	– – –	7/16	9/16	1/16	0.426	0.070±0.003	00–166–0988	00–166–1085
–014	– – –	1/2	5/8	1/16	0.489	0.070±0.003	00–166–0990	00–166–1086
–015	– – –	9/16	11/16	1/16	0.551	0.070±0.003	00–166–0991	00–166–1087
–016	– – –	5/8	3/4	1/16	0.614	0.070±0.003	00–166–0992	00–528–5236
–017	– – –	11/16	13/16	1/16	0.676	0.070±0.003	00–166–0993	00–166–1088
–018	– – –	3/4	7/8	1/16	0.739	0.070±0.003	00–166–0994	00–166–1089
–019	– – –	13/16	15/16	1/16	0.801	0.070±0.003	00–166–0996	01–058–4008
–020	– – –	7/8	1	1/16	0.864	0.070±0.003	00–166–1001	01–127–0849
–021	– – –	15/16	1–1/16	1/16	0.926	0.070±0.003	00–166–1010	00–166–1090

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 2 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568	AN6227 and AN6230	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)			
Dash Nos.	Dash Nos.	ID	OD	W	ID (Mean)	W	MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
–022	– – –	1	1–1/8	1/16	0.989	0.070±0.003	00–166–1011	00–166–1091
–023	– – –	1–1/16	1–3/16	1/16	1.051	0.070±0.003	00–166–1017	01–137–9007
–024	– – –	1–1/8	1–1/4	1/16	1.114	0.070±0.003	00–166–1020	00–556–7513
–025	– – –	1–3/16	1–5/16	1/16	1.176	0.070±0.003	00–166–1022	00–166–1092
–026	– – –	1–1/4	1–3/8	1/16	1.239	0.070±0.003	00–166–1025	
–027	– – –	1–5/16	1–7/16	1/16	1.301	0.070±0.003	00–166–1026	
–028	– – –	1–3/8	1–1/2	1/16	1.364	0.070±0.003	00–166–1030	
–029*	– – –	1–1/2	1–5/8	1/16	1.489	0.070±0.003	00–166–1036	
–030*	– – –	1–5/8	1–3/4	1/16	1.614	0.070±0.003	00–166–8390	
–031*	– – –	1–3/4	1–7/8	1/16	1.739	0.070±0.003	00–166–8391	
–032*	– – –	1–7/8	2	1/16	1.864	0.070±0.003	00–166–8392	
–033*	– – –	2	2–1/8	1/16	1.989	0.070±0.003	00–194–1670	
–034*	– – –	2–1/8	2–1/4	1/16	2.114	0.070±0.003	00–166–8394	
–035*	– – –	2–1/4	2–3/8	1/16	2.239	0.070±0.003	00–166–8395	
–036*	– – –	2–1/8	2–1/2	1/16	2.364	0.070±0.003	00–172–7187	
–037*	– – –	2–1/2	2–5/8	1/16	2.489	0.070±0.003	00–166–8396	
–038*	– – –	2–5/8	2–3/4	1/16	2.614	0.070±0.003	00–166–8397	
–039*	– – –	2–3/4	2–7/8	1/16	2.739	0.070±0.003	00–166–8398	
–040*	– – –	2–7/8	3	1/16	2.864	0.070±0.003	01–006–3931	
–041*	– – –	3	3–1/8	1/16	2.989	0.070±0.003	00–166–1041	
–042*	– – –	3–1/4	3–3/8	1/16	3.239	0.070±0.003	00–166–1046	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 3 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–043*	– – –	3–1/2	3–5/8	1/16	3.489	0.070±0.003	00–166–1049	
–044*	– – –	3–3/4	3–7/8	1/16	3.739	0.070±0.003	00–245–5611	
–045*	– – –	4	4–1/8	1/16	3.989	0.070±0.003	01–013–3718	
–046*	– – –	4–1/4	4–3/8	1/16	4.239	0.070±0.003	00–166–1055	
–047*	– – –	4–1/2	4–5/8	1/16	4.489	0.070±0.003	00–303–0091	
–048*	– – –	4–3/4	4–7/8	1/16	4.739	0.070±0.003	01–010–3369	
–049*	– – –	5	5–1/8	1/16	4.989	0.070±0.003	01–010–3370	
–050*	– – –	5–1/4	5–3/8	1/16	5.239	0.070±0.003	01–009–6735	
–102*	– – –	1/16	1/4	3/32	0.049	0.103±0.003	01–005–0502	
–103*	– – –	3/32	9/32	3/32	0.081	0.103±0.003	01–005–0503	
–104*	– – –	1/8	5/16	3/32	0.112	0.103±0.003	01–005–0504	
–105*	– – –	5/32	11/32	3/32	0.143	0.103±0.003	01–005–0505	
–106*#	– – –	3/16	3/8	3/32	0.174	0.103±0.003	01–005–0506	
–107*#	– – –	7/32	13/32	3/32	0.206	0.103±0.003	01–005–0507	
–108*#	– – –	1/4	7/16	3/32	0.237	0.103±0.003	00–762–9964	
–109*#	– – –	5/16	1/2	3/32	0.299	0.103±0.003	01–007–4887	
–110	AN6227–8	3/8	9/16	3/32	0.362	0.103±0.003	00–166–1058	00–166–1098
–111	AN6227–9	7/16	5/8	3/23	0.424	0.103±0.003	00–166–1059	01–258–6853
–112	AN6227–10	1/2	11/16	3/23	0.487	0.103±0.003	00–166–1060	00–166–1099
–113	AN6227–11	9/16	3/4	3/32	0.549	0.103±0.003	00–166–1062	01–121–8092
–114	AN6227–12	5/8	13/16	3/32	0.612	0.103±0.003	00–166–1063	01–133–9790

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 4 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–115	AN6227–13	11/16	7/8	3/32	0.674	0.103±0.003	00–166–1066	01–105–9153
–116	AN6227–14	3/4	15/16	3/32	0.737	0.103±0.003	00–166–1068	00–211–9143
–117	– – –	13/16	1	3/32	0.799	0.103±0.003	00–166–1071	01–106–0936
–118	– – –	7/8	1–1/16	3/32	0.862	0.103±0.003	00–166–1072	01–144–2252
–119	– – –	15/16	1–1/8	3/32	0.924	0.103±0.003	00–166–1074	01–229–8081
–120	– – –	1	1–3/16	3/32	0.987	0.103±0.003	00–166–1076	01–106–0942
–121	– – –	1–1/16	1–1/4	3/32	1.049	0.103±0.003	00–166–5110	00–166–1100
–122	– – –	1–1/8	1–5/16	3/32	1.112	0.103±0.003	00–167–5111	01–182–8670
–123	– – –	1–3/16	1–3/8	3/32	1.174	0.103±0.003	00–167–5112	00–166–1101
–124	– – –	1–1/4	1–7/16	3/32	1.237	0.103±0.003	00–167–5113	01–208–2920
–125	– – –	1–5/16	1–1/2	3/32	1.299	0.103±0.003	00–322–6397	01–184–7576
–126	– – –	1–3/8	1–9/16	3/32	1.362	0.103±0.003	00–167–5114	01–219–7478
–127	– – –	1–7/16	1–5/8	3/32	1.424	0.103±0.003	00–167–5115	00–166–1104
–128	– – –	1–1/2	1–11/16	3/32	1.487	0.103±0.003	00–167–5116	01–104–4906
–129	– – –	1–9/16	1–3/4	3/32	1.549	0.103±0.003	00–167–5117	01–105–9154
–130	– – –	1–5/8	1–13/16	3/32	1.612	0.103±0.003	00–167–5118	01–176–4014
–131	– – –	1–11/16	1–7/8	3/32	1.674	0.103±0.003	00–167–5119	01–058–4009
–132	– – –	1–3/4	1–15/16	3/32	1.737	0.103±0.003	00–167–5120	01–253–5939
–133	– – –	1–13/16	2	3/32	1.799	0.103±0.003	00–167–5121	01–049–6595
–134	– – –	1–7/8	2–1/16	3/32	1.862	0.103±0.003	00–167–5122	00–267–0769
–135	– – –	1–15/16	2–1/8	3/32	1.925	0.103±0.003	01–005–0508	01–128–0432

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 5 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–136	– – –	2	2–3/16	3/32	1.987	0.103±0.003	00–167–5123	
–137	– – –	2–1/16	2–1/4	3/32	2.050	0.103±0.003	01–005–0509	01–185–1678
–138	– – –	2–1/8	2–5/16	3/32	2.112	0.103±0.003	00–005–0510	01–209–9419
–139	– – –	2–3/16	2–3/8	3/32	2.175	0.103±0.003	00–167–5124	01–188–7636
–140	– – –	2–1/4	2–7/16	3/32	2.237	0.103±0.003	01–010–3371	01–194–8963
–141	– – –	2–5/16	2–1/2	3/32	2.300	0.103±0.003	00–330–3307	
–142	– – –	2–3/8	2–9/16	3/32	2.362	0.103±0.003	00–537–3888	
–143	– – –	2–7/16	2–5/8	3/32	2.425	0.103±0.003	00–167–5125	
–144	– – –	2–1/2	2–11/16	3/32	2.487	0.103±0.003	00–167–5126	
–145	– – –	2–9/16	2–3/4	3/32	2.550	0.103±0.003	00–167–5127	
–146	– – –	2–5/8	2–13/16	3/32	2.612	0.103±0.003	00–172–7188	
–147	– – –	2–11/16	2–7/8	3/32	2.675	0.103±0.003	00–167–5128	
–148	– – –	2–3/4	2–15/16	3/32	2.737	0.103±0.003	00–167–5129	
–149	– – –	2–13/16	3	3/32	2.800	0.103±0.003	00–167–5135	
–150*	– – –	2–7/8	3–1/16	3/32	2.862	0.103±0.003	00–167–5136	
–151*	– – –	3	3–3/16	3/32	2.987	0.103±0.003	00–167–5137	
–152*	– – –	3–1/4	3–7/16	3/32	3.237	0.103±0.003	00–167–5138	
–153*	– – –	3–1/2	3–11/16	3/32	3.487	0.103±0.003	00–167–5139	
–154*	– – –	3–3/4	3–15/16	3/32	3.737	0.103±0.003	00–166–8399	
–155*	– – –	4	4–3/16	3/32	3.987	0.103±0.003	00–166–8400	
–156*	– – –	4–1/4	4–7/16	3/32	4.237	0.103±0.003	00–166–8401	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 6 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–157*	– – –	4–1/2	4–11/16	3/32	4.487	0.103±0.003	00–530–6990	
–158*	– – –	4–3/4	4–15/16	3/32	4.737	0.103±0.003	00–165–1935	
–159*	– – –	5	5–3/16	3/32	4.987	0.103±0.003	00–165–1936	
–160*	– – –	5–1/4	5–7/16	3/32	5.237	0.103±0.003	00–005–0482	
–161*	– – –	5–1/2	5–11/16	3/32	5.487	0.103±0.003	00–165–1937	
–162*	– – –	5–3/4	5–15/16	3/32	5.737	0.103±0.003	00–165–1938	
–163*	– – –	6	6–3/16	3/32	5.987	0.103±0.003	00–537–3944	
–164*	– – –	6–1/4	6–7/16	3/32	6.237	0.103±0.003	00–364–9913	
–165*	– – –	6–1/2	6–11/16	3/32	6.487	0.103±0.003	01–005–0515	
–166*	– – –	6–3/4	6–15/16	3/32	6.737	0.103±0.003	01–921–0020	
–167*	– – –	7	7–3/16	3/32	6.987	0.103±0.003	00–549–3628	
–168*	– – –	7–1/4	7–7/16	3/32	7.237	0.103±0.003	00–173–3022	
–169*	– – –	7–1/2	7–11/16	3/32	7.487	0.103±0.003	00–364–8103	
–170*	– – –	7–3/4	7–15/16	3/32	7.737	0.103±0.003	01–019–2452	
–171*	– – –	8	8–3/16	3/32	7.987	0.103±0.003	01–PAC–2463	
–172*	– – –	8–1/4	8–7/16	3/32	8.237	0.103±0.003	01–005–0514	
–173*	– – –	8–1/2	8–11/16	3/32	8.487	0.103±0.003	01–007–4889	
–174*	– – –	8–3/4	8–15/16	3/32	8.737	0.103±0.003	01–007–4888	
–175*	– – –	9	9–3/16	3/32	8.987	0.103±0.003	01–005–0513	
–176*	– – –	9–1/4	9–7/16	3/32	9.237	0.103±0.003	01–005–0512	
–177*	– – –	9–1/2	9–11/16	3/32	9.487	0.103±0.003	01–005–0511	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 7 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–178*	– – –	9–3/4	9–15/16	3/32	9.737	0.103±0.003	01–005–0516	
–201*#	– – –	3/16	7/16	1/8	0.171	0.139±0.004	01–005–0517	
–202*#	– – –	1/4	1/2	1/8	0.234	0.139±0.004	01–005–3200	
–203*#	– – –	5/16	9/16	1/8	0.296	0.139±0.004	01–004–9552	
–204*#	– – –	3/8	5/8	1/8	0.359	0.139±0.004	01–006–9034	
–205*#	– – –	7/16	11/16	1/8	0.421	0.139±0.004	01–005–0518	
–206*#	– – –	1/2	3/4	1/8	0.484	0.139±0.004	01–005–0521	
–207*#	– – –	9/16	13/16	1/8	0.546	0.139±0.004	01–005–3701	
–208*#	– – –	5/8	7/8	1/8	0.609	0.139±0.004	01–005–0519	
–209*#	– – –	11/16	15/16	1/8	0.671	0.139±0.004	01–005–0520	
–210	AN6227–15	3/4	1	1/8	0.734	0.139±0.004	00–166–8402	01–127–0971
–211	AN6227–16	13/16	1–1/16	1/8	0.796	0.139±0.004	00–166–8428	
–212	AN6227–17	7/8	1–1/8	1/8	0.859	0.139±0.004	00–166–8403	00–166–1109
–213	AN6227–18	15/16	1–3/16	1/8	0.921	0.139±0.004	00–165–1940	
–214	AN6227–19	1	1–1/4	1/8	0.984	0.139±0.004	00–165–1941	01–017–6535
–215	AN6227–20	1–1/16	1–5/16	1/8	1.046	0.139±0.004	00–166–8404	01–125–1731
–216	AN6227–21	1–1/8	1–3/8	1/8	1.109	0.139±0.004	00–165–1942	00–166–1110
–217	AN6227–22	1–3/16	1–7/16	1/8	1.171	0.139±0.004	00–165–1943	01–027–4703
–218	AN6227–23	1–1/4	1–1/2	1/8	1.234	0.139±0.004	00–166–8405	01–106–7288
–219	AN6227–24	1–5/16	1–9/16	1/8	1.296	0.139±0.004	00–166–8406	01–106–7290
–220	AN6227–25	1–3/8	1–5/8	1/8	1.359	0.139±0.004	00–166–8411	00–166–1111

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 8 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–221	AN6227–26	1–7/16	1–11/16	1/8	1.421	0.139±0.004	00–166–8412	00–338–1392
–222	AN6227–27	1–1/2	1–3/4	1/8	1.484	0.139±0.004	00–194–1675	01–006–2129
–223	AN6230–1	1–5/8	1–7/8	1/8	1.609	0.139±0.004	00–166–8415	01–205–2857
–224	AN6230–2	1–3/4	2	1/8	1.734	0.139±0.004	00–166–8422	01–187–7680
–225	AN6230–3	1–7/8	2–1/8	1/8	1.859	0.139±0.004	00–165–1944	00–338–1440
–226	AN6230–4	2	2–1/4	1/8	1.984	0.139±0.004	00–421–9387	00–166–1112
–227	AN6230–5	2–1/8	2–3/8	1/8	2.109	0.139±0.004	00–173–3023	01–106–0940
–228	AN6230–6	2–1/4	2–1/2	1/8	2.234	0.139±0.004	00–165–1946	01–119–3220
–229	AN6230–7	2–3/8	2–5/8	1/8	2.359	0.139±0.004	00–165–1947	00–338–1441
–230	AN6230–8	2–1/2	2–3/4	1/8	2.484	0.139±0.004	00–165–1948	01–180–5228
–231	AN6230–9	2–5/8	2–7/8	1/8	2.609	0.139±0.004	00–165–1949	01–113–9871
–232	AN6230–10	2–3/4	3	1/8	2.734	0.139±0.004	00–165–1950	01–174–7868
–233	AN6230–11	2–7/8	3–1/8	1/8	2.859	0.139±0.004	00–165–1951	01–189–3822
–234	AN6230–12	3	3–1/4	1/8	2.984	0.139±0.004	00–165–1952	01–194–8964
–235	AN6230–13	3–1/8	3–3/8	1/8	3.109	0.139±0.004	00–165–1953	01–127–0972
–236	AN6230–14	3–1/4	3–1/2	1/8	3.234	0.139±0.004	00–165–1954	01–006–2130
–237	AN6230–15	3–3/8	3–5/8	1/8	3.359	0.139±0.004	00–165–1955	01–167–9770
–238	AN6230–16	3–1/2	3–3/4	1/8	3.484	0.139±0.004	00–165–1956	00–167–5167
–239	AN6230–17	3–5/8	3–7/8	1/8	3.609	0.139±0.004	00–165–1957	01–050–1537
–240	AN6230–18	3–3/4	4	1/8	3.734	0.139±0.004	00–165–1958	01–129–2730
–241	AN6230–19	3–7/8	4–1/8	1/8	3.859	0.139±0.004	00–165–1959	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 9 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–242	AN6230–20	4	4–1/4	1/8	3.984	0.139±0.004	00–165–1960	
–243	AN6230–21	4–1/8	4–3/8	1/8	4.109	0.139±0.004	00–165–1961	
–244	AN6230–22	4–1/4	4–1/2	1/8	4.234	0.139±0.004	00–165–1962	
–245	AN6230–23	4–3/8	4–5/8	1/8	4.359	0.139±0.004	00–165–1963	
–246	AN6230–24	4–1/2	4–3/4	1/8	4.484	0.139±0.004	00–165–1964	
–247	AN6230–25	4–5/8	4–7/8	1/8	4.609	0.139±0.004	01–005–3201	
–248	AN6230–26	4–3/4	5	1/8	4.734	0.139±0.004	00–165–1965	
–249	AN6230–27	4–7/8	5–1/8	1/8	4.859	0.139±0.004	00–537–3940	
–250	AN6230–28	5	5–1/4	1/8	4.984	0.139±0.004	00–404–1473	
–251	AN6230–29	5–1/8	5–3/8	1/8	5.109	0.139±0.004	00–165–1966	
–252	AN6230–30	5–1/4	5–1/2	1/8	5.234	0.139±0.004	00–165–1967	
–253	AN6230–31	5–3/8	5–5/8	1/8	5.359	0.139±0.004	00–165–1968	
–254	AN6230–32	5–1/2	5–3/4	1/8	5.484	0.139±0.004	00–165–1969	
–255	AN6230–33	5–5/8	5–7/8	1/8	5.609	0.139±0.004	00–554–0990	
–256	AN6230–34	5–3/4	6	1/8	5.734	0.139±0.004	00–165–1970	
–257	AN6230–35	5–7/8	6–1/8	1/8	5.859	0.139±0.004	00–167–5140	
–258	AN6230–36	6	6–1/4	1/8	5.984	0.139±0.004	00–167–5141	
–259	AN6230–37	6–1/4	6–1/2	1/8	6.234	0.139±0.004	00–167–5142	
–260	AN6230–38	6–1/2	6–3/4	1/8	6.484	0.139±0.004	00–167–5143	
–261	AN6230–39	6–3/4	7	1/8	6.734	0.139±0.004	00–167–5144	
–262	AN6230–40	7	7–1/4	1/8	6.984	0.139±0.004	00–167–5145	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 10 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–263	AN6230–41	7–1/4	7–1/2	1/8	7.234	0.139±0.004	01–005–3702	
–264	AN6230–42	7–1/2	7–3/4	1/8	7.484	0.139±0.004	00–167–5146	
–265	AN6230–43	7–3/4	8	1/8	7.734	0.139±0.004	00–167–5147	
–266	AN6230–44	8	8–1/4	1/8	7.984	0.139±0.004	00–167–5148	
–267	AN6230–45	8–1/4	8–1/2	1/8	8.234	0.139±0.004	01–005–3202	
–268	AN6230–46	8–1/2	8–3/4	1/8	8.484	0.139±0.004	00–167–5149	
–269	AN6230–47	8–3/4	9	1/8	8.734	0.139±0.004	00–167–5150	
–270	AN6230–48	9	9–1/4	1/8	8.984	0.139±0.004	00–167–5151	
–271	AN6230–49	9–1/4	9–1/2	1/8	9.234	0.139±0.004	00–167–5152	
–272	AN6230–50	9–1/2	9–3/4	1/8	9.484	0.139±0.004	00–167–5153	
–273	AN6230–51	9–3/4	10	1/8	9.734	0.139±0.004	01–005–0522	
–274	AN6230–52	10	10–1/4	1/8	9.984	0.139±0.004	01–005–3203	
–275*	– – –	10–1/2	10–3/4	1/8	10.484	0.139±0.004	01–005–0523	
–276*	– – –	11	11–1/4	1/8	10.984	0.139±0.004	00–159–9152	
–277*	– – –	11–1/2	11–3/4	1/8	11.484	0.139±0.004	01–005–0524	
–278*	– – –	12	12–1/4	1/8	11.984	0.139±0.004	01–005–0525	
–279*	– – –	13	13–1/4	1/8	12.984	0.139±0.004	00–167–5154	
–280*	– – –	14	14–1/4	1/8	13.984	0.139±0.004	00–167–5155	
–281*	– – –	15	15–1/4	1/8	14.984	0.139±0.004	01–006–2103	
–282*	– – –	16	16–1/4	1/8	15.955	0.139±0.004	00–537–3923	
–283*	– – –	17	17–1/4	1/8	16.955	0.139±0.004	00–537–3927	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 11 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–284*	– – –	18	18–1/4	1/8	17.955	0.139±0.004	00–539–6313	
–309*#	– – –	7/16	13/16	3/16	0.412	0.210±0.005	01–006–0302	
–310*#	– – –	1/2	7/8	3/16	0.475	0.210±0.005	01–005–3703	
–311*#	– – –	9/16	15/16	3/16	0.537	0.210±0.005	01–005–3705	
–312*#	– – –	5/8	1	3/16	0.600	0.210±0.005	01–005–3706	
–313*#	– – –	11/16	1–1/16	3/16	0.662	0.210±0.005	01–005–4042	
–314*#	– – –	3/4	1–1/8	3/16	0.725	0.210±0.005	01–005–4043	
–315*#	– – –	13/16	1–3/16	3/16	0.787	0.210±0.005	01–005–4044	
–316*#	– – –	7/8	1–1/4	3/16	0.850	0.210±0.005	01–005–4046	
–317*#	– – –	15/16	1–5/16	3/16	0.912	0.210±0.005	01–006–0304	
–318*#	– – –	1	1–3/8	3/16	0.975	0.210±0.005	01–006–0305	
–319*#	– – –	1–1/16	1–7/16	3/16	1.037	0.210±0.005	01–006–0307	
–320*#	– – –	1–1/8	1–1/2	3/16	1.100	0.210±0.005	01–006–0308	
–321*#	– – –	1–3/16	1–9/16	3/16	1.162	0.210±0.005	01–006–0306	
–322*#	– – –	1–1/4	1–5/8	3/16	1.225	0.210±0.005	01–006–0303	
–323*#	– – –	1–5/16	1–11/16	3/16	1.287	0.210±0.005	01–005–4045	
–324*#	– – –	1–3/8	1–3/4	3/16	1.350	0.210±0.005	01–005–3704	
–325	AN6227–28	1–1/2	1–7/8	3/16	1.475	0.210±0.005	00–167–5156	01–028–8289
–326	AN6227–29	1–5/8	2	3/16	1.600	0.210±0.005	01–005–3212	01–045–5605
–327	AN6227–30	1–3/4	2–1/8	3/16	1.725	0.210±0.005	01–005–3213	01–289–3214
–328	AN6227–31	1–7/8	2–1/4	3/16	1.850	0.210±0.005	01–007–5144	01–137–8392

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 12 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–329	AN6227–32	2	2–3/8	3/16	1.975	0.210±0.005	01–005–4057	00–167–5170
–330	AN6227–33	2–1/8	2–1/2	3/16	2.100	0.210±0.005	01–005–4058	01–183–9169
–331	AN6227–34	2–1/4	2–5/8	3/16	2.225	0.210±0.005	00–167–5157	
–332	AN6227–35	2–3/8	2–3/4	3/16	2.350	0.210±0.005	01–005–4409	01–171–6057
–333	AN6227–36	2–1/2	2–7/8	3/16	2.475	0.210±0.005	00–167–5158	
–334	AN6227–37	2–5/8	3	3/16	2.600	0.210±0.005	01–005–4055	01–047–0437
–335	AN6227–38	2–3/4	3–1/8	3/16	2.725	0.210±0.005	01–005–4056	
–336	AN6227–39	2–7/8	3–1/4	3/16	2.850	0.210±0.005	01–009–7216	01–243–9299
–337	AN6227–40	3	3–3/8	3/16	2.975	0.210±0.005	01–005–4059	
–338	AN6227–41	3–1/8	3–1/2	3/16	3.100	0.210±0.005	00–367–4374	01–199–5375
–339	AN6227–42	3–1/4	3–5/8	3/16	3.225	0.210±0.005	00–167–5159	
–340	AN6227–43	3–3/8	3–3/4	3/16	3.350	0.210±0.005	01–005–4062	
–341	AN6227–44	3–1/2	3–7/8	3/16	3.475	0.210±0.005	00–167–5160	
–342	AN6227–45	3–5/8	4	3/16	3.600	0.210±0.005	01–005–4060	
–343	AN6227–46	3–3/4	4–1/8	3/16	3.725	0.210±0.005	01–005–3214	
–344	AN6227–47	3–7/8	4–1/4	3/16	3.850	0.210±0.005	01–005–4061	
–345	AN6227–48	4	4–3/8	3/16	3.975	0.210±0.005	00–184–3472	
–346	AN6227–49	4–1/8	4–1/2	3/16	4.100	0.210±0.005	01–005–3215	
–347	AN6227–50	4–1/4	4–5/8	3/16	4.225	0.210±0.005	01–005–3216	
–348	AN6227–51	4–3/8	4–3/4	3/16	4.350	0.210±0.005	01–005–3205	
–349	AN6227–52	4–1/2	4–7/8	3/16	4.475	0.210±0.005	01–005–3206	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 13 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–350*	– – –	4–5/8	5	3/16	4.600	0.210±0.005	01–005–3207	
–351*	– – –	4–3/4	5–1/8	3/16	4.725	0.210±0.005	01–005–3208	
–352*	– – –	4–7/8	5–1/4	3/16	4.850	0.210±0.005	01–005–3209	
–353*	– – –	5	5–3/8	3/16	4.975	0.210±0.005	01–006–0310	
–354*	– – –	5–1/8	5–1/2	3/16	5.100	0.210±0.005	01–006–0311	
–355*	– – –	5–1/4	5–5/8	3/16	5.225	0.210±0.005	01–006–0312	
–356*	– – –	5–5/8	5–3/4	3/16	5.350	0.210±0.005	01–006–0313	
–357*	– – –	5–1/2	5–7/8	3/16	5.475	0.210±0.005	01–006–0314	
–358*	– – –	5–5/8	6	3/16	5.600	0.210±0.005	01–006–0315	
–359*	– – –	5–3/4	6–1/8	3/16	5.725	0.210±0.005	01–009–6732	
–360*	– – –	5–7/8	6–1/4	3/16	5.850	0.210±0.005	01–006–0316	
–361*	– – –	6	6–3/8	3/16	5.975	0.210±0.005	01–006–0309	
–362*	– – –	6–1/4	6–5/8	3/16	6.225	0.210±0.005	01–006–0317	
–363*	– – –	6–1/2	6–7/8	3/16	6.475	0.210±0.005	01–006–0322	
–364*	– – –	6–3/4	7–1/8	3/16	6.725	0.210±0.005	01–006–2105	
–365*	– – –	7	7–3/8	3/16	6.975	0.210±0.005	01–006–0323	
–366*	– – –	7–1/4	7–5/8	3/16	7.225	0.210±0.005	01–006–0324	
–367*	– – –	7–1/2	7–7/8	3/16	7.475	0.210±0.005	01–006–0325	
–368*	– – –	7–3/4	8–1/8	3/16	7.725	0.210±0.005	01–006–2121	
–369*	– – –	8	8–3/8	3/16	7.975	0.210±0.005	01–006–0326	
–370*	– – –	8–1/4	8–5/8	3/16	8.225	0.210±0.005	01–006–0328	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 14 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–371*	– – –	8–1/2	8–7/8	3/16	8.475	0.210±0.005	01–006–0329	
–372*	– – –	8–3/4	9–1/8	3/16	8.725	0.210±0.005	01–006–2122	
–373*	– – –	9	9–3/8	3/16	8.975	0.210±0.005	01–006–0327	
–374*	– – –	9–1/4	9–5/8	3/16	9.225	0.210±0.005	01–006–0330	
–375*	– – –	9–1/2	9–7/8	3/16	9.475	0.210±0.005	01–006–2123	
–376*	– – –	9–3/4	10–1/8	3/16	9.725	0.210±0.005	01–006–3932	
–377*	– – –	10	10–3/8	3/16	9.975	0.210±0.005	01–005–2305	
–378*	– – –	10–1/2	10–7/8	3/16	10.475	0.210±0.005	01–004–9551	
–379*	– – –	11	11–3/8	3/16	10.975	0.210±0.005	01–005–0526	
–380*	– – –	11–1/2	11–7/8	3/16	11.475	0.210±0.005	01–005–0527	
–381*	– – –	12	12–3/8	3/16	11.975	0.210±0.005	01–005–0528	
–382*	– – –	13	13–3/8	3/16	12.975	0.210±0.005	01–005–0529	
–383*	– – –	14	14–3/8	3/16	13.975	0.210±0.005	01–005–0530	
–384*	– – –	15	15–3/8	3/16	14.975	0.210±0.005	01–005–0531	
–385*	– – –	16	16–3/8	3/16	15.955	0.210±0.005	01–005–0532	
–386*	– – –	17	17–3/8	3/16	16.955	0.210±0.005	01–005–0533	
–387*	– – –	18	18–3/8	3/16	17.955	0.210±0.005	01–005–0534	
–388*	– – –	19	19–3/8	3/16	18.955	0.210±0.005	01–005–0535	
–389*	– – –	20	20–3/8	3/16	19.955	0.210±0.005	01–005–0536	
–390*	– – –	21	21–3/8	3/16	20.955	0.210±0.005	01–005–0537	
–391*	– – –	22	22–3/8	3/16	21.955	0.210±0.005	01–007–4890	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 15 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–392*	– – –	23	23–3/8	3/16	22.940	0.210±0.005	01–005–0538	
–393*	– – –	24	24–3/8	3/16	23.940	0.210±0.005	01–005–0539	
–394*	– – –	25	25–3/8	3/16	24.940	0.210±0.005	01–005–3211	
–395*	– – –	26	26–3/8	3/16	25.940	0.210±0.005	01–005–0540	
–425	AN6227–88	4–1/2	5	1/4	4.475	0.275±0.006	01–005–0541	
–426	AN6227–53	4–5/8	5–1/8	1/4	4.600	0.275±0.006	01–005–0542	
–427	AN6227–54	4–3/4	5–1/4	1/4	4.725	0.275±0.006	01–005–0543	
–428	AN6227–55	4–7/8	5–3/8	1/4	4.850	0.275±0.006	01–007–4891	
–429	AN6227–56	5	5–1/2	1/4	4.975	0.275±0.006	01–006–9035	
–430	AN6227–57	5–1/8	5–5/8	1/4	5.100	0.275±0.006	01–005–0544	
–431	AN6227–58	5–1/4	5–3/4	1/4	5.225	0.275±0.006	01–005–3204	
–432	AN6227–59	5–3/8	5–7/8	1/4	5.350	0.275±0.006	01–006–2104	
–433	AN6227–60	5–1/2	6	1/4	5.475	0.275±0.006	01–005–4047	
–434	AN6227–61	5–5/8	6–1/8	1/4	5.600	0.275±0.006	01–005–4048	
–435	AN6227–62	5–3/4	6–1/4	1/4	5.725	0.275±0.006	01–005–4049	
–436	AN6227–63	5–7/8	6–3/8	1/4	5.850	0.275±0.006	01–005–4050	
–437	AN6227–64	6	6–1/2	1/4	5.975	0.275±0.006	01–005–4051	
–438	AN6227–65	6–1/4	6–3/4	1/4	6.225	0.275±0.006	01–005–4052	
–439	AN6227–66	6–1/2	7	1/4	6.475	0.275±0.006	00–167–5162	
–440	AN6227–67	6–3/4	7–1/4	1/4	6.725	0.275±0.006	01–007–4892	
–441	AN6227–68	7	7–1/2	1/4	6.975	0.275±0.006	01–007–4893	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 16 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–442	AN6277–69	7–1/4	7–3/4	1/4	7.225	0.275±0.006	01–007–4894	
–443	AN6227–70	7–1/2	8	1/4	7.475	0.275±0.006	01–005–2307	
–444	AN6227–71	7–3/4	8–1/4	1/4	7.725	0.275±0.006	01–005–4408	
–445	AN6227–72	8	8–1/2	1/4	7.975	0.275±0.006	01–005–2308	
–446	AN6227–73	8–1/2	9	1/4	8.475	0.275±0.006	01–005–2309	
–447	AN6227–74	9	9–1/2	1/4	8.975	0.275±0.006	01–007–4895	
–448	AN6227–75	9–1/2	10	1/4	9.475	0.275±0.006	01–008–6808	
–449	AN6227–76	10	10–1/2	1/4	9.975	0.275±0.006	01–005–4053	
–450	AN6227–77	10–1/2	11	1/4	10.475	0.275±0.006	00–167–5163	
–451	AN6227–78	11	11–1/2	1/4	10.975	0.275±0.006	00–167–5164	
–452	AN6227–79	11–1/2	12	1/4	11.475	0.275±0.006	01–005–4054	
–453	AN6227–80	12	12–1/2	1/4	11.975	0.275±0.006	01–005–2310	
–454	AN6227–81	12–1/2	13	1/4	12.475	0.275±0006	01–005–2311	
–455	AN6227–82	13	13–1/2	1/4	12.975	0.275±.0006	01–005–2312	
–456	AN6227–83	13–1/2	14	1/4	13.475	0.275±0.006	01–005–2313	
–457	AN6227–84	14	14–1/2	1/4	13.975	0.275±0.006	01–005–2314	
–458	AN6227–85	14–1/2	15	1/4	14.475	0.275±0.006	01–005–2315	
–459	AN6227–86	15	15–1/2	1/4	14.975	0.275±0.006	01–006–0318	
–460	AN6227–87	15–1/2	16	1/4	15.475	0.275±0.006	01–006–0319	
–461*	– – –	16	16–1/2	1/4	15.955	0.275±0.006	01–006–0320	
–462*	– – –	16–1/2	17	1/4	16.455	0.275±0.006	01–006–0321	

Table 078–3–2. STANDARD O–RING SIZES AND CROSS REFERENCE CHART FOR AS, AN, MS, AND M83248 DASH NUMBERS (SHEET 17 OF 17)

MS9021, MS29513, MS28775, MS29561, M83248, and AS568 Dash Nos.	AN6227 and AN6230 Dash Nos.	Nominal Size (Inches) (Reference Only)			Standard O–Ring Size (Inches)		MIL–R–83248/1 (NSN 5330–)	MIL–R–83248/2 (NSN 5330–)
		ID	OD	W	ID (Mean)	W		
–463*	– – –	17	17–1/2	1/4	16.955	0.275±0.006	01–006–2106	
–464*	– – –	17–1/2	18	1/4	17.455	0.275±0.006	01–006–2107	
–465*	– – –	18	18–1/2	1/4	17.955	0.275±0.006	01–006–2108	
–466*	– – –	18–1/2	19	1/4	18.455	0.275±0.006	01–006–2109	
–467*	– – –	19	19–1/2	1/4	18.955	0.275±0.006	01–006–2110	
–468*	– – –	19–1/2	20	1/4	19.455	0.275±0.006	01–006–2111	
–469*	– – –	20	20–1/2	1/4	19.955	0.275±0.006	01–006–2112	
–470*	– – –	21	21–1/2	1/4	20.955	0.275±0.006	01–006–2113	
–471*	– – –	22	22–1/2	1/4	21.955	0.275±0.006	01–006–2114	
–472*	– – –	23	23–1/2	1/4	22.940	0.275±0.006	01–006–2115	
–473*	– – –	24	24–1/2	1/4	23.940	0.275±0.006	01–006–2116	
–474*	– – –	25	25–1/2	1/4	24.940	0.275±0.006	01–006–2117	
–475*	– – –	26	26–1/2	1/4	25.940	0.275±0.006	01–006–2118	

* These dash numbers are not included in MS29561 Series.
\# These dash numbers are not included in MS9021 Series.

NOTES:

1. M83248/1 dash numbers are 75 durometer while M83248/2 dash numbers are 90 durometer.
2. O–ring dash number sizes –013 through –028, –117 through –149, and –223 through –247 are intended for use only as static seals and are not normally used for applications involving reciprocating or rotary movement.

Table 078–3–3. O–RING GASKET SIZES AND CROSS REFERENCE OF AS, AN, MS, AND M83248 DASH NUMBERS

AS568 M83248 Dash No.	MS29512 MS9020 Dash No.	MS28778 AN6290 Dash No.	Tube Size OD (Reference Only)	O–Ring Size (Inches)		MIL–R–83248/2 NSNs (5330–)
				ID	W	
–901	–01	–	3/32	0.185±0.005	0.056±0.003	01–088–6870
–902	–02	–2	1/8	0.239±0.005	0.064±0.003	00–167–5171
–903	–03	–3	3/16	0.301±0.005	0.064±0.003	01–011–4057
–904	–04	–4	1/4	0.351±0.005	0.072±0.003	00–167–5172
–905	–05	–5	5/16	0.414±0.005	0.072±0.003	00–165–1980
–906	–06	–6	3/8	0.468±0.005	0.078±0.003	00–165–1981
–907	–07	–	7/16	0.530±0.005	0.082±0.003	01–089–2575
–908	–08	–8	1/2	0.644±0.005	0.087±0.003	00–167–5173
–909	–09	–	9/16	0.706±0.005	0.097±0.003	01–088–8963
–910	–10	–10	5/8	0.755±0.005	0.097±0.003	00–167–5174
–911	–11	–	11/16	0.863±0.005	0.116±0.004	01–018–5663
–912	–12	–12	3/4	0.924±0.006	0.116±0.004	00–167–5175
–913	–13	–	13/16	0.986±0.006	0.116±0.004	01–089–2576
–914	–14	–14	7/8	1.047±0.006	0.116±0.004	01–088–6106
–916	–16	–16	1	1.171±0.006	0.116±0.004	00–167–5176
–918	–18	–	1–1/8	1.355±0.006	0.116±0.004	01–088–6107
–920	–20	–20	1–1/4	1.475±0.010	0.118±0.004	01–024–2512
–924	–24	–24	1–1/2	1.720±0.010	0.118±0.004	00–172–7189
–928	–28	–28	1–3/4	2.090±0.010	0.118±0.004	01–088–5362
–932	–32	–32	2	2.337±0.010	0.118±0.004	01–088–6871

NOTE:

These O–rings are intended for use with internal straight thread connection bosses and tube fittings such as AND 10049, AND 10050, MS16142, MS33649, MS33656, MS33657, AND SAE straight thread O–ring boss style fittings. MIL–R–83248/1 O–rings are 75 durometer hardness. MIL–R–83248/2 O–rings are 90 durometer hardness. Since boss seals are subject to twisting and abrasion, it is preferable to use the harder substance (90 durometer) whenever possible.

Table 078–3–4. RECOMMENDED REPLACEMENT O–RINGS FOR VARIOUS SHIPBOARD PIPING SYSTEMS (SHEET 1 OF 3)

System	Preferred Material**		Acceptable Material**	
	Material and Specifications	Dimensional Standard	Material and Specifications	Dimensional Standard
Aqueous Monoethanolamine CO_2 Scrubbers	Ethylene Propylene Rubber NAS 1613 (80 durometer)	NAS 1601 NAS 1602	Ethylene Propylene Rubber NAS 1613 (80 durometer)	NAS 1601 NAS 1602
Fuel Oil Gasoline JP–3, 4, 5, 6	Fluorocarbon Rubber MIL–R–83248 (75 durometer)	M83248/1*	Nitrile Rubber MIL–P–5315 (60 to 80 durometer)	MS 29512 MS 29513
Water, Seawater, Condensate and Feedwater for 600 & 1200 psi fossil fired boilers **Dynamic Applications**	Ethylene Propylene Rubber ## (80 durometer) NAS 1613	NAS 1601	Fluorocarbon Rubber MIL–R–83248 (75 durometer)	M83248/1
			Nitrile Rubber MIL–R–83461	M83461/1#
Water, Seawater, Condensate and Feedwater for 600 & 1200 psi fossil fired boilers **Static Applications**	Fluorocarbon Rubber MIL–R–83248 (75 durometer)	M83248/1*	Ethylene Propylene Rubber (80 durometer) ## NAS 1613	NAS 1601 NAS 1602
			Nitrile Rubber MIL–R–83461	M83461/1#
Steam, Below 350° F	Ethylene Propylene Rubber NAS 1613	NAS 1601 NAS 1602	See Steam, Below 400° F	
Steam, Below 400° F	Ethylene Propylene Rubber ASTMD 2000/SAE J200 Specification 8BA712B13Z1 (75 durometer)	AS 568	For temperature above 400° F, consult NAVSEA for recommendation	

Table 078–3–4. RECOMMENDED REPLACEMENT O–RINGS FOR VARIOUS SHIPBOARD PIPING SYSTEMS (SHEET 2 OF 3)

System	Preferred Material**		Acceptable Material**	
	Material and Specifications	Dimensional Standard	Material and Specifications	Dimensional Standard
High–Pressure Gas (Above 1,000 psi) Air, Helium, Nitrogen and Oxygen **Static and Dynamic Applications Subject to Rapid Decompression**	Fluorocarbon Rubber MIL–F–83248 (90 durometer)	M83248/2	See paragraph 078–2.2.6.1	
High–Pressure Gas (Above 1,000 psi) Air, Helium, Nitrogen and Oxygen **Static Applications Not Subject to Rapid Decompression**	Fluorocarbon Rubber MIL–F–83248 (90 durometer)	M83248/2	Fluorocarbon Rubber MIL–R–83248*** (75 durometer)	M83248/1*
			Ethylene Propylene Rubber ## (80 durometer) NAS 1613	NAS 1601 NAS 1602
High–Pressure Gas (Above 1,000 psi) **Dynamic Applications Not Subject to Rapid Decompression**	Fluorocarbon Rubber MIL–R–83248 (75 durometer)	M83248/1*	Ethylene Propylene Rubber*** (80 durometer) NAS 1613	NAS 1601 NAS 1602
Low–Pressure Gas (Below 1,000 psi) Air, Helium, Nitrogen and Oxygen	Fluorocarbon Rubber MIL–R–83248 (75 durometer)	M83248/1*	Nitrile Rubber MIL–R–83461 Ethylene Propylene Rubber (80 durometer) NAS 1613	M83461/1# NAS 1601 NAS 1602

Table 078–3–4. RECOMMENDED REPLACEMENT O–RINGS FOR VARIOUS SHIPBOARD PIPING SYSTEMS (SHEET 3 OF 3)

System	Preferred Material**		Acceptable Material**	
	Material and Specifications	**Dimensional Standard**	**Material and Specifications**	**Dimensional Standard**
Torpedo Tube High–Pressure Air	Fluorocarbon Rubber MIL–R–83248 (75 durometer)	M83248/1*	Nitrile Rubber MIL–R–83461	M83461/1#
Hydraulic Fluid (Petroleum Base) Lube Oil	Fluorocarbon Rubber MIL–R–83248 (75 durometer)	M83248/1*	Nitrile Rubber MIL–R–83461	M83461/1#
Hydraulic Fluid Phosphate Ester Base (MIL–H–19457)	Fluorocarbon Rubber MIL–R–83248 (75 durometer)	M83248/1*	Ethylene Propylene Rubber NAS 1613 (80 durometer)	NAS 1601 NAS 1602
Hydraulic Fluid (Water Gycol Includes MIL–H–22072)	Fluorocarbon Rubber MIL–R–83248 (75 durometer)	M83248/1*	Nitrile Rubber MIL–R–83461	M83461/1#
			Ethylene Propylene Rubber NAS 1613 (80 durometer)	NAS 1601 NAS 1602

NOTES:

* M83248/2 (90 durometer) is preferred for 900 series dash numbers which are used in boss style fitting and are subject to twisting and abrasion.

MS28775 O–rings to MIL–P–25732 may also be used. Use MS28778 (88 durometer) O–rings for 900 series dash number O–rings (see Table 078–3–3) in boss style fittings.

** This table does not apply to systems and equipment under the cognizance of NAVSEA 08 where the use of fluorocarbon O–rings is generally prohibited. Preferred material minimizes the number of seal materials required and problems resulting from installing incorrect material. In some cases, the acceptable material may have slightly superior performance characteristics. MIL–R–83248 O–rings are not recommended as the preferred material in application below –20°C(–4°F). MIL–R–83485/1 fluorocarbon O–rings have better low temperature performance characteristics and may be substituted for M83248/1 O–rings.

Do not use ethylene propylene O–rings in application where petroleum products may be present such as bilge water subject to oily discharge or in hydraulic accumulator air flasks for systems with petroleum base hydraulic fluids.

*** In high pressure gas systems, Nitrile O–rings may also be used, but only in emergency situations where preferred or accepted materials are not available. Nitrile O–rings have significantly shorter life and greatly increase compressor maintenance due to excessive system leakage.

for metric glands and backup–rings are not currently available. Any additional questions regarding metric o–rings and seal design should be addressed to NAVSEA.

078–3.4.3 O–RING DIMENSIONS. The critical dimensions of an O–ring are its inside diameter (ID), its cross sectional diameter (W), and the height (usually 0.003–inch) and width (usually 0.005–inch) of the residual molding flash (see Figure 078–3–4).

078–3.4.3.1 Actual Dimensions. The actual dimensions and tolerances for O–rings are listed in AS568 and in many military specifications and standards. For convenience, the O–ring size is identified by a dash number rather than the actual dimensions.

078–3.4.3.2 Nominal Dimensions. Nominal dimensions have been used to describe O–ring sizes, although this practice is rapidly being replaced by the use of dash numbers. The nominal and actual cross section diameter (W) for the most commonly used O–rings are listed in Table 078–3–2. The actual inside diameter of a seal will be slightly less than the nominal inside diameter, but the actual outside diameter will be slightly larger than the nominal outside diameter. For example, an AS568–429 O–ring would be described in nominal dimensions as 5 inches IDc by 5–1/2 inches OD by 1/4–inch W. Actual dimensions would be 4.975 inches IDc by 5.525 inches OD by 0.275 inches W. Figure 078–3–4 illustrates the critical dimensions of an O–ring.

078–3.4.4 O–RING SPECIFICATIONS. Material and performance requirements for O–rings are often identified in military specifications. The dimensions of these O–rings will usually be found in accompanying slash sheets (which bear the specification number and are a part of the specification) or will be identified by various drawings and standards that relate to the specification. Included among the specifications are Air Force–Navy Standards (AN), Military Standards (MS) and National Aerospace Standards (NAS). If the specification does not identify sizes, the sizes should be identified by the AS568 dash number (see Table 078–3–1 and paragraph 078–3.4.1.1). Some of the more frequently used military specification O–rings are described in paragraphs 078–3.4.4.1 through 078–3.4.4.11. Usually, drawings, technical manuals, and Allowance Parts Lists (APL's) can be used to identify replacement O–rings.

NOTE

Drawings and APL's may not yet have been updated to reflect the preferred use of MIL–R–83248 fluorocarbon O–rings in submarine refrigeration, lube oil, and hydraulic systems.

078–3.4.4.1 Dimensions and Dash Numbers. Table 078–3–2 contains standard O–ring size dimensions and a cross–reference of dash numbers for some AN, MS, and AS568 O–rings. Table 078–3–3 contains dimensions and a cross–reference of dash numbers for AS568, AN, and MS O–ring gaskets.

078–3.4.4.2 MIL–P–5315. O–ring packings conforming to MIL–P–5315 are hydrocarbon fuel resistant and are intended for aircraft and engine fuel systems using gasoline and kerosene type fuels. They have a Shore A durometer hardness between 60 and 70 and are intended for use at temperatures from –54 to 71°C (–65 to 160°F). MS29512 covers O–ring gaskets for straight thread tube fitting bosses and MS29513 covers other standard O–ring gasket sizes.

078–3.4.4.3 MIL–P–5510. MIL–P–5510 covers O–ring gaskets for straight thread tube fitting bosses for temperatures from –54 to 71°C (–65 to 160°F). MS28778 sizes are dimensionally and functionally interchangeable with AN6290 sizes. MIL–P–5510 O–ring gaskets with a minimum Shore A hardness of 88 are for pneumatic systems and for hydraulic systems using MIL–H–5606 fluid. For hydraulic and lube oil systems using petroleum base fluids other than MIL–R–5606, O–rings conforming to MIL–R–83248/2 are more compatible with the fluid and provide improved performance.

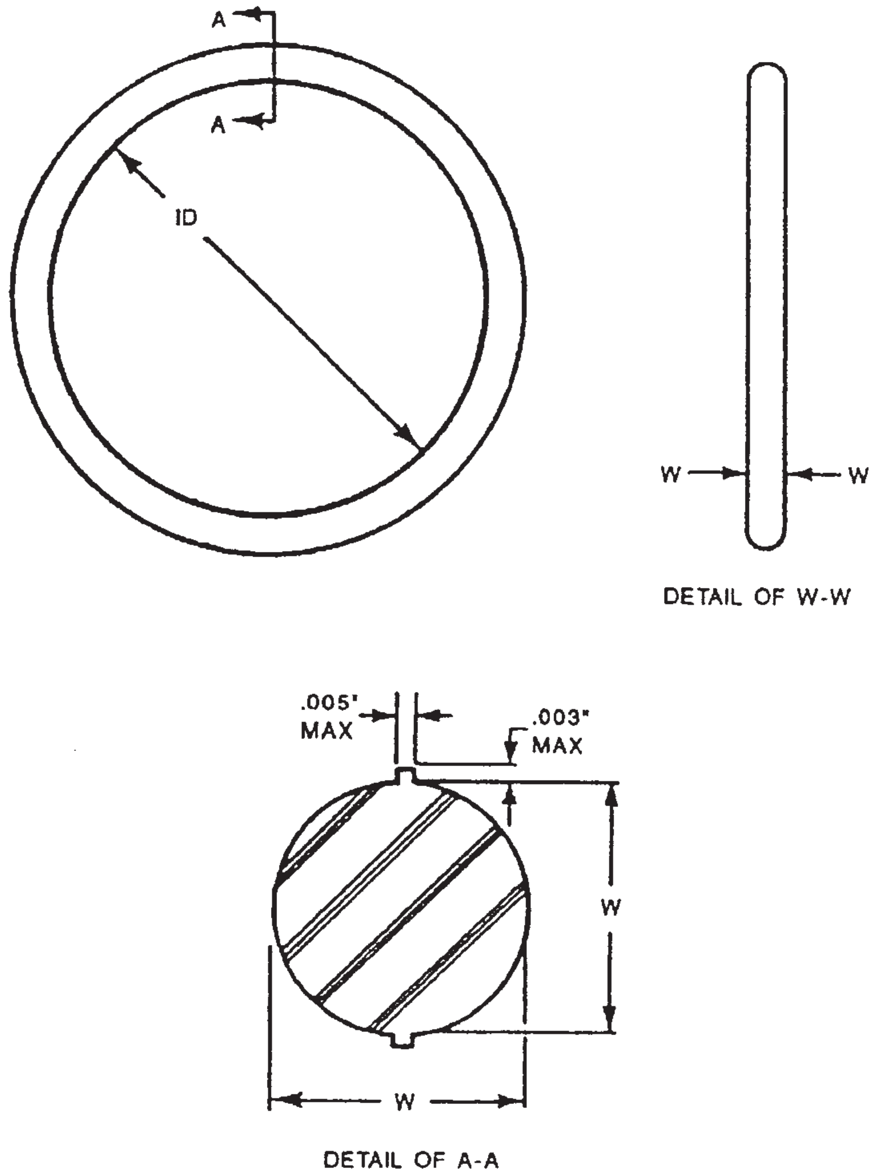


Figure 078–3–4. Critical Dimensions of an O–Ring

078–3.4.4.4 MIL–P–5516. MIL–P–5516 nitrile O–rings, which are obsolete for new applications, are designed to be used with MIL–H–5606 hydraulic fluid at temperatures from –54 to 71°C (–65 to 160°F). Class A O–rings have a minimum Shore A durometer hardness of 88 and are identified as MIL–P–5516 Class A with the AS568 dash number to determine size. Only a few sizes are listed in **Forces Afloat Shopping Guide**. Class B O–rings have a minimum Shore A durometer hardness of 68 and are available in the sizes listed in AN6227 and AN6230. For all shipboard applications, the Navy will logistically support AN6227 and AN6230 O–rings with equivalent size MS28775 O–rings per MIL–P–25732, and the stocking of AN6227 and AN6230 O–rings will be discontinued. For petroleum base hydraulic fluid and lube oil systems, fluorocarbon O–rings conforming to MIL–R–83248 are more compatible with the fluid than nitrile rubber O–rings conforming to MIL–P–5516 and provide better performance.

078–3.4.4.5 MIL–G–22050. MIL–G–22050 is a material specification for two grades of O–ring material made from an ethylene propylene compound. Grade 1 O–rings have a hardness of 65 durometer and are suitable for use up to 110°C (230°F) while Grade 2 O–rings have a hardness of 80 durometer and are suitable for temperatures up to 138°C (280°F). MIL–G–22050 O–rings are compatible with hot air, hot water, steam, and certain polar fluids such as aryl phosphate ester hydraulic fluids and aqueous monoethanolamine (MEA). These seals are also used in water–glycol hydraulic systems, CO_2 scrubbers, and coolant discharge systems.

078–3.4.4.6 NAS 1613. NAS 1613 is a material specification for 80 durometer ethylene propylene rubber. This material for alkyl aryl phosphate ester aircraft hydraulic fluid is suitable for use in ship applications requiring ethylene propylene rubber. O–rings of this material are much more likely to be available from the supply system than are MIL–G–22050 ethylene propylene rubber O–rings. NAS 1601 and NAS 1611 O–rings use NAS 1613 material and have dash numbers equivalent to SAE AS 568, as shown in Table 078–3–2. Despite different tolerances on the diameter, NAS 1601 and NAS 1611 O–rings are interchangeable. Likewise, NAS 1602 and NAS 1612 both use NAS 1613 material. NAS 1602 dash numbers are equivalent to AS 568 dash numbers of Table 078–3–3 and NAS 1612 dash numbers are equivalent to MS 28778 dash numbers of the same table. NAS 1602 and NAS 1612 O–rings are interchangeable, although the tolerances differ. NAS 1611 and NAS 1612 are inactive for new design.

078–3.4.4.7 MIL–G–23652. This fluorocarbon O–ring specification has been superseded by MIL–R–83248. When supplies of O–rings per this specification are exhausted the supply system will substitute MIL–R–83248/1 rings for type I (70 durometer) and MIL–R–83248/2 for type II (90 durometer). The MIL–G–23652 O–rings are identified by AS 568 (or ARP 568) dash numbers for size. See Table 078–3–2 and Table 078–3–3 for cross–reference with dimensions and MIL–R–83248 dash numbers.

078–3.4.4.8 MIL–P–25732. These nitrile O–rings are designed for use with MIL–H–5606 hydraulic fluid from –54 to 135°C (–65 to 275°F) but have been used in many shipboard applications. The O–rings have a minimum Shore A durometer hardness of 68 and are available in sizes shown on MS 28775 (see Table 078–3–2). O–rings to this specification may exhibit shrinkage in water and most petroleum base oils and hydraulic fluids used in ship systems. The supply system is substituting MIL–P–83461/1 O–rings for MS 28775 O–rings because of the improved high temperature characteristics of the MIL–P–83461 material. However, as identified in Table 078–3–4, fluorocarbon rubber per MIL–R–83248 is the preferred replacement material for most shipboard applications using this nitrile material.

078–3.4.4.9 Mare Island O–Ring Compound P–52–2 (Substitute for MIL–P–25732). This nitrile rubber compound is for use in shipboard systems in place of MIL–P–25732 O–rings. This compound is primarily for use when special sizes, installation procedures or schedule requirements preclude the use of MIL–R–83248 O–rings. For example, the splicing procedure of paragraph 078–3.9.2 is applicable to P–52–2 O–rings but not MIL–R–83248 O–rings. Compound P–52–2 is more compatible with sea and fresh water, and most petroleum base fluids used on ships than MIL–P–25732 which tends to shrink in size when exposed to water and petroleum–base fluids due to plasticizer extraction. However, compound P–52–2 cannot be used with fluids such as MIL–H–5606, MIL–H–6083 or MIL–F–17111 since these hydraulic fluids cause excessive swelling of the compound. Therefore, use of compound P–52–2 is limited to applications involving the fluids listed below unless otherwise specifically approved by NAVSEA:

- Water, Seawater
- Petroleum Base Hydraulic Fluids (MIL–H–17672)
- Lube Oil (MIL–L–17331)
- Water–glycol (MIL–H–22072)
- Silicone fluid (MIL–S–81087)

a. Mare Island Naval Shipyard Rubber Laboratory compound P–52–2 can be manufactured using the following recipe:

Ingredients	Parts by Weight
Paracril AJ	95
Nat syn 2200	5
Philblack N550	55
Stearic Acid	1
Protox 166	5
Santoflex 13	2
Sunproof Improved	1
Sulfur	0.5
Ethyl Tuads	3.5
Altax	1
KP-140	3
Total	172
Cure: 20 minutes at 320°F	

b. When manufacturing O–rings from P–52–2 compound, sample O–rings from each batch should be subjected to the following Quality Assurance Tests (see ASTM D1414 for applicable test procedures):

Test	Requirements
Tensile strength	2,200 psi, minimum
Ultimate Elongation	190 percent, minimum
Specific gravity	1.16 to 1.18
Hardness, *Shore A, 3 seconds	65 to 75
*May be conducted on a 1/4-inch minimum thickness disk due to difficulty of testing relatively small cross-section O-rings	

c. Additional information about Mare Island Naval Shipyard Rubber Laboratory compound P–52–2 may be obtained from Portsmouth Naval Shipyard, Code 260.1, (Phone: DSN 684–3323). In addition, Portsmouth Naval Shipyard maintains over 50 sizes of O–ring mold.

078–3.4.4.10 MIL–R–25897. This specification covering fluorocarbon O–rings has been superseded by MIL–R–83248. Class 1 MIL–R–25897 O–rings had a Shore A durometer hardness of 75 and were available in NAS 1594, NAS 1596, and AS 568 sizes. MIL–R–83248 O–rings of the appropriate hardness will provide improved performance. See Table 078–3–2 and Table 078–3–3 for cross–reference of dimensions and dash numbers.

078–3.4.4.11 MIL–R–83248. These fluorocarbon O–rings were designed for use when resistance to jet fuel, synthetic engine lubricants, and petroleum hydraulic fluids is required. Generally, materials meeting this specification are usable over a temperature range of –34°C to 260°C (–30°F to 500°F). MIL–R–83248 seals should not be used as substitutes in applications below –20°C (–4°F) without specific NAVSEA approval. As shown in Table 078–3–4, MIL–R–83248 O–rings are the preferred material for most ship systems as the fluorocarbon material is compatible with most fluids. However, care must be exercised to ensure that replacement fluorocarbon O–rings are of the same durometer hardness as the O–ring being replaced. Also, fluorocarbon O–rings may not be suitable substitutes for O–rings made of specially engineered materials such as polyurethane. M83248/1 seals have a Shore A durometer hardness of 75 while M83248/2 seals have a Shore A durometer hardness of 90. The 90 durometer seals are preferable for use as boss seals as they are more resistant to twisting and abrasion. See Table 078–3–2 and Table 078–3–3 for cross–reference of dimensions, dash numbers and National Stock Numbers.

078–3.4.4.12 MIL–R–83461. This nitrile O–ring is designed for use with MIL–H–5606 and MIL–H–83282 fluids over a temperature range of –54°C to 135°C (–65°F to 275°F). This material has better high temperature characteristics than MIL–P–25732 and can be used to replace MS 28775 O–rings. The dimensional standard is M83461/1 and provides a Shore A durometer hardness of 75. Dash numbers are equivalent to AS 568 dash numbers in Table 078–3–2. The O–rings listed in table I of this military specification sheet are recommended for use in packing glands specified in MIL–G–5514. O–rings listed in table II of M83461/1 cover the remainder of the O–ring sizes listed in AS 568, however, the applicable gland sizes for these O–rings are not specified in MIL–G–5514. The table II sizes for these O–rings are not recommended for hydraulic applications.

078–3.4.4.13 MIL–R–83485. This fluorocarbon rubber material has improved low temperature performance (approximately 25°F) over fluorocarbon rubber to MIL–R–83248. O–rings to this specification are several times more expensive than MIL–R–83248 O–rings, but should be used in ship systems when improved low–temperature performance is required. Shore A durometer hardness is 75 and dimensions are per M83485/1 with dash numbers the same as AS 568 and M83248.

078–3.4.4.14 MIL–P–70341. MIL–P–70341 is a general specification for O–rings that are fabricated from 100 percent polytetrafluoroethylene (PTFE). PTFE is a material that is impervious to virtually all fluids and gases over a range from –196°C (–320°F) to 232°C (450°F). MIL–P–70341/1 is the dimensional standard for these PTFE O–rings. The dash numbers identified in MIL–P–70431/1 for the MIL–P–70431 O–rings correspond to the standard sizes specified by AS 568.

078–3.4.5 IDENTIFICATION OF REPLACEMENT O–RINGS FOR SHIP PIPING SYSTEMS AND COMPONENTS. Many O–rings on drawings are identified to obsolete specifications. Other O–rings are designated by dimensions or AS 568 (formerly ARP 568) sizes and a Military Specification rather than a standard (AN, MS, NAS or Military Specification) part number. Table 078–3–5 provides a cross reference of the obsolete and current replacement specifications for O–rings frequently used in shipboard systems. O–rings in stock that were developed to obsolete specifications may generally be used, but orders for replacement O–rings should be to current specifications. In most cases, O–rings to obsolete specifications will be filled by the supply system with O–rings to the superseding specification. To minimize the number of O–ring materials which must be stocked by maintenance activities, Table 078–3–4 has been developed to indicate preferred and acceptable O–ring replacements for shipboard piping systems and components which may be used in addition to those identified in component Allowance Part Lists (APL's). When APL's are updated, the preferred material in Table 078–3–4 should be identified for O–rings unless overriding guidance has been issued for a specific component. Use of the replacement O–rings, identified in Table 078–3–4, is authorized even though APL's have not been updated

Table 078–3–5. CROSS–REFERENCE OF OBSOLETE AND CURRENT O–RING SPECIFICATION FOR SHIP APPLICATIONS

Obsolete O-Ring Specification		Current O-Ring Specification	
Material and Specification	**Dimensional Standard**	**Material and Specification**	**Dimensional Standard**
Nitrile (Buna N) Rubber MIL–P–5516, Class B	AN 6227 AN6230	Nitrile Rubber MIL–P–83461	M83461/1
Nitrile (Buna N) Rubber MIL–P–5510 (88 durometer)	AN 6290	Nitrile (Buna N) Rubber, MIL–P–5510 (88 durometer)	MS 28778
Fluorocarbon Rubber MIL–R–25897 Class 1 (75 durometer)	NAS 1593 NAS 1595 AS 568	Fluorocarbon Rubber MIL–R–83248, Class 1 (75 durometer)	M83248/1
Fluorocarbon Rubber MIL–R–25897 Class 2 (90 durometer)	NAS 1594 NAS 1596 AS 568	Fluorocarbon Rubber MIL–R–83248, Class 2 (90 durometer)	M83248/2
Fluorocarbon Rubber AMS 7278 (75 durometer)	MS 9387 MS 9388 MS 17413	Fluorocarbon Rubber MIL–R–83248 Class 1 (75 durometer)	M83248/1
Fluorocarbon Rubber MIL–G–23652 Type 1 (70 durometer)	AS 568 (formerly ARP 568)	Fluorocarbon Rubber MIL–R–83248, Class 1 (75 durometer)	M83248/1
Fluorocarbon Rubber MIL–G–23652 Type 2 (90 durometer)	AS 568 (formerly ARP 568)	Fluorocarbon Rubber MIL–R–83248 Class 2 (90 durometer)	M83248/2
MIL–G–18586 Class 1 (Butadiene-styrene copolymer) (70 durometer) Class 2 (Butadiene-acrylonitrile copolymer) (70 durometer)	MIL–G–18586	Nitrile Rubber MIL–P–83461	M83461/1
Ethylene Propylene Rubber (80 durometer) MIL–R–24102 (For HP Air Systems)	ARP 568	Fluorocarbon Rubber MIL–R–83248 Class 2 (90 durometer)	M83248/2
Nitrile Rubber MIL–P–25732	MS 28775	Nitrile Rubber MIL–P–83461	M83461/1
Ethylene Propylene Rubber NAS 1613	NAS 1611 NAS 1612	Ethylene Propylene Rubber, NAS 1613	NAS 1601 NAS 1602

NOTE

In most cases, drawings will not be revised to reflect the preferred replacement O–ring material. Update of all APL's will take many years. If priority updating of a specific APL is required, forces afloat may submit an OPNAV 4790–CK Form, Request For Configuration Change to NAVSEALOGSUPENGACT, Mechanicsburg. Information regarding O–ring requirements for procurement of replacement components should be referred to the cognizant NAVSEA Life Cycle Manager.

078–3.4.5.1 National Stock Numbers. National Stock Numbers (NSN’s) for O–rings are usually listed on equipment Allowance Parts Lists (APL’s). An NSN can be determined if either the standard part number or the O–ring size is known. An NSN can be obtained from the **Afloat Shopping Guide (ASG)** or the **Navy Master Cross Reference List (NMCRL)** as described in paragraphs 078–3.4.5.1.1 and 078–3.4.5.1.2.

078–3.4.5.1.1 Use of Afloat Shopping Guide**.** In the ASG, O–rings are under class 5330. O–rings are listed under the applicable specification for various nominal cross sections by inside diameter and dash number. If either the dimensions or the applicable specification dash number is known, the NSN can be obtained directly from the ASG. In most cases, O–ring durometer hardness is indicated in the ASG alone with limited guidance on fluid compatibility.

078–3.4.5.1.2 Use of Navy Master Cross Reference List. Stock numbers, for O–rings are listed in the NMCRL by AN, MS, or military specification O–ring dash numbers. If the O–ring dimensions are known but the dash numbers are not known, Table 078–3–2 and Table 078–3–3 may be used to obtain the dash number. Many earlier military specifications do not contain a standard part numbering system. To obtain stock numbers for O–rings conforming to such military specifications it is necessary to enter the NMCRL under the AS568 dash number.

NOTE

Although AS568 has superseded ARP568, O–rings are currently listed under both designations in the NMCRL and it may be necessary to check ARP568 in addition to AS568.

078–3.4.5.1.3 The O–ring listing should have the AS568 dash number followed by the military specification and the type, grade, or class designation if the military specification covers more than one hardness of O–ring. For example:

a. AS568–011, MIL–G–23652, Type II

b. ARP568–011, MIL–G–22050, Grade 2

c. AS568–011, MIL–R–25897, Class 2

078–3.5 O–RING GLANDS

078–3.5.1 BOSS GLANDS O–rings are widely used to seal the ends of straight thread tube fittings where they are screwed into mounting holes or bosses. Two standard boss series exist and in each series the same size boss takes the same O–ring and same tube fitting. The so–called military boss conforming to the MS 33649 design (formerly the AND 10050 boss) is the older design and is more difficult to machine properly. The newer MS 16142 design is equivalent to the SAE J514 boss design.

078–3.5.1.1 MS 33649 (Formerly AND 10050) Military Boss. As shown in Figure 078–3–5, a 120 degree countersink forms a part of the O–ring cavity. The A diameter of the countersink has a tolerance of +0.015–inch –0.000–inch but the angle relative to the flat surface makes the diameter difficult to measure and control. This can result in variations in the size of the cavity which may cause the O–ring to be extruded when the fitting is torqued down. In other cases there may not be enough squeeze on the O–ring to obtain satisfactory sealing.

078–3.5.1.2 MS 16142 (SAE J1926) Boss. As shown in Figure 078–3–6, the SAE boss uses a countersink with an included 24 degree or 30 degree angle depending on the tube size. The diameter of this countersink has a tolerance of +0.005–inch –0.000–inch, but the countersink (being a nearly cylindrical cavity) can be measured and controlled more easily than the military boss. Fewer problems are experienced with the SAE boss than with the military boss because of better dimensional control.

078–3.5.2 RADIAL SEAL GLANDS. Most O–ring applications use glands of rectangular cross section in accordance with military or industrial standards. For pressures above 1500 lb/in^2 backup (anti–extrusion) rings are normally required. Industrial standards for glands usually provide more O–ring squeeze for static applications than does the MIL–G–5514 gland specification which provides the same squeeze for both static and dynamic applications. If gland dimensions are not available on drawings or technical repair standards, the standards in Table 078–3–6 are recommended.

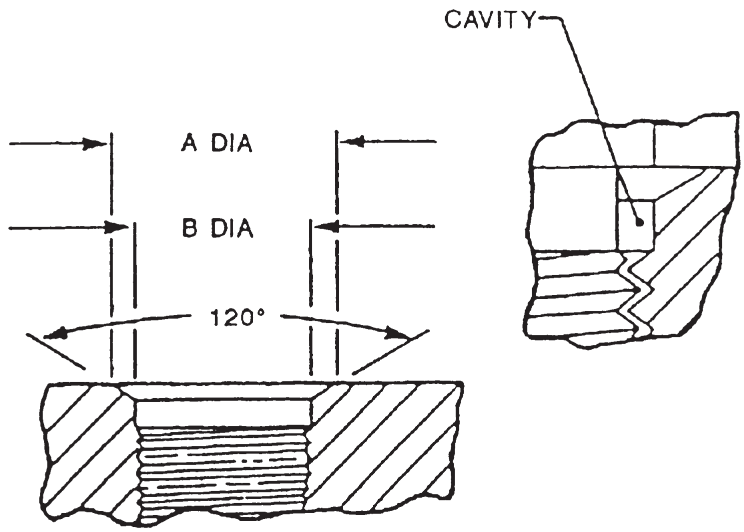


Figure 078–3–5. MS33649 Military Boss

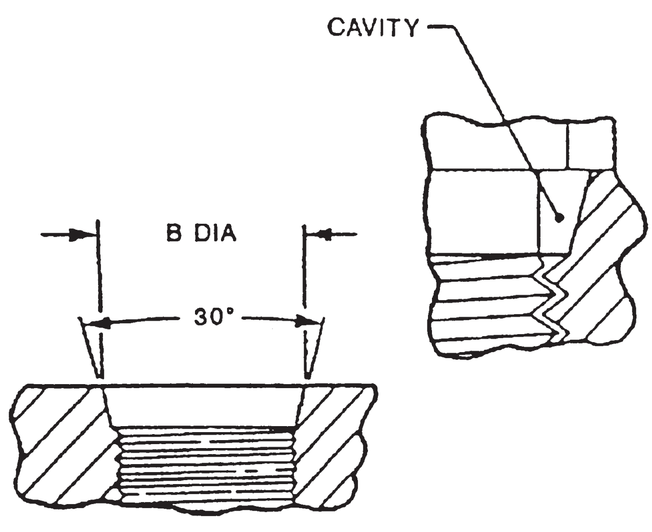


Figure 078–3–6. MS16142 (SAE J1926) Boss Design

Table 078–3–6. RECOMMENDED O–RING GLANDS

Type of Seal Application	Operating Pressure	
	1500 lb/in^2 Maximum	1500 lb/in^2 and Above
Static	ARP–1232	MIL–G–5514 or AS 4716
Dynamic	ARP–1233	MIL–G–5514 or AS4716

078–3.5.2.1 MIL–G–5514 Military O–Ring Glands. General design requirements for O–ring installations for hydraulic equipment are contained in MIL–G–5514. MIL–G–5514 was specifically developed for aircraft hydraulic installations but the guidance usually is satisfactory for shipboard applications with operating pressures of 1500 lb/in^2 and higher. MIL–G–5514 provides the same O–ring squeeze for both static and dynamic gland applications. The squeeze is limited because the gland depth is sized to accommodate backup rings which are generally required above 1500 lb/in^2. Information which may be found in this specification includes:

a. O–ring packing gland dimensions for applications with zero, one and two backup rings

b. O–ring dimensions and dash numbers

c. Minimum and maximum squeeze obtained with the recommended gland dimensions

d. Surface roughness height rating requirements for packing glands.

e. Requirements for nonextrusion devices (backup rings).

078–3.5.2.2 Industrial O–Ring Glands. Industrial glands often differ from MIL–G–5514 requirements in several ways. The military specification calls for the same squeeze on an O–ring for both static and dynamic applications. Industrial practice is to apply a heavier squeeze in static applications to increase reliability at low temperatures. The military design in most cases requires less stretch on the inside diameter of the O–ring, which should tend to reduce aging caused by stress, particularly for smaller sizes. On the larger sizes this difference would probably be insignificant and industrial dimensions may allow the use of standard stock rod diameters and boring tools for production savings. Recommended industrial O–ring gland dimensions can be found in handbooks published by seal manufacturers.

078–3.5.2.3 SAE O–Ring Gland Standards. The Society of Automotive Engineers (SAE) has published several Aerospace Recommended Practices (ARP) and an Aerospace Standard (AS) on O–ring gland design. They are:

a. **ARP–1231. Gland Design Elastomeric O–ring Seals, General Considerations** provides general guidance on the design of O–ring glands.

b. **ARP–1232**. **Gland Design, Elastomeric O–Ring Seals, Static Radial** establishes standard gland dimensions for static radial O–ring seal applications, without anti–extrusion devices, which are suitable for use with most O–ring materials at pressures up to 1500 lb/in^2. Depending on the cross section diameter of the O–ring this standard provides a nominal squeeze of 17.5 to 21 percent for static radial seals.

c. **ARP–1233. Gland Design, Elastomeric O–Ring Seals, Dynamic Radial, 1500 PSI Max** establishes standard gland design criteria and dimensions for dynamic radial O–ring seal applications, without anti–extrusion devices, which are suitable for use with most O–ring materials at pressures up to 1500 lb/in^2. This standard provides a nominal squeeze ranging from 19 percent for 0.070–inch cross section diameter O–rings to 10.5 percent for 0.275–inch cross section diameter O–rings.

d. **AS 4716. Gland Design, O–Ring and Other Elastomeric Seals** provides standardized gland design criteria and dimensions for elastomeric seal glands used in static and dynamic new design applications. The glands have been specifically designed for new design applications using SAE AS 568 size O–rings at pressures exceeding 1500 lb/in^2 utilizing one or two anti–extrusion (backup) rings and applications at pressures under 1500 lb/in^2 without backup rings. These glands have been designed to provide a minimum of.005 inches seal deflection (squeeze) under adverse tolerance conditions. While these glands are sized for use with standard O–rings, they are also to be used with other elastomeric seals.

078–3.5.2.4 Submarine Antenna System O–Ring Glands. Glands for O–rings in static applications on submarine antenna systems have been designed in accordance with gland dimensions identified in **O–ring Seals for Submarine Antenna System Applications**, NAVSEA 0280–LP–661–5000, and provide greater squeeze than do MIL–G–5514 glands.

078–3.5.3 FACE TYPE SEAL GLANDS. The face type seal gland consists of a groove in a flat surface plus a mating flat surface which covers the groove when assembled. (See Figure 078–3–2). While the face seal can be manufactured using MIL–G–5514 dimensions, more reliable service will probably be obtained by using industrial standards which call for a heavier squeeze. In applications where the pressure is outward, the outside diameter of the O–ring should hug the groove wall even at zero pressure. Thus, when pressure is applied, the ring cannot slide further outward in the groove. The ring will flow slightly into corner voids of the groove without sliding or significant stretching.

078–3.5.3.1 If the O–ring has room to move outward when pressure is removed, the resultant cyclic motion will cause gradual wear. This cyclic motion can result in leakage because a small amount of confined fluid (liquid or gas) can be carried past the seal with each pressure pulse. The use of static face seal should be avoided in applications where pressure is alternately applied or removed or where a radial squeeze seal design is feasible.

078–3.5.3.2 Typical industrial O–ring face seal gland dimensions are shown in Figure 078–3–7 and Table 078–3–7. These dimensions do not supersede those shown on component drawings but may be used for guidance when detailed drawings are not available.

Table 078–3–7. TYPICAL INDUSTRIAL O–RING FACE SEAL GLAND DIMENSIONS

AS568 O-Ring Size	W- Cross Section	L- Gland Depth	Squeeze		G-Gland Width		R- Groove Radius
			Actual	%	Liquids	Vacuum and Gases	
004 through 050	0.070±0.003	0.050 to 0.054	0.013 to 0.023	19 to 32	0.101 to 0.107	0.083 to 0.088	0.005 to 0.015
102 through 178	0.103±0.003	0.074 to 0.080	0.020 to 0.032	20 to 30	0.136 to 0.142	0.118 to 0.123	0.005 to 0.015
201 through 284	0.139±0.004	0.101 to 0.107	0.028 to 0.042	20 to 30	0.177 to 0.187	0.157 to 0.163	0.010 to 0.025
309 through 395	0.210±0.005	0.152 to 0.162	0.043 to 0.063	21 to 30	0.270 to 0.290	0.236 to 0.241	0.020 to 0.035
425 through 475	0.275±0.006	0.201 to 0.211	0.058 to 0.080	21 to 29	0.342 to 0.362	0.305 to 0.310	0.020 to 0.035

NOTE:
1. All dimensions are in inches.
2. All dimensions are for face type seals.
3. To calculate gland diameter see Figure 078–3–7 and Table 078–3–2.

078–3.5.4 NONSTANDARD GLANDS. Some applications require the use of nonstandard O–ring glands. Two types of nonstandard glands are described in paragraphs 078–3.5.4.1 through 078–3.5.4.2.

078–3.5.4.1 Dovetail Grooves. Dovetail grooves are used where it is important to retain the O–ring in its groove when the mating parts are separated. This design should be avoided where it is not absolutely necessary, because:

a. A dovetail groove is both difficult and expensive to machine

b. Dimensions and tolerances are critical and difficult to check

Angles at the bottom of the groove lead to stress concentrations which can sometimes cause wall segments to break out.

078–3.5.4.2 Noncircular Face Grooves. For some applications (such as sealing rectangular covers) an O–ring must be used in a face type groove which does not follow a circular path. If an O–ring is placed in a noncircular face groove, problems may develop at the corners if the groove changes directions too sharply, and the O–ring may tend to pop out of the groove. In addition, the sharp bends can set up stresses in the rubber to cause early stress cracking, or the rubber may crease or fold at the corners creating leakage paths. As a rule of thumb, the inside radius at the corners or other sharp bends should be at least 3 times the cross section diameter of the O–ring. If this rule is observed, noncircular seal grooves should provide essentially the same effect as circular grooves

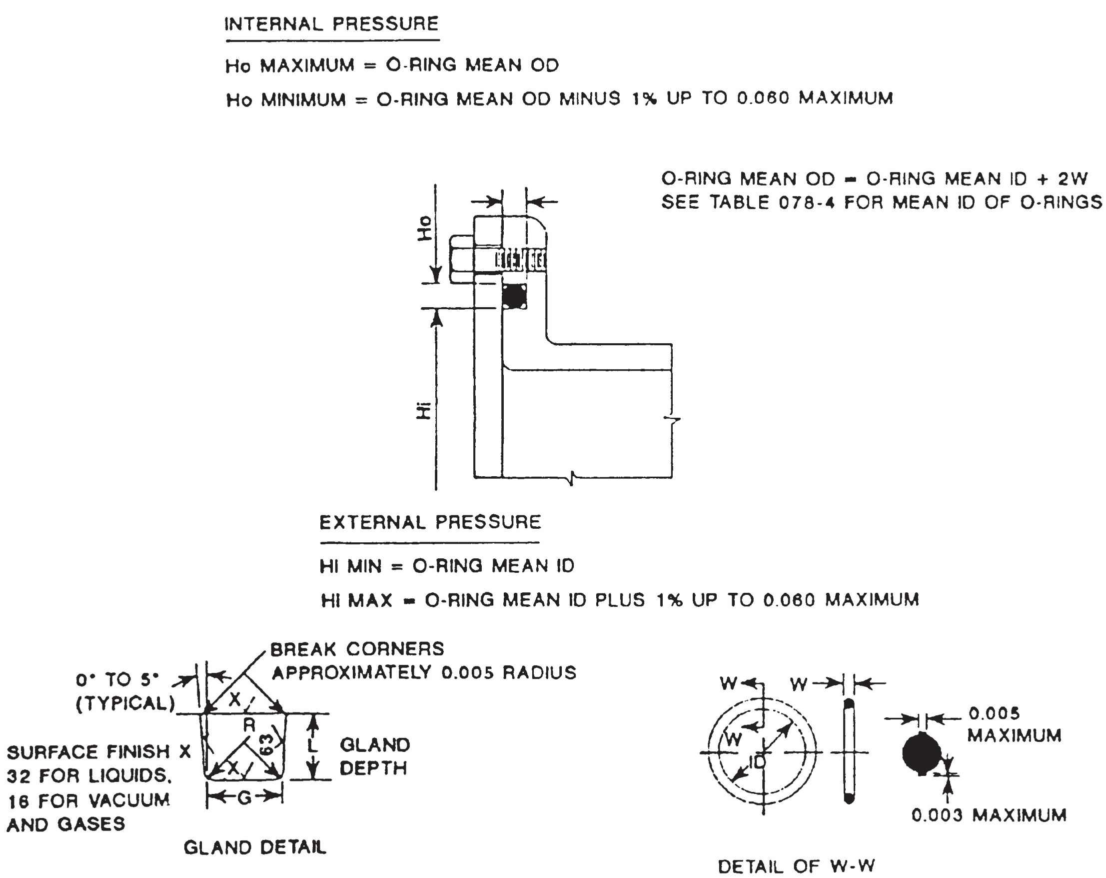


Figure 078−3−7. Face Seal Gland Diameters

078–3.5.5 SURFACE FINISHES FOR O–RING GLANDS. Tolerances for metal finish of the groove and mating parts are not usually as critical for static seals as for dynamic seals since packing motion is limited to that caused by the application of pressure. Porous castings, out–of–tolerance parts, tool marks, and distorted glands frequently contribute to static seal malfunction.

078–3.5.5.1 MIL–G–5514 Requirements. The surface finish requirements for O–rings for liquid (specifically hydraulic) service identified in MIL–G–5514 are given in Table 078–3–8.

Table 078–3–8. O–RING FINISH REQUIREMENTS

Part of Unit	Surface Roughness/Height Rating (maximum)
Cylinder Bore or Piston Rod (diameter over which packing must slide)	16
O-Ring Gland Diameter:	
Dynamic Seals	32
Static Seals	63
O-Ring Gland Sides When No Backup Ring is Used:	
Dynamic Seals	32
Static Seals	63
O-Ring Gland Sides When Backup Rings Are Used	63

078–3.5.5.2 Gas and Vacuum Applications. For static gas or vacuum applications a sealing surface maximum roughness of 16 microinches roughness height rating (rhr) is recommended and the groove diameter and sides should not exceed 32 microinches rhr. Even smoother finishes may be required for dynamic gas or vacuum seals.

078–3.5.5.3 Reciprocating Seals. In reciprocating seal applications, small amounts of fluid are trapped in microscopic irregularities in the rod and cylinder surfaces. As the rod travels, entrapped droplets pass through the sealing line and are lost. A smoother mating surface will reduce leakage from this source roughly in proportion to the reduction of volume of the surface irregularities, **but it is possible to make the rod too smooth**. Some slight roughness in the surface is needed to hold enough fluid for lubrication. If the rod surface roughness is much less than 10 microinches, the sealing element will often wipe the rod so dry during its extension that the rod will have no lubrication on the return stroke. Early failure could result from friction, wear, and overheating. As a rule of thumb, mating surfaces for reciprocating or other dynamic seals should have a roughness value between 10 and 20 microinches for minimum leakage consistent with low friction and long seal life.

078–3.5.5.4 Rotary Seals. In rotary seal applications, the slight lead (that is, the microscopic helical grooving) remaining on the shaft after grinding is enough to cause rotary seals to leak when rotation is in a direction that carries the lead out of the seal. Conversely, a lead in the opposite direction can minimize leakage by continuously carrying the liquid back into the seal. The latter arrangement can be used to minimize leakage when the direction of rotation is mainly in one direction.

078–3.5.6 REPAIR ACCEPTANCE STANDARDS FOR O–RING GLAND DIMENSIONS AND FINISHES. Relaxed repair acceptance criteria for O–ring gland dimensions and surface finishes are provided in paragraphs 078–3.5.6.1 through 078–3.5.6.4. These criteria are general in nature and may not cover all configurations and applications. Ensure that existing equipment or component technical repair standards do not provide more stringent criteria before applying the following criteria.

078–3.5.6.1 Acceptance criteria for static radial seals (Figure 078–3–8):

a. The size and spacing of surface defects may be estimated visually.

b. Rhr surface finish requirements apply only to surfaces surrounding allowable surface defects and not to the surface defect areas themselves.

c. Diametral clearance, gland depth, and gland width requirements apply to surfaces surrounding allowable surface defects and not to the surface defect areas themselves.

d. Scratches that penetrate O–ring or other sealing surfaces are not acceptable.

e. Any metal removal shall be held to the minimum necessary to meet acceptable criteria.

f. Where repairs will not conform to the acceptance criteria specified herein, a waiver request must be submitted to NAVSEA.

g. When pressure is applied from two directions or when direction of applied pressure is unknown, both sides of the O–ring gland must be considered sealing surfaces.

1. The O–ring gland and mating sealing surface for static radial seals (Figure 078–3–8) shall meet the requirements of Table 078–3–9.

2. The O–ring gland sealing surface finish, except for surface defects allowable by Table 078–3–9, shall be 125 rhr or smoother.

3. The mating sealing surface finish, except for surface defects allowable by Table 078–3–9, must be 63 rhr or smoother.

4. Raised edges of allowable surface defects of an O–ring gland and mating sealing surface are not acceptable.

5. Gland face angle (dimension H, Figure 078–3–8) must not exceed 5° maximum.

6. For specific cases that use quad rings or quad–x–seals, the maximum gland depth is given in Table 078–3–10.

7. For glands without backup rings, Table 078–3–11 provides the diametrical clearances. Table 078–3–12 provides diametrical clearance for glands with backup rings.

078–3.5.6.2 Acceptance criteria for dynamic radial seals (Figure 078–3–9):

a. The size and spacing of surface defects may be estimated visually.

Table 078–3–9. ALLOWABLE O-RING GLAND SURFACE DEFECTS

Nominal O-ring Cross-Section	Maximum Gland Depth D*	Static Seals				Dynamic Seals			
		Maximum Allowable Surface Defect Spacing		Minimum Allowable Surface Defect Spacing		Maximum Allowable Surface Defect Spacing		Minimum Allowable Surface Defect Spacing	
		Max Width or Length	Max Depth	Avg	Min	Max Width or Length	Max Depth	Avg	Min
1/16	0.060	0.004	0.002	3/64	1/64	0.003	0.002	1/32	1/64
3/32	0.093	0.006	0.003	1/16	1/32	0.004	0.002	3/64	1/64
1/8	0.126	0.008	0.004	3/32	1/32	0.005	0.003	1/16	1/64
3/16	0.190	0.012	0.008	1/8	3/64	0.008	0.004	5/64	1/64
1/4	0.250	0.015	0.010	5/32	1/16	0.010	0.005	7/64	1/32

$$\text{*Maximum Gland Depth (D)} = \frac{\text{B (maximum)} - \text{A (minimum)}}{2} \quad \text{or (D)} = \frac{\text{E (maximum)} - \text{F (minimum)}}{2}$$

*For dimensions A, B, D, E, and F, refer to Figures 078–3–8 and 078–3–9

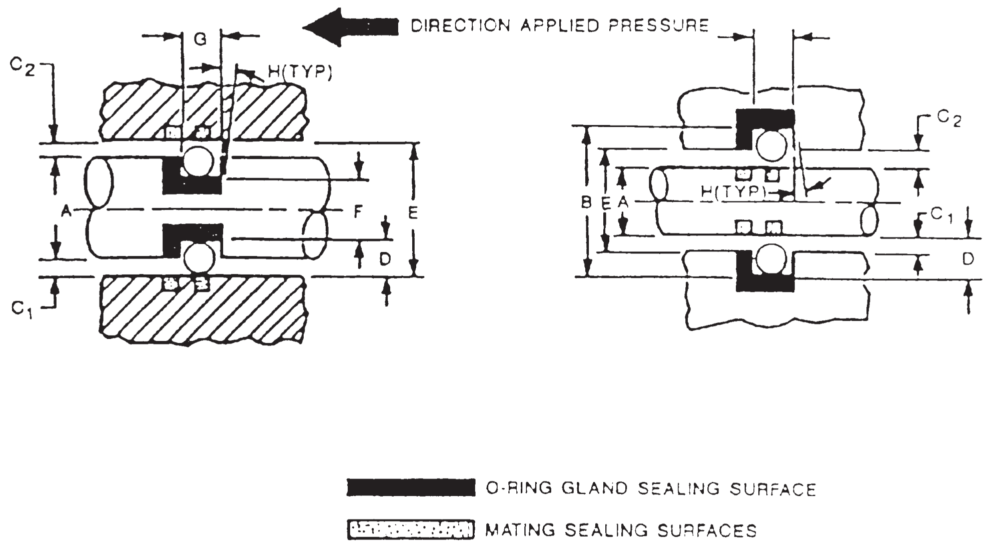


Figure 078–3–8. Static Radial Seals

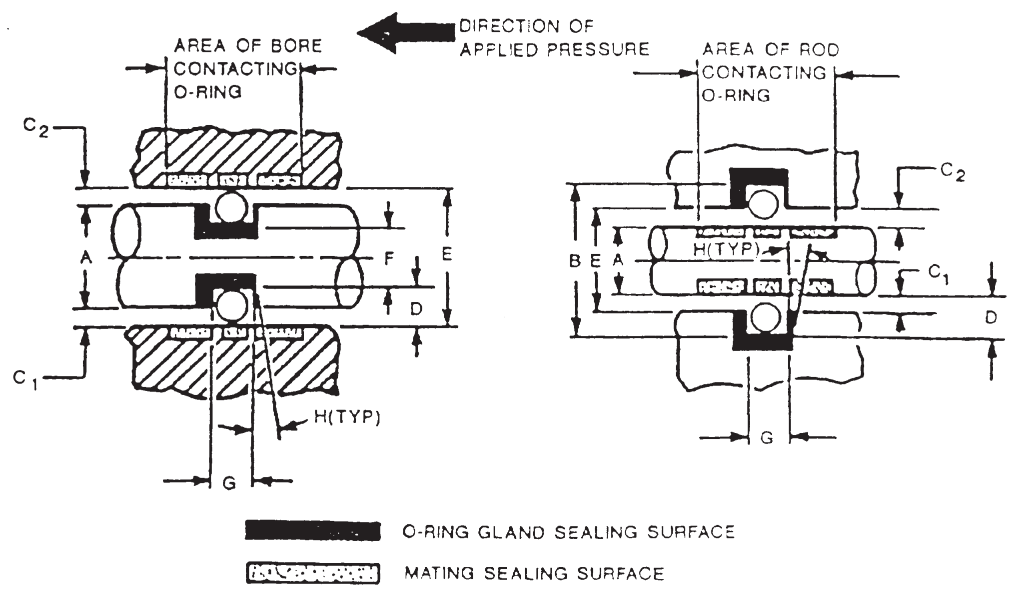


Figure 078–3–9. Dynamic Radial Seals

Table 078–3–10. MAXIMUM O-RING GLAND DEPTH

AS 568 Dash Numbers	Cross Section (inches)	Maximum Gland Depth (Quad Rings or Quad-X-Seals) D*
004–099	1/16	0.062
100–199	3/32	0.095
200–299	1/8	0.129
300–399	3/16	0.197
400–499	1/4	0.257

$$\text{*Maximum Gland Depth (D)} = \frac{\text{B (maximum)} - \text{A (minimum)}}{2}$$

or

$$\frac{\text{E (maximum} - \text{F (minimum)}}{2}$$

*For dimensions A, B, D, E, and F, refer to Figure 078–3–8 and Figure 078–3–9

Table 078–3–11. MAXIMUM RECOMMENDED DIAMETRAL CLEARANCE (C) FOR O-RING GLANDS WITHOUT BACKUP RINGS

Pressure (Maximum)	O-Ring Hardness Shore A - Durometer			
	70	**75**	**80**	**90**
1500	0.003	0.004	0.006	0.010
1000	0.006	0.008	0.010	0.014
600	0.010	0.012	0.014	0.018
300	0.016	0.018	0.020	0.024

*Maximum Diametral Clearance (C) = E (maximum) – A (minimum)
= $C_1 + C_2$

*For dimensions A, C_1, C_2, and E, refer to Figure 078–3–8 and Figure 078–3–9

b. Rhr surface finish requirements apply only to surfaces surrounding allowable surface defects and not to the surface defect area themselves.

c. Diametral clearance, gland depth, and gland width requirements apply to surfaces surrounding allowable surface defects and not to the surface defect areas themselves.

d. Scratches that penetrate O–ring or other sealing surfaces are not acceptable

e. Any metal removal shall be held to the minimum necessary to meet acceptance criteria.

f. Where repairs will not conform to the acceptance criteria specified herein, a waiver request must be submitted to NAVSEA.

g. When pressure is applied from two directions or when direction of applied pressure is unknown, both sides of the O–ring gland must be considered sealing surfaces.

1. The O–ring gland and mating sealing surface for dynamic radial seals (Figure 078–3–9) must meet the requirements of Table 078–3–9.

2. The O–ring gland sealing surface finish, except for surface defects allowable by Table 078–3–9, must be 63 rhr or smoother.

3. The mating sealing surface finish, except for surface defects allowed by Table 078–3–9, must be 32 rhr or smoother.

4. Raised edges of allowable surface defects on an O–ring gland and mating sealing surface are not acceptable.

5. Gland face angle (dimension H, Figure 078–3–9) must not exceed 5° maximum.

6. For specific cases that use quad rings or quad–x–seals, the maximum gland depth is given in Table 078–3–10.

7. For glands without backup rings, Table 078–3–11 provides the diametrical clearances. Table 078–3–12 provides diametrical clearance for glands with backup rings.

Table 078–3–12. MAXIMUM RECOMMENDED DIAMETRAL CLEARANCE (C) FOR GLANDS WITH BACKUP RINGS

AS 568 Dash Numbers	Maximum Diametral Clearance per MIL–G–5514 (inches)	AS 568 Dash Numbers	Maximum Diametral Clearance per MIL–G–5514 (inches)	AS 568 Dash Numbers	Maximum Diametral Clearance per MIL–G–5514 (inches)
004–012	0.004	210–222	0.005	330–345	0.007
013–028	0.005	223–227	0.006	346–349	0.008
110–129	0.005	228–243	0.007	425–445	0.009
130–140	0.006	244–247	0.008	446	0.010
141–149	0.007	325–329	0.006	447–460	0.011

*Maximum Diametral Clearance (C) = E (maximum) – A (minimum) – C_1 + C_2

NOTES: *For dimensions A, C_1, C_2, and E, refer to Figure 078–3–8 and Figure 078–3–9

If the maximum diametral clearance exceeds that permitted by MIL–G–5514 for a particular size O-ring, all gland dimensions shall be compared with those in MIL–G–5514.

Repair acceptance criteria for MIL–G–5514 glands is that all dimensions shall be within 0.002 inches of the requirements in the specification and that the maximum diametral clearances shown above shall not be exceeded by more than 0.002 inches.

078–3.5.6.3 Acceptance criteria for static face seals (Figure 078–3–10):

a. The size and spacing of surface defects may be estimated visually.

b. Rhr surface finish requirements apply only to surface surrounding allowable surface defects and not to the surface defect areas themselves.

c. Diametral clearance, gland depth, and gland width requirements apply to surfaces surrounding allowable surface defects and not to the surface defect areas themselves.

d. Scratches that penetrate O–ring or other sealing surfaces are not acceptable.

e. Any metal removal shall be held to the minimum necessary to meet acceptance criteria.

f. Where repairs will not conform to the acceptance criteria specified herein, a waiver request must be submitted to NAVSEA.

g. When pressure is applied from two directions or when direction of applied pressure is unknown, both sides of the O–ring gland must be considered sealing surfaces.

1. The O–ring gland and mating sealing surface for static face seals (Figure 078–3–10) must meet the requirements of Table 078–3–9.

2. The O–ring gland sealing surface and mating sealing surface finish, except for surface defects allowed by Table 078–3–13, must be 125 rhr or smoother.

3. Raised edges of allowable surface defects on an O–ring gland an mating sealing surface are not acceptable.

4. Gland face angle (dimension H, Figure 078–3–10) must not exceed 5° maximum

078–3.5.6.4 Acceptance criteria for MS type straight thread tube fitting seals (see Figure 078–3–11):

a. The size and spacing of surface defects may be estimated visually.

b. Rhr surface finish requirements apply only to surfaces surrounding allowable surface defects and not to the surface defect areas themselves.

c. Diametral clearance, gland depth, and gland width requirements apply to surfaces surrounding allowable surface defects and not to the surface defect areas themselves.

d. Scratches that penetrate O–ring or other sealing surfaces are not acceptable.

e. Any metal removal shall be held to the minimum necessary to meet acceptance criteria.

f. Where repairs will not conform to the acceptance criteria specified herein, a waiver request must be submitted to NAVSEA.

g. When pressure is applied from two directions or when direction of applied pressure is unknown, both sides of the O–ring gland must be considered sealing surfaces.

1. Sealing surfaces (Figure 078–3–11) must meet the requirements of Table 078–3–14.

2. Sealing surface finish, except for surface defects allowed by Table 078–3–14, must be 125 rhr or smoother.

3. Raised edges of allowable surface defects on sealing surfaces are not acceptable.

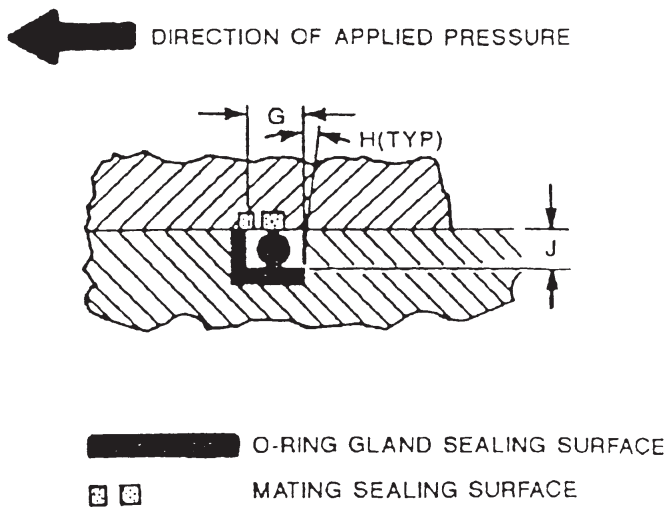


Figure 078–3–10. Static Face Seal

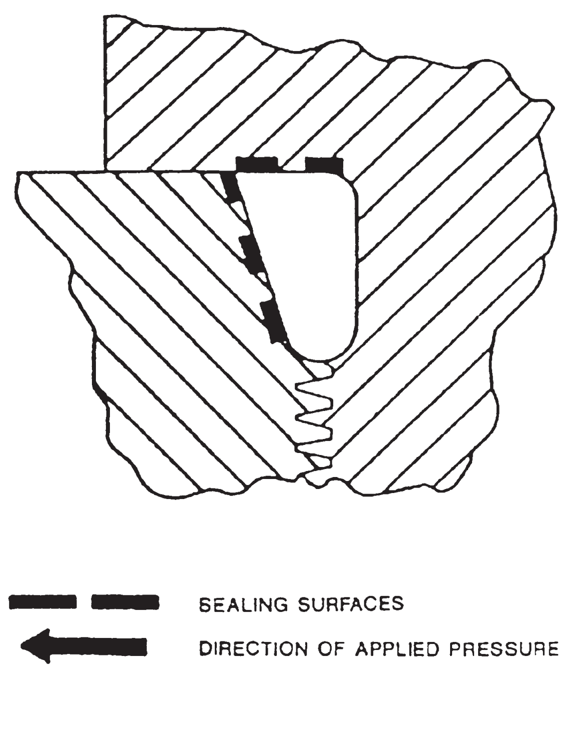


Figure 078–3–11. Static Face Seal

078–3.5.7 REPAIR PROCEDURES FOR O–RING GLANDS. When required, O–ring mating sealing areas shall be repaired in accordance with the following general guidance. Specific guidance has been developed for some applications and the general guidance is to be used only when specific guidance has not been developed. For submarine fresh and salt water systems components, see paragraph 078–3.5.8.

078–3.5.7.1 Cleaning. Thoroughly clean the component surfaces using local procedures such as a caustic dip, or wiping with clean, lint free, solvent dampened, cloths. Do not allow solvent to contact seals.

078–3.5.7.2 Inspection. Inspect the O–ring sealing areas to determine if the repairs are necessary. Inspect the areas as specified in the applicable Technical Repair Standard (TRS). Those defects which do not exceed the TRS criteria are acceptable and require no further inspection or repair.

078–3.5.7.3 Reconditioning. Remove rust, corrosion pitting, nicks, and scratches by wiping with fine crocus cloth, soft cleaning compound, soft wire brush, or by light machining. Hairline scratches shall not exceed six inches (150mm) in length. When surface defects exceed the specified acceptance criteria, machine the seal areas within the maximum tolerance specified on the applicable detail drawing. When the repair by machining alone is not possible due to other controlling limits, restore the static sealing areas to required dimensions by application of epoxy, polymer, or plating. Repair by the application of epoxy or other polymer can be accomplished using the procedures provided by NAVSEA S9520–AA–MMA–010 Volume 1 **(Repair of Submarine Sea Water Ball Valves (Non–Nuclear))** for epoxy repair of seals and by NAVSEA Technical Publication 03Y3/100, **Pump Repairs Using Polymeric Compounds,** for repair of seals by polymers other than epoxy. When plating buildup is used to restore surfaces to the required dimensions, fill the surface irregularities with copper and apply nickel or cobalt nickel plating to the surfaces in accordance with the requirements specified in NAVSEA 0900–LP–038–6010, **Deposition of Metal by Contact (Brush–On Method) Electroplating.** Surface finish for the sealing areas shall meet the TRS drawings, applicable drawing requirements, or if not specified on either of these, the guidance provided herein. For static seals without backup rings, O–ring grooves and mating areas may be restored to meet the increased squeeze requirements in SAE Aerospace Recommended Practice ARP 1232, **Gland Design, Elastomeric O–ring Seals, Static Radial.**

078–3.5.7.4 Wall Thickness Criteria. For repair of pressure-containing sealing areas by the machining procedure, the maximum allowable wall thickness **reduction** by machining is 10 percent of the original drawing minimum wall thickness. When the **reduction** from original drawing minimum wall thickness exceeds 10 percent, or 10 percent of the actual wall thickness when a minimum wall thickness is not specified, stress analysis and engineering approval is required.

078–3.5.7.5 Final Inspection. Inspect the parts for the surface finish and dimensional requirements. Parts are ready for reassembly after all parts have been found to be satisfactory.

078–3.5.8 REPAIR PROCEDURE FOR SUBMARINE FRESH AND SALT WATER SYSTEMS. Where the specified acceptance criteria for surface defects are exceeded, the preferred method of repair is machining when defects can be removed within the gland dimensional requirements. However, when the repair of the submarine fresh and salt water systems components by machining alone is not possible due to other controlling limits, repair of O–ring seal areas shall be accomplished by the application of epoxy using the procedures specified in NAVSEA S9520–AA–MMA–010 Volume 1, **Repair of Submarine Sea Water Ball Valves (Non–Nuclear).** Use of this repair method is subject to the following limitations:

a. Flange thickness and wall thickness criteria of Sections 7 and 8, respectively, of Submarine TRS 7650–086–001, **General Acceptance Criteria,** are met prior to repair but after all metal removal preparations to the repair have been accomplished.

b. Area of repair must be in contact only with fresh or salt water at less than 180°F design temperature and not subject to steam plant cleanliness requirements.

078–3.6 TROUBLESHOOTING O–RING FAILURES

078–3.6.1 In most cases, O–ring failures will be caused by factors which can be corrected by maintenance personnel. Some failures may be identified as resulting from design deficiencies which can be corrected only by design modifications or change in O–ring materials. Identification of the various failure modes, causes of the failure, and possible corrective action are discussed in paragraphs 078–3.7 through 078–3.7.8. Design deficiencies and persistent seal problems should be referred to NAVSEA.

078–3.7 O–RING FAILURE MODES

078–3.7.1 TROUBLESHOOTING. The easiest and first step to take in troubleshooting O–ring problems is to inspect the O–ring seal. Carefully remove the O–ring and determine if a backup ring is installed and, if so, where it is installed relative to the O–ring. Inspection of old, damaged rings can indicate failure from wear, extrusion, excessive permanent set, torsional strain, or excessive rolling in the groove. Examples of O–ring failures are illustrated in Figure 078–3–12; failure modes are shown and described in Table 078–3–15. After an old ring has been inspected, it should be cut in half and discarded, unless the ring is to be forwarded for engineering analysis.

078–3.7.2 EXTRUSION. Excessive extrusion can indicate that the wrong O–ring was installed. The O–ring may have the wrong cross section if an O–ring for a boss seal is substituted for a regular O–ring. In addition, O–rings

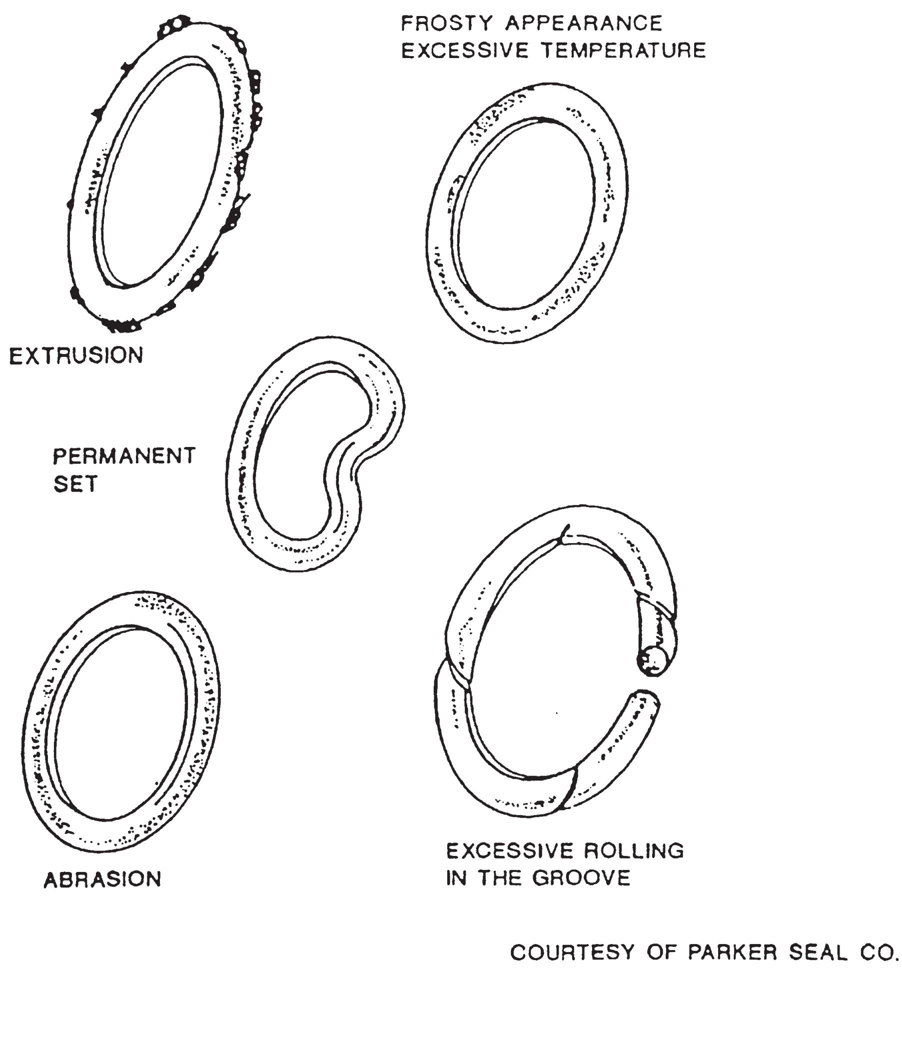


Figure 078–3–12. Examples of O–Ring Failure

of unsuitable material or hardness may be more susceptible to extrusion. Other causes of extrusion are the failure to install a backup ring or backup ring installed on the wrong side of the O–ring.

078–3.7.3 HARDENED O–RINGS. O–rings that have hardened and lack sufficient resilience may have been subjected to excessive temperatures. Overheated rings are hardened, crack when flexed, take a permanent set, and lack resilience. If it is known that O–rings have been subjected to excessive temperatures, the O–rings should be replaced regardless of their appearance. If persistent overheating occurs, an engineering analysis of the need for an O–ring material with greater heat resistance should be requested.

078–3.7.4 RUPTURED O–RINGS. Rupture can result from excessive stretch of the O–ring. Corrective action usually requires either redesign of the groove to reduce the stretch or squeeze of the O–ring, or the use of a larger diameter ring. In some cases, use of a more heat–resistant rubber compound may be required.

078–3.7.5 EXCESSIVE SWELL. If excessive swell (usually greater than 20 percent) occurs, the O–ring material is probably unsuitable. For example, petroleum base fluids can cause excessive swelling of butyl O–rings used in phosphate ester hydraulic systems. Such O–rings should be replaced with O–rings made of materials compatible with the service fluid (see Section 2 for discussion of the compatibility of various fluids and materials). In some cases of excessive swelling it may be necessary to request a design evaluation to determine if a material more resistant to the gas or fluid being sealed is required. In rare instances, a design change to increase groove width may be necessary since a groove which is too narrow can result in increased friction and excessive stress, which may cause premature seal failure.

078–3.7.6 SHRINKAGE OR CONTRACTION. Leakage may result from shrinkage caused by use of O–ring materials not compatible with the fluid being sealed. If leakage occurs at low temperature, make certain the O–ring compound is intended for operation at low temperature and check the squeeze of the O–ring. The coefficient of contraction of rubber is approximately 10 times that of steel and several times greater than that of aluminum.

078–3.7.7 O–RING CUTS OR SURFACE DEFECTS. Occasionally an O–ring may be installed with a surface defect that should have been found by a careful pre–installation inspection. In other cases an O–ring can be cut or damaged by improper installation.

078–3.7.8 INSPECTION OF O–RING GLANDS. When leakage is a problem, or when examination of the O–ring indicates that the problem may be related to the gland, inspection of the gland is necessary. Make a visual check for the surface defects that could cause leakage. If no defects are found, it may be necessary to check gland dimensions to determine if the proper squeeze is being obtained on the O–ring cross section. Other checks can be made for groove width, surface finish of metal rubbing surfaces, and eccentric machining of the gland. Remember that a very small amount of leakage can be expected and is desirable when an O–ring is used as a reciprocating seal. An O–ring which does not allow wetting of the sealing surface is running dry, and high friction and rapid wear may result.

078–3.8 INSTALLATION AND REMOVAL OF O–RING SEALS

078–3.8.1 O–RING TOOLS. For installing or removing O–rings and similar types of seals tools should be used which will not damage the critical surface finishes of O–ring glands and related mating parts. Hardened–steel, pointed, or sharp–edged tools (such as knives, screwdrivers, or can openers) should not be used for removing or installing seals. Tools of soft metal such as brass or aluminum are the best tools for removing or installing seals. Tools formed of phenolic rod, plastics, or wood can be useful in O–ring removal and installation. An O–ring tool kit (Parker part PSGD0077–887–200, **EXKIT**) is stocked (NSN 5120–01–021–7381). The type of tools available in the kit are shown in Figure 078–3–13. Tool surfaces must be well rounded, polished, and free of burrs. Check the tools often, especially the surfaces that come in contact with O–ring grooves and critical polish surfaces. See paragraphs 078–3.8.6 through 078–3.8.6.3 for O–ring installation procedures and use of O–ring entering sleeves.

Table 078–3–13. STATIC FACE SEAL ALLOWABLE DEFECT SIZE AND SPACING

Nominal O-ring Cross-Section	Maximum Allowable Surface Defect Size		Minimum Allowable Surface Defect Spacing	
	Max Width or Length	Max Depth	Ave	Min
1/16	0.004	0.002	3/64	1/64
3/32	0.006	0.003	1/16	1/32
1/8	0.008	0.004	3/32	1/32
3/16	0.012	0.008	1/8	3/64
1/4	0.015	0.010	5/32	1/16
Nominal O-ring Cross-Section	**Max Gland Depth, J**	**Min Gland Depth*, J**	**Max Gland Width, G**	
1/16	0.058	0.050	0.106	
3/32	0.091	0.074	0.154	
1/8	0.124	0.101	0.202	
3/16	0.188	0.152	0.297	
1/4	0.242	0.201	0.392	

*Drawing requirements apply if the minimum gland depth is less than that which is specified in Table 078–3–13.

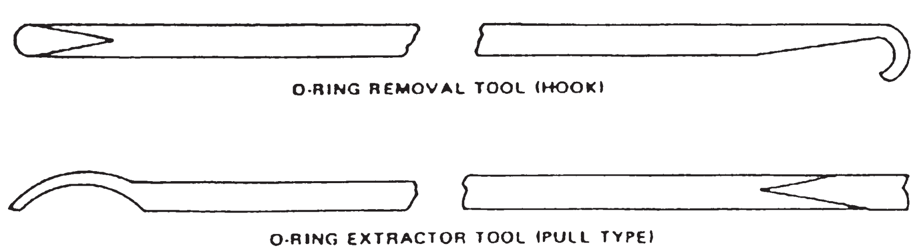


Figure 078–3–13. O–Ring Tools

Table 078–3–14. MS TYPE STRAIGHT THREAD TUBE FITTING SEAL ALLOWABLE DEFECT SIZE AND SPACING

AS 568 Uniform Dash No.	Nominal O-ring Cross-Section	Maximum Allowable Surface Defect Size		Minimum Allowable Surface Defect Spacing	
		Max Width or Length	Max Depth	Avg	Min
−901 thru −908	0.056 thru 0.087	0.004	0.002	3/64	1/64
−909 thru −932	0.097 thru 0.118	0.006	0.003	1/16	1/32

Table 078–3–15. MODES OF O-RING FAILURE

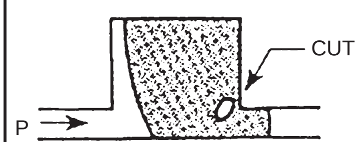
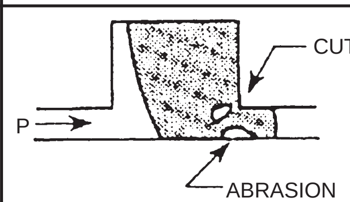
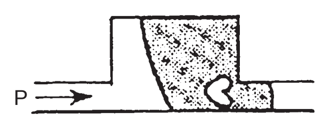
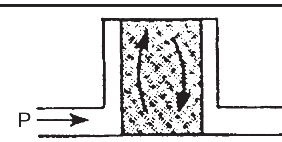
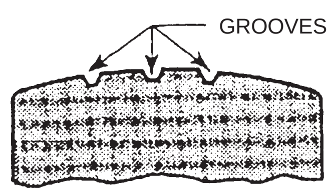
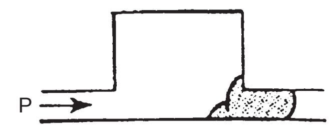
Failure	General Condition	General
Progressive cutting by corner of piston groove.	Pulsating pressure on O-rings.	
Progressive cutting as in static packing plus abrasive wear.	Pulsating pressure on O-ring.	
Nibbling extrusion. Rupture of material, large pieces torn off.	Fatigue from shock loads, high temperature, local seizure, pulsating pressure, etc.	
Rotation of part or all of circumference of packing in groove (sometimes called “spiral failure”).	Complete explanation not found. Occurrence not predictable. Possible sudden increase in friction on working face.	 FOUND TO OCCUR CHIEFLY WHEN PACKING MOVES IN SAME DIRECTION AS PRESSURE
Axial grooves work in working surface.	Imperfections in cylinder surface. Particles of dirt, metal, or rubber.	 SEGMENT OF PLAN VIEW

Table 078–3–15. MODES OF O-RING FAILURE (Continued)

Failure	General Condition	General
Axial grooves as above.	Rapid passage of oil across working face.	SEE ABOVE SKETCH
Packing totally extrudes through clearance space.	Large radial clearance. Soft packing.	

The Federal Supply System also carries an O–ring installation kit manufactured by the Port Seal Assembly Tool Corporation. This tool may be used to assemble O–rings over the fitting threads without cutting or damaging the seal. The use of this tool is highly recommended because it will prevent many of the leaks that are the direct result of the O–ring damage that often occurs during installation. The tool, depicted in Figure 078–3–14, is placed over the fitting threads until it bottoms. Then, the O–ring is slid over the small end of the tool (which is the “Go–No Go” Gage for seals because a seal of the proper size will fit snug over this end) and off the tool into the O–ring groove. The kit includes tools that fit the following fittings: SAE J514, SAE J1926, and the new SAE J1453 O–ring face seal fittings. The P.S.A.T. kit includes tools that fit SAE dash sizes –2, –3, –4, –5, –6, –8, –10, –12, –14, –16, –20, –24, and –32. The National Stock Number assigned to this O–ring installation tool kit is NSN 5120–01–319–0786.

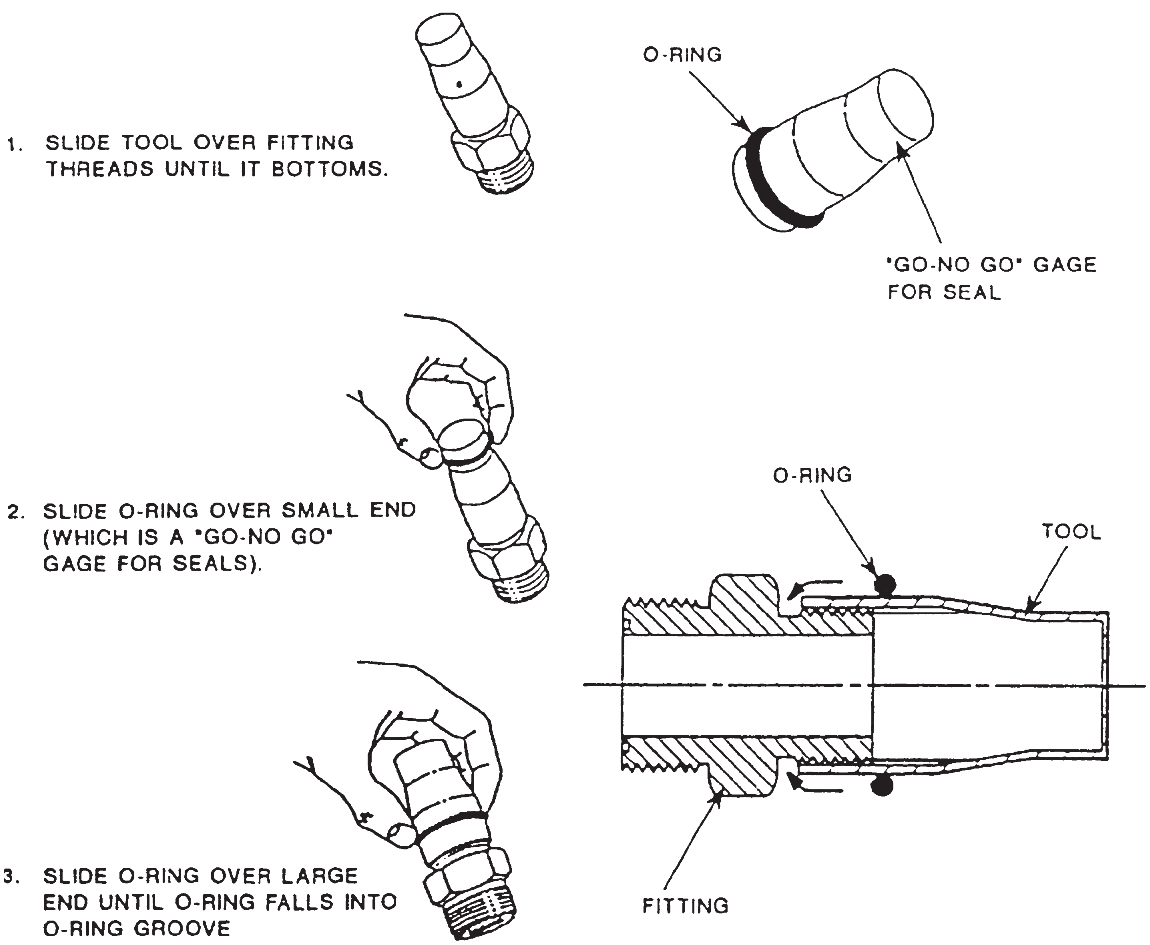


Figure 078–3–14. How To Use the O–Ring Installation Kit

078–3.8.2 O–RING REMOVAL. Often, a poor O–ring installation begins when an old seal is removed. O–ring removal involves working with parts that have critical surface finishes. If hardened–steel, pointed, or sharp–edge tools are used for removal of O–rings or backup rings, scratches, abrasions, dents, and other deformities on critical sealing surfaces can result in seal failure which, in turn, can result in functional failure of the equipment. Use proper O–ring tools as described in paragraph 078–3.8.1 for O–ring removal as well as installation.

CAUTION

Because static charges may develop, do not use MIL–C–85043 wiping cloths to wipe down plastic areas. In addition, do not use these cloths with volatile solvents which have flash points of less than 37.8°C (100°F) or with P–D–680. Cotton flannel or cheesecloth shall be used for these applications.

078–3.8.3 CLEANING THE O–RING GLAND. Before installing the new ring, inspect both the ring and the metal surfaces. Metal surfaces must be free of dust, dirt, and other particles before assembly. Stoddard solvent or trichlorotrifluoroethane (MIL–C–81302 type II) can be used to clean parts and will leave a good surface for lubricants to adhere to. To reduce the possibility of lint and fiber contamination during solvent cleaning and seal installation, components and system internals which will be in contact with the system fluid shall be wiped with lint free cloths. The use of wiping rags and paper wipes for these shall be avoided. In shipboard and shop areas used for disassembly and maintenance of components or systems, low–lint cleaning cloths (MIL–C–85043 type II) stocked in 10 pound boxes (250 count) under NSN 7920–00–044–9281 are recommended. For clean room work and for systems where noncontamination requirements are critical, the more expensive **very–low lint** grade of cleaning cloths (MIL–C–85043 type I) stocked in 10 pound boxes under NSN 7920–00–165–7195 are recommended. These wipers are lint free, nonabrasive, generally fiber–free, and absorb oil, grease, and solvents well, but have poor water absorbency.

CAUTION

Cleaning fluids can cause some O–rings to swell and interfere with performance or cause seal failure. Ensure that the cleaning fluid is completely removed and does not contact any O–rings.

078–3.8.4 O–RING INSPECTION. Each O–ring to be installed shall be removed from its sealed package and inspected for defects such as blemishes, abrasions, cuts, or punctures, all of which are often capable of preventing satisfactory O–ring performance. Faulty O–rings shall be cut and discarded. Be sure the smooth surface of the ring is not scratched by fingernails, tools, or fitting threads. Watch for sharp edges on the gland groove shoulder or fitting. Thread burrs can often be removed by running a nut onto the thread.

078–3.8.5 LUBRICATION. Rubber has an inherently high coefficient of friction with all metals and most nonmetallic surfaces. Lack of sufficient lubrication of a rubber O–ring can result in high friction, excessive abrasion, heat buildup, and rapid wear. In many systems, such as hydraulic systems, the system fluid may act as a lubricant and additional lubrication is not required. The gas in a pneumatic system does not act as a lubricant and most O–rings which fail prematurely in pneumatic systems do so because of inadequate lubrication. Before installation, lubricate the O–ring and bearing surfaces with a light coat of system fluid or a lubricant approved for the system in which the O–ring is installed. Do not use skydrol base greases with fluorocarbon rubber.

078–3.8.5.1 Fluid System Applications. For fluid system applications, lubricating the O–ring with system fluid is usually adequate. For systems using petroleum base fluids (hydraulic, lube oil, and fuel oil) a light application of petroleum grease may be used, particularly where additional holding power is required to retain the seal in position for difficult installations. Table 078–3–16 lists O–ring seal lubricants and stock numbers for petrolatum grease. Do not use silicone grease for the installation of seals in systems using either phosphate ester or petroleum base fluids (see Table 078–3–16 for lubricants for phosphate ester systems). A list of O–ring lubricants for sea water is provided in Table 078–3–16. Preferred O–ring lubricant in the sea water systems is Termolene grease per CID A–A–50433 due to its superior washout resistance and the fact that it helps prevent crevice corrosion and pitting. Silicon compound per MIL–S–8660 is also an acceptable O–ring lubricant for sea water systems.

078–3.8.5.2 Pneumatic System Applications. A list of O–ring lubricants for various life support and for air and gas systems is provided in Table 078–3–16 and reflects requirements of **NSTM Chapter 262**.

078–3.8.6 INSTALLATION PROCEDURES. The O–ring should be replaced whenever a gland which has been in service is disassembled and reassembled. Assembly must be made with care so the O–ring is properly placed in the groove and not damaged as the gland is closed. During some installations, such as on a piston, it will be necessary to stretch the O–ring. Stretch the O–ring as little and as uniformly as possible. The stretching of the O–ring during assembly usually should be limited to twice the ring's original size. For very small diameter O–rings it may be necessary to exceed this limit. If this is the case, sufficient time should be allowed for the O–ring to return to its normal diameter before the gland is closed. When an O–ring has been installed in its final position in the groove, the diameter shall not have a permanent stretch of more than 5 percent because stretch will shorten the life of most O–ring materials. Stretching also tends to flatten the cross–sectional dimension of the O–ring, reducing its sealing effectiveness.

078–3.8.6.1 Avoid rolling or twisting the O–ring when maneuvering it in place. Keep the position of the O–ring mold line constant. O–rings shall not be left in a twisted condition after assembly. Twist can easily occur when the diameter of an O–ring is large compared to its cross section diameter. After the O–ring is placed in the cavity provided, gently roll the O–ring with the fingers to remove any twist that might have occurred during the installation.

078–3.8.6.2 O–rings should never be forced over sharp corners, keyways, slots, spliners, ports, or other sharp edges. If the O–ring installation requires spanning or inserting through sharp–threaded areas, ridges, slots, and edges, use protective measures such as the O–ring entering sleeves shown in view A of Figure 078–3–15. If the recommended O–ring entering sleeve (a soft, thin wall, metallic sleeve) is not available, paper sleeves and covers may be fabricated by using the seal package (glossy side out) or lint–free bond paper (see views B and C of Figure 078–3–15). Newly installed rings that prove to be too tight should be removed and discarded. Even though new, these O–rings should not be returned to storage because they may have been slightly damaged during installation.

078–3.8.6.3 After installation, an O–ring should seat snugly but freely in its groove. If backup rings are installed in the groove, be certain the backup rings are reinstalled on the correct side of the ring. Many O–ring installations use two backup rings, one on each side of the O–ring, to ensure that the backup ring will be on the correct side of the O–ring. Additional guidance on selection and installation of backup rings is provided in paragraphs 078–3.10 through 078–3.10.3. Glands should be closed with a straight longitudinal movement; for example, when putting a piston into a cylinder, push it straight in with no turning motion. Turning motion tends to bunch up and cut the O–ring, eventually causing leakage. Avoid pinching the O–ring at groove corners when closing the gland.

078–3.9 SPLICING OF O–RINGS

078–3.9.1 REASONS FOR USE OF SPLICED O–RINGS. Splicing of O–rings is not usually recommended. There are occasions when the use of spliced O–rings can be justified. Valid reasons for the use of spliced O–rings include:

a. Uncut O–rings of the required size cannot be obtained within the available time.

b. Installation of uncut O–rings would require excessive additional disassembly of system components.

078–3.9.1.1 A properly spliced O–ring is expected to provide satisfactory performance in static applications.

078–3.9.2 LIMITATIONS ON USE OF SPLICED O–RINGS. This O–ring splicing procedure is applicable to any Buna N O–rings or cording. Do not attempt to bond an O–ring if unsure of its composition because cyanoacrylate adhesives will not satisfactorily bond silicone and most grades of fluorocarbon rubbers. The limitations which apply to the use of spliced O–rings are:

Table 078–3–16. O–RING SEAL LUBRICANTS

Type of System	Lubricant Specification	NSN	Type Lubricant	Lubricant Temp. Range	Compatible Seal Materials
Petroleum System (Fuel and Hydraulic)	MIL–G–24508	1–lb can, 9150–00–149–1593	Synthetic Hydrocarbon	–29 to 149° C (–20 to 300° F)	fluorocarbon, neoprene, nitrile
Pneumatic (low pressure, 200 lb/in^2g, maximum Vacuum Electrical Connectors	MIL–S–8660	8–oz tube, 6850–00–880–7616 10–lb can, 6850–00–295–7685	Silicone	–54 to 204° C (–65 to 400° F)	butyl, ethylene–propylene, fluorocarbon, neoprene, nitrile, polychloroprene
Life Support Systems and Hydraulic Systems (Phosphate Esters, Water Glycol and Petroleum Base Fluids)	MIL–G–27617* Type III (Krytox 240AC)	8–oz tube, 9150–00–961–8995 or 1–lb can, 9150–00–083–5589	Fluorinated Hydrocarbon	–34.4 to 204° C (–30 to 400° F)	butyl, ethylene–propylene, fluorocarbon fluorosilicone nitrile
High Pressure Air, Oxygen and Nitrogen Systems	MIL–G–27617* Type III (Krytox 240AC)	8–oz tube, 9150–00–961–8995 or 1–lb can, 9150–00–083–5589	Fluorinated Hydrocarbon	–34.4 to 204° C (–30 to 400° F)	ethylene propylene fluorocarbon, nitrile
Sea Water Systems	MIL–S–8660	8–oz tube, 6850–00–880–7616 10–lb can, 6850–00–295–7685	Silicone	–54 to 204° C (–65 to 400° F)	butyl, ethylene propylene, fluorocarbon, neoprene, nitrile, polychloroprene
	CID–A–A–50433	35–lb can, 9150–01–306–9167	Petroleum Hydrocarbon	–9 to 177° C (–15 to 350° F)	fluorocarbon neoprene, nitrile

*Note: Information listed for Life Support and High Pressure air/gas systems reflects **NSTM Chapter 262** requirements.

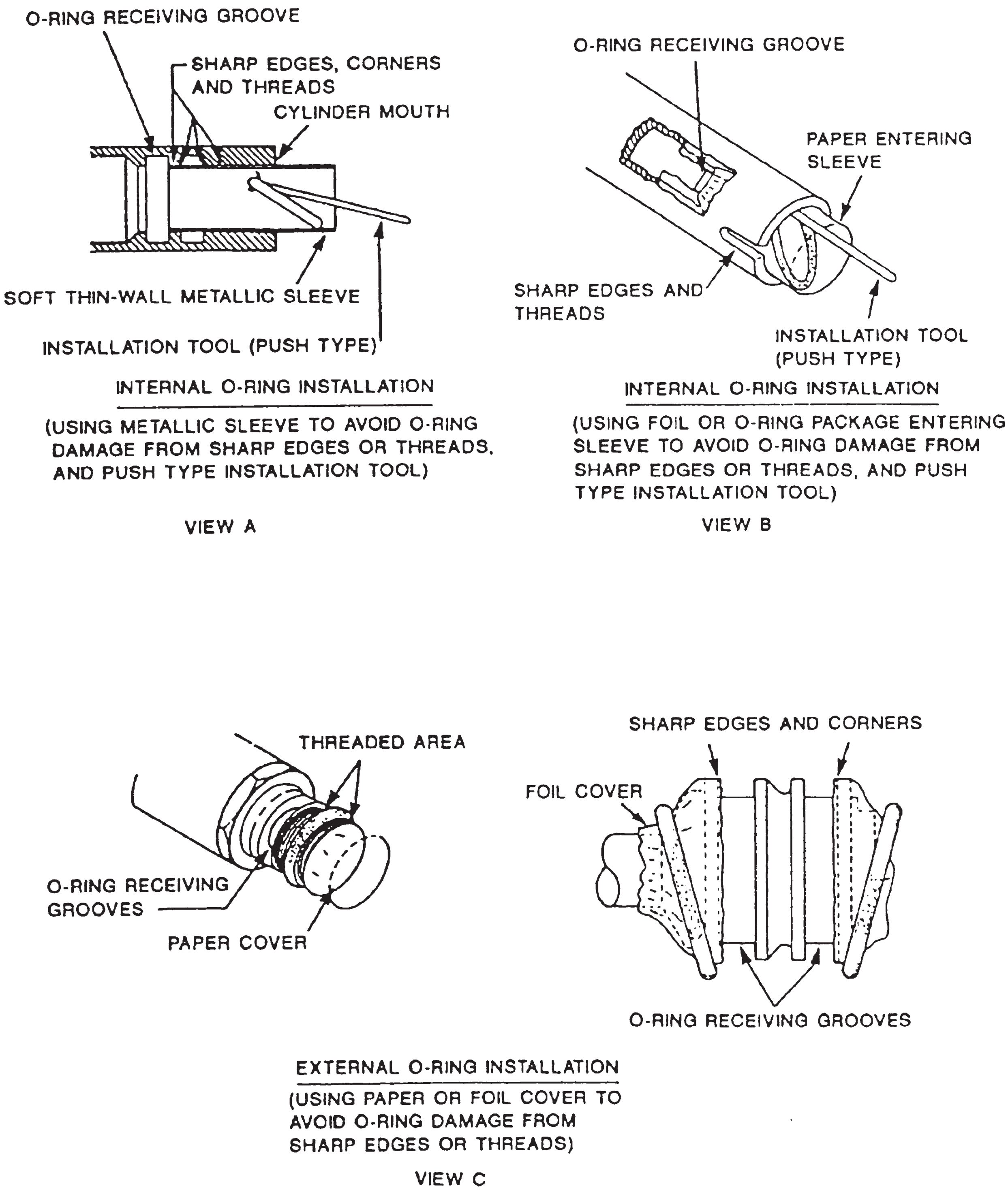


Figure 078–3–15. O–Ring Installation

a. The use of spliced O–rings shall be limited to emergency situations unless otherwise approved by NAVSEA. For dynamic seals, spliced O–rings used for emergency repair must be replaced at the first opportunity.

b. The use of spliced Buna N O–rings as permanent static seals in crosshead guide cylinder covers for fairwater planes, stern planes, and rudders on submarines is approved for situations in which the use of an uncut ring would necessitate an otherwise unnecessary disassembly of the guide cylinder connecting rod coupling.

c. The splicing procedure described in paragraphs 078–3.9.3 through 078–3.9.3.4 is not intended for use in applications with continuous temperatures in excess of 80°C (176°F) or occasional temperatures exceeding 95°C (203°F). Use in applications with exposure to steam or combinations of high temperature and high humidity is not recommended.

d. Unless otherwise directed, the splicing procedure is not applicable to nuclear systems or to emergency main ballast tank blowdown systems.

078–3.9.3 SPLICING PROCEDURE. The splicing of an O–ring requires O–ring material (either cording or an uncut O–ring) and an O–ring splicing kit. Splicing an O–ring requires observance of several precautions during the preparation and splicing procedures. The following procedure is for cyanoacrylate adhesive splicing. For alternate vulcanizing splicing procedure refer to **NSTM Chapter 243, Propulsion Shafting.**

078–3.9.3.1 Splicing Kit and O–Ring Material. For O–ring material, either Buna N cording or an uncut O–ring may be used. An O–ring splicing kit (Loctite Splicing Kit 0112) is available under NSN 2010–00–882–7073 and contains:

a. Single–edge razor blade

b. Cutting and splicing fixture

c. Clean–up solvent (usually Di–Methyl Formamide)

d. Cyanoacrylate adhesive (Quick set 404 or equivalent)

e. Waterproofing solution (Neoprene solution with Methyl–ethyl–keytone and Toluene)

f. Three feet each of 3/32–inch 1/8–inch, 3/16–inch, and 1/4–inch Buna N cord stock

WARNING

Clean–up solvent and waterproofing solution are toxic. The waterproofing solution is essential to the splicing procedure if the joint is exposed to water or a water contaminated environment. The clean–up solvent is desirable but not essential to the splicing procedure. Any permitted degreasing solvent or soap and water may be used for cleaning. The clean–up solvent or the waterproofing solution should be applied sparingly and only under an exhaust hood. These two solutions should be removed from the splicing kit when the kit is carried aboard submarines. Use eye protection and rubber gloves when using the toxic solutions. In case of skin contact, wash skin with soap and water. In case of eye contamination, flush with water and get medical attention immediately.

078–3.9.3.2 Preparation for Splicing. Clean the razor blade with a degreasing solvent before each cut. If the clean–up solvent in the kit is used, rinse hands with soap and water following cleaning and follow the precautions described in the warning. With an uncut O–ring of the correct diameter, lay the O–ring on a clean flat surface and make a single vertical cut to form an O cross section. When using cording, measure the length required and use the splicing fixture and razor blade to cut both ends squarely. When using an O–ring of a larger diameter than required, make a single cut so that the ring resembles cord stock, measure the length required, and then use the splicing fixture and razor blade to cut both ends squarely. Use a sharp razor blade to make clean cuts. Avoid jagged edges because cyanoacrylic adhesive will not satisfactorily bridge gaps between surfaces being bonded;

surface irregularities should be less than 0.0002–inch. Do not touch cut ends and prevent contamination of the cut ends with dirt and oil. If the cut ends are touched or contaminated, reclean before splicing.

078–3.9.3.3 Verification of O–Ring Size. Always verify that the cording or O–ring being used is of the correct cross section for the groove. When cording or larger diameter O–rings are used, make certain that the O–ring or cording to be spliced is cut to the proper length. In some applications, verification can be accomplished before splicing, but in other applications it can be most easily accomplished following splicing. The finished ring shall not bunch up in the O–ring groove nor be stretched more than 5 percent on the inside diameter. In a radial seal application, the O–ring should hug the bottom of the O–ring groove. In a face seal, the spliced O–ring should hug the outside of the O–ring groove if the seal is to be pressurized from the inside. If the face seal O–ring is to be pressurized from the outside, the spliced O–ring should hug the inside diameter of the O–ring groove.

078–3.9.3.4 Making the Splice. Proper alignment and bonding of cord ends cannot be made with the O–ring material in the O–ring groove or while in a stretched position. Make the bond in an area where the diameter of the rod or shaft is smaller than the inside diameter of the finished ring. The splicing procedure is:

a. Apply a small drop of adhesive to only one end of the cord stock or cut O–ring. If excess adhesive is applied, strike cord stock or O–ring on a hard surface to shake off excess

WARNING

Cyanoacrylic adhesives are eye irritants. In case of accident, flush the eyes with water only and obtain medical attention. Cyanoacrylic adhesives bond strongly and quickly on contact. If the skin of the splicer’s fingers become stuck together or to anything else, carefully peel or cut apart contacted areas. Do not pull apart. The adhesive is stronger than the skin and will tear off the skin. A skin bond may be softened by soaking in acetone or nail polish remover

b. Join ends of rubber as soon as possible. Position loose ends in the splicing fixture alignment guide. Ensure that the rubber is not twisted; align according to the stripe or mold mark. Slide ends along the guide until they are in contact with each other. Hold in contact, with firm pressure on the bond, for 10 to 30 seconds.

c. Allow the adhesive to cure for 30 seconds, then remove the residue from the surface of the O–ring with a clean, dry rag, or by scraping with a smooth plastic or brass tool, using care not to cut or scuff the O–ring surfaces. Do not use clean–up solvent to clean O–ring.

d. Allow adhesive to cure at least 1 hour at room temperature before flexing or scratching.

e. Waterproofing the joint will improve joint strength when the joint is exposed to water or a water–contaminated environment. If waterproofing is desirable, it is recommended that a thin film of waterproofing solution be applied to the bond line (joint) and allowed to dry for 5 minutes (see paragraph 078–3.9.3.1 and the WARNING on the use of waterproofing solution).

078–3.9.3.5 Cleaning Splicing Fixture. Upon completion of O–ring splice, remove adhesive from cutting and splicing fixture using clean–up solvent or by a gently scraping and wiping action (see WARNING in paragraph 078–3.9.3.1 on the use of the clean–up solvent).

078–3.9.4 INSTALLING THE SPLICED O–RING. After the 1–hour cure time has elapsed, flex the bonded joint and examine the joint for lack of bond. Do not install any spliced O–ring which shows lack of bond. Ensure that the spliced O–ring fits the O–ring groove (see paragraph 078–3.9.3.3). Carefully install the ring, using normal installation procedures. Pressurize the seal and inspect for leakage. Any leakage indicates an unsatisfactory seal and the seal shall be replaced.

078–3.10 ANTI–EXTRUSION (BACKUP) RINGS

078–3.10.1 STANDARD BACKUP RINGS. The most commonly used backup rings are designed either to fit MIL–G–5514 glands or for use with standard bosses. Table 078–3–17 lists backup ring specifications and standard drawings for various materials. Standard backup rings are described in paragraphs 078–3.10.1.1 through 078–3.10.1.3.

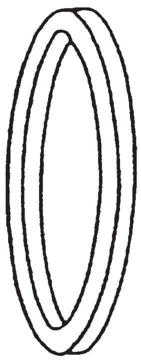
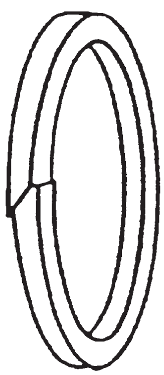
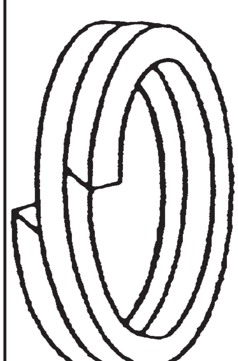
078–3.10.1.1 Materials. Backup rings can be made of polytetrafluoroethylene, hard rubber, leather, and other materials. The most common material currently used is tetrafluoroethylene (TFE), commonly called Teflon, a DuPont registered trademark. TFE is virtually impervious to oils and solvents and has excellent resistance to acids and salts. TFE exhibits excellent chemical resistance and can safely be used over a temperature range of –73.3°C to 177°C (–100°F to 350°F) depending on the fluid pressure being sealed. MIL–R–8791 applies to backup rings made of TFE. Leather is one of the oldest materials used for backup rings and still is used in some applications. Leather is highly resistant to extrusion and has excellent nonabrasive qualities but is unsatisfactory for use with certain chemicals, strong acids, and caustic solutions. Leather backup rings can be used in low temperature and high pressure situations, but operating temperature must not exceed 93°C (200°F). With leather backup rings, leather tannage for backup washers in accordance with MIL–W–5521 ensures against the production of soft backup washers which are particularly unsuitable at higher pressure.

078–3.10.1.2 Types. Standard backup rings are available as single–turn continuous (uncut or solid), single turn (bias) cut, and spiral cut. See Table 078–3–17 for illustrations of the various types of rings, and a listing of materials and military standards for various applications. Leather rings are always furnished in solid ring form (unsplit). Rings of Tetrafluoroethylene (TFE), the most commonly used material, are available in all three types. Installation of single turn continuous rings may require a split gland design or special tools for handling, stretching and resizing, except when used for boss seal applications. Single turn continuous rings intended for use in MIL–G–5514 glands should not be cut. Single turn continuous rings are preferred for rod seals as cut rings may tend to expand under pressure to the gland OD and be less effective. If a cut ring is required, use a single turn bias cut ring or a spiral cut ring. The single turn cut ring is considered preferable to the spiral cut ring with the possible exception of large diameter applications expected to undergo large temperature variations causing overlap at the ring ends. Substitution of spiral cut rings for single turn cut rings is recommended only when the single turn cut ring is not available. For best performance, it is recommended that MIL–R–8791/1 rings be used in place of MS28774 rings in glands to dimensions of MIL–G–5514 revision C and later.

078–3.10.1.3 Packaging and Storage. Backup rings are not color–coded or otherwise marked and must be identified from the packaging labels. The dash number following the military standard number found on the package indicates the size, and the dash number usually relates directly to the dash number of the O–rings for which the backup ring is dimensionally suited. Backup rings made of TFE do not deteriorate with age and do not have shelf life limitations. Precautions must be taken to avoid contamination of backup rings. TFE backup rings are stocked in individually sealed packages similar to those in which O–rings are packaged. If individual packaging is not available, several backup rings may be installed on a cylindrical mandrel. If unpackaged rings are stored for a long time without the use of mandrels, a condition of overlap may develop. To correct this overlap condition, stack TFE rings on a mandrel of the correct diameter, and clamp the rings with their coils flat and parallel. Place the rings in an oven at maximum temperature of 177°C (350°F) for approximately 10 minutes. Do not overheat because fumes from decomposing TFE are toxic. Remove and water–quench the rings. The rings should then be stored at room temperature for 48 hours prior to use.

078–3.10.1.4 Installation Procedures. Care must be taken in handling and installing backup rings. Backup rings shall not be inserted with sharp tools. Backup rings must be inspected prior to use for evidence of compression damage, scratches, cuts, nicks, or frayed conditions. If O–rings are to be replaced where backup rings are installed in the same groove, never replace the O–ring without replacing the backup rings, or vice versa. Many seals use two backup rings, one on either side of the O–ring. Two backup rings are used primarily in situations (such as a reciprocating piston seal) where alternating pressure direction can cause packing to be extruded on both sides of the gland. The two–backup–ring configuration also has been used to facilitate standardization of groove dimensions and maintenance procedures even when the pressure is applied from one direction only. By installing two backup rings, one on each side of the O–ring, even though only one is required because of pressure considerations, the O–ring can be guaranteed to be on the proper side, away from the pressure. If only one backup ring is used, the backup ring should be placed on the low–pressure side of the packing. When a backup ring is placed on the high pressure side of the packing, the pressure against the relatively hard surface of the backup ring

Table 078–3–17. STANDARD BACKUP RINGS

Type	Material Specification	Military Standard	Application
SINGLE TURN CONTINUOUS 	MIL–R–8791 Tetrafluoro-ethylene (TFE)	MS27595	For use in packing grooves with bottom corner radii conforming to MIL–G–5514 Dash numbers correspond to equivalent dash numbers for MS28775, M83248 and AS568 O-rings.
	MIL–W–5521 Leather	MS35803	For use with AS568, MS 28775, and M83248 O-rings with corresponding dash numbers.
		MS28777	For boss type O-ring gaskets. Dash numbers correspond to equivalent dash numbers for AN 6290 O-ring gaskets.
	AMS3651 Polytetra-fluoroethylene	MS 9058	For boss type O-ring gaskets
SINGLE TURN BIAS CUT 	MIL–R–8791 Tetrafluoro-ethylene (TFE)	MS28773	For use with MS28778 (and AN6290) straight thread boss packing. Dash numbers correspond to the equivalent dash numbers for MS28778 (also AN6290) preformed packings and the AN6289 nut.
		MS28774	For use in MIL–G–5514 revision B and earlier glands. Dash numbers correspond with AS568, MS28775, and M83248 O-ring dash numbers. Can also be used with other equivalent size O-rings.*
		MIL–R–8791/1	For use in MIL–G–5514 revision C and later glands. Dash numbers correspond to equivalent dash numbers for AS568, MS28775, and M83248 O-rings.
SPIRAL CUT 	MIL–R–8791 Tetrafluoro-ethylene (TFE)	MS28782	For use in MIL–G–5514 glands. Dash numbers correspond to AN6227 O-ring dash numbers. Can also be used with other O-rings equivalent in size to AN6227.*
		MS28783	For boss applications. Dash numbers correspond to AN6230 O-ring gasket dash numbers. Can also be used with other O-rings equivalent in size to AN 6230.*
*See Table 078–3–2 for cross-reference of equivalent O-ring sizes.			

forces the softer packing against the low pressure side of the gland, resulting in a rapid failure rate due to extrusion.

078–3.10.2 TFE CUT RINGS. When dual backup rings are installed, the split scarfed ends must be staggered, as shown in Figure 078–3–16. When installing a spiral cut backup ring (MS28782 or MS28783), the ring must be

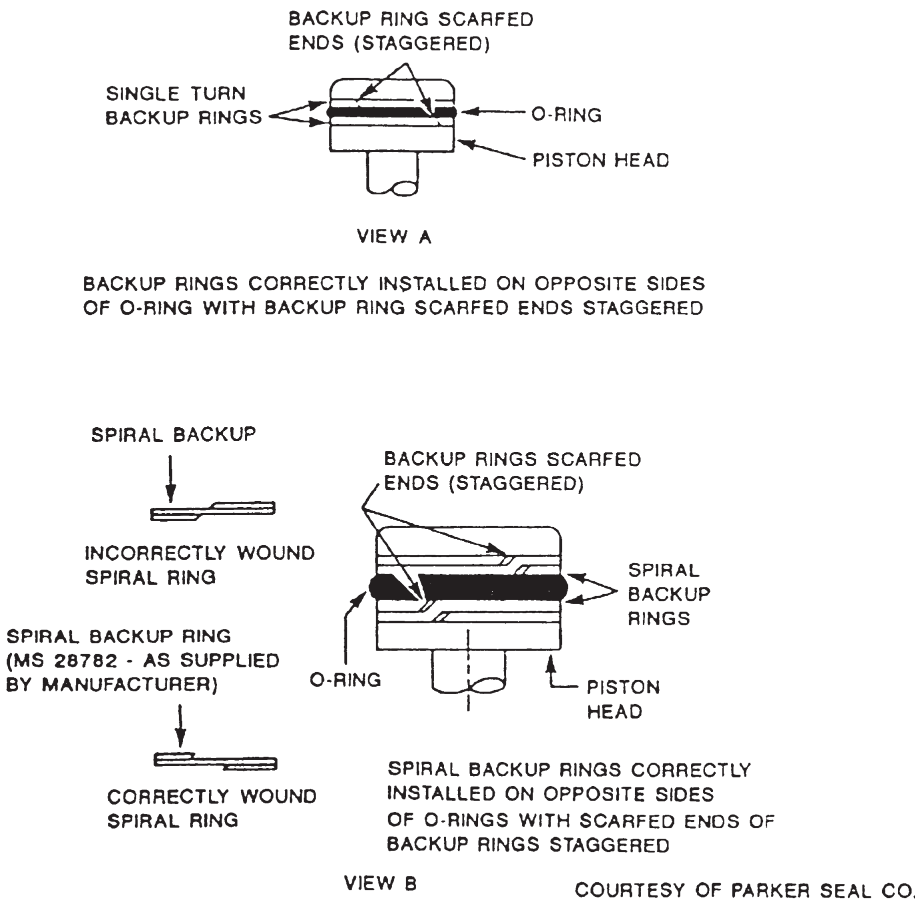


Figure 078–3–16. Installation of Cut Backup Rings

correctly wound to facilitate installation and ensure optimum performance. The spiral backup ring should be correctly wound by the manufacturer but should be checked prior to installation.

078–3.10.3 LEATHER RINGS. In applications where a leather backup ring is called for, the smooth–grained side of the leather is placed next to the ring. Do not cut leather backup rings. Use a leather backup ring as one continuous ring and lubricate the ring prior to installing, particularly the smaller sizes. If stretching is necessary to facilitate proper installation, soak the backup ring in the system fluid or in an acceptable lubricant at room temperature for at least 30 minutes.

078–3.11 TROUBLESHOOTING BACKUP RING PROBLEMS

078–3.11.1 Operational seal problems can result from the use of split backup rings in dynamic piston and rod applications. The split ends of the backup rings, under pressure, occasionally damage the O–ring or pinch the O–ring cross section enough to set up a leakage path. Although damage or pinching of the O–ring cross section may arise in static application, the problem is more likely to occur in a dynamic O–ring seal. In a dynamic seal, TFE from a backup ring can be rubbed onto the mating surface, filling any minute irregularities. This tends to make the mating surface even smoother (frequently smoother than 10 microinches) so that in some instances, the O–ring can wipe the extending rod almost completely dry. When the rod is retracted, there is virtually no lubricant left and the seal may fail because of high friction and overheating. Seal failure can occur even though TFE on the metal surface reduces friction. Apparently, the friction between an elastomer and a TFE–coated metal surface is higher than between an elastomer and an oiled metal surface. In addition, it may be that this type of TFE coating deposits primarily in the very small pits and grooves of the metal surfaces, leaving the high areas uncoated and dry. For these reasons, a backup ring should improve the pressure–retention ability of an O–ring, but cannot be relied on to improve the wear and friction characteristics of the O–ring itself. If improvement is required, various types of TFE caps and slipper rings can be used.

078–3.12 SLIPPER RINGS AND TFE CAPS

078–3.12.1 Slipper rings, like backup rings, improve extrusion resistance, but being less resilient than the O–ring, slipper rings provide a less positive seal. Typical configuration slipper rings and TFE caps of U–shaped, L–shaped, and plain bands for use with O–rings are shown in Figure 078–3–17. Slipper rings also prevent grabbing or seizing of smooth surfaces under high pressure. Slipper rings are usually made of tetrafluoroethylene (TFE) and often require different techniques for installation than O–rings because the TFE does not deform easily. Sometimes it is necessary to **double–back** the TFE portion of the high pressure O–ring assembly. Once positioned, the TFE ring must be worked, or pressed, into its original shape in the O–ring groove. A smooth nylon tool should be used to prevent scratching and marring the metal and slipper rings. For guidance in the selection, use and installation of slipper sealing devices, refer to SAE Aerospace Information Report AIR–1244, **Selecting Slipper Seals for Hydraulic–Pneumatic Fluid Power Applications.**

078–3.13 PROPRIETARY EXTRUSION RESISTANT SEALS USING O–RINGS

078–3.13.1 NONSTANDARD BACKUP SEALS. Nonstandard proprietary backup seals are used with O–rings in some applications to obtain improved sealing. Such seals include Shamban rings, manufactured by W. S. Shamban and Company, which are used in some shipboard applications and are described briefly in paragraphs 078–3.13.3 through 078–3.13.6.

078–3.13.2 SHAMBAN RINGS. Because Shamban rings are industry–type seals, NSN's have been established only for sizes of seals supplied as original equipment. Special tools are necessary for some installations. For guidance, see applicable equipment technical manuals or the manufacturer's catalog.

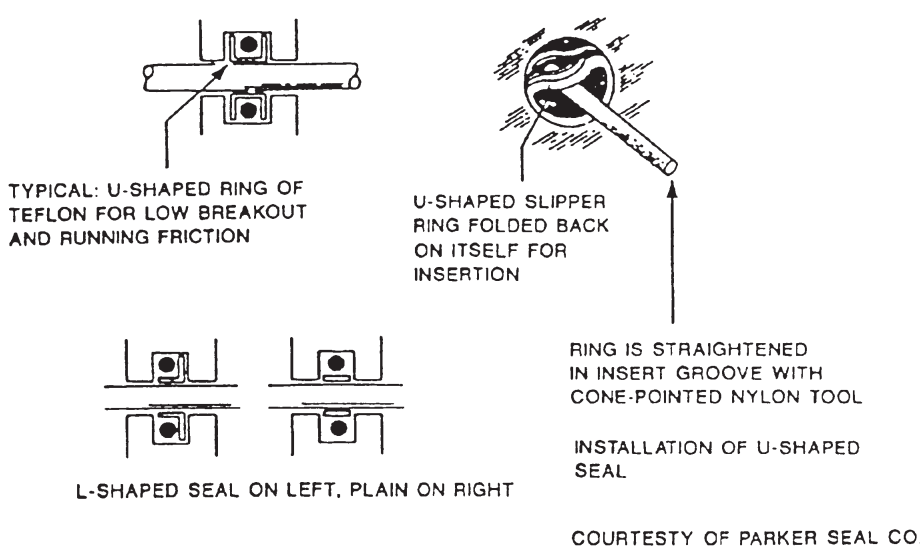


Figure 078–3–17. Slipper Rings

078–3.13.3 GLYD RINGS. Figure 078–3–18 shows a Glyd ring which is designed to prevent O–ring extrusion. No backup rings are required. The Glyd ring and the cap seal shown in Figure 078–3–18 are similar to the anti–extrusion slipper rings and TFE caps discussed in paragraph 078–3.12.1.

078–3.13.4 CAP SEAL. The cap seal shown in Figure 078–3–19 is less frequently used and is not recommended for new design applications. The cap seal is a ring designed to prevent O–ring extrusion and is usually used in grooves designed for O–rings with no backup rings. Because of crowding in the groove, cap seals often present installation difficulties.

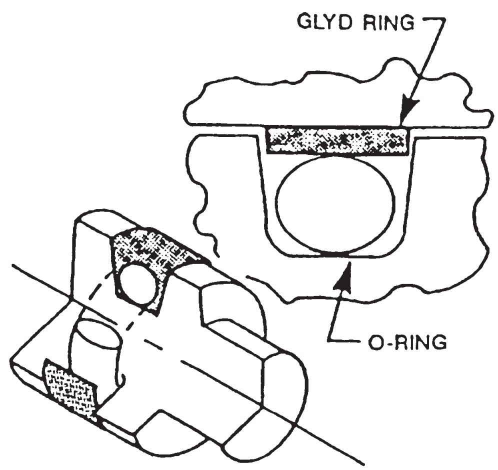


Figure 078–3–18. Typical Glyd Ring Installation

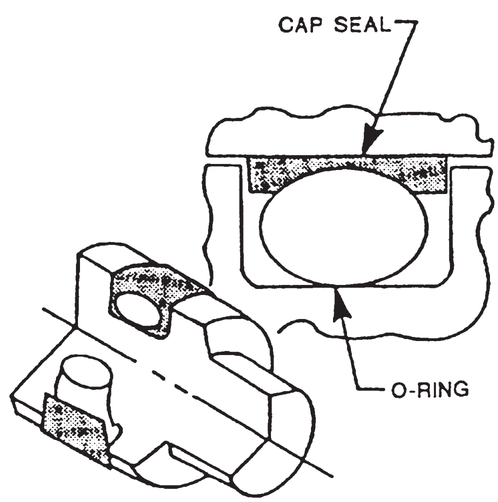


Figure 078–3–19. Typical Cap Seal Installation

078–3.13.5 CHANNEL SEAL. Figure 078–3–20 shows a channel seal which is designed as a replacement for conventional sealing methods (O–ring backup rings in combination) and is directly interchangeable with a dual backup and O–ring combination. Channel seals are manufactured to the gland and groove dimensions specified in MIL–G–5514. Channel seals are used primarily in dynamic hydraulic and pneumatic sealing applications.

078–3.13.6 DOUBLE DELTA CHANNEL SEAL. Figure 078–3–21 shows a double delta channel seal which is a type of seal particularly effective in sealing excessive clearances and high pressure. The double delta channel seal is used in combination with O–rings. The double delta channel seal is manufactured to gland and groove dimensions specified in MIL–G–5514.

078–3.14 ADVANCED SEAL PRODUCTS

078–3.14.1 PLUS SEAL II. The Plus Seal II, shown in Figure 078–3–22, is an advanced slipper seal for use in dynamic applications. They are used as the primary seal in dual rod seal systems and in piston applications where leakage control is critical. The Plus Seal II is manufactured to the gland and groove dimensions specified in MIL–G–5514. This seal is designed to operate at pressures up to 3000 psi and temperatures between –65°F and 400°F. According to Shamban, the special shaped elastomer and thicker cap may provide for 25% greater service life over standard O–ring energized slipper seals.

078–3.14.2 WEDGPAK. The Wedgpak is an advanced no leak rubber contact seal that can be used in both static and dynamic applications. The Wedgpak's major value is as a dynamic seal. Its design provides for a smaller rubber sealing footprint than that of O–rings and T–seals (see Figure 078–3–23). This feature results in lower breakout and running friction. Wedgpaks may offer twice the service life of T–seals in dynamic applications. The Wedgpak seal is manufactured to the gland and groove dimensions specified in MIL–G–5514. This seal is designed to operate at pressures up to 5000 psi and temperatures between –65°F and 400°F.

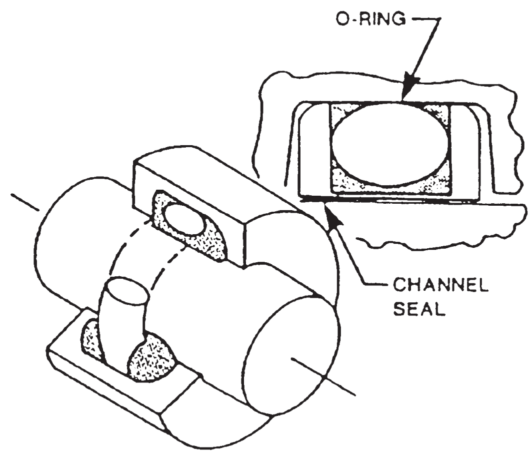


Figure 078–3–20. Typical Channel Seal Installation

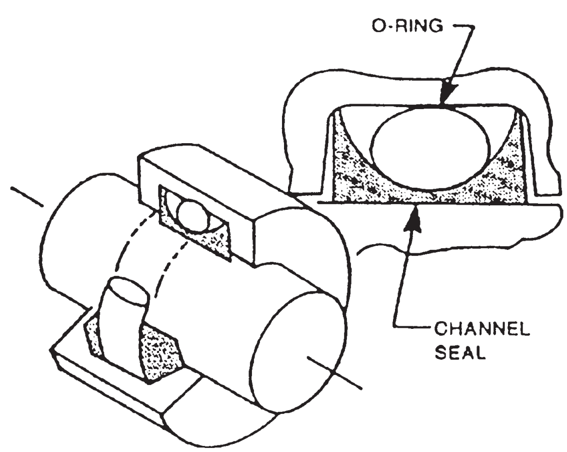


Figure 078–3–21. Typical Double Delta Channel Seal

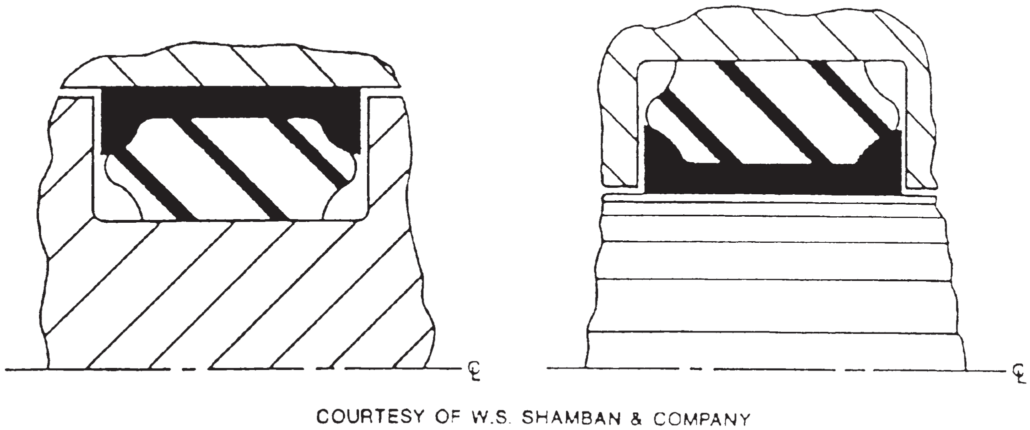


Figure 078–3–22. Plus Seal II

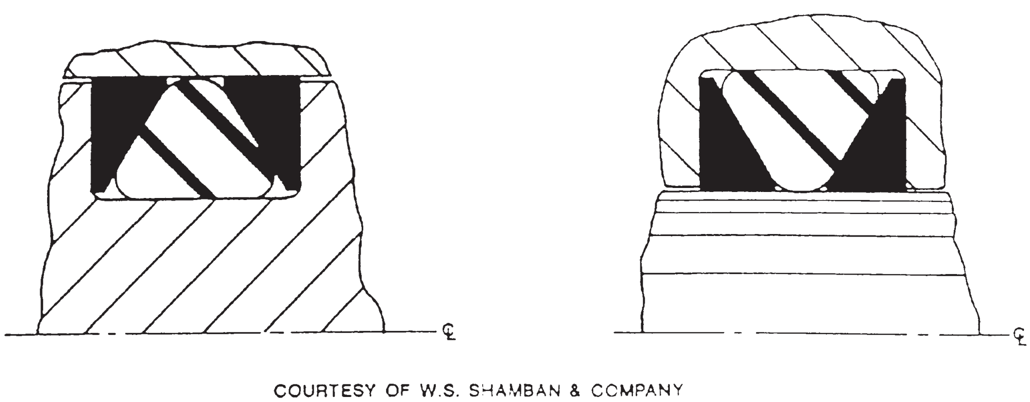


Figure 078–3–23. Wedgpak

SECTION 4.
V–RING PACKINGS

078–4.1 GENERAL

078–4.1.1 INTRODUCTION. The V–ring is one of the most frequently used dynamic seals in ship service although its identification, installation, and performance are probably most misunderstood. V–ring packings, because of the fact that they may be installed and used split, are often the seal of choice where a seal must be replaced without complete disassembly of the item being sealed. Properly selected and installed, V–rings can provide excellent service life; otherwise, problems associated with friction, rod and seal wear, noise, and leakage can be expected. The information in this section will help the user understand and accomplish a satisfactory V–ring packing installation. In the absence of military standards for V–ring stuffing boxes, basic design criteria are also provided in this section to ensure that proper standard dimensions are used.

078–4.1.2 DESCRIPTION. The V–ring is the part of the packing set that does the sealing. It has a cross section resembling the letter V, from which its name is derived. To achieve a seal, the V–ring must be installed as part of a packing set or stack which includes one male adapter, one female adapter, and several V–rings. The male adapter is the first ring on the pressure end of the packing stack and is flat on one side and wedge shaped on the other to contain the V of the adjacent V–ring. The female adapter, the last ring of the packing stack, is flat on one side and V–shaped on the other to properly support the adjacent V–ring. Proper design and installation of the female adapter has significant impact on the service life and performance of the V–rings because the female adapter bridges the clearance gap between the moving surfaces and resists extrusion.

078–4.1.2.1 The nominal overall height of a V–ring packing set, including the male and female adapters as measured before installation, is called the free stack height. The packing set is installed in a cavity which is slightly deeper than the free stack height and is as wide as the nominal cross section of the V–rings. This cavity, called a packing gland or stuffing box, contains and supports the packing around the shaft, rod, or piston. Adjustment of the packing gland depth through the use of shims or spacers is usually necessary to obtain the correct squeeze or clearance on the packing stack for good service life.

078–4.1.3 TYPICAL V–RING PACKING INSTALLATIONS. Two basic installations apply to V–ring packings. The more common is referred to as an outside packed installation, in which the packing seals against a shaft or rod, as shown in Figure 078–4–1. The inside packed installation, shown as a piston seal in Figure 078–4–2, is an infrequent application on Navy ships, but is identified in this section to provide complete treatment on V–rings. When V–ring packing is to be used in an inside packed installation, only endless ring packing shall be used. Where pressures exist in both directions, as on a double–acting piston, opposing sets of packing should always be installed so the sealing lips face away from each other, as in Figure 078–4–2, preventing locking pressures between the sets of packings. The female adapters in inside packed installations should always be located adjacent to a fixed or rigid part of the piston.

078–4.2 GLAND DESIGN FOR V–RING PACKINGS

078–4.2.1 GENERAL DESIGN CONSIDERATIONS. Packing glands (and stuffing boxes) have generally been designed to accept V–rings and adapters of standard dimensions. The dimensions of accepted standard V–rings conform to Air Force – Navy Aeronautical Standard, **Packing, Preformed**, AN 6225; the female and male adapters usually conform to **V–Ring Female Hydraulic Packing**, AN 6228, and **V–Ring Male Hydraulic Packing Adapter**, AN 6229, respectively. For design purposes these AN specification sheets have been in an inactive status since 1952, probably because the specifications restricted the materials used to make the V–ring adapters. In the absence of government standards for V–rings and associated adapters, responsibility for standardization and control passed to industry. The manufacturers, however, still follow the basic AN design and dimensions for most V–rings, and use the same dash number identification as that given on the AN sheets. Even though a given V–ring set may differ from the AN type V–rings, the set will usually work as well or better because manufacturers have altered dimensions to optimize seal performance for that application. Such factors as

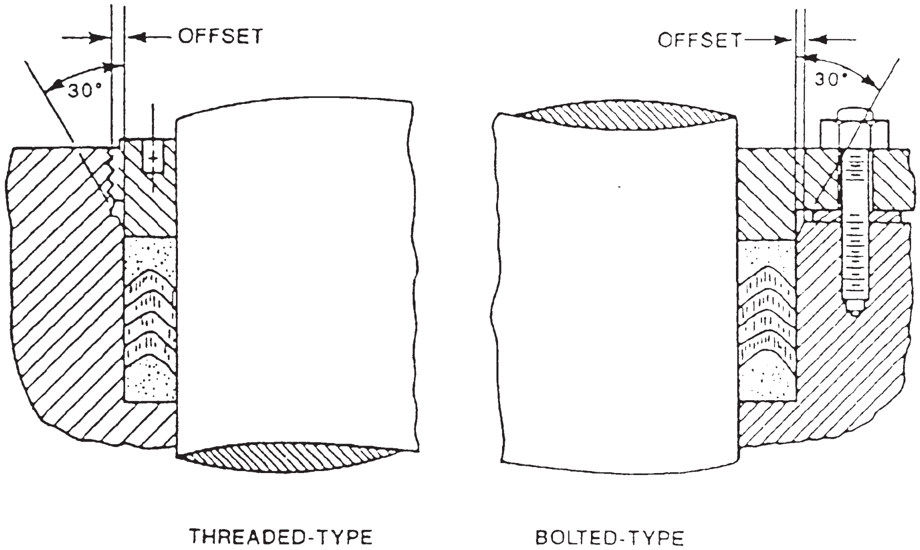


Figure 078–4–1. Outside Packed V–Ring Installation

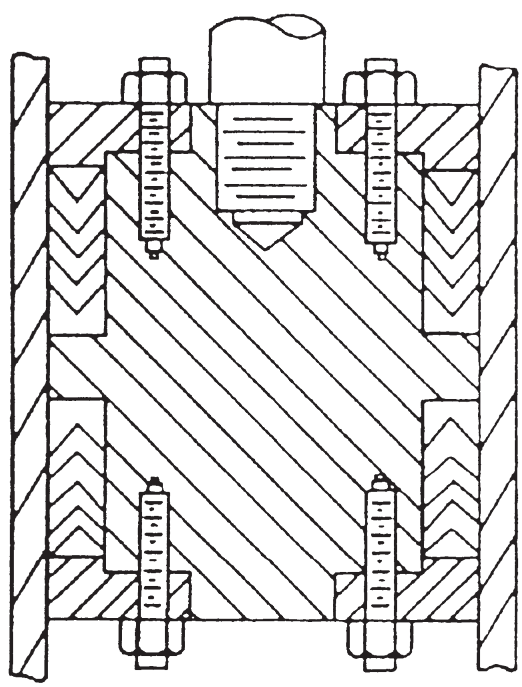


Figure 078–4–2. Inside Packed V–Ring Installation

seal diameter, seal cross section, fluid, pressure, and material may dictate the need for change. In spite of the dimensional variations possible with V–rings, the respective glands will be found to be surprisingly standard, particularly in width.

078–4.2.2 PACKING GLAND WIDTH. The packing gland width (or cross section) can be matched to the nominal cross section of the V–ring, and is fairly standard among manufacturers and users. The optimum packing space design provides packing space width equal to the nominal cross section of the V–packing but not less than the nominal cross section of the seal. The V–packing is designed to compensate for packing space widths which are greater than optimum because of tolerance buildup of machined parts. The larger the seal cross section, the greater the allowable deviation. Table 078–4–1 gives recommended V–ring packing standards for selecting cross section and determining packing gland width.

078–4.2.3 PACKING GLAND DEPTH. Packing gland depth is not as easily defined as a width and is subject to several variables inherent in the V–packing set; for example, if numerous V–rings are included between the adapters, the V–rings will require a deeper gland.

078–4.2.3.1 Quantity of V–Rings Installed. As seen from Table 078–4–2, the number of V–rings in the set depends upon system pressure and fabrication materials. The combinations in Table 078–4–2 have not always been used in the past, so existing shipboard gland designs may require different quantities of rings. Packing material changes made after the initial design could change the number of rings needed for the installation. Specific guidance on V–ring packing installations is provided in paragraphs 078–4.5 through 078–4.5.6.

078–4.2.3.2 Dimensional Tolerances of V–Rings. Another significant variable to be considered in gland depth is the ± 0.010–inch tolerance which applies to each component in a V–ring stack. A five V–ring stack would have seven components, or a total tolerance of ± 0.070–inch.

078–4.2.3.3 V–Ring Stack Heights. Other variables result from the fact that stack heights are identified in terms of free stack height. Table 078–4–3 gives V–ring free stack heights for three set, four set, five set, and six set stacks for several cross section dimensions.

078–4.2.3.3.1 Most stacks, including those made of AN 6225 type V–rings, are considerably longer when installed than when they are measured in the free stack. Table 078–4–4 shows a comparison between free and installed heights for V–rings.

078–4.2.3.3.2 The increase in V–ring height is caused by the flared–out lip of the V–ring, which automatically preloads the packing when the V–ring is installed in the gland. The height increase may vary with manufacturers, materials, and even cross section sizes. Leather V–rings and some special synthetic rubber V–rings do not have the flared–out lip and are referred to as straight–wall V–rings. For straight–wall V–rings, there is no difference between the free stack height and the installed height. Figure 078–4–3 shows a comparison between flare molded and straight–wall V–rings.

078–4.2.3.4 Adapter Stack Heights. Some variation in stack height can be attributed to the male and female adapters. Like the V–rings, the dimensions and shapes of the adapters can vary among manufacturers and for the materials used, in order to obtain the best seal. Unlike V–rings, the height of an adapter is the same whether installed or free. Typical dimensions and illustrations of female and male adapters are shown in Table 078–4–5. These adapters differ somewhat from those shown on the inactive specification sheets AN6228 and AN6229, which were for metal female and male adapters.

078–4.2.3.5 Fixed Versus Adjustable Gland Depth. The proper fitting of a V–ring stack in a packing gland is essential to good sealing and wear. When the packing gland is adjustable, the proper fit of the correct V–ring set can be obtained by screwing down on the packing until the required clearance (float space) or squeeze is obtained. When the packing gland is fixed (nonadjustable), it is usually necessary to provide a shim under the gland ring, or as part of the packing set, to obtain the required squeeze or clearance. Both fixed (bolted type) and adjustable (threaded type) glands are shown in Figure 078–4–1. Because of the variations of height that can occur in V–packings, a perfect fit in a fixed gland without the use of a shim is unusual. For fixed glands, the packing gland depth for the V–packing set to be installed is calculated in accordance with the guidance provided in paragraphs 078–4.2.3.6 through 078–4.2.5. Shims are then required to hand–fit the individual V–ring packing to that particular gland depth, in accordance with the guidance provided in paragraphs 078–4.5.3 through 078–4.5.3.7.

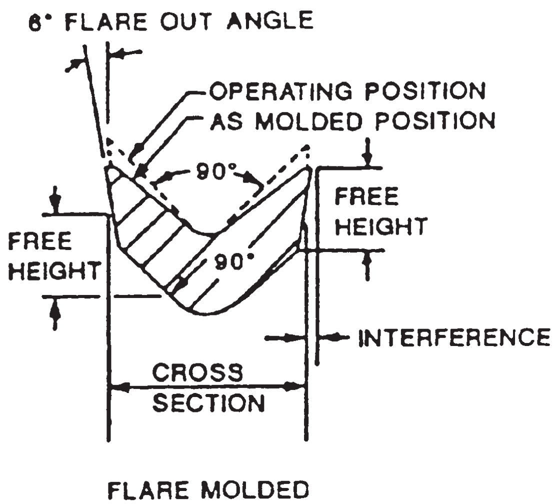


Figure 078–4–3. Comparison of Flare Molded and Straight–Wall V–Rings

Table 078–4–1. RECOMMENDED V–RING PACKINGS STANDARDS FOR SELECTING CROSS SECTIONS AND DETERMINING PACKING GLAND WIDTH

Inside Diameter (inches)*	Available Increments (inch)*	Nominal Cross Section (inch)	Packing Gland Width (inch)
1/4 to 1-1/4	1/8	1/4	0.251 – 0.256
1-1/4 to 2-1/2	1/8	5/16	0.313 – 0.319
2-1/2 to 3-3/4	1/4	3/8	0.376 – 0.382
4 to 5-1/2	1/4	7/16	0.438 – 0.445
5-1/2 to 11	1/2	1/2	0.501 – 0.509
12 to 15	1	1/2	0.501 – 0.509
* Smaller ID’s and incremental sizes are usually available for homogeneous V-packings, as identified in Air Force-Navy Aeronautical Standard AN6225.			

Table 078–4–2. RECOMMENDED NUMBER OF V–RINGS PER SET

Pressure (lb/in^2)	Leather	Synthetic Rubber	
		Homogeneous	Fabric-Reinforced
Zero to 500	3	3	3
500 to 1500	4	4	4
1500 to 3000	4	5	4
3000 to 5000	4	5	5
5000 to 10,000	5	-	6
10000 and over	6	-	-
NOTE: Quantities given in this table are based on solid (endless) rings; when split rings are used, one additional ring is usually recommended. The numbers given do not include adapters.			

Table 078–4–3. V–RING FREE STACK HEIGHT

Cross Section (inch)	3/Set (inch)	4/Set (inch)	5/Set (inch)	6/Set (inch)
1/4	5/8	23/32	51/64	7/8
5/16	55/64	1	1-9/64	1-9/32
3/8	31/32	1-1/8	1-9/32	1-7/16
7/16	1-5/32	1-23/64	1-35/64	1-3/4
1/2	1-7/32	1-13/32	1-39/64	1-13/16
NOTE: Stack height numbers include adapters.				

Table 078–4–4. COMPARISON OF FREE AND INSTALLED HEIGHTS FOR INDIVIDUAL V–RINGS

Cross Section	Free Height ±0.010 Inch	Approximate Installed Height ±0.010		
		Leather	Homogeneous	Fabric Reinforced
1/4	0.083	0.083	0.088	0.098
5/16	0.140	0.140	0.150	0.165
3/8	0.156	0.156	0.166	0.190
7/16	0.197	0.197	0.212	0.232
1/2	0.197	0.197	0.205	0.225
NOTE: Adapter heights are not affected by installation				

078–4.2.3.6 Fixed Glands. V–ring seals may be outside or inside packed as described in paragraph 078–4.5. Additionally, fixed gland V–ring seals are usually shimmed, either internally with the shim adjacent to a seal adapter within the gland cavity, or externally with the shim between the retaining ring and gland body as in Figure 078–4–4. The shim in a fixed gland is used to compensate for variations in installed stack height and its correct thickness must be determined and used every time a packing is installed to ensure proper seal performance (see paragraphs 078–4.5.3 through 078–4.5.3.7).

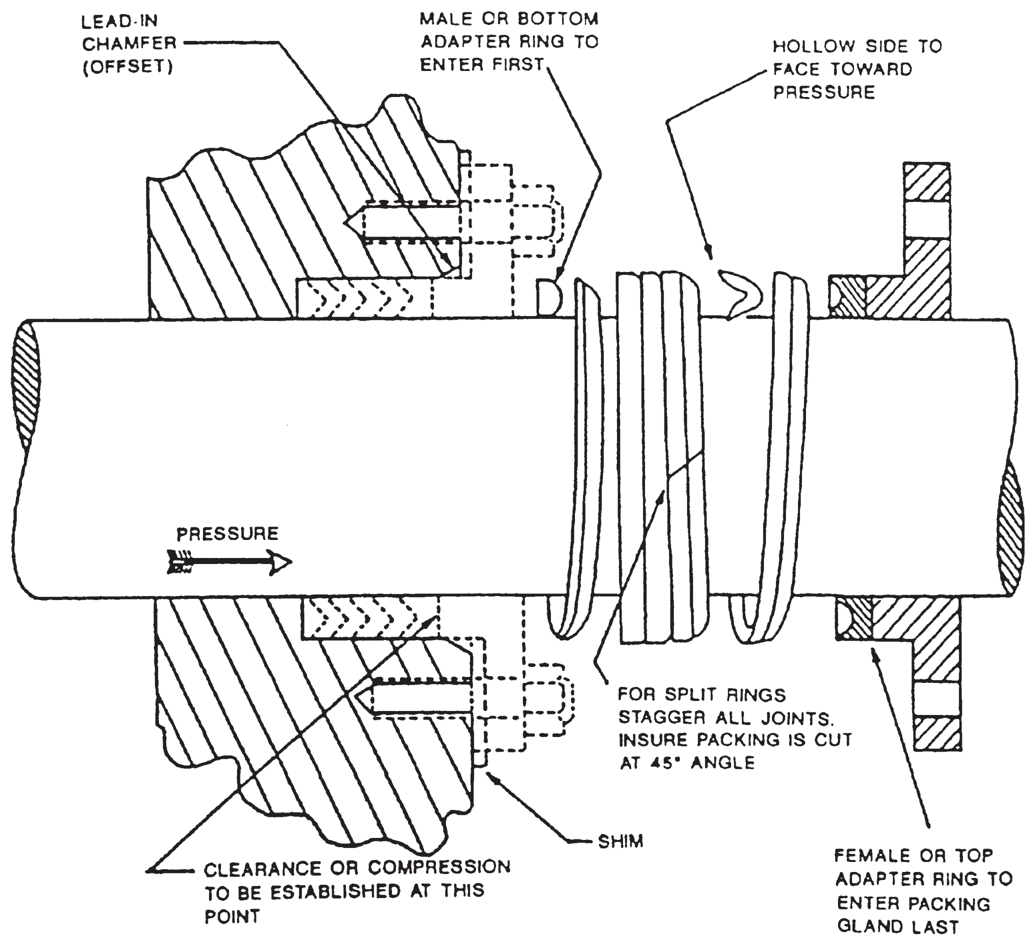


Figure 078–4–4. Fixed Gland V–Ring Packing Installation

Table 078–4–5. RECOMMENDED ADAPTER DIMENSIONS FOR STANDARDIZING PACKING GLAND DEPTH

Cross Section (inch)	Height/Female (H/F) (inch)	Height/Male (H/M) (inch)	Radius (inch)
1/4	1/4	1/8	1/16
5/16	5/16	1/8	7/64
3/8	3/8	1/8	1/8
7/16	7/16	1/8	5/32
1/2	1/2	1/8	5/32

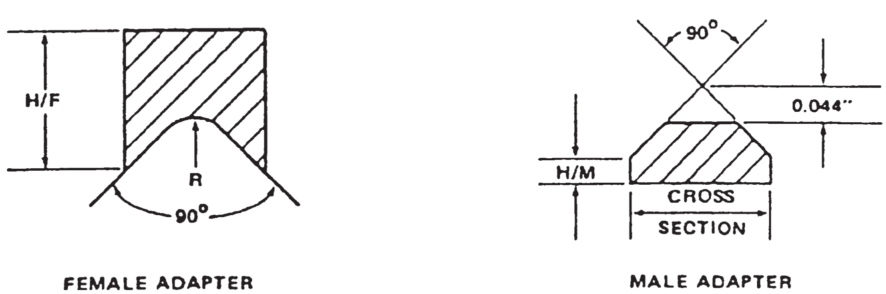


Table 078–4–6. INSTALLED PACKING HEIGHTS FOR FIBER REINFORCED V–RINGS WITH ADAPTERS

Cross Section (inch)	Nominal Installed Heights (inch)			
	Three V-Rings	Four V-Rings	Five V-rings	Six V-Rings
1/4	0.669	0.767	0.865	0.963
5/16	0.933	1.098	1.263	1.428
3/8	1.070	1.260	1.450	1.640
7/16	1.259	1.491	1.723	1.955
1/2	1.300	1.525	1.750	1.975
Tolerance (+/–inch)	0.050	0.060	0.070	0.080

NOTES:
1. Installed packing heights from Table 078–4–4 for fabric reinforced rings and Table 078–4–5 for adapter heights.
2. Tolerances based on +/–0.010 (inch) per packing set component.

078–4.2.3.7 Fixed Gland Shims. Shims may be made of various materials; plastic, metal or composite. The shim will generally require accurate machining to the correct thickness every time a seal is installed (see paragraphs 078–4.5.3 through 078–4.5.3.7). For internal shims the material chosen should be softer than the moving surface and its inner and outer diameters must be such that it will not contact the moving surface, (see paragraph 078–4.5.3.7). A nominal shim thickness of 3/8 (0.375) inch is generally acceptable for gland design, ensuring a margin when gland dimensions are based on nominal dimensions of the seal components, leaving sufficient shim thickness for accurate machining in case of extreme tolerance buildup.

078–4.2.3.8 Fixed Gland Dimensions. The gland's inner and outer diameters must ensure adequate V–ring lip contact to provide low pressure sealing and prevent leakage. Generally, good performance will be obtained with standard sized (see Table 078–4–1) commercially produced V–rings installed where: the rod diameter is 0.000 to 0.006 inch smaller than the packing's nominal inner diameter; and the gland bore diameter is 0.000 to 0.006 inch larger than the packing's nominal outer diameter. Based on the equipment operating pressures the number of V–rings required for sealing are found in Table 078–4–2, where split rings are used add one V–ring. The height of the installed packing that must be accommodated in the gland may be taken from Table 078–4–6 or Table 078–4–4 and Table 078–4–5. Generally acceptable nominal cavity depth and retaining ring dimensions may be based on the nominal installed packing height, including adapters, when a nominal shim thickness of 3/8 (0.375) inch is used for design.

078–4.2.4 CALCULATING FIXED GLAND DIMENSIONS, AN EXAMPLE. Consider a cylinder with nominal rod diameter of 4–1/4 inches to operate at 3,000 psi and use split rings;

a. From Table 078–4–1, V–rings of 7/16 inch nominal cross section will be used. Nominal gland bore diameter will be 5–1/8 inch. Actual width of the gland will be 0.438 to 0.445 inch.

b. From Table 078–4–2, choosing fabric reinforced V–rings; six V–rings (five rings plus one for split), one male and one female adapter will be required.

c. From Table 078–4–6 the nominal installed packing set height is 1.955 inch.

d. With an internal shim thickness of 3/8 (0.375) inch the nominal gland depth will be $1.955 \pm 0.375 =$ 2.330 inches.

078–4.2.5 FIXED GLAND DESIGN. Paragraphs 078–4.2.3.8 and 078–4.2.4 provide a simplified but workable method for design of packing glands. The design of seal geometries may be much refined by careful consideration of materials to be used and manufacturing capabilities to determine the minimum dimensions and tolerances attainable. Refined gland design is not discussed in this text. It should be noted, however, that fixed glands have been developed that use an internally placed spring (waved washer, etc.) instead of a shim at the male adapter to provide controlled compression to the packing stack. Controlled compression (spring loaded) packing designs are not currently standardized enough at this time to be addressed in detail here but may be used as an alternative to solid shimmed designs, as they do not require determination and use of carefully machined shim thicknesses upon every packing replacement.

078–4.2.6 PACKING GLAND SURFACE FINISH. The recommended surface finishes for optimum service life of V–ring packing sets, regardless of material, are 16 microinches RMS (maximum) for dynamic surfaces against which the packing moves and 32 microinches RMS (maximum) for static surfaces which the packing contacts. If rougher surface finishes are used, the service life and sealing efficiency of the V–ring packing sets will be reduced considerably.

078–4.2.7 PACKING GLAND OFFSET. For installations where V–rings must pass threaded surfaces or other sharp projections, the offset must be sufficient to provide adequate clearance between the diameter of the packing ring and the projection (see Figure 078–4–1). The packing gland should have approximately a 30 degree chamfer at its entrance for ease of installation and to reduce the chance of damaging the packing as shown in Figure 078–4–1. Glands for packing cross sections should have an offset in accordance with Table 078–4–7 and Figure 078–4–1.

078–4.2.8 PACKING GLAND DIAMETRAL CLEARANCE. Proper support of the packing at its shoulder is important to long service life of a seal, regardless of the type of packing (for example, U–packing, flanges, cup packings, V–packings). If excessive clearance exists on the back supporting ring, operating pressure will extrude the shoulder of the packing into the clearance. Table 078–4–8 provides the suitable diametral clearances for either inside or outside–packed installations.

078–4.2.9 PACKING GLAND REPAIR. Repair procedure similar to those for O–rings identified in paragraph 078–3.5.7 may be used for repair of V–ring packing glands.

078–4.3 V–RING PACKING PROCUREMENT

078–4.3.1 ALLOWANCE PARTS LIST IDENTIFICATION. The correct V–ring packing for each application should be identified on the applicable Allowance Parts List (APL). APL ordering information is not always clear and may be limited to a part number (such as NAVSEA drawing number, military standard, or a vendor plan), a basic description with some dimensions (such as **Packing Assy – 4.000 I.D.**), and a National Stock Number (NSN). If needed, additional information on the packing can be obtained directly from the applicable NAVSEA or vendor drawing. There should be no discrepancies between the APL information and that provided on applicable drawings.

078–4.3.2 DISC NAVY IDENTIFICATION LIST. If the NSN is not known for the required V–ring packing, the number can be found by referring to the Defense Industrial Supply Center (DISC) Navy Identification List (NIL). To find an NSN on the NIL, the free stack height, inside diameter, and outside diameter of the packing must be known. Table 173 of the NIL identifies NSN's for a variety of packing assemblies, including V–rings. There may be more than one kind of packing with the same inside diameter, outside diameter, and free stack height; therefore, a coded description (A, B, C, D) of the packing rings is also provided in Table 173 of the NIL and illustrations forthese codes can be found in the beginning of that section (FSC 5330) of the NIL.

Table 078–4–7. V–RING PACKING GLAND OFFSET

Packing Cross–Section (inch)	Offset (inch)
3/16 to 1/4	1/16
5/16 to 3/8	3/32
7/16 to 1/2	1/8
9/16 to 3/4	3/16
over 3/4	1/4

Table 078–4–8. SUITABLE ALLOWANCE FOR DIAMETRAL CLEARANCES FOR V–RING PACKING GLANDS

For Leather or Fabric-Reinforced Rubber Packings			
Cylinder Diameter (inches)	Lb/in^2		
	Under 500	500–3000	3000 and over
under 3	0.012	0.008	0.006
3 to 8	0.014	0.010	0.008
8 to 10	0.016	0.012	0.010
10 to 12	0.018	0.014	0.012
12 to 16	0.020	0.016	0.014
16 to 24	0.022	0.018	0.016

For Homogeneous Rubber Packings		
Cylinder Diameter (inches)	Lb/in^2	
	Under 500	500 – 1500
under 2	0.006	0.005
2 to 5	0.008	0.006
5 to 8	0.010	0.008
8 to 10	0.012	0.010
10 to 12	0.014	0.012
12 to 16	0.016	0.014

078–4.3.2.1 Briefly, code A provides an illustration number for the bottom ring. For V–packing sets, the illustration number is 50, and reference to that illustration shows a male adapter. Code B provides an illustration number for the intermediate rings, which is nine for V–rings. Code C is a number equivalent to the number of intermediate rings in the assembly. Code D provides the illustration number for the top ring in the packing assembly. Illustration number three shows a female adapter. Occasionally the illustration numbers for Codes A and D are interchanged; this means that the top ring is called out as the bottom ring, and the bottom as the top. The illustrations still show male and female adapters regardless of whether they are located on top or bottom. An ABCD code of 50, 9, 6 and 3 will produce the same packing set as code 3, 6, 9, and 50. Some additional information such as type of material used in the packing set and the type of joint on split rings may be provided.

078–4.4 V–RING PACKING REPLACEMENT

078–4.4.1 LEAKAGE CRITERIA. Usually V–ring packings are replaced because they leak excessively. This may be caused by wear and scoring of the moving metal surfaces, or simply because of worn out packing. It is difficult to specify exact acceptable leakage rates for V–rings because their operation differs from other types of dynamic seals. Each V–ring in the stack carries a portion of the total differential pressure across the whole stack. This means that some fluid (liquid or gas) contacts each V–ring throughout the set. When the moving seal changes direction during operation, differences in the fluid pressure against the packing cause some flexing or pumping action along the V–ring sealing areas and a very slight amount of fluid can escape. This fluid serves to lubricate the V–ring stack. The ideal situation is to have sufficient seepage to lubricate the seal without excessive system fluid or pressure loss, or housekeeping problems. Guidance for minimizing hydraulic system seal leakage is provided in **NSTM Chapter 556, Hydraulic Equipment Power Transmission and Control**, and **NSTM Chapter 561, Submarine Steering and Diving Systems**.

078–4.4.1.1 When excessive leakage occurs, V–ring packings must be replaced. A leaking V–ring seal cannot be corrected by tightening or otherwise putting more squeeze on the packing. Although the leak may temporarily stop as a result of the increased compression of the packing, the friction created during later movements may cause damage to the metal sealing surfaces, may slow down operating rates, may create noise problems or chattering, and can be expected to permit leakage. For a new installation, relief from excessive leakage may be obtained by tightening or increasing packing squeeze slightly, because this action can assist in properly seating a packing set that has become cocked or has been assembled with a leakage path.

078–4.4.2 SPLIT VERSUS UNSPLIT V–RING PACKINGS. Ideally the rings should be installed without being split. These are commonly referred to as endless or unsplit rings. Endless rings seal easier, wear better, and do not require squeeze. The recommended axial clearance for an installed endless ring packing set is 0.000 to 0.030 inch although clearances up to 0.050 inch are expected to work satisfactorily. Sets of V–ring packings should never be allowed to function too loosely (to be sloppy) in a gland, as they may become cocked. On installations with fast reversals, a sloppy set will cause a pumping action resulting in leakage. For many installations, the rings must be split in order to get them on the shaft or rod. For a stack of split rings, a total squeeze of 0.020 to 0.030 inch is recommended, although a squeeze as great as 0.050 inch is expected to perform satisfactorily. Squeeze is required to seat split rings. Split rings should be avoided in installations where rotation is involved.

078–4.4.3 SPRING–LOADED V–RING PACKINGS. In some instances, springs have been used to preload V–ring packing sets in fixed packing glands. Experience indicates that spring–loading is usually unnecessary when the gland is properly designed and the installation is correct. The preload pressure provided by the flared design of the V–ring is sufficient, both initially and during service, to seal against leakage under pressures for which the equipment is designed. For this reason, spring–loading of packing is not recommended.

078–4.4.4 PRELIMINARY MAINTENANCE ACTIONS Steps required to install the packing are described in paragraphs 078–4.4.5 through 078–4.4.9.

078–4.4.5 VERIFICATION OF PACKING AVAILABILITY. Before disassembling components to replace V–ring packings, make sure the required packing is available. V–rings are not as common as other seals in service (such as O–rings) and slight differences in cross section or diameter may not be readily apparent. If possible, ensure that the packing is in accordance with the size and material requirements specified on the applicable drawing. If discrepancies are suspected, verify selection of the proper V–ring set by reviewing Table 078–4–1 through Table 078–4–6 and paragraph 078–4.2.4.

078–4.4.6 CHECKING THE OLD PACKING. Compare the removed packing with the new packing to further verify that the new packing is correct; in particular, count the number of V–rings. Sometimes, as a result of earlier repair actions, use of shims, or packing material substitutions, it is possible that more or fewer rings are installed than are provided in the packing stack as purchased. If the old and new packings appear significantly different, do not install the new packing without ensuring that it is correct. Any discrepancy should be referred to NAVSEA for resolution. After removing old packings, discard them. Do not mix old and new packings. Do not reuse parts of the old packings, except possibly for some older installations where the male or female adapters are made of metal and are confirmed to be in good condition.

078–4.4.7 CUTTING RINGS IF NECESSARY. If equipment requires the installation of split packing rings, those split by the manufacturer should be used. If only solid rings are available, a razor–sharp instrument should be used to cut the ring as shown in Figure 078–4–5. The packing should not be cut with a saw as this removes excess amounts of vital seal material. The preferred V–type packing installation uses endless (also called nonsplit or solid) packing. The split–ring type packing should be used only where seal availability, lack of time, or complex seal installation prevents use of solid–ring packings. Solid–ring packings should be used at overhaul and where rotation is a factor.

078–4.4.8 LUBRICATING PACKINGS. Prior to installing new V–ring packings, saturate the packing with the type of fluid used in the component, then install the packing. If more lubrication is needed, apply a light coating of a lubricant which is compatible with the system application as identified in Table 078–3–16. Avoid excessive use of lubricants. Do not use any substitute lubricants without proper authorization. Do not use combustible lubricants in air and oxygen systems.

078–4.4.9 REPAIR ACCEPTANCE STANDARDS FOR V–RING PACKING Relaxed repair acceptance criteria for V–ring packing sealing surfaces are provided in paragraphs 078–4.4.10 through 078–4.4.12. See Figure 078–4–6 for typical packing installation and terminology.

a. The size and spacing of surface defects may be estimated visually.

b. Rhr surface finish requirements apply only to surfaces surrounding allowable surface defects and not to the surface defect areas themselves.

c. Diametral clearance and cavity height and width requirements apply to surfaces surrounding allowable surface defects and not to the surface defect areas themselves.

078–4.4.10 ACCEPTANCE CRITERIA FOR V–RING PACKING SEALING SURFACES.

a. Surface finish of dynamic sealing surfaces must be rhr 32 or smoother.

b. Surface finish of static sealing surfaces must be rhr 63 or smoother.

c. Surface defects must meet the requirements of Table 078–4–9.

d. Raised edges on allowable surface defects are not acceptable.

e. Packing cavity width must not exceed maximum drawing dimensions or the requirements of Table 078–4–10, whichever is greater.

078–4.4.11 ACCEPTANCE CRITERIA FOR V–RING PACKING GLAND.

a. Surface defects must meet the requirements of Table 078–4–11.

b. Raised edges on allowable surface defects are not acceptable.

c. Diametral clearance with rod must not exceed maximum drawing dimensions or the requirements of Table 078–4–12, whichever is greater.

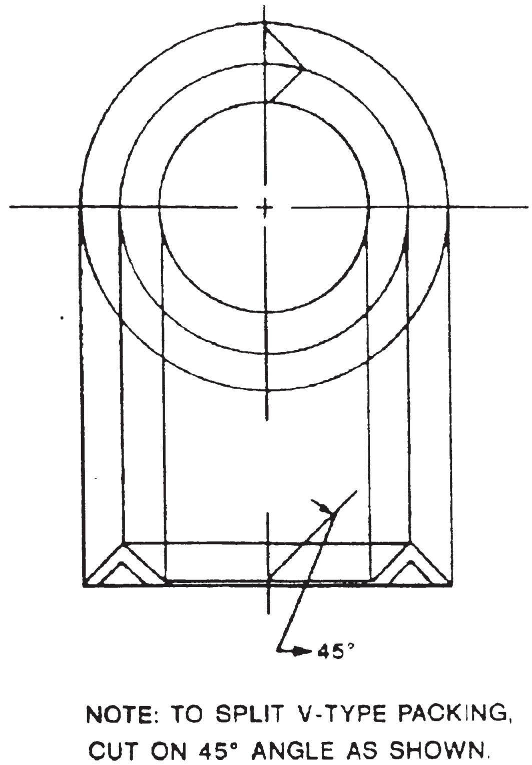


Figure 078–4–5. Cutting V–Type Packing

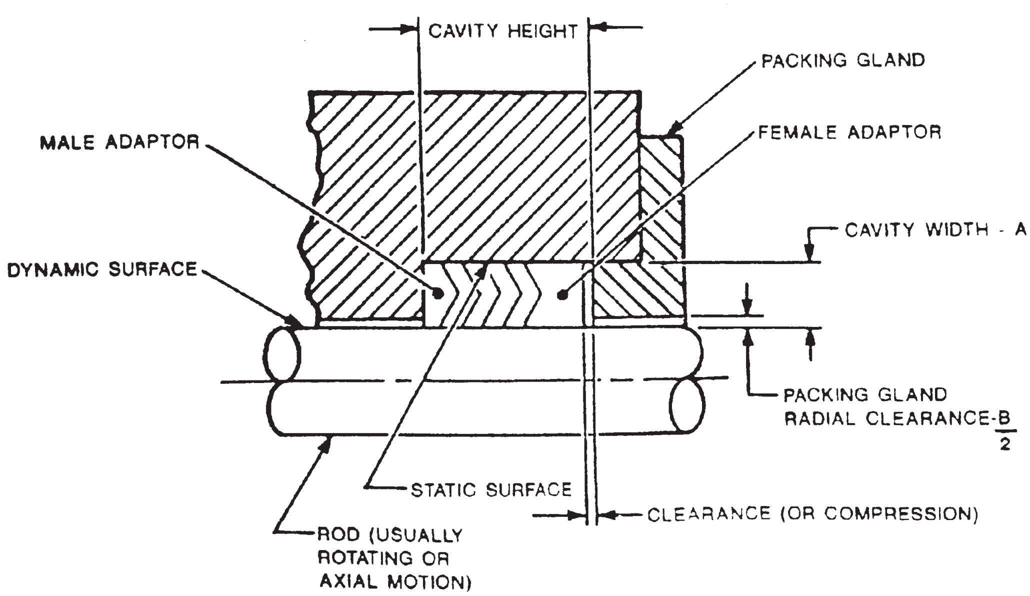


Figure 078–4–6. Typical Packing Installation

Table 078–4–9. V–RING SURFACE ALLOWABLE DEFECT SIZE AND SPACING

Surfaces	Maximum Allowable Surface Defect Size		Minimum Allowable Surface Defect Spacing	
	Max Width or Length	Max Depth	Avg	Min
Dynamic Sealing Surfaces	0.010	0.005	7/64	1/32
Static Sealing Surfaces	0.015	0.010	5/32	1/16

Table 078–4–10. V–RING PACKING CAVITY WIDTH

Nominal V-Ring Cross Section	Maximum Packing Cavity Width (in.), A
3/16	0.194
1/4	0.256
5/16	0.321
3/8	0.385
7/16	0.452
1/2	0.515

Table 078–4–11. V–RING GLAND ALLOWABLE DEFECT SIZE AND SPACING

Surfaces	Maximum Allowable Surface Defect Size		Minimum Allowable Surface Defect Spacing	
	Max Width or Length	Max Depth	Avg	Min
Packing Gland Bore	0.060	0.030	1/8	——
Packing Gland Face (in way of adaptor)	0.040	0.020	3/8	3/16

Table 078–4–12. V–RING DIAMETRICAL CLEARANCE

Packing Gland	Max Diametral Clearance with Rod OD, B		
		Non–Metallic Adaptors	
Nominal V-Ring Cross Section, A	Metallic Adaptors	Max System Pressure 1500 psi	Max System Pressure 3000 psi
3/16	.030	.005	.003
1/4	.035	.006	.004
5/16	.040	.007	.005
3/8	.045	.009	.006
7/16	.050	.010	.007
1/2	.055	.012	.008

078–4.4.12 ACCEPTANCE CRITERIA FOR V–RING PACKING CAVITY HEIGHT.

a. Endless rings. Clearance (float space) between packing and gland ring must be between 0 and 0.030 inches, inclusive.

b. Split rings. Compression of installed packing must be between 0.010 and 0.030 inches, inclusive.

NOTE

Compression equals the total decrease over installed stack height which the packing undergoes due to installation and adjustment of the packing gland. Installed stack height is the total height which the packing occupies when installed in the packing cavity with no clearance between assembly components. This height may be greater than the free stack.

078–4.5 V–RING PACKING INSTALLATION

078–4.5.1 INSERTING THE PACKING RINGS. The packing shall be installed as shown in Figure 078–4–4. When installing a set of packings, never install the set as a single complete unit. Each packing and adapter must be installed individually. Ensure that the hollow side of the packing faces the pressure. Be sure each part is properly seated before installing the next part. As each V–ring packing is installed, pinch the lips of the packing together slightly. This will allow for easier entrance into the packing gland. Be careful not to roll the lips backward. Always install V–ring packings with sealing lips toward the pressure. To eliminate air which is trapped between endless packing rings when they are inserted, collapse a short section of the packing by placing a thin brass or soft metal rod between the sealing lip and packing gland wall as shown in Figure 078–4–7. Use extreme care to avoid scratching or marring the surface of the packing gland wall or packing ring while inserting the rod. If split ring packing is being installed, open the joints sideways when placing the rings around the shaft. Do not pull the joints straight apart. When split ring packing is used as a replacement, joints shall be staggered on each successive packing ring at least 90 degrees. The correct sequence, as shown on Figure 078–4–4, is to alternate joints first 180 degrees apart, then 90 degrees, and again 180 degrees, and so on, to minimize possible leakage. Joints should never be placed one over the other. Ensure that the packing rings and adapters are not cocked, and that beveled (cut) ends of the joints make face–to–face contact (no gap) but do not override or overlap. Split rings tend to stretch during insertion, resulting in a slightly longer ring than is needed. If stretching occurs, do not allow the ends of the ring to overlap. Attempt to compress ring ends to achieve a smooth butted joint. If necessary, the extra material may be cut or filed off one end of the ring.

078–4.5.2 SEATING THE PACKING RINGS. After the packing stack has been inserted into the packing gland, ensure that no space exists between any of the components. If the packing is too tall for the packing gland confined depth, the gland rings will not completely fit into the gland and a space will exist between the gland ring flange and the body (see Figure 078–4–8). Shims will be required to fill this gap. If the gland has been designed to the dimensions of Table 078–4–1, through Table 078–4–6, the packing stack will be just the right height or shorter than the confined gland depth, in which case the gland ring will make metal–to–metal contact with the body (see Figure 078–4–9). The use of shims within the packing gland may still be required to provide the necessary squeeze or eliminate excessive clearance above the packing.

078–4.5.3 OBTAINING THE PROPER PACKING SQUEEZE OR CLEARANCE IN FIXED GLANDS. After installing V–ring packings, check for clearance and make necessary adjustments to the fixed packing gland in accordance with the requirements and procedures described in paragraphs 078–4.5.3.1 through 078–4.5.3.7.

078–4.5.3.1 Packing Too Tall. If the packing is taller (or higher) than the space provided within the packing gland, there will be a clearance between the gland ring flange and the body (see Figure 078–4–8). Measure this clearance at four points, approximately 90 degrees apart. If the four measurements are not equal it indicates that V–ring packings and adapters are cocked; this condition must be corrected before flange shims are installed

NOTE

In some cases where the packing stack is taller than required for proper fit in the confined packing gland, some material can be machined off the male or female adapters. Material removed should not exceed 10 percent of the adapter height. Machining the adapters should be considered if it can eliminate the use of very thin shims.

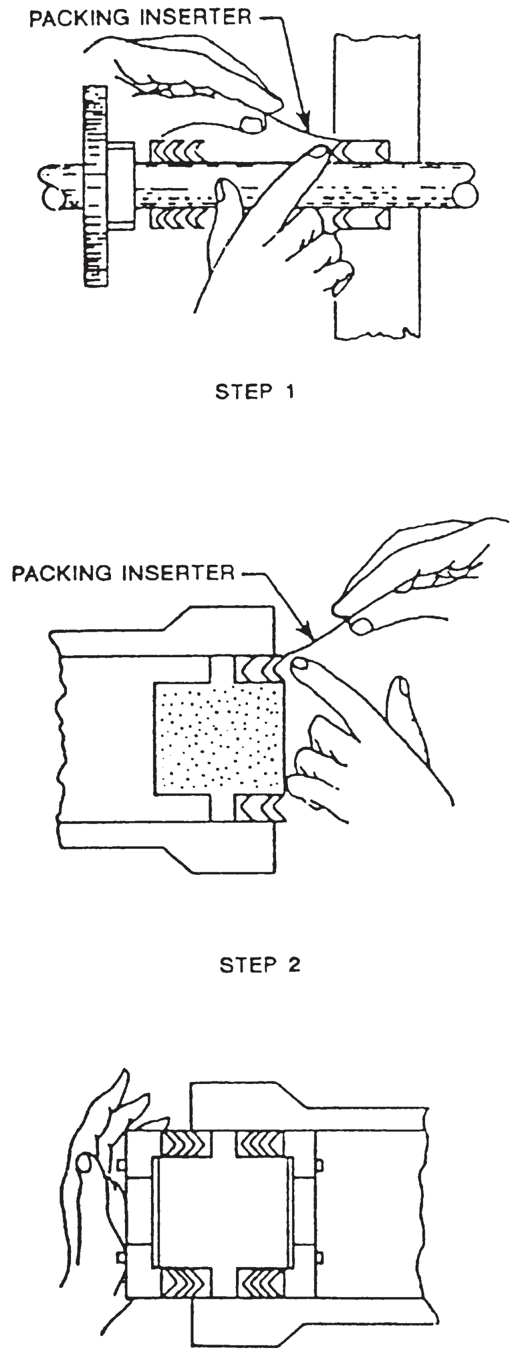


Figure 078–4–7. V–Ring Installation Technique

078–4.5.3.2 Packing Too Short. If there is no clearance between the gland ring flange and the body (see Figure 078–4–9), the packing is probably too short for the space provided within the packing gland, although it is possible that the fit is correct. Measurements are required to determine with certainty which condition exists. Withdraw gland ring and measure the depth in the packing gland

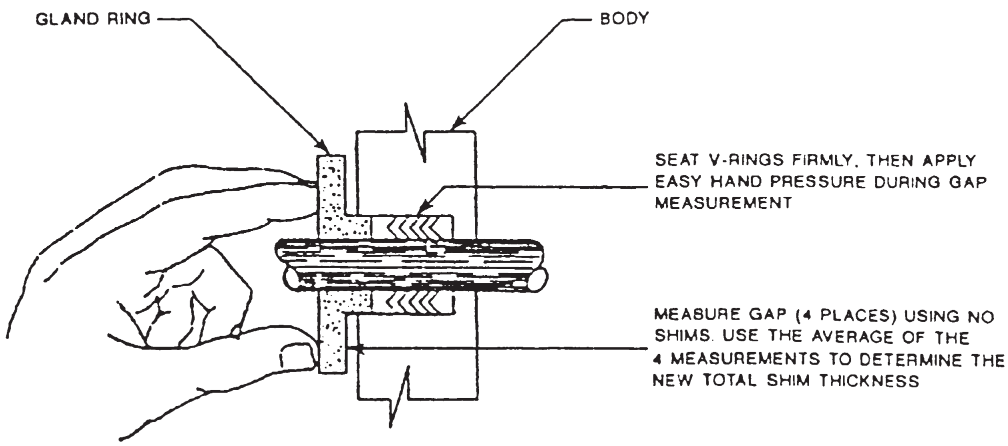


Figure 078–4–8. Checking Gap Between Gland Flange and Body

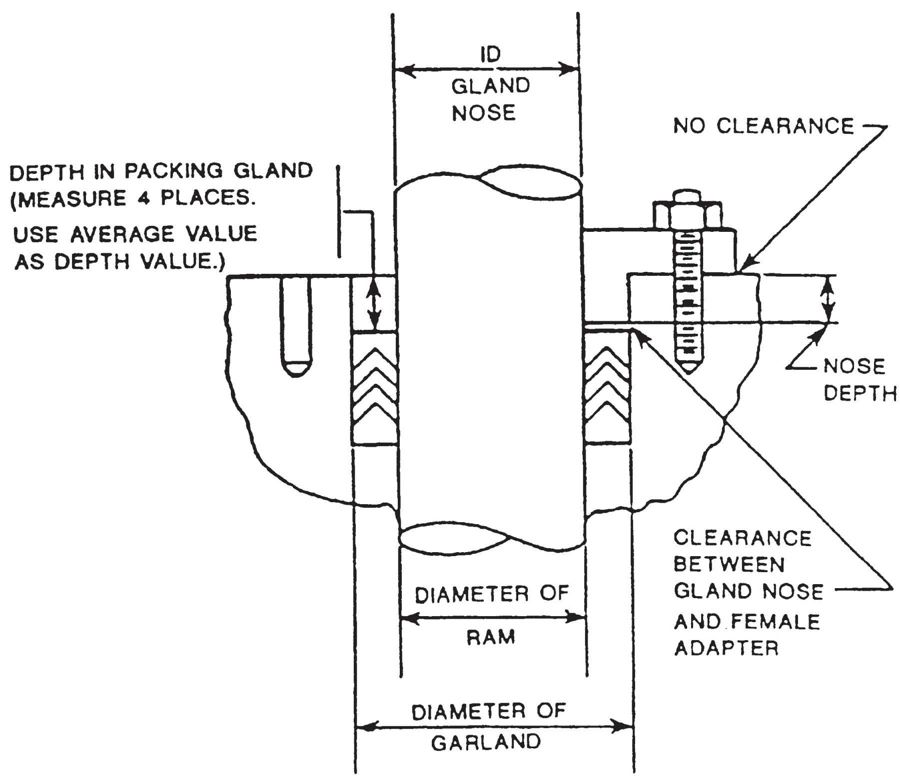


Figure 078–4–9. Measuring Packing Clearance

NOTE

Depth of packing gland is the distance from the top surface of the female adapter to the body surface.

078–4.5.3.2.1 Measure nose depth of the gland ring (length of the gland ring from the inner surface of the flange to the end which contacts the adapter). Subtract the nose depth measurement from the depth measurement of the packing gland. The difference is the clearance above the packing after the gland ring is installed. Shims may be required to reduce this clearance space, as detailed in paragraphs 078–4.5.3.3 and 078–4.5.3.4.

078–4.5.3.3 Correcting Packing Space for Endless Rings. If endless rings have been installed, a float space of 0.000 to 0.030 inch above the packing set is recommended. When the packing is too tall for the packing gland, as described in paragraph 078–4.5.3.1, the flange shim thickness will be 0.000 to 0.030 inch greater than the clearance between the gland ring flange and the body (see Figure 078–4–8). When the packing is more than 0.030 inch shorter than the measured gland space, as described in paragraph 078–4.5.3.2, shims of suitable thickness shall be installed on top of the female adapter to reduce the clearance to less than 0.030 inch. If the packing is less than 0.030 inch shorter than the measured gland space (that is, the clearance is less than 0.030 inch), no shims are needed.

078–4.5.3.4 Correcting Packing Space for Split Rings. If split rings have been installed, compression (squeeze) of 0.020 to 0.030 inch on the packing set is recommended. When the packing is too tall for the packing gland, as described in paragraph 078–4.5.3.1, the flange shim thickness will be 0.020 to 0.030 inch less than the clearance between the flange and the body. If the clearance between the flange and the body is 0.030 inch or less, no shimming is required in this area. If the clearance between the flange and the body is very small (less than 0.010 inch), consideration should be given to the fabrication of a shim for use inside the packing gland. Although 0.020 to 0.030–inch packing squeeze is recommended, as little as a few thousandths may be sufficient to achieve a seal. If the packing installation is simple, non–critical, and readily accessible, it may be prudent to test the seal with only the little available squeeze, before taking the time and effort to make a precision shim for use within the packing gland. For split ring installation where the packing stack is not taller than the available gland space (Figure 078–4–9), the required shim thickness is the sum of the measured clearance between the female adapter and the gland nose, as defined in paragraphs 078–4.5.3.2 and 078–4.5.3.2.1, plus 0.020 to 0.030 inch required for squeeze.

078–4.5.3.5 Making Shim Thickness Measurements. The clearances or squeezes which have been recommended fall in the range of 0.000 to 0.030 inch. To make these precise measurements, the use of ruler or other crude scales is unsatisfactory. For determining the gap between the gland flange and the body, feeler gages are recommended. For determining the clearance between the female adapter and gland ring nose, the use of a micrometer depth gage with a ratchet stop, similar to the gage shown in Figure 078–4–10, is recommended. A suitable depth gage, with a rod diameter of 3/32 inch, complete with 12 rods capable of measuring to 0.001 inch over a 0– to 12–inch range, can be obtained under NSN 9Q 5210–00–826–5368.

078–4.5.3.6 Shim Materials. For use between the gland ring flange and body, metal shims the same size as the flange should be used. These shims should have holes to accommodate the fasteners. For use within the packing gland, shims of a variety of hard materials (including phenolics and metal) would be suitable. Recommended metallic shim materials are identified as MIL–S–22499 Composition 1 (aluminum) and Composition 2 (brass), Class 1 (0.002–inch laminations), available in two standard thicknesses (0.062 inch and 0.125 inch). These materials are listed in Federal Supply Catalog under codes FSC 9515 and 9535. Recommended phenolic materials are Teflon filled Acetal (Dupont trade name: Delrin “AF”) in accordance with the requirements of NAVSEA Drawing 803–4384678 and Ultra–High–Molecular–Weight Polyethylene (UHMWPE) in accordance with ASTM D4020. Phenolic materials are preferred for seawater seal applications since they resist seawater corrosion.

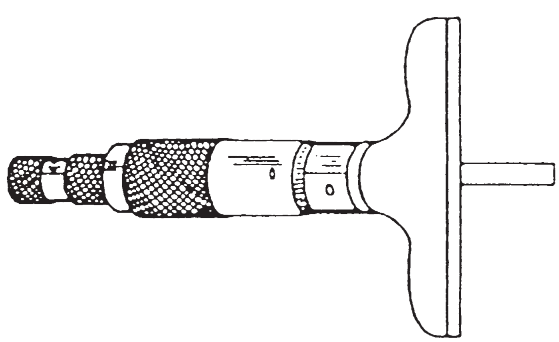


Figure 078–4–10. Micrometer Depth Gage

078–4.5.3.7 Shim Fabrication. Shim thickness should be determined using the method described in paragraph 078–4.5.3.5. With the current V–ring packing and gland design, there will be cases where a spacer thickness of less than 1/16 inch will be required. These spacers may be difficult to machine, especially if the packing OD is 6 inches or greater. Future designs should increase the depth of the stuffing box so that a spacer of.100 inch minimum will be required to maintain a nominal squeeze of.025 inch. It is important that shims do not contact moving surfaces such as the piston rod or cylinder wall. The inside and outside diameters of shims should be in accordance with the following:

a. For outside packed installations (Figure 078–4–1), the recommended outside diameter (OD) for the shim equals the minimum OD of the packing gland bore minus 0.006 inch; the recommended inside diameter (ID) for the shim equals the maximum ID of the ram plus 0.030 inch.

b. For inside packed installations (Figure 078–4–2), the recommended OD for the shim equals the maximum ID of the cylinder minus 0.030 inch; the recommended ID for the shim equals the maximum ID or the packing gland (measured across the piston) plus 0.006 inch.

078–4.5.4 SECURING THE PACKING GLAND RING. If metal adapters or shims are used in the packing installation, check for excessive clearance or binding, especially between the female adapter or shims and the ram. In cases of inside packed installations, check for excessive clearance or binding between metal adapters and the cylinder wall. After proper clearance, skim thickness, and adjustment for correct packing float or squeeze have been obtained, secure the gland ring to seal the hydraulic joint. Tighten all gland ring nuts evenly. Torque to proper values, making certain there is metal–to–metal contact at all points between the body surfaces and flanges. Guidance on torquing is included in **NSTM Chapter 556, Hydraulic Equipment Power Transmission and Control**. Ensure that clearance exists between the ID of the gland ring and the OD of the shaft (rod). After nuts are set, safety wire should be applied to prevent them from vibrating loose. This is mandatory on inside packed installations.

078–4.5.5 OBTAINING THE PROPER PACKING SQUEEZE OR CLEARANCE IN ADJUSTABLE GLANDS. On adjustable installations where the gland ring screws into a cylinder (see Figure 078–4–1), the clearance or squeeze values specified in paragraphs 078–4.5.3 through 078–4.5.4 are also applicable. When securing a screw–type gland ring, be sure to screw in the gland ring until it makes contact with the packing. Then back off or tighten the gland ring enough to obtain 0.000 to 0.030–inch clearance for endless rings or 0.020 to 0.030–inch squeeze for split rings. This can be determined by counting the number of threads per inch on the gland ring. For example, if there are 16 threads per inch, one revolution will result in a 1/16–inch clearance or squeeze. After proper set, be sure to safety–wire the gland ring to prevent it from rotating.

078–4.5.6 INSPECTING THE INSTALLATION. It is normal for a small leak or weep to appear after a V–ring has been replaced, but the leakage should cease after a short period of operation. If leaking continues, the V–ring packing may have cocked or become unseated. Reopen the gland and check for proper packing squeeze. New shims or other means of adjusting the packing stack space may be required. Avoid unnecessary removal of newly installed packing. Do not overtighten packing to stop leaks. The V–ring packing, when under excess pressure from the gland, will not only function improperly and wear faster, but will apply uncalculated forces on the ram or piston which may cause improper operation of the machinery. If leakage continues after reasonable readjustment of a newly–installed packing installation, inspect for metal contact between gland ring flange and body; there should be no clearance between these surfaces. Next, remove the gland ring, and carefully disassemble the packing. Observe each ring for a gap or an overlap at the joint. Inspect each ring for uneven wear or damage, particularly at the sealing lips. Check the packing gland space to be sure it is free from dirt, packing material, or other foreign matter. Check the gland surface for scoring, galling, wear, or other damage from dirt, cocked adapters, or rolled V–packing lips. Wipe contact sealing surfaces of the rod, piston, or cylinder interior with a clean lint–free cloth. Then, inspect for scratches, burrs, and sharp edges. Hone down rough spots with a fine carborundum stone. Clean all parts before reinstalling. If the cause of the leak is determined to be other than the V–ring packing stack, and the packing is in as–new condition, the packing may be reinstalled. If the cause of the leak is determined to be the V–ring packing stack, replace the packing, even though the installation is new. Always replace packing to correct leakage in existing installations.

SECTION 5.
SPRING–LOADED COMPRESSION LIP SEALS

078–5.1 GENERAL

078–5.1.1 INTRODUCTION. This section provides complete information on the identification and use of a new industrial packing design, a spring–loaded compression lip seal. This type of seal is gaining in popularity although at the present time there is no Military Standard for the design. The longer seal life obtained in dynamic applications is the impetus for using this new packing design. In appropriate sizes, the spring–loaded compression lip seal can replace O–rings, U–cups, V–rings, and various other packings which fit into the standard glands. In the absence of Military Standards, several manufacturers have built similar packings which are interchangeable and generally perform equally well. As illustrated in Figure 078–5–1, the basic seal design uses a special U–cup shape with a spring–loaded mechanism fitted into the recess of the U to maintain sealing pressure on the flared sealing lips of the U. Both components, the U and the spring, can be made of special materials. Generally the U is made of polyurethane (90–95 durometer) and the spring is an elastic (70–75 durometer) molded ring insert. To seals of this particular configuration, the term **Elastomeric Spring–Loaded Compression Lip (ESCL) Seals** is applied.

078–5.1.2 DEFINITIONS. The following definitions provide a common base of terminology for the use of ESCL seals.

078–5.1.2.1 Lip Seal. A lip seal is designed to rely on system pressure to expand the lips and create the sealing force. The degree of sealing is proportional to the amount of system pressure applied. The greater the pressure, the more effective the seal. V–rings and U–cups are lip seals.

078–5.1.2.2 Compression Seal (Squeeze Seal). The compression seal is designed to rely on interference between the packing and the mating surfaces to effect a seal. Examples of molded compression seals include O–rings, D–rings, quad–rings, and T–rings.

078–5.1.2.3 Compression Lip Seal. Unlike the pure lip seal, the compression lip seal is designed to effect the seal between two mating parts through a combination of lip sealing plus compression of the heavy cross section in the lip area. System pressure does not have as much effect upon these seals as on pure lip seals. ESCL seals are examples of compression lip seals.

078–5.1.2.4 Monodirectional Seal. A monodirectional seal is a one–way seal designed to provide sealing with pressure from only one side. A monodirectional seal must be installed correctly; otherwise the system fluid will leak out. V–rings, U–cups and ESCL seals are examples of these seals.

078–5.1.2.5 Bidirectional Seal. A bidirectional seal is a seal that will hold against pressure from either direction. A single piston seal in a two–way cylinder which is subjected to pressure cycles alternately from side must provide sealing from both directions. Examples of bidirectional seals include O–rings and T–rings.

078–5.1.2.6 Nominal Size. The nominal size of a seal is the dimensions of a seal given in approximate fractional numbers. For example, actual dimensions of 0.989–inch ID by 0.070–inch cross section would be specified as a nominal size of 1–inch ID by 1/16–inch cross section. The use of nominal sizes provides a fast and convenient (although sometimes confusing) method of describing a seal. Seal charts usually provide a nominal size column. If the nominal size of one seal equals that of another type of seal, the seals should be dimensionally interchangeable.

078–5.2 ESCL SEAL CONFIGURATIONS

078–5.2.1 BASIC SEAL CONFIGURATIONS. Two basic seal design configurations are being recommended for Navy ship applications. They are designated as the **Standard ESCL** and the **Deep Type B ESCL**. A third configuration, which resembles a combination of Standard and Deep Type B seals, is also commercially

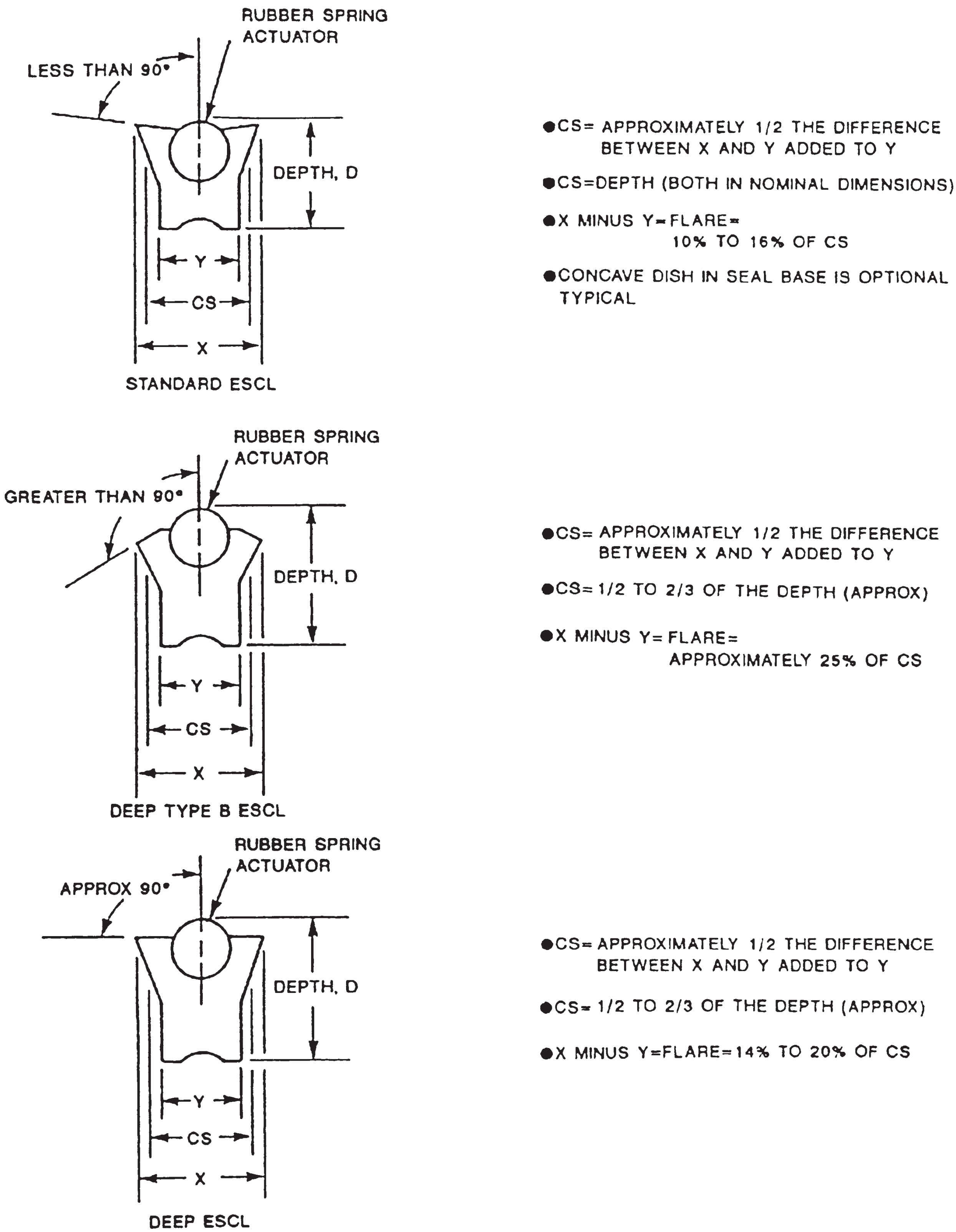


Figure 078–5–1. ESCL Seal Configurations

manufactured, but is not recommended for Navy ship applications and should be avoided. The third seal is designated a **Deep ESCL**, and is discussed in this section for background information only. These three seal configurations, with appropriate dimensional notations, are illustrated in Figure 078–5–1. It can be seen that all ESCL seals use a rubber spring actuator to impart preload pressure to the sealing lips.

078–5.2.1.1 Standard ESCL Seal Configuration. The Standard seal which is illustrated in Figure 078–5–2, has a square shape; that is, the depth, D, is approximately equal to the cross–section width, CS. These seals are used as direct replacement for O–rings or quad–rings (see paragraph 078–5.5.2) whether or not the existing seals were installed with back–up rings. The lip configuration provides a good seal as well as providing a wiping effect to eliminate contaminants in dynamic applications. Unlike O–rings and quad–rings, ESCL seals cannot be used as face seals.

078–5.2.1.2 Deep Type B ESCL Seal Configuration. As seen in Figure 078–5–1, the Deep Type B version of the ESCL seal differs from the Standard seal primarily in depth and in the shape of the sealing lips. The increased depth provides additional strength to the seal for greater resistance to extrusion and to rolling or twisting during dynamic sealing. The beveled shape of the sealing lips is primarily for ease of installation because Deep Type B seals are somewhat wider across the lips even though the nominal cross section is the same as the Standard seal. The total outward projection of the seal lips beyond the cross section is called the flare, and is expressed as a percentage of the cross section. For Deep Type B seals, the amount of flare is about 25 percent of the cross section, as compared with 10 to 16 percent for the Standard seals. Because the higher squeeze forces of this seal create dry, well–wiped sealing surfaces, it is generally restricted to rod seal applications. However, the larger dimensions of Deep Type B seals can sometimes be used in oversized packing glands to better fill the packing space and to compensate for wear in used components. The Deep Type B seal creates one problem because of the edge form; in dynamic applications, the leading bevel will tend to funnel contaminants into the seal contract area instead of scraping them away, as with the Standard seal.

078–5.2.2 COMMERCIAL TRADE NAMES AND CONFIGURATIONS. Several manufacturers are engaged in ESCL seal production. Their products are similar in appearance but have subtle, visible differences, usually in the spring portion. These minor variations have but little or no effect on seal performance if properly designed. Some of these seals are identified in paragraphs 078–5.2.2.1 through 078–5.2.2.4.

078–5.2.2.1 PolyPak. Commercial ESCL seals under the trade name of PolyPak are manufactured and sold by Parker Seal Company. PolyPak seals are also sold by Aerospace Supply Inc. under an agreement with Parker. PolyPaks use a circular cross–section rubber spring which resembles an O–ring to provide the necessary preload for lip sealing.

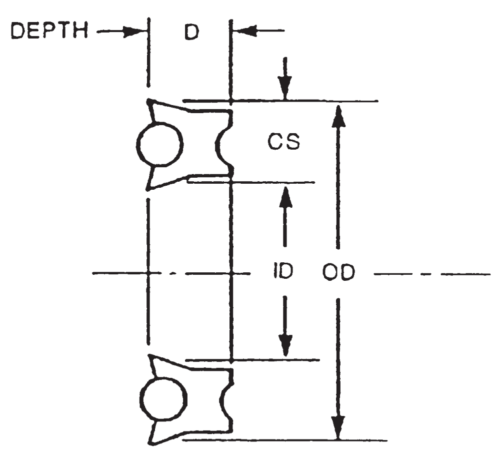


Figure 078–5–2. Standard ESCL Seal Dimensions

078–5.2.2.2 Poly Seal. Commercial ESCL seals sold under the trade name of Poly Seal are made by Microdot Products. These seals have a four–lobed cross–section rubber spring, which resembles a quad–ring, to preload the sealing lips.

078–5.2.2.3 Seal Pac. Commercial ESCL seals sold under the trade name of Seal Pac are identical to Poly Seals, but are sold by the Stillman Seal Company.

078–5.2.2.4 RSA Seal. Greene, Tweed, and Company has added a minor variation to their seal – the RSA seal – in which the rubber O–spring is retained between the sealing lips in an elliptically–shaped annulus, compared to the round O–shaped space used in other seals to contain an O–shaped spring. Greene, Tweed, and Company also makes a similar seal called an **FSA Lubrethane seal**, which uses a flat radially–energizing metal spring rather than an elastomer (rubber) spring. The FSA seal is not an ESCL seal and is not recommended for use without specific NAVSEA approval.

078–5.2.3 ESCL SEAL IDENTIFICATION. ESCL seals discussed in this section are selected commercial products chosen by NAVSEA because they have demonstrated satisfactory performance under specific operating conditions. NAVSEA has implemented a common numbering system for ease of identification, and set up logistic support with National Stock Numbers (NSN’s) in the Federal Supply System.

078–5.2.3.1 ESCL Seal Numbering System. The ESCL seal part numbering system uses only the letters ESCL followed by either a three digit dash number for the Standard version, or a three–digit dash number with the letters DB for the Deep Type B version. Table 078–5–1 provides a listing of various O–ring sizes that can be replaced by ESCL seals. The dash numbers which have been applied to the respective ESCL seals are the same as those used in the AS568 Standard Numbering System for O–rings, as well as O–ring specification sheet MIL–R–83248 and MS28775. Table 078–5–2 identifies V–rings in accordance with AN6225 dimensions that are interchangeable with the ESCL seals. Table 078–5–2 also identifies the interchangeability with U–cup packings in accordance with AN6226 for the –2 through –40 sizes. For these ESCL sizes, the AN6225 and AN6226 dash numbers are interchangeable. When the required ESCL seal part number has been determined, this product can be ordered from the supply system by its NSN (where available) and the ESCL part number. Whichever acceptable manufacturer’s product is in stock at that time will be delivered.

078–5.2.3.2 ESCL Seal Manufacturers’ Part Numbers. Five of the currently approved manufacturers, with their respective ESCL seal part numbers, are identified in Table 078–5–1 and Table 078–5–2. This listing is not to be considered an endorsement of those manufacturers’ products; it is provided primarily to allow users of the ESCL seals to verify that the proper seal has been provided for installation. Future stock procurements may be made from manufacturers other than those listed, when their products have been approved by NAVSEA for competitive stocking under these NSN’s. As long as the right ESCL size is ordered, the seal which is received from the supply system bearing that ESCL number may be considered correct and should be installed, regardless of the manufacturer.

078–5.3 ESCL SEAL PROPERTIES (ENGINEERING DATA)

078–5.3.1 POLYURETHANE SEALS WITH NITRILE RUBBER ELASTOMERIC SPRINGS. Criteria discussed in paragraphs 078–5.3.1.1 through 078–5.3.1.5 must be considered in order to obtain satisfactory system performance from the installation of ESCL seals.

078–5.3.1.1 Fluid Compatibility. ESCL seals discussed in this section are currently recommended for use only with petroleum based hydraulic fluids compatible with MIL–L–17672, MIL–L–17331, MIL–H–6083, and MIL–H–5606. The materials used in the ESCL seals are polyurethane (for the U portion) with a nitrile rubber spring insert. Since the exact formulation of these materials can and does vary among manufacturers, compatibility or FSCL seals with other fluids can only be generalized. For other fluid applications, compatibility with the formulations of the various ESCL manufacturers must be established by the user. General information on other seal materials is covered in paragraph 078–5.3.2.

078–5.3.1.2 Operating Temperatures. ESCL seals will perform continuously at the operating temperatures currently established for ship hydraulic systems. High temperatures over extended time periods can severely deteriorate the seal and degrade performance (see paragraph 078–5.6.4.4 for symptoms). In general, seal applications at temperatures below 82°C (180°F) are acceptable. For applications above 82°C (180°F) or below –18°C (0°F), NAVSEA approval is required.

078–5.3.1.3 Operating Pressures. When confined in typical O–ring, or V–ring glands found in shipboard installations, ESCL seals will seal at operating pressures from vacuum up to 3000 lbs/in^2. When diametral clearances are closely controlled, tests have shown satisfactory Performance at pressures of 4000 lb/in^2, and the literature indicates that containment of fluids at 5000 lb/in^2 is possible.

078–5.3.1.4 Directional Sealing. ESCL seals are monodirectional and must be installed with the spring member facing the pressure. The seal cannot be used in a dual acting piston unless there are two seal grooves. Although ESCL seals are intended for reciprocating applications, literature indicates slow rotation application up to 50 inches/sec surface speed would be satisfactory. Testing under rotation conditions is recommended.

078–5.3.1.5 Static Sealing. ESCL seals are designed for dynamic (moving) sealing; they are expensive and not required for the average static application. In special applications where the seal gland has been worn or enlarged by repair actions, the ESCL seal may provide sealing where O–rings will not, and should be considered as an alternate to more expensive or time consuming corrective actions.

078–5.3.2 OTHER ESCL SEAL MATERIALS. For special applications, the ESCL design can be used in the molding of other rubber compounds. It is possible to buy proprietary seals of ESCL design which have either or both parts made of nitrile rubber, fluorocarbon rubber, ethylene propylene rubber, or any combination of these and many other materials. These special products require NAVSEA approval for use in problem installations where conditions such as high temperature (up to 204°C (400°F)) or chemical incompatibility are encountered (as with Phosphate ester fluids).

078–5.4 ESCL SEAL GLANDS

078–5.4.1 GENERAL. The ESCL seals are designed to fit into a variety of glands, including O–ring and V–ring glands, and will often work better than the originally installed seals. The squeeze on the ESCL occurs on the ID and OD contact points of the sealing lips, as shown in Figure 078–5–3. Under no conditions shall the heel width of the ESCL seal (dimension a) be greater than the width W of the gland. The heel is allowed to contact the moving surface of the gland, but should never be compressed within the gland. Similarly, the depth D of the gland should be at least 10 percent longer than seal depth to allow for thermal expansion or material swell. See Figure 078–5–3 for assembled view. Gland depth greater than 110 percent of the seal depth will not be detrimental as long as the pressure on the seal is in one direction.

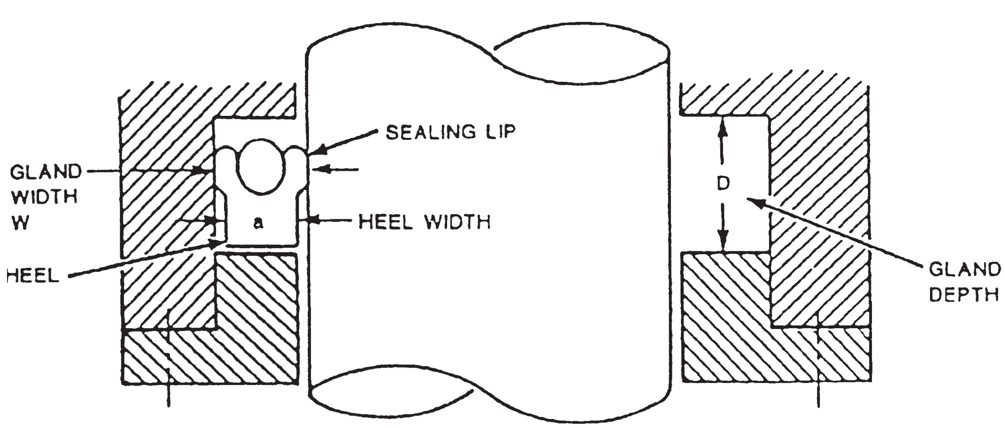


Figure 078–5–3. ESCL Seal Gland

Table 078–5–1. ESCL SEAL TO O–RING CROSS REFERENCE LISTING
(Sheet 1 of 5) LEFT SIDE

ESCL	O-Ring Seal Dash No.		ESCL Nominal Size		Minimum O-Ring Seal Gland Length MIL–G–5514		
Dash No. (See Note 2)	AS568 MS28775 MIL–R–83248	AN 6277B	ID	DS	With No Backup Ring	With 2 Backup Rings	ESCL National Stock Numbers
–210	–210	–15	3/4	1/8	0.188	–	5330–00–605–1273
–210DB	–210	–15	3/4	1/8	–	0.304	5330–01–033–2699
–211	–211	–16	13/16	1/8	0.188	–	5330–01–031–5428
–211DB	–211	–16	13/16	1/8	–	0.304	5330–01–031–5126
–212	–212	–17	7/8	1/8	0.188	–	5330–00–622–8502
–212DB	–212	–17	7/8	1/8	–	0.304	5330–01–031–5125
–213	–213	–18	15/16	1/8	0.188	–	5330–01–031–5427
–213DB	–213	–18	15/16	1/8	–	0.304	5330–01–031–5124
–214	–214	–19	1	1/8	0.188	–	5330–01–031–5426
–214DB	–214	–19	1	1/8	–	0.304	5330–01–531–5123
–215	–215	–20	1-1/16	1/8	0.188	–	–
–215DB	–215	–20	1-1/16	1/8	–	0.304	–
–216	–216	–21	1-1/8	1/8	0.188	–	5330–00–605–1277
–216DB	–216	–21	1-1/8	1/8	–	0.304	5330–01–031–5122
–217	–217	–22	1-3/16	1/8	0.188	–	5330–00–156–2298
–217DB	–217	–22	1-3/16	1/8	–	0.304	5330–01–031–5121
–218	–218	–23	1-1/4	1/8	0.188	–	5330–00–627–4268
–218DB	–218	–23	1-1/4	1/8	–	0.304	5330–01–032–0579
–219	–219	–24	1-5/16	1/8	0.188	–	–
–219DB	–219	–24	1-5/16	1/8	–	0.304	–
220	–220	–25	1-3/8	1/8	0.188	–	5330–01–031–5425
220DB	–220	–25	1-3/8	1/8	–	0.304	5330–01–032–0578
221	–221	–26	1-7/16	1/8	0.188	–	5330–01–031–5424
221DB	–221	–26	1-7/16	1/8	–	0.304	5330–01–031–7143
–222	–222	–27	1-1/2	1/8	0.188	–	5330–00–605–0896
–222DB	–222	–27	1-1/2	1/8	–	0.304	5330–01–003–9087
–325	–325	–28	1-1/2	3/16	0.281	–	5330–01–031–5422
–325DB	–325	–28	1-1/2	3/16	–	0.424	5330–01–031–7142
–326	–326	–29	1-5/8	3/16	0.281	–	2030–00–136–5293
–326DB	–326	–29	1-5/8	3/16	–	0.424	5330–01–032–0577

Table 078–5–1. ESCL SEAL TO O–RING CROSS REFERENCE LISTING (Sheet 1 of 5) RIGHT SIDE

ESCL Dash No.	Manufacturer's Part Numbers			
	Parker Seal Co.	Aerospace Supply, Inc.	Sargent Industries, Stillman Seal, & Microdot, Inc.	Greene, Tweed & Co., Inc.
–210	–	2023–G5514	125–00.750	–
–210DB	–	4021B–G5514	125–00.750–250B	3442–00748–0122–0304
–211	–	2027–G5514	125–00.812	–
–211DB	–	4025B–G5514	125–00.812–250B	3442–00810–0122–0304
–212	–	2031–G5514	125–00.875	–
–212DB	–	4029B–G5514	125–00.875–250B	3442–00873–0122–0304
–213	–	2036–G5514	125–00.937	–
–213DB	–	4033B–G5514	125–00.937–2501	3442–00935–0122–0304
–214	–	2040–G5514	125–01.000	–
–214DB	–	4037B–G5514	125–01.000–2501	3442–00998–0122–0304
–215	–	2045–G5514	125–01.062	–
–215DB	–	4042B–G5514	125–01.062–2501	3442–01060–0122–0304
–216	–	2050–G5514	125–01.125	–
–216DB	–	4047B–G5514	125–01.125–2501	3442–01123–0122–0304
–217	–	2055–G5514	125–01.187	–
–217DB	–	4052B–G5514	125–01.187–2501	3442–01185–0122–0304
–218	–	2060–G5514	125–01.250	–
–218DB	–	4058B–G5514	125–01.250–2501	3442–01248–0122–0304
–219	–	2065–G5514	125–01.312	–
–219DB	–	4063B–G5514	125–01.312–2501	3442–01310–0122–0304
220	–	2070–G5514	125–01.375	–
220DB	–	4068B–G5514	125–01.375–2501	3442–01373–0122–0304
221	–	2075–G5514	125–01.437	–
221DB	–	4073B–G5514	125–01.437–2501	3442–01435–0122–0304
–222	–	2080–G5514	125–01.500	–
–222DB	–	4078B–G5514	125–01.500–250	3442–01498–0122–0304
–325	18701500	2089–G5514	187–01.500	–
–325DB	18701500–375B	4087B–G5514	187–01.500–375	3442–01495–0137–0424
–326	18701625	2096–G5514	187–01.625	–
–326DB	18701625–375B	4094B–G5514	187–01.625–375	3442–01620–0187–0424

Table 078–5–1. ESCL SEAL TO O–RING CROSS REFERENCE LISTING (Sheet 2 of 5) LEFT SIDE

ESCL Dash No. (See Note 2)	O-Ring Seal Dash No. AS568 MS28775 MIL–R–83248	O-Ring Seal Dash No. AN 6277B	ESCL Nominal Size ID	ESCL Nominal Size DS	Minimum O-Ring Seal Gland Length MIL–G–5514 With No Backup Ring	Minimum O-Ring Seal Gland Length MIL–G–5514 With 2 Backup Rings	ESCL National Stock Numbers
–327	–327	–30	1-3/4	3/16	0.281	–	5330–00–606–9777
–327DB	–327	–30	1-3/4	3/16	–	0.424	5330–01–032–8599
–328	–328	–31	1-7/8	3/16	0.281	–	5330–00–621–4621
–328DB	–328	–31	1-7/8	3/16	–	0.424	5330–01–032–0576
–329	–329	–32	2	3/16	0.281	–	5330–01–031–5421
–329DB	–329	–32	2	3/16	–	0.424	5330–01–032–0575
–330	–330	–33	2-1/8	3/16	0.281	–	5330–01–021–3787
–330DB	–330	–33	2-1/8	3/16	–	0.424	5330–01–032–0581
–331	–331	–34	2-1/4	3/16	0.281	–	5330–01–032–0582
–331DB	–331	–34	2-1/4	3/16	–	0.424	5330–01–033–2700
–332	–332	–35	2-3/8	3/16	0.281	–	5330–01–031–5128
–332DB	–332	–35	2-3/8	3/16	–	0.424	5330–01–032–0584
–333	–333	–36	2-1/2	3/16	0.281	–	5330–01–031–5129
–333DB	–333	–36	2-1/2	3/16	–	0.424	5330–01–033–2701
–334	–334	–37	2-5/8	3/16	0.281	–	5330–01–032–0586
–334DB	–334	–37	2-5/8	3/16	–	0.424	5330–01–033–2702
–335	–335	–38	2-3/4	3/16	0.281	–	5330–00–621–4724
–335DB	–335	–38	2-3/4	3/16	–	0.424	5330–01–032–0588
–336	–336	–39	2-7/8	3/16	0.281	–	5330–01–031–5130
–336DB	–336	–39	2-7/8	3/16	–	0.424	5330–01–033–2703
–337	–337	–40	3	3/16	0.281	–	5330–01–031–5131
–337DB	–337	–40	3	3/16	–	0.424	5330–01–033–2704
–338	–338	–41	3-1/8	3/16	0.281	–	5330–01–031–5132
–338DB	–338	–41	3-1/8	3/16	–	0.424	5330–01–032–8601
–339	–339	–42	3-1/4	3/16	0.281	–	5330–00–622–8540
–339DB	–339	–42	3-1/4	3/16	–	0.424	5330–01–032–0592
–340	–340	–43	3-3/8	3/16	0.281	–	5330–01–031–5133
–340DB	–340	–43	3-3/8	3/16	–	0.424	5330–01–033–8162
–341	–341	–44	3-1/2	3/16	0.281	–	5330–00–605–1279
–341DB	–341	–44	3-1/2	3/16	–	0.424	5330–01–032–0593

Table 078–5–1. ESCL SEAL TO O–RING CROSS REFERENCE LISTING (Sheet 2 of 5) RIGHT SIDE

ESCL Dash No.	Manufacturer's Part Numbers			
	Parker Seal Co.	Aerospace Supply, Inc.	Sargent Industries, Stillman Seal, & Microdot, Inc.	Greene, Tweed & Co., Inc.
–327	18701750	2104–G5514	187–01.750	–
–327DB	18701750–375B	4102B–G5514	187–01.750–3751	3442–01746–0187–0424
–328	18701875	2108–G5514	187–01.875	–
–328DB	18701975–375B	4106B–G5514	187–01.875–3751	3442–01871–0187–0424
–329	18702000	2113–G5514	187–02.000	–
–329DB	18702000–375B	4111B–G5514	187–02.000–3751	3442–01996–0187–0424
–330	18702125	2118–G5514	187–02.125	–
–330DB	18702125–375B	4116B–G5514	187–02.125–375	3442–02121–0187–0424
–331	18702250	2124–G5514	187–02.250	–
–331DB	18702250–375B	4122B–G5514	187–02.250–375	3442–02246–0187–0424
–332	18702375	2128–G5514	187–02.375	–
–332DB	18702375–375B	4126B–G5514	187–02.375–375	3442–02371–0187–0424
–333	13702500	2134–G5514	187–02.500	–
–333DB	18702500–375B	4132B–G5514	187–02.500–3751	3442–02496–0187–0424
–334	18702625	2138–G5514	187–02.625	–
–334DB	18702625–375B	4136B–G5514	187–02.625–3751	3442–02621–0187–0424
–335	18702750	2144–G5514	187–02.750	–
–335DB	18702750–375B	4142B–G5514	187–02.750–3751	3442–02746–0187–0424
–336	18702875	2148–G5514	187–02.875	–
–336DB	18702875–375B	4146B–G5514	187–02.375–375	3442–02871–0187–0424
–337	18703000	2154–G5514	187–03.000	–
–337DB	18703000–375B	5152B–G5514	187–03.000–375	3442–02996–0187–0424
–338	13703125	2159–G5514	187–03.125	–
–338DB	18702125–375B	4157B–G5514	187–03.125–375	3442–03121–0187–0424
–339	18703250	2165–G5514	187–03.250	–
–339DB	18703250–375B	4163–G5514	187–03.250–375	3442–03246–0187–0424
–340	18703375	2169–G5514	187–03.375	–
–340DB	18703375–375B	4167B–G5514	187–03.375–375	3442–03371–0187–0424
–341	18703500	2175–G5514	187–03.500	–
–341DB	18703500–375B	4173B–G5514	187–03.500–375	3442–03496–0187–0424

Table 078–5–1. ESCL SEAL TO O–RING CROSS REFERENCE LISTING (Sheet 3 of 5) LEFT SIDE

ESCL	O-Ring Seal Dash No.		ESCL Nominal Size		Minimum O-Ring Seal Gland Length MIL–G–5514		
Dash No. (See Note 2)	AS568 MS28775 MIL–R–83248	AN 6277B	ID	DS	With No Backup Ring	With 2 Backup Rings	ESCL National Stock Numbers
–342	–342	–45	3-5/8	3/16	0.281	–	5330–01–032–0594
–342DB	–342	–45	3-5/8	3/16	–	0.424	5330–01–032–0595
–343	–343	–46	3-3/4	3/16	0.281	–	5330–01–031–5134
–343DB	–343	–46	3-3/4	3/16	–	0.424	5330–01–032–8602
–344	–344	–47	3-7/8	3/16	0.281	–	–
–344DB	–344	–47	3-7/8	3/16	–	0.424	–
–345	–345	–48	4	3/16	0.281	–	5330–00–606–9783
–345DB	–345	–48	4	3/16	–	0.424	–
–346	–346	–49	4-1/8	3/16	0.281	–	–
–346DB	–346	–49	4-1/8	3/16	–	0.424	–
–347	–347	–50	4-1/4	3/16	0.281	–	5330–01–031–5135
–347DB	–347	–50	4-1/4	3/16	–	0.424	5330–01–032–8603
–348	–348	–51	4-3/8	3/16	0.281	–	5330–01–032–0599
–348DB	–348	–51	4-3/8	3/16	–	0.424	5330–01–033–2705
–349	–349	–52	4-1/2	3/16	0.281	–	5330–01–032–0601
–349DB	–349	–52	4-1/2	3/16	–	0.424	5330–01–032–0602
–425	–425	–88	4-1/2	1/4	0.375	–	–
–425DB	–425	–88	4-1/2	1/4	–	0.579	–
–426	–426	–53	4-5/8	1/4	0.375	–	5330–01–032–0603
–426DB	–426	–53	4-5/8	1/4	–	0.579	5330–01–033–2706
–427	–427	–54	4-3/4	1/4	0.375	–	–
–427DB	–427	–54	4-3/4	1/4	–	0.579	–
–428	–428	–55	4-7/8	1/4	0.375	–	–
–428DB	–428	–55	4-7/8	1/4	–	0.579	–
–429	–429	–56	5	1/4	0.375	–	–
–429DB	–429	–56	5	1/4	–	0.579	–
–430	–430	–57	5-1/8	1/4	0.375	–	5330–01–032–0596
–430DB	–430	–57	5-1/8	1/4	–	0.579	–
–431	–431	–58	5-1/4	1/4	0.375	–	5330–01–031–5136
–431DB	–431	–58	5-1/4	1/4	–	0.579	–

Table 078–5–1. ESCL SEAL TO O–RING CROSS REFERENCE LISTING (Sheet 3 of 5) RIGHT SIDE

ESCL Dash No.	Manufacturer's Part Numbers			
	Parker Seal Co.	Aerospace Supply, Inc.	Sargent Industries, Stillman Seal, & Microdot, Inc.	Greene, Tweed & Co., Inc.
–342	18703625	2179–G5514	187–03.625	–
–342DB	18703625–375B	4177B–G5514	187–03.625–375	3442–03621–0187–0424
–343	18703750	2185–G5514	187–03.750	–
–343DB	18703750–375B	4183B–G5514	187–03.750–375	3442–03746–0187–0424
–344	18703875	2189–G5514	187–03.87	–
–344DB	18703875–375B	4187B–G5514	187–03.875–375	3442–03871–0187–0424
–345	1870400	2195–G5514	187–04.000	–
–345DB	18704000–375B	4193B–G4415	187–04.000–375	3442–03996–0187–0424
–346	18704125	2199–G5514	187–04.125	–
–346DB	18704125–375B	4197B–G5514	187–04.125–375	3442–04121–0187–0424
–347	18704250	2206–G5514	187–04.250	–
–347DB	18704250–375B	4204B–G5514	187–04.250–3751	3442–04246–0187–0424
–348	18704375	2210–G5514	187–04.375	–
–348DB	18704375–375B	4208B–G5514	187–04.375–375B	3442–04371–0187–0424
–349	18704500	2217–G5514	187–04.500	–
–349DB	18704500–375B	4215–G5514	187–04.500–375B	3442–04496–0187–0424
–425	25004500	2221–G5514	250–04.500	–
–425DB	–	–	–	3442–04497–0240–0579
–426	25004625	2228–G5514	250–04.625	–
–426DB	–	–	–	3442–04622–0240–0579
–427	25004750	2231–G5514	250–04.750	–
–427DB	–	–	–	3442–04747–0240–0579
–428	25004875	2238–G5514	250–04.875	–
–428DB	–	–	–	3442–04872–0240–0579
–429	25005000	2242–G5514	250–05.000	–
–429DB	–	–	–	3442–04997–0240–0579
–430	25005125	2249–G5514	250–05.125	–
–430DB	–	–	–	3442–05122–0240–0579
–431	25005250	2252–G5514	250–05.250	–
–431DB	–	–	–	3442–05247–0240–0579

Table 078–5–1. ESCL SEAL TO O–RING CROSS REFERENCE LISTING (Sheet 4 of 5) LEFT SIDE

ESCL	O-Ring Seal Dash No.		ESCL Nominal Size		Minimum O-Ring Seal Gland Length MIL–G–5514		
Dash No. (See Note 2)	AS568 MS28775 MIL–R–83248	AN 6277B	ID	DS	With No Backup Ring	With 2 Backup Rings	ESCL National Stock Numbers
–432	–432	–59	5-3/8	1/4	0.375	–	–
–432DB	–432	–59	5-3/8	1/4	–	0.579	–
–433	–433	–60	5-1/2	1/4	0.375	–	5330–01–008–6807
–433DB	–433	–60	5-1/2	1/4	–	0.579	–
–434	–434	–61	5-5/8	1/4	0.375	–	–
–434DB	–434	–61	5-5/8	1/4	–	0.579	–
–435	–435	–62	5-3/4	1/4	0.375	–	5330–00–621–4680
–435DB	–435	–62	5-3/4	1/4	–	0.579	
–436	–436	–63	5-7/8	1/4	0.375	–	–
–436DB	–436	–63	5-7/8	1/4	–	0.579	–
–437	–437	–64	6	1/4	0.375	–	5330–00–622–8505
–437DB	–437	–64	6	1/4	–	0.579	–
–438	–438	–65	6-1/4	1/4	0.375	–	–
–438DB	–438	–65	6-1/4	1/4	–	0.579	–
–439	–439	–66	6-1/2	1/4	0.375	–	5330–01–032–0580
–439DB	–439	–66	6-1/2	1/4	–	0.579	–
–440	–440	–67	6-3/4	1/4	0.375	–	5330–01–032–0605
–440DB	–440	–67	6-3/4	1/4	–	0.579	–
–441	–441	–68	7	1/4	0.375	–	–
–441DB	–441	–68	7	1/4	–	0.579	–
–442	–442	–69	7-1/4	1/4	0.375	–	–
–442DB	–442	–69	7-1/4	1/4	–	0.579	–
–443	–443	–70	7-1/2	1/4	0.375	–	5330–00–622–8518
–443DB	–443	–70	7-1/2	1/4	–	0.579	–
–444	–444	–71	7-3/4	1/4	0.375	–	–
–444DB	–444	–71	7-3/4	1/4	–	0.579	–
–445	–445	–72	8	1/4	0.375	–	–
–445DB	–445	–72	8	1/4	–	0.579	–
–446	–446	–73	8-1/2	1/4	0.375	–	–
–446DB	–446	–73	8-1/2	1/4	–	0.579	–

Table 078–5–1. ESCL SEAL TO O–RING CROSS REFERENCE LISTING (Sheet 4 of 5) RIGHT SIDE

ESCL Dash No.	Manufacturer's Part Numbers			
	Parker Seal Co.	Aerospace Supply, Inc.	Sargent Industries, Stillman Seal, & Microdot, Inc.	Greene, Tweed & Co., Inc.
–432	25005375	2259–G5514	250–05.375	–
–432DB	–	–	–	3442–05372–0240–0579
–433	25005500	2262–G5514	250–05.500	–
–433DB	–	–	–	3442–05497–0240–0579
–434	25005625	2269–G5514	250–05.625	–
–434DB	–	–	–	3442–05622–0240–0579
–435	25005750	2272–G5514	250–05.750	–
–435DB	–	–	–	3442–05747–0240–0579
–436	25005875	2279–G5514	250–05.875	–
–436DB	–	–	–	3442–05872–0240–0579
–437	25006000	2283–G5514	250–06.000	–
–437DB	–	–	–	3442–05997–0240–0579
–438	25006250	2291–G5514	250–06.250	–
–438DB	–	–	–	3442–06247–0240–0579
–439	25006500	2298–G5514	250–06.500	–
–439DB	–	–	–	3442–06497–0240–0579
–440	25006750	2305–G5514	250–06.750	–
–440DB	–	–	–	3442–06747–0240–0579
–441	25007000	2312–G5514	250–07.000	–
–441DB	–	–	–	3442–06997–0240–0579
–442	25007250	2319–G5514	250–07.250	–
–442DB	–	–	–	3442–07247–0240–0579
–443	25007500	2236–G5514	250–07.500	–
–443DB	–	–	–	3442–07497–0240–0579
–444	25007750	2333–G5514	250–07.750	–
–444DB	–	–	–	3442–07747–0240–0579
–445	25008000	2340–G5514	250–08.000	–
–445DB	–	–	–	3442–07997–0240–0579
–446	25008500	2354–G5514	250–08.500	–
–446DB	–	–	–	3442–08497–0240–0579

Table 078–5–1. ESCL SEAL TO O–RING CROSS REFERENCE LISTING
(Sheet 5 of 5) LEFT SIDE

ESCL Dash No. (See Note 2)	O-Ring Seal Dash No. AS568 MS28775 MIL–R–83248	O-Ring Seal Dash No. AN 6277B	ESCL Nominal Size ID	ESCL Nominal Size DS	Minimum O-Ring Seal Gland Length MIL–G–5514 With No Backup Ring	Minimum O-Ring Seal Gland Length MIL–G–5514 With 2 Backup Rings	ESCL National Stock Numbers
–447	–447	–74	9	1/4	0.375	–	–
–447DB	–447	–74	9	1/4	–	0.579	–
–448	–448	–75	9-1/2	1/4	0.375	–	–
–448DB	–448	–75	9-1/2	1/4	–	0.579	–
–449	–449	–76	10	1/4	0.375	–	5330–00–622–8521
–449DB	–449	–76	10	1/4	–	0.579	–
–450	–450	–77	10-1/2	1/4	0.375	–	–
–450DB	–450	–77	10-1/2	1/4	–	0.579	–
–451	–451	–78	11	1/4	0.375	–	–
–451DB	–451	–78	11	1/4	–	0.579	–
–452	–452	–79	11-1/2	1/4	0.375	–	–
–452DB	–452	–79	11-1/2	1/4	–	0.579	–
–453	–453	–80	12	1/4	0.375	–	–
–453DB	–453	–80	12	1/4	–	0.579	–
–454	–454	–81	12-1/2	1/4	0.375	–	–
–454DB	–454	–81	12-1/2	1/4	–	0.579	–
–455	–455	–82	13	1/4	0.375	–	–
–455DB	–455	–82	13	1/4	–	0.579	–
–456	–456	–83	13-1/2	1/4	0.375	–	–
–456DB	–456	–83	13-1/2	1/4	–	0.579	–
–457	–457	–84	14	1/4	0.375	–	–
–457DB	–457	–84	14	1/4	–	0.579	–
–458	–458	–85	14-1/2	1/4	0.375	–	–
–458DB	–458	–85	14-1/2	1/4	–	0.579	–
–459	–459	–86	15	1/4	0.375	–	–
–459DB	–459	–86	15	1/4	–	0.579	–
–460	–460	–87	15-1/2	1/4	0.375	–	–
–460DB	–460	–87	15-1/2	1/4	–	0.579	–

Table 078–5–1. ESCL SEAL TO O–RING CROSS REFERENCE LISTING (Sheet 5 of 5) RIGHT SIDE

ESCL Dash No.	Manufacturer's Part Numbers			
	Parker Seal Co.	Aerospace Supply, Inc.	Sargent Industries, Stillman Seal, & Microdot, Inc.	Greene, Tweed & Co., Inc.
–447	25009000	2368–G5514	250–09.000	–
–447DB	–	–	–	3442–08997–0240–0579
–448	25009500	2382–G5514	250–09.5000	–
–448DB	–	–	–	3442–09497–0240–0579
–449	25010000	2396–G5514	250–10.000	–
–449DB	–	–	–	3442–09997–0240–0579
–450	25010500	2410–G5514	–	–
–450DB	–	–	–	3442–10497–0240–0579
–451	25011000	2424–G5514	–	–
–451DB	–	–	–	3442–10997–0240–0579
–452	25011500	2438–G5514	250–11.500	–
–452DB	–	–	–	3442–11497–0240–0579
–453	25012000	2452–G5514	250–12.000	–
–453DB	–	–	–	3442–11997–0240–0579
–454	25012500	2466–G5514	–	–
–454DB	–	–	–	3442–12497–0240–0579
–455	25013000	2480–G5514	–	–
–455DB	–	–	–	3442–12997–0240–0579
–456	25013500	2494–G5514	–	–
–456DB	–	–	–	3442–13497–0240–0579
–457	25014000	2508–G5514	–	–
–457DB	–	–	–	3442–13997–0240–0579
–458	25014500	2522–G5514	–	–
–458DB	–	–	–	3442–14497–0240–0579
–459	25015000	2536–G5514	–	–
–459DB	–	–	–	3442–14997–0240–0579
–460	25015500	2550–G5514	–	–
–460DB	–	–	–	3442–15497–0240–0579

NOTES:
1. Abbreviations are: CS – Cross Section, ID – Inside diameter, ESCL – Elastomeric Spring-loaded Lip Seal.
2. Dash number without suffix indicates Standard packings. DB suffix indicates Deep Type B packings.

Table 078–5–2. ESCL SEAL TO U-CUP AND V-RING CROSS REFERENCE (Sheet 1 of 3)

ESCL Dash No.	AN6226 AN6225 Dash No.*	Nominal Seal Size ID	Nominal Seal Size CS	Nominal Seal Size OD	Compression Type Lip Seal: Stack Depth For One Standard Seal Depth (Min)	Compression Type Lip Seal: Stuffing Box Height For Three Standard Seals Depth (Min)	National Stock Number (NSN)	ASI Part Number Piston Rod	Microdot Or Stillmann Part Number	Parker Part Number
002	–2	3/16	3/16	9/16	0.207	0.621		ASIP 2004	187–00.187	18700187
003	–3	1/4	3/16	5/8	0.207	0.621		ASIP 2007	187–00.250	18700250
004	–4	5/16	3/16	11/16	0.207	0.621		ASIP 2008	187–00.312	18700312
005	–5	3/8	3/16	3/4	0.207	0.621		ASIP 2011	187–00.375	18700375
006	–6	7/16	3/16	13/16	0.207	0.621		ASIP 2015	187–00.437	18700437
007	–7	1/2	3/16	7/8	0.207	0.621		ASIP 2018	187–00.500	18700500
008	–8	1/4	1/4	3/4	0.275	0.825		ASIP 2012	250–00.250	25000250
009	–9	5/16	1/4	13/16	0.275	0.825		ASIP 2016	250–00.312	25000312
010	–10	3/8	1/4	7/8	0.275	0.825		ASIP 2019	250–00.375	25000375
011	–11	7/16	1/4	15/16	0.275	0.825		ASIP 2022	250–00.437	25000437
012	–12	1/2	1/4	1	0.275	0.825		ASIP 2025	250–00.500	25000500
013	–13	9/16	1/4	1-1/16	0.275	0.825		ASIP 2029	250–00.562	25000562
014	–14	5/8	1/4	1-1/8	0.275	0.825		ASIP 2033	250–00.625	25000625
015	–15	11/16	1/4	1-3/16	0.275	0.825		ASIP 2038	250–00.687	25000687
016	–16	3/4	1/4	1-1/4	0.275	0.825		ASIP 2042	250–00.750	25000750
017	–17	13/16	1/4	1-5/16	0.275	0.825		ASIP 2047	250–00.812	25000812
018	–18	7/8	1/4	1-3/8	0.275	0.825		ASIP 2052	250–00.875	25000875
019	–19	15/16	1/4	1-7/16	0.275	0.825		ASIP 2057	250–00.937	25000937
020	–20	1	1/4	1-1/2	0.275	0.825		ASIP 2062	250–01.000	25001000
021	–21	1-1/6	1/4	1-9/16	0.275	0.825		ASIP 2067	250–01.062	25001062
022	–22	1-1/8	1/4	1-5/8	0.275	0.825		ASIP 2072	250–01.125	25001125
023	–23	1-3/16	1/4	1-11/16	0.275	0.825		ASIP 2077	250–01.187	25001187
024	–24	1-1/4	1/4	1-3/4	0.275	0.825		ASIP 2082	250–01.250	25001250
025	–25	1-1/4	5/16	1-7/8	0.344	1.032		ASIP 2091	312–01.250	31201250

Table 078–5–2. ESCL SEAL TO U-CUP AND V-RING CROSS REFERENCE (Sheet 2 of 3)

ESCL Dash No.	AN6226 AN6225 Dash No.*	Nominal Seal Size			Compression Type Lip Seal		National Stock Number (NSN)	ASI Part Number Piston Rod	Microdot Or Stillmann Part Number	Parker Part Number
					Stack Depth For One Standard Seal	Stuffing Box Height For Three Standard Seals				
		ID	CS	OD	Depth (Min)	Depth (Min)				
026	–26	1-3/8	5/16	2	0.344	1.032	5330–00–606–9776	ASIP 2098	312–01.375	31201375
027	–27	1-1/2	5/16	2-1/8	0.344	1.032		ASIP 2106	312–01.500	31201500
028	–28	1-5/8	5/16	2-1/4	0.344	1.032		ASIP 2110	312–01.625	31201625
029	–29	1-3/4	5/16	2-3/8	0.344	1.032	5330–00–610–4118	ASIP 2115	312–01.750	31201750
030	–30	1-7/8	5/16	2-1/2	0.344	1.032		ASIP 2120	312–01.875	31201875
031	–31	2	5/16	2-5/8	0.344	1.032		ASIP 2126	312–02.000	31202000
032	–32	2-1/8	5/16	2-3/4	0.344	1.032	5330–00–621–4629	ASIP 2130	312–02.125	31202125
033	–33	2-1/4	5/16	2-7/8	0.344	1.032		ASIP 2136	312–02.250	31202250
034	–34	2-3/8	5/16	3	0.344	1.032		ASIP 2140	312–02.375	31202375
035	–35	2-1/2	5/16	3-1/8	0.344	1.032		ASIP 2146	312–02.500	31202500
036	–36	2-1/2	3/8	3-1/4	0.413	1.239		ASIP 2151	375–02.500	37502500
037	–37	2-5/8	3/8	3-3/8	0.413	1.239		ASIP 2157	375–02.625	37502625
038	–38	2-3/4	3/8	3-5/8	0.413	1.239		ASIP 2162	375–02.750	37502750
039	–39	2-7/8	3/8	3-5/8	0.413	1.239		ASIP 2168	375–02.875	37502875
040	–40	3	3/8	3-5/8	0.413	1.239		ASIP 2172	375–03.000	37503000
041	–41	3-1/8	3/8	3-7/8	0.413	1.239	5330–00–606–9781	ASIP 2178	375–03.125	37503125
042	–42	3-1/4	3/8	4	0.413	1.239		ASIP 2182	375–03.250	37503250
043	–43	3-3/8	3/8	4-1/8	0.413	1.239		ASIP 2188	375–03.375	37503375
044	–44	3-1/2	3/8	4-1/4	0.413	1.239		ASIP 2192	375–03.500	37503500
045	–45	3-5/8	3/8	4-3/8	0.413	1.239		ASIP 2198	375–03.625	37503625
046	–46	3-3/4	3/8	4-1/2	0.413	1.239		ASIP 2202	375–03.750	37503750
047	–47	3-7/8	3/8	4-5/8	0.413	1.239		ASIP 2209	375–03.875	37503875
056	–56	5-1/2	1/2	6-1/2	0.550	1.650		ASIP 2286	500–05.500	50005500
057	–57	5-3/4	1/2	6-3/4	0.550	1.650		ASIP 2294	500–05.750	50005750

Table 078–5–2. ESCL SEAL TO U-CUP AND V-RING CROSS REFERENCE (Sheet 3 of 3)

ESCL Dash No.	AN6226 AN6225 Dash No.*	Nominal Seal Size			Compression Type Lip Seal		National Stock Number (NSN)	ASI Part Number Piston Rod	Microdot Or Stillmann Part Number	Parker Part Number
		ID	CS	OD	Stack Depth For One Standard Seal Depth (Min)	Stuffing Box Height For Three Standard Seals Depth (Min)				
058	–58	6	1/2	7	0.550	1.650		ASIP 2301	500–06.000	50006000
059	–59	6-1/4	1/2	7-1/4	0.550	1.650		ASIP 2308	500–06.250	50006250
060	–60	6-1/2	1/2	7-1/2	0.550	1.650		ASIP 2315	500–06.500	50006500
061	–61	6-3/4	1/2	7-3/4	0.550	1.650		ASIP 2322	500–06.750	50006750
062	–62	7	1/2	8	0.550	1.650		ASIP 2329	500–07.000	50007000
063	–63	7-1/4	1/2	8-1/4	0.550	1.650		ASIP 2336	500–07.250	50007250
064	–64	7-1/2	1/2	8-1/2	0.550	1.650	5330–00–622–8511	ASIP 2343	500–07.500	50007500
065	–65	7-3/4	1/2	8-3/4	0.550	1.650		ASIP 2350	500–07.750	50007750
066	–66	8	1/2	9	0.550	1.650		ASIP 2357	500–08.000	50008000
067	–67	8-1/2	1/2	9-1/2	0.550	1.650		ASIP 2371	500–08.500	50008500
068	–68	9	1/2	10	0.550	1.650		ASIP 2385	500–09.000	50009000
069	–69	9-1/2	1/2	10-1/2	0.550	1.650		ASIP 2399	500–09.500	50009500
070	–70	10	1/2	11	0.550	1.650		ASIP 2413	500–10.000	50010000
071	–71	10-1/2	1/2	11-1/2	0.550	1.650		ASIP 2427	500–10.500	50010500
072	–72	11	1/2	12	0.550	1.650		ASIP 2441	500–11.000	50011000
073	–73	11-1/2	1/2	12-1/2	0.550	1.650		ASIP 2455	500–11.500	50011500
074	–74	12	1/2	13	0.550	1.650		ASIP 2469	500–12.000	50012000
075	–75	12-1/2	1/2	13–1/2	0.550	1.650		ASIP 2483	Not Listed	50012500
076	–76	13	1/2	14	0.550	1.650		ASIP 2497	500–13.000	50013000
077	–77	13-1/2	1/2	14-1/2	0.550	1.650		ASIP 2511	Not Listed	50013500
078	–78	14	1/2	15	0.550	1.650		ASIP 2525	Not Listed	50014000
079	–79	14-1/2	1/2	15-1/2	0.550	1.650		ASIP 2539	Not Listed	50014500
080	–80	15	1/2	16	0.550	1.650		ASIP 2553	500–15.000	50015000

*AN6226 U–cup dash no. for sizes –2 thru –40 only

078–5.4.2 SUITABILITY OF MIL–G–5514 GLANDS. For standardization, the preferred gland design should be in accordance with the requirements specified in MIL–G–5514 for O–rings, so that if an ESCL seal is not available during repair action, an O–ring of the same nominal cross section can be installed, although the service life may be considerably reduced. The dimensions required by MIL–G–5514 are slightly different from the dimensions prescribed by various manufacturers, but are close enough to provide for excellent seal performance. O–ring grooves that are designed in accordance with MIL–G–5514 (for no–backup–ring application) will be the correct axial depth for the Standard ESCL seal. Grooves designed for two–backup–ring application are necessary for the Deep Type B seal, but such grooves are also acceptable for the Standard seal.

078–5.4.3 COMMERCIAL GLANDS. As shown in Figure 078–5–2. when seal glands have been fabricated to commercial requirements, the nominal ID and OD seal dimensions are the precise dimensions of the gland. The seal is molded larger than its nominal dimensions to provide the necessary preload lip sealing forces. For example, a nominal 5 inch ID by 5–1/2 inch OD ESCL seal (equivalent to a –429 size O–ring) in a rod application, would be used with a 5.000 inch rod diameter and housed in a groove diameter of 5.500 inch. As required by MIL–G–5514, the rod diameter would be only 4.997 inch (maximum) and the groove diameter 5.474 inch (minimum).

078–5.4.4 COMPARISON OF MIL–G–5514 AND COMMERCIAL GLAND SQUEEZE. In general, MIL–G–5514 dimensional requirements provide for slightly more squeeze on the sealing lips, which would be expected to provide better wiping, but more drag friction and a somewhat reduced life. Since the actual life of ESCL seals in MIL–G–5514 has proven to be so much longer than that of conventional seals (such as O–rings), any reduction is considered to be negligible. On the other hand, the advantages of standardization and the capability of ESCL seals to function well in reworked glands with relaxed repair dimensions, are recognized benefits of using MIL–G–5514 glands. In terms of actual numbers, a 1/4 inch cross section seal with a 5 inch ID would be under 0.0115 inch more radial squeeze in a MIL–G–5514 gland than would normally be expected in a commercial gland. As a comparison for different sizes, a 1/8 inch cross section seal with a 3 inch ID would have only 0.0035 inch more radial squeeze in a MIL–G–5514 gland than in a commercial gland.

078–5.5 SUBSTITUTION OF ESCL SEALS IN EXISTING APPLICATIONS

078–5.5.1 ESCL SEAL INTERCHANGEABILITY. ESCL seals are interchangeable with many seals now used in the Navy, such as O–rings, U–cups, V–rings and quad–rings of 1/8 inch cross section and larger, in monodirectional applications, ESCL seals can be used in double–acting, bidirectional application as shown in Figure 078–5–4, only by using two seals installed back–to–back. ESCL seals can provide a seal in areas where the original seal was not performing satisfactory (due to worn mating metal components where clearances have increased beyond the capabilities of the original seal), or where the original seal used in a component may have been a poor choice. ESCL seals are to be used to reduce maintenance workload and to minimize leakage. Since these seals are more expensive than simple O–ring type seals, their cost must be weighed against the benefits. The seal is not to be used as a replacement for existing seals for the sake of change. If the existing seal is satisfactory, the original seal design shall be selected when normal seal replacement is required.

078–5.5.2 RETROFIT AUTHORIZATION. The identification of ESCL applications and the implied benefits described in this section are not to be construed as a blanket approval for the replacement of existing seal designs now in use. Replacement shall generally be on a case basis when it has been determined by NAVSEA, Forces Afloat, or repair activities, that the existing seal design is either inadequate or that periodic maintenance action has increased the maintenance load to unsatisfactory proportions, both of which can be so documented. As indicated in **NSTM Chapter 556, Hydraulic Equipment Power Transmission and Control**, two styles of ESCL seals are recommended for use in rack–and–pinion type actuators. Unless otherwise directed, in all other cases where ESCL seals are desired for permanent installation, the installing activity shall submit to NAVSEA a justification for using the ESCL seals, in accordance with paragraph 078–1.3.2.3. The approved ESCL seals are limited to those proprietary products of manufacturers either specifically listed in Table 078–5–1 and Table 078–5–2, or competitively stocked under the appropriate NSN shown in the tables.

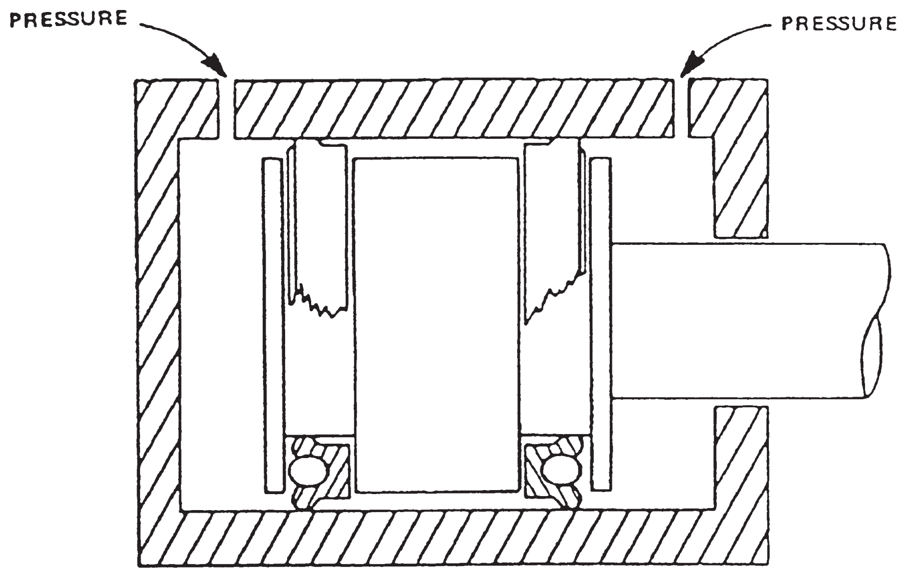


Figure 078–5–4. Bidirectional Installation

078–5.5.3 RETROFIT SOFTWARE UPDATE. To ensure the correct logistic support of equipment using ESCL seals, the equipment APL must be revised for all permanent installations. The fleet or industrial support activity installing an ESCL seal shall provide NAVSEA with the equipment APL number, the NSN or part number, and a description of which seal(s) it is replacing. NAVSEA will review the data and coordinate a request to the Ships Parts Control Center (SPCC) to be sure the affected APL's are revised to reflect the ESCL seal as an alternate. The original seal should be referenced on the APL to provide complete logistic support. If required, additional NSN's will be made available when the usage demand is sufficient to warrant supply system purchase of ESCL seals in new sizes.

078–5.5.4 REPLACEMENTS FOR O–RINGS AND QUAD–RINGS. O–rings and quad–rings with cross sections greater than 1/8–inch are usually replaced with Standard ESCL seals. For rod seal applications, installations where excessive tolerances exist across the gland width, Deep Type B ESCL seals will usually provide better performance than the Standard ESCL seal. Adapters or backup rings should not be installed, even though they may have been used in the original installation. A bidirectional sealing O–ring or quad–ring shall not be replaced with an ESCL seal, and ESCL seals shall not be split to provide replacement for an O–ring or quad–ring. Complete cross referencing information correlating ESCL sizes with O–ring sizes, including available NSN's, is provided in Table 078–5–1. Additional guidance in the use of ESCL seals for replacing O–rings in rack–and–pinion type actuators is provided in **NSTM Chapter 556, Hydraulic Equipment Power Transmission and Control**.

078–5.5.5 REPLACEMENTS FOR U–CUPS. Most U–cups may be replaced with ESCL seals identified in Table 078–5–2. All spacers such as adapters and pedestal rings must be removed from the gland space to provide a typical unobstructed rectangular area of minimum depth as defined in Table 078–5–2. For dash numbers –2 through –40, the listed ESCL seals are dimensionally equivalent (ID, OD and CS) to the nominal dimensions established for U–cup seals of AN6226.

078–5.5.6 REPLACEMENTS FOR V–RINGS. Commercially, either Standard or Deep Type B equivalents to the ESCL seals are used as V–ring replacements. Only the Standard ESCL seals are recommended for Navy V–ring replacements, and appropriate ESCL part numbers, manufacturers' part numbers, and available NSNs are provided in Table 078–5–2. The Deep Type B seal is considered unnecessary in these applications, for reasons of standardization and economy as well as for the fact that the Deep Type B seals are not suitable for stacking if splitting the seals is required to complete an installation. The Standard ESCL seal will perform satisfactorily with existing V–ring glands, as well as with new glands designed to the requirements discussed in Section 4.

078–5.6 ESCL INSTALLATION PROCEDURE

078–5.6.1 SEAL GLAND FIT. In matching ESCL seals to existing glands, it is most important that the cross sectional relationship between the seal and the gland be maintained, though the ID and OD dimensions may differ slightly. The optimum design of packing space is to have the packing space width W equal to the nominal cross section of the seal as shown in Figure 078–5–3. Under these conditions, the seal can be permanently stretched or compressed diametrically as much as 5 percent of its mean diameter without reducing its sealing ability. W should not be less than the nominal cross section of the seal. Caution must be exercised when installing 1/8 and 1/4 inch cross section ESCL seals in some existing grooves because the heel of the packing (see Figure 078–5–3, dimension (a) may be slightly wider than the packing space width W. In a high cyclic application this can cause excessive friction, heat build–up, and premature seal failure. When 1/8 and l/4 inch cross section seals are installed in dynamic applications, the W dimension should be at least 0.001 inch greater than the measured heel dimension (a) of the seal. When stretching is required to get the ESCL seal over the gland shoulder and into the seal groove, it should be stretched only to the extent necessary (not overstretched). ESCL seals are not as elastic as O–rings and similar seals. After stretching the seal, time should be allowed for the seal to return to its original dimensions in the gland before completing installation. Uncut ESCL seals shall not be compressed axially. Normally at least 10 percent clearance space shall be allowed (see paragraph 078–5.4 for gland details). Since ESCL seals function best as monodirectional seals, it is essential that the elastomeric spring member face the pressure source (see Figure 078–5–4 and Figure 078–5–5).

078–5.6.2 UNSPLIT ESCL SEALS. As with V–rings, installations which use unsplit seals are expected to perform significantly better than those where the seals must be split. The preferred ESCL seal installation is unsplit. In such a case, only a single seal is required to replace the entire V–ring stack, including male and female adapters and any shims and springs associated with the V–ring installation, as illustrated in Figure 078–5–5. The U portion of the ESCL seal is usually strong enough to bridge the clearance or extrusion gap between the gland and the mating moving surface and to resist extrusion without the need for additional supporting rings. If an excessive extrusion gap exists that affects seal performance, a modular bearing or similar anti–extrusion device may be used in conjunction with the ESCL seal. See paragraphs 078–5.6.4 through 078–5.6.4.6 for troubleshooting ESCL seal problems. As illustrated in Figure 078–5–5, the ESCL seal should not fill the entire

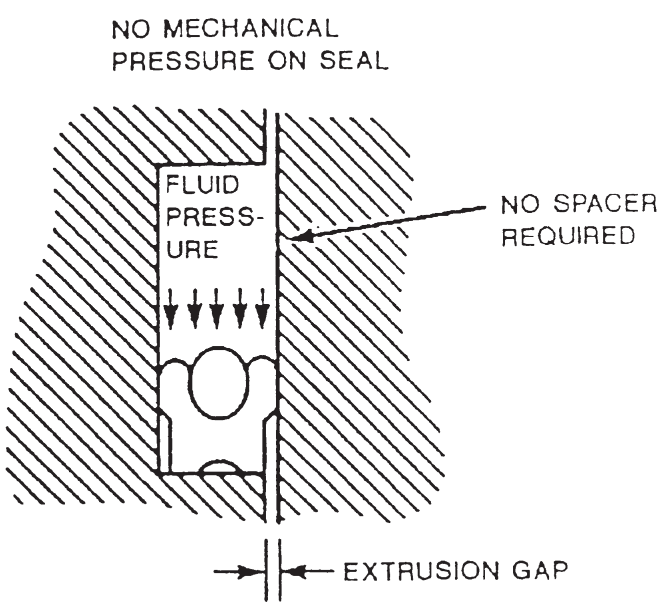


Figure 078–5–5. Typical V–Ring Replacement Installation

depth (axial space) of the packing gland; the extra space will fill with fluid. A combination of fluid pressure and friction will hold the seal in place against the end of the groove. No shims or other gland adjustments are required to complete the installation.

078–5.6.3 SPLIT ESCL SEALS. The use of split ESCL seals has not been completely evaluated by NAVSEA, and is discussed in this section primarily for information purposes. The installation of split ESCL seals is considered acceptable by the various manufacturers and is suggested in commercial literature. No data are available to confirm the expected improved performance of split ESCL seals over split V–ring packings. Laboratory tests are being performed to obtain this data: in the interim, the use of split ESCL seals should be considered only where the installed V–ring packings are unsatisfactory. As with V–ring installations, the concept of splitting ESCL seals for installation is acceptable only if the alternative of installing one unsplit ring would require costly, difficult, or time–consuming component disassembly. When split seals are used, exactly three standard ESCL seals are required, as shown in Figure 078–5–6. The minimum gland depth (often called stuffing box height for V–rings) required for three seals is identified for the appropriate sizes in Table 078–5–2. Split rings would usually be applicable only to rod seal installations because most piston seal glands are made for O–rings, quad–rings, or U–cups and are not deep enough for three ESCL seals. Cutting, stacking, and squeezing the ESCL seals is described in paragraphs 078–5.6.3.1 through 078–5.6.3.3.

078–5.6.3.1 Cutting the Seals. ESCL seals should be split by cutting straight through both the rubber spring and the U shell. The cut should be straight and square, not at an angle, as V–rings are cut; a single–edge razor blade works well for making this cut.

078–5.6.3.2 Stacking the Seals. After cutting, the rubber spring is carefully removed. The shell is opened with a sideways motion and placed around the rod. The seal should not be pulled apart nor excessive force used, which may damage the seal. The cut rubber spring is installed so that the cut line in the shell and that in the spring are 180° apart. This procedure is repeated for each of the other two seals. The seals are placed in the gland one at a time, and stacked so that the cut line in each shell is 120° from the preceding one, as illustrated in Figure 078–5–7. The seals must be placed in the groove with the rubber spring facing the pressure source.

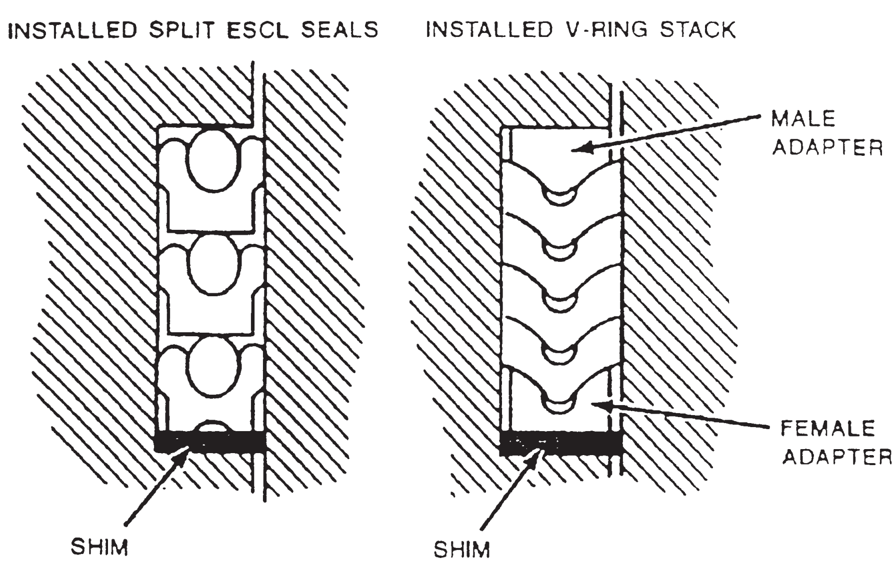


Figure 078–5–6. Split ESCL Seal Installation

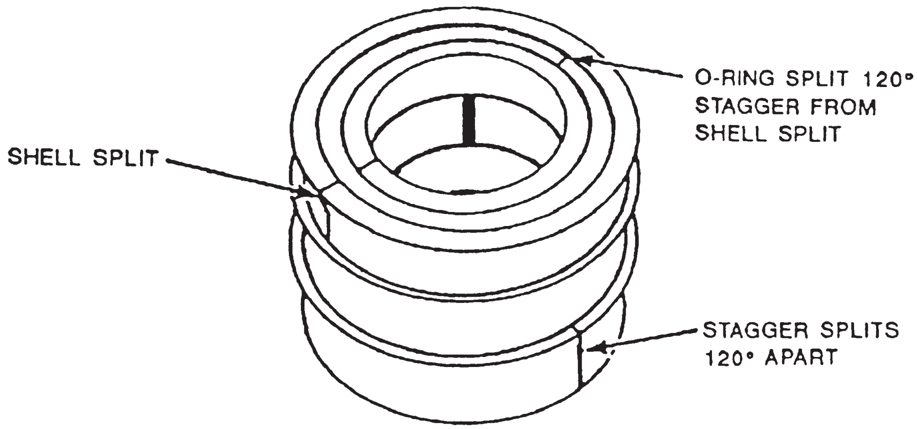


Figure 078–5–7. Stacking Split Seals

078–5.6.3.3 Squeezing the Seals. As with V–rings, clearance space above the ESCL seal stack to be avoided. Shims of proper thickness must be installed to put a slight squeeze (approximately 0.010 to 0.030 inch) on the seal stack. Shim thickness may be determined as shown in Figure 078–5–8.

078–5.6.3.4 The seals to be used are stacked and their combined height Z measured before they are split. Then the available depth D (or height) of the groove is calculated by subtracting the Y dimension from the X dimension (Figure 078–5–8). Shims are placed either under the gland cover flange or in the gland space, as illustrated in Figure 078–5–9, so that the available space D is 0.010 to 0.030 inch less than Z, (Figure 078–5–8).

078–5.6.4 TROUBLESHOOTING ESCL SEAL PROBLEMS. Problems with ESCL seal installations can generally be isolated to one of the situations described in paragraphs 078–5.6.4.1 through 078–5.6.4.5.

078–5.6.4.1 Wrong Gland Groove Dimensions. If the seal is put into a cavity that is too large in cross section, leakage past the seal will be obvious. If the cavity is too small either in cross section (width) or axially (depth), overheating and extrusion of the seal will result. Often the increased friction may cause the component operation to slow down, chatter, or become noisy.

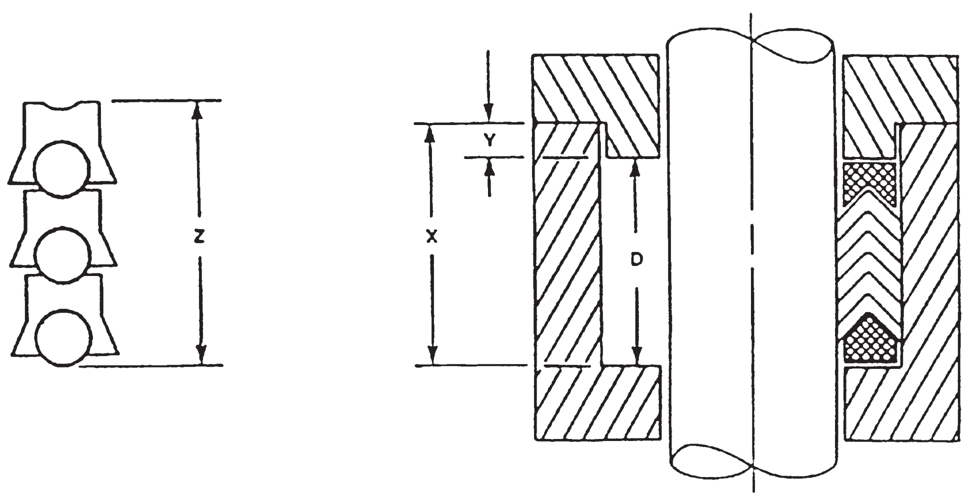


Figure 078–5–8. Determining Shim Thickness

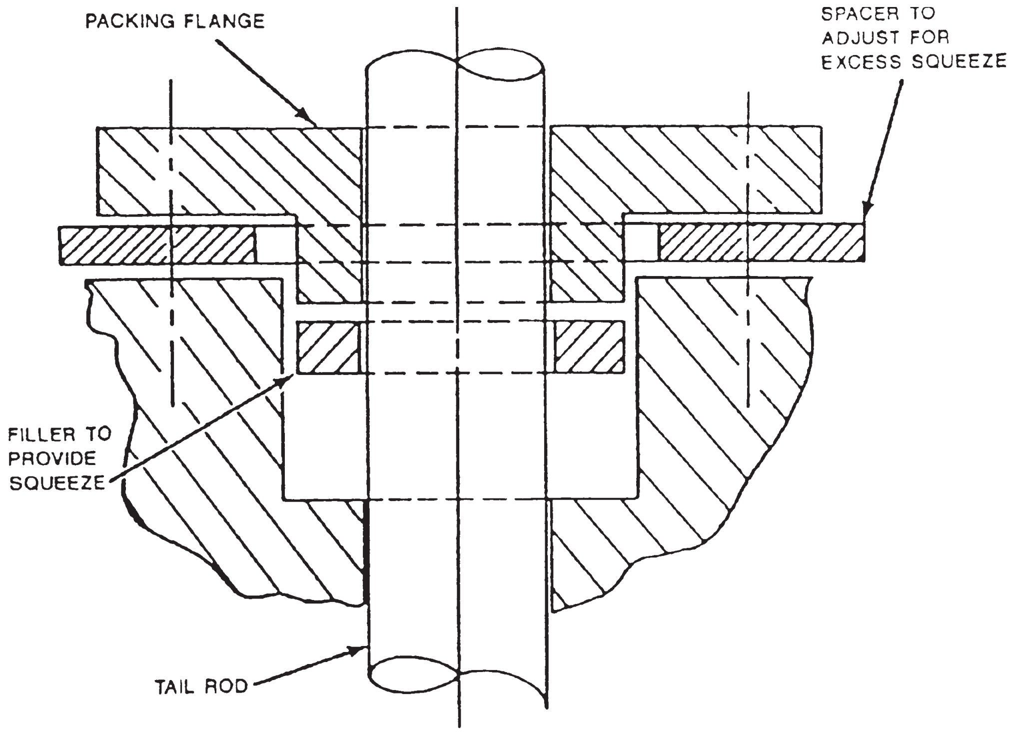


Figure 078–5–9. Locating Shim Spacers

078–5.6.4.2 Excessive Extrusion Gap. When the clearance space between moving pads is too large for the pressures being contained, the heel of the seal will show extrusion and nibbling at the corner of the seal where the moving parts contact.

078–5.6.4.3 Fluid Incompatibility. Incompatible fluids will usually result in catastrophic failure of the seal. Examination of the seal will show swelling, softening, tackiness, or other obvious signs of deterioration.

078–5.6.4.4 Excessive Temperature. Low temperatures do not usually cause irreversible seal degradation, although under extreme conditions the seal may become brittle and be subject to fracture. High temperatures have a more deteriorating impact on seals, usually evidenced by severe compression set, extrusion at the heel, blistering, or cracking.

078–5.6.4.5 Dieseling Effect. A dieseling effect occurs when air is trapped in spaces adjacent to the seals. If the trapped air is compressed rapidly by a shock load to the cylinder or by other unusual operating modes, the resulting rise in temperature and pressure can cause a small, diesel–type explosion of any oil mixed with that air. The flame from the explosion will overheat and possibly burn the seal, with resultant sealing loss. Although the dieseling effect is rare, it is discussed because its occurrence is serious. If dieseling is suspected, NAVSEA should be advised immediately.

078–5.6.4.6 Hydraulic Lock. When two seals are installed on a double–acting piston without venting the space between the seals, a pressure trap can be created between the two seals. The trapped pressure will increase the friction on the seals, sometimes to an extent capable of preventing the piston from moving. The lips of the failed seal will have a feathered edge caused by wear and extrusion into the clearance space.

SECTION 6.
OTHER CONFIGURATION PREFORMED PACKINGS

078–6.1 GENERAL

078–6.1.1 INTRODUCTION. There are many different preformed packing configurations in Navy use, and even more are available in the commercial market. The standard and probably the best overall packing is the common O–ring. However, there are special applications in which seal configurations other than O–rings provide superior performance. These other configuration preformed packings often vary in chemical composition and mechanical properties as well as in shape. This section identifies the more common packing configurations found in Navy service.

078–6.2 T–SEALS

078–6.2.1 DESCRIPTION. The T–seal has an elastomeric bidirectional sealing element resembling an inverted letter T. This sealing element is always paired with two special extrusion–resisting backup rings, one on each side of the T. The basic T–seal configuration is shown in Figure 078–6–1. Backup rings are single turn, bias cut and are usually made of TFE, molybdenum–disulfide–impregnated nylon, or a combination of TFE and nylon. Nylon is widely used for T–seal backup rings because it provides excellent resistance to extrusion and has low friction characteristics. TFE is less often used for T–seal backup rings even though it is chemically inert to most fluids and will endure a much wider temperature range than will the nylon. The extra expense of TFE and its tendency to cold–flow slowly under a constant load limits its use to comparatively few applications.

078–6.2.2 T–SEAL INSTALLATION. T–seals are commercially available in sizes to fit every groove defined in MIL–G–5514. The T base must sit on the groove bottom as shown in Figure 078–6–1. The special T–ring configuration adds stability to the seal, eliminating spiralling and rolling. T–seals are used in applications where large clearances could occur as a result of the expansion of the thin–walled hydraulic cylinder. The T–ring is installed under radial compression and provides a positive seal at zero or low pressure. Backup rings, one on each side, ride free of T–ring flanges and the rod or cylinder wall. These clearances keep seal friction to a minimum at low pressure. When pressure is applied, the T–ring acts to provide positive sealing action as fluid pressure increases. One frequently used T–ring, manufactured by Greene, Tweed, and Company (appropriately called a G–T ring), incorporates a unique, patented backup ring feature. One corner on the inside diameter (ID) of each radius–styled backup ring on the G–T ring set has been rounded to mate with the inside corner of the rubber T. When installing radius–styled G–T rings, ensure that each backup ring is installed on the proper side of the T so that the rounded corner of each is inward toward the T (see Figure 078–6–1, item B).

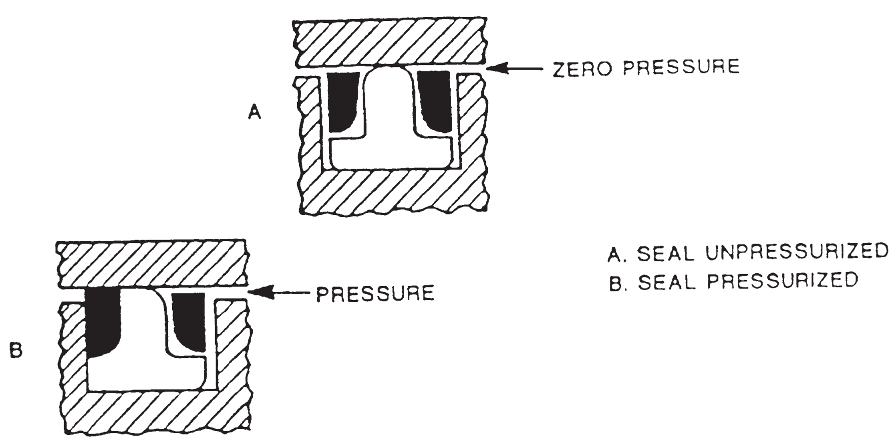


Figure 078–6–1. T–Seal

078–6.2.3 HYDRAULIC ACTUATOR T–SEALS. G–T seals can be used as replacement seals for specific hydraulic system rotary actuators as described in **NSTM Chapter 556, Hydraulic Equipment Power Transmission and Control**. These seals are intended to minimize leakage and allow component sealing area rework without excessive sealability reduction. As set forth in **NSTM Chapter 556, Hydraulic Equipment Power Transmission and Control**, G–T seals can be used in dynamic applications in which the seal groove is wide enough to accommodate an O–ring and two backup rings.

078–6.2.4 T–SEAL IDENTIFICATION PART NUMBERS. There is no Military Standard part numbering system by which T–seals can be identified. In general, each manufacturer issues proprietary part numbers to identify seals. However, it is common practice to identify T–seal sizes by the same dash numbers used for equivalent O–ring sizes as defined by AS568 and MS28775 dimension standards. These standard dash numbers for O–rings are identified in Table 078–3–2. Typically, an O–ring groove that accepts a certain O–ring dash number will accept the same dash number T–seal. Care must be taken to ensure that the proper width T–seal is obtained, because the O–ring groove width will vary according to the number of backup rings installed with the O–ring. Often there will be three widths available for each T–seal dash number in order to accommodate O–ring grooves made for no backup rings, one backup ring, and two backup rings. For each dash size, it is also necessary to specify whether the T–seal will be installed in an external groove (such as in a piston seal) or an internal groove (such as in a rod seal).

078–6.2.4.1 Navy Standard T–Seal Numbering System. In the absence of an existing military standard for identifying T–seals, a new and simple numbering system was created to identify T–seals required for hydraulic actuators (piston seals only) without reference to a particular manufacturer's part number. The Navy number is composed of the letters G–T followed by a dash number of three digits and one letter R, S, or T, (e.g., G–T–217T). The three digits are the appropriate O–ring size dash number per AS568 or MS28775. The letters R, S, and T designate the number of backup rings that the groove of the T–seal is designed to accommodate: none, one, or two, respectively. National Stock Numbers (NSNs) have been assigned to these T–seals for every –XXXT number of O–ring in equivalent sizes –210 through –221 and –325 through –460. As various manufacturers' T–seals are approved, they will be competitively procured and stocked under the appropriate NSN.

078–6.2.4.2 G–T Numbering System. In general accordance with the standard Greene, Tweed, and Company part numbering system, a special part number series has been established for G–T seals used for actuator applications. The 15–digit part number for hydraulic actuator G–T seals is coded as 126–_ _ _ 16–731–0050.

In the first set of digits (126), 12 designates radius–styled backup rings; 6 designates a piston seal wide enough to require a groove designed for an O–ring and two back ups. In_ _ _16, the three missing digits are the same as the appropriate O–ring size dash number per AS568 or MS28775; 16 is a proprietary sequential code for the required two backup rings. (If the original groove contained no backup rings, the sequential code would be 14, and if only one backup ring existed, the code would be 15. G–T rings coded 16 are the only ones authorized for use in hydraulic actuators.) The next set of digits, 731, designates the T–ring compound as fluorocarbon rubber per MIL–R–83248. In the last set of digits (0050), 005 designates the backup ring compound as TFE per MIL–R–8791, and 0 designates standard size backup rings (digits 1 through 9 would be the sequential code for nonstandard sized rings).

078–6.3 QUAD–RINGS

078–6.3.1 DESCRIPTION. A Quad–ring is a special configuration ring packing manufactured by Minnesota Rubber and Gasket Company. As opposed to an O–ring, a Quad–ring has a more square cross–sectional shape with rounded corners, rather resembling a four–lobed seal (see Figure 078–6–2). The four–lobed design offers more stability than the O–ring design and thereby practically eliminates the spiraling or twisting occasionally encountered in failed O–ring packings.

078–6.3.2 INSTALLATION. Quad–rings, as well as O–rings, may be installed with or without backup rings, depending upon the specific groove application and width. The Quad–ring will work well in both static and dynamic applications for liquid and gas systems. Quad–rings have been installed in submarine hydraulic systems as piston seals in most control surface operating cylinders and as piston, tail rod, and head seals in some main and

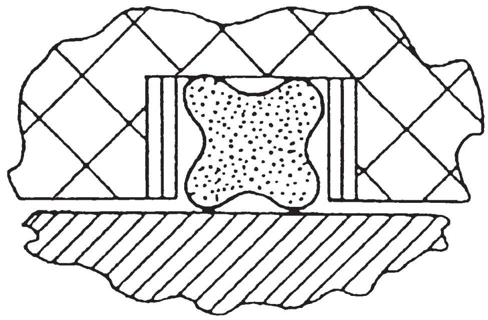


Figure 078–6–2. Quad–Ring

vital accumulators. Quad–rings do not necessarily require as much squeeze as O–rings. If Quad–rings are installed in glands made to Minnesota Rubber recommendations, the squeeze will be less than if they are installed in glands conforming to MIL–G–5514. This means that original commercial Quad–ring grooves are deeper than those specified in MIL–G–5514. However, for Navy equipment with Quad–ring seals, the gland should conform to MIL–G–5514. The resulting increased squeeze on Quad–rings should not adversely affect seal performance, and if Quad–rings are not available for maintenance actions, appropriate sized O–rings can be installed and will work satisfactorily.

078–6.3.3 IDENTIFICATION. Quad–rings are completely interchangeable with O–rings in sizes offered by the manufacturer. Quad–rings in manufacturers' sizes designated as Q1 through Q88 are interchangeable with O–rings conforming, to AN6227 in the respective dash sizes from –1 through –88, i.e., Quad–ring Q31 is interchangeable with AN6227–31. Similarly, Quad–rings in commercial sizes Q101 through Q152 are interchangeable with O–rings conforming to AN6230 in the respective dash sizes from –1 through –52; i.e., Quad–ring Q131 is interchangeable with AN6230–31. Note that these latter Quad–ring sizes are composed of the letter Q and the digit one, followed by the same two digits that denote comparable–sized O–rings in AN6230. Thus, Q31 and Q131 are identifiable to O–ring sizes AN6227–31 and AN6230–31 respectively (Table 078–3–2 gives AN6227 and AN6230 dash numbers and dimensions).

078–6.3.4 FEDERAL SUPPLY NUMBERING SYSTEM. Many Quad–rings sizes have been assigned NSN's and are stocked in the Federal Supply System. The Quad–ring stock part number utilizes the AN standard O–ring designations AN6227 and AN6230 and the commercial Q dash number designations. For example, NSN's would be found under such reference part numbers as AN6227Q10 and AN6230Q103. If special material formulations have been used to make the quad–ring, additional descriptions follow the Q number, such as AN6227Q72MILG22050A. If the letter Q does not follow AN6227 or AN6230, the part number is an O–ring not a Quad–ring. Such numbers as AN6227–30, AN6227–23VITON, AN6227A20, AN6227B10, AN6230–30, AN6230A1, AN6230B9, and AN6230–16MILR25897 are all O–rings.

078–6.4 QUAD–O–DYN SEALS

078–6.4.1 DESCRIPTION. Quad–O–Dyn is a special form of Quad–ring also proprietary to Minnesota Rubber (Figure 078–6–3). The Quad–O–Dyn differs from the Quad–ring in configuration (six lobes versus four lobes), is harder (80 durometer rather than 70 durometer), is subject to greater squeeze, and is made of a slightly different material. Quad–O–Dyn rings are also more expensive than Quad–rings. As do Quad–rings, the Quad–O–Dyn seals work well in O–ring glands conforming to MIL–G–5514.

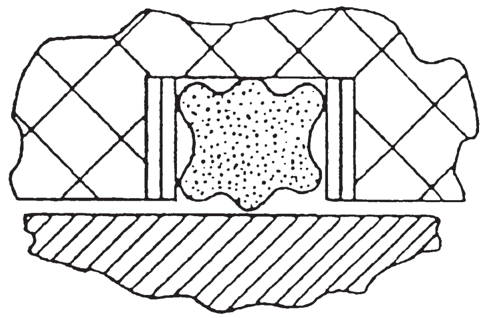


Figure 078–6–3. Quad–O–Dyn Seal

078–6.4.2 APPLICATIONS. The Quad–O–Dyn is used in relatively few applications. However, for difficult dynamic sealing applications, the Quad–O–Dyn can perform better than the Quad–ring. Tests in submarine hydraulic systems have shown that the Quad–O–Dyn seal (when compared to the Quad–ring) extends accumulator operating time between seal replacements by a factor of about three. As a result, dynamic Quad–ring seals in most submarine hydraulic system plant accumulators have been replaced with Quad–O–Dyn seals. For additional information and stock numbers on these applications, refer to **NSTM Chapter 556, Hydraulic Equipment Power Transmission and Control**. Contrary to Quad–rings, Quad–O–Dyn seals are not widely used nor abundantly stocked in the supply system. Where they are used, identification of NSN's for required seals can probably best be obtained by referring to the applicable Allowance Parts Lists (APL's). However, the user may be able to get the stock number from Federal Stock catalogues using the manufacturers' part numbers as obtained from equipment manuals or drawings.

078–6.5 U–CUPS AND U–PACKINGS

078–6.5.1 GENERAL. The distinction between U–cups and U–packing results from the difference in materials used in fabrication. The U–cup is usually made of homogeneous synthetic rubber; U–packings are usually made of leather or fabric–reinforced rubber. Special aspects of each type will be discussed separately. However, all U–cups and U–packings have cross sections resembling the letter U. Both types are balanced packings, both seal on the ID and outside diameter (OD), and both are applied individually, not in stacks like V–rings. Size differences between U–cups and U–packings are usually substantial enough to prevent interchangeability. There are a few sizes with smaller diameters and cross sections that may appear to be dimensionally equivalent but are not. Therefore, U–packings should not be substituted for U–cups (or vice versa) in any installation.

078–6.5.2 U–CUPS. The U–cup has been popular packing in the past because of installation ease and low friction. U–cups are used primarily for pressures below 1,500 pounds per square inch (lb/in^2), but higher pressures are possible with the use of antiextrusion rings. Normal hardness for U–cups is 70 durometer. In the interest of standardization and is a result of improvements in seal design and new materials that allow sealing at higher pressures, other compression lip seals such as ESCL seals (Section 5) are replacing U–cups in many applications.

078–6.5.2.1 Identification. U–cups have been made to dimensions specified in AN6226 (canceled 1 November 1974) from a 70 durometer nitrile rubber conforming to MIL–P–5516. U–cups to AN6226 dimensions are available in size increments of 1/16 inch, ranging from 3/8 inch to 1–3/4 inch OD and in 1/8 inch increments ranging from 1 inch to 3–3/4 inch OD for a variety of appropriately matched cross sections. U–cups conforming to AN6226 will have the specification number and size dash number stamped on the bottom of the packing. Replacement seals for maintenance actions are generally available through the Federal Supply System and can be ordered by the AN number for the appropriate dash size. In the absence of a current government standard, dimensions for U–cups and their packing glands may be obtained from industry standards. AN6226 size dash numbers usually correspond exactly with dash numbers identified in commercial literature on hydraulic and pneumatic packings.

078–6.5.2.2 Installation. Because of minor but significant differences (1/16 or 1/8 inch) between U–cup sizes, ensure that the size is correct prior to installation (Figure 078–6–4). The nominal U–cup OD and ID are the OD and ID of the gland which will receive the cup. These dimensions will provide the proper heel clearance and lip preload. The operating width (W) is one–half the difference between the nominal OD and ID which, for U–cups, is the same dimensional size as the packing height (L). Accordingly, to accept the packing height, the axial gland should measure L plus 1/16 inch. If metal supports or backup washers are used with the U–cup, a deeper gland will be necessary to accept these components. Diametrical clearance between the packing retaining ring or gland cover and cylinder wall or rod shall be adequate and in accordance with dimensions shown in Table 078–4–8 to ensure against interference of moving parts or excessive clearance between moving parts. Industrial dimensions are available and acceptable for support rings. Metal support rings are not recommended for inside packed installations (such as a piston seal) but are recommended for outside packed installations such as rod seals, though not always used. If metal support rings have been provided in an installation, be sure to reinstall them during maintenance actions. For double acting pistons, two U–cups are installed in separate grooves, **back–to–back** or **heel–to–hee**l. Two U–cups shall never be used in the same groove. This heel–to–heel type of installation is common in single acting (monodirectional) seals such as U–cups and V–rings and is necessary to prevent a pressure trap (also known as **hydraulic lock)** between two packings. Installation of two U–cups with sealing lips facing each other can result in hydraulic lock and must be avoided.

078–6.5.3 LEATHER U–PACKINGS. As a rule, leather U–packings are made with straight side walls (no flared sealing lips). The leather may be chemically treated or otherwise impregnated to improve its performance. Leather U–packings are available in standard sizes conforming to industrial specifications (see Table 078–6–1 for a summary of dimensions). For maintenance actions, commercial part numbers and stock numbers should be available from appropriate equipment and components manuals, drawings, or APL’s.

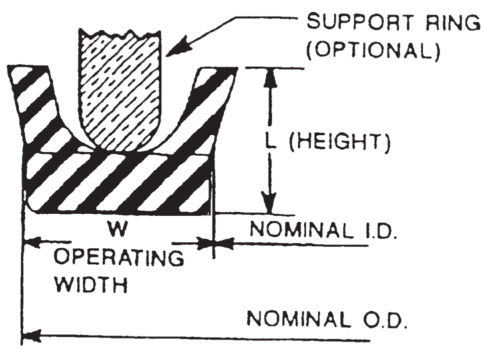
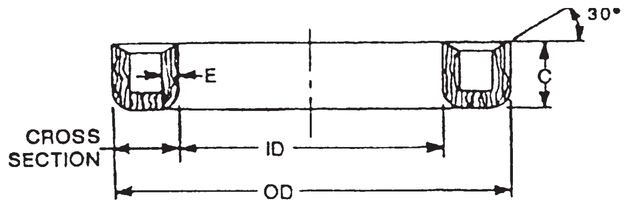


Figure 078–6–4. U–Cup

Table 078–6–1. STANDARD SIZES FOR LEATHER U–PACKINGS BASED ON ID IN INCHES



Note: The following are standard sizes recommended for new designs. Other sizes for equipment in use are available.

ID	Increment	Cross Connection	C
1/2 thru 7/8	1/8	1/4	5/16
1 thru 1–3/4	1/8	3/8	3/8
1–7/8 thru 2–1/2	1/8	1/2	7/16
2–3/4 thru 3–3/4	1/4	1/2	1/2
4 thru 5–1/2	1/4	5/8	5/8
5–1/2 thru 11	1/2	3/4	3/4
12 thru 15	1	3/4	1
16 thru 36	1	3/4	1–1/4

078–6.5.3.1 Installation. For support, the cavity of the U–packing should contain a metal pedestal ring as shown in Figure 078–6–5 or should be filled with a suitable material like flax, hemp, or rubber as shown in Figure 078–6–6. When a pedestal ring is used, there must be a clearance between each side of the pedestal and the inside packing wall to allow for swell and to eliminate binding. Clearance (approximately 1/8 inch) must also be maintained between the U–packing beveled lip and the pedestal ring base to allow free lip movement and ensure

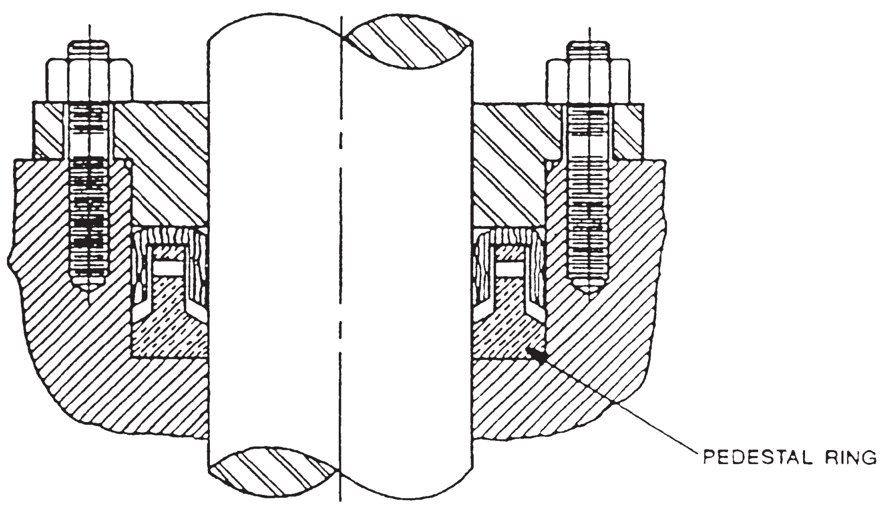


Figure 078–6–5. Typical U–Packing Installation with Pedestal Ring

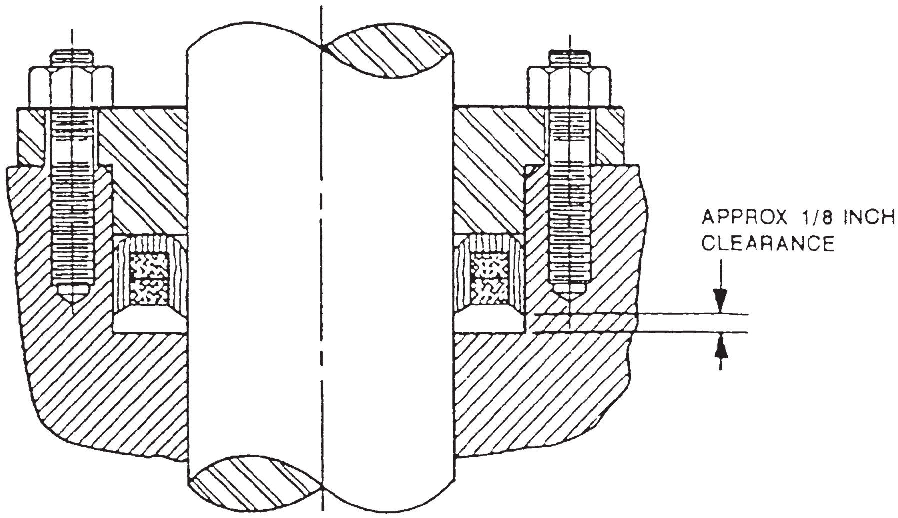


Figure 078–6–6. Typical U–Packing Installation with Filler

that the lips will not strike the pedestal ring base causing seal damage. The overall pedestal ring height must be sufficient to provide 1/64 inch compression on the U–packing bottom to hold the packing securely in place. In some gland designs, the pedestal is fabricated as part of the packing retainer or gland cover. Leather U–packings with an integral pedestal support have been installed in some submarine steering and diving ram piston seals. If the U–packing recess is filled with hemp or other material instead of a pedestal ring, ensure that the recess is completely filled and extends to the inside packing bevel as shown in Figure 078–6–6. For these filled packings, allow a clearance of 1/8 inch between the beveled lip of the U and the gland bottom. If excessive clearances exist between the moving part and the gland cover or packing retainer or if high pressure exists across the packing, the packing can fail due to extrusion at the shoulder (bottom of the U). This condition may be alleviated by using a leather antiextrusion washer under the packing shoulder. This washer is usually made from two plies of leather 5/16 inch thick. The washer OD should be the same as the rod gland or piston OD, and the hole or ID should be the same as the piston gland or rod ID. Under pressure, the washer will compress and bridge the clearance to protect the U–packing shoulder.

078–6.5.4 FABRIC–REINFORCED U–PACKINGS. Fabric–reinforced U– packings perform in a manner similar to leather packings but are used less often because of the high cost of rubber molds. No standards have been established for fabric–reinforced U–packings, and the availability of molds varies with individual packing manufacturers. Unlike the leather packing, the fabric–reinforced U is molded with the bottom thicker than the side walls. Side walls are flared resulting in a preloaded packing when installed. No filler of flax, metal, or any other support is required for the recess of this packing.

078–6.6 CUP PACKINGS

078–6.6.1 DESCRIPTION. Cup packings resemble a cup or deep dish with a hole in the center for mounting. Cup seals are used exclusively to seal pistons in both low and high pressure hydraulic and pneumatic service. They are produced in leather, homogeneous synthetic rubber, and fabric–reinforced synthetic rubber. Although the cup packing lip flares outward, the rubbing contact is made at the lip only when the fluid pressure is low. As the fluid pressure increases, the cup heel expands outward until it contacts the cylinder wall at which point high pressure scaling is effected. As the pressure loading shifts the sealing line to the clip heel, the lip is actually pulled into the cup and away from the cylinder wall. On the return stroke when the pressure is relaxed, the heel will shrink slightly leaving only the lip in contact with the wall, avoiding unnecessary wear at the heel.

078–6.6.2 INSTALLATION. For proper installation, the cup must be clamped firmly to prevent leakage through the center hole. It must not, however, be overtightened. Overtightening will force material out from under the clamp and will push the heel into rubbing contact with the cylinder wall before fluid pressure is applied. Excessive friction and rapid wear will result. As are U–cups and V–rings, cup packings are single–acting seals; i.e., they seal from one direction only. For reciprocating pistons, two cups installed back–to–back in separate glands will be required. Industrial standards have been established for leather and fabric–reinforced cups. For maintenance actions, replacement cups shall be procured in accordance with equipment manuals, drawings, or applicable APL's.

078–6.7 FLANGE PACKINGS

078–6.7.1 DESCRIPTION. Flange packings are used exclusively as low pressure outside–packed installations, such as rod seals. The flange (sometimes called hat) is made of leather, fabric–reinforced rubber, or homogeneous rubber. Lip sealing occurs only on the packing ID (Figure 078–6–7). Flange packings are generally used only for rod seals when other packings such as V–rings or U–seals cannot be used. Design conditions requiring a shallow gland depth or narrow cross sectional width might necessitate flange use. For rod diameters above 5–1/2 inches, the use of V's and U's is recommended over flanges. Industrial standards have been established for leather flange packing up to 5–1/2 inches ID. Replacement packings for maintenance actions shall be procured in accordance with applicable manuals, drawings, or APL's.

078–6.7.2 INSTALLATION. While the packing will seal as a result of the actuating pressure on the side wall ID, mechanical base compression is required to seal the OD. Therefore, the gland ring must be tightened enough to seal against the maximum operating pressure. Clearance should exist between the packing side wall and the cylinder body to allow for swell and between the beveled packing lip and the gland bottom to prevent packing damage.

078–6.8 D–RINGS

078–6.8.1 GENERAL. The D–ring packing was designed primarily for use in lieu of O–rings for landing gear shock strut rod seals where O–ring spiral failure was a problem. However, D–rings can be found in other installations. The material specification for these rings is MIL–P–5516. As the name implies, the cross section of this ring resembles the letter D. D–ring dimensions, identified by dash numbers –335 through –349 and –425 through –460, are provided in MS28772. D–ring ID and OD in these sizes are equivalent to the MS28775 (and AS568) O–ring ID and OD in sizes –335 through –460. For diametrical gland dimensions needed for D–rings, dimensions established in MIL–G–5514 for O–rings are recommended. MIL–G–5514 also provides a table for D–ring gland width dimensions. D rings can be used without any backup rings or with one or two backup rings.

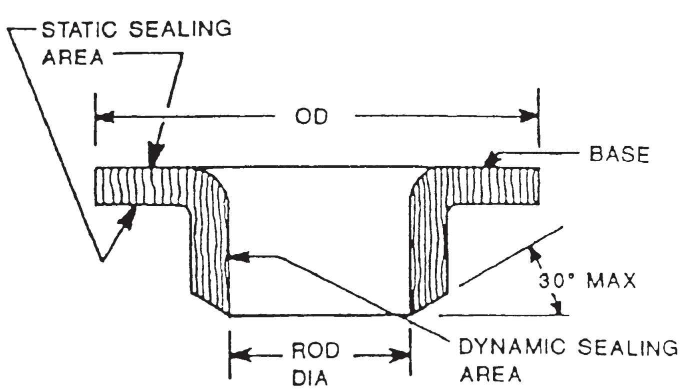


Figure 078–6–7. Typical Flange Packing Cross Section

078–6.9 OMNISEALS

078–6.9.1 GENERAL. The Omniseal is a proprietary product of Fluorocarbon Mechanical Seal Division. This seal is a pressure and selfactuated sealing ring consisting of a tetrafluoroethylene cover partially surrounding a helical–wound flat wire support spring. The Omniseal sealing action principle, in which the spring action exerts equal pressure and provides permanent resiliency to assure a reliable seal, is shown in Figure 078–6–8. Omniseals must always be installed so that the open side of the cover faces toward system pressure. Omniseals are manufactured in various sizes and shapes conforming to the groove and gland dimensions of MIL–G–5514. Since the Omniseal is not as flexible as conventional O–rings, care must be exercised when installing the seal. Special tooling is usually required to install Omniseals. For specific installation techniques, procedures, and tooling requirements, refer to the applicable maintenance instruction manual.

078–6.10 DIRT EXCLUSION SEALS (WIPERS AND SCRAPERS)

078–6.10.1 GENERAL. Direct exclusion devices are essential if a satisfactory life is to be obtained from most rod seals. The smooth finished moving rod surface, if not enclosed or protected by some sort of covering, will accumulate a coating of dust or abrasive material that will be dragged or carried into the packing assembly area on the return rod stroke. Exclusion devices called **wipers** or **scrapers** are designed to remove this coating. While the terms **wiper** and **scraper** are often used interchangeably, it is useful to reserve the term **scraper** for metal lip–type devices that remove heavily encrusted deposits of dirt or other abrasive material that would merely deflect a softer lip and be carried into the cylinder. Sometimes a rod will have both a scraper and a wiper, the former to remove heavy deposits and the latter to exclude any dust particles that remain. Whenever metallic wipers or scrapers are used with felt wipers in the same groove, the felt wiper shall not be compressed nor restricted in any way that affects its function as a lubricator. Note that a wiper installed in a seal assembly in a pneumatic application may remove too much oil from the rod, requiring some method of replacing the oil. A common remedy is to provide a periodically–oiled felt ring between the wiper and the seal. Felt wipers provide lubrication to extended operating rods, thus increasing component wear–life. These wipers are only used to provide lubrication to parts.

078–6.10.2 MAINTENANCE. Much longer life could be obtained from most seals if proper attention were given to wipers and scrapers. Often, wiper or scraper failure is not noticed when a seal packing fails. As a result, only the packing is replaced, and the same worn wiper or scraper is reinstalled to destroy another packing. Check the wiper or scraper condition upon removal. If worn, dirty, or embedded with metallic particles, replace the wiper with a new one. It is usually good procedure to replace the wiper every time the seal is replaced and even more frequently if the wiper is readily accessible without component disassembly. If replacements are not available, dirty wipers that are still in good condition may be washed with suitable solvent and reinstalled. Remember that a

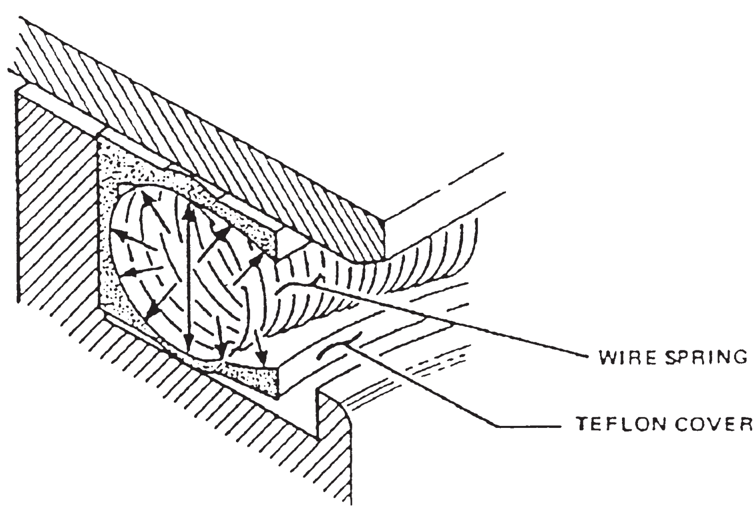


Figure 078–6–8. Typical Omniseal Cross Section

wiper or scraper is deliberately installed as a sacrificial part to protect and preserve the sealing packing. Among manufacturers, there are a variety of wipers and scrapers of different materials and shapes that may or may not be interchangeable. Therefore, from a user's standpoint, wipers and scrapers should be inspected and replaced as necessary. If identification is uncertain, refer to the appropriate equipment manual, drawing, or APL for the correct part description.

078–6.10.3 WIPERS. Wipers are generally relatively soft and squeeze against the shaft or rod to wipe off loose particles. Wipers are made of elastomeric materials leather, felt, or metal in many styles.

078–6.10.3.1 Standard Wipers. MIL–R–8913 covers suitable metallic, polytetrafluoroethylene, and rubber wiper rings for removing dirt and other foreign matter from hydraulic and pneumatic component piston rods. Wiper rings to this specification comply with dimensions and part numbers of MS28903 and fit into glands conforming to dimensions in MS33675 (formerly AND10075). Military Standards are also available to define felt wipers. For example, MS51917 identifies 15 dash sizes with pertinent seal and housing dimensions for the installation of a plain encased single felt sealing member (internal type). MS28932 (formerly AN6232) provides for bulk and cut lengths of rectangular felt strips (.125 ± .014 inch by.188 ± .016 inch) up to 60 inches long.

078–6.10.3.2 Commercial Wipers. Many wipers in service conform to commercial standards rather than to military standards. For example, one commercial nitrile rubber wiper made for general pneumatic and hydraulic applications has been widely used in submarine hydraulic systems. Wiper cross section and wiper groove details are shown in Figure 078–6–9. This wiper is stocked in the Federal Supply System under NSN 5330–00–768–7196. For installation, a length of wiper strip equal to the rod circumference is cut off the roll and inserted in the recess to form the seal. For some severe duty installations such as submarine hydraulic system power plant accumulators, another commercial wiper is being used to provide longer wiper life and less seal maintenance. Manufactured by C.E. Conover and Company, this wiper is stocked in the Federal Supply System in some sizes. Dimensions of this wiper also allow its adaptation to glands conforming to MS33675.

078–6.10.3.3 Seal–Type Wipers. Some installations use typical seal configurations outboard of the primary seal to keep dirt away from primary seals. Standard U–cup seals have been used as wipers where extra resilience is needed to maintain firm contact with the rod surface for prolonged periods. For O–ring seals, a second O–ring is sometimes used as a wiper. Often, a small bleed hole is provided between the two seals, so the second ring serves only as a wiper and not as a seal. Another technique is to cut the second O–ring so it will not function as a seal. The O–ring used as a wiper may have the same squeeze as the seal ring or a lesser amount down to approximately half the standard squeeze if it is necessary to reduce friction.

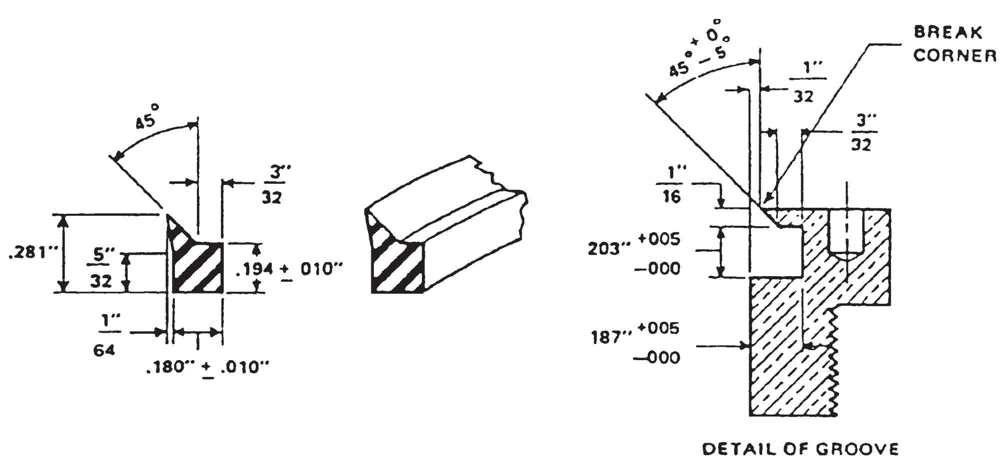


Figure 078–6–9. Typical Commercial Wiper

078–6.10.4 SCRAPERS. MS28776 (formerly AN6231) provides dimensional requirements for piston rod scrapers that conform to MIL–S–5049 and are capable of removing dirt and ice. These scrapers are usually a split bronze ring (with or without rubber) designed to clean the surface of a piston rod. Gland dimensions for these scrapers are provided in MS33675. There are also a number of non–metallic commercial scrapers in service which may provide better performance in most applications. These scrapers are manufactured by Greene Tweed, Shamban and Tetrafluor. Many of these commercial scrapers will fit glands per SAE AS 4088. The AS 4088 gland configuration is larger than the MS33675 gland and permits installation of a more effective scraper.

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