Radial Seal Design Guide

Extruded and Machined Elastomeric Products

aerospace
climate control
electromechanical
filtration
fluid & gas handlin
hydraulics
pneumatics
process control
sealing & shieldin

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

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1. Introduction - Radial Seals

Radial seals differ from face seals (aka axial seals) in the direction in which compression or squeeze is applied to the seal cross sections. Radial seals have compression applied to their outside diamter (O.D.) and inside diameter (I.D.) *(see Figure 1.1)*, whereas face seals have squeeze applied to the top and bottom of the seal's cross sections *(see Figure 1.2)*. Radial seals are commonly used in cap and plug, piston and bore type applications.

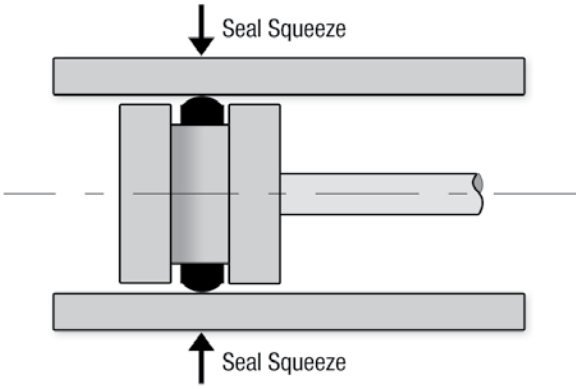

Figure 1.1. Radial Seal

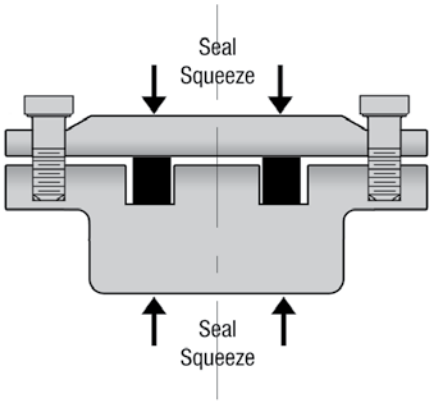

Figure 1.2. Face Seal

The radial seals can be used in both static and dynamic applications. Both types present different operating environmental factors and therefore require different design parameters.

Static Radial Seals

Static radial seals operate in an environment in which there is no relative motion between the mating surfaces being sealed. Other than the assembly of the mating components these seals do not see any motion.

Generally, static seals are more forgiving because they do not see the wear and tear of constant motion. For this reason they can typically handle larger gaps, rougher surface finishes and higher pressures.

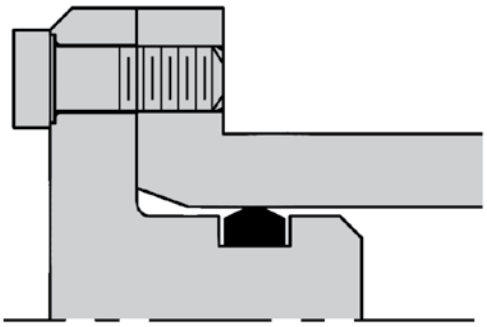

Figure 1.3. Static Radial Seal

Dynamic Radial Seals

Dynamic radial seals operate in an environment that has a relative reciprocating, rotating or oscillating motion between the mating components.

Because TechSeal's double chamfer seals and D-rings are often used in reciprocating applications, this design guide will focus on reciprocating seals and their design parameters. For more information on other dynamic seals types, see Appendix B page 28.

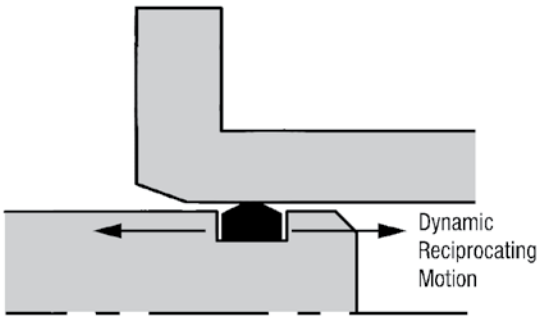

Figure 1.4. Dynamic Radial Seal

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1. Introduction - Double Chamfer Seals and D-ring Seals

TechSeal's double chamfer seals and D-rings are radial seals that have flat inner diameters and machined outer diameters. These seals are commonly used in static applications; in dynamic applications they are mostly seen in reciprocating applications.

In most radial seal applications seals can be subject to rolling and twisting during installation and consequently cause seal failure during operation. This phenomenon is commonly known as spiral failure. The double chamfer seals and D-rings have flat bases and thus can prevent the spiral failure mode in many radial applications.

Figure 1.5. Spiral Failture

Double Chamfer Seals

Double chamfer seals are homogeneous radial seals with flat bases and a chamfered profile, as shown in Figure 1.6. These seals are mostly used in static and reciprocating dynamic situations, but can be used in rotational applications under certain circumstances.

The seal geometry uses the flat base to provide superior gland stability and to therefore prevent seal twisting or spiral failure. In addition, the chamfered surface allows the seal to maintain its performance in high pressure environment up to 15,000 psi [103 MPa] in some cases.

The chamfered profile of the seal also helps in installation by providing a gradual compression rather than an abrupt installation point. When used with the recommended installation chamfer *(see Figure 2.1a)*, the installation process is significantly improved.

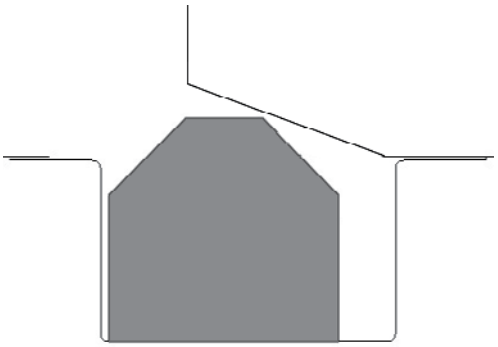

Figure 1.6.
Double Chamfer Cross Section

D-ring Seals

D-ring seals (or D-rings) are another style of homogeneous radial seal consisting of a flat base and a rounded sealing surface, creating a cross sectional geometry similar to a capital "D" *(see Figure 1.7)*.

These seals are used in very similar applications to the double chamfer seals, mostly in static and reciprocating applications. D-ring seals also provide excellent stability in the groove and can help prevent spiral failure in radial seal grooves.

The rounded surface of the D-ring requires similar installation forces to the double chamfer designs, and also works well by providing a gradual compression profile. We also recommend using the installation chamfer *(see Figure 2.1a)* with D-rings to ease the installation force and protect the seal.

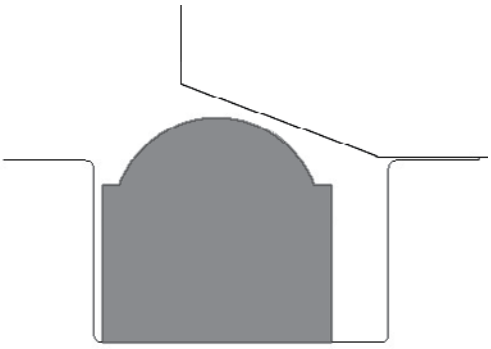

Figure 1.7.
D-ring Cross Section

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Manufacturing Capabilities

TechSeal manufactures elastomeric radial seals using an extrusion, precision cutting and machining process. These unique manufacturing technologies give TechSeal the ability to easily customize the radial seal configurations and dimensions.

TechSeal's machining technology allows for the production of complex cross sections such as D-rings, double chamfers, L-gaskets, short lip seals and many other special configurations *(see inside back cover)*.

Custom Configurations

In addition to the standard sizes listed in this design guide, custom configurations are available for both double chamfer seals and D-rings. TechSeal's team of Application Engineers can consult and custom design the optimal sealing solution for customer's specific application if the application calls for configurations different from the standard sizes offered in this guide by TechSeal.

Double Chamfer Seals:

Double chamfer seals are easily the most customizable radial seals on the market. With TechSeal's extrusion manufacturing process, these seals can be customized to a specific I.D., O.D., width, or chamfer geometry with no tooling required.

Figure 1.9. Examples of Custom Double Chamfer Configurations

O-Rings:

O-rings are also very customizable. With TechSeal's extrusion manufacturing process, these seals can be customized to a specific I.D., O.D., width, or machined geometry. A non-recurring setup charge may be required if the profile deviates from which seen in the standard profiles throughout this guide.

Figure 1.10. Examples of Custom D-ring Configurations

Design Assistance

Application Engineers:

Our Application Engineering team is available to develop customized sealing solutions for even the most demanding applications. The team is able to help with:

- Non-linear elastomeric Finite Element Analysis
- Material recommendations
- Optimized configuration design

Finite Elements Analysis (FEA):

Using non-linear elastomeric Finite Element Analysis (FEA) software we can perform accurate simulations of seal performance based on material test data.

This advanced computer simulation technology is employed to predict the behavior characteristics of different cross-sectional seal designs, bypassing the developmental trial-and-error testing of successive prototypes and reducing development time.

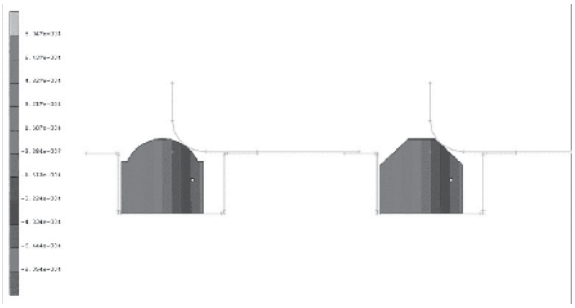

Figure 1.10. Examples of FEA Simulations for D-ring and Double Chamfer Cross Sections

Material Recommendations:

TechSeal has a wide array of active compounds in both standard and special material families for many demanding application environments.

In addition to the featured compound offerings listed in table 3.1 on page 24, the team of Chemists at the TechSeal Division can develop new compounds in case the existing selection does not meet a particular application's requirement.

Material Test Lab

TechSeal's material laboratory can test existing compounds to confirm the material's compatibility with the application's environment.

Material Characterizations:

Our lab has the ability to perform series of tests on a particular compound to determine the original physical properties of that compound:

- Durometer hardness
- Tensile, elongation, modulus
- Tear B, C and Trouser
- Elevated temperature mechanicals
- Compression set
- Heat age and high-pressure-high-temp aging
- Fluid resistance and compatibility
- High and low temperature
- and many more

Printing and Marking on Parts

TechSeal offers a variety of part marking technologies to aid with seal installation, identification and traceability.

Printing Options:

- Part numbers or batch / lot numbers
- Contact information
- Date and time
- Alphabetical and / or numeric characters
- Other relevant seal information

Marking Options:

- Logos (Parker's, customer's)
- O.D. and / or I.D. stripes
- O.D. painting
- Color coating

Quality Commitment

Parker TechSeal is committed to continuous quality improvement in order to deliver premier products and customer service. Each of the TechSeal Division's manufacturing facilities are ISO 9001:2008 and ISO / TS 16949 certified.

Additionally, the facilities of TechSeal utilize various quality practices such as:

- Six Sigma
- Kaizen events
- Lean transformation activities
- Total quality management (TQM)
- Statistical process control (SPC)

Additional Services

- Seal surface coatings
- Functional testing
- Packaging and kitting
- Worldwide distribution and service center network

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Scenario 1: NO Standard O-ring Groove Available:

Please choose the standard recommended groove closest to your application dimensions, and check with an applica engineer to make sure the design is appropriate.

Scenario 2: Standard O-ring Groove Available:

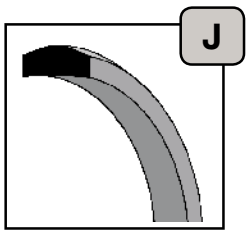
Please follow the steps below to determine the appropriate double chamfer seal or D-ring design:

(1) In Design Table 1, match the O-ring 2- series (200, 300, or 400) with the existing groove and ensure the existing groove dimensions match the recommendations based on the number of backup rings used with the original O-r The Design Table 1 will also give the recommended cross section dimensions for the double chamfer or D-ring.

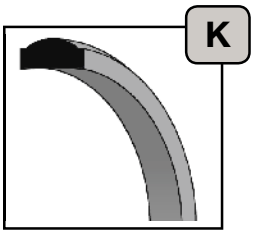
(2) Next, determine if the groove is a male groove or female groove, based on Figure 2.1.
   (a) If the groove is Male – use Design Table 2.1 to match the O-ring dash number to the recommended seal an groove dimensions.
   (b) If the groove is Female – use Design Table 2.2 to match the O-ring dash number to the recommended seal and groove dimensions.

(3) Determine which material to use by referencing Table 3.1 on page 24.

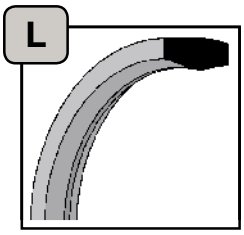
(4) Lastly, construct your seal part number by choosing the geometry from the illustrations below, and follow the TechSeal part numbering instructions.



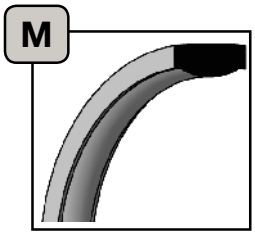
Male Double Chamfer



Male D-ring



Female Double Chamfer



Female D-ring

TechSeal Part Numbering System

Profile	J or K or L or M
Equivalent O-ring size	-2xx or -3xx or -4xx
Number of O-ring backups in original design	-0 or -1 or -2
Material	VM100
Example Final Part Number Male Double Chamfer -2xx Oring size, 2 back-ups, VM100 material	J2102VM100

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Figure 2.1. Industrial Static Seal Glands

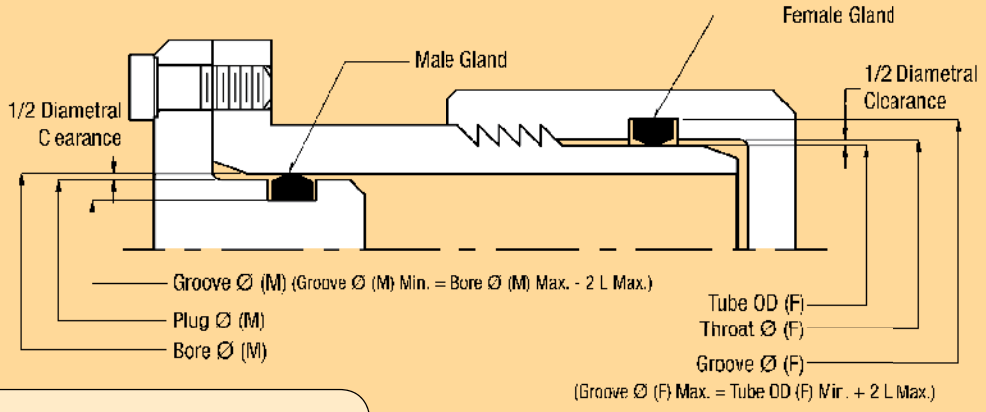
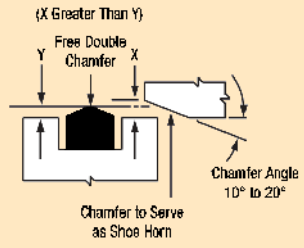
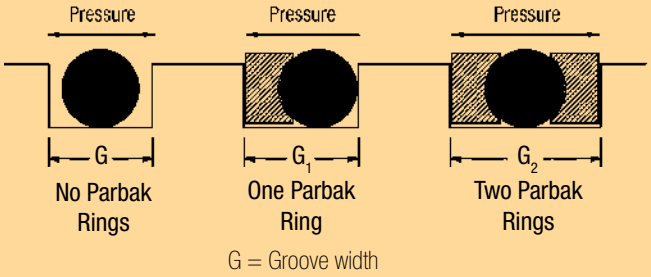
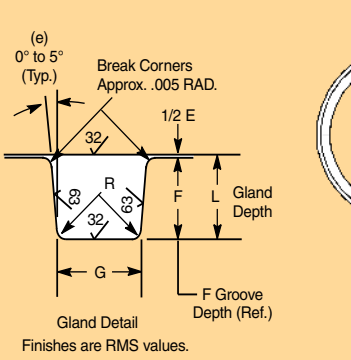


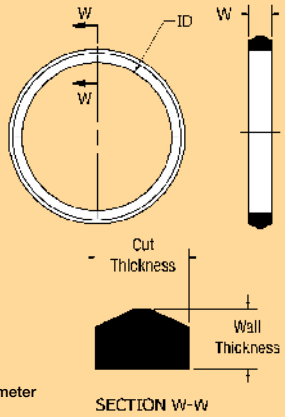
Figure 2.1a - Proper Design for Installation of D-Rings and Double Chamfer

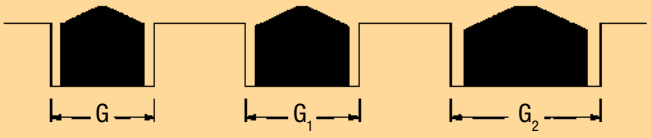




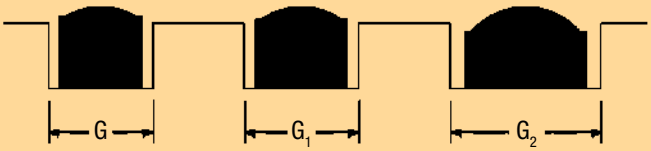


metric conversion 32 microinches = .8 micrometer





Double Chamfer Seal Equivalences



D-Ring Seal Equivalences

Design Table 1. Groove Width

O-ring Size	Wall Thick-ness	±	Gland Depth (L)	±	Diametral Clearance (E)	No O-ring Backups			One O-ring Backup			Two O-ring Backup		
						Groove Width (G)	Cut Thick-ness	±	Groove Width (G_1)	Cut Thick-ness	±	Groove Width (G_2)	Cut Thick-ness	±
-200	0.139	0.004	0.112	0.001	0.003 to 0.006	0.187 to 0.192	0.140	0.004	0.208 to 0.213	0.158	0.004	0.275 to 0.280	0.218	0.005
-300	0.210	0.005	0.171	0.002	0.003 to 0.006	0.281 to 0.286	0.214	0.005	0.311 to 0.316	0.235	0.005	0.410 to 0.415	0.335	0.005
-400	0.275	0.005	0.227	0.002	0.004 to 0.007	0.375 to 0.380	0.295	0.005	0.408 to 0.413	0.316	0.005	0.538 to 0.543	0.448	0.005

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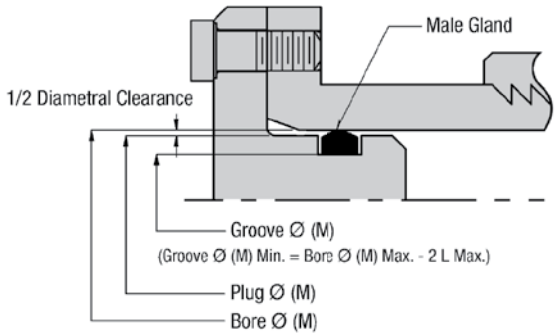
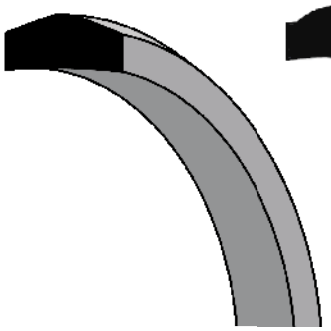
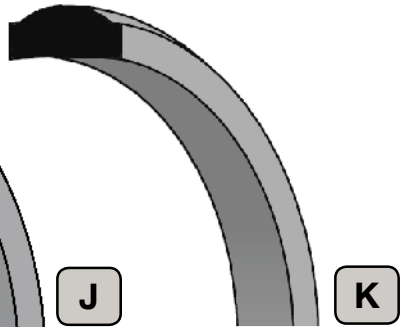
2. Standard Sizes

Design Table 2.1. Male Gland







O-ring Size	Seal Dimensions							Bore Diameter	Groove Diameter		Plug Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
207	0.546	0.008	0.139	0.140	0.158	0.218	0.824	0.812	0.590		0.809
208	0.609	0.009	0.139	0.140	0.158	0.218	0.887	0.875	0.653		0.872
209	0.671	0.009	0.139	0.140	0.158	0.218	0.949	0.937	0.715		0.934
210	0.734	0.009	0.139	0.140	0.158	0.218	1.012	1.000	0.778		0.997
211	0.796	0.010	0.139	0.140	0.158	0.218	1.074	1.062	0.840		1.059
212	0.859	0.010	0.139	0.140	0.158	0.218	1.137	1.125	0.903		1.122
213	0.921	0.011	0.139	0.140	0.158	0.218	1.199	1.187	0.965		1.184
214	0.984	0.011	0.139	0.140	0.158	0.218	1.262	1.250	1.028		1.247
215	1.046	0.011	0.139	0.140	0.158	0.218	1.324	1.312	1.090		1.309
216	1.109	0.012	0.139	0.140	0.158	0.218	1.387	1.375	1.153		1.372
217	1.171	0.012	0.139	0.140	0.158	0.218	1.449	1.437	1.215		1.434
218	1.234	0.013	0.139	0.140	0.158	0.218	1.512	1.500	1.278		1.497
219	1.296	0.013	0.139	0.140	0.158	0.218	1.574	1.562	1.340		1.559
220	1.359	0.013	0.139	0.140	0.158	0.218	1.637	1.637	0.002		1.375
221	1.421	0.014	0.139	0.140	0.158	0.218	1.699	1.700	1.437	0.002	1.465
222	1.484	0.014	0.139	0.140	0.158	0.218	1.762	1.750	1.528		1.747
223	1.609	0.015	0.139	0.140	0.158	0.218	1.887	1.875	1.653		1.872
224	1.734	0.016	0.139	0.140	0.158	0.218	2.012	2.000	1.778		1.997
225	1.859	0.016	0.139	0.140	0.158	0.218	2.137	2.125	1.903		2.122
226	1.984	0.017	0.139	0.140	0.158	0.218	2.262	2.250	2.028		2.247
227	2.109	0.018	0.139	0.140	0.158	0.218	2.387	2.375	2.153		2.372
228	2.234	0.019	0.139	0.140	0.158	0.218	2.512	2.500	2.278		2.497
229	2.359	0.019	0.139	0.140	0.158	0.218	2.637	2.625	2.403		2.622
230	2.484	0.020	0.139	0.140	0.158	0.218	2.762	2.750	2.528		2.747
231	2.609	0.021	0.139	0.140	0.158	0.218	2.887	2.875	2.653		2.872
232	2.734	0.022	0.139	0.140	0.158	0.218	3.012	3.000	2.778		2.997
233	2.859	0.022	0.139	0.140	0.158	0.218	3.137	3.125	2.903		3.122
234	2.984	0.023	0.139	0.140	0.158	0.218	3.262	3.250	3.028		3.247
235	3.109	0.024	0.139	0.140	0.158	0.218	3.387	3.375	3.153		3.372
236	3.234	0.025	0.139	0.140	0.158	0.218	3.512	3.500	3.278		3.497
237	3.359	0.025	0.139	0.140	0.158	0.218	3.637	3.625	3.403		3.622
238	3.484	0.026	0.139	0.140	0.158	0.218	3.762	3.750	3.528		3.747
239	3.609	0.027	0.139	0.140	0.158	0.218	3.887	3.875	3.653		3.872
240	3.734	0.028	0.139	0.140	0.158	0.218	4.012	4.000	3.778		3.997

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

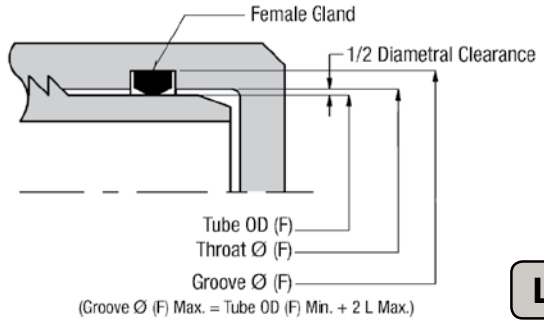
Design Table 2.1. Male Gland (continued)

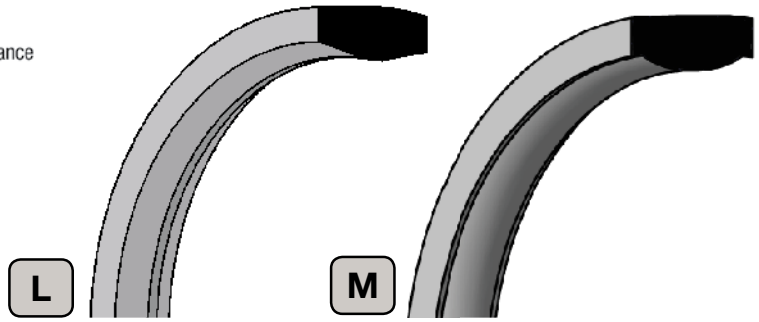
O-ring Size	Seal Dimensions							Bore Diameter	Groove Diameter		Plug Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
241	3.859	0.029	0.139	0.140	0.158	0.218	4.137	4.125	3.903		4.122
242	3.984	0.029	0.139	0.140	0.158	0.218	4.262	4.250	4.028		4.247
243	4.109	0.030	0.139	0.140	0.158	0.218	4.387	4.375	4.153		4.372
244	4.234	0.031	0.139	0.140	0.158	0.218	4.512	4.500	4.278		4.497
245	4.359	0.032	0.139	0.140	0.158	0.218	4.637	4.625	4.403		4.622
246	4.484	0.032	0.139	0.140	0.158	0.218	4.762	4.750	4.528		4.747
247	4.609	0.033	0.139	0.140	0.158	0.218	4.887	4.875	4.653		4.872
248	4.734	0.034	0.139	0.140	0.158	0.218	5.012	5.000	4.778		4.997
249	4.859	0.035	0.139	0.140	0.158	0.218	5.137	5.125	4.903		5.122
250	4.984	0.035	0.139	0.140	0.158	0.218	5.262	5.250	5.028		5.247
251	5.109	0.036	0.139	0.140	0.158	0.218	5.387	5.375	5.153		5.372
252	5.234	0.037	0.139	0.140	0.158	0.218	5.512	5.500	5.278		5.497
253	5.359	0.038	0.139	0.140	0.158	0.218	5.637	5.625	5.403		5.622
254	5.484	0.038	0.139	0.140	0.158	0.218	5.762	5.750	5.528		5.747
255	5.609	0.039	0.139	0.140	0.158	0.218	5.887	5.875	5.653		5.872
256	5.734	0.040	0.139	0.140	0.158	0.218	6.012	6.000	5.778		5.997
257	5.859	0.041	0.139	0.140	0.158	0.218	6.137	6.125	5.903		6.122
258	5.984	0.042	0.139	0.140	0.158	0.218	6.262	6.250	6.028		6.247
259	6.234	0.043	0.139	0.140	0.158	0.218	6.512	6.500	6.278		6.497
260	6.484	0.045	0.139	0.140	0.158	0.218	6.762	6.750	6.528	0.002	6.747
261	6.734	0.046	0.139	0.140	0.158	0.218	7.012	7.000	6.778		6.997
262	6.984	0.048	0.139	0.140	0.158	0.218	7.262	7.250	7.028		7.247
263	7.234	0.049	0.139	0.140	0.158	0.218	7.512	7.500	7.278		7.497
264	7.484	0.051	0.139	0.140	0.158	0.218	7.762	7.750	7.528		7.747
265	7.734	0.052	0.139	0.140	0.158	0.218	8.012	8.012	0.002		7.750
266	7.984	0.054	0.139	0.140	0.158	0.218	8.262	8.262	8.000		8.028
267	8.234	0.055	0.139	0.140	0.158	0.218	8.512	8.500	8.278		8.497
268	8.484	0.057	0.139	0.140	0.158	0.218	8.762	8.750	8.528		8.747
269	8.734	0.058	0.139	0.140	0.158	0.218	9.012	9.000	8.778		8.997
270	8.984	0.060	0.139	0.140	0.158	0.218	9.262	9.250	9.028		9.247
271	9.234	0.061	0.139	0.140	0.158	0.218	9.512	9.500	9.278		9.497
272	9.484	0.063	0.139	0.140	0.158	0.218	9.762	9.750	9.528		9.747
273	9.734	0.064	0.139	0.140	0.158	0.218	10.012	10.000	9.778		9.997
274	9.984	0.066	0.139	0.140	0.158	0.218	10.262	10.250	10.028		10.247
275	10.484	0.069	0.139	0.140	0.158	0.218	10.762	10.750	10.528		10.747
276	10.984	0.072	0.139	0.140	0.158	0.218	11.262	11.250	11.028		11.247
277	11.484	0.075	0.139	0.140	0.158	0.218	11.762	11.750	11.528		11.747
278	11.984	0.078	0.139	0.140	0.158	0.218	12.262	12.250	12.028		12.247
279	12.984	0.084	0.139	0.140	0.158	0.218	13.262	13.250	13.028		13.247
280	13.984	0.090	0.139	0.140	0.158	0.218	14.262	14.250	14.028		14.247
281	14.984	0.096	0.139	0.140	0.158	0.218	15.262	15.250	15.028		15.247
282	15.955	0.102	0.139	0.140	0.158	0.218	16.233	16.250	16.028		16.247
283	16.955	0.108	0.139	0.140	0.158	0.218	17.233	17.250	17.028		17.247
284	17.955	0.115	0.139	0.140	0.158	0.218	18.233	18.250	18.028		18.247

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

2. Standard Sizes

Design Table 2.2. Female Gland





O-ring Size	Seal Dimensions							Tube OD	Groove Diameter		Throat Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
207*	0.546	0.008	0.139	0.140	0.158	0.218	0.824	0.562	0.784		0.565
208*	0.609	0.009	0.139	0.140	0.158	0.218	0.887	0.625	0.847		0.628
209*	0.671	0.009	0.139	0.140	0.158	0.218	0.949	0.687	0.909		0.690
210*	0.734	0.009	0.139	0.140	0.158	0.218	1.012	0.750	0.972		0.753
211*	0.796	0.010	0.139	0.140	0.158	0.218	1.074	0.812	1.034		0.815
212*	0.859	0.010	0.139	0.140	0.158	0.218	1.137	0.875	1.097		0.878
213*	0.921	0.011	0.139	0.140	0.158	0.218	1.199	0.937	1.159		0.940
214*	0.984	0.011	0.139	0.140	0.158	0.218	1.262	1.000	1.222		1.003
215*	1.046	0.011	0.139	0.140	0.158	0.218	1.324	1.062	1.284		1.065
216*	1.109	0.012	0.139	0.140	0.158	0.218	1.387	1.125	1.347		1.128
217*	1.171	0.012	0.139	0.140	0.158	0.218	1.449	1.187	1.409		1.190
218*	1.234	0.013	0.139	0.140	0.158	0.218	1.512	1.250	1.472		1.253
219*	1.296	0.013	0.139	0.140	0.158	0.218	1.574	1.312	1.534		1.315
220*	1.359	0.013	0.139	0.140	0.158	0.218	1.637	1.375	1.597		1.378
221*	1.421	0.014	0.139	0.140	0.158	0.218	1.699	1.437	1.659		1.440
222*	1.484	0.014	0.139	0.140	0.158	0.218	1.762	1.500	1.722	0.002	1.503
223*	1.609	0.015	0.139	0.140	0.158	0.218	1.887	1.625	1.847		1.628
224*	1.734	0.016	0.139	0.140	0.158	0.218	2.012	1.750	1.972		1.753
225*	1.859	0.016	0.139	0.140	0.158	0.218	2.137	1.875	2.097		1.878
226*	1.984	0.017	0.139	0.140	0.158	0.218	2.262	2.000	2.222		2.003
227*	2.109	0.018	0.139	0.140	0.158	0.218	2.387	2.125	2.347		2.128
228*	2.234	0.019	0.139	0.140	0.158	0.218	2.512	2.250	2.472		2.253
229*	2.359	0.019	0.139	0.140	0.158	0.218	2.637	2.375	2.597		2.378
230*	2.484	0.020	0.139	0.140	0.158	0.218	2.762	2.500	2.722		2.503
231*	2.609	0.021	0.139	0.140	0.158	0.218	2.887	2.625	2.847		2.628
232*	2.734	0.022	0.139	0.140	0.158	0.218	3.012	2.750	2.972		2.753
233*	2.859	0.022	0.139	0.140	0.158	0.218	3.137	2.875	3.097		2.878
234*	2.984	0.023	0.139	0.140	0.158	0.218	3.262	3.000	3.222		3.003
235*	3.109	0.024	0.139	0.140	0.158	0.218	3.387	3.125	3.347		3.128
236*	3.234	0.025	0.139	0.140	0.158	0.218	3.512	3.250	3.472		3.253
237*	3.359	0.025	0.139	0.140	0.158	0.218	3.637	3.375	3.597		3.378
238*	3.484	0.026	0.139	0.140	0.158	0.218	3.762	3.500	3.722		3.503
239*	3.609	0.027	0.139	0.140	0.158	0.218	3.887	3.625	3.847		3.628
240*	3.734	0.028	0.139	0.140	0.158	0.218	4.012	3.750	3.972		3.753

* sizes availability is dependent on material selection.

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

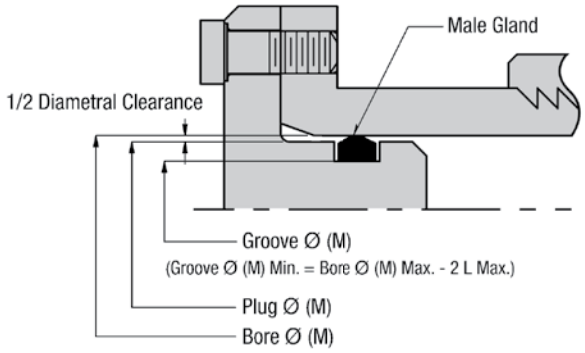
Design Table 2.2. Female Gland (continued)

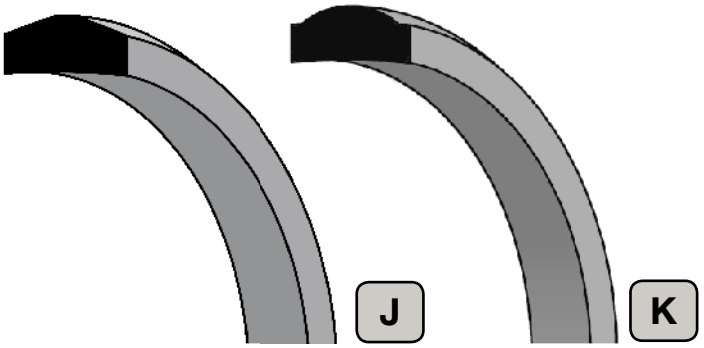
O-ring Size	Seal Dimensions							Tube OD	Groove Diameter		Throat Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
241*	3.859	0.029	0.139	0.140	0.158	0.218	4.137	3.875	4.097		3.878
242*	3.984	0.029	0.139	0.140	0.158	0.218	4.262	4.000	4.222		4.003
243*	4.109	0.030	0.139	0.140	0.158	0.218	4.387	4.125	4.347		4.128
244*	4.234	0.031	0.139	0.140	0.158	0.218	4.512	4.250	4.472		4.253
245*	4.359	0.032	0.139	0.140	0.158	0.218	4.637	4.375	4.597		4.378
246*	4.484	0.032	0.139	0.140	0.158	0.218	4.762	4.500	4.722		4.503
247*	4.609	0.033	0.139	0.140	0.158	0.218	4.887	4.625	4.847		4.628
248*	4.734	0.034	0.139	0.140	0.158	0.218	5.012	4.750	4.972		4.753
249*	4.859	0.035	0.139	0.140	0.158	0.218	5.137	4.875	5.097		4.878
250*	4.984	0.035	0.139	0.140	0.158	0.218	5.262	5.000	5.222		5.003
251	5.109	0.036	0.139	0.140	0.158	0.218	5.387	5.125	5.347		5.128
252	5.234	0.037	0.139	0.140	0.158	0.218	5.512	5.250	5.472		5.253
253	5.359	0.038	0.139	0.140	0.158	0.218	5.637	5.375	5.597		5.378
254	5.484	0.038	0.139	0.140	0.158	0.218	5.762	5.500	5.722		5.503
255	5.609	0.039	0.139	0.140	0.158	0.218	5.887	5.625	5.847		5.628
256	5.734	0.040	0.139	0.140	0.158	0.218	6.012	5.750	5.972		5.753
257	5.859	0.041	0.139	0.140	0.158	0.218	6.137	5.875	6.097		5.878
258	5.984	0.042	0.139	0.140	0.158	0.218	6.262	6.000	6.222		6.003
259	6.234	0.043	0.139	0.140	0.158	0.218	6.512	6.250	6.472		6.253
260	6.484	0.045	0.139	0.140	0.158	0.218	6.762	6.500	6.722		6.503
261	6.734	0.046	0.139	0.140	0.158	0.218	7.012	6.750	6.972	0.002	6.753
262	6.984	0.048	0.139	0.140	0.158	0.218	7.262	7.000	7.222		7.003
263	7.234	0.049	0.139	0.140	0.158	0.218	7.512	7.250	7.472		7.253
264	7.484	0.051	0.139	0.140	0.158	0.218	7.762	7.500	7.722		7.503
265	7.734	0.052	0.139	0.140	0.158	0.218	8.012	7.750	7.972		7.753
266	7.984	0.054	0.139	0.140	0.158	0.218	8.262	8.000	8.222		8.003
267	8.234	0.055	0.139	0.140	0.158	0.218	8.512	8.250	8.472		8.253
268	8.484	0.057	0.139	0.140	0.158	0.218	8.762	8.500	8.722		8.503
269	8.734	0.058	0.139	0.140	0.158	0.218	9.012	8.750	8.972		8.753
270	8.984	0.060	0.139	0.140	0.158	0.218	9.262	9.000	9.222		9.003
271	9.234	0.061	0.139	0.140	0.158	0.218	9.512	9.250	9.472		9.253
272	9.484	0.063	0.139	0.140	0.158	0.218	9.762	9.500	9.722		9.503
273	9.734	0.064	0.139	0.140	0.158	0.218	10.012	9.750	9.972		9.753
274	9.984	0.066	0.139	0.140	0.158	0.218	10.262	10.000	10.222		10.003
275	10.484	0.069	0.139	0.140	0.158	0.218	10.762	10.500	10.722		10.503
276	10.984	0.072	0.139	0.140	0.158	0.218	11.262	11.000	11.222		11.003
277	11.484	0.075	0.139	0.140	0.158	0.218	11.762	11.500	11.722		11.503
278	11.984	0.078	0.139	0.140	0.158	0.218	12.262	12.000	12.222		12.003
279	12.984	0.084	0.139	0.140	0.158	0.218	13.262	13.000	13.222		13.003
280	13.984	0.090	0.139	0.140	0.158	0.218	14.262	14.000	14.222		14.003
281	14.984	0.096	0.139	0.140	0.158	0.218	15.262	15.000	15.222		15.003
282	15.955	0.102	0.139	0.140	0.158	0.218	16.233	16.000	16.222		16.003
283	16.955	0.108	0.139	0.140	0.158	0.218	17.233	17.000	17.222		17.003
284	17.955	0.115	0.139	0.140	0.158	0.218	18.233	18.000	18.222		18.003

* sizes availability is dependent on material selection.

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

Design Table 3.1. Male Gland





O-ring Size	Seal Dimensions							Bore Diameter	Groove Diameter		Plug Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
311	0.537	0.008	0.210	0.214	0.235	0.335	0.957	0.937	0.597		0.934
312	0.600	0.009	0.210	0.214	0.235	0.335	1.020	1.000	0.660		0.997
313	0.662	0.009	0.210	0.214	0.235	0.335	1.082	1.062	0.722		1.059
314	0.725	0.009	0.210	0.214	0.235	0.335	1.145	1.125	0.785		1.122
315	0.787	0.010	0.210	0.214	0.235	0.335	1.207	1.187	0.847		1.184
316	0.850	0.010	0.210	0.214	0.235	0.335	1.270	1.250	0.910		1.247
317	0.912	0.011	0.210	0.214	0.235	0.335	1.332	1.312	0.972		1.309
318	0.975	0.011	0.210	0.214	0.235	0.335	1.395	1.375	1.035		1.372
319	1.037	0.011	0.210	0.214	0.235	0.335	1.457	1.437	1.097		1.434
320	1.100	0.012	0.210	0.214	0.235	0.335	1.520	1.500	1.160		1.497
321	1.162	0.012	0.210	0.214	0.235	0.335	1.582	1.562	1.222		1.559
322	1.225	0.012	0.210	0.214	0.235	0.335	1.645	1.625	1.285		1.622
323	1.287	0.013	0.210	0.214	0.235	0.335	1.707	1.687	1.347		1.684
324	1.350	0.013	0.210	0.214	0.235	0.335	1.770	1.750	1.410		1.747
325	1.475	0.014	0.210	0.214	0.235	0.335	1.895	1.875	1.535	0.004	1.872
326	1.600	0.015	0.210	0.214	0.235	0.335	2.020	2.000	1.660		1.997
327	1.725	0.016	0.210	0.214	0.235	0.335	2.145	2.125	1.785		2.122
328	1.850	0.016	0.210	0.214	0.235	0.335	2.270	2.250	1.910		2.247
329	1.975	0.017	0.210	0.214	0.235	0.335	2.395	2.375	2.035		2.372
330	2.100	0.018	0.210	0.214	0.235	0.335	2.520	2.500	2.160		2.497
331	2.225	0.019	0.210	0.214	0.235	0.335	2.645	2.625	2.285		2.622
332	2.350	0.019	0.210	0.214	0.235	0.335	2.770	2.750	2.410		2.747
333	2.475	0.020	0.210	0.214	0.235	0.335	2.895	2.875	2.535		2.872
334	2.600	0.021	0.210	0.214	0.235	0.335	3.020	3.000	2.660		2.997
335	2.725	0.022	0.210	0.214	0.235	0.335	3.145	3.125	2.785		3.122
336	2.850	0.022	0.210	0.214	0.235	0.335	3.270	3.250	2.910		3.247
337	2.975	0.023	0.210	0.214	0.235	0.335	3.395	3.375	3.035		3.372
338	3.100	0.024	0.210	0.214	0.235	0.335	3.520	3.500	3.160		3.497
339	3.225	0.025	0.210	0.214	0.235	0.335	3.645	3.625	3.285		3.622
340	3.350	0.025	0.210	0.214	0.235	0.335	3.770	3.750	3.410		3.747
341	3.475	0.026	0.210	0.214	0.235	0.335	3.895	3.875	3.535		3.872
342	3.600	0.027	0.210	0.214	0.235	0.335	4.020	4.000	3.660		3.997
343	3.725	0.028	0.210	0.214	0.235	0.335	4.145	4.125	3.785		4.122
344	3.850	0.028	0.210	0.214	0.235	0.335	4.270	4.250	3.910		4.247

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

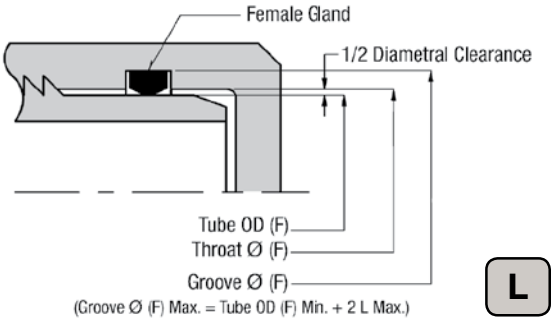
Design Table 3.1. Male Gland (continued)

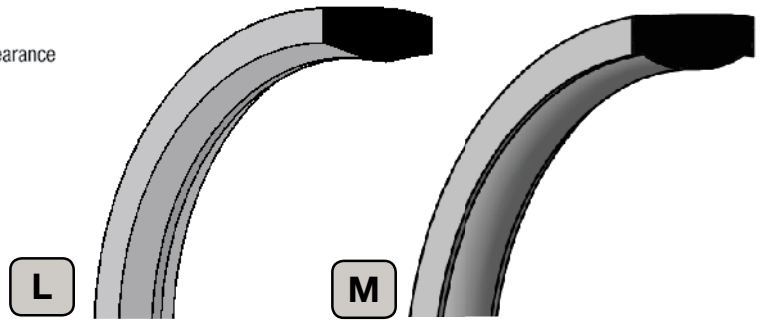
O-ring Size	Seal Dimensions							Bore Diameter	Groove Diameter		Plug Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
345	3.975	0.029	0.210	0.214	0.235	0.335	4.395	4.375	4.035		4.372
346	4.100	0.030	0.210	0.214	0.235	0.335	4.520	4.500	4.160		4.497
347	4.225	0.031	0.210	0.214	0.235	0.335	4.645	4.625	4.285		4.622
348	4.350	0.032	0.210	0.214	0.235	0.335	4.770	4.750	4.410		4.747
349	4.475	0.032	0.210	0.214	0.235	0.335	4.895	4.875	4.535		4.872
350	4.600	0.033	0.210	0.214	0.235	0.335	5.020	5.000	4.660		4.997
351	4.725	0.034	0.210	0.214	0.235	0.335	5.145	5.125	4.785		5.122
352	4.850	0.035	0.210	0.214	0.235	0.335	5.270	5.250	4.910		5.247
353	4.975	0.035	0.210	0.214	0.235	0.335	5.395	5.375	5.035		5.372
354	5.100	0.036	0.210	0.214	0.235	0.335	5.520	5.500	5.160		5.497
355	5.225	0.037	0.210	0.214	0.235	0.335	5.645	5.625	5.285		5.622
356	5.350	0.038	0.210	0.214	0.235	0.335	5.770	5.750	5.410		5.747
357	5.475	0.038	0.210	0.214	0.235	0.335	5.895	5.875	5.535		5.872
358	5.600	0.039	0.210	0.214	0.235	0.335	6.020	6.000	5.660		5.997
359	5.725	0.040	0.210	0.214	0.235	0.335	6.145	6.125	5.785		6.122
360	5.850	0.041	0.210	0.214	0.235	0.335	6.270	6.250	5.910		6.247
361	5.975	0.041	0.210	0.214	0.235	0.335	6.395	6.375	6.035		6.372
362	6.225	0.043	0.210	0.214	0.235	0.335	6.645	6.625	6.285		6.622
363	6.475	0.044	0.210	0.214	0.235	0.335	6.895	6.875	6.535		6.872
364	6.725	0.046	0.210	0.214	0.235	0.335	7.145	7.125	6.785		7.122
365	6.975	0.048	0.210	0.214	0.235	0.335	7.395	7.375	7.035	0.004	7.372
366	7.225	0.049	0.210	0.214	0.235	0.335	7.645	7.625	7.285		7.622
367	7.475	0.051	0.210	0.214	0.235	0.335	7.895	7.875	7.535		7.872
368	7.725	0.052	0.210	0.214	0.235	0.335	8.145	8.125	7.785		8.122
369	7.975	0.054	0.210	0.214	0.235	0.335	8.395	8.375	8.035		8.372
370	8.225	0.055	0.210	0.214	0.235	0.335	8.645	8.625	8.285		8.622
371	8.475	0.057	0.210	0.214	0.235	0.335	8.895	8.875	8.535		8.872
372	8.725	0.058	0.210	0.214	0.235	0.335	9.145	9.125	8.785		9.122
373	8.975	0.060	0.210	0.214	0.235	0.335	9.395	9.375	9.035		9.372
374	9.225	0.061	0.210	0.214	0.235	0.335	9.645	9.625	9.285		9.622
375	9.475	0.063	0.210	0.214	0.235	0.335	9.895	9.875	9.535		9.872
376	9.725	0.064	0.210	0.214	0.235	0.335	10.145	10.125	9.785		10.122
377	9.975	0.066	0.210	0.214	0.235	0.335	10.395	10.375	10.035		10.372
378	10.475	0.069	0.210	0.214	0.235	0.335	10.895	10.875	10.535		10.872
379	10.975	0.072	0.210	0.214	0.235	0.335	11.395	11.375	11.035		11.372
380	11.475	0.075	0.210	0.214	0.235	0.335	11.895	11.875	11.535		11.872
381	11.975	0.078	0.210	0.214	0.235	0.335	12.395	12.375	12.035		12.372
382	12.975	0.084	0.210	0.214	0.235	0.335	13.395	13.375	13.035		13.372
383	13.975	0.090	0.210	0.214	0.235	0.335	14.395	14.375	14.035		14.372
384	14.975	0.096	0.210	0.214	0.235	0.335	15.395	15.375	15.035		15.372
385	15.955	0.102	0.210	0.214	0.235	0.335	16.375	16.375	16.035		16.372
386	16.955	0.108	0.210	0.214	0.235	0.335	17.375	17.375	17.035		17.372
387	17.955	0.115	0.210	0.214	0.235	0.335	18.375	18.375	18.035		18.372
388	18.955	0.121	0.210	0.214	0.235	0.335	19.375	19.375	19.035		19.372

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

2. Standard Sizes

Design Table 3.2. Female Gland





O-ring Size	Seal Dimensions							Tube OD	Groove Diameter		Throat Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
311*	0.537	0.008	0.210	0.214	0.235	0.335	0.957	0.562	0.902		0.565
312*	0.600	0.009	0.210	0.214	0.235	0.335	1.020	0.625	0.965		0.628
313*	0.662	0.009	0.210	0.214	0.235	0.335	1.082	0.687	1.027		0.690
314*	0.725	0.009	0.210	0.214	0.235	0.335	1.145	0.750	1.090		0.753
315*	0.787	0.010	0.210	0.214	0.235	0.335	1.207	0.812	1.152		0.815
316*	0.850	0.010	0.210	0.214	0.235	0.335	1.270	0.875	1.215		0.878
317*	0.912	0.011	0.210	0.214	0.235	0.335	1.332	0.937	1.277		0.940
318*	0.975	0.011	0.210	0.214	0.235	0.335	1.395	1.000	1.340		1.003
319*	1.037	0.011	0.210	0.214	0.235	0.335	1.457	1.062	1.402		1.065
320*	1.100	0.012	0.210	0.214	0.235	0.335	1.520	1.125	1.465		1.128
321*	1.162	0.012	0.210	0.214	0.235	0.335	1.582	1.187	1.527		1.190
322*	1.225	0.012	0.210	0.214	0.235	0.335	1.645	1.250	1.590		1.253
323*	1.287	0.013	0.210	0.214	0.235	0.335	1.707	1.312	1.652		1.315
324*	1.350	0.013	0.210	0.214	0.235	0.335	1.770	1.375	1.715		1.378
325*	1.475	0.014	0.210	0.214	0.235	0.335	1.895	1.500	1.840	0.004	1.503
326*	1.600	0.015	0.210	0.214	0.235	0.335	2.020	1.625	1.965		1.628
327*	1.725	0.016	0.210	0.214	0.235	0.335	2.145	1.750	2.090		1.753
328*	1.850	0.016	0.210	0.214	0.235	0.335	2.270	1.875	2.215		1.878
329*	1.975	0.017	0.210	0.214	0.235	0.335	2.395	2.000	2.340		2.003
330*	2.100	0.018	0.210	0.214	0.235	0.335	2.520	2.125	2.465		2.128
331*	2.225	0.019	0.210	0.214	0.235	0.335	2.645	2.250	2.590		2.253
332*	2.350	0.019	0.210	0.214	0.235	0.335	2.770	2.375	2.715		2.378
333*	2.475	0.020	0.210	0.214	0.235	0.335	2.895	2.500	2.840		2.503
334*	2.600	0.021	0.210	0.214	0.235	0.335	3.020	2.625	2.965		2.628
335*	2.725	0.022	0.210	0.214	0.235	0.335	3.145	2.750	3.090		2.753
336*	2.850	0.022	0.210	0.214	0.235	0.335	3.270	2.875	3.215		2.878
337*	2.975	0.023	0.210	0.214	0.235	0.335	3.395	3.000	3.340		3.003
338*	3.100	0.024	0.210	0.214	0.235	0.335	3.520	3.125	3.465		3.128
339*	3.225	0.025	0.210	0.214	0.235	0.335	3.645	3.250	3.590		3.253
340*	3.350	0.025	0.210	0.214	0.235	0.335	3.770	3.375	3.715		3.378
341*	3.475	0.026	0.210	0.214	0.235	0.335	3.895	3.500	3.840		3.502
342*	3.600	0.027	0.210	0.214	0.235	0.335	4.020	3.625	3.965		3.628
343*	3.725	0.028	0.210	0.214	0.235	0.335	4.145	3.750	4.090		3.753
344*	3.850	0.028	0.210	0.214	0.235	0.335	4.270	3.875	4.215		3.878

* sizes availability is dependent on material selection.

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

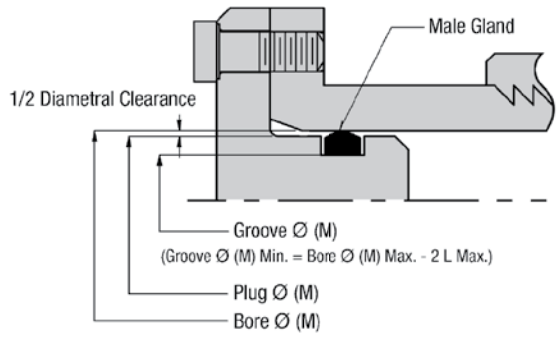
Design Table 3.2. Female Gland (continued)

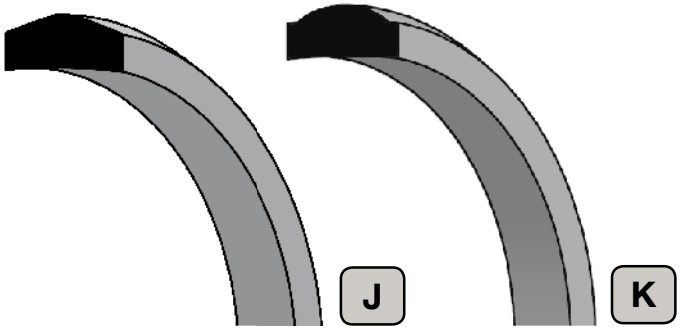
O-ring Size	Seal Dimensions							Tube OD	Groove Diameter		Throat Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
345*	3.975	0.029	0.210	0.214	0.235	0.335	4.395	4.000	4.340		4.003
346*	4.100	0.030	0.210	0.214	0.235	0.335	4.520	4.125	4.465		4.128
347*	4.225	0.031	0.210	0.214	0.235	0.335	4.645	4.250	4.590		4.253
348*	4.350	0.032	0.210	0.214	0.235	0.335	4.770	4.375	4.717		4.378
349*	4.475	0.032	0.210	0.214	0.235	0.335	4.895	4.500	4.840		4.503
350*	4.600	0.033	0.210	0.214	0.235	0.335	5.020	4.625	4.965		4.628
351*	4.725	0.034	0.210	0.214	0.235	0.335	5.145	4.750	5.090		4.753
352*	4.850	0.035	0.210	0.214	0.235	0.335	5.270	4.875	5.215		4.878
353*	4.975	0.035	0.210	0.214	0.235	0.335	5.395	5.000	5.340		5.003
354	5.100	0.036	0.210	0.214	0.235	0.335	5.520	5.125	5.465		5.128
355	5.225	0.037	0.210	0.214	0.235	0.335	5.645	5.250	5.590		5.253
356	5.350	0.038	0.210	0.214	0.235	0.335	5.770	5.375	5.715		5.378
357	5.475	0.038	0.210	0.214	0.235	0.335	5.895	5.500	5.840		5.503
358	5.600	0.039	0.210	0.214	0.235	0.335	6.020	5.625	5.965		5.628
359	5.725	0.040	0.210	0.214	0.235	0.335	6.145	5.750	6.090		5.753
360	5.850	0.041	0.210	0.214	0.235	0.335	6.270	5.875	6.215		5.878
361	5.975	0.041	0.210	0.214	0.235	0.335	6.395	6.000	6.340		6.003
362	6.225	0.043	0.210	0.214	0.235	0.335	6.645	6.250	6.590		6.253
363	6.475	0.044	0.210	0.214	0.235	0.335	6.895	6.500	6.840		6.503
364	6.725	0.046	0.210	0.214	0.235	0.335	7.145	6.750	7.090		6.753
365	6.975	0.048	0.210	0.214	0.235	0.335	7.395	7.000	7.340	0.004	7.003
366	7.225	0.049	0.210	0.214	0.235	0.335	7.645	7.250	7.590		7.253
367	7.475	0.051	0.210	0.214	0.235	0.335	7.895	7.500	7.840		7.503
368	7.725	0.052	0.210	0.214	0.235	0.335	8.145	7.750	8.090		7.753
369	7.975	0.054	0.210	0.214	0.235	0.335	8.395	8.000	8.340		8.003
370	8.225	0.055	0.210	0.214	0.235	0.335	8.645	8.250	8.590		8.253
371	8.475	0.057	0.210	0.214	0.235	0.335	8.895	8.500	8.840		8.503
372	8.725	0.058	0.210	0.214	0.235	0.335	9.145	8.750	9.090		8.753
373	8.975	0.060	0.210	0.214	0.235	0.335	9.395	9.000	9.340		9.003
374	9.225	0.061	0.210	0.214	0.235	0.335	9.645	9.250	9.590		9.253
375	9.475	0.063	0.210	0.214	0.235	0.335	9.895	9.500	9.840		9.503
376	9.725	0.064	0.210	0.214	0.235	0.335	10.145	9.750	10.090		9.753
377	9.975	0.066	0.210	0.214	0.235	0.335	10.395	10.000	10.340		10.003
378	10.475	0.069	0.210	0.214	0.235	0.335	10.895	10.500	10.840		10.503
379	10.975	0.072	0.210	0.214	0.235	0.335	11.395	11.000	11.340		11.003
380	11.475	0.075	0.210	0.214	0.235	0.335	11.895	11.500	11.840		11.503
381	11.975	0.078	0.210	0.214	0.235	0.335	12.395	12.000	12.340		12.003
382	12.975	0.084	0.210	0.214	0.235	0.335	13.395	13.000	13.340		13.003
383	13.975	0.090	0.210	0.214	0.235	0.335	14.395	14.000	14.340		14.003
384	14.975	0.096	0.210	0.214	0.235	0.335	15.395	15.000	15.340		15.003
385	15.955	0.102	0.210	0.214	0.235	0.335	16.375	16.000	16.340		16.003
386	16.955	0.108	0.210	0.214	0.235	0.335	17.375	17.000	17.340		17.003
387	17.955	0.115	0.210	0.214	0.235	0.335	18.375	18.000	18.340		18.003
388	18.955	0.121	0.210	0.214	0.235	0.335	19.375	19.000	19.340		19.003

* sizes availability is dependent on material selection.

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

Design Table 4.1. Male Gland



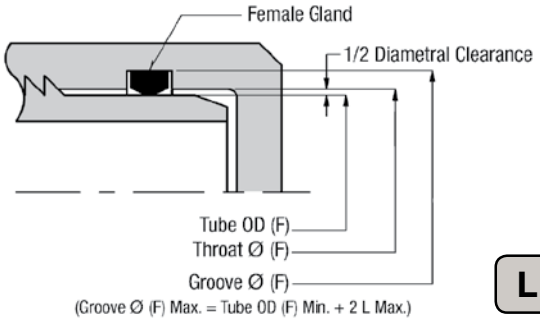


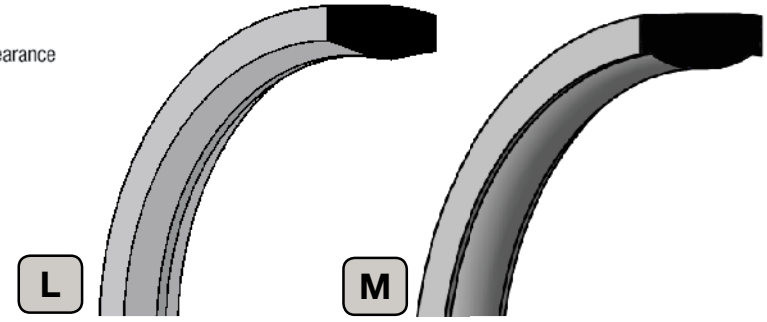
O-ring Size	Seal Dimensions							Bore Diameter	Groove Diameter		Plug Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
425	4.475	0.032	0.275	0.295	0.316	0.448	5.025	5.000	4.548		4.996
426	4.600	0.033	0.275	0.295	0.316	0.448	5.150	5.125	4.673		5.121
427	4.725	0.034	0.275	0.295	0.316	0.448	5.275	5.250	4.798		5.246
428	4.850	0.035	0.275	0.295	0.316	0.448	5.400	5.375	4.923		5.371
429	4.975	0.035	0.275	0.295	0.316	0.448	5.525	5.500	5.048		5.496
430	5.100	0.036	0.275	0.295	0.316	0.448	5.650	5.625	5.173		5.621
431	5.225	0.037	0.275	0.295	0.316	0.448	5.775	5.750	5.298		5.746
432	5.350	0.038	0.275	0.295	0.316	0.448	5.900	5.875	5.423		5.871
433	5.475	0.038	0.275	0.295	0.316	0.448	6.025	6.000	5.548		5.996
434	5.600	0.039	0.275	0.295	0.316	0.448	6.150	6.125	5.673		6.121
435	5.725	0.040	0.275	0.295	0.316	0.448	6.275	6.250	5.798		6.246
436	5.850	0.041	0.275	0.295	0.316	0.448	6.400	6.375	5.923		6.371
437	5.975	0.041	0.275	0.295	0.316	0.448	6.525	6.500	6.048		6.496
438	6.225	0.043	0.275	0.295	0.316	0.448	6.775	6.750	6.298		6.746
439	6.475	0.044	0.275	0.295	0.316	0.448	7.025	7.000	6.548		6.996
440	6.725	0.046	0.275	0.295	0.316	0.448	7.275	7.250	6.798	0.004	7.246
441	6.975	0.048	0.275	0.295	0.316	0.448	7.525	7.500	7.048		7.496
442	7.225	0.049	0.275	0.295	0.316	0.448	7.775	7.750	7.298		7.746
443	7.475	0.051	0.275	0.295	0.316	0.448	8.025	8.000	7.548		7.996
444	7.725	0.052	0.275	0.295	0.316	0.448	8.275	8.250	7.798		8.246
445	7.975	0.054	0.275	0.295	0.316	0.448	8.525	8.500	8.048		8.496
446	8.475	0.057	0.275	0.295	0.316	0.448	9.025	9.000	8.548		8.996
447	8.975	0.060	0.275	0.295	0.316	0.448	9.525	9.500	9.048		9.496
448	9.475	0.063	0.275	0.295	0.316	0.448	10.025	10.000	9.548		9.996
449	9.975	0.066	0.275	0.295	0.316	0.448	10.525	10.500	10.048		10.496
450	10.475	0.069	0.275	0.295	0.316	0.448	11.025	11.000	10.548		10.996
451	10.975	0.072	0.275	0.295	0.316	0.448	11.525	11.500	11.048		11.496
452	11.475	0.075	0.275	0.295	0.316	0.448	12.025	12.000	11.548		11.996
453	11.975	0.078	0.275	0.295	0.316	0.448	12.525	12.500	12.048		12.496
454	12.475	0.081	0.275	0.295	0.316	0.448	13.025	13.000	12.548		12.996
455	12.975	0.084	0.275	0.295	0.316	0.448	13.525	13.500	13.048		13.496
456	13.475	0.087	0.275	0.295	0.316	0.448	14.025	14.000	13.548		13.996
457	13.975	0.090	0.275	0.295	0.316	0.448	14.525	14.500	14.048		14.496
458	14.475	0.093	0.275	0.295	0.316	0.448	15.025	15.000	14.548		14.996

Design Table 4.1. Male Gland (continued)

O-ring Size	Seal Dimensions							Bore Diameter	Groove Diameter		Plug Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
459	14.975	0.096	0.275	0.295	0.316	0.448	15.525	15.500	15.048		15.496
460	15.475	0.099	0.275	0.295	0.316	0.448	16.025	16.000	15.548		15.996
461	15.955	0.102	0.275	0.295	0.316	0.448	16.505	16.500	16.048		16.496
462	16.455	0.105	0.275	0.295	0.316	0.448	17.005	17.000	16.548		16.996
463	16.955	0.108	0.275	0.295	0.316	0.448	17.505	17.500	17.048		17.496
464	17.455	0.111	0.275	0.295	0.316	0.448	18.005	18.000	17.548	0.004	17.996
465	17.955	0.115	0.275	0.295	0.316	0.448	18.505	18.500	18.048		18.496
466	18.455	0.118	0.275	0.295	0.316	0.448	19.005	19.000	18.548		18.996
467	18.955	0.121	0.275	0.295	0.316	0.448	19.505	19.500	19.048		19.496

Design Table 4.2. Female Gland





O-ring Size	Seal Dimensions							Tube OD	Groove Diameter		Throat Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
425*	4.475	0.032	0.275	0.295	0.316	0.448	5.025	4.500	4.952		4.504
426*	4.600	0.033	0.275	0.295	0.316	0.448	5.150	4.625	5.077		4.629
427*	4.725	0.034	0.275	0.295	0.316	0.448	5.275	4.750	5.202		4.754
428*	4.850	0.035	0.275	0.295	0.316	0.448	5.400	4.875	5.327		4.879
429*	4.975	0.035	0.275	0.295	0.316	0.448	5.525	5.000	5.452		5.004
430	5.100	0.036	0.275	0.295	0.316	0.448	5.650	5.125	5.577		5.129
431	5.225	0.037	0.275	0.295	0.316	0.448	5.775	5.250	5.702		5.254
432	5.350	0.038	0.275	0.295	0.316	0.448	5.900	5.375	5.827		5.379
433	5.475	0.038	0.275	0.295	0.316	0.448	6.025	5.500	5.952		5.504
434	5.600	0.039	0.275	0.295	0.316	0.448	6.150	5.625	6.077		5.629
435	5.725	0.040	0.275	0.295	0.316	0.448	6.275	5.750	6.202		5.754
436	5.850	0.041	0.275	0.295	0.316	0.448	6.400	5.875	6.327		5.879
437	5.975	0.041	0.275	0.295	0.316	0.448	6.525	6.000	6.452		6.004
438	6.225	0.043	0.275	0.295	0.316	0.448	6.775	6.250	6.702		6.254
439	6.475	0.044	0.275	0.295	0.316	0.448	7.025	6.500	6.952		6.504
440	6.725	0.046	0.275	0.295	0.316	0.448	7.275	6.750	7.202	0.004	6.754
441	6.975	0.048	0.275	0.295	0.316	0.448	7.525	7.000	7.452		7.004
442	7.225	0.049	0.275	0.295	0.316	0.448	7.775	7.250	7.702		7.254
443	7.475	0.051	0.275	0.295	0.316	0.448	8.025	7.500	7.952		7.504
444	7.725	0.052	0.275	0.295	0.316	0.448	8.275	7.750	8.202		7.754
445	7.975	0.054	0.275	0.295	0.316	0.448	8.525	8.000	8.452		8.004
446	8.475	0.057	0.275	0.295	0.316	0.448	9.025	8.500	8.952		8.504
447	8.975	0.060	0.275	0.295	0.316	0.448	9.525	9.000	9.452		9.004
448	9.475	0.063	0.275	0.295	0.316	0.448	10.025	9.500	9.952		9.504
449	9.975	0.066	0.275	0.295	0.316	0.448	10.525	10.000	10.452		10.000
450	10.475	0.069	0.275	0.295	0.316	0.448	11.025	10.500	10.952		10.504
451	10.975	0.072	0.275	0.295	0.316	0.448	11.525	11.000	11.452		11.004
452	11.475	0.075	0.275	0.295	0.316	0.448	12.025	11.500	11.952		11.504
453	11.975	0.078	0.275	0.295	0.316	0.448	12.525	12.000	12.452		12.004
454	12.475	0.081	0.275	0.295	0.316	0.448	13.025	12.500	12.952		12.504
455	12.975	0.084	0.275	0.295	0.316	0.448	13.525	13.000	13.452		13.004
456	13.475	0.087	0.275	0.295	0.316	0.448	14.025	13.500	13.952		13.504
457	13.975	0.090	0.275	0.295	0.316	0.448	14.525	14.000	14.452		14.004
458	14.475	0.093	0.275	0.295	0.316	0.448	15.025	14.500	14.952		14.504

* sizes availability is dependent on material selection.

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

Design Table 4.2. Female Gland (continued)

O-ring Size	Seal Dimensions							Tube OD	Groove Diameter		Throat Diameter
	ID	±	Wall	Cut (w/o backups)	Cut (w/ 1 backup)	Cut (w/ 2 backups)	OD (ref)	+0.000 - 0.002	+0.000	-	+0.001 - 0.000
459	14.975	0.096	0.275	0.295	0.316	0.448	15.525	15.000	15.452		15.004
460	15.475	0.099	0.275	0.295	0.316	0.448	16.025	15.500	15.952		15.504
461	15.955	0.102	0.275	0.295	0.316	0.448	16.505	16.000	16.452		16.004
462	16.455	0.105	0.275	0.295	0.316	0.448	17.005	16.500	16.952		16.504
463	16.955	0.108	0.275	0.295	0.316	0.448	17.505	17.000	17.452	0.004	17.004
464	17.455	0.111	0.275	0.295	0.316	0.448	18.005	17.500	17.952		17.504
465	17.955	0.115	0.275	0.295	0.316	0.448	18.505	18.000	18.452		18.004
466	18.455	0.118	0.275	0.295	0.316	0.448	19.005	18.500	18.952		18.504
467	18.955	0.121	0.275	0.295	0.316	0.448	19.505	19.000	19.452		19.004

NOTES:
(1) Please consult TechSeal's Applications Engineering Department for availability and designs if desired sizes are not shown.
(2) Refer to page 8 for information on how to specify a TechSeal's profile part number.

Acrylonitrile-Butadiene / Nitrile (NBR)

NBR is the general term for acrylonitrile butadiene terpolymer. The acrylonitrile content of nitrile sealing compounds varies considerably (18% to 50%) and influences the physical properties of the finished material.

The higher the acrylonitrile content, the better the resistance to oil and fuel. At the same time, elasticity and resistance to compression set is adversely affected. In view of these opposing realities, a compromise is often drawn and a medium acrylonitrile content selected. NBR has good mechanical properties and high wear resistance when compared with other elastomers but is not resistant to weather and ozone.

Heat resistance:

Up to 212°F [100°C] with shorter life @ 250°F [121°C]

Cold flexibility:

Depending on individual compound, between -30°F [-34°C] and -70°F [-57°C]

Chemical resistance:

- Aliphatic hydrocarbons (propane, butane, petroleum oil, mineral oil and grease, diesel fuel, fuel oils), vegetable and mineral oils, and greases
- HFA, HFB, and HFC fluids
- Dilute acids, alkali and salt solutions at low temperatures
- Water special compounds up to 212°F [100°C]

Not compatible with:

- Fuels of high aromatic content (for flex fuels a special compound must be used)
- Aromatic hydrocarbons (benzene)
- Chlorinated hydrocarbons (trichlorethylene)
- Polar solvents (ketone, acetone, acetic acid, ethylene-ester)
- Strong acids
- Brake fluid with glycol base
- Ozone, weather and atmospheric aging

Ethylene Propylene Rubber (EPM, EPDM)

EPDM is a copolymer of ethylene and propylene. EPDM is produced using a third monomer and is particularly useful when sealing phosphate-ester hydraulic fluids and in brake systems that use fluids having a glycol base.

Heat resistance:

Up to 250°F [121°C] (max. 400°F [204°C] in water and / or steam)

Cold flexibility:

Down to approximately -70°F [-57°C]

Chemical resistance:

- Hot water and steam up to 300°F [149°C] with special compounds up to 400°F [204°C]
- Brake fluids on glycol base up to +300°F [149°C]
- Many organic and inorganic acids
- Cleaning agents, soda and potassium alkalis
- Hydraulic fluids based on phosphate-ester (HFD-R)
- Silicone oil and grease
- Many polar solvents (alcohols, ketones, esters)
- Skydrol 500 and 7000
- Ozone, aging and weather resistant

Not compatible with:

Mineral oil products (oils, greases and fuels)

Fluorocarbon (FKM)

FKM has excellent resistance to high temperatures, ozone, oxygen, mineral oil, synthetic hydraulic fluids, fuels, aromatics, and many organic solvents and chemicals. Low temperature resistance is normally not favorable and for static applications is limited to approximately -15°F [-26°C] although in certain situations it is suitable down to -40°F [-40°C]. Under dynamic conditions, the lowest temperature expected is between 5°F and 0°F [-15°C and -18°C].

Gas permeability is very low and similar to that of butyl rubber. Special FKM compounds exhibit a higher resistance to acids, fuels, water and steam.

Heat resistance:

Up to 400°F [204°C] and higher temperatures with shorter life expectancy.

Cold flexibility:

Down to -15°F [-26°C] some to -40°F [-40°C]

Chemical resistance:

- Mineral oil and grease, low swelling in ASTM oils No.1 through No. 3
- Non-flammable hydraulic fuels in the group HFD
- Silicone oil and grease
- Mineral and vegetable oil and grease
- Aliphatic hydrocarbons (fuel, butane, propane, natural gas)
- Aromatic hydrocarbons (benzene, toluene)
- Chlorinated hydrocarbons (trichlorethylene and carbon tetrachloride)
- Fuels, also fuels with methanol content
- High vacuum
- Very good ozone, weather and aging resistance

Not compatible with:

- Brake fluids with glycol base
- Ammonia gas, amine, alkalis
- Superheated steam
- Low molecular organic acids (formic and acetic acids)

Hydrogenated Nitrile (HNBR)

HNBR is a synthetic polymer that results from the hydrogenation of nitrile rubber (NBR). HNBR offers superior mechanical characteristics, particularly high strength, and helps reduce extrusion and wear.

Heat resistance:

Up to approximately 300°F [150°C]

Cold flexibility:

Down to approximately -55°F [-48°C]

Chemical resistance:

- Aliphatic hydrocarbons
- Vegetable and animal fats and oils
- HFA, HFB and HFC hydraulic fluids
- Dilute acids, bases and salt solutions at moderate temperatures
- Water and steam up to 300°F [149°C]
- Ozone, aging and weathering

Not compatible with:

- Chlorinated hydrocarbons
- Polar solvents (ketones, esters and ethers)
- Strong acids

Note: TechSeal's selection of radial seals is not limited to only these polymer families. There are other polymer families available for the radial seals to be manufactured from. Please consult TechSeal's Application Engineering department if the application requires materials other than the ones listed in this design guide.

Table 3.1. TechSeal's Featured Compounds for Radial Seals

FKM (Fluorocarbon)	
Properties	**VM100-75**
Color	Black
Tensile Strength (psi)	2248
Elongation (%)	187
100% Modulus (psi)	1239
Compression Set, 22hrs @ 200°C	8
Temperature Range	-15 to +400°F [-26 to 200°C]

FKM (Fluorocarbon)	
Properties	**VA153-90**
Color	Black
Tensile Strength (psi)	2562
Elongation (%)	115
100% Modulus (psi)	1743
Compression Set, 22hrs @ 200°C	27
Temperature Range	-15 to +400°F [-26 to 200°C]

HNBR (Hydrogenated Nitrile)	
Properties	**N1922-75**
Color	Black
Tensile Strength (psi)	3161
Elongation (%)	181
100% Modulus (psi)	1200
Compression Set, 22hrs @ 150°C	12
Temperature Range	-25 to +300°F [-32 to 150°F]

HNBR (Hydrogenated Nitrile)	
Properties	**KB255-90**
Color	Black
Tensile Strength (psi)	3480
Elongation (%)	167
100% Modulus (psi)	2566
Compression Set, 22hrs @ 150°C	22
Temperature Range	-25 to +300°F [-32 to 150°F]

NBR (Nitrile / Acrylonitrile-Butadiene)	
Properties	**NB104-75**
Color	Black
Tensile Strength (psi)	2610
Elongation (%)	229
100% Modulus (psi)	725
Compression Set, 22hrs @ 100°C	9
Temperature Range	-30 to +250°F [-35 to 120°C]

NBR (Nitrile / Acrylonitrile-Butadiene)	
Properties	**NA259-90**
Color	Black
Tensile Strength (psi)	2346
Elongation (%)	261
100% Modulus (psi)	1333
Compression Set, 22hrs @ 100°C	11
Temperature Range	-30 to +250°F [-35 to 120°C]

Note: While this design guide contains the most popular materials for the extruded and machined radial seals, TechSeal also has a broad selection of other compounds with different colors, durometers and specifications. Please consult TechSeal's Application Engineers if the application requires materials other than the ones listed in this design guide.

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

There are standard ASTM procedures for conducting tests on rubber materials. These procedures must be followed carefully and properly if consistent test results are to be generated.

Aging

Deterioration over time, or aging, relates to the nature of the rubber molecule itself: long chain-like structures (polymers) composed of many smaller molecules (monomers) joined together. The points where the individual molecules are joined together are called bond sites. Bond sites and other areas may be susceptible to chemical reaction, of which three basic types are associated with aging:

1. Scission:

The molecular bonds are cut, dividing the chains into smaller fragments. Ozone, ultraviolet light and radiation exposure are typical causes.

2. Cross-Linking:

An oxidation process whereby additional intermolecular bonds are formed, usually caused by heat and oxygen exposure.

3. Modification of Side Groups:

A change in the complex, weaker fringe areas of the molecular construction due to chemical reaction. Moisture is an example of a cause contributor. All mechanisms by which rubber deteriorates are due to the environment and exposure.

All mechanisms by which rubber deteriorates are due to the environmental and exposure. Therefore it is the environment, not age, that impacts seal life, in both storage and actual service.

Environmental Change

High humidity in air will reduce the tensile properties of some materials. Changes to a fluid can occur in service due to the effect of heat and / or contaminants that can cause a rubber material to react differently than when exposed to new fluid. For this reason tests are sometimes conducted in used fluid, to essentially duplicate the environment the seal will be exposed to in actual service.

Storage

Storage, or shelf life, can vary with the resistance of each synthetic elastomer to normal storage conditions as well as the method of packaging. Consult the TechSeal Division for specific information on storage and shelf life of individual elastomer materials. The ideal elastomer product storage environment would provide:

- Ambient temperatures not exceeding 120°F [49°C]
- Exclusion of air (oxygen)
- Exclusion of contamination
- Exclusion of light (especially sunlight)
- Exclusion of ozone
- Exclusion of radiation
- Exclusion of moisture

Test Specimens

ASTM test procedures include descriptions of the standard specimen sizes needed for each test.

Part geometry can play a very large role in establishing physical properties variation. As an example, in fluid immersion tests smaller cross section seals can swell more than larger cross section seals. Using direct property readings from hollow cross section seals is not recommended.

While it is possible to establish a performance envelope that is part specific, tolerance stack-ups, normal batch-to-batch variation and cross-sectional geometry can provide a wide fluctuation in test results. This effect can be realized even when comparing the part-specific properties of two different profiles of the same configuration (i.e., hollow round) that are produced from the same lot of material.

It is recommended that if test data is required and / or if samples of the cured material are required for user evaluation, that standard ASTM test specimens be utilized.

Appendix B - Glossary of Radial Seals

A

Abrasion Resistance - the ability of a rubber material to withstand mechanical wear; an important factor in dynamic sealing applications.

Aging - deterioration or changes in the seal physical properties over time.

Ambient Temperature - the temperature of the surrounding environment relative to a given point of application at a given time.

> **Note:** ambient temperature is not necessarily the same as the atmospheric temperature.

Axial Seal - (aka face seal) seal that has compression applied on the top and bottom of the seal surface.

B

Back-up Ring - (aka anti-extrusion device) a ring of relatively hard and tough material placed in the gland between the O-ring and groove side walls to prevent extrusion of the O-ring.

C

Chemical Resistance - (aka fluid compatibility) the ability of a material to maintain its operational characteristics after exposure to chemicals and fluids after a period of time.

> **Note:** Operational characteristics refer to the sealability, not physical properties, of the seals or gaskets. A seal that swells excessively in a fluid, or develops a large increase or decrease in hardness, tensile strength, or elongation, can often continue to serve well as a static seal in spite of undesirable conditions.

Cold Flexibility - (aka low temp flexibility) the flexibility of an elastomer at a given low temperature, which should be the lowest temperature the candidate seal material is expected to be exposed to in an application.

Coefficient of Friction (COF) - the ratio of the force of friction between two bodies and the force pressing them together. COF of a moving elastomer seal relates to a number of factors including material hardness, lubrication and surface characteristics of surrounding materials.

Coefficient of Thermal Expansion - the ratio of the change in length per °C to the length at 0°C.

Compound - a mixture of polymers and other ingredients to produce a usable rubber material.

Compression - (aka squeeze or compressive force) the force required to compress a seal cross section the proper amount to maintain an effective seal.

Compression Set - the amount that a material fails to recover to its original size after being compressed a specific distance or precentage of the cross section.

Compression Set Relaxation - the decrease in resistant force over time that a material exhibits when exposed to a constant compressive force (typically 25%).

Configuration - see Cross Section *(see figure 1.9 and 1.10 for examples)*.

Copolymer - a polymer formed from two or more types of monomers.

Corrosion - the result of chemical action of a fluid and / or the compound on the metal surface of the seal gland; fluid corrosion of the metal gland will cause a change of finish that can vitally effect the seal.

Cross Section - (aka profile) the geometry of the seal observed when cutting straight across the seal.

Cure - see Vulcanization.

D

Deterioration - a chemical change in the elastomer that results in a permanent loss of properties; not to be mistaken with reversible or temporary property losses. Temporary condition is due to physical permeation of the fluid without chemical alteration.

Diametral Clearance - the difference between the piston's diameter and the bore's diameter.

Double Chamfer Seal - a seal with flat bases and a chamfered profile *(see Figure 1.6).*

Durometer - (a) a numerical scale to measure rubber hardness, presented in increments of 5 or 10. (b) an instrument, typically called Shore A durometer in the seal industry, used to measure the hardness of most rubber compounds.

D-Ring Seal - a seal with flat bases and a rounded sealing surface, creating a cross sectional geometry similar to a capital "D" *(see Figure 1.7)*.

Dynamic Seal - the sealing environment has a relative reciprocating, rotating, or oscillating motion between the mating components.

Appendix B - Glossary of Radial Seals

E

Elasticity - the property of a substance that enables it to deform in direct response to a force and to recover its original form once the force is removed.

Elastomer - a term used for natural and synthetic material, such as rubber, that is able to resume its original shape once the deforming force is removed; the term derived from “elastic polymer.”

Elongation - percent increase in length over the initial length of the seal; usually expressed as ultimate elongation which is the percent value attained when the test specimen breaks.

Extrusion - distortion or flow, under pressure, of portion of seal into clearance between mating metal parts; not to be confused with a manufacturing method extruding.

F

Face Seal - see Axial Seal.

Flash - excess rubber left around rubber part after molding due to space between mating mold surfaces; removed by trimming.

Friction - resistance to motion due to the contact of surfaces.

Friction (Breakout) - friction developed during initial or starting motion.

Friction (Running) - constant friction developed during operation of a dynamic seal.

Fuel (Aromatic) - fuel which contains bezene or aromatic hydrocarbons; causes high swell of rubber.

Fuel (Nonaromatic) - fuel which is composed of straight chain hydrocarbons; causes little swell of rubber.

G

Gland - a device where a seal is installed to prevent leakage of fluid; often consists of a flanged metal sleeve and a groove.

Gland Depth - the distance from the bottom of the groove to the mating flange *(see Figure 2.1)*.

Gland Stability - the seal stability in gland during installation for static application and both installation and operation for dynamic application.

H

Hardness - resistance to a distorting force; measure by the relative resistance of the material to an indentor point of any one of a number of standard hardness testing instruments.

Homogeneous seal - a rubber seal without metal or fabric reinforcement.

Heat Resistance - the ability to withstand the effects of high temperature.

I

Identification - part marking technologies to aid with seal installation, identification and traceability.

Immersion - placing an article into a fluid so it is completely covered.

Installation Chamfer - (aka leading angle) chamfer of leading edge to prevent damage of seals during installation and assembly.

L

Leakage - the tendency of a fluid to go around a seal; not to be mistaken with permeability.

Low Temperature Resistance - (aka cold resistance) the ability of a material to withstand the effects of low temperatures.

M

Modulus - the amount of tensile stress measured in pounds per square inch at a predetermined elongation, usually at 100%; used only in the rubber industry.

Modulus of Elasticity - (aka Young’s Modulus) one of the several measurements of stiffness or resistance to deformation; not to be mistaken with rubber tensile modulus.

Moisture - the presence of a liquid, especially water, found in an operating environment of an application.

Monomer - a low molecular weight substance that may react chemically with other molecules to form a polymer.

N

Nominal Dimension - nearest fractional equivalent to actual decimal dimension.

Appendix B - Glossary of Radial Seals

O

Oil Resistance - ability of a rubber material to resist the swelling and deteriorating effects of various oil types.

Oil Swell - the change in volume of a rubber article due to absorption of oil or other fluids.

O-Ring - a torus; a circle of material with round cross section which affects a seal through squeeze and pressure.

O-Ring Seal - the combination of a gland and an O-ring proving a fluid-tight closure.

Oscillating Seal - the sealing environment involves the inner or outer element of the seal assembly moving in an arc around the shaft axis within the gland.

Oxidation - a chemical reaction of oxygen with a substance that typically causes seal deterioration; detected by a change in the appearance or feel of the surface, or by a change in physical properties or both.

Ozonization - a process of ozone attack which causes cracking on rubber and deteriorates rubber seals.

P

Permeability - the tendency of a gas to pass or diffuse through the elastomer; not to be mistaken with leakage. A most important factor in vacuum service and a few pneumatic applications involving extended storage.

Polymer - a large molecular substance composed of many monomers via a polymerization process; synonymous with elastomer.

Porosity - quality or state of being porous.

Post Cure - the second step in the vulcanization process for the more exotic elastomers; provides stabilization of parts and drives off decomposition products resulting from the vulcanization process.

Profile - see Cross Section.

R

Radial Seal - seal that has compression applied to its outside diamter (O.D.) and inside diameter (I.D.).

Radiation - An emission of varying energy content from a disturbed atom undergoing internal change. There are two broad classifications or types:

(a) Corpuscular, comprising streams of **particles** either neutral or charged, e.g. protons, electrons, neutrons.

(b) Electromagnetic, comprising **wave-like** emissions as gamma, ultraviolet, etc.

Radiation Damage - a measure of the loss in certain physical properties of organic substances such as elastomers, due principally to ionization process *(i.e. electron loss)* results in redundant cross-linking and possible scission of the mocule. This effect is **cummulative**.

Radiation Dosage - the total amount of radiation energy absorbed by a substance; usually expressed in ergs per gram and denoted by the following units:

(a) Roentgen - a quantity of gamma or X-ray radiation equal to approximately 83 ergs of absorbed energy per gram of air.

(b) REP (Roentgen Equivalent-Physical) - a quantity of ionizinf radiation that causes an energy absorption of approximately 83 to 93 ergs per gram of tissue.

(c) REM (Roentgen Equivalent-Man) - similar to REP except used to denote biological effects.

Reciprocating Seal - the sealing environment has a relative reciprocating motion between the inner and outer elements, typically used in situations involving a moving piston and a rod.

Relative Humidity - the ratio of the quantity of water vapor actually present in the atmosphere to the greatest amount possible at the given temperature.

Resilience - the ability of a material to return quickly to its original shape after temporary deflection; primarily an inherent property of the elastomer.

Rubber - a material that is capable of recovering from large deformation quickly and forcibly.

Rubber, Natural - raw rubber obtained from a botanical source.

Rubber, Synthetic - artificial elastomer mainly produced from petroleum byproducts.

Rotary Seal - the sealing environment has either the inner or outer element rotating around the shaft axis in one direction only.

Appendix B - Glossary of Radial Seals

S

Seal - any device used to prevent the passage of a fluid (gas or liquid).

Service - operating conditions to be met.

Shore A Hardness - see Durometer and Hardness.

Shrinkage - (a) a decrease in volume of a specimen caused by extraction of soluble constituents by fluids followed by air drying; almost always accompanied by an increase in hardness. (b) a difference in seal dimensions before and after the curing process.

Specific Gravity - the ratio of the weight of a given substance to the weight of an equal volume of water at a specified temperature.

Spiral Failure - a failure mode seen in most radial seal applications where the seals can be subject to rolling and twisting during installation and consequently cause seal failure during operation.

Squeeze - see Compression.

Static Seal - the sealing environment has no relative motion between the mating flanges.

Strain - deflection due to a force.

Stress - force per unit of original cross section area.

Swell - an increase in volume of a specimen caused by immersion in a fluid (usually a liquid); almost always accompanied by a decrease in hardness.

T

Temperature Range - maximum and minimum temperature limits within which a seal compound will function in a given application.

Tensile Strength - force per unit area, measured in pounds per square inch, obtained by stretching a standard test specimen of rubber until it ruptures.

Tear Resistance - (aka tear strength) the ability of a material to withstand the effects of tearing, usually measured in pounds per inch thickness. Seal compounds with poor tear resistance will fail quickly under further flexing or stress, once a crack is started.

Thermal Expansion - expansion caused by increase in temperature; maybe linear or volumetric.

V

Vacuum - a given space that is occupied by a gas at less than atmospheric pressure.

Viscosity - a property of a fluid or solid substance which measures its resistance to gradual deformation by shear stress or tensile stress, i.e., resistance to flow.

Void - the absence of material or an area devoid of materials where not intended.

Volume Change - a change in volume of a seal as a result of immersion in a fluid; expressed as a percentage of the original volume.

Volume Swell - an increase in physical size caused by the swelling action of a liquid.

Vulcanization - a thermosetting reaction involving the use of heat and pressure, resulting in greatly increased strength and elasticity of rubber-like materials.

W

Width - seal cross section or thickness.

Wall Thickness - the distance between the seal's inner diameter and outer diameter, in the case of double chamfer and D-ring seals *(see Figure 2.1)*.

Weathering - the process by which natural and environmental elements such as rain, wind, humidity, sun, etc., affect the seal and cause it to deteriorate.

Notes

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

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8. Loss to Buyer's Property. Any designs, tools, patterns, materials, drawings, confidential information or equipment furnished by Buyer or any other items which become Buyer's property, will be considered obsolete and may be destroyed by Seller after two consecutive years have elapsed without Buyer ordering the items manufactured using such property. Seller shall not be responsible for any loss or damage to such property while it is in Seller's possession or control.

9. Special Tooling. A tooling charge may be imposed for any special tooling, including without limitation, dies, fixtures, molds and patterns, acquired to manufacture Products. Such special tooling shall be and remain Seller's property notwithstanding payment of any charges by Buyer. In no event will Buyer acquire any interest in apparatus belonging to Seller which is utilized in the manufacture of the Products, even if such apparatus has been specially converted or adapted for such manufacture and notwithstanding any charges paid by Buyer. Unless otherwise agreed, Seller shall have the right to alter, discard or otherwise dispose of any special tooling or other property in its sole discretion at any time.

10. Buyer's Obligation; Rights of Seller. To secure payment of all sums due or otherwise, Seller shall retain a security interest in the goods delivered and this agreement shall be deemed a Security Agreement under the Uniform Commercial Code. Buyer authorizes Seller as its attorney to execute and file on Buyer's behalf all documents Seller deems necessary to perfect its security interest.

11. Improper use and Indemnity. Buyer shall indemnify, defend, and hold Seller harmless from any claim, liability, damages, lawsuits, and costs (including attorney fees), whether for personal injury, property damage, patent, trademark or copyright infringement or any other claim, brought by or incurred by Buyer, Buyer's employees, or any other person, arising out of: (a) improper selection, improper application or other misuse of Products purchased by Buyer from Seller; (b) any act or omission, negligent or otherwise, of Buyer; (c) Seller's use of patterns, plans, drawings, or specifications furnished by Buyer to manufacture Product; or (d) Buyer's failure to comply with these terms and conditions. Seller shall not indemnify Buyer under any circumstance except as otherwise provided.

12. Cancellations and Changes. Orders shall not be subject to cancellation or change by Buyer for any reason, except with Seller's written consent and upon terms that will indemnify, defend and hold Seller harmless against all direct, incidental and consequential loss or damage. Seller may change product features, specifications, designs and availability with notice to Buyer.

13. Limitation on Assignment. Buyer may not assign its rights or obligations under this agreement without the prior written consent of Seller.

14. Force Majeure. Seller does not assume the risk and shall not be liable for delay or failure to perform any of Seller's obligations by reason of circumstances beyond the reasonable control of Seller (hereinafter "Events of Force Majeure"). Events of Force Majeure shall include without limitation: accidents, strikes or labor disputes, acts of any government or government agency, acts of nature, delays or failures in delivery from carriers or suppliers, shortages of materials, or any other cause beyond Seller's reasonable control.

15. Waiver and Severability. Failure to enforce any provision of this agreement will not waive that provision nor will any such failure prejudice Seller's right to enforce that provision in the future. Invalidation of any provision of this agreement by legislation or other rule of law shall not invalidate any other provision herein. The remaining provisions of this agreement will remain in full force and effect.

16. Termination. Seller may terminate this agreement for any reason and at any time by giving Buyer thirty (30) days written notice of termination. Seller may immediately terminate this agreement, in writing, if Buyer: (a) commits a breach of any provision of this agreement (b) appointments a trustee, receiver or custodian for all or any part of Buyer's property (c) files a petition for relief in bankruptcy on its own behalf, or by a third party (d) makes an assignment for the benefit of creditors, or (e) dissolves or liquidates all or a majority of its assets.

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18. Indemnity for Infringement of Intellectual Property Rights. Seller shall have no liability for infringement of any patents, trademarks, copyrights, trade dress, trade secrets or similar rights except as provided in this Section. Seller will defend and indemnify Buyer against allegations of infringement of U.S. patents, U.S. trademarks, copyrights, trade dress and trade secrets ("Intellectual Property Rights"). Seller will defend at its expense and will pay the cost of any settlement or damages awarded in an action brought against Buyer based on an allegation that a Product sold pursuant to this Agreement infringes the Intellectual Property Rights of a third party. Seller's obligation to defend and indemnify Buyer is contingent on Buyer notifying Seller within ten (10) days after Buyer becomes aware of such allegations of infringement, and Seller having sole control over the defense of any allegations or actions including all negotiations for settlement or compromise. If a Product is subject to a claim that it infringes the Intellectual Property Rights of a third party, Seller may, at its sole expense and option, procure for Buyer the right to continue using the Product, replace or modify the Product so as to make it noninfringing, or offer to accept return of the Product and return the purchase price less a reasonable allowance for depreciation. Notwithstanding the foregoing, Seller shall have no liability for claims of infringement based on information provided by Buyer, or directed to Products delivered hereunder for which the designs are specified in whole or part by Buyer, or infringements resulting from the modification, combination or use in a system of any Product sold hereunder. The foregoing provisions of this Section shall constitute Seller's sole and exclusive liability and Buyer's sole and exclusive remedy for infringement of Intellectual Property Rights.

19. Entire Agreement. This agreement contains the entire agreement between the Buyer and Seller and constitutes the final, complete and exclusive expression of the terms of sale. All prior or contemporaneous written or oral agreements or negotiations with respect to the subject matter are herein merged.

20. Compliance with Law, U. K. Bribery Act and U.S. Foreign Corrupt Practices Act. Buyer agrees to comply with all applicable laws and regulations, including both those of the United Kingdom and the United States of America, and of the country or countries of the Territory in which Buyer may operate, including without limitation the U. K. Bribery Act, the U.S. Foreign Corrupt Practices Act ("FCPA") and the U.S. Anti-Kickback Act (the "Anti-Kickback Act"), and agrees to indemnify and hold harmless Seller from the consequences of any violation of such provisions by Buyer, its employees or agents. Buyer acknowledges that they are familiar with the provisions of the U. K. Bribery Act, the FCPA and the Anti-Kickback Act, and certifies that Buyer will adhere to the requirements thereof. In particular, Buyer represents and agrees that Buyer shall not make any payment or give anything of value, directly or indirectly to any governmental official, any foreign political party or official thereof, any candidate for foreign political office, or any commercial entity or person, for the purpose of influencing such person to purchase products or otherwise benefit the business of Seller.

WARNING: These products can expose you to chemicals including carbon black (airborne and extracts), antimony trioxide, titanium dioxide, silica (crystalline), di(2-ethylhexyl)phthalate, ethylene thiourea, acrylonitrile, 1,3-butadiene, epichlorohydrin, toluenediisocyanate, tetrafluoroethylene, ethylbenzene, formaldehyde, furfuryl alcohol, glass fibers, methyl isobutyl ketone, nickel (metallic and compounds), lead and lead compounds which are known to the State of California to cause cancer; and 1,3-butadiene, epichlorohydrin, di(2-ethylhexyl)phthalate, di-isodecyl phthalate, ethylene thiourea, methyl isobutyl ketone, methanol, toluene, lead and lead compounds which are known to the State of California to cause birth defects and other reproductive harm. For more information go to www.P65Warnings.ca.gov.

Other Special Configurations

RADIAL SEALS

D-Ring

External U-Section with Angled Bottom

External T-Section with Radiused Shoulder

Double External Angle

Single External Angle

Single Internal Angle

Double External Corner

AXIAL SEALS

Rectangular Section

Square Section

Single Internal Corner

Single Internal-External Corner

Single External Corner

Internal Angle & Internal-External Corner

Double Internal Angle

SPECIALTY SEALS

V-Hicular Section

L-Gasket

Angle L Seal Section

Short Lip Seal Section

External Angle & Internal-External Corner

Single Opposite Internal-External Corner

Double Internal-External Corner

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