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O-Ring Applications

3.0 Introduction

In designing an O-ring seal, it is best to determine the O-ring compound first, as the selected compound may have significant influence on gland design parameters.

Essentially, the application determines the rubber compound; the primary factor being the *fluid* to be sealed. The elastomer however, must also resist *extrusion* when exposed to the maximum anticipated system pressure and be capable of maintaining good physical properties through the full *temperature* range expected. In dynamic applications, the selected material must also have the *toughness* and *abrasion* resistance so important in reciprocating and rotary seals.

The Fluid Compatibility Tables in Section VII suggest potential Parker Compounds for over two thousand different gases, fluids and solids. Normally, the "Recommended Parker O-Ring Compound" indicated in the tables should be the one specified for initial testing and evaluation.

In some instances, where there are two or more fluids to be sealed, it may be necessary to compromise on a seal material having the best overall resistance to all the fluids involved. Whenever possible this should be a compound rated "1" for all the fluids under consideration. For a static seal application, a "2" rating is usually acceptable, but it should, in all cases, be tested. Where a "2" rated compound must be used, do not expect to re-use it after disassembly. It may have degraded enough that it cannot safely be reinstalled.

When a compound rated "3" is selected, be certain it is first thoroughly tested under the full range of anticipated operating conditions. Some of these 3-rated compounds may prove to be satisfactory as static seals, but many will not.

Note the operating temperature range of the chosen compound. The temperatures shown in Table 7-1 are general temperature ranges, but the presence of a particular fluid may modify the published limits. Remember, only appropriate testing can safely determine an acceptable O-ring seal material.

If a compound designated "Static only" is the only compound recommended for the fluids, and the application is dynamic, the compound may nevertheless be suitable in some unique situations. Bear in mind that "Static only" compounds are not as tough and abrasion resistant as other materials, and would normally wear more rapidly in a dynamic environment.

If the anticipated seal motion is infrequent, or if the seal can be replaced often, a "Static only" compound will probably be satisfactory.

If, for some reason a compound of different shore hardness from the one suggested in the Fluid Compatibility Table is needed, compounds of other hardnesses in the same polymer are available. Contact the O-Ring Division.

When two or more compounds are suitable for a given application, price and stock availability may become determining factors. Current piece-price and in-stock availability can be obtained from your nearest Authorized Parker O-Ring Distributor.

Following this introduction are discussions on a number of special applications that require additional attention. It is recommended that the designer consult the applications listed and read carefully any of those paragraphs which apply to his application.

3.1 Factors Applying to All O-Ring Types

For the majority of standard applications, the design of the O-ring seal has generally already been accomplished. The necessary data for gland dimensions are simply selected from the tables in the sections on Static and Dynamic O-Ring Sealing, Sections IV and V, respectively. The value of making a detailed comparison between previously satisfactory installations and a new one cannot be over-emphasized. Such comparison should disclose any weak points where modification may be desirable or required, thus simplifying the process and facilitating the design effort.

The following paragraphs discuss the more important design factors that generally apply to all O-ring seals. Data and procedures enabling the designer to depart from the standard designs in order to meet peculiar requirements, or to obtain improved performance from the seal will also be found in this section.

Specific design and dimensional data applicable to static seals is provided in the Static O-Ring Sealing Section (IV), and information on dynamic seals is contained in the Dynamic O-Ring Sealing Section (V).

3.1.1 Compatibility

Compatibility between the O-ring and the fluid or fluids to be sealed must be the first consideration in the design process. If the fluid will have an *immediate* adverse effect (chemical reaction resulting in surface destruction, loss of strength, degradation, or other marked change in physical properties) resulting in shortened seal life, there is little advantage to be gained by proceeding further with the design until this basic problem is resolved.

If more than one fluid is involved, both the sequence of exposure and time of contact with the O-ring need be considered. If compatibility cannot be determined from specific data in this section or the Fluid Compatibility Tables in Section VII, refer the problem to your Parker Field Engineer, Parker O-Ring Distributor or contact the Application Engineering Department of the Parker O-Ring Division at (859) 269-2351.

3.1.2 Temperature

Operating temperature, or more properly, the *range* of system temperature, may require some minor modification of the gland design. Gland dimensions given in the static and dynamic seal design sections are calculated for the temperature ranges listed for standard compounds. If the operation is *only* to be at a high temperature, gland volume may need to be increased to compensate for thermal expansion of the O-ring. Conversely, for operation only at low temperature, a better seal may result by reducing the gland depth, thereby obtaining the proper squeeze on the contracted O-ring. Table 2-4, which lists the approximate rate of linear thermal expansion for typical elastomers and other materials, may be utilized to calculate compensated gland dimensions. For either high or low temperature seal designs, however, there must normally be sufficient squeeze to prevent leakage at room temperature. Figure 3-1 illustrates another possible type of design to improve low temperature sealing capability by spring loading the O-ring.

Such special designs for high and low temperature environments are seldom required. The minimum squeeze values for the various O-ring cross-section diameters given in the design charts of the static and dynamic seal design sections are generally satisfactory.

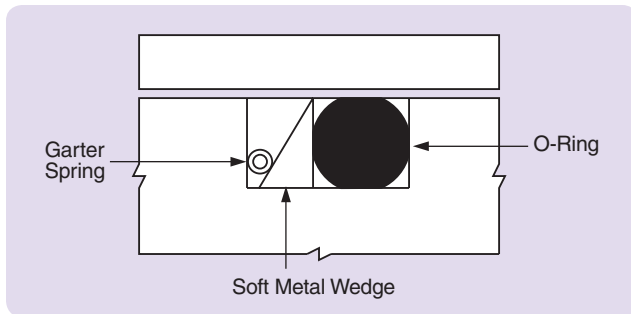


Figure 3-1: Spring-Loading for Low Temperature

3.1.3 Pressure

Pressure has a bearing on O-ring seal design as it can affect the choice of compound shore hardness. At very low pressures, proper sealing may be more easily obtained with lower durometer hardness (50-60 shore A). With higher pressures, the combination of pressure and material shore hardness determine the maximum clearance that may safely be tolerated (see Figure 3-2). Cyclic fluctuation of pressure can cause local extrusion of the O-ring resulting in "nibbling" (see Section X, Failure Modes), particularly if peak system pressures are high enough to cause expansion of the cylinder wall. One remedy may be to stiffen the cylinder to limit the expansion so that the bore to piston clearance does not exceed a safe value.

3.1.4 Extrusion

Extrusion of O-rings may also be prevented by the use of anti-extrusion (back-up) devices. These are thin rings of much harder material fitted into the gland between the seal and the clearance gaps, which essentially provide zero clearance. They are available in hard elastomer compounds, leather, PTFE, Nylon and other similar materials. Parker Parbaks® are elastomer back-up rings and are generally recommended based on their proven functional superiority. The exact point at which it becomes necessary to use anti-extrusion devices will depend on the pressure, type of elastomer being used, its Shore hardness, the size of the clearance gap, and the degree of "breathing" of the metal parts which will be encountered. Figure 3-2 may be used as a guide in determining whether or not anti-extrusion rings should be used. When using the data, include in the diametral clearance any "breathing," or expansion of the cylinder bore that may be anticipated due to pressure. Although based on data obtained from O-rings, the ninety durometer curve can also be used as a guide to back-up ring performance. The Parbak Back-Up Rings Section (VI), describes in greater detail Parker Parbak back-up rings, and provides size and part number data. Also see "Patterns of O-Ring Failure" in Section IX for more information on extrusion.

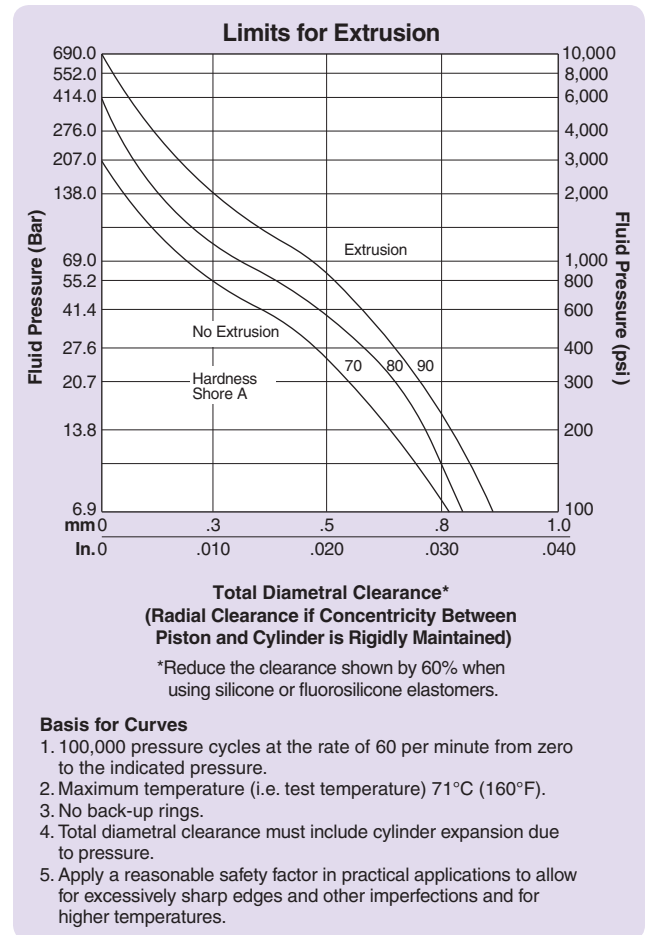


Figure 3-2: Limits for extrusion

3.1.5 Lubrication

Lubrication of O-ring seals is extremely important for installation and operation of dynamic seals as well as proper seating of static seals. The general rule for use of lubrication is: **The greatest benefit in using a lubricant is obtained during the initial installation of the O-ring.**

Lubricants are commonly used on O-rings and other elastomeric seals. Using a suitable grease or oil during assembly helps protect the O-ring from damage by abrasion, pinching, or cutting. It also helps to seat the O-ring properly, speeds up assembly operations, and makes automated assembly line procedures possible. An additional benefit is the protection that the lubricant provides as a surface film. Proper lubrication also helps protect some polymers from degradation by atmospheric elements such as ozone and its presence helps extend the service life of any O-ring. A lubricant is almost essential in pneumatic applications requiring dynamic service. In vacuum applications, appropriate lubricants help reduce the overall leak rate by filling the microfine inclusions of the gland's metal surfaces and lowering permeation rates of the elastomer.

Parker Seal offers two lubricants that will satisfy most service needs: Parker O-Lube and Parker Super-O-Lube. These two lubricants are described in the following paragraphs. Table 3-1 lists their key properties along with others used in specific types of services. Table 3-2 provides part number information for O-Lube and Super O-Lube.

Parker O-Ring Lubricants

O-Lube		Super-O-Lube	
Part Number	Description	Part Number	Description
OLUBE 884-2GRAMS	2 gr. tube	SLUBE 884-Grams	2 gr. tube
OLUBE .25OZ	¼ oz. tube	SLUBE .25OZ	¼ oz. tube
OLUBE 884-.50	½ oz. tube	SLUBE 884-.5	½ oz. tube
OLUBE 884-4	4 oz. tube	SLUBE 884-2	2 oz. tube
OLUBE 884-35	35 lb. pail	SLUBE 884-8	8 lb. can
OLUBE 884-400	400 lb. drum	SLUBE 884-40	40 lb pail

Note: MSDS are available at www.parkerorings.com

Table 3-2: O-Ring Lubricants

3.1.5.1 Parker O-Lube

Parker O-Lube is an outstanding general-purpose grease intended for use with O-ring and other seals in hydrocarbon service. It can also be used in pneumatic service. The useful temperature is from -29°C to 82°C (-20°F to 180°F).

3.1.5.2 Parker Super-O-Lube

Parker Super-O-Lube is an all-purpose O-ring lubricant. It is not a grease, but rather a high-viscosity silicone oil. It is especially useful as a seal lubricant. The temperature range is -54°C to 204°C (-65°F to 400°F).

Parker Super-O-Lube can be used as an assembly lubricant on all rubber polymers, including silicones. (Note: Silicones require special consideration.) In addition, Parker Super-

Lubricants

Type of Elastomer	Type of Service	Best	Manufacturer	Temp Range °F
NBR, Nitrile	Hydraulic Oils & Fuels Extreme Service Pneumatic Vacuum	O-Lube	Parker	-20 to 180
		Petrolatum	Many	-20 to 180
		Barium Grease	Many	-20 to 300
		Super O-Lube	Parker	-65 to 400
		DC-55	Dow Corning Co.	-65 to 275
		Celvacene	Consolidated Vacuum Corp.	-40 to 200
CR, Neoprene	Hydraulic Oils & Freon® Vacuum	O-Lube	Parker	-20 to 180
		Petrolatum	Many	-20 to 180
		Celvacene	Consolidated Vacuum Corp.	-40 to 200
EPDM	Skydrol® Steam & Hot Water	MCS-352	Aviation Fluid Service Co.	-65 to 300
		Super O-Lube	Parker	-65 to 400
		DC4, DC-7, DC55	Dow Corning Co.	+32 to 350
Silicone	General High Temperature	Petrolatum	Many	-20 to 300
		FS1292	Dow Corning Co.	-20 to 400
		Mil P 37649	Many	-20 to 180
Fluorosilicone	Oil or Fuel High Temperature	Petrolatum	Many	-65 to 350
		Super O-Lube	Parker	-65 to 400
		DC 4 or DC-7	Dow Corning Co.	+32 to 350
		Petrolatum	Many	-20 to 180
Fluorocarbon	Hydraulic Vacuum & High Temperature	Super O-Lube	Parker	-65 to 400
		DC-55	Dow Corning	-65 to 400

Notes: Assembly lubricants should always be used sparingly during application. A light film is all that is required. This is doubly important in cases 1 and 2 below.

1. When only a thin film of O-Lube is used for assembly purposes, the assembly may be subject to higher temperatures, with limits determined by the fluid and elastomer being used.

2. Use only a thin film of Super-O-Lube on silicone rubber if the temperature will exceed 149°C (300°F).

Table 3-1: Parker O-Ring Lubricants

Freon® is a registered trademark of E.I. du Pont de Nemours & Co.
Skydrol® is a registered trademark of Solutia Inc.

O-Lube has some unique advantages. It clings tenaciously to rubber or metal surface helping to prevent it from being flushed away by action of the system fluid. It has one of the widest temperature ranges of any seal lubricant available. It can be used for high pressure systems or in **hard vacuum environments**. Super-O-Lube's inert nature lends itself to a wide variety of fluid systems. Since there are no organic fillers, there can be no clogging of microfilters.

In addition to its outstanding performance in internal service, Parker Super-O-Lube gives protection to rubber polymers that are normally age sensitive when exposed to the atmosphere. This is a typical concern with ozone sensitive polymers that require age control.

There are special situations that may exist where one of the two Parker lubricants would **not** be the best recommendation. For instance, there may be a need for a special high vacuum grease, or a lubricant that would be especially suited to phosphate ester service. For guidance in handling these unique situations consult a Parker O-Ring Division Application Engineer.

Before selecting a lubricant (other than the primary fluid being sealed) for use with O-rings, determine that it meets the following requirements:

1. It or any additives that it contains, should not cause shrinkage or excessive swelling of the O-ring compound being used.
2. It should not excessively soften or solidify over the anticipated service temperature range.
3. It should not break-down and leave gummy or gritty deposits after cycling, or show any adverse chemical reaction with the primary fluid being sealed.
4. It should be capable of forming a thin, strong (high surface tension) film over the metal being lubricated that the O-ring's dynamic motion cannot wipe away.
5. It should pass through any filters used in the system.

3.1.5.3 PTFE Coatings

PTFE coatings of O-rings is an ideal low-friction coating where operational flexibility is a major consideration. PTFE also offers additional benefits such as:

- Positive identification at the assembly line
- Ease of installation
- Lower break-in torques
- Reduces costly "hang-ups" on automatic systems
- Lower initial running friction
- Eliminates sticking of components after long storage
- Reduces twisting of rings during installation

The following colors are available: standard blue, medium blue, light blue, white, purple, red, yellow, medium green, dark green, grey, clear, black, orange, brown umber, pink and green/gold.

3.1.5.4 Other Friction Reduction Methods

Besides O-Lube and Super-O-Lube, Parker Seal can supply O-rings that have received various friction reducing treatments. These may include internal lubrication and Parker's Proprietary Lube Treatment. Both are valuable aids for automated assembly operations, and may also be used in many types of applications to reduce friction in service.

Note: While it is always preferable to use a lubricant, keep in mind that there are certain systems in which lubricants would introduce unacceptable contamination, such as semiconductor fabrication and processing equipment or medical and food processing devices.

3.1.5.5 Internal Lubrication

Internal lubrication involves the incorporation of friction reducing ingredients into the elastomer formula. Since this process alters the material's chemistry, Parker's internally lubricated materials are assigned unique compound numbers to differentiate them from their non-lubricated counterparts.

Internal lubricants consist of organic materials such as graphite, molybdenum disulfide, powdered PTFE or, more commonly, a proprietary Parker organic lubricant. Because the lubricant is dispersed throughout the body of an O-ring, this method of friction reduction generally functions longer in service than external lubrication, but to a somewhat lesser degree.

Graphite-impregnated compounds are commonly used to seal rotary shafts. It should not however, be used in contact with stainless steel surfaces because graphite tends to cause corrosive pitting of stainless materials. For such applications, compounds containing molybdenum disulfide are often a successful alternative.

Compound V0848-75 contains powdered PTFE to reduce friction.

Compounds containing this organic lubricant have become quite popular. PTFE migrates through the O-ring and gradually blooms to the surface, prolonging its lubricating effectiveness. It takes a long time to degrade a significant portion of the coating when it is lost only through the mechanical action of the mating surface. Fluids, however, tend to dissolve it, and some solvents can leach out much of the internal lubricant in a short time.

Internally lubricated compounds, where applicable, are available from the O-Ring Division.

3.1.6 Accessories

3.1.6.1 Extraction Tools

These unique double-ended tools make life easier for those who have to frequently install or remove O-rings from hydraulic or pneumatic cylinders and equipment. They are available in brass or plastic with or without a convenient carrying case.

3.1.6.2 O-Ring Sizing Cone

A unique measuring cone and circumference “Pi” tape provide quick and easy o-ring sizing information to determine the nearest standard Parker o-ring size. Please note: the cone and tape do not measure actual dimensions of a part and cannot be used for pass/fail inspections. See table 3-3 for part number information.

3.1.6.3 O-Ring Kits

When part numbers are missing, seal dimensions are unknown, and the parts themselves are unavailable from the equipment OEM, these o-ring kits can save the day, not to mention hours of downtime. More than eight different standard kits give you a choice of compounds and o-ring sizes for a wide range of sealing applications. The end result? Multiple sealing solutions for the same cost as a single OEM replacement part. We’ll even build custom kits using any of our 200-plus compounds. Please see table 3-4 through table 3-7 for detailed kit information.

O-Ring Extraction Tools and Cone Part Numbers

Part Number	Description
Brass Extraction Kit	Brass extraction pick and spat in plastic pouch
Plastic O-ring Pick	Plastic extraction pick
Plastic Sizing Cone	O-ring sizing kit

Notes: Private labeling is available.

Table 3-3: Extraction Tools and Cone Part Numbers

O-Ring Kits

Part Number	Description
Plastic Std. Kit E0515	Compound E0515-80 EPDM 80 durometer O-rings per NAS 1613 rev. 2 in 37 popular AS568 sizes / 513 O-rings
Plastic Std. Kit N0552	Compound N0552-90 NBR 90 durometer O-rings in 37 popular AS568 sizes / 513 O-rings
Plastic Std. Kit N0674	Compound N0674-70 NBR 70 durometer O-rings in 37 popular AS568 sizes / 513 O-rings
Plastic Std. Kit V0747	Compound V0747-75 FKM 75 durometer O-rings in 37 popular AS568 sizes / 513 O-rings
Plastic Std. Kit V0884	Compound V0884-75 FKM (brown) 75 durometer O-rings in 37 popular AS568 sizes / 513 O-rings
N1470 AS568 Kit #1	Compound N1470-70 NBR 70 durometer in 30 popular sizes / 382 O-rings
N1470 Metric Kit #1	Compound N1470-70 NBR 70 durometer in 32 popular metric sizes / 372 O-rings
N1490 Boss Kit	Compound N1490-90 NBR 90 durometer in 20 standard tube fitting sizes

Note: Boxes and plugs are available as separate items.

Table 3-4: O-Ring Kits

AS568 Kit #1 Sizes

Size	Dimensions	Quantity
2-006	0.114 x .070	20
2-007	0.145 x .070	20
2-008	0.176 x .070	20
2-009	0.208 x .070	20
2-010	0.239 x .070	20
2-011	0.239 x .070	20
2-012	0.364 x .070	20
2-110	0.362 x .103	13
2-111	0.424 x .103	13
2-112	0.487 x .103	13
2-113	0.549 x .103	13
2-114	0.612 x .103	13
2-115	0.674 x .103	13
2-116	0.737 x .103	13
2-210	0.734 x .139	10
2-211	0.796 x .139	10
2-212	0.859 x .139	10
2-213	0.921 x .139	10
2-214	0.984 x .139	10
2-215	1.046 x .139	10
2-216	1.109 x .139	10
2-217	1.171 x .139	10
2-218	1.234 x .139	10
2-219	1.296 x .139	10
2-220	1.359 x .139	10
2-221	1.421 x .139	10
2-222	1.484 x .139	10
2-225	1.475 x .210	7
2-226	1.600 x .210	7
2-227	1.725 x .210	7

Table 3-5: AS568 Kit #1 Sizes

Parker Metric Kit #1 Sizes

Dimensions	Quantity	Dimensions	Quantity
3.00 x 2.00	20	22.00 x 2.50	14
5.00 x 2.00	20	22.00 x 3.50	10
6.00 x 2.00	18	23.00 x 3.50	10
8.00 x 2.00	18	25.00 x 3.50	10
10.00 x 2.00	18	27.00 x 3.50	10
10.00 x 2.50	14	28.00 x 3.50	10
12.00 x 2.50	14	30.00 x 3.50	10
13.00 x 2.00	18	31.00 x 3.50	10
14.00 x 2.50	14	32.00 x 3.50	10
15.00 x 2.50	14	34.00 x 3.50	10
16.00 x 2.50	14	36.00 x 3.50	10
18.00 x 2.50	14	38.00 x 3.50	10
18.00 x 3.50	10	41.00 x 3.50	10
20.00 x 2.50	14	44.00 x 3.50	10
20.00 x 3.50	10	46.00 x 3.50	10
21.00 x 2.50	14	50.00 x 3.50	10

Table 3-6: Parker Metric Kit #1 Sizes

Parker Boss Kit Sizes

Size	Dimensions	Tube OD	Quantity
3-901	0.185 x .056	$\frac{3}{32}$	10
3-902	0.239 x .064	$\frac{1}{8}$	10
3-903	0.301 x .064	$\frac{3}{16}$	10
3-904	0.351 x .072	$\frac{1}{4}$	10
3-905	0.414 x .072	$\frac{5}{16}$	12
3-906	0.468 x .078	$\frac{3}{8}$	12
3-907	0.530 x .082	$\frac{7}{16}$	12
3-908	0.644 x .087	$\frac{1}{2}$	12
3-909	0.706 x .097	$\frac{9}{16}$	12
3-910	0.755 x .097	$\frac{5}{8}$	12
3-911	0.863 x .116	$1\frac{1}{16}$	10
3-912	0.924 x .116	$\frac{3}{4}$	10
3-913	0.986 x .116	$1\frac{3}{16}$	10
3-914	1.047 x .116	$\frac{7}{8}$	10
3-916	1.171 x .116	1	10
3-918	1.355 x .116	$1\frac{1}{8}$	10
3-920	1.475 x .118	$1\frac{1}{4}$	10
3-924	1.720 x .118	$1\frac{1}{2}$	10
3-928	2.090 x .118	$1\frac{3}{4}$	10
3-932	2.337 x .118	2	10

Table 3-7: Parker Boss Kit Sizes

3.2 Cleanliness

Cleanliness is vitally important to assure proper sealing action and long O-ring life. Every precaution must be taken to insure that all component parts are clean at time of assembly. Foreign particles — dust, dirt, metal chips, grit, etc. — in the gland may cause leakage and can damage the O-ring, reducing its life.

It is equally important to maintain clean hydraulic fluids *during* the normal operation of dynamic seal systems. Costly shut downs necessitated by excessive seal wear and requiring early seal replacement may be prevented by the use of effective filters in the fluid power system as well as installing wiper rings on actuating rods exposed to external dust, dirt and other contaminants.

3.3 Assembly

Assembly must be done with great care so that the O-ring is properly placed in the groove and is not damaged as the gland assembly is closed. Some of the more important design features to insure this are:

1. The I.D. stretch, as installed in the groove, should not be more than 5%. Excessive stretch will shorten the life of most O-ring materials. Also, see Figure 3-3 for data on the flattening effect produced by installation stretch.
2. The I.D. expansion needed to reach the groove during assembly ordinarily does not exceed 25-50% and should not exceed 50% of the ultimate elongation of the chosen compound. However, for small diameter O-rings, it may be necessary to exceed this rule of thumb. If so, sufficient time should be allowed for the O-ring to return to its normal diameter before closing the gland assembly.
3. The O-ring should not be twisted. Twisting during installation will most readily occur with O-rings having a large ratio of I.D. to cross-section diameter.
4. O-rings should never be forced over unprotected sharp corners, threads, keyways, slots, splines, ports, or other sharp edges. If impossible to avoid by proper design, then thimbles, supports, or other shielding arrangements must be used during assembly to prevent damage to the seal. See Figure 3-4.
5. Closure of the gland assembly must not pinch the O-ring at the groove corners.
6. Gland closure should be accomplished by straight longitudinal movement. Rotary or oscillatory motion is undesirable since it may cause bunching, misalignment and pinching or cutting of the seal.

3.4 Selecting the Best Cross-Section

In designing an O-ring seal, there are usually several standard cross-section diameters available. There are a number of factors to consider in deciding which one to use, and some of these factors are somewhat contradictory.

In a dynamic, reciprocating application, the choice is automatically narrowed because the design charts and tables do not include all the standard O-ring sizes. For any given piston or rod diameter, O-rings with smaller cross-section diameters are inherently less stable than larger cross-sections, tending to twist in the groove when reciprocating motion occurs. This leads to early O-ring spiral failure and leakage. The smaller cross-sections for each O-ring I.D. dimension are therefore omitted in the reciprocating seal design tables.

Nevertheless, for many dynamic applications, there is still some choice as to cross-section, and the larger cross-sections will prove to be the more stable. Counterweighing this factor, is the reduced breakaway and running friction obtainable with a smaller cross-section O-ring. These and other factors to be considered are tabulated on Table 3-8.

Effects of Cross Section

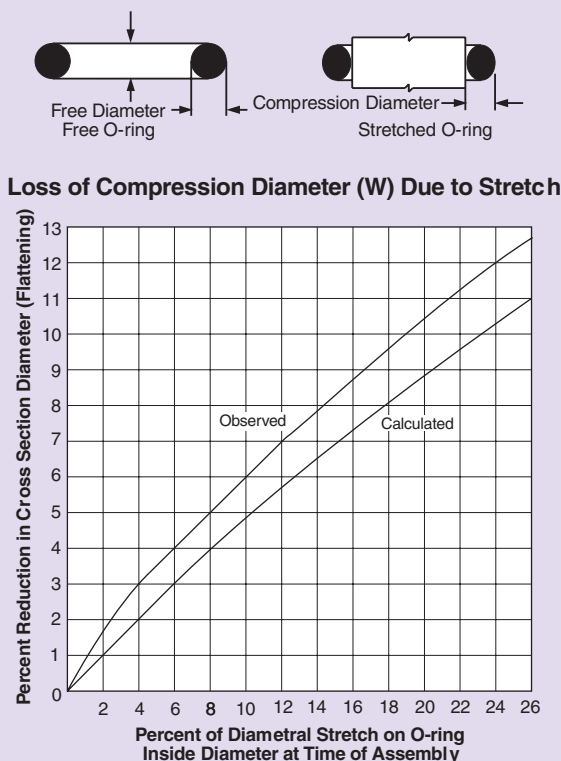
Larger Section	Smaller Section
Dynamic Reciprocating Seals	
More stable	Less stable
More friction	Less friction
All Seals	
Requires larger supporting structure	Requires less space — reduces weight
Better compression set ⁽¹⁾	Poorer compression set ⁽¹⁾
Less volume swell in fluid	More volume swell in fluid
Less resistant to explosive decompression	More resistant to explosive decompression
Allows use of larger tolerances while still controlling squeeze adequately	Requires closer tolerances to control squeeze. More likely to leak due to dirt, lint, scratches, etc.
Less sensitive to dirt, lint, scratches, etc.	Better physical properties ⁽²⁾
Poorer physical properties ⁽²⁾	
Cost and availability are other factors to consider, and these would need to be determined for the particular sizes being considered.	

- (1) Particularly true for nitrile and fluorocarbon elastomers. Doubtful for ethylene propylenes and silicones.
 (2) Applies to tensile and elongation of nitriles, elongation of fluorocarbons.

Table 3-8: Effects of Cross Section

3.5 Stretch

When an O-ring is stretched, its cross-section is reduced and flattened. When the centerline diameter is stretched more than two or three percent, the gland depth must be reduced to retain the necessary squeeze on the reduced and flattened cross-section. The "observed" curve shown in Figure 3-3 indicates how much the compression diameter is reduced. The necessary percentage of squeeze should be applied to this corrected compression diameter, reducing the gland depth below the recommended dimensions shown in the standard design charts.



The "observed" curve is reproduced by courtesy of the Research Laboratories of General Motors Corporation at the General Motors Technical Center in Warren, Michigan. This curve is based on a statistical analysis of a much larger volume of experimental data than has been available previously.

In the stretched condition, an O-ring cross section is no longer circular. It is often necessary to compensate for the loss in squeeze resulting from the reduced "compression diameter." Dimensional changes in the "free diameter" do not affect the seal.

Empirical formulas for observed curve:

0 to 3% Inside Dia. Stretch:

$$Y = -0.005 + 1.19X - 0.19X^2 - 0.001X^3 + 0.008X^4$$

3 to 25% Inside Dia. Stretch:

$$Y = .56 + .59X - .0046X^2$$

Where X = percent stretch on inside diameter

(i.e. for 5% stretch, X = 5)

Y = percent reduction in cross section diameter.

The calculated curve is based on the assumption that the O-ring section remains round and the volume does not change after stretching.

$$\text{Formula: } Y = 100 \left(1 - \frac{10}{\sqrt{100 + X}} \right)$$

Figure 3-3: Loss of Compression Diameter (W) Due to Stretch

Note: Figure 3-3 is valid for approximation purposes and even the majority of O-ring applications. However, more recent research has been done for the low stretch cases (i.e., 0–5%) where the observed values conform to a more complex hyperbolic function. For more information, refer to inPHorm seal design and material selection software.

Extra stretch may be necessary when a non-standard bore or rod diameter is encountered. In male gland (piston type) assemblies of large diameter, the recommended stretch is so slight that the O-ring may simply sag out of the groove. There is then the danger of pinching if the O-ring enters the bore "blind," i.e. in a location where the seal cannot be watched and manually guided into the bore. For large diameter assemblies of this kind, it is well to use an O-ring one size smaller than indicated, but then the gland depth must be reduced as indicated above because the stretch may approach five percent.

Proper Designs for Installation of O-rings

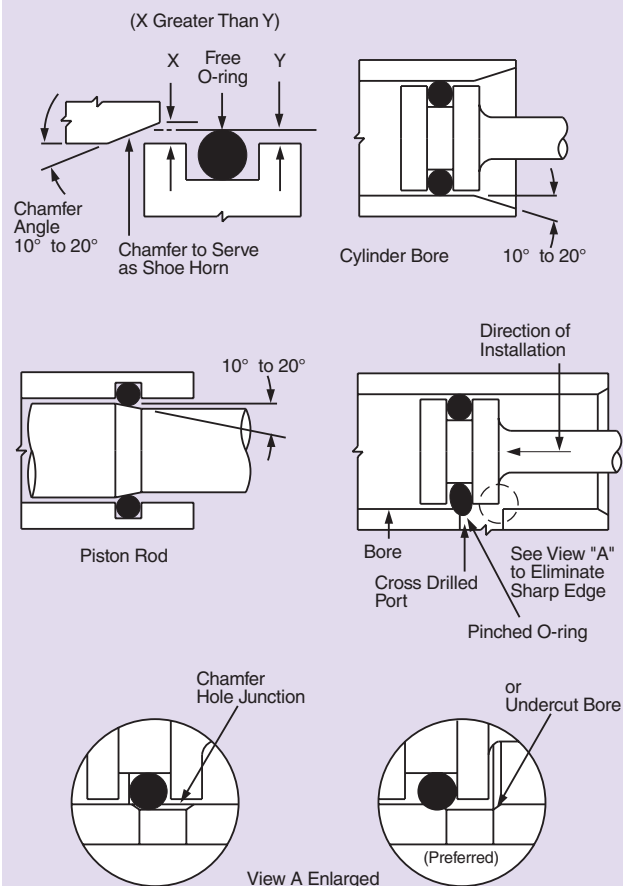


Figure 3-4: Proper Designs for Installation of O-rings

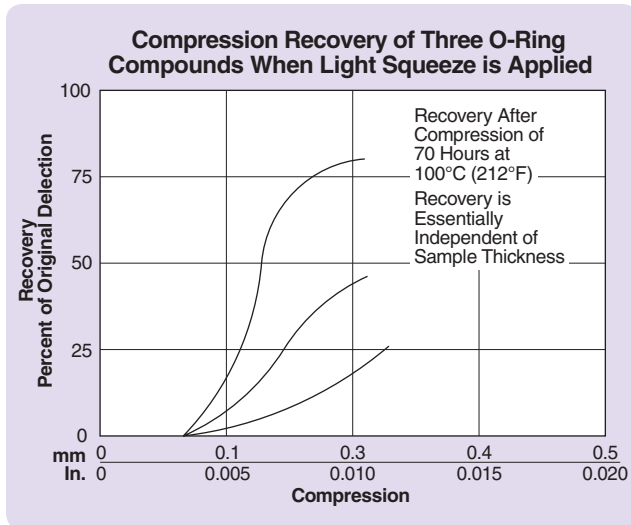


Figure 3-5: Compression Recovery of Three O-ring Compounds When Light Squeeze is Applied

An assembled stretch greater than five percent is not recommended because the internal stress on the O-ring causes more rapid aging. Over five percent stretch may sometimes be used, however, if a shorter useful life is acceptable.

Of the commonly used O-ring seal elastomers, the reduction in useful life is probably greatest with nitrile materials. Therefore, where high stretch is necessary, it is best to use ethylene propylene, fluorocarbon, polyurethane or neoprene, whichever material has the necessary resistance to the temperatures and fluids involved.

3.6 Squeeze

The tendency of an O-ring to attempt to return to its original uncompressed shape when the cross-section is deflected is the basic reason why O-rings make such excellent seals. Obviously then, squeeze is a major consideration in O-ring seal design.

In dynamic applications, the *maximum* recommended squeeze is approximately 16%, due to friction and wear considerations, though smaller cross-sections may be squeezed as much as 25%.

When used as a static seal, the maximum recommended squeeze for most elastomers is 30%, though this amount may cause assembly problems in a radial squeeze seal design. In a face seal situation, however, a 30% squeeze is often beneficial because recovery is more complete in this range, and the seal may function at a somewhat lower temperature. There is a danger in squeezing much more than 30% since the extra stress induced may contribute to early seal deterioration. Somewhat higher squeeze may be used if the seal will not be exposed to high temperatures nor to fluids that tend to attack the elastomer and cause additional swell.

The minimum squeeze for all seals, regardless of cross-section should be about .2 mm (.007 inches). The reason is that with a very light squeeze almost all elastomers quickly take 100% compression set. Figure 3-5 illustrates this lack of

recovery when the squeeze is less than .1 mm (.005 inch). The three curves, representing three nitrile compounds, show very clearly that a good compression set resistant compound can be distinguished from a poor one only when the applied squeeze exceeds .1 mm (.005 inches).

Most seal applications cannot tolerate a “no” or zero squeeze condition. Exceptions include low-pressure air valves, for which the floating pneumatic piston ring design is commonly used, and some rotary O-ring seal applications. See the Dynamic O-Ring Sealing, Section V, and Tables A6-6 and A6-7 for more information on pneumatic and rotary O-ring seal design.

3.7 Gland Fill

The percentage of gland volume that an O-ring cross-section displaces in its confining gland is called “gland fill”. Most O-ring seal applications call for a gland fill of between 60% to 85% of the available volume with the optimum fill being 75% (or 25% void). The reason for the 60% to 85% range is because of potential tolerance stacking, O-ring volume swell and possible thermal expansion of the seal. It is essential to allow at least a 10% void in any elastomer sealing gland.

3.8 O-Ring Compression Force

The force required to compress each linear inch of an O-ring seal depends principally on the shore hardness of the O-ring, its cross-section, and the amount of compression desired. Even if all these factors are the same, the compressive force per linear inch for two rings will still vary if the rings are made from different compounds or if their inside diameters are different. The anticipated load for a given installation is not fixed, but is a range of values. The values obtained from a large number of tests are expressed in the bar charts of Figures 2-4 through 2-8 in Section II. If the hardness of the compound is known quite accurately, the table for O-ring compression force, Table 2-3 may be used to determine which portion of the bar is most likely to apply.

Increased service temperatures generally tend to soften elastomeric materials (at least at first). Yet the compression force decreases very little except for the hardest compounds. For instance, the compression force for O-rings in compound N0674-70 decreased only 10% as the temperature was increased from 24°C (75°F) to 126°C (258°F). In compound N0552-90 the compression force decrease was 22% through the same temperature range.

Refer to Figure 3-6 for the following information:

The dotted line indicates the approximate linear change in the cross section (W) of an O-ring when the gland prevents any change in the I.D. with shrinkage, or the O.D., with swell. Hence this curve indicates the change in the effective squeeze on an O-ring due to shrinkage or swell. Note that volumetric change may not be such a disadvantage as it appears at first glance. A volumetric shrinkage of six percent results in only three percent

linear shrinkage when the O-ring is confined in a gland. This represents a reduction of only .003" of squeeze on an O-ring having a .103" cross-section (W) dimension. The solid lines indicate linear change in both I.D. and cross-section for a free-state (unconfined) O-ring.

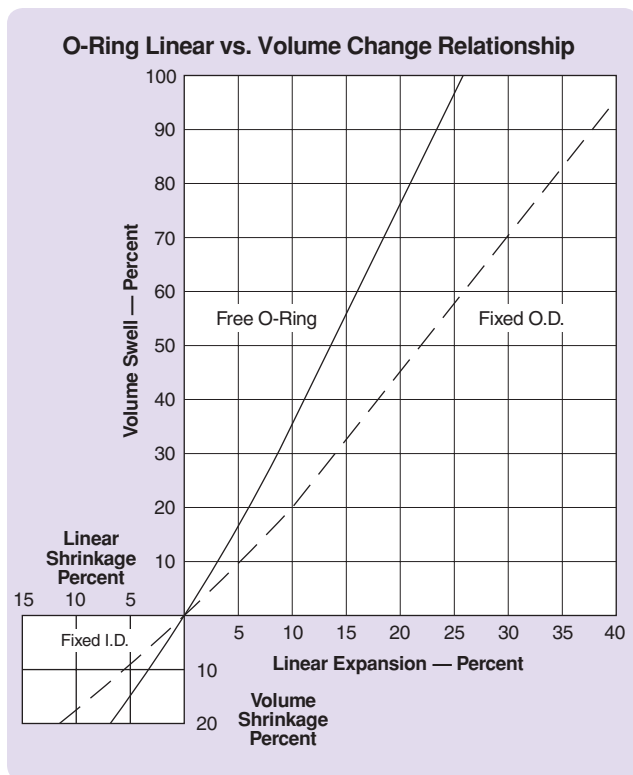


Figure 3-6: O-ring Linear vs. Volume Change Relationship

3.9 Specific Applications

3.9.1 Automotive

The types of elastomer compound required by this industry are numerous and the variety of applications quite extensive. The following examples can be viewed as a brief analysis of the problems found in the automotive industry.

The demands made on an elastomer at high and low temperatures are even greater than normal while compatibility with new chemical additives which improve the physical properties of automotive fuels and oils, require continuous improvement in elastomeric compounds for automotive service.

The selection of the proper O-ring compound depends on the temperature at the sealing interface and of the contact medium. Each group of elastomers have a working range of temperatures.

The low temperature requirements for many automotive applications are often below the brittleness point for elastomers like FKM, ACM and NBR. However, static applications, leakage at low temperatures may not occur because of O-ring deformation and the high viscosity of the sealed medium. The critical temperature often is bridged when the seal warms quickly in service.

3.9.2 Engine

See Table 3-9.

General requirements:

Temperature: -40°C to 125°C (-40°F to 250°F)
(sometimes higher)

Medium: Engine oil, cooling water, fuel, hot air and mixtures of these media

Engine Applications

		Compounds	
Application	Medium	Temperature Range °C (°F)	ASTM D1418 Parker
Motor oil Oil filter	SAE-Oils	-35°C to 110°C (-31°F to 230°F)	NBR N0674-70
		-30°C to 120°C (-22°F to 248°F)	NBR N0951-75
		-25°C to 200°C (-13°F to 392°F)	FKM V1164-75
		-25°C to 150°C (-13°F to 392 °F)	ACM AA150-70
Wet cylinders (Diesel)	Water/ Oil	-30°C to 100°C (-22°F to 212°F)	NBR N0951-75
		-25°C to 120°C (-13°F to 248°F)	FKM V1164-70
Air-filter	Air/Fuel	-35°C to 90°C (-31°F to 194°F)	NBR N0674-70
		-60°C to 210°C (-76°F to 410°F)	VMQ S1224-70

Table 3-9: Engine Applications

3.9.3 Brake System

General requirements:

Temperature: -40°C to 150°C (-40°F to 302°F)

Medium: Synthetic brake fluid (Dot3, Dot4, Dot5)
with glycol or glycol-ether base to
Department of Transportation and
SAE recommendations

Compound: E0667-70, E1022-70

3.9.4 Fuel System

Gasoline and diesel fuels are used in normal commercial vehicles. Fuels are more aggressive than mineral oils and cause higher swelling of the elastomer which increases with temperature. Swelling of an elastomer in fuel is, however, generally reversible when the absorbed fuel vaporizes completely. When parts of a compound are dissolved or leached out of the elastomer however, shrinkage takes place which is permanent. If a nitrile-based compound is required, a compound must be selected which contains minimum amounts of plasticisers, anti-aging or anti-ozone additives. By careful selection of the seal compound, the tendency to shrinkage or cold brittleness is avoided.

3.9.5 Fuels for Automobile Engines

There are several automotive fuels on the market; gasoline (which can contain 10-20% ethanol), ethanol/E85, diesel and biodiesel are the most common. Parker is at the forefront in testing elastomer materials for use in traditional and alternative fuels. For the latest information and test data regarding this rapidly changing industry, please contact Parker's O-Ring Division.

The best rubber compound to use depends not only on the fuel itself, but also on the temperature range anticipated and the type of usage; i.e. whether in a static or a dynamic application. In automotive fuel applications, extremely high temperatures are not anticipated, but in northern climates, temperatures as low as -40°C (-40°F) or even -54°C (-65°F) are sometimes encountered.

Most of the compounds recommended for use in fuel have rather poor low temperature capability in air, but in a fluid that swells them the low temperature capability improves. In studying the effects of volume swell on low temperature, it was found that for each percent of volume swell in a fuel, the low temperature capability (TR-10) was improved between 0.5°C and 1°C (1°F and 2°F).

The TR-10 value is a good indicator of the low temperature limit of a dynamic seal or a static seal exposed to pulsating pressure. In a static steady pressure application, an O-ring will generally function to a temperature approximately 8°C (15°F) lower than the TR-10 temperature.

The volume swell chart that follows, therefore, can be used to approximate the low temperature capability of a given compound in a given automotive fuel. The results will not be precise because the effect of volume swell on the TR-10 value is not precise, and also because the composition of the fuels themselves is not uniform.

In static applications, even in most extreme volume cases, swell can sometimes be tolerated. An O-ring can swell only until it completely fills the cavity. Further increase in volume is not possible, regardless of how much volume swell

is observed in a full immersion test. If the free state swell exceeds 50 percent, however, a radial squeeze assembly may be almost impossible to take apart because of the osmotic forces generated.

In dynamic applications, volume swell up to 15 or 20 percent is usually acceptable, but higher values are likely to increase friction and reduce toughness and abrasion resistance to the point that use of the particular compound is no longer feasible.

With these factors in mind, the data in Table 3-10 can be helpful in finding a suitable compound to use in a given automotive fuel application.

3.9.6 Transmission

General requirements:

- Temperature: 90°C (158°F)
(short periods up to 150°C) (302°F)
- Medium: Gear oil (reference oil SAE 90)

For automatic transmission:

- Medium: ATF oil (Automatic Transmission Fluid)
- Compound: N0674-70, N0552-90, AA150-70, AE152-70 (Vamac), V1164-75, V0884-75 (brown)

3.9.7 Cooling and Heating Systems

General requirements:

- Temperature: -40°C to 100°C (-40°F to 212°F)
(short periods up to 120°C (257°F))
- Medium: a) Water-glycol mixture 1:1 (with 1 to 2% corrosion retarding additives)
- Medium: b) Water-ethylene glycol mixture 1:1 (Prestone® antifreeze)
- Compound: E0803-70

Volume Swell of Compounds

Compound No.	47-071 ⁽²⁾	N0497-70	N0674-70 ⁽²⁾	V0747-75 ⁽²⁾	V0834-70
TR-10 in air	-40°F	-23°F	-15°F	+5°F	+5°F
FUEL					
Unleaded gasoline	12%	14%	36%	1%	1%
Unleaded +10% ethanol ⁽³⁾	26%	24%	53%	5%	2%
Unleaded +20% ethanol	24%	24%	56%	4%	5%
Unleaded +10% methanol	35%	33%	66%	14%	16%
Unleaded +20% methanol	32%	30%	67%	26%	36%

(1) Volume swell of 2-214 O-ring immersed in the fuel for 70 hours at room temperature.

(2) Stock standard compounds. Generally available off-the-shelf.

(3) The "gasohol" mixture most commonly used in the United States consists of unleaded gasoline plus 10% ethanol (ethyl alcohol).

Table 3-10: Volume Swell of Compounds

Prestone® is a registered trademark of Prestone Products Corporation.



3.9.8 Air Conditioning

Automotive A/C units are almost exclusively charged with refrigerant R134a, whereas existing units are generally filled with the older (and now banned in US) R12 Freon refrigerant.

Special oils are added to the refrigerant in order to lubricate the compressor: R134a systems use mostly polyalkylene glycol oils, whereas R12 systems employ mostly mineral oils.

General requirements:

Temperature: -40°C to 80°C (-40°F to 175°F)

Medium: refrigerant R134a
refrigerant R12
polyalkylene glycol oil
mineral oil

Compound: C0873-70, N1173-70

3.9.9 Power Steering Systems

General requirements:

Temperature: Up to 120°C (-40°F to 257°F)
(short periods up to 150°C (302°F))

Medium: Power steering fluid

Compound: N0674-70, N0552-90, AA150-70,
AE152-70 (Vamac), V1164-75,
V0884-75 (brown)

Compound Recommendation for Refrigerants

Fluorinated Hydrocarbons Refrigerant (R)	ASTM D1418	Parker
11	NBR	N0674-70
12	CR	C0873-70
12 and ASTM oil no. 2 (mixed 50:50)	FKM	V1164-75
12 and Suniso 4G (mixed 50:50)	FKM	V1164-75
13	CR	C0873-70
13 B1	CR	C0873-70
14	CR	C0873-70
21	CR	C0873-70
22	CR	C0873-70
22 and ASTM oil no. 2 (mixed 50:50)	CR	C0873-70
31	CR	C0873-70
32	CR	C0873-70
112	FKM	V1164-75
113	CR	C0873-70
114	CR	C0873-70
114 B2	CR	C0873-70
115	CR	C0873-70
502	CR	C0873-70
134a	CR	C0873-70
BF (R112)	FKM	V1164-75
C318	CR	C0873-70
K-152a	CR	C0873-70
K-142b	CR	C0873-70
MF (R11)	NBR	N0674-70
PCA (R113)	CR	C0873-70
TF (R113)	CR	C0873-70

Table 3-11: Compound Recommendation for Refrigerants

Frigen® is a registered trademark of Canadian Hoechst Limited Corporation.

Kaltron® is a registered trademark of Joh A. Benckiser GMBH Joint Stock Company.

Oils are preferred which tend to have a constant viscosity over a wide temperature range. These highly developed oils can be very aggressive.

FKM or ACM based materials are often preferred when high operating temperatures are involved.

3.9.10 Refrigeration and Air Conditioning

Seals used in cooling systems should be fully compatible with the refrigerant. Refrigerants often are coded "R" and consist of fluids based on fluorinated and chlorinated hydrocarbons.

Trade names, e.g. Freon, Frigen®, Kaltron® are used together with the type number.

Examples:

- R13 corresponds to Freon 13 and Kaltron 13
- R13 B1 corresponds to Freon 13 B1, Frigen 13 B1 and Kaltron 13 B1

Fire extinguishers are propelled with Halon R1301 corresponding to Freon 13 B1.

Several of these refrigerants also are used as propellants in aerosol containers. Further information on compounds can be found in the Fluid Compatibility Tables in Section VII. See Table 3-11.

3.9.11 Food, Beverage and Potable Water

The Food and Drug Administration (FDA) has established a list of rubber compounding ingredients which tests have indicated are neither toxic nor carcinogenic (cancer producing). Rubber compounds produced entirely from these ingredients and which also pass the FDA extraction tests are said to "meet the FDA requirements" per 21 CFR177.2600. The FDA does not approve rubber compounds. It is the responsibility of the manufacturer to compound food grade materials from the FDA list of ingredients and establish whether they pass the necessary extraction requirements.

3-A Sanitary Standards have been formulated by the United States Public Health Service, the International Association of Milk Food and Environmental Standards, and the Dairy and Food Industries Supply Association. A similar document, E-3A Sanitary Standards, was later formulated by this same group plus the United States Department of Agriculture and the Institute of American Poultry Industries. The 3-A standards are intended for elastomers to be used as product contact surfaces in dairy equipment, while the E-3A standards are intended for elastomers used as product contact surfaces in egg processing equipment. The requirements of the two specifications are essentially identical, the intent in each case being to determine whether rubber materials are capable of being cleaned and receiving an effective bactericidal treatment while still maintaining their physical properties after repeated applications of the cleaning process chemicals.

Parker Seal produces a number of compounds that meet FDA requirements, and the most popular of these have been tested to the 3-A and E-3A standards. Information on some of these and other Parker food grade compounds is contained in Table 3-12 to assist the user in selecting the most suitable compound for their particular food application.

Parker Compounds that Meet FDA Requirements			
Polymer	FDA Compound Number	3A and E3A Classes	Color/Other Features
Ethylene Propylene	E1028-70	NT ⁽¹⁾	Black
Fluorocarbon	V0680-70	1,2,3,4	Red/USDA
Nitrile	N1069-70	NT ⁽¹⁾	Black
	N1219-60	NT ⁽¹⁾	Black
	N1220-70	NT ⁽¹⁾	Black
	N0508-75	1,2,3,4	Black, USDA ⁽²⁾
Silicone	S0802-40	2,3,4	White
	S0317-60	1,2,3,4	Rust/ZZ-R-765, Classes 1A, 1B, 2A, 2B/USDA
	S1138-70	NT ⁽¹⁾	Rust
	S0355-75	1,2,3,4	Rust/USDA ⁽²⁾

(1) NT = Not tested

(2) USDA = Declared "chemically acceptable" by United States Department of Agriculture, Animal and Plant Health Inspection Service, Meat and Poultry Inspection Program. "They may be used in processing or storage areas for contact with meat or poultry food product prepared under Federal inspection..."

Table 3-12: Parker Compounds That Meet FDA Requirements

National Sanitation Foundation

Additional requirements have been imposed upon seal manufacturers regarding food, beverage and potable water service. NSF 51, Food and Beverage, and NSF 61, Potable Water, deal with indirect additives that may arise by migration into food, beverage and potable water from rubber, plastic, metal or other materials. Parker Seal has developed a number of compounds, which meet NSF 51 and NSF 61 requirements. Some of these are listed below.

NSF 51 Certified Materials	NSF 61 Certified Materials
N1219-60	N0757-70
N1220-70	E3609-70
V0680-70	E1244-70
E3609-70	E1512-70
	E1549-70
	E1561-60
	E1571-70
	E1570-70
	E1583-70
	EJ273-70
	EJ274-70

3.9.12 Aerospace Technology

The aerospace industry demands the most from elastomeric compounds. Special materials often must be developed to meet specification requirements. Additionally many special requirements must be met during the production of finished parts, not least to meet safety, technical and quality requirements.

Our experience in aerospace sealing has been gained by working with a variety of global airframe and jet engine customers and as well as being represented on a number of standardization committees.

3.9.12.1 Jet Fuels

In static applications, jet fuels can generally be sealed with nitrile O-ring materials such as Parker's N0602-70. In the older jet fuels, such as JP-3, JP-4, and JP-5, and the later JP-8 and RJ-4, the swell seldom exceeds 20%. In JP-9 and JP-10, the normal volume swell is 24 to 40%. In a standard O-ring cavity, the rubber is confined, and cannot swell to this extent. The standard cavities have at least 10% excess void, allowing the O-rings to swell this amount before they are contained. This extra space greatly reduces the pressures that can be generated by a confined elastomer and avoids damaging any but the very lightest type of structure.

In dynamic applications, Parker's V1164-75 fluorocarbon elastomer may be used because it swells less than 2% in these fluids, but its low temperature capability does not normally extend below -29°C (-20°F).

3.9.12.2 Liquid Rocket Propellants

(Nitrogen Tetroxide/Aerozine 50) Rocket propulsion systems utilizing oxidizer and fuel combinations such as nitrogen tetroxide (N₂O₄) and Aerozine 50 (50/50 mixture of UDMH and hydrazine) prompted development of an elastomeric compound to seal against these fluids. The fuel system (i.e. Aerozine 50) does not pose as difficult a sealing problem as does the oxidizer. Most currently available elastomeric compounds are degraded by the extremely vigorous N₂O₄ oxidizer. However, Parker developed a number of compounds which demonstrate markedly improved resistance to N₂O₄ in both liquid and vapor phases.

The expected life of a seal of conventional design immersed in N₂O₄ is limited. Considerable useful seal life with the material however, has been realized through special design practices. In the Gask-O-Seal rubber/metal configuration, where only a minute portion of the sealing element is exposed to the fluid, Parker compounds have sealed nitrogen tetroxide at room temperature for more than a year.

3.9.13 Nuclear Technology

Elastomers which are compounded for exposure to radiation must satisfy stringent quality and material qualification tests. In addition to resisting radiation, the elastomer also must be compatible with the contact medium under the working environment (temperature, pressure, etc).

In the majority of these applications, the radiation dosage level remains below 10^6 rad, a level normally attained after years of operation. Practically all elastomers suffer no change of their physical properties at radiation levels up to 1 M rad ($= 10^6$ rad $= 10^4$ J/kg). Parker has developed compounds with resistance to radiation levels of 10^7 rad.

Water and steam are common media in nuclear applications. Typical nuclear operating conditions are:

Temperature: 180°C (350°F)

Irradiation: 10^7 rad

3.9.14 Radiation

One of the most important properties if an elastomer used as an O-ring seal is its resistance to compression set. On exposure to gamma radiation, it is compression set that is most severely affected. After experiencing 1×10^8 rads, all elastomers tested had taken over 85% set, enough loss of "memory" that leakage would be expected. At 1×10^7 rads, there were big differences between compounds, while at 1×10^6 rads, the effects on all compounds were minor. It is therefore in the range of 1×10^7 , that an O-ring compound must be selected with care, while at higher levels they should not be considered, and at lower levels factors other than radiation will be more significant.

In a reactor, seals are often exposed to hot water, steam, hot air, silicone fluids or other influences in addition to the radiation. The total effect is probably greater than a simple addition of the indi-

vidual effects, and it is therefore important to test a seal in conditions similar to those it will encounter in service. Because effects vary with the individual compound, it is important that the exact compound be specified, and not merely the type of polymer.

Table 3-13 gives data to aid in selecting the most promising compounds to test for many combinations of conditions.

3.9.15 Energy, Oil and Gas

Applications in the offshore industry pose new and unique problems for seal manufacturers. Working conditions are very difficult involving:

- Aggressive contact media
- High pressures
- Wide range of temperatures

Critical conditions occur in connection with:

- Oil additives causing chemical attack
- Explosive decompression
- Clearance gap extrusion at high pressure
- High and low temperatures

Contact media are gas, oil, water (sea water, ground water), drilling mud, sour gas, CO₂, steam, rinsing water, lubricants (additives in lubricants as rust inhibitors), etc.

Working conditions vary greatly to location and function.

Temperatures: up to 225°C (450°F) plus peaks

Working pressures: 100 to 1000 Bar and higher
(1450 psi to 14500 psi and higher)

Contact our Application Engineering Department regarding the above and more difficult conditions.

Data on Radiation Resistant Compounds

Compound	Polymer	Comp. Set at 10 ⁷ Rads ⁽¹⁾	Max. Temp. ⁽²⁾	Steam & Water Resistance	Silicone Fluid Resistance
S0604-70	Silicone	20.0%	204°C (400°F)	Poor	Poor
N0674-70	Nitrile	24.3%	149°C (300°F)	OK to 49°C (120°F)	Good
N0741-75	Nitrile	24.3%	149°C (300°F)	OK to 49°C (120°F)	Good
E0740-75	Ethylene Propylene	28.6%	177°C (350°F)	Good	Good
S0455-70	Silicone (Hi Temp)	31.4%	177°C (350°F)	Poor	Poor
E0515-80	Ethylene Propylene	46.6%	149°C (300°F)	Good	Good
P0642-70	Polyurethane	55.2%	82°C (180°F)	Poor	Good
A0607-70 ⁽³⁾	Polyacrylate	61.5%	149°C (300°F)	Poor	Good
V0747-75	Fluorocarbon	66.7%	204°C (400°F)	Poor	Good
L0677-70 ⁽³⁾	Fluorosilicone	67.6%	204°C (400°F)	Poor	Good

(1) Compression set after exposure to 10^7 rads of gamma radiation at room temperature. The lower values are preferred. If over 40%, use only at lower dosage level.

(2) Temperature at which .139 cross section ring takes a 90% compression set after 1000 hours when not exposed to radiation or fluids.

(3) Material is obsolete, data presented represents family of materials.

Note: Some of these compounds may no longer be available.

Table 3-13: Data on Radiation Resistant Compounds

3.9.16 Fungus-Resistant Compounds

Both the extreme environmental conditions experienced by the military and efforts in space have focused attention on many previously overlooked facets of hardware. Among these is the ability of materials to resist degradation caused by fungus. Fungus is a problem in tropical regions such as southeast Asia. A number of Parker compounds have been submitted to an independent laboratory for fungus resistance exposure tests. The results of this study document that the Parker compounds shown in Table 3-14 are non-nutrient to fungus as defined by MIL-STD-810F, Method 508.5.

With the possible exceptions of natural rubber and polyurethane, the base polymers for elastomers are normally non-nutrient to fungi. Nevertheless, there are compounds that will support fungus growth because they contain nutrient type ingredients. The plasticizer used is of particular importance in this respect. By studying all the ingredients of a particular compound, a chemist can predict quite accurately whether it will support fungus growth, without conducting a test. Therefore, if it is desirable to use some compound not listed below in an application that requires a non-nutrient material, contact Parker's Application Engineering Department to determine whether the compound is a good candidate for the application.

Fungus Tests on Compounds

Fungus testing per MIL-STD-810F, Method 508.5⁽¹⁾

Non-Nutrient to Fungus Growth (Rating = 0)		Supports Fungus Growth (Rating >0)	
Butyl	Nitrile	Silicone	Neoprene
B0612-70	N0545-40	S0595-50	C0267-50
	N0299-50	S0317-60	
Neoprene	N0406-60	S0613-60	Ethylene Propylene
C0873-70	N0525-60	S0455-70	E0603-70
C1124-70	N0506-65	S0604-70	E0652-90
	47-071	S0355-75	
Ethylene Propylene	N0103-70	S0614-80	Nitrile
E0692-75	N0497-70		N1069-70
E0740-75	N0602-70	Fluorocarbon	N0756-75
E0515-80	N0674-70	V0680-70	
E0540-80	N0818-70	V0747-75	Polyurethane
	N0304-75	V1164-75	P0642-70
	N0951-75	V0709-90	
	N0507-90		
	N0552-90	Fluorosilicone	
		L1120-70	

(1) Testing performed on U.S. fungal species only.

Note: Some of these compounds may no longer be available

Table 3-14: Fungus Tests on Compounds

3.9.17 Hydraulic Fluids

There are so many types of hydraulic fluids that only the highest performance O-ring compounds can be used to seal all of them. If a specific fluid is not listed in Section VII, a good candidate O-ring material can be selected from Table 3-15 if the type of the hydraulic fluid is known. Of course, it is important to select a seal compound having a temperature range that is suitable for the application.

3.9.17.1 Fire-Resistant Hydraulic Fluids

When mineral oils represent a high fire risk, fire-resistant hydraulic fluids are used. Three groups of such fluids are:

- Water emulsions (HFA and HFB groups)
- Water solutions (HFC)
- Water-free synthetic fluids (HFD)

The types of fire-resistant hydraulic fluids are presented in Table 3-16.

Fluids containing water rely on their water content to prevent fire. To remain effective, such fluids must be regularly checked and their water concentration maintained. Working temperatures are limited to between 50°C and 65°C (120°F to 150°F) because water easily evaporates at higher temperatures. All fluids containing water have one common feature: they have a negative effect upon bearings.

According to ISO Specification 6071, HFA, HFB and HFC hydraulic fluids are differentiated further by the suffix letters C, M, E and S:

- C indicates that no wear inhibitor is present
- M indicates that a wear inhibitor is present
- E indicates a mineral oil based HFA fluid
- S indicates a synthetic HFA fluid

Table 3-17 shows a comparison of the most important properties of the four groups of non-flammable fluids together with the recommended type of elastomer.

3.9.17.1.1 HFA Fluids

HFA fluids contain more than 80% water. In practice 95% to 98% water is more common, the balance being "concentrates" which improve wear and corrosion resistance.

The relationship between water content and concentrate offers the greatest threat to the proper function of HFA fluids. The local water supply is not only different from one area to the next, but its various constituents may cause the hardness to vary. The operating solution is mixed by the user and not by the manufacturer. HFA concentrates can have mineral oil or synthetic oil bases.

Types of Non-Flammable Hydraulic Fluids

Type of Hydraulic Fluid	Content	Application
Hydraulic fluid HFA	Oil in water emulsion	Hydraulic fluid e.g. for hydraulic presses
Hydraulic fluid HFB	Water in oil emulsion	Hydraulic fluid e.g. for hydraulic presses
Hydraulic fluid HFC	Water polymer solutions	Fire risk systems to max. 60°C at low pressure
Hydraulic fluid HFD	Waterless synthetic fluid	For fire risk systems at high temperatures and pressures

Table 3-17: Types of Non-Flammable Hydraulic Fluids

Compounds for Hydraulic Fluids

	Temp. Range	O-Ring Compounds
High-Water-Base Fluids (95-5 Fluids)	4°C to 49°C (40°F to 120°F)	N0674-70, nitrile E0540-80, ethylene propylene
Hydrocarbon Base Hydraulic Fluids (including petroleum base)	-54°C to 149°C (-65°F to 300°F)	-34°C to 121°C (-30°F to 250°F), N0674-70, nitrile -29°C to 135°C (-20°F to 275°F), N0951-75, nitrile -54°C to 135°C (-65°F to 275°F), N0756-75, nitrile -26°C to 204°C (-15°F to 400°F), V1164-75, fluorocarbon -26°C to 204°C (-15°F to 400°F), V1226-75, fluorocarbon
Phosphate Esters Aircraft types (alkyl phosphate esters)	-54°C to 149°C (-65°F to 300°F)	E1267-80, ethylene propylene (NAS1613)
Phosphate Esters Industrial types (aryl phosphate esters)	-34°C to 93°C (-30°F to 200°F)	E0540-80, ethylene propylene V1164-75, fluorocarbon V1226-75, fluorocarbon
Phosphate Ester-Petroleum Oil Blends	-1°C to 100°C (30°F to 212°F)	V1164-75, fluorocarbon V1226-75, fluorocarbon
Silicate Esters	-54°C to 288°C (-65°F to 550°F)	-26°C to 204°C (-15°F to 400°F), V1164-75, fluorocarbon -26°C to 204°C (-15°F to 400°F), V0884-75, fluorocarbon -54°C to 149°C (-65°F to 300°F), C0873-70, neoprene
Silicone Hydraulic Fluids	-73°C to 288°C (-100°F to 550°F)	-73°C to 177°C (-100°F to 350°F), LM159-70 fluorosilicone (static only) -54°C to 149°C (-65°F to 300°F), E0540-80, ethylene propylene -26°C to 204°C (-15°F to 400°F), V1164-75, fluorocarbon -26°C to 204°C (-15°F to 400°F), V1226-75, fluorocarbon (brown Chromassure)
Water-Glycol	-18°C to 60°C (0°F to 140°F)	E0540-80, ethylene propylene N0674-70, nitrile (limited life as dynamic (But wider range seal anticipated above 43°C (110°F)) as a coolant) N0951-75, nitrile (for higher temperature coolant use)
Water-in-Oil Emulsions ("Invert" emulsions)	-12°C to 49°C (10°F to 120°F)	N0674-70, nitrile

Note: Due to variations in each type of fluid, and the many variables possible in the application of O-rings, these compound listings are intended only as general guides. Users must test under their own operating conditions to determine the suitability of any compound in a particular application.

Table 3-15: Compounds for Hydraulic Fluids

Properties of the Four Groups of Non-Flammable Fluids

Properties	HFA/HFB	Reference	
		HFC	HFD
kinematic viscosity (mm ² /s) to 50°C (122°F)	0.3 to 2	20 to 70	12 to 50
viscosity/temperature relationship	good	very good	bad
density at 15°C (59°F)	ca. 0.99	1.04 to 1.09	1.15 to 1.45
temperature range	3°C to 55°C (37°F to 131°F)	-25°C to 60°C (-13°F to 140°F)	-20°C to 150°C (-4°F to 302°F)
water content (weight %)	80 to 98	35 to 55	none
stability	emulsion poor solution very good	very good	very good
life of bearings	5 to 10%	6 to 15%	50 to 100%
heat transfer	excellent	good	poor
lubrication	acceptable	good	excellent
corrosion resistance	poor to acceptable	good	excellent
combustion temperature	not possible	after vaporizing of water under 1000°C (1832°F)	ca. 600°C (1112°F)
environmental risk	emulsion: used oil synth.: dilution	special waste	special waste
regular inspection	pH-level concentration water hardness micro-organisms	viscosity water content pH-level	viscosity neutral pH spec. gravity
seal material	NBR, FKM	NBR	FKM, EPDM⁽¹⁾

(1) only for pure (mineral oil free) phosphate-ester (HFD-R)

Table 3-16: Properties of the Four Groups of Non-Flammable Fluids

3.9.17.2 Concentrates Containing Mineral Oils (Oil-in-Water-Solutions)

Oil is not soluble in water. Only by employing emulsifiers it is possible to bring about a stable oil-in-water-solution. The level of concentrates is limited by the stability of the emulsion.

Mineral oil concentrates can contain practically all types of chemical additives that have thus far been developed. When the water evaporates, mineral oil remains behind, containing all required anti-corrosion additives. The concentrates are mostly based on naphthenic oils and can cause problems with certain O-ring compounds. Such emulsions have been used as hydraulic press fluids for decades. In general, emulsions take longer to filter.

With these kinds of fluids there is a great risk of micro-bacteriological growth which can lead to problems. Such growth however, can be brought under control without difficulty by adding a biocide to the mixture.

3.9.17.3 Micro-Emulsions

Recently, new synthetic concentrates, which are similar to oils, have been developed which form micro-emulsions when mixed by 5% with water. This is neither a true *solution* nor an *emulsion*, but can be better described as a highly stable *colloidal suspension* of high viscosity oil drops in water.

The concentrate contains both water and oil soluble, wear resistant additives which form a high-pressure resistant film with good lubricating properties. They are not prone to the micro-biological attack, and have a useful life of more than one year.

Concentrates currently available at this time are limited to 100 Bar (1450 psi) working pressure and are mostly used in automated production lines, industrial robots, etc.

3.9.17.4 Synthetic HFA Concentrates (Solutions)

Recently a number of synthetic HFA concentrates have been developed which form a stable solution in water and are also suitable carriers of semi-soluble additives whose purpose is to protect metal components such as **brass and copper**.

These fluids can be filtered finely as required because they are in complete solution. Should the water evaporate however, the residual fluid has a high pH value, which may cause corrosion.

The most important physical properties of HFA fluids depend on their water proportion and vary greatly from mineral oils. As described above, wear and lubricating properties can be greatly improved by the addition of suitable concentrates. In spite of this, the working life of a hydraulic system using HFA fluid is significantly shorter than of a system using conventional hydraulic oils.

Oil based hydraulic systems are increasingly being replaced by HFA fluids. The tendency to leakage of these low-viscosity fluids has caused a search for additives that would increase the fluid's viscosity. The working temperature ranges from 5°C to 55°C (42°F to 130°F).

3.9.17.5 HFC Fluids

HFC hydraulic fluids consist of a solution of polyethylene and polypropylene glycols in a proportion of between 35% and 55%. The two glycols behave differently, bringing about a wide variation in the fluid's properties.

While polyethylene glycols exhibit relatively high resistance to shear, tests have shown that they suffer damage by shearing of the chains after only 2000 to 3000 working hours. Most elastomer compounds that are compatible with mineral oils also can be used in HFC fluids (NBR for example). Certain FKM compounds are not compatible with HFC fluids.

The wear resistant properties and viscosity of HFC fluids is good and corrosion may be controlled by additives. The temperature range is an improvement over mineral oil based fluids. Exposed bearings however, still remain very susceptible to corrosion due to high water content and the working life of equipment is thereby shortened. This is especially true with working pressures over 200 Bar (2900 psi).

HFC fluids are regarded as special refuse and should be handled accordingly. Working temperature ranges from -25°C to 60°C (-14°F to 140°F).

3.9.17.6 HFD Fluids

This group of hydraulic fluids consists of pure synthetic, water-free fluid and does not suffer from most of the previously mentioned difficulties. On the down side however, compatibility with most seal materials is rather limited.

The earliest developments in HFD fluids have disappeared from the market because they were extremely poisonous. Their place has been taken by pure phosphate esters, both synthetic and natural, which are essentially non-toxic. Although much easier to handle, these materials have a very steep viscosity/temperature relationship curve which makes the working range of temperature very narrow; this means that more cooling capacity is necessary to avoid overheating the system.

The fluid can be used at pressures in the range of 300 to 350 Bar (4350 to 5075 psi) and represents the most expensive hydraulic fluid on the market. Disposal is problem-free but must still be classified as special refuse.

HFD fluids can be used at temperatures between -20°C and 150°C (-5°F and 300°F).

3.10 Temperature Extremes

3.10.1 High Temperature

The fluorocarbons are the most useful for high temperature sealing applications. In a 1000 hour air age test at 204°C (400°F), Parker's fluorocarbon compound V0747-75 took a 66% set, leaving enough recovery to continue sealing for many additional hours at that temperature. At 232°C (450°F), however, the anticipated useful life is reduced to approximately 336 hours.

The effect of the environment must be carefully assessed. In the presence of hot water or steam, the fluorocarbons tend to harden and take a premature set. Under these conditions, ethylene propylene is generally superior to fluorocarbon.

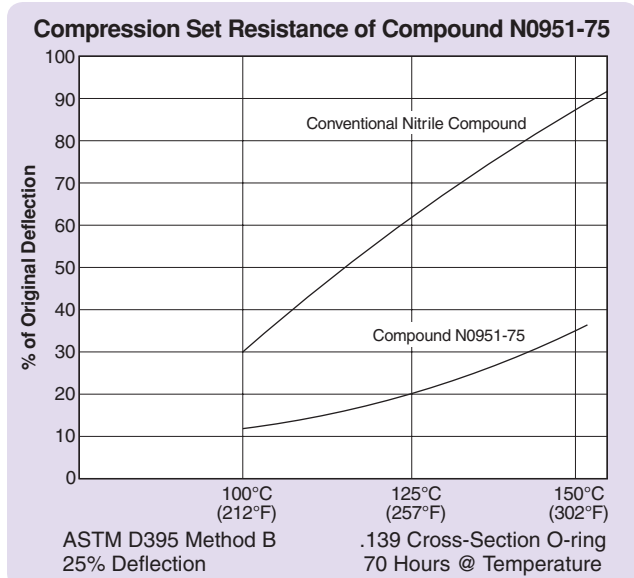


Figure 3-7: Compression Set Resistance of Compound N0951-75

High temperature silicones, such as Parker's S0455-70, appear superior to the fluorocarbons in air aging tests, but this is true only when the test specimen is exposed to circulating air.

Among the nitrile compounds that provide good resistance to petroleum fluids, adequate low temperature properties, good tensile strength, and good abrasion resistance for dynamic applications, compound N0951-75 has the best high temperature properties. It is recommended for temperatures up to 135°C (275°F) in air or petroleum oil. Its recommended low temperature limit is -32°C (-25°F). Figure 3-7, showing compression set values of this compound at various temperatures, demonstrates its fine high temperature capabilities.

Where media compatibility is not optimum, elevated temperatures are additionally dangerous. As a direct comparison, Table 3-18 shows the maximum long-term temperature limits in a compatible contact medium.

3.10.2 Low Temperature

When cooled, elastomer compounds lose their elasticity. At very low temperatures they harden and have glasslike brittleness, and may shatter if struck a sharp blow. As long as they are not mechanically disturbed, they remain intact, and upon return to normal temperatures, regain their original properties, the condition being fully reversible.

The low temperature flexibility of a given compound can be slightly improved if a contact medium causes swelling and softening. Softening can occur through adsorption of fluid that acts like a plasticizer.

As indicated by the Fluid Compatibility Tables in Section VII, silicone (S1224-70) and fluorosilicone (L1120-70) should be selected for low temperature applications. These compounds have poor wear resistance properties and are recommended only for static applications. Other elastomer types with good cold flexibility are CR, EPDM and special NBR compounds.

Comparison of Elastomers in a Compatible Contact Medium and Maximum Allowable

Compound DIN/ISO 1629	Temperatures in °C (°F)		
	Lubrication with mineral oil base	Water	Air
NBR	110°C (230°F)	70°C (158°F)	90°C (194°F)
High temperature NBR	120°C (248°F)	100°C (212°F)	100°C (212°F)
FKM	200°C (392°F) ⁽¹⁾	120°C (248°F) ⁽²⁾	200°C (392°F)
EPDM	not compatible	150°C (302°F) 200°C (392°F) ⁽⁵⁾	150°C (302°F)
VMQ	not compatible	100°C (212°F)	210°C (410°F)
FVMQ	175°C (347°F) ⁽¹⁾	100°C (212°F)	175°C (347°F)
ACM	150°C (302°F) ⁽¹⁾	— ⁽³⁾	150°C (302°F)
CR	100°C (212°F)	80°C (176°F) ⁽⁴⁾	90°C (194°F)

(1) At these temperatures lubricants degrade after a short time.

(2) Special compound.

(3) High swelling at room temperature, hydrolysis at high temperatures.

(4) Medium to high swelling according to temperature.

(5) In water/steam.

Table 3-18: Comparison of Elastomers in a Compatible Contact Medium and Maximum Allowable Temperatures

The Fluid Compatibility Tables can be used only as a guideline. The actual lifetime of a seal at low temperature depends on the application and on the medium to be sealed.

Temperature at the TR-10 point should be taken for all elastomers to determine a minimum functional temperature.

In practice, a static seal may have a minimum functional temperature of about 15°C (-8°F) lower than the TR-10 point, assuming a correctly designed gland.

When air or other gases must be contained at temperatures below -54°C (-65°F) (the low temperature limit recommended for most silicones) compound S0383-70 may be used to reach temperatures to -115°C (-175°F) or lower.

If the permeability rate of silicones is thought to be too high for the application, bear in mind that the rate decreases as the temperature goes down. For applications requiring moderately high temperatures as well as low, it is sometimes feasible to use two O-rings, S0383-70 to maintain the seal at the extreme low temperature plus a butyl or fluorocarbon to reduce permeability when the seal is warmer.

If a low temperature seal must have resistance to a fluid that attacks silicone, the answer may be a fluorosilicone. This material has excellent resistance to a wide range of fluids, is usable up to 177°C (350°F) or higher in many applications, and will often seal at temperatures as low as -73°C (-100°F). Its primary disadvantage is its lack of toughness, giving it limited usefulness as a dynamic seal, yet in certain dynamic applications, fluorosilicone O-rings have served well as springs to activate a U-type shell of fluorocarbon elastomer or other wear resistant material.

Other compounds will often seal at temperatures below their normal low temperature limit by increasing the squeeze. This procedure, however, is generally limited to static face type designs, as a heavy squeeze makes a radial seal difficult to assemble.

Where temperatures do not go below -40°C (-40°F), O-rings in Parker's low temperature fluorocarbon compound, VM835-75, can be utilized. Its other properties are similar to the standard fluorocarbon compounds. For temperatures down to -45°C (-50°F), Parker's V1289-75 should be considered.

The fluid medium often assists a low-temperature seal by acting as a plasticizer, keeping the elastomer soft and flexible below its normal low temperature limit. This low temperature benefit is most likely to occur in fluids that swell the elastomer.

For normal low temperature limits of several Parker Seal compounds, see Figure 2-3.

3.11 Vacuum Applications

Butyl rubber has long been the preferred material for vacuum applications. Among the rubber polymers used for seals, it has one of the lowest permeability rates for gases. This, together with the fact that butyl compounds have low outgassing or weight loss characteristics, good physical properties for a seal, a useful temperature range of -59°C to 121°C (-75°F to 250°F), and good moisture resistance, has established this preferred position. The need for special environmental considerations in addition to low permeability will often change the recommendation. Service requirements such as high temperature, radiation resistance, long term exposure to water or combinations of fluid media may take a careful study to determine the proper recommendation.

3.11.1 Vacuum Weight Loss

It is particularly important in many space and other vacuum applications that optical surfaces and electrical contact surfaces remain clean to serve their intended purpose. Some rubber compounds contain small quantities of oil or other

ingredients that become volatile under high vacuum conditions and deposit as a thin film on all the surrounding surfaces. Table 3-19 indicates the weight loss of several Parker Seal compounds due to vacuum exposure. Where sensitive surfaces are involved, the higher weight loss compounds should be avoided.

In those compounds which show low weight loss, the small amount of volatile material that is indicated is primarily water vapor. It is not likely to deposit on nearby surfaces.

3.11.2 Vacuum Seal Considerations

The rate of flow of gases from the pressure side to the vacuum side of an elastomeric seal depends to a great extent on how the seal is designed. Compound B0612-70 has been tested in face type O-ring seals, using grooves that provided 15%, 30% and 50% squeeze. It will be seen from the results plotted in Figure 3-8 that increasing the squeeze reduced the leak rate dramatically. Lubricating the O-rings with a high vacuum grease also reduced the leakage of the lightly squeezed (15%) rings significantly, but the effect of the grease was considerably less at 30% squeeze. At 50% squeeze the effect of the grease was not detectable. Several other compounds were tested in this way with similar results.

Increased O-ring squeeze reduces permeability by increasing the length of the path the gas has to travel (width of ring) and decreasing the area available to the entry of the gas (groove depth). Increasing the squeeze also tends to force the rubber into any small irregularities in the mating metal surface, and thus prevents leakage around the seal. The vacuum grease aids the seal by filling these microscopic pits and grooves, thus reducing leakage around the ring, and at the same time it may be changing the surface tension favorably with the effect of a reduced rate of surface absorption.

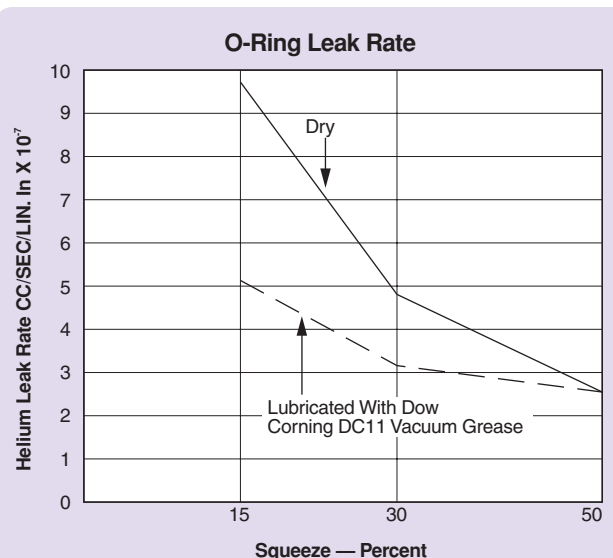
Weight Loss of Compounds in Vacuum

Test Samples: Approximately .075" thick
Vacuum Level: Approximately 1×10^{-6} torr
Time: 336 hours (two weeks)
Room Temperature

Compound Number	Polymer	Percent Weight Loss
B0612-70	Butyl	.18
C0873-70	Neoprene	.13
E0515-80	Ethylene Propylene	.39
E0529-60	Ethylene Propylene	.92
E0692-75	Ethylene Propylene	.76
L0449-65	Fluorosilicone	.28
L0677-70	Fluorosilicone	.25
N0406-60	Nitrile	3.45
N0674-70	Nitrile	1.06
P0648-90	Polyurethane	1.29
S0455-70	Silicone	.03
S0604-70	Silicone	.31
V0747-75	Fluorocarbon	.09
V0884-75	Fluorocarbon	.07
V0894-90	Fluorocarbon	.07

Note: Some of these compounds may no longer be available.

Table 3-19: Weight Loss of Compounds in Vacuum



O-ring I.D. = 4.850, W. = .070, CPD = B0612-70 (Butyl)
Temperature = 25°C (77°F), Pressure Differential = 4.1 Bar (60 psi)

Figure 3-8: O-ring Leak Rate

It is recommended, therefore, that face type O-ring grooves be used whenever possible for static vacuum seals, using a silicone grease as a seating lubricant and surface coating in addition to a heavy squeeze of the O-ring cross section. When a radial seal is required, or when a heavy squeeze is not possible for some other reason, it becomes more important to use a vacuum grease.

As an example of the benefit of high squeeze, we have found that Gask-O-Seals and Integral Seals both make effective vacuum seals because of the generous squeeze that is built into them. Gask-O-Seals have the added advantage of a high percent fill of the groove together with a shallow depth which reduces the seal area that can be exposed to the effects of vacuum, and prevents the rubber sealing element from moving due to vibration or pressure changes. An additional benefit of high percentage confinement is the fact that increased temperatures do not increase the leak rate as much as normally expected with a lesser confinement.

Although a very heavy squeeze is necessary to reduce leakage to an absolute minimum in an O-ring seal, this kind of design may require heavy construction. When such a shallow gland is desirable, it must be wide enough to receive the full O-ring volume.

For most purposes, the gland design shown for vacuum and gasses in Design Chart 4-2 is a reasonable compromise in a face seal situation. The squeeze recommended in that design chart, however, is sufficiently heavy that a male or female gland assembly with the same dimensions may be very difficult to assemble. For these, then, Design Chart 4-1 and Design Table 4-1 are generally followed.

There is very little data available on dynamic vacuum seals, but reasonably low leak rates have been reported using two O-ring seals designed according to Design Chart 5-2 and Design Table 5-2. In sealing gases and vacuum, it is quite feasible to use two O-ring seals in tandem, unlike reciprocating applications that seal a liquid, where pressure traps are often a problem.

Surface Finish of Vacuum Gland

	Surface Roughness of Vacuum Gland Load Area $t_p > 50\%$			
	A Contact Area		B Gland Flanks	
	R_a	R_{max}	R_a	R_{max}
Vacuum	0.8	3.2	1.6	6.3
to 10^{-8} Torr	0.4	1.6	1.6	6.3
to 10^{-11} Torr	0.10	0.40	1.6	6.3

Table 3-20 Surface Finish of Vacuum Gland (See also Figure 3-9)

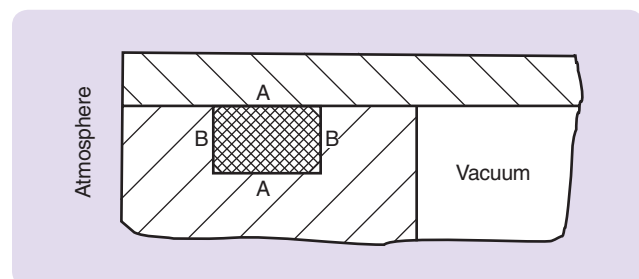


Figure 3-9: Vacuum O-ring Gland

Surface roughness of the gland surfaces is more critical in sealing pressurized gases or vacuum, as a gas will find its way through extremely minute passages. Therefore, surfaces against which an O-ring must seal should have a surface roughness value smoother than usual. Surface finishes of 16 RMS are quite common, but 32 RMS finishes have been used successfully also.

3.11.3 Vacuum Leak Rate

To determine approximate leak rate for a vacuum seal, use the "Leak Rate Approximation" method in the section on Gases. Note that where the external pressure is one atmosphere, the pressure differential across the seal (P) is 14.7 psi.

Many parameters should be observed to seal a vacuum. In general apply the following recommendations:

- Select correct O-ring compound;
- The surfaces to be sealed and the gland must have a significantly better surface finish than for "normal" seals Table 3-20;
- The O-ring should fill the gland (nearly 100%, Figure 3-9). Larger contact areas are thereby created and the diffusion rate through the elastomer is slowed;
- To increase efficiency, two seals can be fitted in tandem in separate glands;
- The total leakage rate is reduced using a suitable vacuum grease.

Requirements for the O-ring compound are:

- Low gas permeation rate
- Good, i.e. low compression set
- Compatibility of medium
- Temperature compatibility
- Low weight loss in vacuum

For more detailed information see Rate of gas leakage.

3.12 Gases-Permeability

All elastomers are permeable to some extent, allowing air, other gases under pressure or volatile liquids to penetrate into the seal material and gradually escape on the low pressure side.

The permeability rate of various gases through different rubber materials varies in an unpredictable way. In fact, the permeability of a given base polymer will vary according to the proportions of the copolymer, among other things. Figure 3-10 shows this very clearly for one class of butadiene-acrylonitrile copolymers.

The permeability also varies with temperature, and though the rate increases with increasing temperature, there is no easily defined relationship between these two variables. Table 3-24 (found at the end of this section) lists some permeability rates at various temperatures that may be helpful in approximating leak rates through O-ring seals.

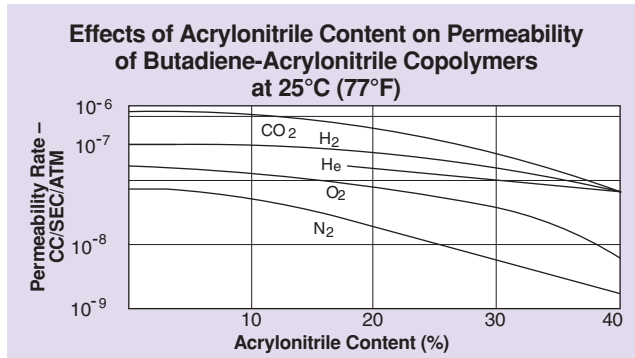


Figure 3-10: Effect of Acrylonitrile Content on Permeability of Butadiene-Acrylonitrile Copolymers at 25°C (77°F) from "Gas Permeability of Hycar Polymers" by B. F. Goodrich Company

3.12.1 Leak Rate Approximation

The leak rate of a gas through an O-ring seal may be roughly approximated when the permeability of the gas through the particular elastomer is known for the temperature at which the seal must function. The following formula is useful for this approximation:

$$L = 0.7 F D P Q (1-S)^2$$

where

- L = Approximate leak rate of the seal, std. cc/sec.
- F = Permeability rate of the gas through the elastomer at the anticipated operating temperature, std. cc cm/cm² sec bar (Many of these permeability rates are listed in Table 3-18, found at the end of this section)
- D = Inside diameter of the O-ring, inches.
- P = Pressure differential across the seal, lb/in²
- Q = Factor depending on the percent squeeze and whether the O-ring is lubricated or dry (from Figure 3-11)
- S = Percent squeeze on the O-ring cross section expressed as a decimal. (i.e., for a 20% squeeze, S = .20)

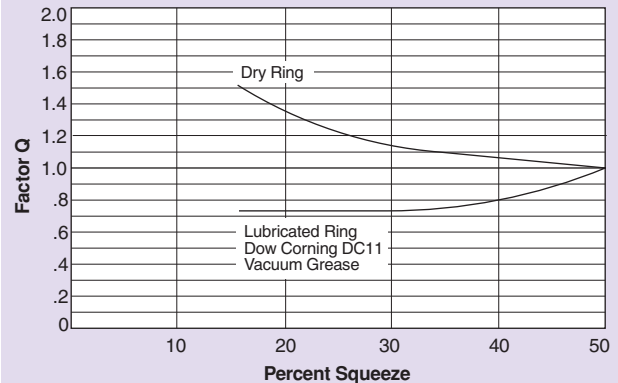
This formula gives only a rough order of magnitude approximation because permeability varies between compounds in the same polymer, and because the assumptions on which it is based are not all exact.

These assumptions are:

1. The cross section of a squeezed O-ring is rectangular.
2. The cross section area of a squeezed O-ring is the same as its area in the free condition.
3. The permeability rate of a gas through an O-ring is proportional to the pressure differential across the seal.

For convenience, the formula contains mixed units. It was set up this way because in the United States O-ring diameters are usually given in inches, and pressures in pounds per square inch while permeability figures are usually shown in metric units. The 0.7 factor resolves these inconsistencies.

Effect of Squeeze and Lubricant on O-ring Leak Rate



For helium leak rate, a variation of $\pm 50\%$ from the predicted value should be anticipated to allow for limitations in the accuracy of test equipment and available standards, and for variations between samples.

Figure 3-11: Effect of Squeeze and Lubricant on O-Ring Leak Rate

3.13 Gases-High Pressure

Because all elastomers are permeable, gases under pressure penetrate into the seal material. Naturally, the greater the pressure, the larger the quantity of gas forced into the rubber. When gas pressure around a seal is released after a soak period, gas trapped inside the seal expands and may escape harmlessly into the atmosphere, or it may form blisters on the surface. Some of these may rupture, leaving cracks or pits. This phenomenon is called explosive decompression.

The severity of the damage varies with pressure, the gas, the rubber compound, the size of the cross section, and other factors, such as pressure drop rate.

We rarely see problems when the pressure is below 27.6 Bar (400 psi), and generally carbon dioxide causes more swelling and damage than does nitrogen, as mentioned, although any pressurized gas may cause the condition. As mentioned, elevated temperature increases the damage, as does a rapid rate of pressure drop.

Where problems due to explosive decompression are anticipated, it may help to use a small cross section O-ring, as smaller cross sections are less subject to explosive decompression problems than are large ones.

In laboratory tests, it was found that soaking compound N0304-75 in MIL-H-5606 oil for 24 hours at 135°C (275°F) prior to testing dramatically curtailed the severity of the damage, presumably because the oil permeates the rubber and reduces the amount of gas that can enter. This principle should be helpful in many applications.

3.14 Acids

Resistance of elastomeric compounds to acids often changes dramatically with temperature and with concentration.

In strong solutions, the acid resistant fluorocarbon compound often maintains its properties rather well, particularly at room temperature. In the Fluid Compatibility Table in Section VII, it is shown as the only compound that is likely to withstand the effects of concentrated nitric and hydrochloric acids at room temperature. At higher temperatures in these acids, only a perfluoroelastomer can be expected to maintain a seal on a long term basis.

In dilute solutions, an ethylene propylene compound is usually preferred, particularly if there is any elevated temperature involved, because ethylene propylene has excellent resistance to water as well as quite good acid resistance.

It is particularly important to test seal compounds under service conditions when a strong acid is to be sealed at elevated temperatures.

3.14.1 Plastic Contact Surfaces

Sometimes when an O-ring is used in contact with a plastic material, the plastic will develop a series of fine cracks that weaken it. This "crazing" has been noticed most frequently with polycarbonate resins, such as General Electric's Lexan, but it has also been found in other plastic materials.

This effect is most severe when the plastic material is under the greatest stress, and may be caused by stress alone. For instance, compounds E0515-80, N0522-90 and V0709-90 were rated "marginal," but we feel that the problem with these elastomers may have been caused by their hardness, as we would not expect a chemical effect between them and a polycarbonate resin.

General Electric Company has tested a number of Parker Seal Compounds with Lexan and found that the following materials are generally acceptable in contact with Lexan. See Table 3-21.

Compounds for Use Against Lexan⁽¹⁾ Surfaces

Ethylene Propylene	Fluorocarbon
E0692-75 (marginal)	V0680-70
E0515-80 (marginal)	V0747-75
Nitrile	V0709-90 (marginal)
N0602-70	Neoprene
N0674-70	C0267-50
N0304-75	C0557-70
N0508-75	Polyurethane
N0741-75	P0642-70
N0506-65 (marginal)	Silicone
47-071 (marginal)	S0317-60
N0552-90 (marginal)	S0469-40
	S0604-70

(1) General Electric Trademark

Note: Some of these compounds may no longer be available.

Table 3-21: Compounds for Use Against Lexan Surfaces

3.14.2 Silicone Fluids

Silicone fluids are chemically very stable. Reference to the Fluid Compatibility Table in Section VII, for instance, shows that all types of seal polymers except silicone rubber may be used for silicone oils and greases. There are some individual compound exceptions.

Silicone fluids have a great tendency to remove plasticizer from compounds, causing them to shrink. The effect is most severe with the combination of low viscosity silicone fluids in high temperature environments. Because of this, military nitrile compounds, and any other nitriles with a low temperature limit below -40°C (-40°F) should not be used to seal silicone fluids as such low temperature nitriles must contain large amounts of plasticizers. Other compounds, including the high temperature nitriles, should be tested before use to be certain they will not shrink more than one or two percent.

Silicone rubber is rated 3 (doubtful) in contact with silicone fluids. The poor rating is given because silicone rubber tends to absorb silicone fluids, resulting in swelling and softening of the rubber. Occasionally, however, it is desirable to seal a silicone fluid with a silicone rubber O-ring. This combination is generally acceptable if the viscosity of the silicone fluid is 100,000 centistokes or more, and if the maximum temperature will not exceed 149°C (300°F).

3.14.3 Underwriters' Laboratories

Common Parker compounds are listed by Underwriters' Laboratories (UL) under their "Recognized Compound Program." The listing is based on UL testing of compound for specific service requirements as shown in Table 3-22.

3.14.4 Water and Steam Resistance

Water seems like such an innocuous fluid; people are often surprised to learn that it can bring problems if it is not sealed with the proper O-ring material.

After a long period of water immersion, many compounds will swell quite drastically. In a static seal, this may be quite acceptable. Such a seal surely will not leak, and if it can be replaced with a new one after disassembly, the fact that it has become too large to put back into the gland cavity becomes only an interesting curiosity. In situations where the O-rings are routinely replaced before they have swelled more than a few percent, the user may not even be aware of their strange behavior. Used as a long-term dynamic seal, however, this gradual swelling of many compounds in water can cause a slow but very annoying increase in both breakout and running friction.

Figure 3-12 and Figure 3-13 illustrate this gradual swelling of a number of Parker Seal compounds when exposed to water at two different temperatures. From these curves it will be seen that E0540-80 ethylene propylene rubber is the single compound tested that had virtually no swell. This is our recommended compound for water and steam for temperatures up to 149°C (300°F). Where exposure to steam and hot air alternate, as in tire presses, it serves better than in either one alone.

Underwriters' Laboratories Approved Services

Service	A	B	C	D	E	F	G	H	I	J	L	M				
EA454-50 (3575)																
KA170-55 (21105)																
LM159-70																
N0299-50																
N0497-70																
N0674-70																
N1499-70																
N1585-70																
N1500-75																
N1591-75 (67357)																
NF162-65 (1106)																
N1565-75 (67027)																
N1527-70 (67147)																
V0747-75																
VA151-75 (19357)																
V0884-75																
V1163-75																
V1226-75																
V1262-65																
V1263-75																
V1436-75																

*Contact factory for specific ratios of alcohol (methyl and/or ethyl) and gasoline.

Note: Material certifications are subject to change. Please contact Parker's O-Ring Division for more information.

Table 3-22: Underwriters' Laboratories – JMLU2 – Gaskets and Seals

For even greater resistance to steam, Parker has developed compound E0962-90. This ethylene propylene compound showed very little change in physical properties after 70 hours exposure to steam at 288°C (550°F).

With sealing steam or water with ethylene propylene rubber, it is important to remember that it will deteriorate when exposed to petroleum lubricants. When lubrication is required, silicone oil, glycerin, or ethylene glycol are suggested.

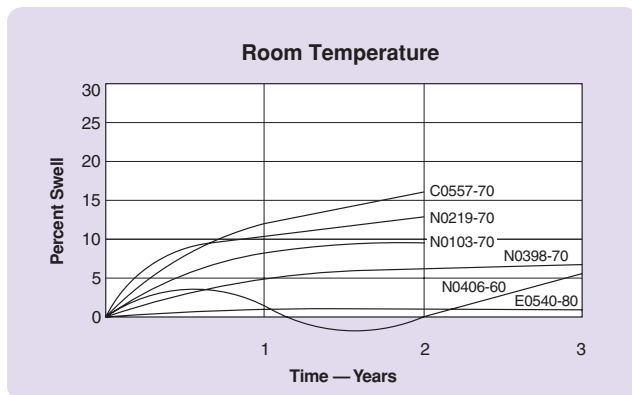


Figure 3-12: Water and Steam Resistance at Room Temperature

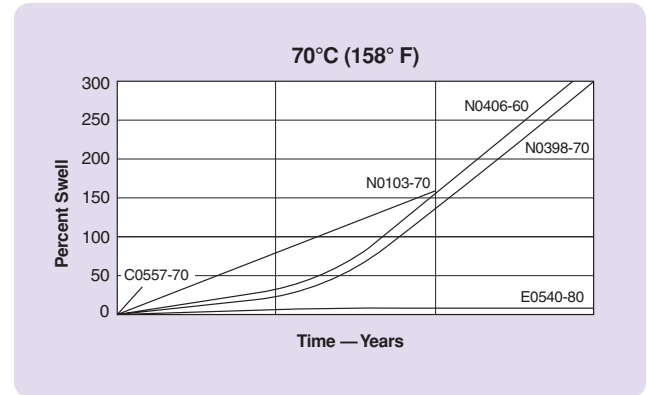


Figure 3-13: Water and Steam Resistance at 70°C (158°F)

3.15 Semiconductor

The semiconductor industry is utilizing increased levels of toxic fluids and gases, which place extreme demands upon seal design and materials. Not only to prevent system contamination from the external environment, but they must not contribute any contaminants to the system in their own right. Specific needs are required by each of the four primary environments employed by the semiconductor industry:

- Gases & Vacuum
- Thermal
- Plasma
- Wet Processing

Working conditions:

Temperatures: up to 300°C (572°F)

Pressures: vacuum to 10^{-9}

Contact our Application Engineering Department regarding Semiconductor sealing applications.

3.16 inPHorm Seal Design and Material Selection Software

Parker recommends utilizing our inPHorm design software to guide the user through the design and selection of an O-ring and corresponding seal gland. Parker's inPHorm not only addresses standard o-ring sizes, but will allow the user to custom design O-ring glands and seals specifically for their application. To obtain inPHorm software contact the O-Ring Division, Parker Product Information at 1-800-C-PARKER or download from www.parkerorings.com. If inPHorm is not readily available manual calculations can be performed.

3.17 Drive Belts

3.17.1 Introduction

O-rings and lathe-cut rings are being used extensively as low power drive belts because they are inexpensive and simple to install. Due to their resilient nature, they do not require the use of belt tensioning devices, and pulley locations do not need to be extremely accurate.

For most elastic drive belt applications, O-rings are preferred over lathe-cut rings for a number of reasons:

- (a) Ease of installation.
- (b) Uniform stress distribution.
- (c) Ready availability of many standard sizes.
- (d) Flexibility of usage.
- (e) No sharp corners on the belt.

Lathe-cuts are often completely adequate for the task, but they are more likely to require special tooling, making the cost prohibitive when only a small quantity is needed. For large quantities, the tooling cost becomes insignificant, and overall cost savings are generally realized in using lathe-cut rings. Due to the special manufacturing techniques employed, all lathe-cut applications are reviewed by the O-Ring Division's Application Engineering Department.

Parker Seal is conducting a continuing program of testing compounds for drive belt service, and developing new drive belt compounds to optimize the properties that are most needed in a drive belt. Minimum stress relaxation and maximum flex

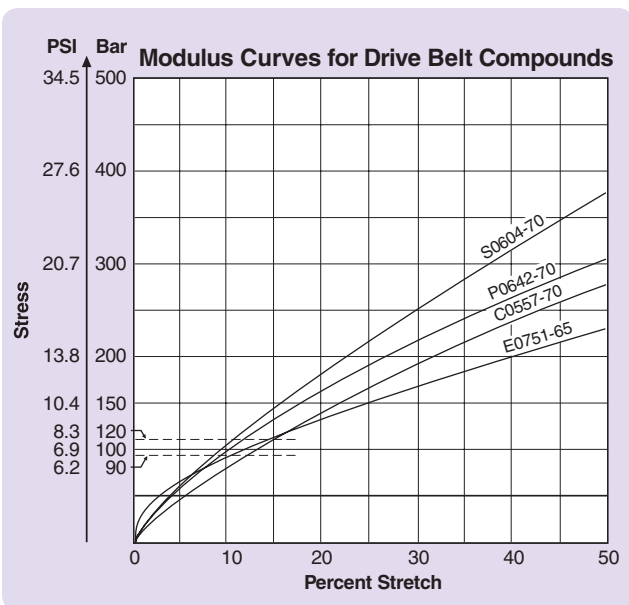


Figure 3-14: Modulus Curves for Drive Belt Compounds

life are especially important in a drive belt, but several compounds must be available to provide resistance to the various fluids and temperature ranges that may be encountered.

3.17.2 Drive Belt Compound Selection

An O-ring compound intended for drive belt service should be selected for minimum stretch relaxation (tensile set) and maximum dynamic properties.

The choice of elastomer is determined by the physical environment:

- Contact medium, ozone, oil, grease.
- Service temperatures.

The general requirements for elastomer drive belt materials are:

- Good aging resistance.
- Wear resistance.
- Relatively low tendency to return to original shape under tension and temperature caused by friction; this means a higher resistance to the Joule effect.
- Good flexibility.

3.17.3 Available Drive Belt Compounds

The information below describes the most suitable drive belt compounds available. The Application Engineering Department should be contacted for additional information.

E0751-65 has been developed specifically for drive belt use. Performance data from production samples show that it has properties superior to O-ring compounds recommended formerly, and E0751-65 has become the "standard" drive belt compound as a result. The most important of its properties are low stress relaxation combined with reliability and resistance to high temperature. A limitation that prevents its use in a few applications is its lack of resistance to petroleum fluids.

Parker Seal Elastic Drive Belt Compound Data ⁽¹⁾					
	Compound Number Specific Gravity, G	DBA ⁽⁵⁾ E0751-65 1.13	DBA ⁽⁵⁾ P0642-70 1.29	DBA ⁽⁵⁾ C0557-70 1.47	DBA ⁽⁵⁾ S0604-70 1.43
Dynamic Stress Relaxation ⁽²⁾ Initial Stress, 120 PSI		13%	19%	14%	21%
	Temp °C (°F)				
Static Stress Relaxation ⁽³⁾ Initial Stress, 120 PSI	24 (75)	14%	21%	14%	2%
	66 (150)	18%	29%	19%	5%
	82 (180)	20%	36%	22%	2%
Flex Life Rating		Good	Excellent	Acceptable	Excellent
Maximum Temperature, °C (°F)		82 (180)	54 (130)	82 (180)	149 (300)
Hardness, Shore A, Durometer		65±5	70±5	70±5	70±5
Tensile Strength, Bar (PSI)		135.9 (1970)	302.2 (4380)	138.0 (2000)	62.1 (900)
Elongation, %		385	535	250	160
Modulus @ 100%, Elongation, Bar (psi)		30.4 (440)	29 (420)	38.0 (550)	41.1 (600)
Resistance to: ⁽⁴⁾					
Petroleum Fluids		Poor	Excellent	Good	Poor
Silicone Fluids		Excellent	Excellent	Excellent	Poor
Water		Excellent	Fair	Good	Good
Ozone		Excellent	Excellent	Good	Excellent
Abrasion		Good	Excellent	Good	Poor

(1) All values shown are typical. Do not use for specification limits. Specimens: 2-153 O-rings.

(2) After three days dynamic testing at room temperature Motor pulley pitch diameter: .611", speed: 1740 rpm. Cast iron driven pulley pitch diameter: 2.623". Duty cycle 3 minutes on, 15 seconds off. Load: inertia of cast iron pulley.

(3) After 48 hours static testing at temperature indicated. Two ½" diameter pulleys.

(4) For information on resistance of these materials to other fluids, see Fluid Compatibility Table in Section VII.

(5) When ordering parts for drive belt applications, the letters "DBA" precede the part number. Example: DBAS0604-70 2-250.

Table 3-23: Parker Seal Elastic Drive Belt Compound Data

Some O-ring seal compounds have been used successfully in many drive belt applications. The three materials described below have been evaluated specifically for this type of use and gave superior performance under the conditions stated:

P0642-70 has been a very successful material for drive belt applications. It is recommended for severe conditions where extra abrasion resistance, long life, and high stress values are required and service temperatures do not exceed 54°C (130°F). Its major attribute is reliability, which is due to the excellent flow characteristics of polyurethane that minimize the possibility of poor knitting. It is a particularly tough material, having high tensile strength and excellent resistance to abrasion, wear, and fatigue.

C0873-70 is recommended where the service temperature exceeds 54°C (130°F) and there is a possibility of contact with petroleum fluids. It has outstanding resistance to stress relaxation at temperatures as high as 82°C (180°F), though its resistance to fatigue is not as good as other Parker drive belt compounds.

S0604-70 is the compound generally selected for high temperature use or for applications where the black color of the other drive belt compounds is not permissible. Being a silicone, however, it does not have the tensile strength or resistance to wear and abrasion of the other compounds. The user, therefore, should not sacrifice these important properties by specifying an unrealistically high temperature to provide a "safety factor". Usually some excess temperature can be tolerated if the exposure time is of short duration and is repeated only a few times during the life of the drive belt. It should be remembered that the physical properties of any compound will be poorer at elevated temperature.

Table 3-23 compares the important properties of these rubber materials. Specific gravity and stress relaxation are listed first

because these data are needed in drive belt design. When drive belts may contact fluids not listed in Table 3-23, refer to the Fluid Compatibility Tables in Section VII. In any case, contact of elastomeric drive belts with any liquid must be kept to an absolute minimum. Almost any liquid on the belt will reduce friction, causing slippage. Since contact with fluids is seldom encountered in drive belt practice, this becomes a minor consideration.

3.18 Applications Summary

In the foregoing discussions on special applications, there are necessarily many references to problems and failures, but the object of pointing out possible pitfalls is to indicate to the designer the steps he can take to avoid them. The object of this whole reference manual, then, is the very positive one of showing how to produce reliable, economical, effective O-ring seals for a diversity of uses.

An important factor in most O-ring seals is the rubber compound from which it is made. For the special applications presented in this chapter, many specific compound recommendations are included. Parker Compound recommendations based on fluid type alone will be found in the Fluid Compatibility Tables in Section VII.

It is an excellent practice, after selecting one or more likely materials, to study those portions of the Elastomers section that apply to that material. Background information is given there that will give the designer a better understanding of the general properties of each of the major polymers, and help him select wisely when a choice or compromise must be made. The explanations of physical properties and how they are tested are also necessary for an adequate understanding of rubber materials and their behaviour in different operating environments.

Gas Permeability Rates

Gas or Liquid	Elastomer	Temperature		Permeability ⁽¹⁾ x 10 ⁻⁸	Source ⁽²⁾
		°C	°F		
Acetone	Silicone	25	77	14,850	I
Acetylene	Butyl	25	77	1.26	I
Acetylene	Butyl	50	122	5.74	I
Acetylene	Natural	25	77	74.5	I
Acetylene	Natural	50	122	192	I
Acetylene	Nitrile	25	77	18.7	I
Acetylene	Nitrile	50	122	67.4	I
Air	Butyl	Room		0.2	DC
Air	Butyl	200	392	100	DC
Air	Fluorosilicone	Room		48.4	DC
Air	Natural	Room		6.7	DC
Air	Natural	200	392	262	DC
Air	Silicone	Room		18.0 to 25.6	DC
Air	Silicone	200	392	74	DC
Air	Polyurethane	Room		0.5	DC
Ammonia	Silicone	25	77	4396	I
Argon	Butyl (B0318-70)	35	95	1.19	A
Argon	Butyl (B0318-70)	82	180	9.04	A
Argon	Butyl (B0318-70)	124	255	36.1	A
Argon	Ethylene Propylene	38	100	11.3 to 22.9	A
Argon	Ethylene Propylene (E0529-65)	40	104	22.9	A
Argon	Ethylene Propylene (E0692-75)	38	100	15.58	A
Argon	Ethylene Propylene	93	200	57.0 to 108.7	A
Argon	Ethylene Propylene (E0529-65)	94	202	105	A
Argon	Ethylene Propylene (E0692-75)	93	199	77	A
Argon	Ethylene Propylene	149	300	170 to 375	A
Argon	Ethylene Propylene (E0529-65)	155	311	375	A
Argon	Ethylene Propylene (E0692-75)	149	300	280	A
Argon	Fluorocarbon-Viton ⁽⁴⁾	93	200	31	A
Argon	Natural	25	77	17.2	I
Argon	Neoprene	36	97	0.67	I
Argon	Neoprene	38	100	18	A
Argon	Neoprene	52	126	1.42	I
Argon	Neoprene	86	187	6.46	I
Argon	Nitrile	38	100	1.60 to 3.88	A
Argon	Nitrile (N0741-75)	39	103	2.06	A
Argon	Nitrile	79	175	6.39 to 16.7	A
Argon	Nitrile (N0741-75)	80	176	7.36	A
Argon	Nitrile	121	250	13.7 to 62.3	A
Argon	Nitrile (N0741-75)	118	245	34	A
Argon	Polyacrylate (A0607-70)	38	100	8.28	A
Argon	Polyacrylate (A0607-70)	91	195	40.66	A
Argon	Polyacrylate (A0607-70)	153	307	327	A
Argon	Polyurethane (P0642-70)	39	103	1.5	A
Argon	Polyurethane (P0648-90)	39	102	0.99	A
Argon	Polyurethane (P0642-70)	66	151	5.45	A
Argon	Polyurethane (P0648-90)	67	152	4.07	A
Argon	Polyurethane (P0642-70)	94	202	20.8	A
Argon	Polyurethane (P0648-90)	94	201	7.3	A
Argon	SBR	38	100	1.09 to 5.24	A
Argon	SBR (G0244-70)	38	101	5.24	A

(1) Std cc cm/cm² sec. bar

(2) "I" denotes information from "Permeability Data for Aerospace Applications" funded by NASA and prepared by IIT Research Institute, March 1968.

"A" denotes information from Atomics International Division, Energy Systems Group, Rockwell International publication AI-AEC-13145,

"Design Guide for Reactor Cover Gas Elastomer Seals" March 7, 1975, and addendum, report ESC-DOE-13245, September 30, 1978.

"DC" denotes information from Dow Corning Bulletin 17-158, October 1972.

"P" denotes information from Parker Seal tests.

(3) "NR" Temperature not reported.

(4) Registered trademark E.I. du Pont de Nemours & Co.

Note: Some of these compounds may no longer be available.

Table 3-24: Gas Permeability Rates

Gas Permeability Rates					
Gas or Liquid	Elastomer	Temperature		Permeability ⁽¹⁾	Source ⁽²⁾
		°C	°F	x 10 ⁻⁸	
Argon	SBR (G0244-70)	84	183	25.5	A
Argon	SBR (G0244-70)	122	251	138	A
Argon	Silicone	38	100	230 to 487	A
Argon	Silicone (S0684-70)	38	101	347	A
Argon	Silicone	93	200	454 to 1500	A
Argon	Silicone (S0684-70)	91	195	454	A
Argon	Silicone	149	300	566 to 2840	A
Argon	Silicone (S0684-70)	156	313	1020	A
Argon	Silicone	Room		450	I
Argon	PTFE	149	300	12	A
Benzene	Silicone	25	77	14300	I
Butane	Silicone	25	77	6750	I
Butane	Silicone	30	86	12980	I
Butane	Silicone	40	104	12380	I
Butane	Silicone	50	122	11630	I
Butane	Silicone	60	140	11030	I
Butane	Silicone	70	158	11330	I
iso-Butane	Silicone	30	86	7250 to 12980	I
iso-Butane	Silicone	40	104	7058 to 12380	I
iso-Butane	Silicone	50	122	6861 to 11630	I
iso-Butane	Silicone	60	140	6691 to 11030	I
iso-Butane	Silicone	70	158	6541 to 11330	I
Carbon Dioxide	Butadiene	25	77	36.3 to 103.6	I
Carbon Dioxide	Butadiene	30	86	103.5	I
Carbon Dioxide	Butadiene	50	122	197.4	I
Carbon Dioxide	Fluorosilicone	Room		514	DC
Carbon Dioxide	Fluorosilicone	26	79	444	I
Carbon Dioxide	Natural	25	77	98.3 to 116	I
Carbon Dioxide	Natural	30	86	98.3	I
Carbon Dioxide	Natural	50	122	218	I
Carbon Dioxide	Neoprene	22.3	72	9.98	I
Carbon Dioxide	Neoprene	25	77	13.9 to 19.2	I
Carbon Dioxide	Neoprene	30	86	14.0 to 18.8	I
Carbon Dioxide	Neoprene	50	122	47.6	I
Carbon Dioxide	Nitrile	20	68	5.63	I
Carbon Dioxide	Nitrile	30	86	47.7	I
Carbon Dioxide	Polysulfide	23	73	7.95	I
Carbon Dioxide	Polysulfide	25	77	2.37	I
Carbon Dioxide	Polyurethane	20	68	10.5	I
Carbon Dioxide	Polyurethane	30	86	5.4 to 30.0	I
Carbon Dioxide	Silicone	20.5	69	1028 to 1530	I
Carbon Dioxide	Silicone	25	77	2280	I
Carbon Dioxide	Silicone	32	90	1025 to 1545	I
Carbon Dioxide	Silicone	43.5	110	1043 to 1538	I
Carbon Dioxide	SBR	25	77	92.8	I
Carbon Dioxide	SBR	30	86	93.0	I
Carbon Dioxide	FEP PTFE	25	77	7.51	I
Carbon Monoxide	Butadiene	25	77	4.64	I
Carbon Monoxide	Natural	25	77	11.8	I
Carbon Monoxide	Silicone	Room		255	I
Carbon Tetrachloride	Silicone	Room		52500	I

(1) Std cc cm/cm² sec. bar

(2) "I" denotes information from "Permeability Data for Aerospace Applications" funded by NASA and prepared by IIT Research Institute, March 1968.

"A" denotes information from Atomics International Division, Energy Systems Group, Rockwell International publication AI-AEC-13145,

"Design Guide for Reactor Cover Gas Elastomer Seals" March 7, 1975, and addendum, report ESC-DOE-13245, September 30, 1978.

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Table 3-24: Gas Permeability Rates

Gas Permeability Rates

Gas or Liquid	Elastomer	Temperature		Permeability ⁽¹⁾ x 10 ⁻⁸	Source ⁽²⁾
		°C	°F		
Carbonyl Chloride	Silicone	Room		11250	I
Ethane	Butadiene	25	77	24.97	I
Ethane	Silicone	25	77	1875	I
Ethylene	Silicone	Room		1013	I
Formaldehyde	Silicone	Room		8830	I
Freon 11	Silicone	25	77	11250	I
Freon 12	Butyl	25	77	1.05 to 55.5	I
Freon 12	Fluorocarbon	25	77	2.4 to 63	I
Freon 12	Neoprene	25	77	8.78	I
Freon 12	Nitrile	25	77	.3 to 5.5	I
Freon 12	Polyurethane	25	77	14.55	I
Freon 12	Silicone	25	77	1035	I
Freon 22	Butyl	25	77	3.0	I
Freon 22	Fluorocarbon	25	77	57	I
Freon 22	Neoprene	25	77	19.5	I
Freon 22	Nitrile	25	77	353	I
Freon 22	Polyurethane	25	77	225	I
Helium	Butadiene	25	77	11.8	I
Helium	Butyl (B0612-70)	25	77	6.5	P
Helium	Butyl (B0612-70)	80	176	52.0	P
Helium	Butyl (B0612-70)	150	302	240	P
Helium	EP (E0515-80)	25	77	19.7	P
Helium	EP (E0515-80)	80	176	61.0	P
Helium	EP (E0515-80)	150	302	320	P
Helium	Fluorocarbon	30	86	12.8	I
Helium	Fluorocarbon (V0747-75)	25	77	12.7	P
Helium	Fluorocarbon (V0747-75)	80	176	131	P
Helium	Fluorocarbon (V0747-75)	150	302	490	P
Helium	Fluorosilicone (L0449-65)	25	77	143	P
Helium	Fluorosilicone (L0449-65)	80	176	461	P
Helium	Fluorosilicone (L0449-65)	150	302	973	P
Helium	Natural	25	77	17.25 to 32.3	I
Helium	Natural	30	86	27.0	I
Helium	Natural	34	93	43.0	I
Helium	Natural	50	122	51.6	I
Helium	Neoprene	0	32	1.7	I
Helium	Neoprene	25	77	.6 to 7.5	I
Helium	Neoprene (C0557-70)	25	77	6.5	P
Helium	Neoprene	30.4	87	5.9	I
Helium	Neoprene	41.5	107	11.8	I
Helium	Neoprene	57	135	26.3	I
Helium	Neoprene	73	163	36.0	I
Helium	Neoprene (C0557-70)	80	176	59.6	P
Helium	Neoprene	101.3	214	70.5	I
Helium	Neoprene (C0557-70)	150	302	187	P
Helium	Nitrile	25	77	7.40	I
Helium	Nitrile (N0674-70)	25	77	8.0	P
Helium	Nitrile	50	122	19.3	I
Helium	Nitrile (N0674-70)	80	176	65.9	P
Helium	Nitrile (N0674-70)	150	302	252	P
Helium	Nitroso	NR3		1050	I

(1) Std cc cm/cm² sec. bar

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"P" denotes information from Parker Seal tests.

(3) "NR" Temperature not reported.

(4) Registered trademark E.I. du Pont de Nemours & Co.

Note: Some of these compounds may no longer be available.

Table 3-24: Gas Permeability Rates

Gas Permeability Rates

Gas or Liquid	Elastomer	Temperature		Permeability ⁽¹⁾ x 10 ⁻⁸	Source ⁽²⁾
		°C	°F		
Helium	Polyacrylate (A0607-70)	25	77	16.3	P
Helium	Polyacrylate (A0607-70)	80	176	110	P
Helium	Polyacrylate (A0607-70)	150	302	310	P
Helium	Polyurethane (P0642-70)	25	77	3.6	P
Helium	Polyurethane (P0642-70)	80	176	33.5	P
Helium	SBR	25	77	17.3	I
Helium	Silicone	25	77	263	I
Helium	Silicone (S0604-70)	25	77	238	P
Helium	Silicone	30	86	173	I
Helium	Silicone (S0604-70)	80	176	560	P
Helium	Silicone (S0604-70)	150	302	1250	P
Helium	TFE PTFE	25	77	523 (sic)	I
Helium	TFE PTFE	30	86	90.0	I
Helium	TFE PTFE	50	122	128	I
Helium	FEP PTFE	25	77	30.1	I
Helium	FEP PTFE	30	86	46.5	I
Helium	FEP PTFE	50	122	58.5	I
Helium	FEP PTFE	75	167	94.4	I
Helium	FEP PTFE	100	212	157	I
Hexane	Silicone	25	77	7050	I
Hydrogen	Butadiene	25	77	31.6	I
Hydrogen	Butadiene	50	122	76.0	I
Hydrogen	Butyl (B0318-70)	35	95	16.1	A
Hydrogen	Butyl (B0318-70)	82	180	68.2	A
Hydrogen	Butyl (B0318-70)	124	255	273	A
Hydrogen	Ethylene Propylene	38	100	28.9 to 111	A
Hydrogen	Ethylene Propylene (E0529-65)	40	104	111	A
Hydrogen	Ethylene Propylene (E0692-75)	38	100	45.3	A
Hydrogen	Ethylene Propylene	93	200	187 to 544	A
Hydrogen	Ethylene Propylene (E0529-65)	94	202	544	A
Hydrogen	Ethylene Propylene (E0692-75)	94	201	252	A
Hydrogen	Ethylene Propylene	152	306	599 to 1730	A
Hydrogen	Ethylene Propylene (E0529-65)	155	311	1730	A
Hydrogen	Ethylene Propylene (E0692-75)	151	304	591	A
Hydrogen	Fluorocarbon-Viton4	93	200	160	A
Hydrogen	Neoprene	38	100	180	A
Hydrogen	Nitrile	38	100	10.3 to 32.1	A
Hydrogen	Nitrile (N0741-75)	39	103	11.9	A
Hydrogen	Nitrile	79	175	47.0 to 125	A
Hydrogen	Nitrile (N0741-75)	80	176	88.2	A
Hydrogen	Nitrile	121	250	98.8 to 330	A
Hydrogen	Polyacrylate (A0607-70)	38	100	49.6	A
Hydrogen	Polyacrylate (A0607-70)	91	195	174	A
Hydrogen	Polyacrylate (A0607-70)	153	307	927	A
Hydrogen	Polysulfide	25	77	1.2	I
Hydrogen	Polyurethane (P0642-70)	39	103	19.3	A
Hydrogen	Polyurethane (P0648-90)	39	102	4.89	A
Hydrogen	Polyurethane (P0642-70)	66	151	70.4	A
Hydrogen	Polyurethane (P0648-90)	67	152	21.3	A
Hydrogen	Polyurethane (P0642-70)	94	202	155	A
Hydrogen	SBR	25	77	30.1	I

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Table 3-24: Gas Permeability Rates

Gas Permeability Rates

Gas or Liquid	Elastomer	Temperature		Permeability ⁽¹⁾ x 10 ⁻⁸	Source ⁽²⁾
		°C	°F		
Hydrogen	SBR (G0244-70)	38	101	46.2	A
Hydrogen	SBR (G0244-70)	84	183	245	A
Hydrogen	SBR (G0244-70)	122	251	539	A
Hydrogen	Silicone	Room		188 to 488	I
Hydrogen	Silicone	25	77	495	I
Hydrogen	Silicone (S0684-70)	39	103	1010	A
Hydrogen	Silicone	93	200	1570 to 2070	A
Hydrogen	Silicone (S0684-70)	91	195	2070	A
Hydrogen	Silicone	149	300	3300 to 8760	A
Hydrogen	Silicone (S0684-70)	156	313	4300	A
Hydrogen	FEP PTFE	-74	-101	.0113	I
Hydrogen	FEP PTFE	-46	-51	.180	I
Hydrogen	FEP PTFE	-18	0	1.05	I
Hydrogen	FEP PTFE	10	50	3.90	I
Hydrogen	FEP PTFE	25	77	9.89	I
Hydrogen	FEP PTFE	38	100	10.1	I
Hydrogen	FEP PTFE	50	122	24.7	I
Hydrogen	FEP PTFE	66	151	22.5	I
Hydrogen	FEP PTFE	75	167	49.5	I
Hydrogen	FEP PTFE	100	212	89.9	I
Hydrogen	TFE PTFE	25	77	17.8	I
Hydrogen	TFE PTFE	30	86	42.0	I
Hydrogen	TFE PTFE	50	122	63.8	I
Hydrogen Sulfide	Silicone	25	77	4870	I
Iodine	Silicone	Room		75000	I
Krypton	Butyl (B0318-70)	35	95	1.39	A
Krypton	Butyl (B0318-70)	82	180	10.3	A
Krypton	Butyl (B0318-70)	124	255	54.7	A
Krypton	Ethylene Propylene (E0529-65)	40	104	38.6	A
Krypton	Ethylene Propylene (E0692-75)	38	101	16.6	A
Krypton	Ethylene Propylene (E0529-65)	94	202	184	A
Krypton	Ethylene Propylene (E0692-75)	94	201	91.2	A
Krypton	Ethylene Propylene (E0529-65)	155	311	324	A
Krypton	Ethylene Propylene (E0692-75)	151	304	289	A
Krypton	Fluorocarbon-Viton ⁽⁴⁾	93	200	25	A
Krypton	Natural	35	95	47.8	I
Krypton	Neoprene	38	100	32	A
Krypton	Nitrile	38	100	.935 to 4.40	A
Krypton	Nitrile (N0741-75)	39	103	1.82	A
Krypton	Nitrile	79	175	10.7 to 30.1	A
Krypton	Nitrile (N0741-75)	80	176	11.6	A
Krypton	Nitrile	121	250	27.8 to 86.6	A
Krypton	Nitrile (N0741-75)	118	245	48.9	A
Krypton	Polyacrylate (A0607-70)	38	100	14.8	A
Krypton	Polyacrylate (A0607-70)	91	195	90.4	A
Krypton	Polyacrylate (A0607-70)	153	307	464	A
Krypton	Polyurethane (P0642-70)	39	103	2.06	A
Krypton	Polyurethane (P0648-90)	39	102	.783	A
Krypton	Polyurethane (P0642-70)	66	151	6.53	A
Krypton	Polyurethane (P0648-90)	67	152	4.35	A
Krypton	Polyurethane (P0642-70)	94	202	31.9	A

(1) Std cc cm/cm² sec. bar

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Note: Some of these compounds may no longer be available.

Table 3-24: Gas Permeability Rates

Gas Permeability Rates

Gas or Liquid	Elastomer	Temperature		Permeability ⁽¹⁾ x 10 ⁻⁸	Source ⁽²⁾
		°C	°F		
Krypton	Polyurethane (P0648-90)	94	201	36.8	A
Krypton	SBR	38	100	7.35 to 30.8	A
Krypton	SBR (G0244-70)	38	101	7.35	A
Krypton	SBR	82	180	43.0 to 82.1	A
Krypton	SBR (G0244-70)	84	183	43.0	A
Krypton	SBR	121	250	144 to 276	A
Krypton	SBR (G0244-70)	122	251	144	A
Krypton	Silicone	Room		735	I
Krypton	Silicone	38	100	521 to 708	A
Krypton	Silicone (S0684-70)	38	101	708	A
Krypton	Silicone	93	200	749	A
Krypton	Silicone (S0684-70)	91	195	1440	A
Krypton	Silicone	149	300	1030 to 3190	A
Krypton	Silicone (S0684-70)	156	313	2320	A
Krypton	PTFE	149	300	24	A
Methane	Butadiene	25	77	9.77	I
Methane	Butyl	25	77	.56	I
Methane	Fluorocarbon	30	86	.12	I
Methane	Natural	25	77	22.7	I
Methane	Neoprene	25	77	2.6	I
Methane	Nitrile	25	77	2.4	I
Methane	Silicone	25	77	705	I
Methane	Silicone	30	86	443	I
Methane	FEP PTFE	25	77	.702 to .83	I
Methane	FEP PTFE	30	86	1.05	I
Methane	FEP PTFE	50	122	2.02	I
Methane	FEP PTFE	75	167	4.50	I
Methane	FEP PTFE	100	212	8.99	I
Methane	TFE PTFE	30	86	1.13	I
Methane	TFE PTFE	50	122	3.0	I
Methanol	Silicone	Room		10430	I
Neon	Natural	35	95	8.5	I
Nitric Oxide	Silicone	Room		450	I
Nitrogen	Butadiene	25	77	3.0	I
Nitrogen	Butadiene	25	77	4.85	I
Nitrogen	Butadiene	50	122	14.3	I
Nitrogen	Butyl	25	77	.244	I
Nitrogen	Butyl	30	86	.234	I
Nitrogen	Butyl	50	122	1.25	I
Nitrogen	Fluorocarbon	30	86	.233	I
Nitrogen	Fluorocarbon	50	122	.975	I
Nitrogen	Fluorosilicone	Room		40	DC
Nitrogen	Isoprene	25	77	5.3	I
Nitrogen	Isoprene	50	122	16.8	I
Nitrogen	Natural	Room		4.8	DC
Nitrogen	Natural	25	77	6.04 to 9.9	I
Nitrogen	Natural	30	86	6.06 to 7.9	I
Nitrogen	Natural	50	122	19.1	I
Nitrogen	Neoprene	25	77	.01 to 2	I
Nitrogen	Neoprene	30	86	.885	I
Nitrogen	Neoprene	54	129	4.35	I

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Table 3-24: Gas Permeability Rates

Gas Permeability Rates

Gas or Liquid	Elastomer	Temperature		Permeability ⁽¹⁾ x 10 ⁻⁸	Source ⁽²⁾
		°C	°F		
Nitrogen	Neoprene	85	185	16.7	I
Nitrogen	Nitrile	20	68	.46	I
Nitrogen	Nitrile	25	77	.177 to 1.89	I
Nitrogen	Nitrile	30	86	.176 to .795	I
Nitrogen	Nitrile	50	122	1.07 to 6.9	I
Nitrogen	Nitrile	79	174	13.4	I
Nitrogen	Nitroso	NR3		108	I
Nitrogen	SBR	25	77	4.7	I
Nitrogen	SBR	30	86	4.76	I
Nitrogen	Silicone	Room		75 to 120	I
Nitrogen	Silicone	Room		210	I
Nitrogen	Silicone	30	86	113 to 188	I
Nitrogen	Silicone	50	122	240	I
Nitrogen	TFE PTFE	25	77	2.4	I
Nitrogen	TFE PTFE	30	86	3.9	I
Nitrogen	TFE PTFE	50	122	7.5	I
Nitrogen	FEP PTFE	25	77	1.44	I
Nitrogen	FEP PTFE	30	86	1.9	I
Nitrogen	FEP PTFE	50	122	4.4	I
Nitrogen	FEP PTFE	75	167	9.2	I
Nitrogen	FEP PTFE	100	212	18.5	I
Nitrogen Dioxide	Silicone	Room		5701	I
Nitrogen Oxides	TFE PTFE	NR3		3475	I
Nitrogen Oxides	FEP PTFE	NR3		485	I
Nitrogen Tetroxide	TFE PTFE	25	77	0.050 to 1.00	I
Nitrogen Tetroxide	TFE PTFE	28	82	12.4	I
Nitrogen Tetroxide	TFE PTFE	28	82	3.9	I
Nitrous Oxide	Silicone	Room		3263	I
Octane	Silicone	25	77	6450	I
Oxygen	Butadiene	25	77	8.5	I
Oxygen	Butadiene	25	77	14.3	I
Oxygen	Butadiene	30	86	14.3	I
Oxygen	Butadiene	50	122	35.5	I
Oxygen	Butyl	Room		.98 to 1.05	I
Oxygen	Butyl	25	77	.89 to 4.2	I
Oxygen	Butyl	30	86	.98	I
Oxygen	Butyl	50	122	3.98	I
Oxygen	Fluorocarbon	26	79	1.7	I
Oxygen	Fluorosilicone	Room		81.3	DC
Oxygen	Fluorosilicone	Room		82.5	I
Oxygen	Fluorosilicone	26	79	78	I
Oxygen	Natural	Room		13.0	DC
Oxygen	Natural	25	77	17.5	I
Oxygen	Natural	30	86	17.48	I
Oxygen	Natural	50	122	46.4	I
Oxygen	Neoprene	23	73	3.1	I
Oxygen	Neoprene	25	77	3.0	I
Oxygen	Neoprene	25	77	1.13	I
Oxygen	Neoprene	38	100	13	A
Oxygen	Neoprene	50	122	4.73	I
Oxygen	Nitrile	25	77	.72 to 6.15	I

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Gas or Liquid	Elastomer	Temperature		Permeability ⁽¹⁾ x 10 ⁻⁸	Source ⁽²⁾
		°C	°F		
Oxygen	Nitrile	30	86	.72	I
Oxygen	Nitrile	50	122	3.45 to 18.9	I
Oxygen	Nitrile	20-30	68-86	.72 to 6.2	I
Oxygen	Polysulfide	23	73	5.78	I
Oxygen	Polysulfide	25	77	.22	I
Oxygen	Polyurethane	32	90	1.3 to 4.0	I
Oxygen	Polyurethane	Room		.80	DC
Oxygen	SBR	25	77	12.8	I
Oxygen	Silicone	Room		330 to 450	I
Oxygen	Silicone	21	70	195 to 443	I
Oxygen	Silicone	32	90	234	I
Oxygen	Silicone	34	93	346	I
Oxygen	Silicone	44	111	257 to 384	I
Oxygen	TFE PTFE	25	77	7.5	I
Oxygen	FEP PTFE	25	77	3.37	I
Oxygen	FEP PTFE	50	122	9.22	I
Oxygen	FEP PTFE	75	167	17.99	I
Oxygen	FEP PTFE	100	212	31.48	I
Pentane	Silicone	25	77	15000	I
Pentane	Silicone	30	86	32600	I
Pentane	Silicone	40	104	28900	I
Pentane	Silicone	50	122	25700	I
Pentane	Silicone	60	140	22900	I
Pentane	Silicone	70	158	20700	I
Phenol	Silicone	25	77	8100	I
Propane	Butadiene	25	77	22 to 40.5	I
Propane	Butyl	25	77	1.28	I
Propane	Natural	25	77	126	I
Propane	Neoprene	25	77	5.4	I
Propane	Polysulfide	25	77	1.09	I
Propane	Silicone	25	77	3080	I
Pyridene	Silicone	25	77	1580	I
Sulfur Dioxide	Silicone	Room		11250	I
Toluene	Silicone	25	77	6850	I
Water Vapor	Ethylene Propylene	Room		550 to 3700	A
Water Vapor	Ethylene Propylene (E0692-75)	Room		550	A
Xenon	Butyl	25	77	.83 to 3.0	I
Xenon	Butyl (B0318-70)	35	95	.70	A
Xenon	Butyl (B0318-70)	82	180	6.73	A
Xenon	Butyl (B0318-70)	124	255	38.1	A
Xenon	Ethylene Propylene	38	100	12.2 to 44.5	A
Xenon	Ethylene Propylene (E0529-65)	40	104	44.5	A
Xenon	Ethylene Propylene (E0692-75)	38	100	37.8	A
Xenon	Ethylene Propylene (E0692-75)	93	200	112 to 214	A
Xenon	Ethylene Propylene (E0529-65)	94	202	195	A
Xenon	Ethylene Propylene (E0692-75)	94	201	167	A
Xenon	Ethylene Propylene	149	300	260 to 520	A
Xenon	Ethylene Propylene (E0529-65)	155	311	520	A
Xenon	Ethylene Propylene (E0692-75)	151	304	460	A
Xenon	Fluorocarbon	93	200	10	A
Xenon	Natural	25	77	17.3 to 32.2	I

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		°C	°F		
Xenon	Natural	35	95	72.5	I
Xenon	Neoprene	25	77	3.4 to 7.5	I
Xenon	Neoprene	38	100	40	A
Xenon	Nitrile	25	77	.60 to 2.85	I
Xenon	Nitrile	38	100	.94	A
Xenon	Nitrile (N0741-75)	38	101	3.31	A
Xenon	Nitrile	79	175	7.83 to 36.8	A
Xenon	Nitrile (N0741-75)	81	178	13.2	A
Xenon	Nitrile	121	250	38.5 to 101	A
Xenon	Polyacrylate (A0607-70)	38	100	10.9	A
Xenon	Polyacrylate (A0607-70)	91	195	108	A
Xenon	Polyacrylate (A0607-70)	153	307	549	A
Xenon	Polyurethane (P0642-70)	39	103	2.57	A
Xenon	Polyurethane (P0648-90)	39	102	1.03	A
Xenon	Polyurethane (P0642-70)	66	151	9.58	A
Xenon	Polyurethane (P0648-90)	67	152	6.58	A
Xenon	Polyurethane (P0642-70)	94	202	43.0	A
Xenon	Polyurethane (P0648-90)	94	201	24.5	A
Xenon	SBR (G0244-70)	38	101	14.9	A
Xenon	SBR (G0244-70)	84	183	66.2	A
Xenon	SBR (G0244-70)	122	251	173	A
Xenon	Silicone	Room		1523	I
Xenon	Silicone	38	100	109 to 1220	A
Xenon	Silicone (S0684-70)	38	101	1220	A
Xenon	Silicone	93	200	1290 to 2180	A
Xenon	Silicone (S0684-70)	91	195	2180	A
Xenon	Silicone (S0684-70)	148	299	700	A
Xenon	Silicone	149	300	1110 (sic) to 2200	A
Xenon	Silicone (S0684-70)	144	291	2200	A
Xenon	PTFE	149	300	5.3	A

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