The Right Seal

Your Guide to Sealing in Semiconductor Processing

Greene Tweed
The Inside Advantage®

The Right Seal

Your Guide to Sealing in Semiconductor Processing

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INTRODUCTION

Hardly anyone notices a critical seal until it fails — costing literally hundreds of thousands of dollars in lost revenue. While every seal will fail eventually, taking proper care in selection of materials and geometries can help you get a higher level of performance and longer, **more predictable** life out of your seals.

The purpose of this handbook is to help you avoid costly surprises. We want to share with you what we at Greene, Tweed have learned over 135 years of sealing manufacture — including more than ten years of solving the unique sealing problems of the semiconductor manufacturing industry. If we can help you increase your yields or reduce your downtime — or both — the book has served its purpose.

Many people contributed their expertise in the preparation of this handbook. A special acknowledgment, together with our thanks, goes to semiconductor industry experts Robert Matthews and Fred Freerks.

This handbook provides detailed technical information about a variety of seal types and materials, specifically for the benefit of individuals who design equipment and select seals and sealing materials for the semiconductor fabrication industry. Each of the seal designs and materials discussed in these pages has a proven track record in the complex and unforgiving applications encountered in semiconductor processing.

Please don't think of this as Greene, Tweed's handbook. We want it to be your handbook. We want to know how you use this book, which parts you find most helpful, and which areas you'd like to see expanded.

The sealing "art" frequently involves compromise. But one area in which we will never compromise is clear communication with our customers. I look forward to hearing from you.

Phil Paino
President
Greene, Tweed & Co.

SEALING REQUIREMENTS IN SEMICONDUCTOR MANUFACTURING

Semiconductor Sealing Basics

Sealing elements used in semiconductor production equipment face challenges which are unique to the industry. These seals must perform under positive pressure and vacuum conditions, in harsh chemical environments and at extremely high temperatures. Most important, they must *not* deteriorate or in any way introduce contaminants (extractables or particles) into the processes in which they are used.

The seals found in semiconductor production (fabrication) equipment are precision components. Typically, they are molded from elastomeric materials or machined from plastics. They are designed to create a barrier to the passage of fluids or gases within the systems or components in which they are used. This barrier, or sealing action, is achieved by the seal material's ability to conform to, or "mate" closely with, the sealing surfaces. It must do so while resisting the effects of chemical exposure, temperature, pressure, aging and cyclic motion, and without bonding to the sealing surface.

There are three primary classifications of seal installations:

- ***Dynamic seals.*** These are installed onto surfaces that *move* relative to each other. This relative motion can be ***reciprocating, oscillatory*** or ***rotary.***
- ***Semi-dynamic seals.*** These are also installed onto mating surfaces that move relative to each other in an "elevator" or *up-down* motion. Seals of this type include Dovetail® Seals (seals especially designed for use in dovetail ***glands*** or ***grooves***) and lid seals.
- ***Static seals.*** These are installed onto mating parts that *do not move* relative to each other. However, as a practical matter, most static seals *do* encounter movement, which can be caused by thermal expansion, vibration, etc. Static seals are categorized according to the direction of the sealing force. There are two basic directions of sealing force: ***axial*** and ***radial.***

In each type of installation, the seal fits into a gland or groove which has been incorporated into one of the mating parts which close the gap or fill the joint.

O-ring seals are the most common type of seal found in semiconductor production equipment. O-rings are torus-shaped elements that can readily be fabricated from high-performance elastomers which are able to withstand the harsh chemistries used in semiconductor production. O-rings are also produced from engineered plastics and metals. They are versatile, easy to use and require little space.

Other types of standard (and even custom) seal designs are employed to meet the myriad sealing requirements found in critical processes used to produce semiconductor components. Sealing elements which are actually bonded to metal surfaces, as opposed to being installed in a gland, are gaining popularity for such components as slit valves. These ***bonded seals*** perform with much less movement, resulting in significantly less particulation than conventional dynamic and static seals.

Sealing action is achieved through the seal material's ability to conform to, or mate closely with, the microscopic peaks and valleys against which it seals. To ensure constant "leakback" rates, sealing devices installed in semiconductor production processes must be able to conform to the sealing surfaces found on a wide range of materials. These materials include a variety of metals, plastics and even the silicon being processed.

The contacting surfaces play an important role in the life of the dynamic seal. The designer must carefully consider the roughness of the surfaces with which a seal will be in contact. This requires familiarity with the techniques and measurements used to determine ***surface roughness,*** and the results that can be expected from the various methods used to produce finishes. Generally, the most desirable surface roughness value is 8 to 16 microinches (Ra) for dynamic seals. Static seals should have a surface roughness not exceeding 32 microinches (Ra). "Face-type" (static) seals in gas applications normally require a mating surface roughness value of 8 to 16 microinches (Ra).

Equally essential to proper sealing action in semiconductor fabrication equipment is the design of the seal/gland configuration. This design must take into consideration not only surface finish, but stretch, squeeze, gland fill, installation and materials selection. We should emphasize that the semiconductor equipment designer will find it enormously helpful to include the seals supplier at the outset of the design process.

Finite Element Analysis

Greene, Tweed uses nonlinear Finite Element Analysis (FEA) extensively in all aspects of seal design and application. Using FEA, stress-strain and thermal analysis of complex structures can be

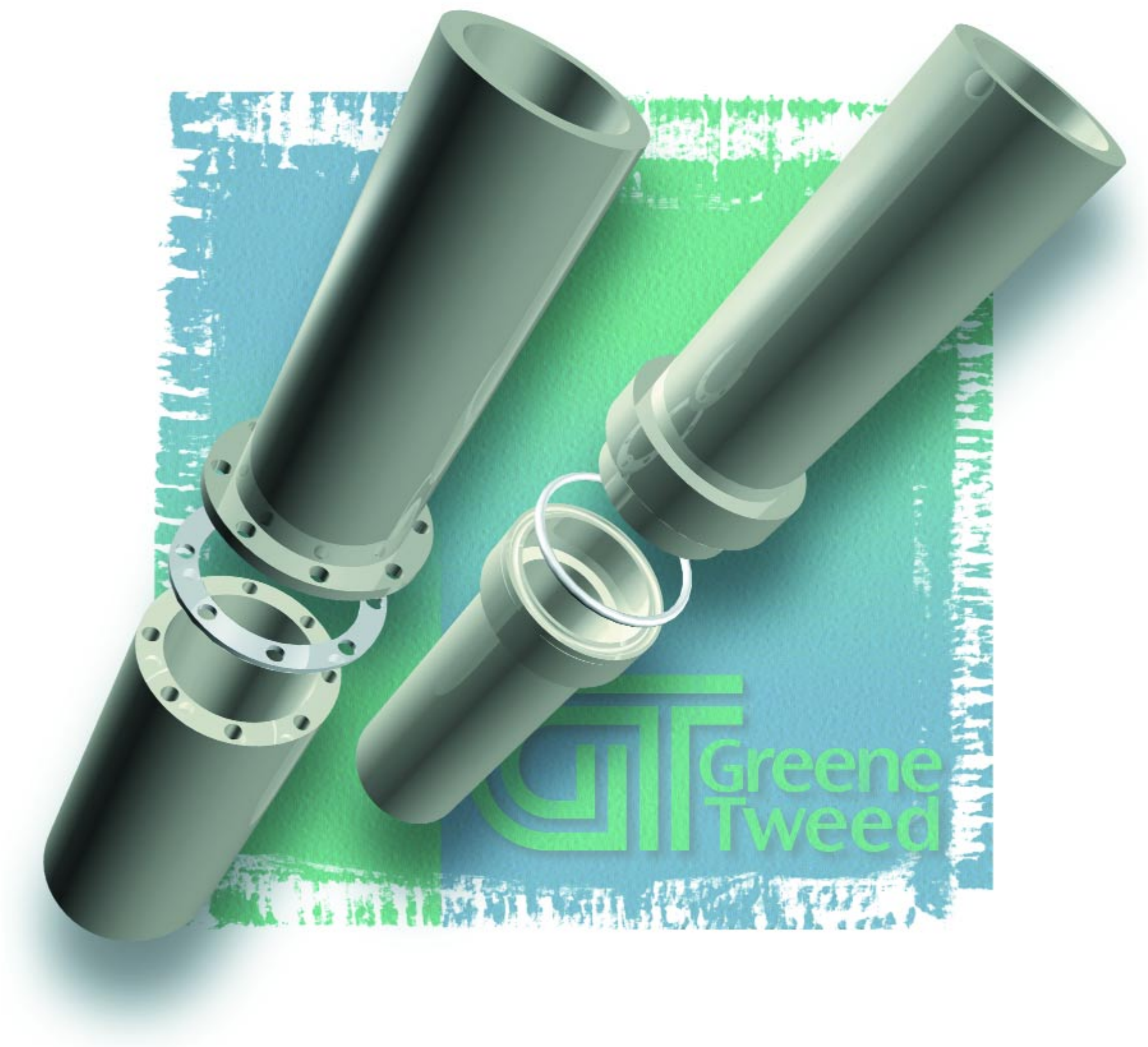


Figure 1-1 *Sealing Elements*

performed quickly and accurately. Because of the extremely large deformations that seals experience, traditional hand calculations are nearly impossible to perform. FEA can be used to design new seals, improve existing seals or determine the causes of failures. FEA provides an easy way to graphically examine how the seal will function, without all of the guesswork usually involved.

There are many parameters that must be considered when designing effective sealing solutions. Sealing footprint, sealing load, gland fill, frictional characteristics and shape characteristics are some of the many aspects of the seal which must be considered in a seal design. Through the use of FEA, a seal design can be created to meet all of the requirements of an application. Design iterations of the seal can be modeled on the computer until the desired seal design is obtained. FEA can provide accurate estimates of the compressive sealing load, the deformed shape of the seal, the length of the sealing footprint and the stress distribution throughout the cross-section.

One of the most critical aspects of creating an FEA model is ensuring the input of the proper information. Material properties for each compound are generated in Greene, Tweed's test laboratory, and material models are created for the software. After the seal geometry is modeled, constraints and boundaries are placed on the seal. These represent the gland in which the seal is placed. Displacements or forces can be applied to the boundaries to simulate the stretch and compression of the seal. Other loads can also be accounted for, such as pressure or temperature. This allows the entire seal configuration to be accurately modeled.

Finite Element Analysis is one of the many tools used to provide sealing solutions for Greene, Tweed's semiconductor production equipment customers. FEA reduces the time required to design a part and eliminates the cost of multiple prototype designs. By modeling the seal application on a computer, the designer can achieve the most effective solution to a particular sealing problem for most types of sealing configurations and application requirements.

Semiconductor Manufacturing Requirements

There are many diverse steps in the semiconductor fabrication process. Each has different sealing needs. In this section, you will find a discussion of several steps that require special sealing elements:

- Ultrapure Deionized Water Systems
- Photolithography (aqueous/solvents/wet and dry strippers)
- Acids
- Plasma Systems
- Diffusion Systems

Ultrapure Deionized Water Systems (UPDI)

UPDI systems require that *O-rings and other sealing elements have extremely low levels of extractables* — PPB (parts per billion) levels moving to PPT (parts per trillion) levels. Extractables that cause concern include TOC's (total oxidizable carbon), cations (metallic elements) and anionic species (fluorides, chlorides, sulfates and iodides). Deionized water is used throughout most of the processing steps and must not contribute any additional contaminants to these processes.

The critical sealing areas in a UPDI system are:

- Filters
- Valves and regulators
- Fittings
- Unions

Ozone is used in most systems to kill bacteria. It will also destroy most O-rings manufactured from standard materials. The resulting deterioration will

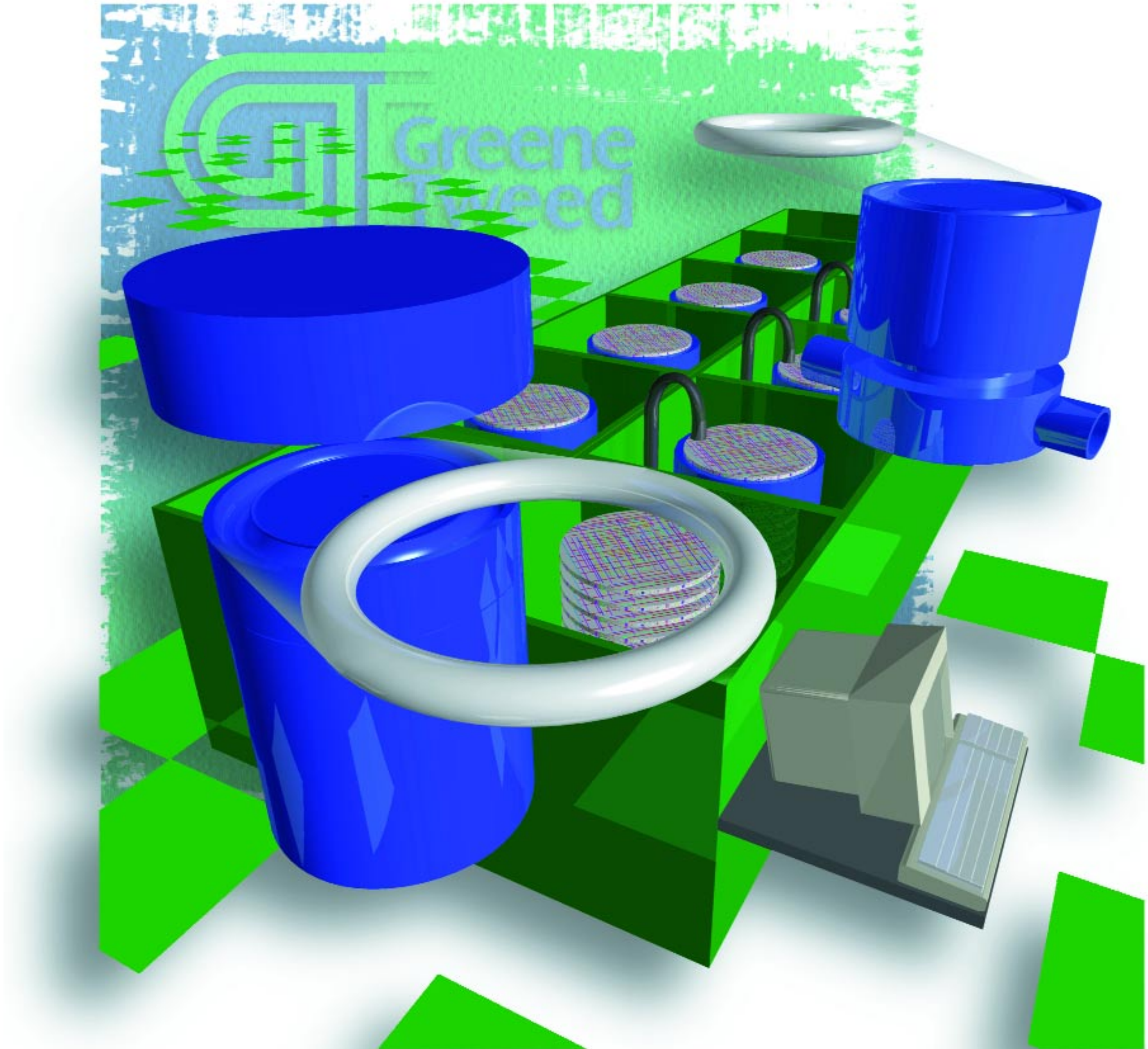


Figure 1-2 *Track System Seal Applications*

introduce into the system massive amounts of the metallic contaminants contained in O-rings. Even ***peroxide*** will degrade standard elastomeric materials. The ***hot deionized water*** (83° C) used to kill bacteria in newer systems affects elastomeric sealing materials in the same manner. Finally, ***UV light*** (added at various exposures to break up organics) can also affect O-rings and other seals.

TOC's are especially critical in UPDI applications, because they can adhere to wafers and result in degraded oxide quality and hazy films. All components of UPDI systems are monitored for acceptable TOC levels.

Photolithography (Aqueous/Solvents)

Resist Strippers

The lithography process includes cleaning, removal of solvents (used in the photoresist), and ***stripping*** or ***ashing*** (used to remove any remaining photoresist materials).

There are several types of resist strippers. Before metal layers are deposited, the semiconductor industry commonly uses aqueous mixtures. However, once metal has been deposited, only solvent strippers are used. The most commonly used solvent stripper is ***NMP*** (N-methyl Pyrrolidone).

Solvents that remove photoresist require O-rings and other elastomeric sealing elements that do not leach or swell. O-rings are used in tracking systems that include valves and regulators, as well as in areas of photoresist sputter and bake. Virtually all available perfluoroelastomer compounds are suitable in this processing stage (Figure 1-2).

Dry Strip

An alternative method of stripping is done using a dry etch process, with O_2 plasma. The need to process small feature sizes on advanced wafers has predicated the use of this type of stripping over wet etching. Many factors favor the use of dry technology; these include toxicity of wet chemistry and ultimate control.

Acids

Seals are used in wet benches or sinks, in valves and regulators, dispensing valves, rinser-dryers and ***bulk chemical distribution*** (BCD) systems. Even the filtration systems incorporated into these areas must be analyzed for compatibility, since chemicals and chemical mixtures such as ***hydrofluoric acid***

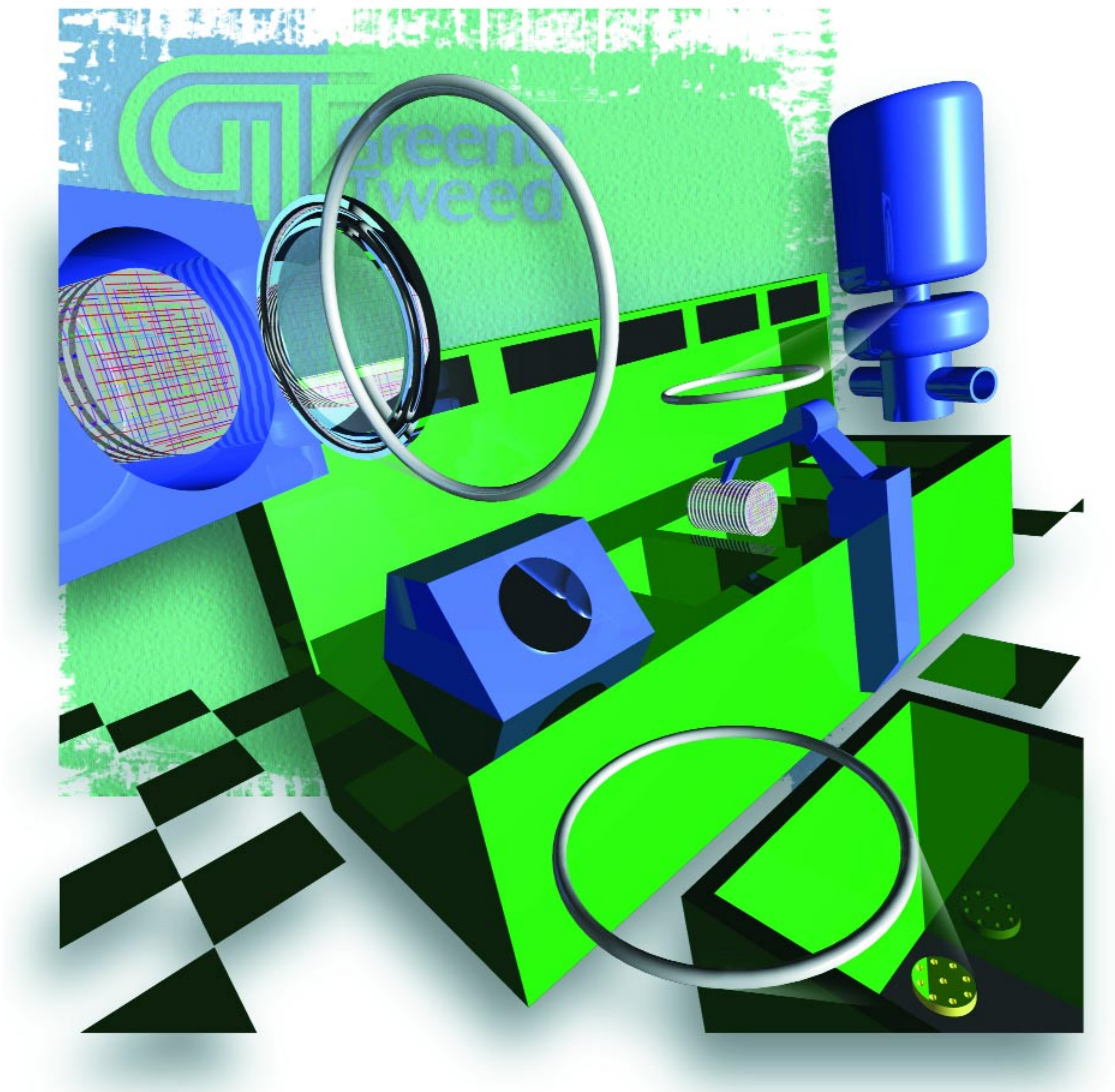


Figure 1-3 *Wet Station*

(HF) and ***Piranha*** will aggressively attack and deteriorate all sealing elements made from conventional compounds.

Low ionic extractables are required. However, TOC's are of minimal concern. Most acids and strong bases (sulfuric, hydrochloric and ammonium hydroxide) are mixed with oxidizers (peroxide or ozone), so that TOC's are converted to carbon dioxide or carbon monoxide and leave the system.

Most high-temperature acid baths are contained in quartz componentry. Quartz, however, cannot be used with hydrofluoric acid. Polymeric materials such as PFA, PTFE, PVDF or polyethylene are typically used to contain HF (Figure 1-3).

Plasma Systems

Etch and CVD (Chemical Vapor Deposition)

The focus of the semiconductor industry has shifted from batch to single-wafer processing. Single-wafer processing requires O-rings that can resist harsh plasma environments, high energy

Figure 1-4 *Plasma Chamber*

Figure 1-5 *Slit Valve*

and high temperatures. Developing O-rings that resist chemistries and also meet physical property requirements is a continuing challenge for seal manufacturers and semiconductor manufacturers alike (Figure 1-4).

Ion bombardment during ***reactive ion etching*** (RIE) creates a damaged layer within several hundred angstroms of the silicon surface. The depth of the damage is more dramatic with increasing ion energy, and ranges from a slight amount of damage for heavier ions to more intense damage for hydrogen ions. Damage from this type of energy affects not only the wafer but the hardware in which it is processed.

Manufacturing is moving from RIE-based systems to ***electron cyclotron resonance*** (ECR, or microwave) based systems. This shift is primarily driven by the excellent control, uniformity and low damage that results from ECR compared to conventional RIE. Etch gases include:

- Gases containing fluorine, chlorine and bromine for etching aluminum
- Gases containing fluorine, chlorine and bromine for etching silicon and polysilicon
- Gases containing hydrogen for etching insulators
- Oxygen for stripping organic films

Current etch and CVD process chambers employ varying degrees of temperature and vacuum pressure in the processing environment. In normal operations, as process temperature increases, vacuum pressure requirements move from typical 10^{-5} Torr to 10^{-8} Torr levels. Processes with lower ambient temperatures typically use less vacuum. These systems are more complex and costly, but they offer the uniformity and control required for complex devices. These can be etch or deposition systems, using high-density plasma to assure uniformity. When these systems use highly reactive gases, standard elastomers exposed to the process will suffer chemical attack and quickly degrade. However, perfluoroelastomers are not normally subject to chemical attack; they will continue to seal for much longer periods.

Contamination Issues

The industry's primary challenge in the area of contamination is the improvement of equipment. The areas of greatest concern are the dynamic steps that generate particles and require cleaning from process deposition. The associated downtime is of significant concern to both equipment and semiconductor manufacturers globally.

The configuration of reactors depends on the physical principles used to obtain high plasma densities. Even though reactors with diverse radio frequency (RF) energies, plasmas and configurations are used, the hardware offers unique challenges in sealing technology.

The primary challenge is the ***slit valve*** (Figure 1-5). The dovetail gland in this valve was designed to contain standard industrial-grade O-rings. However, these O-rings have chemical and physical characteristics that do not meet the contamination and particle generation specifications of this process, resulting in O-ring deterioration and downtime. ***Perfluoroelastomers*** are most suitable for this critical sealing area. (See Chapter 4, "Dovetail® Seals," and Chapter 6, "Bonded Gates," for more information about sealing solutions.

Other critical seals include lid, end-point windows and throttle valves. These seals see the majority of the process and benefit from the characteristics of perfluoroelastomers. Gas inlet seals, isolation valves, KF fittings, exhaust valves and other components using static seals are also exposed to process gases. Such critical seals may require perfluoroelastomers.

Diffusion Systems

Diffusion furnaces have three purposes:

- To deposit layers of pure materials, such as SiO_2
- To distribute atoms within an implant layer
- To anneal the surface damage of an implant step

The large quartz tubes in which the wafers are processed offer unique sealing challenges. This application creates temperatures of *250-300° C at the sealing site,* because there are few possibilities for cooling. Low outgassing and low permeation parameters are critical for optimal operation of this process.

A series of new high-temperature Chemraz® compounds has been developed specifically for diffusion equipment. These perfluoroelastomer compounds can operate continuously at temperatures up to 300° C with excursions to 325° C. This allows greater flexibility for the process and extends preventative maintenance cycles.

Flat Panel Display Manufacturing

The market for flat panel displays is growing rapidly. These space-saving, energy-efficient displays are threatening to take the place of the traditional CRT desktop monitors. The process used to manufacture flat panel displays is very similar to that used in semiconductor fabrication — utilizing deposition, photolithography and etching steps to produce the final product. As with semiconductor processing, in order to reduce production costs, high-purity, high-quality seals are required. This becomes essential when trying to meet the demands for larger, higher-resolution displays.

New Process Areas

Copper

Copper is being introduced into chip fabrication in spite of the many difficulties associated with process integration. Copper offers lower electrical resistance, dramatically reducing circuit delays. Its low-*k* properties are necessary in multilayered designs. Superior electromigration resistance is an even more important advantage as wiring linewidths decrease.

Copper poses unique processing challenges of its own. It is extremely difficult to etch, as most Cu reaction products are nonvolatile. A damascene process, inlaying Cu into lines and vias, is necessary; this ensures that the Cu does not contaminate the circuit structure. Copper will diffuse into the transistors unless a suitable barrier layer is used. Such chemistries as Ta_20_5 (tantalum pentoxide) are utilized, along with Ba and Sr (barium and strontium) or BST.

NF_3

There is a decisive trend to move away from CFC chemistries to "green" chemistries. This trend has forced the semiconductor industry to move toward chemistries such as NF_3 and ClF_3 to replace C_2F_6 and other standard etching and cleaning gases. These chemistries, while environmentally safe, are harsher and more toxic than the gases used for the same processes today. This has necessitated additional measures of containment and seal reliability throughout the chambers. Chamber materials and the sealing elements used in valves, fittings, slit valves, etc., should be reviewed for chemical compatibility with these new, harsher environments.

More Demanding Line Geometries

Chip fabricators are constantly challenged to reduce line geometries. Improvements in copper technology, low-*k* materials and multilayered metal designs are just some of the many concepts that have been incorporated in the pursuit of this objective. Embedded memory has also added to design complexity and to the difficulties encountered in the reduction of line geometries.

As the semiconductor industry pushes the technological envelope, particles and cleanliness issues become limiting factors in productivity. Applying semiconductor standards or guidelines will be a necessity for subcomponents that include O-rings.

Cost of Success

System reliability is an integral part of the success factors in all chip fabrication today. With the advent of 300mm wafers and complex technology, harsher chemistries and high-density plasmas, each process step is a challenge. Each new design is also undertaken in a more surreptitious environment, making it more difficult for suppliers and end-users to resolve issues together. System integrity, therefore, must take into account subcomponents that could inevitably cost end-users a great deal of money. Perfluoroelastomers are proven to resist the harshest of these environments and must be included in areas not always considered as contamination sources, such as gas inlets and end-point windows.

Future Process Technologies

There are other process steps not addressed here. Areas such as ion implant or CMP (Chemical Mechanical Planarization) may be addressed in the future as the focus on sealing technologies expands into these areas.

Although silicone and fluoroelastomers (such as Viton* and Fluorel†) are high-temperature sealing materials, they do not meet all performance criteria. Perfluoroelastomer compounds and special sealing designs are successfully filling this role in vertical and horizontal furnaces. The trend in diffusion systems is toward ***low-pressure CVD*** (LPCVD) in chamber designs, and ***rapid thermal processing*** (RTP) technology. Given this trend, sealing devices in critical areas will again be spotlighted for their temperature resistance as well as their chemical compatibility.

It is important to note that all information in this book is based upon data considered by Greene, Tweed to be reliable. This material is intended only to provide a general overview of process and equipment considerations.

The next chapter discusses the physical properties of elastomers.

* Viton is a registered trademark of DuPont-Dow Elastomers.
† Fluorel is a registered trademark of 3M.

PHYSICAL PROPERTIES OF ELASTOMERS

In selecting semiconductor seals, it is important that elastomeric physical properties be understood and applied correctly. The vast majority of seal failures are mechanical and can be traced to both improperly designed glands and improperly selected compounds. There are significant differences between the physical properties of most base elastomers. There can also be significant variations among compounds from the same base elastomer.

The terminology used to describe standard O-rings is not always useful in semiconductor applications. This chapter includes accepted nomenclature but also points out variations that are critical to semiconductor sealing.

The physical and chemical properties of various elastomers dictate compound selection for use in semiconductor manufacturing. The physical properties discussed in this section are:

- Fluid resistance
- Hardness
- Toughness (a term for six distinct properties)
- Volume change
- Compression set
- Thermal effects
- Resilience
- Deterioration
- Corrosion
- Permeability
- Coefficient of friction
- Coefficient of thermal expansion
- Compression stress relaxation

Fluid Resistance

The most important issue in seal design is the chemical effect of the fluid on the seal. In this handbook, we use the word ***fluid*** to describe the substance with which the seal is in contact; this may be a liquid, a gas or a vapor.

Although we know that any major volume shrinkage will probably result in premature leaking of any O-ring seal, the fluid cannot be allowed to significantly alter the operation or life span of the seal. On the other hand, a compound with apparently significant undesirable immersion test results — excessive swelling, increase or decrease in hardness, tensile strength or elongation — can still provide a very durable static seal.

Hardness

The industry standard for measuring rubber compound hardness is the Shore Type A ***Durometer.*** (The Type D Durometer is best when the Type A reading is greater than 90.) *This property is often misunderstood when changing from one compound choice to another.* However, there is no assurance that different compounds of the same durometer will act the same in the application. The problem is most evident when changing from a standard elastomeric material to a perfluoroelastomer.

Hardness (durometer) ratings are frequently misunderstood and applied incorrectly. This misunderstanding leads to seal failures. For example, if a 75 durometer Viton* is used in sealing, it is not appropriate to apply a 75 durometer Chemraz® perfluoroelastomer compound in the same application.

* Viton is a registered trademark of DuPont-Dow Elastomers.

The Durometer's calibrated spring forces an "indentor" into the test specimen. The scale that measures hardness is calibrated to read 100 if there is no penetration (e.g., on a steel or glass surface).

Softer materials (those with lower ratings) conform more easily to the surface irregularities of the mating part. This matters most in low pressure seals because they are not activated by fluid pressure. Harder materials resist flow better and are less likely to be extruded into the narrow gap beyond the groove.

Hardness is especially important in dynamic applications, such as slit valves. The proper application of compound and hardness can make the difference in leak integrity and optimal seal life. For most semiconductor applications, compounds with Type A hardness between 80 and 90 provide the best compromise. In particular, seals used in dovetail glands require close scrutiny and a judicious consideration of compound choices.

Note: Durometer specifications are normally noted with a tolerance of ±5, and hardness readings are usually rounded off to the nearest 5, e.g., 70 durometer, 85 durometer. Exact readings are not used because of batch-to-batch variability among compounds and differences among Durometers.

Toughness

Toughness is an industry term that refers to resistance to physical, rather than chemical, forces, and encompasses a range of factors — ***tensile strength, elongation, O-ring compression force, modulus, tear resistance*** and ***abrasion resistance.*** Toughness is a relative rather than an absolute term, and the contributing factors are described below.

Tensile Strength

Tensile strength refers to the stress in pounds per square inch (psi) required to rupture a specimen of a compound by stretching it. It is a production control measurement that ensures uniformity of the batch compounding process. Measuring the change in tensile strength after long-term contact with a fluid can tell us to what degree a compound has deteriorated, and this determines its relative life span. Tensile strength does *not* indicate resistance to extrusion, and it is not usually a factor in design calculations. However, a minimum tensile strength of 1,000 psi is usually needed in dynamic applications.

Elongation

This property determines how much a seal can safely be stretched during installation. It is expressed as a percentage increase over the initial length of the seal. ***Ultimate elongation*** is the percentage of stretch at the time the seal breaks.

The smaller the diameter of the seal, the more important its elongation properties, especially when the seal must be stretched for installation. Combined with tensile strength measurements, elongation also tells us about the compound's ability to recover from peak overload, or from force localized in one area of the seal. If the elongation changes significantly after exposure to a fluid, that is a clear signal that the compound has degraded.

Compressive Force

The force required to compress an O-ring enough to maintain the seal is an important factor in some applications, such as face seals that have a limited available compression load. The O-ring's hardness, modulus, cross-section and degree of compression all affect compression force. However, different compounds will exhibit different compressive forces per linear inch, even if these factors are the same. For related technical data, please refer to the insert located at the back of this book.

Modulus

Stress measured at a predetermined elongation is called modulus. In the sealing industry, modulus is usually measured at 50% and 100% elongation and expressed in psi. The higher the modulus, the better the compound resists deformation, and the more likely it is to recover from peak overload or localized force. Modulus usually increases with hardness. All else being equal, modulus is considered to be *the best indicator of toughness.*

Modulus is also emerging as one of the most important parameters for predicting seal life in dynamic and critical applications such as slit valves, lid seals and end-point windows.

Tear Resistance

Most compounds have relatively low tear resistance. However, extremely low resistance (under 100 psi) creates a danger of nicking or cutting the seal during assembly, particularly if the seal must pass over sharp edges. Once a crack has started, compounds with poor tear resistance fail quickly under stress. They are also likely to have poor resistance to abrasion, another factor that can lead to early failure of a dynamic seal.

Abrasion Resistance

While tear resistance refers to the ability to withstand cutting or otherwise rupturing the surface, abrasion resistance refers to the compound's ability to withstand scraping or rubbing — something that happens to a dynamic seal in every cycle. Not all elastomeric compounds have sufficient abrasion resistance to be used in O-rings that come in contact with moving parts. Harder compounds, up to 85 durometer, tend to be more abrasion resistant.

Volume Change

Volume change refers to the increase or decrease in the volume of an elastomer after contact with a fluid. Volume change is measured as a percentage, as referenced to the original seal volume.

Swell (increase in volume) is nearly always accompanied by a decrease in hardness. Excessive swell leads to significant softening of the rubber, and that, in turn, can lead to reduced tear resistance and abrasion resistance. This softening may even allow extrusion of the seal under high pressure. Static O-ring applications can usually tolerate volume swell up to 50%, but dynamic applications usually require special provisions in the gland if swell will exceed 15 or 20%.

Swell can actually improve sealing effectiveness in some instances. For example, if a seal's cross-section is reduced by 15% because of compression set, but the seal swells 20%, the effects tend to cancel each other. In other cases, the fluid absorbed can affect the compound in the same way that the addition of plasticizers does — that is, providing more flexibility at lower temperatures. These effects can and do contribute to improved sealing performance, but they should not be relied on when selecting a compound.

Shrinkage (decrease in volume) is the opposite of swell and is usually accompanied by an increase in hardness. Also, just as swell may compensate for compression set, shrinkage intensifies it. Shrinkage will cause the seal to pull away from the sealing surfaces, creating a path for leaks. Shrinkage is far more problematic than swell. If shrinkage is even a possibility in an application, it must be carefully planned for.

Shrinkage of more than 3 or 4% can cause serious problems for moving seals. Plasticizers are added to some elastomers to improve low-temperature sealing performance. Fluids may extract plasticizers from the seal, causing it to shrink when fluid is temporarily removed ***(dry-out shrinkage).*** Whether or not this shrinkage is serious depends on the amount of shrinkage, the gland design and the degree of leakage that can be tolerated before the seal re-swells. But even if the seal does re-swell, it may not properly re-seat itself. It is important to note that Chemraz® compounds *do not* contain any plasticizers.

Compression Set

Compression set refers to an elastomer's recovery to or near to its original size after a fixed period of time and temperature in a compressed state. Compression set measures the percentage of deflection by which the compound fails to recover, and it is always expressed as a percent of the amount of deflection. A compound which has recovered to its original size — that is, has recovered completely — is said to have 0% compression set. Similarly, one that remains at the compressed dimensions has 100% compression set.

The effect of swell on compression set was mentioned earlier. Under other conditions, a seal will continue to perform, even after taking a 100% compression set, if the temperature and system pressure remain steady and no motion or force causes a break in the contact.

The condition to be most avoided is the combination of high compression set and excessive shrinkage. This is a guaranteed formula for seal failure.

While a low compression set in an O-ring compound is desirable, it is becoming evident that our traditional method of selecting an O-ring compound because it has low compression set may not always apply to all semiconductor processing applications. The multitude of other important parameters, including plasmas, RF, temperature and vacuum, is leading the industry to finding new properties more suitable for predicting seal performance.

Thermal Effects

High-Temperature

Elastomers deteriorate at high temperatures, and heat directly affects both ***volume change*** and ***compression set***. Heat also influences hardness, but in a more complex way (i.e., increased temperature softens the compound; this is a physical change that reverses when the temperature drops). This change is important in high-pressure applications, because a compound hard enough to resist extrusion at room temperature may become soft enough at higher temperatures to extrude beyond the gland. As the time at high temperature increases, chemical changes slowly occur and, because they are chemical, are not reversible. These changes include an increase in hardness, the volume and compression set changes previously mentioned, and changes in toughness.

Low-Temperature

The changes that low temperatures produce are primarily physical. When the compound is re-warmed, it will regain almost all of its original properties. The Temperature Retraction (TR-10) test used in military specifications is considered a standard method for determining low-temperature sealability. Most compounds will continue to seal effectively at 8° C below their TR-10 temperature values.

As temperatures decrease, ***hardness*** increases. Low pressures at low temperatures require careful consideration of hardness, since low pressures require a soft material that can be easily deformed. Materials that respond well at room temperature may be completely inappropriate under low-temperature, low-pressure conditions. Low temperatures also affect flexibility, resilience, compression set, brittleness and dimensional characteristics.

Swell can compensate for increased hardness at low temperatures, since the seal absorbs fluids that may act like a low-temperature plasticizer.

Shrinkage at low temperatures may result in retraction and loss of flexibility, with the seal becoming stiff at a temperature of 5 to 8° C above its low temperature rating, affecting sealing functionality.

Crystallization is another side effect of low temperatures. A crystallized compound becomes rigid, with no resilience. Because crystallization under compression can cause a flat spot on the O-ring, it is sometimes mistaken for compression set. As the seal warms, the flatness gradually disappears. It may take a compound two or three months of exposure to low or moderate temperatures to crystallize, but successive exposures will cause much more rapid crystallization. The end result of crystallization is, of course, leakage.

Resilience

A compound's ability to quickly return to its original shape after a temporary deflection is called resilience. It is an inherent property of the elastomer itself, but can be improved somewhat by compounding. The performance of dynamic seals (like slit valve seals) and door seals depends on good resiliency to optimize their sealability. This is determined by the right choice of elastomer and geometry for the specific application.

Deterioration

A chemical change that results in permanent loss of an elastomer's properties is called deterioration. It should not be confused with reversible or temporary losses of properties, which are usually caused by physical permeation of the fluid without chemical reaction. Additional parts of the process, such as RF power, plasmas and various oxidizing environments, can cause additional deterioration.

Corrosion

The chemical action of either the fluid or the compound — or both — on the surface of the gland has the potential to cause corrosion. Early elastomer compounding ingredients were found to cause corrosion on metal and actual pitting. In the semiconductor industry, ionic bombardment and radical ions will cause permanent damage to the surface of the O-rings. Whether through plasma-enhanced process or large amounts of RF, these phenomena lead to early seal failure.

Permeability

The tendency of gas to pass, or diffuse, *through* an elastomer is called permeability. Permeability leakage can have a significant impact on leakback rates; it is often difficult to distinguish permeability leakage from leakage around the seal. Permeability increases with higher temperatures, different gases have different permeability rates, and the higher the compression on a seal, the lower its permeability. Permeability is always an issue in processes that require vacuum integrity. Most compounds are normally "baked" to dispel any CO_2 or water in the material. Any sign of outgassing can lead to serious process degradation. For related technical data, please refer to the insert located at the back of this book.

Coefficient of Friction

Higher hardness conditions result in higher breakout friction — but lower running friction. The friction coefficient of a moving seal relates to hardness, lubrication and the surface characteristics of surrounding materials. Breakout friction is usually many times higher than running friction. When only the hardness of the seal changes, both breakout and running friction change. With the exception of drive belts, however, this property has very little applicability in the semiconductor industry.

Coefficient of Thermal Expansion

The change in unit length accompanying a unit change of temperature, at a specified temperature, is the coefficient of linear expansion. For solids, the coefficient of volumetric expansion is approximately three times the linear coefficient. Elastomers have a coefficient of expansion approximately ten times that of steel. The coefficient of expansion can be a critical factor:

- At high temperatures, if the gland is almost filled with the seal
- At low temperatures, if the squeeze is marginal

The thermal expansion of the elastomer can cause a seal to exert relatively high forces against the side of a groove. If the gland is 100% filled and the seal is completely confined, it is possible for the seal to rupture the gland when heated, because the dominating force is that of thermal expansion. For this and other reasons, it is important to keep gland fill to less than 95%. For related technical data, please refer to the insert located at the back of this book.

Compression Stress Relaxation

Historically, compression set has been the primary measurement used to determine an elastomer's sealing capacity. However, ***compression stress relaxation*** (CSR) is an even more direct measurement. It measures, as a function of time, the decrease in resistant force exerted by the elastomer when held under constant compressive strain (typically 25%).

CSR gives a direct measure of force; this force and its retention are directly related to sealing capacity. CSR data have been generated for up to one year, and have enabled extrapolations of up to five years and beyond.

Information outlining the physical properties of a wide range of compounds, as well as their specific applications in semiconductor sealing, can be found in the insert at the back of this book.

O-RING SEALS

An O-ring is a donut-shaped seal (the "O" refers to the shape of the seal's cross-section) which can be manufactured from any of a wide range of materials. In the semiconductor industry, O-rings are usually molded from elastomers because of their capacity to "remember" their shape through many cycles.

How an O-Ring Works

A groove (or gland) to capture the O-ring is incorporated into one of the two surfaces that will meet (mate) and thereby seal against liquids or, in the case of vacuum service, gases. As the two surfaces come together, the compression exerted on the O-ring actually deforms the O-ring in order to create a tight seal (Figure 3-1).

In the case of vacuum chambers, permeation must also be taken into account. A seal's proper design and applicability in various media and plasmas will dictate how well it performs.

When the contained fluid exerts higher pressure, the O-ring is forced to the side of the gland and away from the pressure. At maximum pressure, a properly applied O-ring will be forced up to (but not into) the gap between the mating surfaces (Figure 3-1).

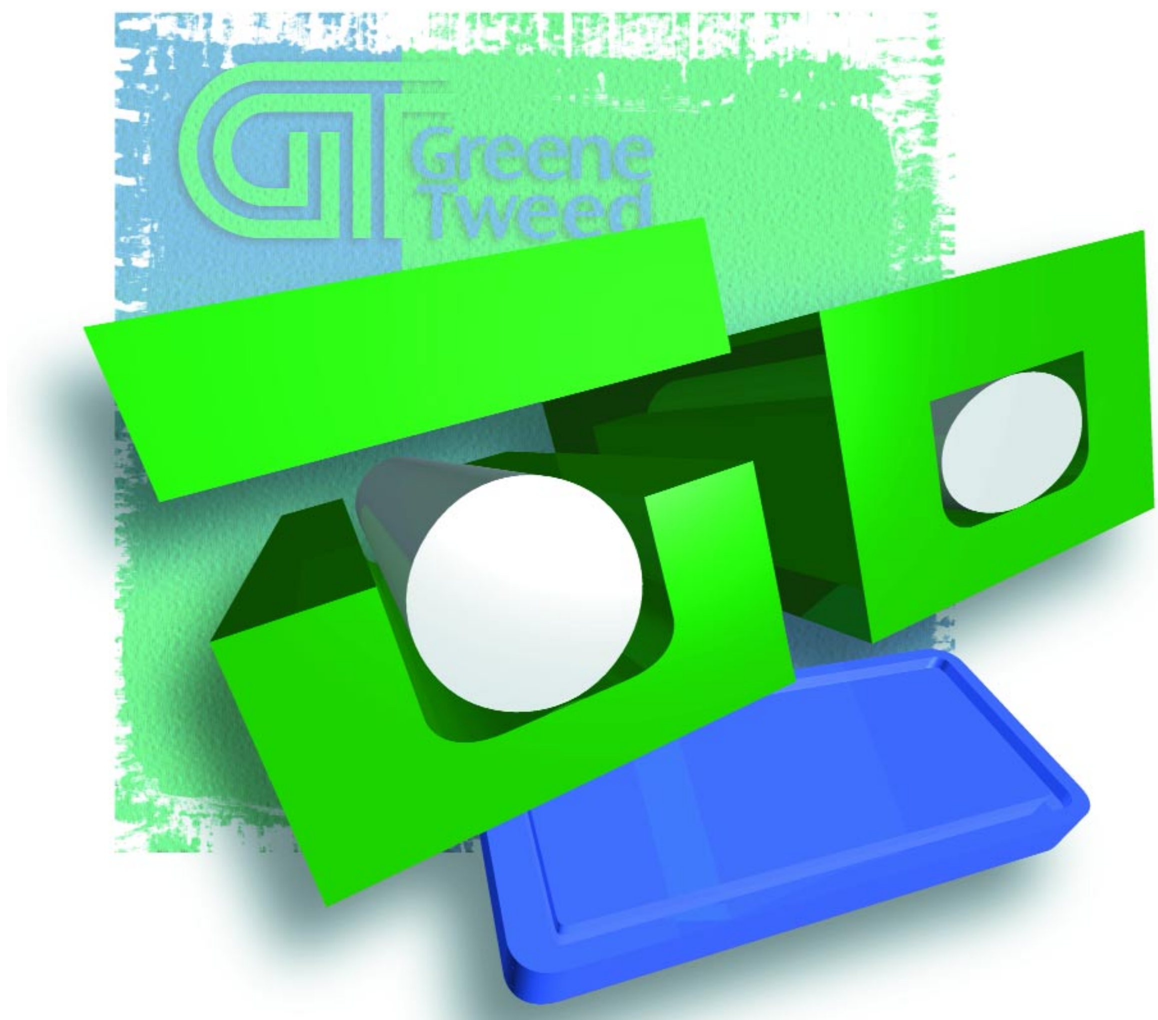


Figure 3-1 *O-Ring in Relaxed State and Compressed*

When pressure is released, the ring returns to approximately its original shape.

An O-ring can seal in both directions, so in a double-acting system, when the pressure application changes from one side of the O-ring to the other, the O-ring moves to the other side of the gland.

Think of the O-ring as a viscous fluid with very high surface tension, and you can easily picture how it seals — and how it can fail.

Failure Modes of O-Rings

Failure When Functionality Is Impaired

There are a variety of reasons for O-ring failure in semiconductor equipment. O-rings that no longer perform their intended sealing function are easily classified as having "failed." These types of failures are usually mechanical, and can occur for any of the following reasons:

Improper Sizing

Improper sizing results in the use of O-rings that are either too large or too small. Seals which are too large will ***bunch*** or ***buckle*** in their

Figure 3-2 *Cracking Caused by Overstretching of O-Ring*

Figure 3-3 *Installed O-Ring — Correct and Twisted*

glands. An O-ring is generally too small when — in an installed state — its inside diameter has been stretched by more than 3%. This condition results in the overstretching of the elastomeric material. ***Overstretching*** causes a reduction in the cross-section of the seal, resulting in lower squeeze. This also makes the seal more susceptible to cutting and tearing during installation. Overstretching conditions can also result in ***cracking*** on the surface of the O-ring (Figure 3-2). This cracking is often misdiagnosed as having resulted from chemical attack. Permanent deformation can also occur due to overstretching. Both cracking and permanent set of the elastomer can cause rapid seal failure.

Improper Installation

Another common cause of O-ring failure is improper installation. An O-ring which is twisted during installation can leak because it is not properly seated in the gland. Also, a twisted parting line is more likely to be affected by direct plasma attack. A major problem, unique to the semiconductor manufacturing industry, is the widespread use of O-rings in ***dovetail*** (undercut) glands. The proper installation of an O-ring into a dovetail gland is a time-consuming and difficult task (Figure 3-3). Since dovetail glands are used in most critical sealing areas — such as slit valves, end-point windows, lid seals and quartz heater windows — O-ring failures here are especially dangerous. This is because some O-ring compounds can contribute to an array of contamination and mechanical problems. (See Chapter 4, "Dovetail® Seals," for more information on this topic.)

Permeation of the Elastomer

The propensity of all elastomers to be permeable to gases is a contributing factor to the failure of O-rings used in vacuum chambers. The permeability of any elastomer increases as temperatures rise. Depending upon their molecular structure, different gases have different rates of permeability in any given elastomer. The more an O-ring is compressed, the more its resistance to permeability improves.

An O-ring failure mode is identifiable through leakback rates, which are initial vacuum integrity qualifications. These are characterized by an inability either to achieve or to sustain low pressure.

Sustaining Vacuum Requirements (achieving low vacuum)

Every O-ring compound is a unique composition. This composition will impact its ability to sustain the proper level of vacuum to perform the process. Standard elastomeric O-rings can usually maintain up to 10^{-8} Torr levels of system vacuum when the glands are properly designed and the O-rings properly fitted to the design. Perfluoroelastomers are included in discussing these requirements, but their sealing properties make proper groove design and sizing a necessity.

Leakback Rate (monitoring process vacuum requirements)

The monitoring of the process by leakback rates is a quantitative measurement. Other qualitative measurements, such as outgassing and chemical breakdown, make it difficult to identify the actual O-ring failure mode.

If unacceptable leakback rates are occurring, an alternate seal design or material (one more compatible with process needs) should be selected.

Failure When Functionality Is Not Impaired

Typically, O-ring compounds used in semiconductor production are formulated from fluoroelastomer or perfluoroelastomer polymers. ***Fluoroelastomers*** are partially fluorinated materials exhibiting fairly good chemical resistance. ***Perfluoroelastomers*** are fully fluorinated materials which are highly resistant to chemical attack.

However, since elastomeric base polymers have no useful mechanical properties, they must be combined with other selected materials to produce a ***compound*** which will have the properties required to perform a sealing function. All elastomeric O-rings are fabricated from compounds consisting of base polymer, fillers and a cross-linking system.

These additives can create weak links in even the most stable polymeric networks, including those based on perfluoroelastomers. In fact, the cross-link is more susceptible to chemical attack than the base polymer. Resultant softening, hardening, volume change or other physical property changes can adversely affect sealing performance.

Semiconductor production requires stringent control of impurities. An improperly formulated O-ring compound can contaminate equipment with ionic, volatile organic or particulate matter. Superficial chemical degradation (or mechanical wear) of installed O-rings can release these contaminants with *no detectable reduction in sealability.*

Especially problematic are the metallic ions present in nearly all fluoroelastomer compounds. Metal oxides, such as magnesium oxide and calcium hydroxide, are normally added as acid acceptors. These can be leached out in wet processes or dislodged mechanically in dry processes.

Chemraz® products are made from perfluoroelastomer compounds which are entirely free of metallic ions, since no metal oxides or salts have been added.

In many instances, it is possible to detect O-ring deterioration before sealing functionality is impaired. Typical visual signs of O-ring deterioration are:

- Black residue left behind in the groove
- Cracking and splitting of the O-ring (can also be indicative of mechanical stresses)
- "Powdering" (white or black); very fine residues
- "Pitting" or flaking
- Roughened O-ring surface

It is important to reiterate that *an O-ring can introduce contaminants and particles into the process long before it stops acting as a seal.*

Standards have yet to be developed to address this issue. However, it seems inevitable that this area will be addressed if manufacturers are to achieve the submicron fabrication capabilities required for future generations of equipment.

O-Ring Seal and Gland Design

There are five main considerations entering into the design of every seal/gland configuration:

- Cross-section squeeze
- Diameter stretch
- Gland volume fill
- Seal and gland material selection
- Gland surface finish

Obviously, seal functionality in the intended application is the main consideration in the design of the O-ring and its gland.

Cross-Section Squeeze

Cross-section squeeze is defined as the compression of the seal cross-section, which is a result of the gland depth being less than the seal cross-section diameter. It is recommended that ***static seals*** have a squeeze percentage of *20-25%* at maximum gland fill. This range ensures that the seal will not be over-compressed, which could result in premature failure. This will also ensure that the sealing footprint and sealing force are sufficient for the application. For ***dynamic seals,*** a squeeze percentage of *12-18%* is recommended to reduce friction and abrasion. Percent-squeeze is calculated according to this formula:

$$\text{Squeeze \%} = \left(\frac{\text{Seal Cross-Section - Gland Cross-Section}}{\text{Seal Cross-Section}}\right) \times 100\%$$

Diameter Stretch

Stretch occurs when the inside diameter (I.D.) of the seal is smaller than the gland I.D., requiring extension of the seal diameter for installation and fit. It is generally recommended that a seal not be

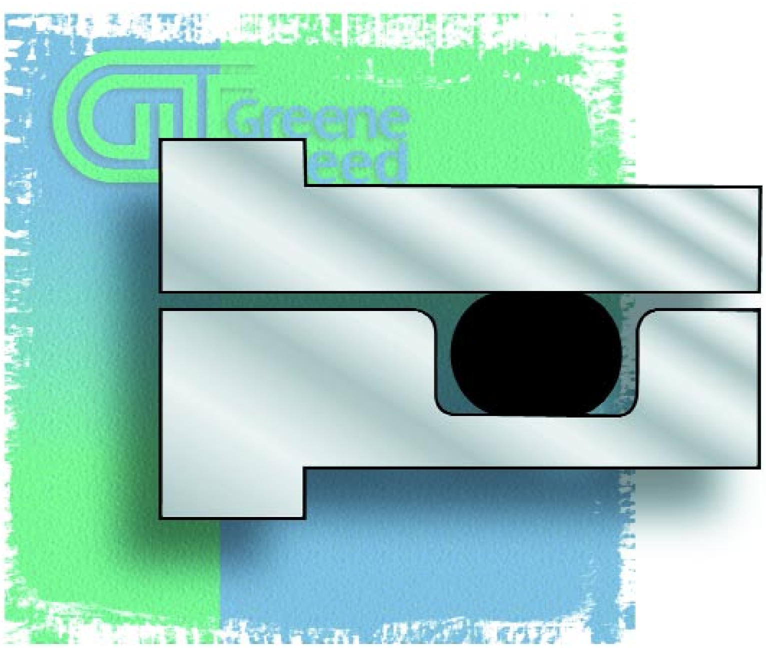


Figure 3-4 *Gland Detail*

stretched more than 50% during installation. This recommendation is frequently difficult to follow, particularly with smaller diameter O-rings. In those cases, where the recommended installation stretch is exceeded, sufficient time should be allowed for the O-ring to return to its normal diameter before closing the gland.

An installed I.D. stretch percentage of 1-3% is recommended for all gland configurations over 0.500″ diameter. The recommended dimensions for glands with diameters less than 0.500″ do provide for stretching the O-ring, in the installed state, greater than this amount. The designer should be aware that any time an I.D. of an O-ring, in its installed state, is stretched greater than 3%, seal life will be compromised.

Even a small amount of stretch on a seal allows a piston to be installed without pinching the seal. On face seals, the stretch ensures the seal will stay in the gland. Overstretching a seal may cause additional stresses in the material and lead to premature failure. Rod seals are normally compressed or have line-to-line fit on the outside diameter without any stretch.

Diameter stretch for rectangular glands:

$$\text{Stretch \%} = \left(\frac{\text{Gland I.D. - Seal I.D.}}{\text{Seal I.D.}}\right) \times 100\%$$

Gland Volume Fill

Gland volume fill is defined as the amount of gland volume occupied by the seal in a compressed state. It is usually expressed as a percentage of gland volume. The recommended ranges for gland volume fill percentage are:

- Static applications: 85-90%
- Dynamic applications: 80-85%

These ranges allow for tolerance variations, thermal expansion and fluid volume. They also prevent excessive movement of the seal in the gland. The calculation for gland volume fill percentage is:

$$\text{Gland Fill \%} = \left(\frac{\text{Seal Volume}}{\text{Gland Volume}}\right) \times 100\%$$

Material Selection

The correct balance of physical properties and service media compatibility ensures that the hardware and seal combination will meet the application requirements. In semiconductor manufacturing, the seal and hardware material face an additional requirement: The combination must not add contaminants during the wafer fabrication process. (See Chapter 2, "Physical Properties of Elastomers," for more information about material selection.)

Gland Surface Finish

The surface finish of the gland is an important consideration in any application. To optimize the sealing integrity and performance life, the gland surface should be free of nicks, dents and scratches. A gland surface finish of 8-16 Ra is recommended for vacuum systems. A gland surface finish of 16-32 Ra is recommended for pressure or atmospheric systems.

Seal Surface Finish

All semiconductor seals should be manufactured in tooling with an 8 Ra finish to optimize the seal surface finish. Resistance to plasma attack is greatly enhanced when microscopic seal surface irregularities are kept to a minimum.

How to Order an O-Ring from Greene, Tweed

The dash numbering system used in AS 568A is the industry standard for establishing O-ring dimensions and tolerances. The tables in Chapter 7 summarize these standard O-ring sizes in inch measurements.

Part Number Selection

Greene, Tweed part numbers for standard AS 568A O-rings are explained below. Nonstandard O-rings require Greene, Tweed Engineering Department input for part number assignment.

AS 568A Standard Part Numbers

9XXX - XXXXX

1	2		3	4

Field # 1 – Series Designator ("9" for O-rings)

Field # 2 – AS 568A Dash Number (See Chapter 7)

Field # 3 – Post-Production Handling/Cleaning and Packaging Designator (See Compound Selection Guide, inserted in back cover)

Field # 4 – Compound Designator (See Compound Selection Guide)

Part Number Example

9254 - SS520

This part number is for an AS 568A -254 O-ring manufactured in Chemraz® 520 compound with "SS" class handling and packaging.

Gland Dimensions

To optimize performance in semiconductor production equipment, Greene, Tweed's recommended gland diameter for a specific AS 568A O-ring dash number size will vary depending upon its intended use and application. Chapter 7 provides all of the information necessary to select the appropriate gland dimensions for a standard ASA 568A O-ring for all typical semiconductor applications.

DOVETAIL® SEALS

Sealing Problems Specific to Dovetail Glands

In the semiconductor industry, the use of undercut (dovetail) glands dates back to the first chamber design, and has persisted in the design of each successive generation of equipment. This gland design has the advantage of containing (retaining) O-rings better than the alternative — conventional, rectangular glands. However, the dovetail gland design has significant drawbacks:

- The gland itself is expensive to machine.
- *Correct* installation of a standard O-ring into a dovetail gland is a difficult and time-consuming procedure. Installation errors can leave the parting line on the sealing surface, where it can become a leak path; and the parting line itself is exposed to direct chemical attack, causing contamination.
- When a dovetail gland is occupied by a standard O-ring, the result is a high-volume gland occupancy. The resulting high gland volumetric fill is required to achieve effective sealing.

Slit Valves

The most problematic dovetail gland application is semi-dynamic door seals (i.e., slit valves and load locks). In most systems, this is the O-ring that will see the most use dynamically; it is critical to chamber uptime. Because of the valve's proximity to the wafers, limiting particle generation in this region is a critical component of slit valve reliability. A common failure of standard O-rings in slit valves is severe compression set, yielding high leak rates that can be accompanied by ***high particle generation.*** This is a result of the high gland fill and squeeze above the recommended levels that are inherent in the use of O-rings in dovetail glands. Because of the limited volume, the O-ring takes a set; particles are a result of mechanical abrasion and extrusion.

Lid Seals

All processing chambers are designed with lids to allow for easy access to the elements within the chamber that need routine cleaning or replacement. The seals incorporated into these lids are critical to maintaining processing integrity in most process environments. The dovetail-designed grooves lead to the same issues which are of concern in slit valves — early seal failure due to difficulty of installation, twisting, bunching or related problems. Only proper sizing and careful compound consideration will extend seal life in this area.

End-Point Windows

This window sees the harsh conditions associated with close proximity to the RF source. Its function as a checkpoint for verifying the integrity of the process makes it an important part of the chamber, and a critical sealing area.

High temperatures and the unique shape of the window accentuate the already tough environments endured by this seal.

Despite these problems, dovetail glands continue to be designed into semiconductor manufacturing equipment.

The Solution: The Dovetail Seal

In recognition of the problems created by installing O-rings in dovetail glands, Greene, Tweed engineers have designed the Dovetail Seal. It is the only seal specifically designed to fit the dovetail glands used in semiconductor manufacturing equipment. The Dovetail Seal is designed to orient itself properly in the gland, quickly and without twisting. Its unique cross-section (slightly flattened on the bottom) prevents twisting. Because the seal doesn't twist, the mold parting lines are also kept inside the gland (Figure 4-1).

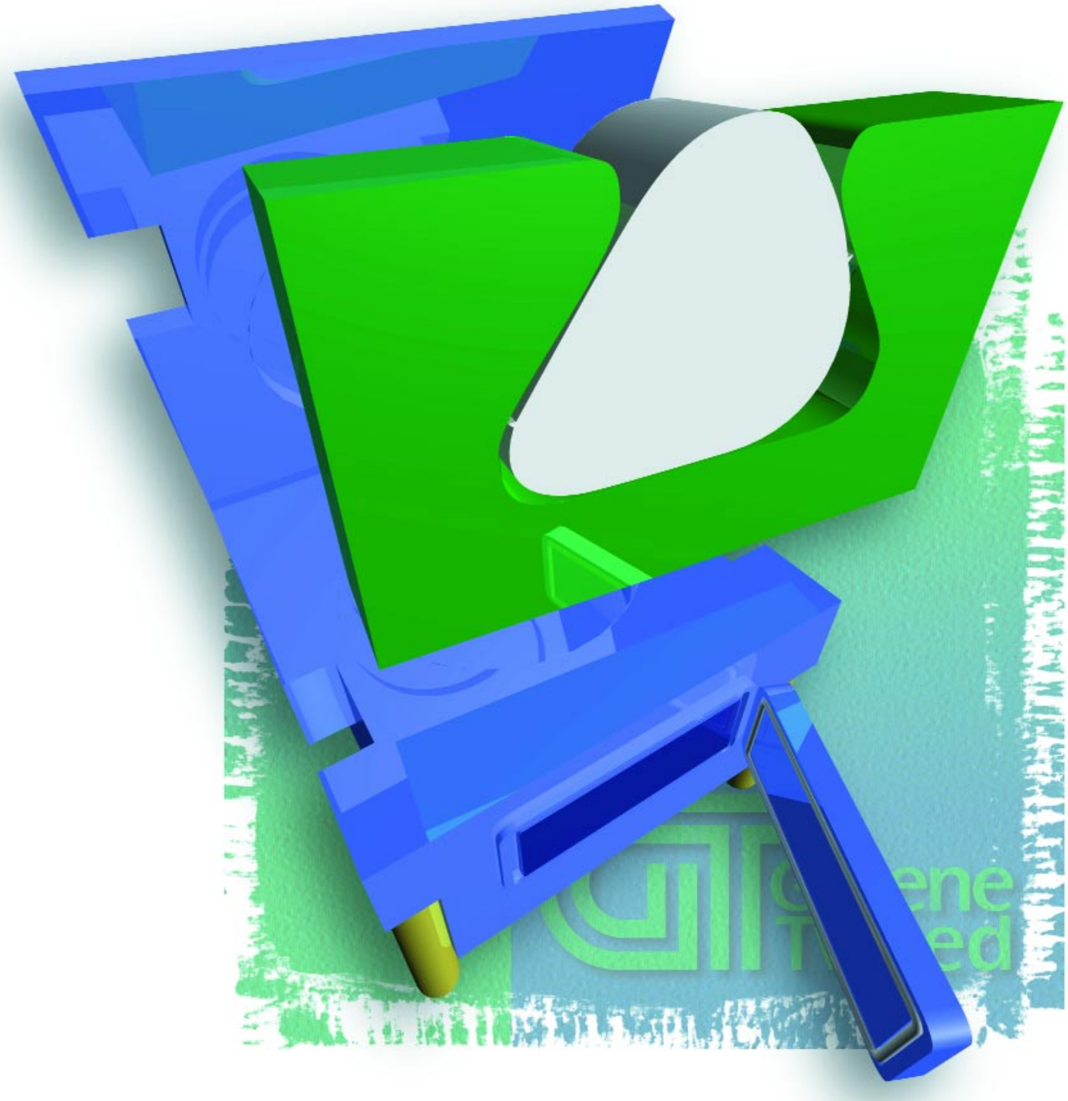


Figure 4-1 *Dovetail Seal Installed*

Not only is the Dovetail Seal *easier to install,* but it also creates an increased sealing surface area while maintaining sealing force. The result: *improved seal integrity.*

Vacuum and Pressure Seals

An important design feature of the Dovetail Seal is the orientation difference between a vacuum and a pressure seal. When the seal is used in an ***internally pressurized system,*** the angled face of the seal should be on the outside diameter of the seal (Figure 4-2). This is known as a Type A Dovetail Seal and should be specified in the seal design.

When the seal is used in an ***internal vacuum system,*** the angled face of the seal should be on the inside diameter of the seal (Figure 4-3). This is known as a Type B Dovetail Seal.

How to Order a Dovetail® Seal from Greene, Tweed

Standard Dovetail Seal sizes have been established to correspond with AS 568A O-ring standards. See Chapter 7, Table 7-10, page 42, for hardware (gland) information.

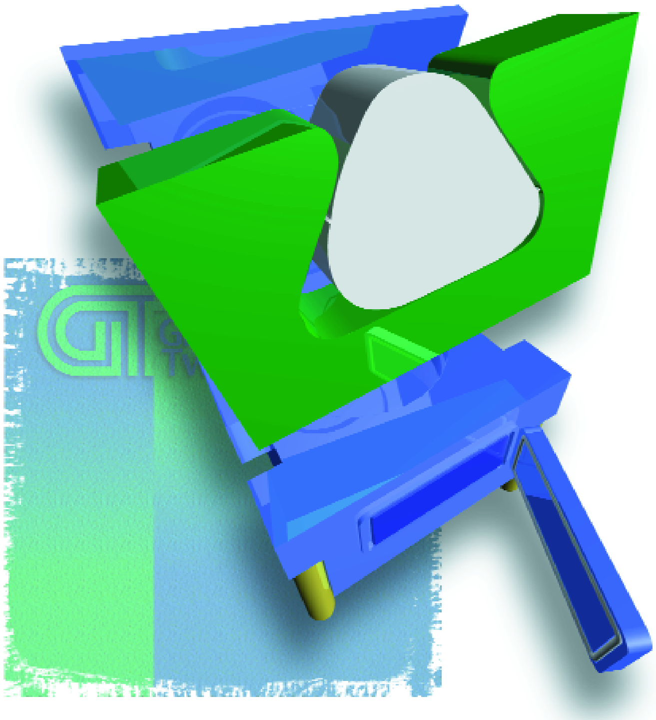


Figure 4-2 *Dovetail Seal for External Vacuum (Type A)*

Part Number Selection

Greene, Tweed part numbers are defined as follows for the standard Dovetail Seal. A nonstandard Dovetail Seal requires Greene, Tweed Engineering Department input for part number assignment.

Dovetail® Seal Standard Part Number

4201XXXX00 - XXXXX

1	2	3	4		5	6
4201	X	XXX	00	-	XX	XXX

Field # 1 – Series Designator ("4201" for all Dovetail Seals)

Field #2 – Seal Orientation Designator (A or B) (See Figures 4-2 and 4-3)

Field #3 – Corresponding AS 568A O-Ring Dash Number (See Chapter 7, Table 7–10, p. 42)

Field #4 – Standard Seal Designator ("00" for all Dovetail Seals)

Field #5 – Post-Production Handling/Cleaning and Packaging Designator (See Compound Selection Guide inside the back cover)

Field #6 – Compound Designator (See Compound Selection Guide)

Part Number Example

4201B25500 - SS513

This part number is for an AS 568A -255 internal vacuum Dovetail Seal manufactured in Chemraz® 513 compound with "SS" class handling and packaging.

Figure 4-3 *Dovetail Seal for Internal Vacuum (Type B)*

MSE® SEALS

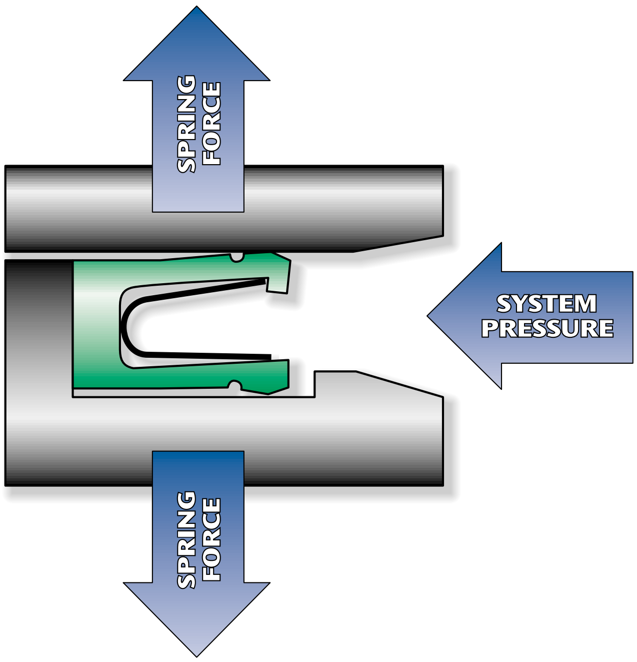


Figure 5-1 *Spring-Loaded MSE Seal*

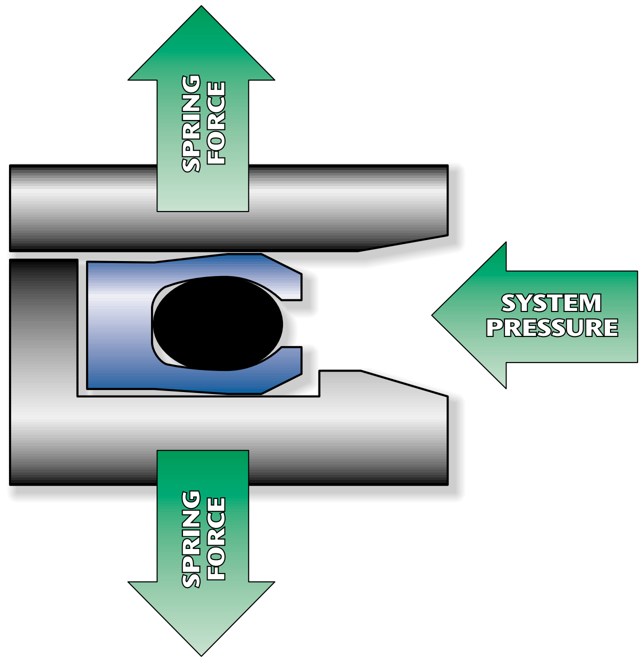


Figure 5-2 *Elastomer-Loaded MSE Seal*

How MSE Seals Work

The MSE seal is a sealing device consisting of a PTFE or other polymeric component, energized by a corrosion-resistant metal spring or an elastomeric O-ring. When the seal is seated in the gland, the spring is under compression applying force on the gland sealing surfaces, thereby creating a tight barrier to prevent gas or fluids from leaking. The spring also provides resiliency to compensate for seal wear, gland misalignment or eccentricity. While spring force provides adequate force for sealing at low pressure, at high pressure the system pressure augments the spring force to provide an even tighter seal. The MSE seals are precision machined from PTFE, filled PTFE and other high-performance polymers.

MSE seals are recommended for applications where elastomeric seals do not work satisfactorily due to extreme operating conditions.

Greene, Tweed & Co. offers over 100 seal materials, a variety of standard spring materials and three standard spring designs to meet your needs. These options allow the design engineer great latitude in developing the best seal for the job.

Features and Benefits

Chemically Inert

- Virtually unlimited chemical compatibility (except molten alkali metals, fluorine gas at high temperatures and chlorine trifluoride ClF_3)

Low Friction

- Smooth and consistent breakout and running friction
- Low power absorption and torque requirements
- Capable of running dry or lubricated

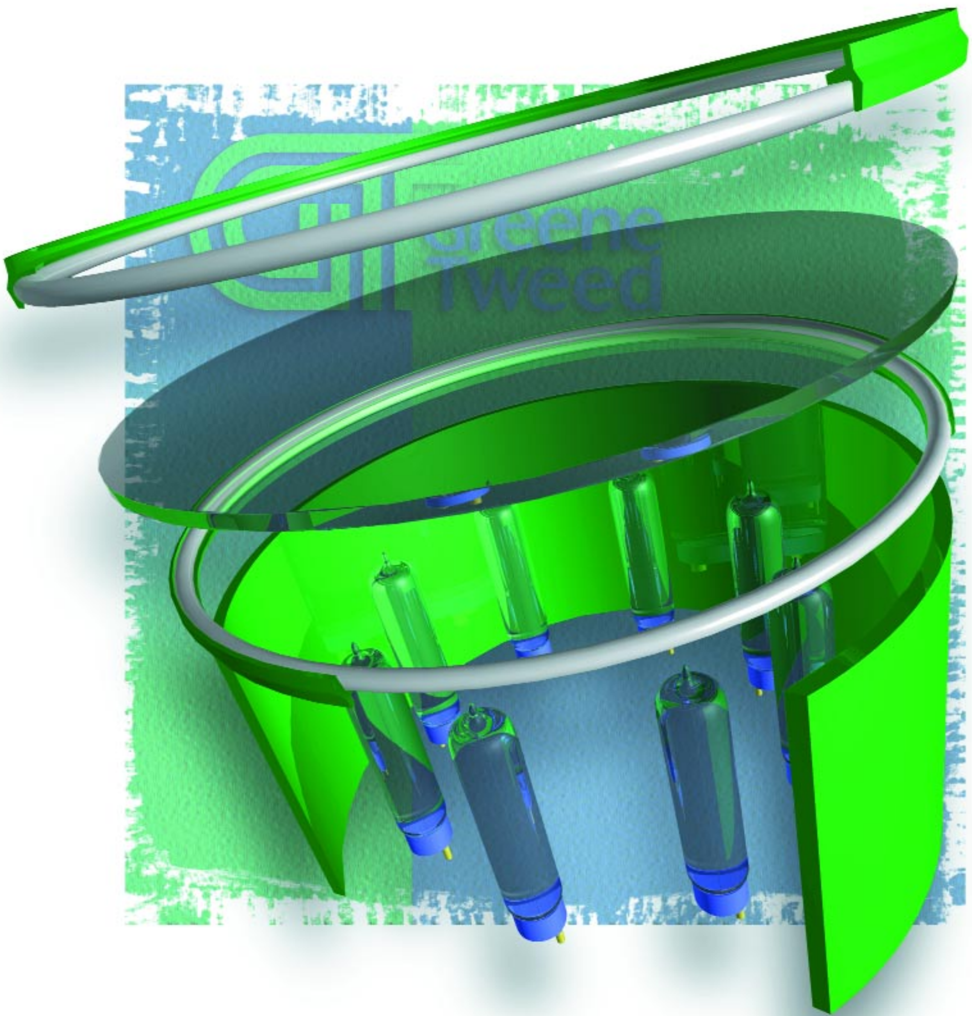


Figure 5-3 *Quartz Heater Window*

Wide Temperature and Pressure Range

- -252° C to 315° C, from cryogenic service to hot air or super-heated steam
- Vacuum to 60,000 psi, vacuum chambers to high-pressure water jet cutters

These features make MSE® seals suitable for a number of semiconductor applications:

- CVD chambers
- Etch chambers
- Quartz windows
- Gas inlets
- Furnaces
- Wafer elevators
- Robotics
- Valves
- Cryogenic pumps

MSE® Seal Types

Finger Spring (Series 2000)

Operating Temperature		Vacuum Sealability
Min	Max	
-65° C	260° C	Fair
Application		
This type of seal is designed mainly for dynamic applications with a balance of good sealability, long life and low friction. Use this type seal in applications where the seals are expected to last over 50,000 inches of travel at speeds up to 250 ft/min. Seals are available in piston, rod, face and special configurations.		

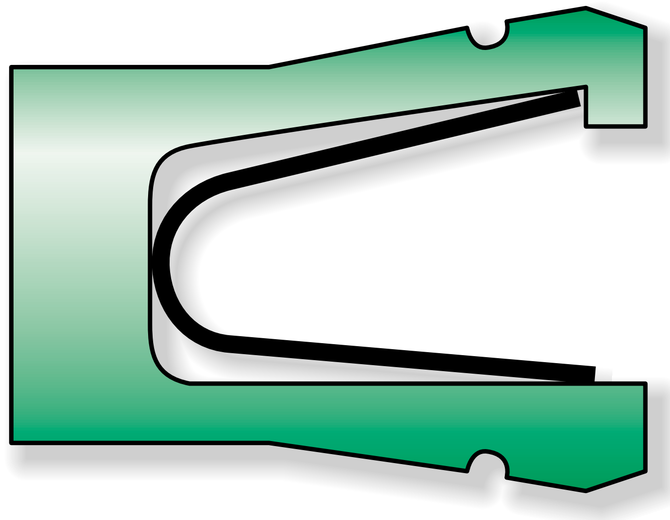


Figure 5-4 *Finger Spring*

Coil Spring (Series 3000)

Operating Temperature		Vacuum Sealability
Min	Max	
-173° C	260° C	Good
Application		
This type of seal is designed for static and slow dynamic applications; sacrificing some flexibility for improved sealability. Use this type of seal where the application is mostly static with occasional dynamic function. Seals are available in piston, rod, face and special configurations.		

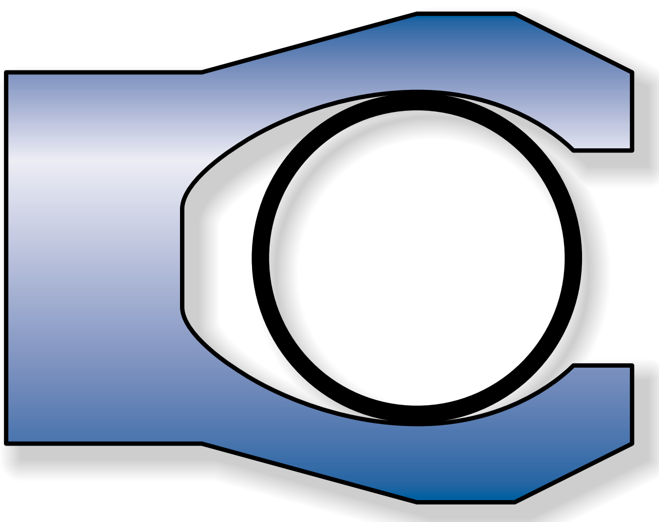


Figure 5-5 *Coil Spring*

Double Coil Spring (Series 5000)

Operating Temperature		Vacuum Sealability
Min	Max	
-268° C	260° C	Best
Application		
This type of seal is designed for static applications. The high spring load ensures better sealability than a single spring seal. Use this type of seal where sealability is most critical. Seals are available in piston, rod, face and special configurations.		

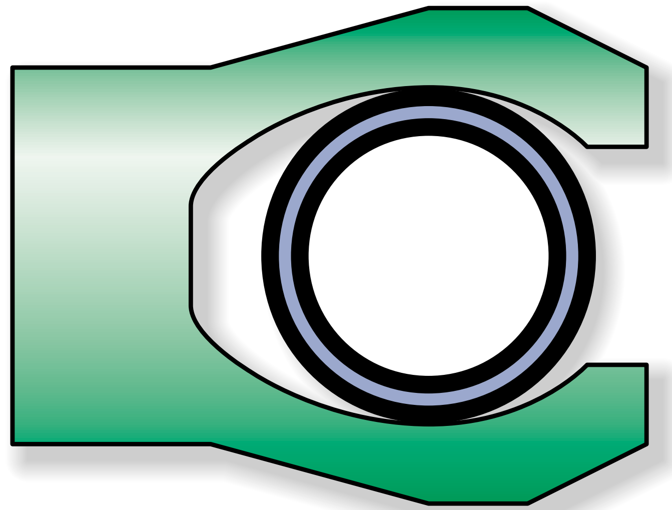


Figure 5-6 *Double Coil Spring*

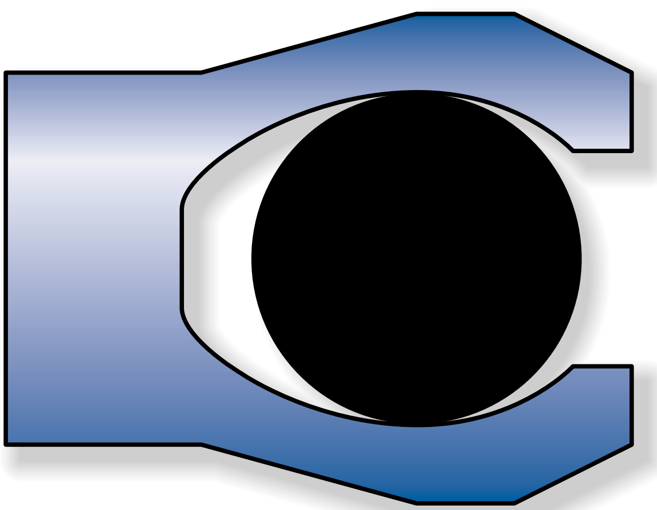


Figure 5-7 *O-Ring Energized*

O-Ring Energized

Operating Temperature		Vacuum Sealability
Min	Max	
*	*	Good
Application		
This type of seal is designed for static or dynamic applications. The O-ring energizer is used in cases where a metal spring is not desirable. Seals are available in piston, rod, face and special configurations.		

* The operating temperature depends on the capabilities of the elastomer being used as an energizer.

Machined Metal Spring (Series 7000)

Operating Temperature		Vacuum Sealability
Min	**Max**	
-273° C	288° C	Best
Application		
This type of seal is designed for static applications only, where sealability is most important. The solid spring design ensures low permeation and uniform spring loading, providing best leakage control. Seals are available in face seal configuration only.		

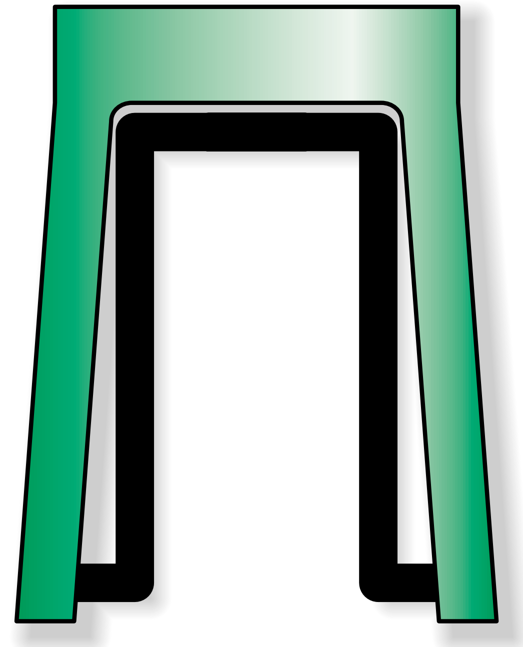


Figure 5-8 *Machined Metal Spring*

Special design MSE seals are also available and are recommended for applications where the temperature exceeds the temperatures shown. The shapes shown are the typical configurations. Every design has many possible permutations and adaptations.

How to Order an MSE® Seal from Greene, Tweed

MSE seals are available in a variety of designs, spring materials and jacket materials. Select the seal that best fits your application.

Part Number Selection

Standard MSE seals can be ordered by determining the Greene, Tweed part number. Special designs and sizes require Greene, Tweed Engineering Department input for part number assignment.

MSE Seal Standard Part Number

X XXXX - XXX X XXX

1	2	3	4	5
X	XXXX	XXX	X	XXX

Field # 1 – Seal Type
R = Rod Seal
P = Piston Seal
E = External Pressure Face Seal
I = Internal Pressure Face Seal

Field # 2 – Seal Series
(See MSE Seal Types, p. 31)

Field # 3 – Dash Size
(See Gland Dimensions, p. 34)

Field # 4 – Spring Material
(See Spring Materials, p. 38)

Field # 5 – Jacket Material
(See Jacket Materials, p. 39)

Gland Dimensions

To select the dash size, refer to Figure 5-9 and Tables 5-10, 5-11 for rod and piston seals and Figure 5-12 and Tables 5-13, 5-14 for internal and external pressure face seals. For diameters larger than the ones shown on these tables, consult the MSE Seal Design Guide.

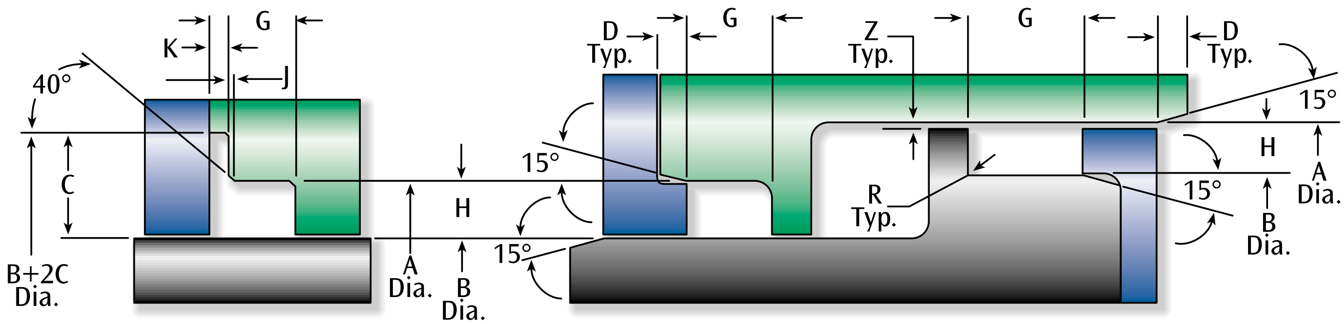


Figure 5-9

Table 5-10: Rod and Piston Gland Designs for MSE® Seals

Dash Size	Nominal X-Section	H Ref	G	C	D Min	J	K	R Max	Z Max
			+.010 -.000	+.004 -.004		+.003 -.003	+.002 -.002		
-006 through -033	1/16"	0.062	0.094	0.158	0.075	0.012	0.012	0.015	0.003
-106 through -150	3/32"	0.094	0.141	0.188	0.100	0.016	0.018	0.015	0.003
-202 through -246	1/8"	0.125	0.188	0.222	0.120	0.018	0.025	0.015	0.003
-318 through -362	3/16"	0.187	0.281	0.347	0.150	0.028	0.030	0.020	0.004
-405 through -449	1/4"	0.250	0.375	0.442	0.190	0.028	0.043	0.030	0.004

Dimensions in inches.

Table 5-11: Rod and Piston Gland Sizes for MSE® Seals

G = .094/.104		
Dash Size	A Dia	B Dia
	+.002 -.002	+.000 -.002
-006	0.250	0.125
-007	0.281	0.156
-008	0.312	0.187
-009	0.343	0.218
-010	0.375	0.250
-011	0.437	0.312
-012	0.500	0.375
-013	0.562	0.437
-014	0.625	0.500
-015	0.687	0.562
-016	0.750	0.625
-017	0.812	0.687
-018	0.875	0.750
-019	0.937	0.812
-020	1.000	0.875
-021	1.062	0.937
-022	1.125	1.000
-023	1.187	1.062
-024	1.250	1.125
-025	1.312	1.187
-026	1.375	1.250
-027	1.437	1.312
-028	1.500	1.375
-029	1.625	1.500
-030	1.750	1.625
-031	1.875	1.750
-032	2.000	1.875
-033	2.125	2.000

Dimensions in inches.

G = .141/.151		
Dash Size	A Dia	B Dia
	+.002 -.002	+.000 -.002
-106	0.375	0.188
-107	0.406	0.219
-108	0.437	0.250
-109	0.500	0.313
-110	0.562	0.375
-111	0.625	0.438
-112	0.687	0.500
-113	0.750	0.563
-114	0.812	0.625
-115	0.875	0.688
-116	0.937	0.750
-117	1.000	0.813
-118	1.062	0.875
-119	1.125	0.938
-120	1.187	1.000
-121	1.250	1.063
-122	1.312	1.125
-123	1.375	1.188
-124	1.437	1.250
-125	1.500	1.313
-126	1.562	1.375
-127	1.625	1.438
-128	1.687	1.500
-129	1.750	1.563
-130	1.812	1.625
-131	1.875	1.688
-132	1.937	1.750
-133	2.000	1.813
-134	2.062	1.875
-135	2.125	1.938
-136	2.187	2.000
-137	2.250	2.063
-138	2.312	2.125
-139	2.375	2.188
-140	2.437	2.250
-141	2.500	2.313
-142	2.562	2.375
-143	2.625	2.438
-144	2.687	2.500
-145	2.750	2.563
-146	2.812	2.625
-147	2.875	2.688
-148	2.937	2.750
-149	3.000	2.813
-150	3.062	2.875

G = .188/.198		
Dash Size	A Dia	B Dia
	+.002 -.002	+.000 -.002
-202	0.500	0.250
-203	0.562	0.312
-204	0.625	0.375
-205	0.687	0.437
-206	0.750	0.500
-207	0.812	0.562
-208	0.875	0.625
-209	0.937	0.687
-210	1.000	0.750
-211	1.062	0.812
-212	1.125	0.875
-213	1.187	0.937
-214	1.250	1.000
-215	1.312	1.062
-216	1.375	1.125
-217	1.437	1.187
-218	1.500	1.250
-219	1.562	1.312
-220	1.625	1.375
-221	1.687	1.437
-222	1.750	1.500
-223	1.875	1.625
-224	2.000	1.750
-225	2.125	1.875
-226	2.250	2.000
-227	2.375	2.125
-228	2.500	2.250
-229	2.625	2.375
-230	2.750	2.500
-231	2.875	2.625
-232	3.000	2.750
-233	3.125	2.875
-234	3.250	3.000
-235	3.375	3.125
-236	3.500	3.250
-237	3.625	3.375
-238	3.750	3.500
-239	3.875	3.625
-240	4.000	3.750
-241	4.125	3.875
-242	4.250	4.000
-243	4.375	4.125
-244	4.500	4.250
-245	4.625	4.375
-246	4.750	4.500

G = .281/.291		
Dash Size	A Dia	B Dia
	+.002 -.002	+.000 -.002
-318	1.375	1.000
-319	1.437	1.062
-320	1.500	1.125
-321	1.562	1.187
-322	1.625	1.250
-323	1.687	1.312
-324	1.750	1.375
-325	1.875	1.500
-326	2.000	1.625
-327	2.125	1.750
-328	2.250	1.875
-329	2.375	2.000
-330	2.500	2.125
-331	2.625	2.250
-332	2.750	2.375
-333	2.875	2.500
-334	3.000	2.625
-335	3.125	2.750
-336	3.250	2.875
-337	3.375	3.000
-338	3.500	3.125
-339	3.625	3.250
-340	3.750	3.375
-341	3.875	3.500
-342	4.000	3.625
-343	4.125	3.750
-344	4.250	3.875
-345	4.375	4.000
-346	4.500	4.125
-347	4.625	4.250
-348	4.750	4.375
-349	4.875	4.500
-350	5.000	4.625
-351	5.125	4.750
-352	5.250	4.875
-353	5.375	5.000
-354	5.500	5.125
-355	5.625	5.250
-356	5.750	5.375
-357	5.875	5.500
-358	6.000	5.625
-359	6.125	5.750
-360	6.250	5.875
-361	6.375	6.000
-362	6.625	6.250

G = .375/.385		
Dash Size	A Dia	B Dia
	+.002 -.002	+.000 -.002
-405	2.500	2.000
-406	2.625	2.125
-407	2.750	2.250
-408	2.875	2.375
-409	3.000	2.500
-410	3.125	2.625
-411	3.250	2.750
-412	3.375	2.875
-413	3.500	3.000
-414	3.625	3.125
-415	3.750	3.250
-416	3.875	3.375
-417	4.000	3.500
-418	4.125	3.625
-419	4.250	3.750
-420	4.375	3.875
-421	4.500	4.000
-422	4.625	4.125
-423	4.750	4.250
-424	4.875	4.375
-425	5.000	4.500
-426	5.125	4.625
-427	5.250	4.750
-428	5.375	4.875
-429	5.500	5.000
-430	5.625	5.125
-431	5.750	5.250
-432	5.875	5.375
-433	6.000	5.500
-434	6.125	5.625
-435	6.250	5.750
-436	6.375	5.875
-437	6.500	6.000
-438	6.750	6.250
-439	7.000	6.500
-440	7.250	6.750
-441	7.500	7.000
-442	7.750	7.250
-443	8.000	7.500
-444	8.250	7.750
-445	8.500	8.000
-446	9.000	8.500
-447	9.500	9.000
-448	10.000	9.500
-449	10.500	10.000

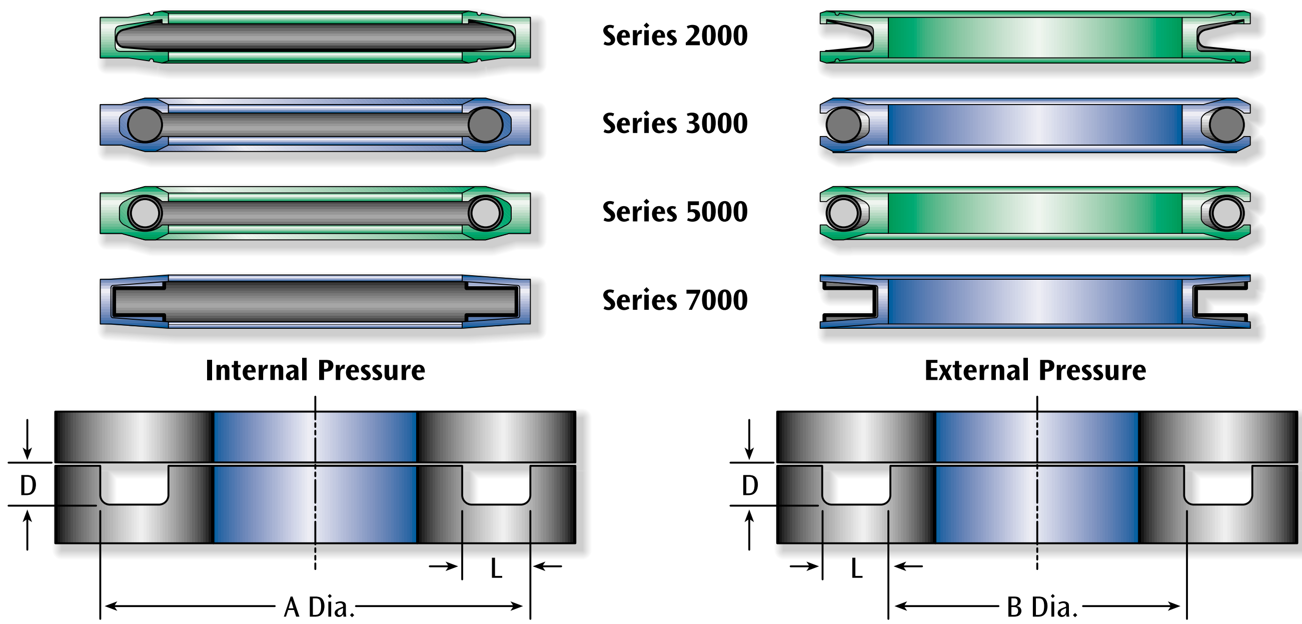


Figure 5-12

Table 5-13: Gland Depth and Length for MSE® Face Seals

Dash Size	Nominal X-Section	Gland Depth D	Gland Length L
-0XX	1/16″	0.061/0.063	0.094/0.104
-1XX	3/32″	0.093/0.095	0.141/0.151
-2XX	1/8″	0.124/0.126	0.188/0.198
-3XX	3/16″	0.186/0.188	0.281/0.291
-4XX	1/4″	0.249/0.251	0.375/0.385

Dimensions in inches.

Table 5-14: Gland Dimensions for Internal and External Pressure MSE® Face Seals

D = .062 +/- .001 L = .094/.104		
Dash Size	A Dia	B Dia
	+.010 -.000	+.000 -.010
-016	0.750	0.625
-017	0.812	0.687
-018	0.875	0.750
-019	0.937	0.812
-020	1.000	0.875
-021	1.062	0.937
-022	1.125	1.000
-023	1.187	1.062
-024	1.250	1.125
-025	1.312	1.187
-026	1.375	1.250
-027	1.437	1.312
-028	1.500	1.375
-029	1.625	1.500
-030	1.750	1.625
-031	1.875	1.750
-032	2.000	1.875
-033	2.125	2.000
-034	2.250	2.125
-035	2.375	2.250
-036	2.500	2.375
-037	2.625	2.500
-038	2.750	2.625
-039	2.875	2.750
-040	3.000	2.875
-041	3.250	3.125
-042	3.500	3.375
-043	3.625	3.500
-044	3.875	3.750
-045	4.125	4.000
-046	4.375	4.250
-047	4.625	4.500

Dimensions in inches.

D = .094 +/- .001 L = .141/.151		
Dash Size	A Dia	B Dia
	+.010 -.000	+.000 -.010
-120	1.187	1.000
-121	1.250	1.063
-122	1.312	1.125
-123	1.375	1.188
-124	1.437	1.250
-125	1.500	1.313
-126	1.562	1.375
-127	1.625	1.438
-128	1.687	1.500
-129	1.750	1.563
-130	1.812	1.625
-131	1.875	1.688
-132	1.937	1.750
-133	2.000	1.813
-134	2.062	1.875
-135	2.125	1.938
-136	2.187	2.000
-137	2.250	2.063
-138	2.312	2.125
-139	2.375	2.188
-140	2.437	2.250
-141	2.500	2.313
-142	2.562	2.375
-143	2.625	2.438
-144	2.687	2.500
-145	2.750	2.563
-146	2.812	2.625
-147	2.875	2.688
-148	2.937	2.750
-149	3.000	2.813
-150	3.062	2.875
-151	3.187	3.000
-152	3.437	3.250
-153	3.687	3.500
-154	3.937	3.750
-155	4.187	4.000
-156	4.437	4.250
-157	4.687	4.500
-158	4.937	4.750
-159	5.187	5.000
-160	5.437	5.250
-161	5.687	5.500

D = .125 +/- .001 L = .188/.198		
Dash Size	A Dia	B Dia
	+.010 -.000	+.000 -.010
-216	1.375	1.125
-217	1.437	1.187
-218	1.500	1.250
-219	1.562	1.312
-220	1.625	1.375
-221	1.687	1.437
-222	1.750	1.500
-223	1.875	1.625
-224	2.000	1.750
-225	2.125	1.875
-226	2.250	2.000
-227	2.375	2.125
-228	2.500	2.250
-229	2.625	2.375
-230	2.750	2.500
-231	2.875	2.625
-232	3.000	2.750
-233	3.125	2.875
-234	3.250	3.000
-235	3.375	3.125
-236	3.500	3.250
-237	3.625	3.375
-238	3.750	3.500
-239	3.875	3.625
-240	4.000	3.750
-241	4.125	3.875
-242	4.250	4.000
-243	4.375	4.125
-244	4.500	4.250
-245	4.625	4.375
-246	4.750	4.500
-247	4.875	4.625
-248	5.000	4.750
-249	5.125	4.875
-250	5.250	5.000
-251	5.375	5.125
-252	5.500	5.250
-253	5.625	5.375
-254	5.750	5.500
-255	5.875	5.625
-256	6.000	5.750
-257	6.125	5.875

D = .187 +/- .001 L = .281/.291		
Dash Size	A Dia	B Dia
	+.010 -.000	+.000 -.010
-329	2.375	2.000
-330	2.500	2.125
-331	2.625	2.250
-332	2.750	2.375
-333	2.875	2.500
-334	3.000	2.625
-335	3.125	2.750
-336	3.250	2.875
-337	3.375	3.000
-338	3.500	3.125
-339	3.625	3.250
-340	3.750	3.375
-341	3.875	3.500
-342	4.000	3.625
-343	4.125	3.750
-344	4.250	3.875
-345	4.375	4.000
-346	4.500	4.125
-347	4.625	4.250
-348	4.750	4.375
-349	4.875	4.500
-350	5.000	4.625
-351	5.125	4.750
-352	5.250	4.875
-353	5.375	5.000
-354	5.500	5.125
-355	5.625	5.250
-356	5.750	5.375
-357	5.875	5.500
-358	6.000	5.625
-359	6.125	5.750
-360	6.250	5.875
-361	6.375	6.000
-362	6.625	6.250
-363	6.875	6.500
-364	7.125	6.750
-365	7.375	7.000
-366	7.625	7.250
-367	7.875	7.500
-368	8.125	7.750
-369	8.375	8.000
-370	8.625	8.250

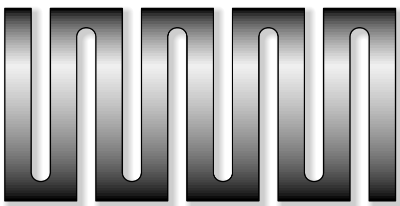
D = .250 +/- .001 L = .375/.385		
Dash Size	A Dia	B Dia
	+.010 -.000	+.000 -.010
-413	3.500	3.000
-414	3.625	3.125
-415	3.750	3.250
-416	3.875	3.375
-417	4.000	3.500
-418	4.125	3.625
-419	4.250	3.750
-420	4.375	3.875
-421	4.500	4.000
-422	4.625	4.125
-423	4.750	4.250
-424	4.875	4.375
-425	5.000	4.500
-426	5.125	4.625
-427	5.250	4.750
-428	5.375	4.875
-429	5.500	5.000
-430	5.625	5.125
-431	5.750	5.250
-432	5.875	5.375
-433	6.000	5.500
-434	6.125	5.625
-435	6.250	5.750
-436	6.375	5.875
-437	6.500	6.000
-438	6.750	6.250
-439	7.000	6.500
-440	7.250	6.750
-441	7.500	7.000
-442	7.750	7.250
-443	8.000	7.500
-444	8.250	7.750
-445	8.500	8.000
-446	9.000	8.500
-447	9.500	9.000
-448	10.000	9.500
-449	10.500	10.000
-450	11.000	10.500
-451	11.500	11.000
-452	12.000	11.500
-453	12.500	12.000
-454	13.000	12.500

Spring Materials

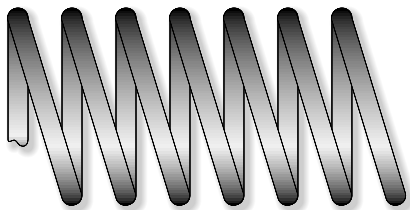
The MSE® seal is energized by a corrosion-resistant metal spring. The spring compresses to apply force for sealing and provides resiliency to compensate for wear and misalignment.

Finger Springs are made by punching the pattern on a metal ribbon and then forming it into a "V" shape by the use of a force slide or a punch press.

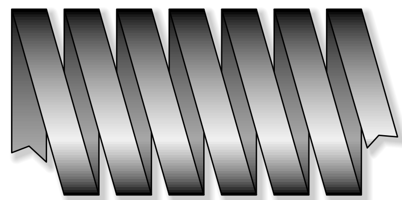
Coil Springs are made by slicing a metal ribbon to the desired width, and then coiling it to a specified diameter with a coiling machine.



Finger Spring



Canted Coil Spring



Flat Ribbon Coil Spring

Figure 5-15

Table 5-16: Composition

Element		**301 SS**	**17-7**	**Elgiloy†**
		%	**%**	**%**
Carbon	C	0.15 - 2.0	0.09 max	0.1
Silicone	Si	1.0 max	1.0	—
Phosphorus	P	0.045 max	0.04	—
Sulphur	S	0.03 max	0.03	—
Chromium	Cr	16 - 18	16 - 18	20.0
Nickel	Ni	6 - 8	6.50 - 7.75	15.0
Manganese	Mn	—	1.0	2.0
Molybdenum	Mo	—	—	7.0
Cobalt	Co	—	—	40.0
Berylium	Be	—	—	0.04
Aluminum	Al	—	1.125	—
Iron	Fe	Balance	Balance	Balance

† Registered trademark of the Elgiloy Company.

Table 5-17: Typical Physical Properties

Material		301 SS	17-7	Elgiloy
Material Code		S	P	E
Condition		FH	Condition C	45% CR
Tensile Strength	psi	185,000	220,000	220,000
Yield Strength	psi	140,000	190,000	185,000
Elongation	%	8	5	4
Hardness	Rc	41	43	45
Temperature Rating	°C	260	315	315
Corrosion Resistance		Good	Better	Best

Jacket Materials

MSE seals are available in a variety of seal jacket materials, all designed for virtually unlimited chemical compatibility, low friction and a wide range of temperatures and pressures.

Avalon 01 — High-quality virgin material with high tensile and elongation properties. Best chemical resistance.

Avalon 40 — Good chemical and electrical properties, better creep resistance than PTFE or PFA, low permeability and more resistant to swelling by solvents than other polymers. CTFE material is also excellent in cryogenic applications.

Avalon 48 — Mineral-filled PTFE. Good chemical and wear properties, nonabrasive in dynamic applications. Not recommended for aqueous applications, since the minerals tend to dissolve.

Avalon 50 — Polyester-filled PTFE. Good wear, chemical and temperature properties. Not compatible with halogens.

Avalon 56 — Modified PTFE. Excellent high temperature, creep and chemical resistance.

Avalon 57 — Polyimide-filled PTFE. Excellent chemical wear and creep resistance. Recommended for dynamic applications. Nonabrasive against soft metals.

Table 5-18: Typical MSE® Seal Materials Used for Semiconductor Applications

Material	Material Code	Description	Color	Tensile Strength	Elongation	Def. Under Load	Wear Factor
				psi	%	%	(K) x 10^{-10} in^3-min/lb-ft-hr
Avalon 01	301	Virgin PTFE	White	5,000	350	8	2,500
Avalon 40	081	CTFE	Transparent White	5,700	150	—	—
Avalon 48	348	Filled PTFE	White	3,000	275	5	1
Avalon 50	069	Filled PTFE	Tan	3,500	300	6	2
Avalon 56	356	Modified PTFE	White	4,600	500	3	2,500
Avalon 57	357	Filled PTFE	Light Brown	2,600	300	2	2

Hardware Surface Finish and Hardness Recommendations

Dynamic surface finish and hardness play a key role in hardware design. Good surface finish will reduce seal friction and increase seal life, while a high surface hardness will increase seal life as well as protect the hardware from being abraded by the seal material or by contaminants in the system.

Seal Installation and Installation Tools

The proper installation and the use of appropriate installation tools is imperative for the correct functioning of the seals. Most seal failures can be attributed to damaged seals resulting from improper installation.

Although MSE® seals can be slightly stretched or compressed (see Table 5-21), *it is strongly recommended that one-piece glands (non-split) are avoided*. If it is absolutely necessary to use one-piece glands, follow the suggestions on gland design and use proper installation tools. Avoid the use of screwdrivers and other metal tools, since the seals can be easily scratched and leakage will result.

Table 5-19: Hardware Surface Finish

Media	Dynamic Surface	Static Surface
Cryogenic Freon Helium Gas Hydrogen Gas	4 - 8 RMA	4 - 8 RMA
Air Argon	6 - 12 RMA	12 - 32 RMA
Water	8 - 16 RMA	16 - 32 RMA

Table 5-20: Hardware Surface Hardness

Service	Optimum Hardness Rockwell "C" Scale
Static	Any hardness
Reciprocating	Rc 45 minimum
Rotary	Rc 55 minimum

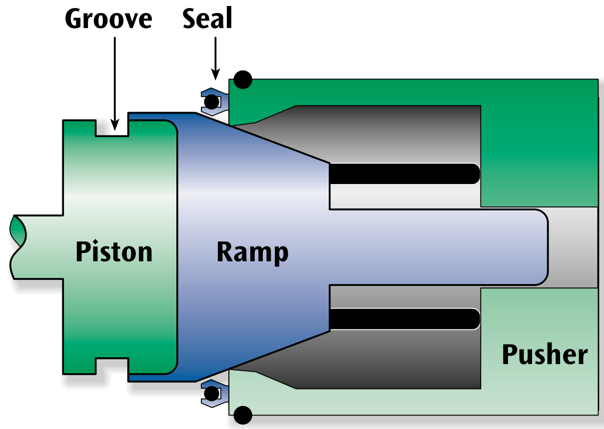
Table 5-21: Maximum % of Seal Stretch or Compression Recommended

Piston Seals (Stretch)			Rod Seals (Compress)		
Series 2000	Series 3000	Series 5000	Series 2000	Series 3000	Series 5000
8%	20%	15%	8%	15%	12%

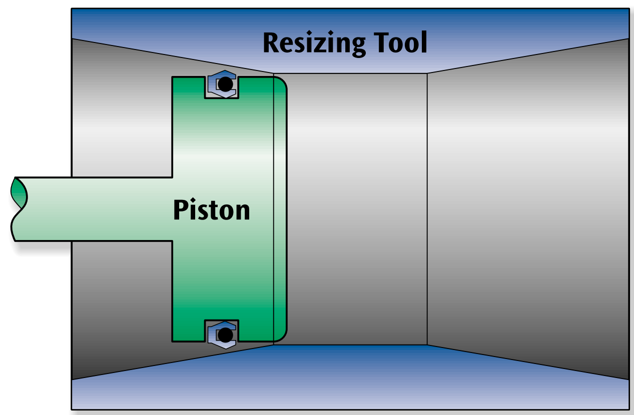
Installation of Piston Seals into Closed Glands

When installing MSE® seals into blind glands, it is important not to overstress the seal material or the spring at localized points. In order to stretch the seal evenly, the use of a ramp and pushing device are recommended. After stretching, the seal will partially return to its original size. To ensure total recovery, the seal needs to be resized with a tool, which has the same inside diameter as the bore of the hardware.

The installation tools can be made out of Delrin,‡ UHMW (Ultra High Molecular Weight Polyethylene), PFA or PTFE.

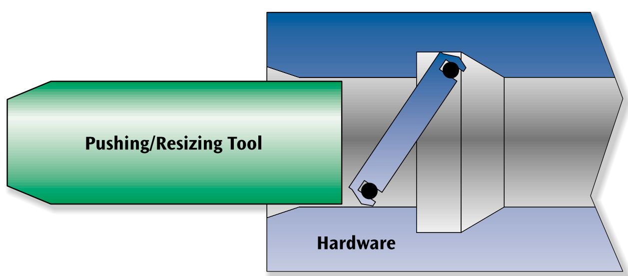


Step 1

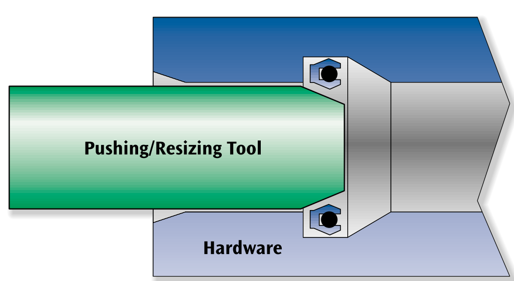


Step 2

Figure 5-22



Step 1



Step 2

Figure 5-23

Installation of Rod Seals into Closed Glands

To minimize the possibility of damage to the seal during installation, it is recommended to make the gland width at least 1.5 times the width of the seal plus a 45° angle at the front of the groove. The seal should be installed sideways until one side rests in the groove; then with the help of a pushing tool, work the rest of the seal into the groove. With the opposite end of the tool, resize the seal into the groove. The installation procedure can be eased by lubricants and by heating up the seal before installation.

‡ Delrin is a registered trademark of DuPont-Dow Elastomers.

SPECIALTY APPLICATIONS Bonded Gates, The Barrel Seal® & Custom Parts

Bonded Gates

The technological evolution of the semiconductor industry is incredibly dynamic. Unlike most other industries, which tend to approach change more conservatively, semiconductor manufacturers address problem areas aggressively, demonstrating a willingness to incorporate drastic changes. One example of this approach is the development of a "bonded gate" solution to one of the critical components of equipment processing – the slit valve.

The slit valve's potential for particle generation has been discussed at length in previous chapters of this handbook. The significant reductions in particle generation achieved through the use of bonded gates will likely result in their becoming greatly preferred over O-rings and Dovetail® Seals for standard slit valve mechanisms.

The bonded gate's sealing configuration alleviates the flattening, twisting and abrading problems associated with the use of O-rings in these applications, as well as other issues which can lead to particle generation. The types of sealing surfaces developed on these gates also promote better sealing footprints which maintain sealability and increase leak integrity.

Standard slit valves require routine preventive maintenance cycles which include O-ring replacement. Bonded gates can be left in place, and will remain functional for longer periods of time. The time saved in replacement costs and reliability factors make the bonded gate a better return on investment than traditional seals.

While most seal materials can readily be bonded to various metallic substrates, *some* perfluoroelastomer compounds do not form durable and lasting rubber-to-metal bonds because of their inert nature. Obviously, only perfluoroelastomer compounds with good bonding properties should be used for these applications.

In the case of Greene, Tweed's bonded products, the elastomeric sealing elements are not molded/vulcanized, then attached to the substrate with adhesives. Instead, the bonding of the sealing material to the substrate takes place as an integral part of the vulcanization process, utilizing primers which promote adhesion.

Improved designs, plus the development of new perfluoroelastomer compounds to address diverse process considerations, are contributing to the greater utilization of bonded gates throughout the semiconductor processing industry.

Greene, Tweed designs and produces bonded gate designs in a number of Chemraz® and Viton* compounds.

The Barrel Seal

The Barrel Seal is designed to solve some of the problems that can occur with O-rings. Twisting of an O-ring seal during installation – a common problem with conventional O-rings – can expose the seal's vulnerable parting line to attack by aggressive processing media. The twisting can also position the parting line as a sealing surface, compromising seal integrity. The unique shape of The Barrel Seal prevents this twisting and the associated problems.

The Barrel Seal is also designed with a larger sealing footprint than a standard O-ring. This larger footprint provides greater coverage and affords the surface more complete protection from chemical attack. An example: applications where anodized and non-anodized aluminum surfaces abut. The larger footprint also improves the sealing efficiency.

The Barrel Seal is available from Greene, Tweed in many elastomeric compounds suitable for the semiconductor industry, including Chemraz® perfluoroelastomer.

* Viton is a registered trademark of DuPont-Dow Elastomers.

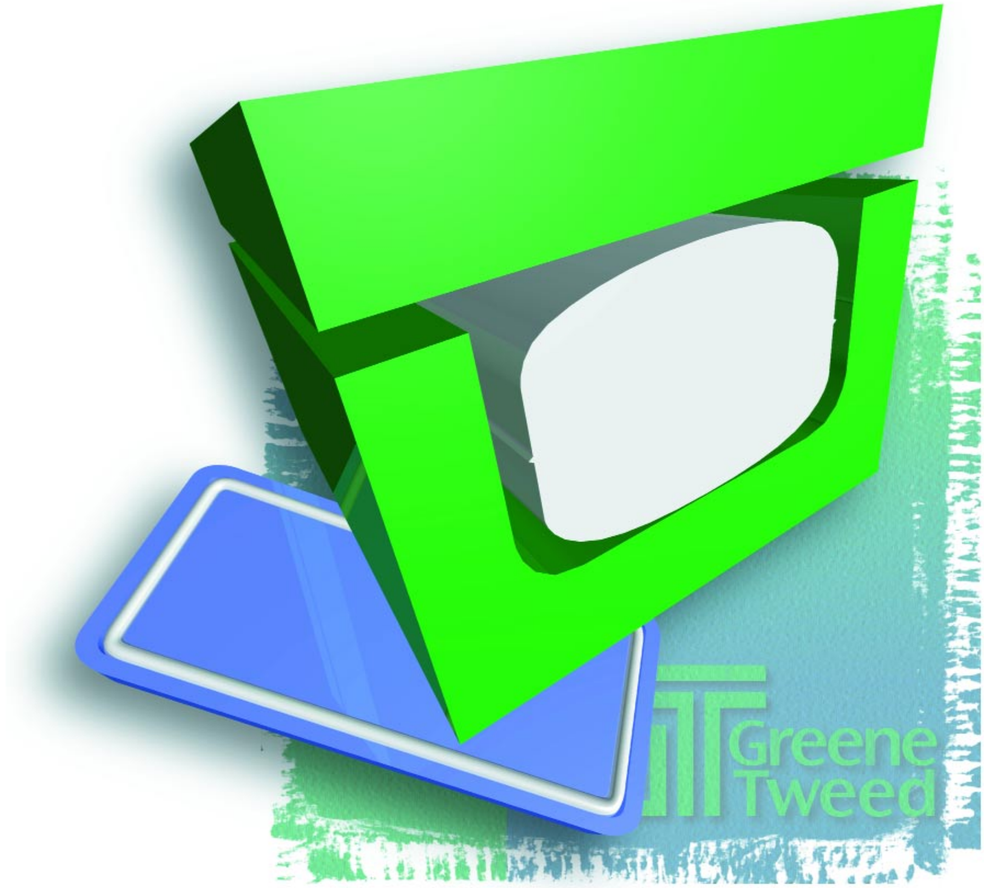


Figure 6-1 *Barrel Seal Cross-Section*

Custom Parts

Greene, Tweed's core business is the design and production of innovative, high-performance seals for demanding applications. We are differentiated from other seal manufacturers by our ability to understand the unique design parameters of each application, whether mechanical or process. We design sealing solutions by combining the assets of critical geometries with proprietary materials, taking full advantage of strengths while minimizing trade-offs.

Greene, Tweed produces a wider range of sealing materials than any other seal manufacturer in the world. If an application or special component requires an elastomer or a plastic, or a combination of both, our company is uniquely qualified to design and manufacture it.

Custom parts produced by Greene, Tweed include:

- Quartz heater window seals
- Formed-to-shape designs
- Specialized chamber seals
- Throttle valve seals
- UPDI gaskets
- Megasonic seals
- Drive belts

As the semiconductor industry continues to push the envelope of technology, fabricators and original equipment manufacturers will see an increased need for custom sealing solutions that will enable them to meet the demands of semiconductor fabrication.

SEAL GLAND DESIGN

The proper design of an O-ring gland is a critical step in attaining optimum seal performance.

This chapter provides the information necessary to select the recommended O-ring gland dimensions for a specific type of application, and to select the corresponding standard O-ring or Dovetail® Seal, along with its AS 568A dash number. The dash numbers are identical for O-rings and Dovetail Seals. (See Chapter 3 for information on creating part numbers for O-rings, and Chapter 4 for information on creating part numbers for Dovetail Seals.)

The gland dimension recommendations presented in the tables of this chapter represent a significant amount of work done by SAE. These dimensions, when used in conjunction with standard AS 568A dash number O-rings, virtually assure satisfactory sealing functionality. A seal extraction groove is recommended whenever possible. This reduces the chance of damage to the gland when removing and replacing the seal.

To determine recommended gland dimensions, standard O-ring sizes and AS 568A dash numbers, the designer should first select the intended sealing application from the following list and refer to the indicated page and tables.

1. Static Face Seal, Rectangular Gland — Internal vacuum/external pressure, page 45.
2. Static Face Seal, Rectangular Gland — Internal pressure/external vacuum, page 47.
3. Static Face Seal, Dovetail Gland — Any pressure combination, page 48.
4. Static I.D./O.D. Seal, Rectangular Gland — Any pressure combination, page 59.
5. Dynamic I.D./O.D. Seal, Rectangular Gland — Any pressure combination, page 69.

Static Face Seal, Rectangular Gland Internal Vacuum/External Pressure

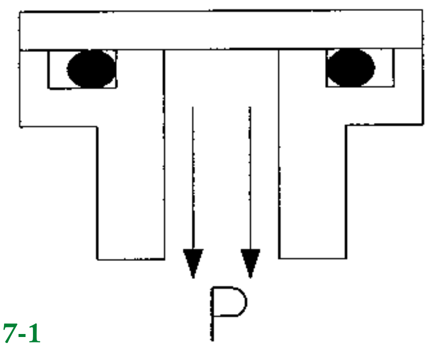


Figure 7-1

If the O-Ring Dash Size Is Known

Step 1. Locate the dash number in Table 7-10, beginning on page 50, to determine the O-ring's dimensions from columns "B" and "C."

Step 2. Select the corresponding gland I.D. from column "D."

Step 3. Determine the appropriate gland cross-section dimensions, see Table 7-3, page 46.

Step 4. To calculate the gland O.D., add 2X the gland width to the gland I.D.

Selecting the O-Ring Dash Size

If the O-ring dash size is not known and all gland dimensions are known:

Step 1. Locate the dimensions of the gland's cross-section in Table 7-3, page 46.

Step 2. Select the corresponding O-ring dash size series that matches the gland's cross-section dimensions.

Step 3. Locate the gland diameter within the O-ring number series in Table 7-10, page 50, to determine the O-ring's dash size.

If the exact gland dimensions cannot be located in these tables, a nonstandard O-ring may be required. Contact Greene, Tweed Engineering.

To choose both the appropriate gland dimensions and the corresponding O-ring dash number:

Step 1. From Table 7-3, page 46, select the desired O-ring cross-section and its corresponding AS 568A O-ring series. The cross-section selection should be based on the desired sealing footprint and allowable clearances within the hardware. A larger cross-section will result in a wider sealing footprint for a given cross-section squeeze percentage and should be generally preferred. However, larger cross-section seals will require a greater compressive load (see Semiconductor Seal Compound Selection Guide, pages 21–26).

Step 2. From Table 7-10, page 50, based on hardware requirements, select the closest standard gland I.D. within the O-ring dash size series. Record the dash number. Note: Not all standard O-ring cross-sections are available for all diameters. If the desired gland I.D. cannot be found within the dash size series that has been selected, a different cross-section must be selected.

Table 7-3: Standard Rectangular Face Sealing Gland Cross-Sectional Dimensions

AS 568A Series	O-Ring Cross-Section		Gland Width (W)		Gland Depth (D)		Gland Corner Radii	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	(R1)	(R2)
-000	**0.070**	0.003	**0.084**	0.002	**0.052**	0.002	**0.010**	**0.005**
-100	**0.103**	0.003	**0.121**	0.003	**0.078**	0.003	**0.010**	**0.005**
-200	**0.139**	0.004	**0.160**	0.003	**0.106**	0.003	**0.018**	**0.005**
-300	**0.210**	0.005	**0.240**	0.003	**0.164**	0.004	**0.028**	**0.005**
-400	**0.275**	0.006	**0.310**	0.003	**0.215**	0.004	**0.028**	**0.005**

Dimensions in inches.

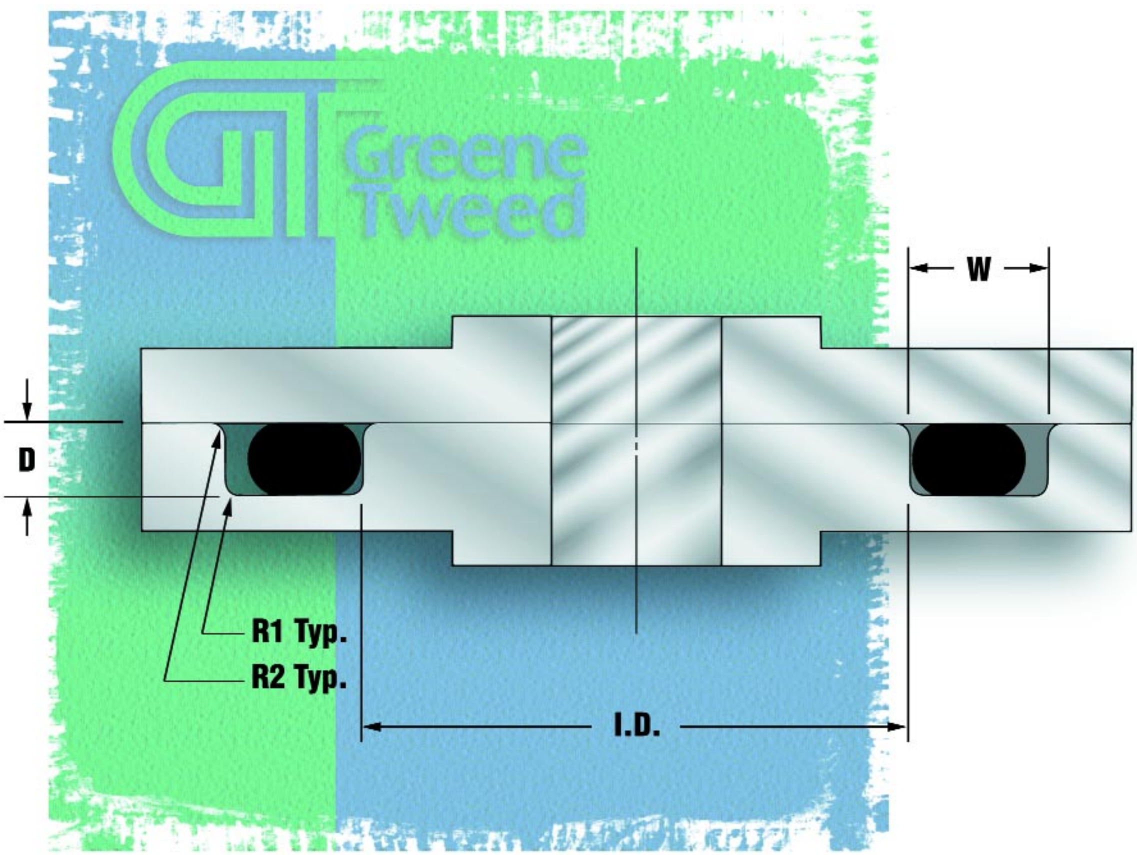


Figure 7-2 *Select Gland I.D. from Table 7-10, Column "D"*

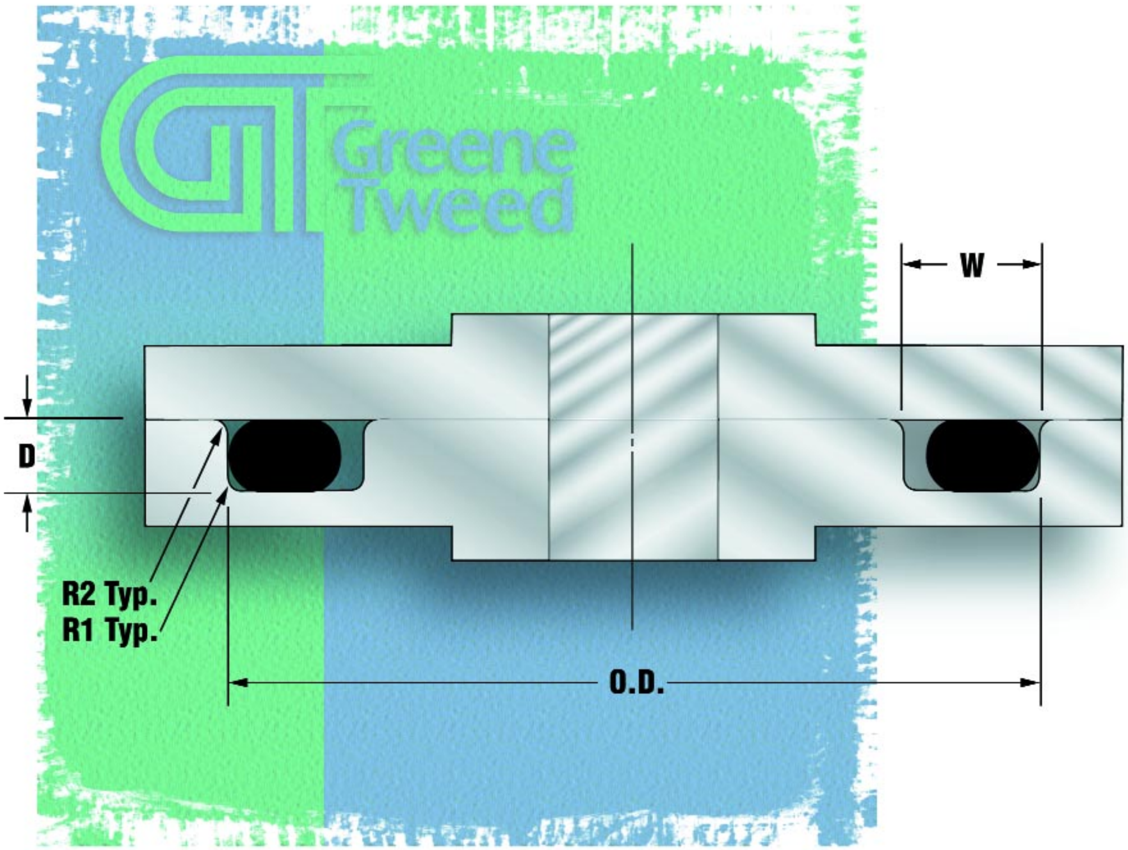


Figure 7-5 *Select Gland O.D. from Table 7-10, Column "E"*

Step 3. From Table 7-3, page 46, select the appropriate gland cross-section dimensions. To calculate the gland O.D., add 2X the gland width to the gland I.D. determined in step 2.

Static Face Seal, Rectangular Gland Internal Pressure/External Vacuum

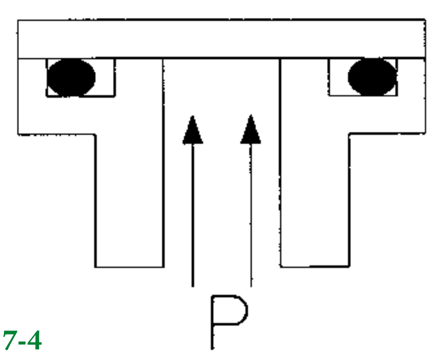


Figure 7-4

If the O-Ring Dash Size Is Known

Step 1. Locate the dash number in Table 7-10, page 50, to determine the O-ring's dimensions from columns "B" and "C."

Step 2. Select the corresponding gland O.D. from column "E."

Step 3. Determine the appropriate gland cross-section dimensions, see Table 7-6, page 48.

Step 4. To calculate the gland I.D., subtract 2X the gland width from the gland O.D.

Selecting the O-Ring Dash Size

If the O-ring dash size is not known and all gland dimensions are known:

Step 1. Locate the dimensions of the gland's cross-section in Table 7-6, page 48.

Step 2. Select the corresponding O-ring dash size series that matches the gland's cross-section dimensions.

Step 3. Locate the gland diameter within the O-ring number series in Table 7-10, page 50, to determine the O-ring's dash size.

If the exact gland dimensions cannot be located in these tables, a nonstandard O-ring may be required. Contact Greene, Tweed Engineering.

Table 7-6: Standard Rectangular Face Sealing Gland Cross-Sectional Dimensions

AS 568A Series	O-Ring Cross-Section		Gland Width (W)		Gland Depth (D)		Gland Corner Radii	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	(R1)	(R2)
-000	**0.070**	0.003	**0.084**	0.002	**0.052**	0.002	**0.010**	**0.005**
-100	**0.103**	0.003	**0.121**	0.003	**0.078**	0.003	**0.010**	**0.005**
-200	**0.139**	0.004	**0.160**	0.003	**0.106**	0.003	**0.018**	**0.005**
-300	**0.210**	0.005	**0.240**	0.003	**0.164**	0.004	**0.028**	**0.005**
-400	**0.275**	0.006	**0.310**	0.003	**0.215**	0.004	**0.028**	**0.005**

Dimensions in inches.

To choose both the appropriate gland dimensions and the corresponding O-ring dash number:

Step 1. From Table 7-6, page 48, select the desired O-ring cross-section and its corresponding AS 568A O-ring series. The cross-section selection should be based on the desired sealing footprint and allowable clearances within the hardware. A larger cross-section will result in a wider sealing footprint for a given cross-section squeeze percentage and should be generally preferred. However, larger cross-section seals will require a greater compressive load (see Semiconductor Seal Compound Selection Guide, pages 21–26).

Step 2. From Table 7-10, page 50, based on hardware requirements, select the closest standard gland O.D. within the O-ring dash size series. Record the dash number. Note: Not all standard O-ring cross-sections are available for all diameters. If the desired gland O.D. cannot be found within the dash size series that has been selected, a different cross-section must be selected.

Step 3. From Table 7-6, page 48, select the appropriate gland cross-section dimensions. To calculate the gland I.D., subtract 2X the gland width from the gland O.D. determined in step 2.

Static Face Seal, Dovetail Gland Any Pressure Combination

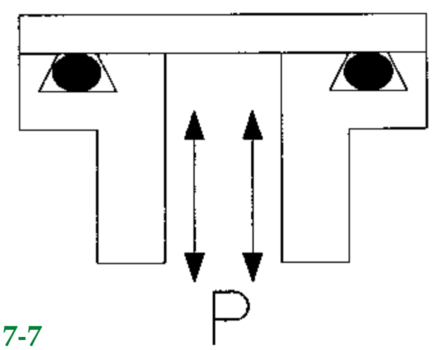


Figure 7-7

Note: The O-ring dash size is the same, whether you are specifying an O-ring or a Dovetail® Seal.

If the O-Ring Dash Size Is Known

Step 1. Locate the dash number in Table 7-10, page 50, to determine the O-ring's dimensions from columns "B" and "C."

Step 2. Select the corresponding gland centerline diameter from column "F."

Step 3. Determine the appropriate gland cross-section dimensions, see Table 7-9, page 49.

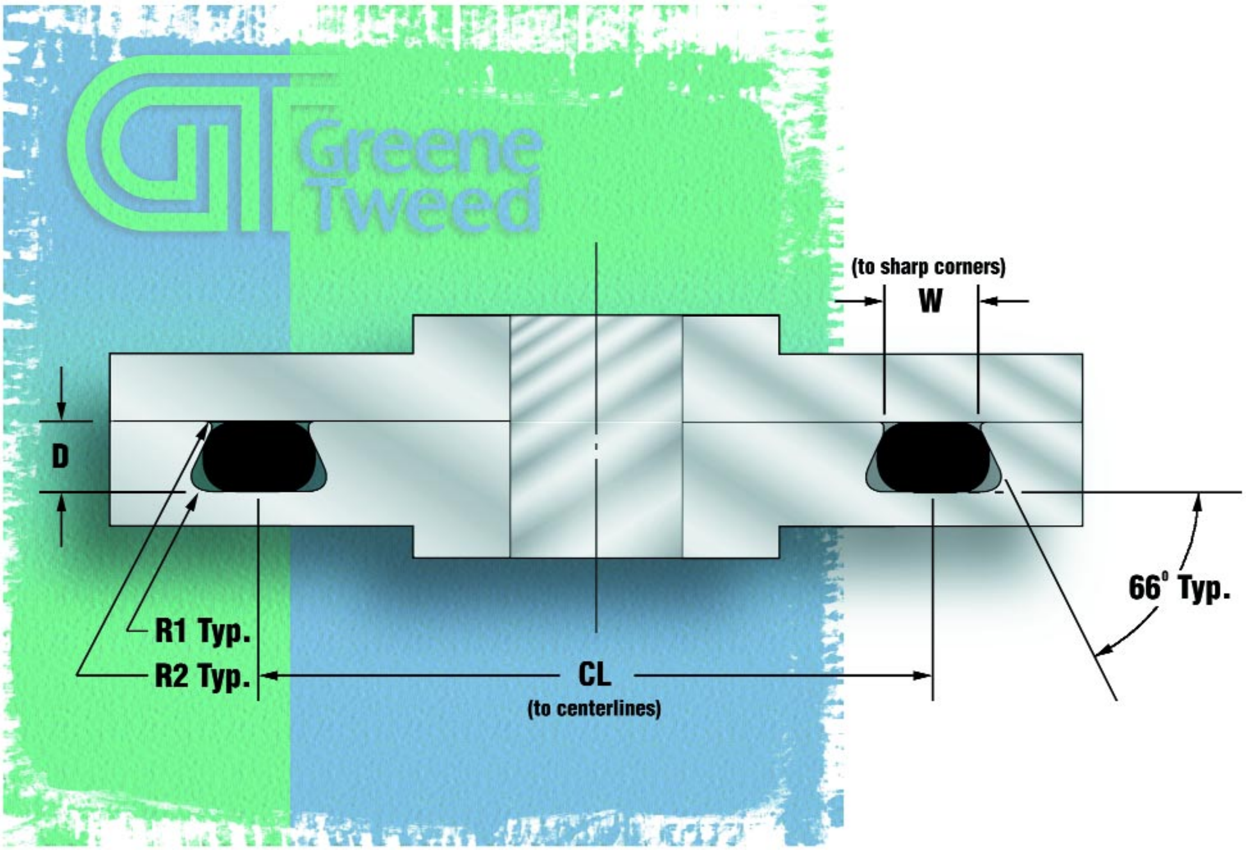


Figure 7-8 *Select Gland Centerline Diameter from Table 7-10, Column "F" for All Dovetail Glands*

Selecting the O-Ring Dash Size

If the O-ring dash size is not known and all gland dimensions are known:

Step 1. Locate the dimensions of the gland's cross-section in Table 7-9, page 49.

Step 2. Select the corresponding O-ring dash size series that matches the gland's cross-section dimensions.

Step 3. Locate the gland's centerline diameter within the O-ring number series in Table 7-10, page 50, to determine the O-ring's dash size.

If the exact gland dimensions cannot be located in these tables, a nonstandard O-ring may be required. Contact Greene, Tweed Engineering.

Table 7-9: Standard Dovetail Face Sealing Gland Cross-Sectional Dimensions

AS 568A Series	O-Ring Cross-Section		Gland Width (W)		Gland Depth (D)		Gland Corner Radii	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	(R1)	(R2)
-000	**0.070**	0.003	**0.064**	0.002	**0.052**	0.002	**0.015**	**0.005**
-100	**0.103**	0.003	**0.088**	0.003	**0.078**	0.003	**0.015**	**0.010**
-200	**0.139**	0.004	**0.120**	0.003	**0.106**	0.003	**0.031**	**0.010**
-300	**0.210**	0.005	**0.176**	0.003	**0.164**	0.004	**0.031**	**0.015**
-400	**0.275**	0.006	**0.235**	0.003	**0.215**	0.004	**0.063**	**0.015**

Dimensions in inches.

To choose both the appropriate gland dimensions and the corresponding O-ring dash number:

Step 1. From Table 7-9, page 49, select the desired O-ring cross-section and its corresponding AS 568A O-ring series. The cross-section selection should be based on the desired sealing footprint and allowable clearances within the hardware. A larger cross-section will result in a wider sealing footprint for a given cross-section squeeze percentage and should be generally preferred. However, larger cross-section seals will require a greater compressive load (see Semiconductor Seal Compound Selection Guide, pages 21–26).

Step 2. From Table 7-10, page 50, based on hardware requirements, select the closest centerline diameter within the O-ring dash size series from column "F." Record the dash number. Note: Not all standard O-ring cross-sections are available for all diameters. If the desired centerline diameter cannot be found within the dash size series that has been selected, a different cross-section must be selected.

Step 3. From Table 7-9, page 49, select the appropriate gland cross-section dimensions.

Table 7-10: Standard Face Sealing Diametrical Dimensions

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-
-005	**0.070**	0.003	**0.101**	0.005	**0.106**	0.002	**0.241**	0.002	**0.178**	0.002
-006	**0.070**	0.003	**0.114**	0.005	**0.119**	0.002	**0.254**	0.002	**0.191**	0.002
-007	**0.070**	0.003	**0.145**	0.005	**0.150**	0.002	**0.285**	0.002	**0.222**	0.002
-008	**0.070**	0.003	**0.176**	0.005	**0.181**	0.002	**0.316**	0.002	**0.253**	0.002
-009	**0.070**	0.003	**0.208**	0.005	**0.213**	0.002	**0.348**	0.002	**0.285**	0.002
-010	**0.070**	0.003	**0.239**	0.005	**0.244**	0.002	**0.379**	0.002	**0.316**	0.002
-011	**0.070**	0.003	**0.301**	0.005	**0.306**	0.002	**0.441**	0.002	**0.378**	0.002
-012	**0.070**	0.003	**0.364**	0.005	**0.369**	0.002	**0.504**	0.002	**0.441**	0.002
-013	**0.070**	0.003	**0.426**	0.005	**0.431**	0.002	**0.566**	0.002	**0.503**	0.002
-014	**0.070**	0.003	**0.489**	0.005	**0.494**	0.002	**0.629**	0.002	**0.568**	0.002
-015	**0.070**	0.003	**0.551**	0.007	**0.558**	0.002	**0.691**	0.002	**0.630**	0.002
-016	**0.070**	0.003	**0.614**	0.009	**0.623**	0.002	**0.754**	0.002	**0.695**	0.002
-017	**0.070**	0.003	**0.676**	0.009	**0.685**	0.002	**0.816**	0.002	**0.757**	0.002
-018	**0.070**	0.003	**0.739**	0.009	**0.750**	0.002	**0.879**	0.002	**0.822**	0.002
-019	**0.070**	0.003	**0.801**	0.009	**0.813**	0.002	**0.941**	0.002	**0.886**	0.002
-020	**0.070**	0.003	**0.864**	0.009	**0.877**	0.002	**1.004**	0.002	**0.950**	0.002
-021	**0.070**	0.003	**0.926**	0.009	**0.940**	0.002	**1.066**	0.002	**1.012**	0.002
-022	**0.070**	0.003	**0.989**	0.010	**1.004**	0.002	**1.129**	0.002	**1.076**	0.002
-023	**0.070**	0.003	**1.051**	0.010	**1.067**	0.002	**1.191**	0.002	**1.139**	0.002
-024	**0.070**	0.003	**1.114**	0.010	**1.131**	0.002	**1.254**	0.002	**1.202**	0.002
-025	**0.070**	0.003	**1.176**	0.011	**1.194**	0.002	**1.316**	0.002	**1.265**	0.002

Dimensions in inches.

Table 7-10: Standard Face Sealing Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-
-026	0.070	0.003	1.239	0.011	1.258	0.002	1.379	0.002	1.328	0.002
-027	0.070	0.003	1.301	0.011	1.321	0.002	1.441	0.002	1.391	0.002
-028	0.070	0.003	1.364	0.013	1.384	0.002	1.504	0.002	1.456	0.002
-029	0.070	0.003	1.489	0.013	1.511	0.002	1.629	0.002	1.582	0.002
-030	0.070	0.003	1.614	0.013	1.638	0.002	1.754	0.002	1.708	0.002
-031	0.070	0.003	1.739	0.015	1.765	0.002	1.879	0.002	1.835	0.002
-032	0.070	0.003	1.864	0.015	1.892	0.002	2.004	0.002	1.961	0.002
-033	0.070	0.003	1.989	0.018	2.019	0.002	2.129	0.002	2.089	0.002
-034	0.070	0.003	2.114	0.018	2.146	0.002	2.254	0.002	2.216	0.002
-035	0.070	0.003	2.239	0.018	2.273	0.002	2.379	0.002	2.341	0.002
-036	0.070	0.003	2.364	0.018	2.399	0.002	2.504	0.002	2.467	0.002
-037	0.070	0.003	2.489	0.018	2.526	0.002	2.629	0.002	2.593	0.002
-038	0.070	0.003	2.614	0.020	2.653	0.002	2.754	0.002	2.720	0.002
-039	0.070	0.003	2.739	0.020	2.780	0.002	2.879	0.002	2.846	0.002
-040	0.070	0.003	2.864	0.020	2.907	0.002	3.004	0.002	2.973	0.002
-041	0.070	0.003	2.989	0.024	3.034	0.002	3.129	0.002	3.100	0.002
-042	0.070	0.003	3.239	0.024	3.288	0.002	3.379	0.002	3.352	0.002
-043	0.070	0.003	3.489	0.024	3.541	0.002	3.629	0.002	3.604	0.002
-044	0.070	0.003	3.739	0.027	3.795	0.002	3.879	0.002	3.859	0.002
-045	0.070	0.003	3.989	0.027	4.049	0.002	4.129	0.002	4.112	0.002
-046	0.070	0.003	4.239	0.030	4.303	0.002	4.379	0.002	4.364	0.002
-047	0.070	0.003	4.489	0.030	4.556	0.002	4.629	0.002	4.618	0.002
-048	0.070	0.003	4.739	0.030	4.810	0.002	4.879	0.002	4.873	0.002
-049	0.070	0.003	4.989	0.037	5.064	0.002	5.129	0.002	5.125	0.002
-050	0.070	0.003	5.239	0.037	5.318	0.002	5.379	0.002	5.379	0.002

Dimensions in inches.

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-
-102	0.103	0.003	0.049	0.004	0.050	0.002	0.255	0.002	0.158	0.002
-103	0.103	0.003	0.081	0.005	0.082	0.002	0.287	0.002	0.191	0.002
-104	0.103	0.003	0.112	0.005	0.114	0.002	0.318	0.002	0.222	0.002
-105	0.103	0.003	0.143	0.005	0.145	0.002	0.349	0.002	0.253	0.002
-106	0.103	0.003	0.174	0.005	0.177	0.002	0.380	0.002	0.284	0.002
-107	0.103	0.003	0.206	0.005	0.209	0.002	0.412	0.002	0.316	0.002
-108	0.103	0.003	0.237	0.005	0.241	0.002	0.443	0.002	0.347	0.002
-109	0.103	0.003	0.299	0.005	0.303	0.002	0.505	0.002	0.409	0.002
-110	0.103	0.003	0.362	0.005	0.367	0.002	0.568	0.002	0.472	0.002
-111	0.103	0.003	0.424	0.005	0.430	0.002	0.630	0.002	0.535	0.002
-112	0.103	0.003	0.487	0.005	0.494	0.002	0.693	0.002	0.600	0.002
-113	0.103	0.003	0.549	0.007	0.557	0.002	0.755	0.002	0.662	0.002
-114	0.103	0.003	0.612	0.009	0.621	0.002	0.818	0.002	0.726	0.002
-115	0.103	0.003	0.674	0.009	0.684	0.002	0.880	0.002	0.789	0.002

Dimensions in inches.

Table 7-10: Standard Face Sealing Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-
-116	0.103	0.003	0.737	0.009	0.748	0.002	0.943	0.002	0.854	0.002
-117	0.103	0.003	0.799	0.010	0.811	0.002	1.005	0.002	0.917	0.002
-118	0.103	0.003	0.862	0.010	0.875	0.002	1.068	0.002	0.982	0.002
-119	0.103	0.003	0.924	0.010	0.938	0.002	1.130	0.002	1.044	0.002
-120	0.103	0.003	0.987	0.010	1.002	0.002	1.193	0.002	1.108	0.002
-121	0.103	0.003	1.049	0.010	1.065	0.002	1.255	0.002	1.170	0.002
-122	0.103	0.003	1.112	0.010	1.129	0.002	1.318	0.002	1.233	0.002
-123	0.103	0.003	1.174	0.012	1.192	0.002	1.380	0.002	1.297	0.002
-124	0.103	0.003	1.237	0.012	1.256	0.002	1.443	0.002	1.361	0.002
-125	0.103	0.003	1.299	0.012	1.318	0.002	1.505	0.002	1.423	0.002
-126	0.103	0.003	1.362	0.012	1.382	0.002	1.568	0.002	1.487	0.002
-127	0.103	0.003	1.424	0.012	1.445	0.002	1.630	0.002	1.548	0.002
-128	0.103	0.003	1.487	0.012	1.509	0.002	1.693	0.002	1.612	0.002
-129	0.103	0.003	1.549	0.015	1.572	0.002	1.755	0.002	1.677	0.002
-130	0.103	0.003	1.612	0.015	1.636	0.002	1.818	0.002	1.741	0.002
-131	0.103	0.003	1.674	0.015	1.699	0.002	1.880	0.002	1.803	0.002
-132	0.103	0.003	1.737	0.015	1.763	0.002	1.943	0.002	1.866	0.002
-133	0.103	0.003	1.799	0.015	1.826	0.002	2.005	0.002	1.929	0.002
-134	0.103	0.003	1.862	0.015	1.890	0.002	2.068	0.002	1.991	0.002
-135	0.103	0.003	1.925	0.017	1.954	0.002	2.131	0.002	2.057	0.002
-136	0.103	0.003	1.987	0.017	2.017	0.002	2.193	0.002	2.120	0.002
-137	0.103	0.003	2.050	0.017	2.081	0.002	2.256	0.002	2.184	0.002
-138	0.103	0.003	2.112	0.017	2.144	0.002	2.318	0.002	2.246	0.002
-139	0.103	0.003	2.175	0.017	2.208	0.002	2.381	0.002	2.309	0.002
-140	0.103	0.003	2.237	0.017	2.271	0.002	2.443	0.002	2.372	0.002
-141	0.103	0.003	2.300	0.020	2.335	0.002	2.506	0.002	2.435	0.002
-142	0.103	0.003	2.362	0.020	2.397	0.002	2.568	0.002	2.500	0.002
-143	0.103	0.003	2.425	0.020	2.461	0.002	2.631	0.002	2.564	0.002
-144	0.103	0.003	2.487	0.020	2.524	0.002	2.693	0.002	2.626	0.002
-145	0.103	0.003	2.550	0.020	2.588	0.002	2.756	0.002	2.688	0.002
-146	0.103	0.003	2.612	0.020	2.651	0.002	2.818	0.002	2.752	0.002
-147	0.103	0.003	2.675	0.022	2.715	0.002	2.881	0.002	2.816	0.002
-148	0.103	0.003	2.737	0.022	2.778	0.002	2.943	0.002	2.878	0.002
-149	0.103	0.003	2.800	0.022	2.842	0.002	3.006	0.002	2.942	0.002
-150	0.103	0.003	2.862	0.022	2.905	0.002	3.068	0.002	3.004	0.002
-151	0.103	0.003	2.987	0.024	3.032	0.002	3.193	0.002	3.133	0.002
-152	0.103	0.003	3.237	0.024	3.286	0.002	3.443	0.002	3.384	0.002
-153	0.103	0.003	3.487	0.024	3.539	0.002	3.693	0.002	3.638	0.002
-154	0.103	0.003	3.737	0.028	3.793	0.002	3.943	0.002	3.891	0.002
-155	0.103	0.003	3.987	0.028	4.047	0.002	4.193	0.002	4.147	0.002
-156	0.103	0.003	4.237	0.030	4.301	0.002	4.443	0.002	4.400	0.002
-157	0.103	0.003	4.487	0.030	4.554	0.002	4.693	0.002	4.657	0.002
-158	0.103	0.003	4.737	0.030	4.808	0.002	4.943	0.002	4.911	0.002
-159	0.103	0.003	4.987	0.035	5.062	0.002	5.193	0.002	5.165	0.002
-160	0.103	0.003	5.237	0.035	5.316	0.002	5.443	0.002	5.419	0.002

Dimensions in inches.

Table 7-10: Standard Face Sealing Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-
-161	**0.103**	0.003	**5.487**	0.035	**5.569**	0.002	**5.693**	0.002	**5.672**	0.002
-162	**0.103**	0.003	**5.737**	0.035	**5.823**	0.002	**5.943**	0.002	**5.926**	0.002
-163	**0.103**	0.003	**5.987**	0.035	**6.077**	0.002	**6.193**	0.002	**6.180**	0.002
-164	**0.103**	0.003	**6.237**	0.040	**6.331**	0.002	**6.443**	0.002	**6.434**	0.002
-165	**0.103**	0.003	**6.487**	0.040	**6.584**	0.002	**6.693**	0.002	**6.687**	0.002
-166	**0.103**	0.003	**6.737**	0.040	**6.838**	0.002	**6.943**	0.002	**6.941**	0.002
-167	**0.103**	0.003	**6.987**	0.040	**7.092**	0.002	**7.193**	0.002	**7.195**	0.002
-168	**0.103**	0.003	**7.237**	0.045	**7.346**	0.002	**7.443**	0.002	**7.449**	0.002
-169	**0.103**	0.003	**7.487**	0.045	**7.599**	0.002	**7.693**	0.002	**7.702**	0.002
-170	**0.103**	0.003	**7.737**	0.045	**7.853**	0.002	**7.943**	0.002	**7.956**	0.002
-171	**0.103**	0.003	**7.987**	0.045	**8.107**	0.002	**8.193**	0.002	**8.210**	0.002
-172	**0.103**	0.003	**8.237**	0.050	**8.361**	0.002	**8.443**	0.002	**8.464**	0.002
-173	**0.103**	0.003	**8.487**	0.050	**8.614**	0.002	**8.693**	0.002	**8.717**	0.002
-174	**0.103**	0.003	**8.737**	0.050	**8.868**	0.002	**8.943**	0.002	**8.971**	0.002
-175	**0.103**	0.003	**8.987**	0.050	**9.122**	0.002	**9.193**	0.002	**9.225**	0.002
-176	**0.103**	0.003	**9.237**	0.055	**9.376**	0.002	**9.443**	0.002	**9.479**	0.002
-177	**0.103**	0.003	**9.487**	0.055	**9.629**	0.002	**9.693**	0.002	**9.732**	0.002
-178	**0.103**	0.003	**9.737**	0.055	**9.883**	0.002	**9.943**	0.002	**9.986**	0.002

Dimensions in inches.

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-
-201	**0.139**	0.004	**0.171**	0.005	**0.174**	0.002	**0.449**	0.002	**0.317**	0.002
-202	**0.139**	0.004	**0.234**	0.005	**0.238**	0.002	**0.512**	0.002	**0.380**	0.002
-203	**0.139**	0.004	**0.296**	0.005	**0.300**	0.002	**0.574**	0.002	**0.442**	0.002
-204	**0.139**	0.004	**0.359**	0.005	**0.364**	0.002	**0.637**	0.002	**0.506**	0.002
-205	**0.139**	0.004	**0.421**	0.005	**0.427**	0.002	**0.699**	0.002	**0.569**	0.002
-206	**0.139**	0.004	**0.484**	0.005	**0.491**	0.002	**0.762**	0.002	**0.633**	0.002
-207	**0.139**	0.004	**0.546**	0.007	**0.554**	0.002	**0.824**	0.002	**0.696**	0.002
-208	**0.139**	0.004	**0.609**	0.009	**0.618**	0.002	**0.887**	0.002	**0.759**	0.002
-209	**0.139**	0.004	**0.671**	0.009	**0.681**	0.002	**0.949**	0.002	**0.823**	0.002
-210	**0.139**	0.004	**0.734**	0.010	**0.745**	0.002	**1.012**	0.002	**0.887**	0.002
-211	**0.139**	0.004	**0.796**	0.010	**0.808**	0.002	**1.074**	0.002	**0.950**	0.002
-212	**0.139**	0.004	**0.859**	0.010	**0.872**	0.002	**1.137**	0.002	**1.015**	0.002
-213	**0.139**	0.004	**0.921**	0.010	**0.935**	0.002	**1.199**	0.002	**1.077**	0.002
-214	**0.139**	0.004	**0.984**	0.010	**0.999**	0.002	**1.262**	0.002	**1.141**	0.002
-215	**0.139**	0.004	**1.046**	0.010	**1.062**	0.002	**1.324**	0.002	**1.203**	0.002
-216	**0.139**	0.004	**1.109**	0.012	**1.126**	0.002	**1.387**	0.002	**1.268**	0.002
-217	**0.139**	0.004	**1.171**	0.012	**1.189**	0.002	**1.449**	0.002	**1.330**	0.002
-218	**0.139**	0.004	**1.234**	0.012	**1.253**	0.002	**1.512**	0.002	**1.394**	0.002
-219	**0.139**	0.004	**1.296**	0.012	**1.315**	0.002	**1.574**	0.002	**1.456**	0.002
-220	**0.139**	0.004	**1.359**	0.012	**1.379**	0.002	**1.637**	0.002	**1.519**	0.002

Dimensions in inches.

Table 7-10: Standard Face Sealing Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-
-221	**0.139**	0.004	**1.421**	0.012	**1.442**	0.002	**1.699**	0.002	**1.582**	0.002
-222	**0.139**	0.004	**1.484**	0.015	**1.506**	0.002	**1.762**	0.002	**1.649**	0.002
-223	**0.139**	0.004	**1.609**	0.015	**1.633**	0.002	**1.887**	0.002	**1.774**	0.002
-224	**0.139**	0.004	**1.734**	0.015	**1.760**	0.002	**2.012**	0.002	**1.899**	0.002
-225	**0.139**	0.004	**1.859**	0.018	**1.887**	0.002	**2.137**	0.002	**2.028**	0.002
-226	**0.139**	0.004	**1.984**	0.018	**2.014**	0.002	**2.262**	0.002	**2.153**	0.002
-227	**0.139**	0.004	**2.109**	0.018	**2.141**	0.002	**2.387**	0.002	**2.280**	0.002
-228	**0.139**	0.004	**2.234**	0.020	**2.268**	0.002	**2.512**	0.002	**2.407**	0.002
-229	**0.139**	0.004	**2.359**	0.020	**2.394**	0.002	**2.637**	0.002	**2.533**	0.002
-230	**0.139**	0.004	**2.484**	0.020	**2.521**	0.002	**2.762**	0.002	**2.660**	0.002
-231	**0.139**	0.004	**2.609**	0.020	**2.648**	0.002	**2.887**	0.002	**2.787**	0.002
-232	**0.139**	0.004	**2.734**	0.024	**2.775**	0.002	**3.012**	0.002	**2.914**	0.002
-233	**0.139**	0.004	**2.859**	0.024	**2.902**	0.002	**3.137**	0.002	**3.041**	0.002
-234	**0.139**	0.004	**2.984**	0.024	**3.029**	0.002	**3.262**	0.002	**3.168**	0.002
-235	**0.139**	0.004	**3.109**	0.024	**3.156**	0.002	**3.387**	0.002	**3.295**	0.002
-236	**0.139**	0.004	**3.234**	0.024	**3.283**	0.002	**3.512**	0.002	**3.422**	0.002
-237	**0.139**	0.004	**3.359**	0.024	**3.409**	0.002	**3.637**	0.002	**3.548**	0.002
-238	**0.139**	0.004	**3.484**	0.024	**3.536**	0.002	**3.762**	0.002	**3.675**	0.002
-239	**0.139**	0.004	**3.609**	0.028	**3.663**	0.002	**3.887**	0.002	**3.802**	0.002
-240	**0.139**	0.004	**3.734**	0.028	**3.790**	0.002	**4.012**	0.002	**3.929**	0.002
-241	**0.139**	0.004	**3.859**	0.028	**3.917**	0.002	**4.137**	0.002	**4.056**	0.002
-242	**0.139**	0.004	**3.984**	0.028	**4.044**	0.002	**4.262**	0.002	**4.183**	0.002
-243	**0.139**	0.004	**4.109**	0.028	**4.171**	0.002	**4.387**	0.002	**4.310**	0.002
-244	**0.139**	0.004	**4.234**	0.030	**4.298**	0.002	**4.512**	0.002	**4.437**	0.002
-245	**0.139**	0.004	**4.359**	0.030	**4.424**	0.002	**4.637**	0.002	**4.563**	0.002
-246	**0.139**	0.004	**4.484**	0.030	**4.551**	0.002	**4.762**	0.002	**4.690**	0.002
-247	**0.139**	0.004	**4.609**	0.030	**4.678**	0.002	**4.887**	0.002	**4.817**	0.002
-248	**0.139**	0.004	**4.734**	0.030	**4.805**	0.002	**5.012**	0.002	**4.944**	0.002
-249	**0.139**	0.004	**4.859**	0.035	**4.932**	0.002	**5.137**	0.002	**5.071**	0.002
-250	**0.139**	0.004	**4.984**	0.035	**5.059**	0.002	**5.262**	0.002	**5.198**	0.002
-251	**0.139**	0.004	**5.109**	0.035	**5.186**	0.002	**5.387**	0.002	**5.325**	0.002
-252	**0.139**	0.004	**5.234**	0.035	**5.313**	0.002	**5.512**	0.002	**5.452**	0.002
-253	**0.139**	0.004	**5.359**	0.035	**5.439**	0.002	**5.637**	0.002	**5.578**	0.002
-254	**0.139**	0.004	**5.484**	0.035	**5.566**	0.002	**5.762**	0.002	**5.705**	0.002
-255	**0.139**	0.004	**5.609**	0.035	**5.693**	0.002	**5.887**	0.002	**5.832**	0.002
-256	**0.139**	0.004	**5.734**	0.035	**5.820**	0.002	**6.012**	0.002	**5.959**	0.002
-257	**0.139**	0.004	**5.859**	0.035	**5.947**	0.002	**6.137**	0.002	**6.086**	0.002
-258	**0.139**	0.004	**5.984**	0.035	**6.074**	0.002	**6.262**	0.002	**6.213**	0.002
-259	**0.139**	0.004	**6.234**	0.040	**6.328**	0.002	**6.512**	0.002	**6.467**	0.002
-260	**0.139**	0.004	**6.484**	0.040	**6.581**	0.002	**6.762**	0.002	**6.720**	0.002
-261	**0.139**	0.004	**6.734**	0.040	**6.835**	0.002	**7.012**	0.002	**6.974**	0.002
-262	**0.139**	0.004	**6.984**	0.040	**7.089**	0.002	**7.262**	0.002	**7.228**	0.002
-263	**0.139**	0.004	**7.234**	0.045	**7.343**	0.002	**7.512**	0.002	**7.482**	0.002
-264	**0.139**	0.004	**7.484**	0.045	**7.596**	0.002	**7.762**	0.002	**7.735**	0.002
-265	**0.139**	0.004	**7.734**	0.045	**7.850**	0.002	**8.012**	0.002	**7.989**	0.002

Dimensions in inches.

Table 7-10: Standard Face Sealing Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-
-266	**0.139**	0.004	**7.984**	0.045	**8.104**	0.002	**8.262**	0.002	**8.243**	0.002
-267	**0.139**	0.004	**8.234**	0.050	**8.358**	0.002	**8.512**	0.002	**8.497**	0.002
-268	**0.139**	0.004	**8.484**	0.050	**8.611**	0.002	**8.762**	0.002	**8.750**	0.002
-269	**0.139**	0.004	**8.734**	0.050	**8.865**	0.002	**9.012**	0.002	**9.004**	0.002
-270	**0.139**	0.004	**8.984**	0.050	**9.119**	0.002	**9.262**	0.002	**9.258**	0.002
-271	**0.139**	0.004	**9.234**	0.055	**9.373**	0.002	**9.512**	0.002	**9.512**	0.002
-272	**0.139**	0.004	**9.484**	0.055	**9.626**	0.002	**9.762**	0.002	**9.765**	0.002
-273	**0.139**	0.004	**9.734**	0.055	**9.880**	0.002	**10.012**	0.002	**10.019**	0.002
-274	**0.139**	0.004	**9.984**	0.055	**10.134**	0.002	**10.262**	0.002	**10.273**	0.002
-275	**0.139**	0.004	**10.484**	0.055	**10.641**	0.002	**10.762**	0.002	**10.780**	0.002
-276	**0.139**	0.004	**10.984**	0.065	**11.149**	0.002	**11.262**	0.002	**11.288**	0.002
-277	**0.139**	0.004	**11.484**	0.065	**11.656**	0.002	**11.762**	0.002	**11.795**	0.002
-278	**0.139**	0.004	**11.984**	0.065	**12.164**	0.002	**12.262**	0.002	**12.303**	0.002
-279	**0.139**	0.004	**12.984**	0.065	**13.179**	0.002	**13.262**	0.002	**13.318**	0.002
-280	**0.139**	0.004	**13.984**	0.065	**14.194**	0.002	**14.262**	0.002	**14.333**	0.002
-281	**0.139**	0.004	**14.984**	0.065	**15.209**	0.002	**15.262**	0.002	**15.348**	0.002
-282	**0.139**	0.004	**15.955**	0.075	**16.194**	0.002	**16.233**	0.002	**16.333**	0.002
-283	**0.139**	0.004	**16.955**	0.080	**17.209**	0.002	**17.233**	0.002	**17.348**	0.002
-284	**0.139**	0.004	**17.955**	0.085	**18.224**	0.002	**18.233**	0.002	**18.363**	0.002

Dimensions in inches.

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-
-309	**0.210**	0.005	**0.412**	0.005	**0.417**	0.004	**0.832**	0.004	**0.631**	0.004
-310	**0.210**	0.005	**0.475**	0.005	**0.480**	0.004	**0.895**	0.004	**0.696**	0.004
-311	**0.210**	0.005	**0.537**	0.007	**0.544**	0.004	**0.957**	0.004	**0.758**	0.004
-312	**0.210**	0.005	**0.600**	0.009	**0.609**	0.004	**1.020**	0.004	**0.823**	0.004
-313	**0.210**	0.005	**0.662**	0.009	**0.671**	0.004	**1.082**	0.004	**0.885**	0.004
-314	**0.210**	0.005	**0.725**	0.010	**0.735**	0.004	**1.145**	0.004	**0.949**	0.004
-315	**0.210**	0.005	**0.787**	0.010	**0.797**	0.004	**1.207**	0.004	**1.013**	0.004
-316	**0.210**	0.005	**0.850**	0.010	**0.861**	0.004	**1.270**	0.004	**1.077**	0.004
-317	**0.210**	0.005	**0.912**	0.010	**0.924**	0.004	**1.332**	0.004	**1.141**	0.004
-318	**0.210**	0.005	**0.975**	0.010	**0.990**	0.004	**1.395**	0.004	**1.205**	0.004
-319	**0.210**	0.005	**1.037**	0.010	**1.053**	0.004	**1.457**	0.004	**1.267**	0.004
-320	**0.210**	0.005	**1.100**	0.012	**1.117**	0.004	**1.520**	0.004	**1.333**	0.004
-321	**0.210**	0.005	**1.162**	0.012	**1.179**	0.004	**1.582**	0.004	**1.395**	0.004
-322	**0.210**	0.005	**1.225**	0.012	**1.243**	0.004	**1.645**	0.004	**1.458**	0.004
-323	**0.210**	0.005	**1.287**	0.012	**1.306**	0.004	**1.707**	0.004	**1.521**	0.004
-324	**0.210**	0.005	**1.350**	0.012	**1.370**	0.004	**1.770**	0.004	**1.584**	0.004
-325	**0.210**	0.005	**1.475**	0.015	**1.497**	0.004	**1.895**	0.004	**1.712**	0.004

Dimensions in inches.

Table 7-10: Standard Face Sealing Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-
-326	0.210	0.005	1.600	0.015	1.624	0.004	2.020	0.004	1.838	0.004
-327	0.210	0.005	1.725	0.015	1.751	0.004	2.145	0.004	1.963	0.004
-328	0.210	0.005	1.850	0.015	1.878	0.004	2.270	0.004	2.090	0.004
-329	0.210	0.005	1.975	0.018	2.005	0.004	2.395	0.004	2.217	0.004
-330	0.210	0.005	2.100	0.018	2.132	0.004	2.520	0.004	2.343	0.004
-331	0.210	0.005	2.225	0.018	2.258	0.004	2.645	0.004	2.469	0.004
-332	0.210	0.005	2.350	0.018	2.385	0.004	2.770	0.004	2.595	0.004
-333	0.210	0.005	2.475	0.020	2.512	0.004	2.895	0.004	2.722	0.004
-334	0.210	0.005	2.600	0.020	2.639	0.004	3.020	0.004	2.849	0.004
-335	0.210	0.005	2.725	0.020	2.766	0.004	3.145	0.004	2.976	0.004
-336	0.210	0.005	2.850	0.020	2.893	0.004	3.270	0.004	3.103	0.004
-337	0.210	0.005	2.975	0.024	3.020	0.004	3.395	0.004	3.230	0.004
-338	0.210	0.005	3.100	0.024	3.147	0.004	3.520	0.004	3.357	0.004
-339	0.210	0.005	3.225	0.024	3.273	0.004	3.645	0.004	3.483	0.004
-340	0.210	0.005	3.350	0.024	3.400	0.004	3.770	0.004	3.610	0.004
-341	0.210	0.005	3.475	0.024	3.527	0.004	3.895	0.004	3.737	0.004
-342	0.210	0.005	3.600	0.028	3.654	0.004	4.020	0.004	3.864	0.004
-343	0.210	0.005	3.725	0.028	3.781	0.004	4.145	0.004	3.991	0.004
-344	0.210	0.005	3.850	0.028	3.908	0.004	4.270	0.004	4.118	0.004
-345	0.210	0.005	3.975	0.028	4.035	0.004	4.395	0.004	4.245	0.004
-346	0.210	0.005	4.100	0.028	4.162	0.004	4.520	0.004	4.372	0.004
-347	0.210	0.005	4.225	0.030	4.288	0.004	4.645	0.004	4.497	0.004
-348	0.210	0.005	4.350	0.030	4.415	0.004	4.770	0.004	4.625	0.004
-349	0.210	0.005	4.475	0.030	4.542	0.004	4.895	0.004	4.752	0.004
-350	0.210	0.005	4.600	0.030	4.669	0.004	5.020	0.004	4.879	0.004
-351	0.210	0.005	4.725	0.030	4.796	0.004	5.145	0.004	5.006	0.004
-352	0.210	0.005	4.850	0.030	4.923	0.004	5.270	0.004	5.133	0.004
-353	0.210	0.005	4.975	0.037	5.050	0.004	5.395	0.004	5.260	0.004
-354	0.210	0.005	5.100	0.037	5.177	0.004	5.520	0.004	5.387	0.004
-355	0.210	0.005	5.225	0.037	5.303	0.004	5.645	0.004	5.513	0.004
-356	0.210	0.005	5.350	0.037	5.430	0.004	5.770	0.004	5.640	0.004
-357	0.210	0.005	5.475	0.037	5.557	0.004	5.895	0.004	5.767	0.004
-358	0.210	0.005	5.600	0.037	5.684	0.004	6.020	0.004	5.894	0.004
-359	0.210	0.005	5.725	0.037	5.811	0.004	6.145	0.004	6.021	0.004
-360	0.210	0.005	5.850	0.037	5.938	0.004	6.270	0.004	6.148	0.004
-361	0.210	0.005	5.975	0.037	6.065	0.004	6.395	0.004	6.275	0.004
-362	0.210	0.005	6.225	0.040	6.318	0.004	6.645	0.004	6.528	0.004
-363	0.210	0.005	6.475	0.040	6.572	0.004	6.895	0.004	6.782	0.004
-364	0.210	0.005	6.725	0.040	6.826	0.004	7.145	0.004	7.036	0.004
-365	0.210	0.005	6.975	0.040	7.080	0.004	7.395	0.004	7.290	0.004
-366	0.210	0.005	7.225	0.045	7.333	0.004	7.645	0.004	7.543	0.004
-367	0.210	0.005	7.475	0.045	7.587	0.004	7.895	0.004	7.797	0.004
-368	0.210	0.005	7.725	0.045	7.841	0.004	8.145	0.004	8.051	0.004
-369	0.210	0.005	7.975	0.045	8.095	0.004	8.395	0.004	8.305	0.004
-370	0.210	0.005	8.225	0.050	8.348	0.004	8.645	0.004	8.558	0.004

Dimensions in inches.

Table 7-10: Standard Face Sealing Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-
-371	**0.210**	0.005	**8.475**	0.050	**8.602**	0.004	**8.895**	0.004	**8.812**	0.004
-372	**0.210**	0.005	**8.725**	0.050	**8.856**	0.004	**9.145**	0.004	**9.066**	0.004
-373	**0.210**	0.005	**8.975**	0.050	**9.110**	0.004	**9.395**	0.004	**9.320**	0.004
-374	**0.210**	0.005	**9.225**	0.055	**9.363**	0.004	**9.645**	0.004	**9.573**	0.004
-375	**0.210**	0.005	**9.475**	0.055	**9.617**	0.004	**9.895**	0.004	**9.827**	0.004
-376	**0.210**	0.005	**9.725**	0.055	**9.871**	0.004	**10.145**	0.004	**10.081**	0.004
-377	**0.210**	0.005	**9.975**	0.055	**10.125**	0.004	**10.395**	0.004	**10.335**	0.004
-378	**0.210**	0.005	**10.475**	0.060	**10.632**	0.004	**10.895**	0.004	**10.842**	0.004
-379	**0.210**	0.005	**10.975**	0.060	**11.140**	0.004	**11.395**	0.004	**11.350**	0.004
-380	**0.210**	0.005	**11.475**	0.065	**11.647**	0.004	**11.895**	0.004	**11.857**	0.004
-381	**0.210**	0.005	**11.975**	0.065	**12.155**	0.004	**12.395**	0.004	**12.365**	0.004
-382	**0.210**	0.005	**12.975**	0.065	**13.170**	0.004	**13.395**	0.004	**13.380**	0.004
-383	**0.210**	0.005	**13.975**	0.070	**14.185**	0.004	**14.395**	0.004	**14.395**	0.004
-384	**0.210**	0.005	**14.975**	0.070	**15.200**	0.004	**15.395**	0.004	**15.410**	0.004
-385	**0.210**	0.005	**15.955**	0.075	**16.194**	0.004	**16.375**	0.004	**16.404**	0.004
-386	**0.210**	0.005	**16.955**	0.080	**17.209**	0.004	**17.375**	0.004	**17.419**	0.004
-387	**0.210**	0.005	**17.955**	0.085	**18.224**	0.004	**18.375**	0.004	**18.434**	0.004
-388	**0.210**	0.005	**18.955**	0.090	**19.239**	0.004	**19.375**	0.004	**19.449**	0.004
-389	**0.210**	0.005	**19.955**	0.095	**20.254**	0.004	**20.375**	0.004	**20.464**	0.004
-390	**0.210**	0.005	**20.955**	0.095	**21.269**	0.004	**21.375**	0.004	**21.479**	0.004
-391	**0.210**	0.005	**21.995**	0.100	**22.325**	0.004	**22.415**	0.004	**22.535**	0.004
-392	**0.210**	0.005	**22.940**	0.105	**23.284**	0.004	**23.360**	0.004	**23.494**	0.004
-393	**0.210**	0.005	**23.940**	0.110	**24.299**	0.004	**24.360**	0.004	**24.509**	0.004
-394	**0.210**	0.005	**24.940**	0.115	**25.314**	0.004	**25.360**	0.004	**25.524**	0.004
-395	**0.210**	0.005	**25.940**	0.120	**26.329**	0.004	**26.360**	0.004	**26.539**	0.004

Dimensions in inches.

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-
-425	**0.275**	0.006	**4.475**	0.033	**4.542**	0.004	**5.025**	0.004	**4.817**	0.004
-426	**0.275**	0.006	**4.600**	0.033	**4.669**	0.004	**5.150**	0.004	**4.944**	0.004
-427	**0.275**	0.006	**4.725**	0.033	**4.796**	0.004	**5.275**	0.004	**5.071**	0.004
-428	**0.275**	0.006	**4.850**	0.033	**4.923**	0.004	**5.400**	0.004	**5.198**	0.004
-429	**0.275**	0.006	**4.975**	0.037	**5.050**	0.004	**5.525**	0.004	**5.325**	0.004
-430	**0.275**	0.006	**5.100**	0.037	**5.177**	0.004	**5.650**	0.004	**5.452**	0.004
-431	**0.275**	0.006	**5.225**	0.037	**5.303**	0.004	**5.775**	0.004	**5.578**	0.004
-432	**0.275**	0.006	**5.350**	0.037	**5.430**	0.004	**5.900**	0.004	**5.705**	0.004
-433	**0.275**	0.006	**5.475**	0.037	**5.557**	0.004	**6.025**	0.004	**5.832**	0.004
-434	**0.275**	0.006	**5.600**	0.037	**5.684**	0.004	**6.150**	0.004	**5.959**	0.004
-435	**0.275**	0.006	**5.725**	0.037	**5.811**	0.004	**6.275**	0.004	**6.086**	0.004

Dimensions in inches.

Table 7-10: Standard Face Sealing Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-	**Nom**	Tol +/-
-436	**0.275**	0.006	**5.850**	0.037	**5.938**	0.004	**6.400**	0.004	**6.213**	0.004
-437	**0.275**	0.006	**5.975**	0.037	**6.065**	0.004	**6.525**	0.004	**6.340**	0.004
-438	**0.275**	0.006	**6.225**	0.040	**6.318**	0.004	**6.775**	0.004	**6.593**	0.004
-439	**0.275**	0.006	**6.475**	0.040	**6.572**	0.004	**7.025**	0.004	**6.847**	0.004
-440	**0.275**	0.006	**6.725**	0.040	**6.826**	0.004	**7.275**	0.004	**7.101**	0.004
-441	**0.275**	0.006	**6.975**	0.040	**7.080**	0.004	**7.525**	0.004	**7.355**	0.004
-442	**0.275**	0.006	**7.225**	0.045	**7.333**	0.004	**7.775**	0.004	**7.608**	0.004
-443	**0.275**	0.006	**7.475**	0.045	**7.587**	0.004	**8.025**	0.004	**7.862**	0.004
-444	**0.275**	0.006	**7.725**	0.045	**7.841**	0.004	**8.275**	0.004	**8.116**	0.004
-445	**0.275**	0.006	**7.975**	0.045	**8.095**	0.004	**8.525**	0.004	**8.370**	0.004
-446	**0.275**	0.006	**8.475**	0.055	**8.602**	0.004	**9.025**	0.004	**8.877**	0.004
-447	**0.275**	0.006	**8.975**	0.055	**9.110**	0.004	**9.525**	0.004	**9.385**	0.004
-448	**0.275**	0.006	**9.475**	0.055	**9.617**	0.004	**10.025**	0.004	**9.892**	0.004
-449	**0.275**	0.006	**9.975**	0.055	**10.125**	0.004	**10.525**	0.004	**10.400**	0.004
-450	**0.275**	0.006	**10.475**	0.060	**10.632**	0.004	**11.025**	0.004	**10.907**	0.004
-451	**0.275**	0.006	**10.975**	0.060	**11.140**	0.004	**11.525**	0.004	**11.415**	0.004
-452	**0.275**	0.006	**11.475**	0.060	**11.647**	0.004	**12.025**	0.004	**11.922**	0.004
-453	**0.275**	0.006	**11.975**	0.060	**12.155**	0.004	**12.525**	0.004	**12.430**	0.004
-454	**0.275**	0.006	**12.475**	0.060	**12.662**	0.004	**13.025**	0.004	**12.937**	0.004
-455	**0.275**	0.006	**12.975**	0.060	**13.170**	0.004	**13.525**	0.004	**13.445**	0.004
-456	**0.275**	0.006	**13.475**	0.070	**13.677**	0.004	**14.025**	0.004	**13.952**	0.004
-457	**0.275**	0.006	**13.975**	0.070	**14.185**	0.004	**14.525**	0.004	**14.460**	0.004
-458	**0.275**	0.006	**14.475**	0.070	**14.692**	0.004	**15.025**	0.004	**14.967**	0.004
-459	**0.275**	0.006	**14.975**	0.070	**15.200**	0.004	**15.525**	0.004	**15.475**	0.004
-460	**0.275**	0.006	**15.475**	0.070	**15.707**	0.004	**16.025**	0.004	**15.982**	0.004
-461	**0.275**	0.006	**15.955**	0.075	**16.194**	0.004	**16.505**	0.004	**16.469**	0.004
-462	**0.275**	0.006	**16.455**	0.075	**16.702**	0.004	**17.005**	0.004	**16.977**	0.004
-463	**0.275**	0.006	**16.955**	0.080	**17.209**	0.004	**17.505**	0.004	**17.484**	0.004
-464	**0.275**	0.006	**17.455**	0.085	**17.717**	0.004	**18.005**	0.004	**17.992**	0.004
-465	**0.275**	0.006	**17.955**	0.085	**18.224**	0.004	**18.505**	0.004	**18.499**	0.004
-466	**0.275**	0.006	**18.455**	0.085	**18.732**	0.004	**19.005**	0.004	**19.007**	0.004
-467	**0.275**	0.006	**18.955**	0.090	**19.239**	0.004	**19.505**	0.004	**19.514**	0.004
-468	**0.275**	0.006	**19.455**	0.090	**19.747**	0.004	**20.005**	0.004	**20.022**	0.004
-469	**0.275**	0.006	**19.955**	0.095	**20.254**	0.004	**20.505**	0.004	**20.529**	0.004
-470	**0.275**	0.006	**20.955**	0.095	**21.269**	0.004	**21.505**	0.004	**21.544**	0.004
-471	**0.275**	0.006	**21.955**	0.100	**22.284**	0.004	**22.505**	0.004	**22.559**	0.004
-472	**0.275**	0.006	**22.940**	0.105	**23.284**	0.004	**23.490**	0.004	**23.559**	0.004
-473	**0.275**	0.006	**23.940**	0.110	**24.299**	0.004	**24.490**	0.004	**24.574**	0.004
-474	**0.275**	0.006	**24.940**	0.115	**25.314**	0.004	**25.490**	0.004	**25.589**	0.004
-475	**0.275**	0.006	**25.940**	0.120	**26.329**	0.004	**26.490**	0.004	**26.604**	0.004

Dimensions in inches.

Table 7-10: Standard Face Sealing Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D Int. Vacuum Gland I.D.		E Int. Pressure Gland O.D.		F Dovetail Gland CL Diameter	
	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-	Nom	Tol +/-
-901	0.056	0.003	0.185	0.005	0.190	0.002	0.297	0.002	0.248	0.002
-902	0.064	0.003	0.239	0.005	0.244	0.002	0.367	0.002	0.310	0.002
-903	0.064	0.003	0.301	0.005	0.306	0.002	0.429	0.002	0.372	0.002
-904	0.072	0.003	0.351	0.005	0.356	0.002	0.495	0.002	0.430	0.002
-905	0.072	0.003	0.414	0.005	0.419	0.002	0.558	0.002	0.493	0.002
-906	0.078	0.003	0.468	0.005	0.473	0.002	0.624	0.002	0.555	0.002
-907	0.082	0.003	0.530	0.007	0.537	0.002	0.694	0.002	0.621	0.002
-908	0.087	0.003	0.644	0.009	0.653	0.002	0.818	0.002	0.742	0.002
-909	0.097	0.003	0.706	0.009	0.715	0.002	0.900	0.002	0.815	0.002
-910	0.097	0.003	0.755	0.009	0.764	0.002	0.949	0.002	0.866	0.002
-911	0.116	0.004	0.863	0.009	0.876	0.002	1.095	0.002	0.996	0.002
-912	0.116	0.004	0.924	0.009	0.938	0.002	1.156	0.002	1.057	0.002
-913	0.116	0.004	0.986	0.010	1.001	0.002	1.218	0.002	1.120	0.002
-914	0.116	0.004	1.047	0.010	1.063	0.002	1.279	0.002	1.181	0.002

Dimensions in inches.

Static I.D./O.D. Seal, Rectangular Gland Any Pressure Combination

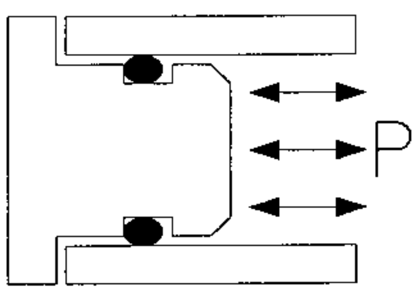


Figure 7-11

If the O-Ring Dash Size Is Known

Step 1. Locate the dash number in Table 7-14, page 61, to determine the O-ring's dimensions from columns "B" and "C."

Step 2. Locate the appropriate gland dimensions in Table 7–14.

Selecting the O-Ring Dash Size

If the O-ring dash size is not known and all gland dimensions are known:

Step 1. Locate the gland's width in Table 7-13, page 60.

Step 2. Select the corresponding O-ring dash size series that matches the gland's width.

Step 3. Locate the gland's dimensions within the O-ring number series in Table 7-14, page 61, to determine the O-ring's dash size.

If the exact gland dimensions cannot be located in these tables, a nonstandard O-ring may be required. Contact Greene, Tweed Engineering.

To choose both the appropriate gland dimensions and the corresponding O-ring dash number:

Step 1. From Table 7-13, page 60, select the desired O-ring cross-section and its corresponding AS 568A O-ring series. The cross-section selection should be based on the desired sealing footprint and allowable clearances within the hardware. A larger cross-section will result in a wider sealing footprint for a given cross-section squeeze percentage and should be generally preferred. However, larger cross-section seals will require a greater compressive load (see Semiconductor Seal Compound Selection Guide, pages 21–26).

Step 2. From Table 7-14, page 61, based on hardware requirements for O.D. sealing, select the closest standard bore diameter, from column "E," within the O-ring dash size series. For I.D. sealing, select the closest standard tube diameter from column "G." Record the dash number. Note: Not all standard O-ring cross-sections are available for all diameters. If the desired gland diameter cannot be found within the dash size series that has been selected, a different cross-section must be selected.

Step 3. With the dash number determined in Step 2, follow the instructions on page 59 to determine complete gland dimensions.

Table 7-13: Standard Static I.D. and O.D. Sealing Gland Cross-Sectional Dimensions

AS 568A Series	O-Ring Cross-Section		Gland Width (W)		Gap (H)	Gland Corner Radii	
	Nom	Tol +/-	Nom	Tol +/-	Tol +/-	(R1)	(R2)
-000	**0.070**	0.003	**0.095**	0.002	0.002	**0.007**	**0.005**
-100	**0.103**	0.004	**0.142**	0.003	0.002	**0.007**	**0.005**
-200	**0.139**	0.004	**0.189**	0.003	0.002	**0.017**	**0.005**
-300	**0.210**	0.005	**0.283**	0.003	0.003	**0.027**	**0.005**
-400	**0.275**	0.006	**0.377**	0.003	0.003	**0.027**	**0.005**

Dimensions in inches.

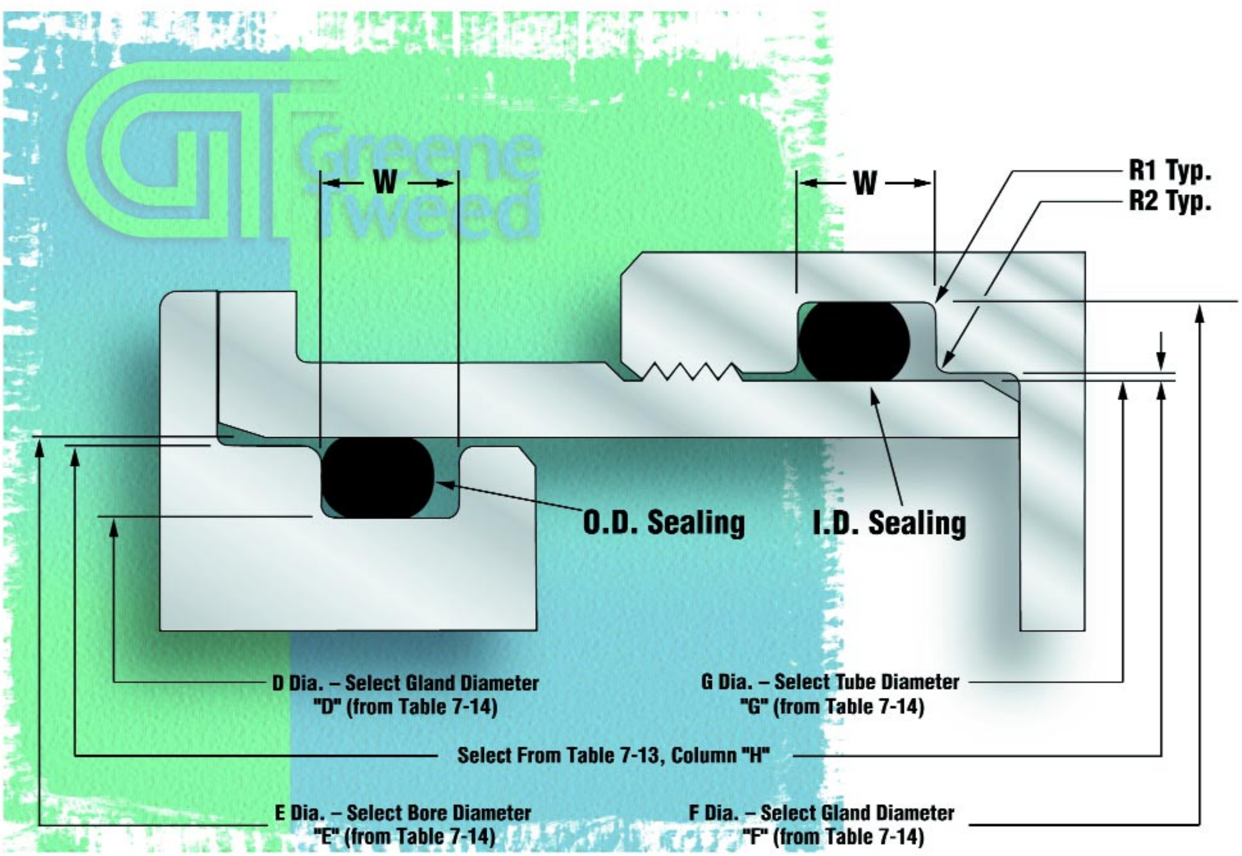


Figure 7-12 *Static I.D./O.D. Sealing Details*

Table 7-14: Standard Static I.D./O.D. Seal Diametrical Dimensions

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D O.D. Sealing Type Gland			E Bore Dia	F I.D. Sealing Type Gland			G Tube Dia
	Nom	Tol +/-	Nom	Tol +/-	Dia	Tol (+)	Tol (-)	+.002 -.000	Dia	Tol (+)	Tol (-)	+.002 -.000
-005	**0.070**	0.003	**0.101**	0.005	**0.137**	0.000	0.002	**0.237**	**0.212**	0.000	0.002	**0.112**
-006	**0.070**	0.003	**0.114**	0.005	**0.150**	0.000	0.002	**0.250**	**0.225**	0.000	0.002	**0.125**
-007	**0.070**	0.003	**0.145**	0.005	**0.181**	0.000	0.002	**0.281**	**0.256**	0.000	0.002	**0.156**
-008	**0.070**	0.003	**0.176**	0.005	**0.212**	0.000	0.002	**0.312**	**0.287**	0.000	0.002	**0.187**
-009	**0.070**	0.003	**0.208**	0.005	**0.243**	0.000	0.002	**0.343**	**0.318**	0.000	0.002	**0.218**
-010	**0.070**	0.003	**0.239**	0.005	**0.275**	0.000	0.002	**0.375**	**0.350**	0.000	0.002	**0.250**
-011	**0.070**	0.003	**0.301**	0.005	**0.337**	0.000	0.002	**0.437**	**0.412**	0.000	0.002	**0.312**
-012	**0.070**	0.003	**0.364**	0.005	**0.400**	0.000	0.002	**0.500**	**0.475**	0.000	0.002	**0.375**
-013	**0.070**	0.003	**0.426**	0.005	**0.462**	0.000	0.002	**0.562**	**0.537**	0.000	0.002	**0.437**
-014	**0.070**	0.003	**0.489**	0.005	**0.525**	0.000	0.002	**0.625**	**0.600**	0.000	0.002	**0.500**
-015	**0.070**	0.003	**0.551**	0.007	**0.587**	0.000	0.002	**0.687**	**0.662**	0.000	0.002	**0.562**
-016	**0.070**	0.003	**0.614**	0.009	**0.650**	0.000	0.002	**0.750**	**0.725**	0.000	0.002	**0.625**
-017	**0.070**	0.003	**0.676**	0.009	**0.712**	0.000	0.002	**0.812**	**0.787**	0.000	0.002	**0.687**
-018	**0.070**	0.003	**0.739**	0.009	**0.775**	0.000	0.002	**0.875**	**0.850**	0.000	0.002	**0.750**
-019	**0.070**	0.003	**0.801**	0.009	**0.837**	0.000	0.002	**0.937**	**0.912**	0.000	0.002	**0.812**
-020	**0.070**	0.003	**0.864**	0.009	**0.900**	0.000	0.002	**1.000**	**0.975**	0.000	0.002	**0.875**
-021	**0.070**	0.003	**0.926**	0.009	**0.962**	0.000	0.002	**1.062**	**1.037**	0.000	0.002	**0.937**
-022	**0.070**	0.003	**0.989**	0.010	**1.025**	0.000	0.002	**1.125**	**1.100**	0.000	0.002	**1.000**
-023	**0.070**	0.003	**1.051**	0.010	**1.087**	0.000	0.002	**1.187**	**1.162**	0.000	0.002	**1.062**
-024	**0.070**	0.003	**1.114**	0.010	**1.150**	0.000	0.002	**1.250**	**1.225**	0.000	0.002	**1.125**
-025	**0.070**	0.003	**1.176**	0.011	**1.212**	0.000	0.002	**1.312**	**1.287**	0.000	0.002	**1.187**
-026	**0.070**	0.003	**1.239**	0.011	**1.275**	0.000	0.002	**1.375**	**1.350**	0.000	0.002	**1.250**
-027	**0.070**	0.003	**1.301**	0.011	**1.337**	0.000	0.002	**1.437**	**1.412**	0.000	0.002	**1.312**
-028	**0.070**	0.003	**1.364**	0.013	**1.400**	0.000	0.002	**1.500**	**1.475**	0.000	0.002	**1.375**
-029	**0.070**	0.003	**1.489**	0.013	**1.525**	0.000	0.002	**1.625**	**1.600**	0.000	0.002	**1.500**
-030	**0.070**	0.003	**1.614**	0.013	**1.650**	0.000	0.002	**1.750**	**1.725**	0.000	0.002	**1.625**
-031	**0.070**	0.003	**1.739**	0.015	**1.775**	0.000	0.002	**1.875**	**1.850**	0.000	0.002	**1.750**
-032	**0.070**	0.003	**1.864**	0.015	**1.900**	0.000	0.002	**2.000**	**1.975**	0.000	0.002	**1.875**
-033	**0.070**	0.003	**1.989**	0.018	**2.025**	0.000	0.002	**2.125**	**2.100**	0.000	0.002	**2.000**
-034	**0.070**	0.003	**2.114**	0.018	**2.150**	0.000	0.002	**2.250**	**2.225**	0.000	0.002	**2.125**
-035	**0.070**	0.003	**2.239**	0.018	**2.275**	0.000	0.002	**2.375**	**2.350**	0.000	0.002	**2.250**
-036	**0.070**	0.003	**2.364**	0.018	**2.400**	0.000	0.002	**2.500**	**2.475**	0.000	0.002	**2.375**
-037	**0.070**	0.003	**2.489**	0.018	**2.525**	0.000	0.002	**2.625**	**2.600**	0.000	0.002	**2.500**
-038	**0.070**	0.003	**2.614**	0.020	**2.650**	0.000	0.002	**2.750**	**2.725**	0.000	0.002	**2.625**
-039	**0.070**	0.003	**2.739**	0.020	**2.775**	0.000	0.002	**2.875**	**2.850**	0.000	0.002	**2.750**
-040	**0.070**	0.003	**2.864**	0.020	**2.900**	0.000	0.002	**3.000**	**2.975**	0.000	0.002	**2.875**
-041	**0.070**	0.003	**2.989**	0.024	**3.025**	0.000	0.002	**3.125**	**3.100**	0.000	0.002	**3.000**
-042	**0.070**	0.003	**3.239**	0.024	**3.275**	0.000	0.002	**3.375**	**3.350**	0.000	0.002	**3.250**
-043	**0.070**	0.003	**3.489**	0.024	**3.525**	0.000	0.002	**3.625**	**3.600**	0.000	0.002	**3.500**
-044	**0.070**	0.003	**3.739**	0.027	**3.775**	0.000	0.002	**3.875**	**3.850**	0.000	0.002	**3.750**
-045	**0.070**	0.003	**3.989**	0.027	**4.025**	0.000	0.002	**4.125**	**4.100**	0.000	0.002	**4.000**
-046	**0.070**	0.003	**4.239**	0.030	**4.275**	0.000	0.002	**4.375**	**4.350**	0.000	0.002	**4.250**
-047	**0.070**	0.003	**4.489**	0.030	**4.525**	0.000	0.002	**4.625**	**4.600**	0.000	0.002	**4.500**
-048	**0.070**	0.003	**4.739**	0.030	**4.775**	0.000	0.002	**4.875**	**4.850**	0.000	0.002	**4.750**
-049	**0.070**	0.003	**4.989**	0.037	**5.025**	0.000	0.002	**5.125**	**5.100**	0.000	0.002	**5.000**
-050	**0.070**	0.003	**5.239**	0.037	**5.275**	0.000	0.002	**5.375**	**5.350**	0.000	0.002	**5.250**

Dimensions in inches.

Table 7-14: Standard Static I.D./O.D. Seal Diametrical Dimensions (continued)

A	B		C		D			E	F			G
Dash Size	O-Ring Cross-Section		O-Ring Diameter		O.D. Sealing Type				I.D. Sealing Type			
					Gland			Bore Dia	Gland			Tube Dia
	Nom	Tol +/-	Nom	Tol +/-	Dia	Tol (+)	Tol (-)	+.002 -.000	Dia	Tol (+)	Tol (-)	+.002 -.000
-102	0.103	0.003	0.049	0.005	0.085	0.000	0.002	0.247	0.224	0.000	0.002	0.062
-103	0.103	0.003	0.081	0.005	0.116	0.000	0.002	0.278	0.256	0.000	0.002	0.094
-104	0.103	0.003	0.112	0.005	0.148	0.000	0.002	0.310	0.287	0.000	0.002	0.125
-105	0.103	0.003	0.143	0.005	0.180	0.000	0.002	0.342	0.318	0.000	0.002	0.156
-106	0.103	0.003	0.174	0.005	0.212	0.000	0.002	0.374	0.349	0.000	0.002	0.187
-107	0.103	0.003	0.206	0.005	0.243	0.000	0.002	0.405	0.381	0.000	0.002	0.219
-108	0.103	0.003	0.237	0.005	0.275	0.000	0.002	0.437	0.412	0.000	0.002	0.250
-109	0.103	0.003	0.299	0.005	0.338	0.000	0.002	0.500	0.474	0.000	0.002	0.312
-110	0.103	0.003	0.362	0.005	0.400	0.000	0.002	0.562	0.537	0.000	0.002	0.375
-111	0.103	0.003	0.424	0.005	0.463	0.000	0.002	0.625	0.599	0.000	0.002	0.437
-112	0.103	0.003	0.487	0.005	0.525	0.000	0.002	0.687	0.662	0.000	0.002	0.500
-113	0.103	0.003	0.549	0.007	0.588	0.000	0.002	0.750	0.724	0.000	0.002	0.562
-114	0.103	0.003	0.612	0.009	0.650	0.000	0.002	0.812	0.787	0.000	0.002	0.625
-115	0.103	0.003	0.674	0.009	0.713	0.000	0.002	0.875	0.849	0.000	0.002	0.687
-116	0.103	0.003	0.737	0.009	0.775	0.000	0.002	0.937	0.912	0.000	0.002	0.750
-117	0.103	0.003	0.799	0.010	0.838	0.000	0.002	1.000	0.974	0.000	0.002	0.812
-118	0.103	0.003	0.862	0.010	0.900	0.000	0.002	1.062	1.037	0.000	0.002	0.875
-119	0.103	0.003	0.924	0.010	0.963	0.000	0.002	1.125	1.099	0.000	0.002	0.937
-120	0.103	0.003	0.987	0.010	1.025	0.000	0.002	1.187	1.162	0.000	0.002	1.000
-121	0.103	0.003	1.049	0.010	1.088	0.000	0.002	1.250	1.224	0.000	0.002	1.062
-122	0.103	0.003	1.112	0.010	1.150	0.000	0.002	1.312	1.287	0.000	0.002	1.125
-123	0.103	0.003	1.174	0.012	1.213	0.000	0.002	1.375	1.349	0.000	0.002	1.187
-124	0.103	0.003	1.237	0.012	1.275	0.000	0.002	1.437	1.412	0.000	0.002	1.250
-125	0.103	0.003	1.299	0.012	1.338	0.000	0.002	1.500	1.474	0.000	0.002	1.312
-126	0.103	0.003	1.362	0.012	1.400	0.000	0.002	1.562	1.537	0.000	0.002	1.375
-127	0.103	0.003	1.424	0.012	1.463	0.000	0.002	1.625	1.599	0.000	0.002	1.437
-128	0.103	0.003	1.487	0.012	1.525	0.000	0.002	1.687	1.662	0.000	0.002	1.500
-129	0.103	0.003	1.549	0.015	1.588	0.000	0.002	1.750	1.724	0.000	0.002	1.562
-130	0.103	0.003	1.612	0.015	1.650	0.000	0.002	1.812	1.787	0.000	0.002	1.625
-131	0.103	0.003	1.674	0.015	1.713	0.000	0.002	1.875	1.849	0.000	0.002	1.687
-132	0.103	0.003	1.737	0.015	1.775	0.000	0.002	1.937	1.912	0.000	0.002	1.750
-133	0.103	0.003	1.799	0.015	1.838	0.000	0.002	2.000	1.974	0.000	0.002	1.812
-134	0.103	0.003	1.862	0.015	1.900	0.000	0.002	2.062	2.037	0.000	0.002	1.875
-135	0.103	0.003	1.925	0.017	1.963	0.000	0.002	2.123	2.099	0.000	0.002	1.937
-136	0.103	0.003	1.987	0.017	2.025	0.000	0.002	2.187	2.162	0.000	0.002	2.000
-137	0.103	0.003	2.050	0.017	2.088	0.000	0.002	2.250	2.224	0.000	0.002	2.062
-138	0.103	0.003	2.112	0.017	2.150	0.000	0.002	2.312	2.287	0.000	0.002	2.125
-139	0.103	0.003	2.175	0.017	2.213	0.000	0.002	2.375	2.349	0.000	0.002	2.187
-140	0.103	0.003	2.237	0.017	2.275	0.000	0.002	2.437	2.412	0.000	0.002	2.250
-141	0.103	0.003	2.300	0.020	2.338	0.000	0.002	2.500	2.474	0.000	0.002	2.312
-142	0.103	0.003	2.362	0.020	2.400	0.000	0.002	2.562	2.537	0.000	0.002	2.375
-143	0.103	0.003	2.425	0.020	2.463	0.000	0.002	2.625	2.599	0.000	0.002	2.437
-144	0.103	0.003	2.487	0.020	2.525	0.000	0.002	2.687	2.662	0.000	0.002	2.500
-145	0.103	0.003	2.550	0.020	2.588	0.000	0.002	2.750	2.724	0.000	0.002	2.562

Dimensions in inches.

Table 7-14: Standard Static I.D./O.D. Seal Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D O.D. Sealing Type Gland			E Bore Dia	F I.D. Sealing Type Gland			G Tube Dia
	Nom	Tol +/-	Nom	Tol +/-	Dia	Tol (+)	Tol (-)	+.002 -.000	Dia	Tol (+)	Tol (-)	+.002 -.000
-146	0.103	0.003	2.612	0.020	2.650	0.000	0.002	2.812	2.787	0.000	0.002	2.625
-147	0.103	0.003	2.675	0.022	2.713	0.000	0.002	2.875	2.849	0.000	0.002	2.687
-148	0.103	0.003	2.737	0.022	2.775	0.000	0.002	2.937	2.912	0.000	0.002	2.750
-149	0.103	0.003	2.800	0.022	2.838	0.000	0.002	3.000	2.974	0.000	0.002	2.812
-150	0.103	0.003	2.862	0.022	2.900	0.000	0.002	3.062	3.037	0.000	0.002	2.875
-151	0.103	0.003	2.987	0.024	3.025	0.000	0.002	3.187	3.162	0.000	0.002	3.000
-152	0.103	0.003	3.237	0.024	3.275	0.000	0.002	3.437	3.412	0.000	0.002	3.250
-153	0.103	0.003	3.487	0.024	3.525	0.000	0.002	3.687	3.662	0.000	0.002	3.500
-154	0.103	0.003	3.737	0.028	3.775	0.000	0.002	3.937	3.912	0.000	0.002	3.750
-155	0.103	0.003	3.987	0.028	4.025	0.000	0.002	4.187	4.162	0.000	0.002	4.000
-156	0.103	0.003	4.237	0.030	4.275	0.000	0.002	4.437	4.412	0.000	0.002	4.250
-157	0.103	0.003	4.487	0.030	4.525	0.000	0.002	4.687	4.662	0.000	0.002	4.500
-158	0.103	0.003	4.737	0.030	4.775	0.000	0.002	4.937	4.912	0.000	0.002	4.750
-159	0.103	0.003	4.987	0.035	5.025	0.000	0.002	5.187	5.162	0.000	0.002	5.000
-160	0.103	0.003	5.237	0.035	5.275	0.000	0.002	5.437	5.412	0.000	0.002	5.250
-161	0.103	0.003	5.487	0.035	5.525	0.000	0.002	5.687	5.662	0.000	0.002	5.500
-162	0.103	0.003	5.737	0.035	5.775	0.000	0.002	5.937	5.912	0.000	0.002	5.750
-163	0.103	0.003	5.987	0.035	6.025	0.000	0.002	6.187	6.162	0.000	0.002	6.000
-164	0.103	0.003	6.237	0.040	6.275	0.000	0.002	6.437	6.412	0.000	0.002	6.250
-165	0.103	0.003	6.487	0.040	6.525	0.000	0.002	6.687	6.662	0.000	0.002	6.500
-166	0.103	0.003	6.737	0.040	6.775	0.000	0.002	6.937	6.912	0.000	0.002	6.750
-167	0.103	0.003	6.987	0.040	7.025	0.000	0.002	7.187	7.162	0.000	0.002	7.000
-168	0.103	0.003	7.237	0.045	7.275	0.000	0.002	7.437	7.412	0.000	0.002	7.250
-169	0.103	0.003	7.487	0.045	7.525	0.000	0.002	7.687	7.662	0.000	0.002	7.500
-170	0.103	0.003	7.737	0.045	7.775	0.000	0.002	7.937	7.912	0.000	0.002	7.750
-171	0.103	0.003	7.987	0.045	8.025	0.000	0.002	8.187	8.162	0.000	0.002	8.000
-172	0.103	0.003	8.237	0.050	8.275	0.000	0.002	8.437	8.412	0.000	0.002	8.250
-173	0.103	0.003	8.487	0.050	8.525	0.000	0.002	8.687	8.662	0.000	0.002	8.500
-174	0.103	0.003	8.737	0.050	8.775	0.000	0.002	8.937	8.912	0.000	0.002	8.750
-175	0.103	0.003	8.987	0.050	9.025	0.000	0.002	9.187	9.162	0.000	0.002	9.000
-176	0.103	0.003	9.237	0.055	9.275	0.000	0.002	9.437	9.412	0.000	0.002	9.250
-177	0.103	0.003	9.487	0.055	9.525	0.000	0.002	9.687	9.662	0.000	0.002	9.500
-178	0.103	0.003	9.737	0.055	9.775	0.000	0.002	9.937	9.912	0.000	0.002	9.750

Dimensions in inches.

Table 7-14: Standard Static I.D./O.D. Seal Diametrical Dimensions (continued)

A	B		C		D			E	F			G
Dash Size	O-Ring Cross-Section		O-Ring Diameter		O.D. Sealing Type				I.D. Sealing Type			
					Gland			Bore Dia	Gland			Tube Dia
	Nom	Tol +/-	Nom	Tol +/-	Dia	Tol (+)	Tol (-)	+.002 -.000	Dia	Tol (+)	Tol (-)	+.002 -.000
-201	0.139	0.004	0.171	0.005	0.215	0.000	0.002	0.437	0.409	0.000	0.002	0.187
-202	0.139	0.004	0.234	0.005	0.278	0.000	0.002	0.500	0.472	0.000	0.002	0.250
-203	0.139	0.004	0.296	0.005	0.340	0.000	0.002	0.562	0.534	0.000	0.002	0.312
-204	0.139	0.004	0.359	0.005	0.403	0.000	0.002	0.625	0.597	0.000	0.002	0.375
-205	0.139	0.004	0.421	0.005	0.465	0.000	0.002	0.687	0.659	0.000	0.002	0.437
-206	0.139	0.004	0.484	0.005	0.528	0.000	0.002	0.750	0.722	0.000	0.002	0.500
-207	0.139	0.004	0.546	0.007	0.590	0.000	0.002	0.812	0.784	0.000	0.002	0.562
-208	0.139	0.004	0.609	0.009	0.653	0.000	0.002	0.875	0.847	0.000	0.002	0.625
-209	0.139	0.004	0.671	0.009	0.715	0.000	0.002	0.937	0.909	0.000	0.002	0.687
-210	0.139	0.004	0.734	0.010	0.778	0.000	0.002	1.000	0.972	0.000	0.002	0.750
-211	0.139	0.004	0.796	0.010	0.840	0.000	0.002	1.062	1.034	0.000	0.002	0.812
-212	0.139	0.004	0.859	0.010	0.903	0.000	0.002	1.125	1.097	0.000	0.002	0.875
-213	0.139	0.004	0.921	0.010	0.965	0.000	0.002	1.187	1.159	0.000	0.002	0.937
-214	0.139	0.004	0.984	0.010	1.028	0.000	0.002	1.250	1.222	0.000	0.002	1.000
-215	0.139	0.004	1.046	0.010	1.090	0.000	0.002	1.312	1.284	0.000	0.002	1.062
-216	0.139	0.004	1.109	0.012	1.153	0.000	0.002	1.375	1.347	0.000	0.002	1.125
-217	0.139	0.004	1.171	0.012	1.215	0.000	0.002	1.437	1.409	0.000	0.002	1.187
-218	0.139	0.004	1.234	0.012	1.278	0.000	0.002	1.500	1.472	0.000	0.002	1.250
-219	0.139	0.004	1.296	0.012	1.340	0.000	0.002	1.562	1.534	0.000	0.002	1.312
-220	0.139	0.004	1.359	0.012	1.403	0.000	0.002	1.625	1.597	0.000	0.002	1.375
-221	0.139	0.004	1.421	0.012	1.465	0.000	0.002	1.687	1.659	0.000	0.002	1.437
-222	0.139	0.004	1.484	0.015	1.528	0.000	0.002	1.750	1.722	0.000	0.002	1.500
-223	0.139	0.004	1.609	0.015	1.653	0.000	0.002	1.875	1.847	0.000	0.002	1.625
-224	0.139	0.004	1.734	0.015	1.778	0.000	0.002	2.000	1.972	0.000	0.002	1.750
-225	0.139	0.004	1.859	0.015	1.903	0.000	0.002	2.125	2.097	0.000	0.002	1.875
-226	0.139	0.004	1.984	0.018	2.028	0.000	0.002	2.250	2.222	0.000	0.002	2.000
-227	0.139	0.004	2.109	0.018	2.153	0.000	0.002	2.375	2.347	0.000	0.002	2.125
-228	0.139	0.004	2.234	0.020	2.278	0.000	0.002	2.500	2.472	0.000	0.002	2.250
-229	0.139	0.004	2.359	0.020	2.403	0.000	0.002	2.625	2.597	0.000	0.002	2.375
-230	0.139	0.004	2.484	0.020	2.528	0.000	0.002	2.750	2.722	0.000	0.002	2.500
-231	0.139	0.004	2.609	0.020	2.653	0.000	0.002	2.875	2.847	0.000	0.002	2.625
-232	0.139	0.004	2.734	0.024	2.778	0.000	0.002	3.000	2.972	0.000	0.002	2.750
-233	0.139	0.004	2.859	0.024	2.903	0.000	0.002	3.125	3.097	0.000	0.002	2.875
-234	0.139	0.004	2.984	0.024	3.028	0.000	0.002	3.250	3.222	0.000	0.002	3.000
-235	0.139	0.004	3.109	0.024	3.153	0.000	0.002	3.375	3.347	0.000	0.002	3.125
-236	0.139	0.004	3.234	0.024	3.278	0.000	0.002	3.500	3.472	0.000	0.002	3.250
-237	0.139	0.004	3.359	0.024	3.403	0.000	0.002	3.625	3.597	0.000	0.002	3.375
-238	0.139	0.004	3.484	0.024	3.528	0.000	0.002	3.750	3.722	0.000	0.002	3.500
-239	0.139	0.004	3.609	0.028	3.653	0.000	0.002	3.875	3.847	0.000	0.002	3.625
-240	0.139	0.004	3.734	0.028	3.778	0.000	0.002	4.000	3.972	0.000	0.002	3.750
-241	0.139	0.004	3.859	0.028	3.903	0.000	0.002	4.125	4.097	0.000	0.002	3.875
-242	0.139	0.004	3.984	0.028	4.028	0.000	0.002	4.250	4.222	0.000	0.002	4.000
-243	0.139	0.004	4.109	0.028	4.153	0.000	0.002	4.375	4.347	0.000	0.002	4.125
-244	0.139	0.004	4.234	0.030	4.278	0.000	0.002	4.500	4.472	0.000	0.002	4.250
-245	0.139	0.004	4.359	0.030	4.403	0.000	0.002	4.625	4.597	0.000	0.002	4.375

Dimensions in inches.

Table 7-14: Standard Static I.D./O.D. Seal Diametrical Dimensions (continued)

A	B		C		D			E	F			G
Dash Size	O-Ring Cross-Section		O-Ring Diameter		O.D. Sealing Type				I.D. Sealing Type			
					Gland			Bore Dia	Gland			Tube Dia
	Nom	Tol +/-	Nom	Tol +/-	Dia	Tol (+)	Tol (-)	+.002 -.000	Dia	Tol (+)	Tol (-)	+.002 -.000
-246	**0.139**	0.004	**4.484**	0.030	**4.528**	0.000	0.002	**4.750**	**4.722**	0.000	0.002	**4.500**
-247	**0.139**	0.004	**4.609**	0.030	**4.653**	0.000	0.002	**4.875**	**4.847**	0.000	0.002	**4.625**
-248	**0.139**	0.004	**4.734**	0.030	**4.778**	0.000	0.002	**5.000**	**4.972**	0.000	0.002	**4.750**
-249	**0.139**	0.004	**4.859**	0.035	**4.903**	0.000	0.002	**5.125**	**5.097**	0.000	0.002	**4.875**
-250	**0.139**	0.004	**4.984**	0.035	**5.028**	0.000	0.002	**5.250**	**5.222**	0.000	0.002	**5.000**
-251	**0.139**	0.004	**5.109**	0.035	**5.153**	0.000	0.002	**5.375**	**5.347**	0.000	0.002	**5.125**
-252	**0.139**	0.004	**5.234**	0.035	**5.278**	0.000	0.002	**5.500**	**5.472**	0.000	0.002	**5.250**
-253	**0.139**	0.004	**5.359**	0.035	**5.403**	0.000	0.002	**5.625**	**5.597**	0.000	0.002	**5.375**
-254	**0.139**	0.004	**5.484**	0.035	**5.528**	0.000	0.002	**5.750**	**5.722**	0.000	0.002	**5.500**
-255	**0.139**	0.004	**5.609**	0.035	**5.653**	0.000	0.002	**5.875**	**5.847**	0.000	0.002	**5.625**
-256	**0.139**	0.004	**5.734**	0.035	**5.778**	0.000	0.002	**6.000**	**5.972**	0.000	0.002	**5.750**
-257	**0.139**	0.004	**5.859**	0.035	**5.903**	0.000	0.002	**6.125**	**6.097**	0.000	0.002	**5.875**
-258	**0.139**	0.004	**5.984**	0.035	**6.028**	0.000	0.002	**6.250**	**6.222**	0.000	0.002	**6.000**
-259	**0.139**	0.004	**6.234**	0.040	**6.278**	0.000	0.002	**6.500**	**6.472**	0.000	0.002	**6.250**
-260	**0.139**	0.004	**6.484**	0.040	**6.528**	0.000	0.002	**6.750**	**6.722**	0.000	0.002	**6.500**
-261	**0.139**	0.004	**6.734**	0.040	**6.778**	0.000	0.002	**7.000**	**6.972**	0.000	0.002	**6.750**
-262	**0.139**	0.004	**6.984**	0.040	**7.028**	0.000	0.002	**7.250**	**7.222**	0.000	0.002	**7.000**
-263	**0.139**	0.004	**7.234**	0.045	**7.278**	0.000	0.002	**7.500**	**7.472**	0.000	0.002	**7.250**
-264	**0.139**	0.004	**7.484**	0.045	**7.528**	0.000	0.002	**7.750**	**7.722**	0.000	0.002	**7.500**
-265	**0.139**	0.004	**7.734**	0.045	**7.778**	0.000	0.002	**8.000**	**7.972**	0.000	0.002	**7.750**
-266	**0.139**	0.004	**7.984**	0.045	**8.028**	0.000	0.002	**8.250**	**8.222**	0.000	0.002	**8.000**
-267	**0.139**	0.004	**8.234**	0.050	**8.278**	0.000	0.002	**8.500**	**8.472**	0.000	0.002	**8.250**
-268	**0.139**	0.004	**8.484**	0.050	**8.528**	0.000	0.002	**8.750**	**8.722**	0.000	0.002	**8.500**
-269	**0.139**	0.004	**8.734**	0.050	**8.778**	0.000	0.002	**9.000**	**8.972**	0.000	0.002	**8.750**
-270	**0.139**	0.004	**8.984**	0.050	**9.028**	0.000	0.002	**9.250**	**9.222**	0.000	0.002	**9.000**
-271	**0.139**	0.004	**9.234**	0.055	**9.278**	0.000	0.002	**9.500**	**9.472**	0.000	0.002	**9.250**
-272	**0.139**	0.004	**9.484**	0.055	**9.528**	0.000	0.002	**9.750**	**9.722**	0.000	0.002	**9.500**
-273	**0.139**	0.004	**9.734**	0.055	**9.778**	0.000	0.002	**10.000**	**9.972**	0.000	0.002	**9.750**
-274	**0.139**	0.004	**9.984**	0.055	**10.028**	0.000	0.002	**10.250**	**10.222**	0.000	0.002	**10.000**
-275	**0.139**	0.004	**10.484**	0.055	**10.528**	0.000	0.002	**10.750**	**10.722**	0.000	0.002	**10.500**
-276	**0.139**	0.004	**10.984**	0.065	**11.028**	0.000	0.002	**11.250**	**11.222**	0.000	0.002	**11.000**
-277	**0.139**	0.004	**11.484**	0.065	**11.528**	0.000	0.002	**11.750**	**11.722**	0.000	0.002	**11.500**
-278	**0.139**	0.004	**11.984**	0.065	**12.028**	0.000	0.002	**12.250**	**12.222**	0.000	0.002	**12.000**
-279	**0.139**	0.004	**12.984**	0.065	**13.028**	0.000	0.002	**13.250**	**13.222**	0.000	0.002	**13.000**
-280	**0.139**	0.004	**13.984**	0.065	**14.028**	0.000	0.002	**14.250**	**14.222**	0.000	0.002	**14.000**
-281	**0.139**	0.004	**14.984**	0.065	**15.028**	0.000	0.002	**15.250**	**15.222**	0.000	0.002	**15.000**
-282	**0.139**	0.004	**15.955**	0.075	**16.028**	0.000	0.002	**16.250**	**16.222**	0.000	0.002	**16.000**
-283	**0.139**	0.004	**16.955**	0.080	**17.028**	0.000	0.002	**17.250**	**17.222**	0.000	0.002	**17.000**
-284	**0.139**	0.004	**17.955**	0.085	**18.028**	0.000	0.002	**18.250**	**18.222**	0.000	0.002	**18.000**

Dimensions in inches.

Table 7-14: Standard Static I.D./O.D. Seal Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D O.D. Sealing Type			E	F I.D. Sealing Type			G
					Gland			Bore Dia	Gland			Tube Dia
	Nom	Tol +/-	Nom	Tol +/-	Dia	Tol (+)	Tol (-)	+.002 -.000	Dia	Tol (+)	Tol (-)	+.002 -.000
-309	**0.210**	0.005	**0.412**	0.005	**0.472**	0.000	0.004	**0.812**	**0.777**	0.000	0.004	**0.437**
-310	**0.210**	0.005	**0.475**	0.005	**0.535**	0.000	0.004	**0.875**	**0.840**	0.000	0.004	**0.500**
-311	**0.210**	0.005	**0.537**	0.007	**0.597**	0.000	0.004	**0.937**	**0.902**	0.000	0.004	**0.562**
-312	**0.210**	0.005	**0.600**	0.009	**0.660**	0.000	0.004	**1.000**	**0.965**	0.000	0.004	**0.625**
-313	**0.210**	0.005	**0.662**	0.009	**0.722**	0.000	0.004	**1.062**	**1.027**	0.000	0.004	**0.687**
-314	**0.210**	0.005	**0.725**	0.010	**0.785**	0.000	0.004	**1.125**	**1.090**	0.000	0.004	**0.750**
-315	**0.210**	0.005	**0.787**	0.010	**0.847**	0.000	0.004	**1.187**	**1.152**	0.000	0.004	**0.812**
-316	**0.210**	0.005	**0.850**	0.010	**0.910**	0.000	0.004	**1.250**	**1.215**	0.000	0.004	**0.875**
-317	**0.210**	0.005	**0.912**	0.010	**0.972**	0.000	0.004	**1.312**	**1.277**	0.000	0.004	**0.937**
-318	**0.210**	0.005	**0.975**	0.010	**1.035**	0.000	0.004	**1.375**	**1.340**	0.000	0.004	**1.000**
-319	**0.210**	0.005	**1.037**	0.010	**1.097**	0.000	0.004	**1.437**	**1.402**	0.000	0.004	**1.062**
-320	**0.210**	0.005	**1.100**	0.012	**1.160**	0.000	0.004	**1.500**	**1.465**	0.000	0.004	**1.125**
-321	**0.210**	0.005	**1.162**	0.012	**1.222**	0.000	0.004	**1.562**	**1.527**	0.000	0.004	**1.187**
-322	**0.210**	0.005	**1.225**	0.012	**1.285**	0.000	0.004	**1.625**	**1.590**	0.000	0.004	**1.250**
-323	**0.210**	0.005	**1.287**	0.012	**1.347**	0.000	0.004	**1.687**	**1.652**	0.000	0.004	**1.312**
-324	**0.210**	0.005	**1.350**	0.012	**1.410**	0.000	0.004	**1.750**	**1.715**	0.000	0.004	**1.375**
-325	**0.210**	0.005	**1.475**	0.015	**1.535**	0.000	0.004	**1.875**	**1.840**	0.000	0.004	**1.500**
-326	**0.210**	0.005	**1.600**	0.015	**1.660**	0.000	0.004	**2.000**	**1.965**	0.000	0.004	**1.625**
-327	**0.210**	0.005	**1.725**	0.015	**1.785**	0.000	0.004	**2.125**	**2.090**	0.000	0.004	**1.750**
-328	**0.210**	0.005	**1.850**	0.015	**1.910**	0.000	0.004	**2.250**	**2.215**	0.000	0.004	**1.875**
-329	**0.210**	0.005	**1.975**	0.018	**2.035**	0.000	0.004	**2.375**	**2.340**	0.000	0.004	**2.000**
-330	**0.210**	0.005	**2.100**	0.018	**2.160**	0.000	0.004	**2.500**	**2.465**	0.000	0.004	**2.125**
-331	**0.210**	0.005	**2.225**	0.018	**2.285**	0.000	0.004	**2.625**	**2.590**	0.000	0.004	**2.250**
-332	**0.210**	0.005	**2.350**	0.018	**2.410**	0.000	0.004	**2.750**	**2.715**	0.000	0.004	**2.375**
-333	**0.210**	0.005	**2.475**	0.020	**2.535**	0.000	0.004	**2.875**	**2.840**	0.000	0.004	**2.500**
-334	**0.210**	0.005	**2.600**	0.020	**2.660**	0.000	0.004	**3.000**	**2.965**	0.000	0.004	**2.625**
-335	**0.210**	0.005	**2.725**	0.020	**2.785**	0.000	0.004	**3.125**	**3.090**	0.000	0.004	**2.750**
-336	**0.210**	0.005	**2.850**	0.020	**2.910**	0.000	0.004	**3.250**	**3.215**	0.000	0.004	**2.875**
-337	**0.210**	0.005	**2.975**	0.024	**3.035**	0.000	0.004	**3.375**	**3.340**	0.000	0.004	**3.000**
-338	**0.210**	0.005	**3.100**	0.024	**3.160**	0.000	0.004	**3.500**	**3.465**	0.000	0.004	**3.125**
-339	**0.210**	0.005	**3.225**	0.024	**3.285**	0.000	0.004	**3.625**	**3.590**	0.000	0.004	**3.250**
-340	**0.210**	0.005	**3.350**	0.024	**3.410**	0.000	0.004	**3.750**	**3.715**	0.000	0.004	**3.375**
-341	**0.210**	0.005	**3.475**	0.024	**3.535**	0.000	0.004	**3.875**	**3.840**	0.000	0.004	**3.500**
-342	**0.210**	0.005	**3.600**	0.028	**3.660**	0.000	0.004	**4.000**	**3.965**	0.000	0.004	**3.625**
-343	**0.210**	0.005	**3.725**	0.028	**3.785**	0.000	0.004	**4.125**	**4.090**	0.000	0.004	**3.750**
-344	**0.210**	0.005	**3.850**	0.028	**3.910**	0.000	0.004	**4.250**	**4.215**	0.000	0.004	**3.875**
-345	**0.210**	0.005	**3.975**	0.028	**4.035**	0.000	0.004	**4.375**	**4.340**	0.000	0.004	**4.000**
-346	**0.210**	0.005	**4.100**	0.028	**4.160**	0.000	0.004	**4.500**	**4.465**	0.000	0.004	**4.125**
-347	**0.210**	0.005	**4.225**	0.030	**4.285**	0.000	0.004	**4.625**	**4.590**	0.000	0.004	**4.250**
-348	**0.210**	0.005	**4.350**	0.030	**4.410**	0.000	0.004	**4.750**	**4.715**	0.000	0.004	**4.375**
-349	**0.210**	0.005	**4.475**	0.030	**4.535**	0.000	0.004	**4.875**	**4.840**	0.000	0.004	**4.500**
-350	**0.210**	0.005	**4.600**	0.030	**4.660**	0.000	0.004	**5.000**	**4.965**	0.000	0.004	**4.625**

Dimensions in inches.

Table 7-14: Standard Static I.D./O.D. Seal Diametrical Dimensions (continued)

A	B		C		D			E	F			G
Dash Size	O-Ring Cross-Section		O-Ring Diameter		O.D. Sealing Type				I.D. Sealing Type			
					Gland			Bore Dia	Gland			Tube Dia
	Nom	Tol +/-	Nom	Tol +/-	Dia	Tol (+)	Tol (-)	+.002 -.000	Dia	Tol (+)	Tol (-)	+.002 -.000
-351	0.210	0.005	4.725	0.030	4.785	0.000	0.004	5.125	5.090	0.000	0.004	4.750
-352	0.210	0.005	4.850	0.030	4.910	0.000	0.004	5.250	5.215	0.000	0.004	4.875
-353	0.210	0.005	4.975	0.037	5.035	0.000	0.004	5.375	5.340	0.000	0.004	5.000
-354	0.210	0.005	5.100	0.037	5.160	0.000	0.004	5.500	5.465	0.000	0.004	5.125
-355	0.210	0.005	5.225	0.037	5.285	0.000	0.004	5.625	5.590	0.000	0.004	5.250
-356	0.210	0.005	5.350	0.037	5.410	0.000	0.004	5.750	5.715	0.000	0.004	5.375
-357	0.210	0.005	5.475	0.037	5.535	0.000	0.004	5.875	5.840	0.000	0.004	5.500
-358	0.210	0.005	5.600	0.037	5.660	0.000	0.004	6.000	5.965	0.000	0.004	5.625
-359	0.210	0.005	5.725	0.037	5.785	0.000	0.004	6.125	6.090	0.000	0.004	5.750
-360	0.210	0.005	5.850	0.037	5.910	0.000	0.004	6.250	6.215	0.000	0.004	5.875
-361	0.210	0.005	5.975	0.037	6.035	0.000	0.004	6.375	6.340	0.000	0.004	6.000
-362	0.210	0.005	6.225	0.040	6.285	0.000	0.004	6.625	6.590	0.000	0.004	6.250
-363	0.210	0.005	6.475	0.040	6.535	0.000	0.004	6.875	6.840	0.000	0.004	6.500
-364	0.210	0.005	6.725	0.040	6.785	0.000	0.004	7.125	7.090	0.000	0.004	6.750
-365	0.210	0.005	6.975	0.040	7.035	0.000	0.004	7.375	7.340	0.000	0.004	7.000
-366	0.210	0.005	7.225	0.045	7.285	0.000	0.004	7.625	7.590	0.000	0.004	7.250
-367	0.210	0.005	7.475	0.045	7.535	0.000	0.004	7.875	7.840	0.000	0.004	7.500
-368	0.210	0.005	7.725	0.045	7.785	0.000	0.004	8.125	8.090	0.000	0.004	7.750
-369	0.210	0.005	7.975	0.045	8.035	0.000	0.004	8.375	8.340	0.000	0.004	8.000
-370	0.210	0.005	8.225	0.050	8.285	0.000	0.004	8.625	8.590	0.000	0.004	8.250
-371	0.210	0.005	8.475	0.050	8.535	0.000	0.004	8.875	8.840	0.000	0.004	8.500
-372	0.210	0.005	8.725	0.050	8.785	0.000	0.004	9.125	9.090	0.000	0.004	8.750
-373	0.210	0.005	8.975	0.050	9.035	0.000	0.004	9.375	9.340	0.000	0.004	9.000
-374	0.210	0.005	9.225	0.055	9.285	0.000	0.004	9.625	9.590	0.000	0.004	9.250
-375	0.210	0.005	9.475	0.055	9.535	0.000	0.004	9.875	9.840	0.000	0.004	9.500
-376	0.210	0.005	9.725	0.055	9.785	0.000	0.004	10.125	10.090	0.000	0.004	9.750
-377	0.210	0.005	9.975	0.055	10.035	0.000	0.004	10.375	10.340	0.000	0.004	10.000
-378	0.210	0.005	10.475	0.060	10.535	0.000	0.004	10.875	10.840	0.000	0.004	10.500
-379	0.210	0.005	10.975	0.060	11.035	0.000	0.004	11.375	11.340	0.000	0.004	11.000
-380	0.210	0.005	11.475	0.065	11.535	0.000	0.004	11.875	11.840	0.000	0.004	11.500
-381	0.210	0.005	11.975	0.065	12.035	0.000	0.004	12.375	12.340	0.000	0.004	12.000
-382	0.210	0.005	12.975	0.065	13.035	0.000	0.004	13.375	13.340	0.000	0.004	13.000
-383	0.210	0.005	13.975	0.070	14.035	0.000	0.004	14.375	14.340	0.000	0.004	14.000
-384	0.210	0.005	14.975	0.070	15.035	0.000	0.004	15.375	15.340	0.000	0.004	15.000
-385	0.210	0.005	15.955	0.075	16.035	0.000	0.004	16.375	16.340	0.000	0.004	16.000
-386	0.210	0.005	16.955	0.080	17.035	0.000	0.004	17.375	17.340	0.000	0.004	17.000
-387	0.210	0.005	17.955	0.085	18.035	0.000	0.004	18.375	18.340	0.000	0.004	18.000
-388	0.210	0.005	18.955	0.090	19.035	0.000	0.004	19.375	19.340	0.000	0.004	19.000
-389	0.210	0.005	19.955	0.095	20.035	0.000	0.004	20.375	20.340	0.000	0.004	20.000
-390	0.210	0.005	20.955	0.095	21.035	0.000	0.004	21.375	21.340	0.000	0.004	21.000
-391	0.210	0.005	21.995	0.100	22.035	0.000	0.004	22.375	22.340	0.000	0.004	22.000
-392	0.210	0.005	22.940	0.105	23.035	0.000	0.004	23.375	23.340	0.000	0.004	23.000
-393	0.210	0.005	23.940	0.110	24.035	0.000	0.004	24.375	24.340	0.000	0.004	24.000
-394	0.210	0.005	24.940	0.115	25.035	0.000	0.004	25.375	25.340	0.000	0.004	25.000
-395	0.210	0.005	25.940	0.120	26.035	0.000	0.004	26.375	26.340	0.000	0.004	26.000

Dimensions in inches.

Table 7-14: Standard Static I.D./O.D. Seal Diametrical Dimensions (continued)

A	B		C		D			E	F			G
Dash Size	O-Ring Cross-Section		O-Ring Diameter		O.D. Sealing Type				I.D. Sealing Type			
					Gland			Bore Dia	Gland			Tube Dia
	Nom	Tol +/-	Nom	Tol +/-	Dia	Tol (+)	Tol (-)	+.002 -.000	Dia	Tol (+)	Tol (-)	+.002 -.000
-425	0.275	0.006	4.475	0.033	4.548	0.000	0.004	5.000	4.952	0.000	0.004	4.500
-426	0.275	0.006	4.600	0.033	4.673	0.000	0.004	5.125	5.077	0.000	0.004	4.625
-427	0.275	0.006	4.725	0.033	4.798	0.000	0.004	5.250	5.202	0.000	0.004	4.750
-428	0.275	0.006	4.850	0.033	4.923	0.000	0.004	5.375	5.327	0.000	0.004	4.875
-429	0.275	0.006	4.975	0.037	5.048	0.000	0.004	5.500	5.452	0.000	0.004	5.000
-430	0.275	0.006	5.100	0.037	5.173	0.000	0.004	5.625	5.577	0.000	0.004	5.125
-431	0.275	0.006	5.225	0.037	5.298	0.000	0.004	5.750	5.702	0.000	0.004	5.250
-432	0.275	0.006	5.350	0.037	5.423	0.000	0.004	5.875	5.827	0.000	0.004	5.375
-433	0.275	0.006	5.475	0.037	5.548	0.000	0.004	6.000	5.952	0.000	0.004	5.500
-434	0.275	0.006	5.600	0.037	5.673	0.000	0.004	6.125	6.077	0.000	0.004	5.625
-435	0.275	0.006	5.725	0.037	5.798	0.000	0.004	6.250	6.202	0.000	0.004	5.750
-436	0.275	0.006	5.850	0.037	5.923	0.000	0.004	6.375	6.327	0.000	0.004	5.875
-437	0.275	0.006	5.975	0.037	6.048	0.000	0.004	6.500	6.452	0.000	0.004	6.000
-438	0.275	0.006	6.225	0.040	6.298	0.000	0.004	6.750	6.702	0.000	0.004	6.250
-439	0.275	0.006	6.475	0.040	6.548	0.000	0.004	7.000	6.952	0.000	0.004	6.500
-440	0.275	0.006	6.725	0.040	6.798	0.000	0.004	7.250	7.202	0.000	0.004	6.750
-441	0.275	0.006	6.975	0.040	7.048	0.000	0.004	7.500	7.452	0.000	0.004	7.000
-442	0.275	0.006	7.225	0.045	7.298	0.000	0.004	7.750	7.702	0.000	0.004	7.250
-443	0.275	0.006	7.475	0.045	7.548	0.000	0.004	8.000	7.952	0.000	0.004	7.500
-444	0.275	0.006	7.725	0.045	7.798	0.000	0.004	8.250	8.202	0.000	0.004	7.750
-445	0.275	0.006	7.975	0.045	8.048	0.000	0.004	8.500	8.452	0.000	0.004	8.000
-446	0.275	0.006	8.475	0.055	8.548	0.000	0.004	9.000	8.952	0.000	0.004	8.500
-447	0.275	0.006	8.975	0.055	9.048	0.000	0.004	9.500	9.452	0.000	0.004	9.000
-448	0.275	0.006	9.475	0.055	9.548	0.000	0.004	10.000	9.952	0.000	0.004	9.500
-449	0.275	0.006	9.975	0.055	10.048	0.000	0.004	10.500	10.452	0.000	0.004	10.000
-450	0.275	0.006	10.475	0.060	10.548	0.000	0.004	11.000	10.952	0.000	0.004	10.500
-451	0.275	0.006	10.975	0.060	11.048	0.000	0.004	11.500	11.452	0.000	0.004	11.000
-452	0.275	0.006	11.475	0.060	11.548	0.000	0.004	12.000	11.952	0.000	0.004	11.500
-453	0.275	0.006	11.975	0.060	12.048	0.000	0.004	12.500	12.452	0.000	0.004	12.000
-454	0.275	0.006	12.475	0.060	12.548	0.000	0.004	13.000	12.952	0.000	0.004	12.500
-455	0.275	0.006	12.975	0.060	13.048	0.000	0.004	13.500	13.452	0.000	0.004	13.000
-456	0.275	0.006	13.475	0.070	13.548	0.000	0.004	14.000	13.952	0.000	0.004	13.500
-457	0.275	0.006	13.975	0.070	14.048	0.000	0.004	14.500	14.452	0.000	0.004	14.000
-458	0.275	0.006	14.475	0.070	14.548	0.000	0.004	15.000	14.952	0.000	0.004	14.500
-459	0.275	0.006	14.975	0.070	15.048	0.000	0.004	15.500	15.452	0.000	0.004	15.000
-460	0.275	0.006	15.475	0.070	15.548	0.000	0.004	16.000	15.952	0.000	0.004	15.500
-461	0.275	0.006	15.955	0.075	16.048	0.000	0.004	16.500	16.452	0.000	0.004	16.000
-462	0.275	0.006	16.455	0.075	16.548	0.000	0.004	17.000	16.952	0.000	0.004	16.500
-463	0.275	0.006	16.955	0.080	17.048	0.000	0.004	17.500	17.452	0.000	0.004	17.000
-464	0.275	0.006	17.455	0.085	17.548	0.000	0.004	18.000	17.952	0.000	0.004	17.500
-465	0.275	0.006	17.955	0.085	18.048	0.000	0.004	18.500	18.452	0.000	0.004	18.000

Dimensions in inches.

Table 7-14: Standard Static I.D./O.D. Seal Diametrical Dimensions (continued)

A	B		C		D			E	F			G
Dash Size	O-Ring Cross-Section		O-Ring Diameter		O.D. Sealing Type				I.D. Sealing Type			
					Gland			Bore Dia	Gland			Tube Dia
	Nom	Tol +/-	Nom	Tol +/-	Dia	Tol (+)	Tol (-)	+.002 -.000	Dia	Tol (+)	Tol (-)	+.002 -.000
-466	**0.275**	0.006	**18.455**	0.085	**18.548**	0.000	0.004	**19.000**	**18.952**	0.000	0.004	**18.500**
-467	**0.275**	0.006	**18.955**	0.090	**19.048**	0.000	0.004	**19.500**	**19.452**	0.000	0.004	**19.000**
-468	**0.275**	0.006	**19.455**	0.090	**19.548**	0.000	0.004	**20.000**	**19.952**	0.000	0.004	**19.500**
-469	**0.275**	0.006	**19.955**	0.095	**20.048**	0.000	0.004	**20.500**	**20.452**	0.000	0.004	**20.000**
-470	**0.275**	0.006	**20.955**	0.095	**21.048**	0.000	0.004	**21.500**	**21.452**	0.000	0.004	**21.000**
-471	**0.275**	0.006	**21.955**	0.100	**22.048**	0.000	0.004	**22.500**	**22.452**	0.000	0.004	**22.000**
-472	**0.275**	0.006	**22.940**	0.105	**23.048**	0.000	0.004	**23.500**	**23.452**	0.000	0.004	**23.000**
-473	**0.275**	0.006	**23.940**	0.110	**24.048**	0.000	0.004	**24.500**	**24.452**	0.000	0.004	**24.000**
-474	**0.275**	0.006	**24.940**	0.115	**25.048**	0.000	0.004	**25.500**	**25.452**	0.000	0.004	**25.000**
-475	**0.275**	0.006	**25.940**	0.120	**26.048**	0.000	0.004	**26.500**	**26.452**	0.000	0.004	**26.000**

Dimensions in inches.

Dynamic I.D./O.D. Seal, Rectangular Gland Any Pressure Combination

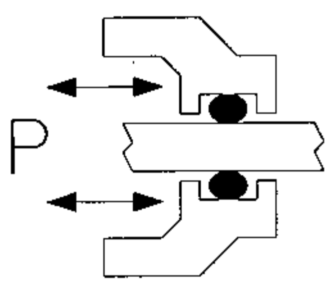


Figure 7-15

If the O-Ring Dash Size Is Known

Step 1. Locate the dash number in Table 7-18, page 71, to determine the O-ring's dimensions from columns "B" and "C."

Step 2. Locate the appropriate gland dimensions in Table 7–18.

Selecting the O-Ring Dash Size

If the O-ring dash size is not known and all gland dimensions are known:

Step 1. Locate the gland's width in Table 7-17, page 70.

Step 2. Select the corresponding O-ring dash size series that matches the gland's width.

Step 3. Locate the gland diameter within the O-ring number series in Table 7-18, page 71, to determine the O-ring's dash size.

If the exact gland dimensions cannot be located in these tables, a nonstandard O-ring may be required. Contact Greene, Tweed Engineering.

To choose both the appropriate gland dimensions and the corresponding O-ring dash number:

Step 1. From Table 7-17, page 70, select the desired O-ring cross-section and its corresponding AS 568A O-ring series. The cross-section selection should be based on the desired sealing footprint and allowable clearances within the hardware. A larger cross-section will result in a wider sealing footprint for a given cross-section squeeze percentage and should be generally preferred.

Step 2. From Table 7-18, page 71, based on hardware requirements for O.D. sealing, select the closest standard bore diameter from column "F" within the O-ring dash size series. For I.D. sealing, select the closest standard rod diameter from column "H" within the O-ring dash size series. Record the dash number. Note: Not all standard O-ring cross-sections are available for all diameters. If the desired gland diameter cannot be found within the dash size series that has been selected, a different cross-section must be selected.

Step 3. With the dash number determined in Step 2, follow the instructions on page 69 to determine complete gland dimensions.

Table 7-17: Standard Dynamic I.D. and O.D. Sealing Gland Cross-Sectional Dimensions

AS 568A Series	O-Ring Cross-Section		Gland Width (W)		Gland Corner Radii	
	Nom	Tol +/-	Nom	Tol +/-	(R1)	(R2)
-000	0.070	0.003	0.095	0.002	0.007	0.005
-100	0.103	0.004	0.142	0.003	0.007	0.005
-200	0.139	0.004	0.189	0.003	0.017	0.005
-300	0.210	0.005	0.283	0.003	0.027	0.005
-400	0.275	0.006	0.377	0.003	0.027	0.005

Dimensions in inches.

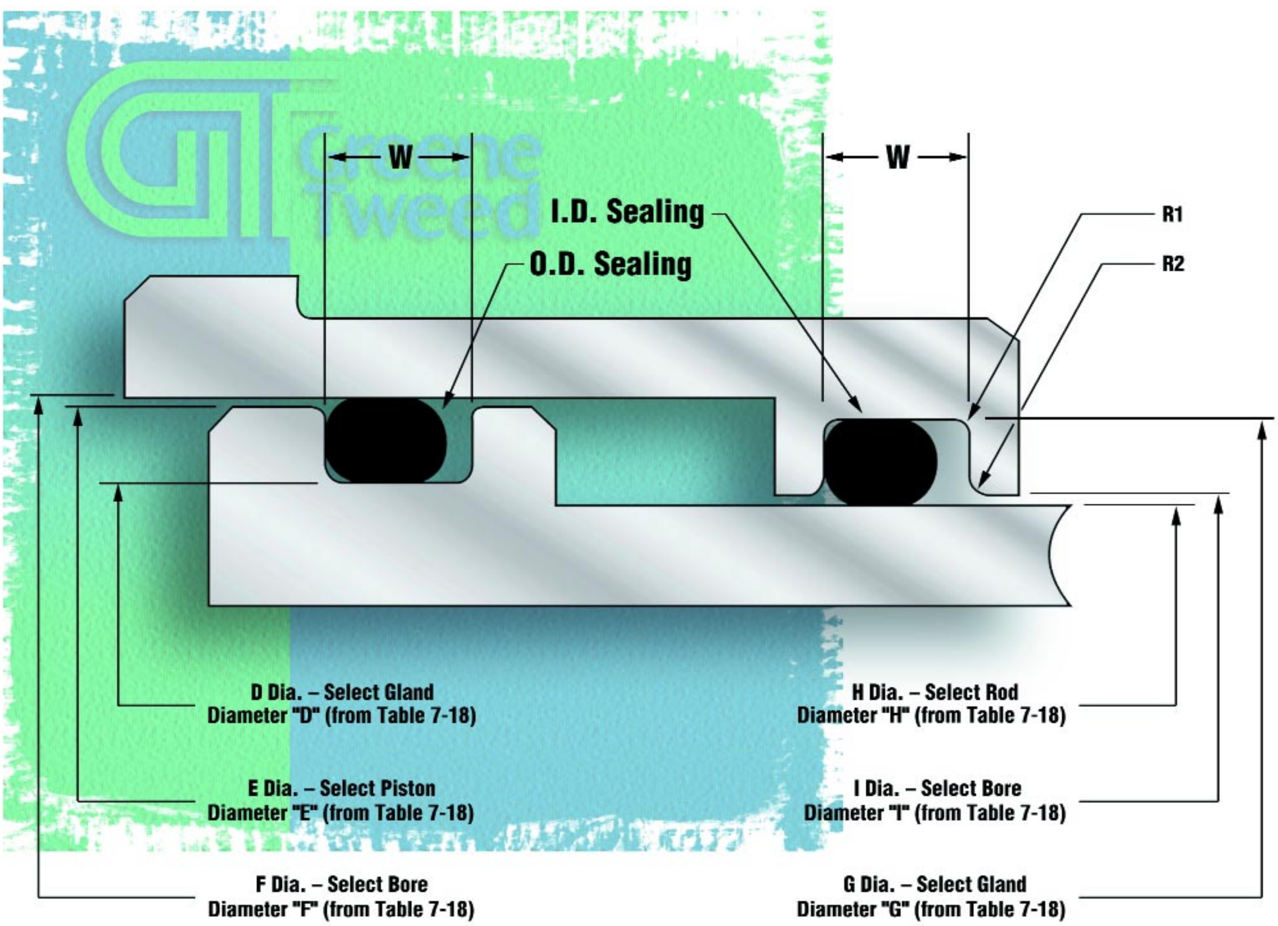


Figure 7-16 *Dynamic I.D./O.D. Sealing Details*

Table 7-18: Standard Dynamic I.D./O.D. Sealing Diametrical Dimensions

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D	E	F	G	H	I
					O.D. Sealing Type			I.D. Sealing Type		
					Gland Dia	Piston Dia	Bore Dia	Gland Dia	Rod Dia	Bore Dia
	Nom	Tol +/-	Nom	Tol +/-	+.000 -.002	+.000 -.001	+.002 -.000	+.002 -.000	+.000 -.002	+.001 -.000
-006	**0.070**	0.003	**0.114**	0.005	**0.139**	**0.247**	**0.249**	**0.234**	**0.124**	**0.126**
-007	**0.070**	0.003	**0.145**	0.005	**0.170**	**0.278**	**0.280**	**0.265**	**0.155**	**0.157**
-008	**0.070**	0.003	**0.176**	0.005	**0.201**	**0.309**	**0.311**	**0.296**	**0.186**	**0.188**
-009	**0.070**	0.003	**0.208**	0.005	**0.233**	**0.341**	**0.343**	**0.328**	**0.218**	**0.220**
-010	**0.070**	0.003	**0.239**	0.005	**0.264**	**0.372**	**0.374**	**0.359**	**0.249**	**0.251**
-011	**0.070**	0.003	**0.301**	0.005	**0.326**	**0.434**	**0.436**	**0.421**	**0.311**	**0.313**
-012	**0.070**	0.003	**0.364**	0.005	**0.389**	**0.497**	**0.499**	**0.484**	**0.374**	**0.376**

Dimensions in inches.

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D	E	F	G	H	I
					O.D. Sealing Type			I.D. Sealing Type		
					Gland Dia	Piston Dia	Bore Dia	Gland Dia	Rod Dia	Bore Dia
	Nom	Tol +/-	Nom	Tol +/-	+.000 -.002	+.000 -.001	+.002 -.000	+.002 -.000	+.000 -.002	+.001 -.000
-104	**0.103**	0.003	**0.112**	0.005	**0.136**	**0.310**	**0.312**	**0.300**	**0.124**	**0.126**
-105	**0.103**	0.003	**0.143**	0.005	**0.167**	**0.341**	**0.343**	**0.331**	**0.155**	**0.157**
-106	**0.103**	0.003	**0.174**	0.005	**0.198**	**0.372**	**0.374**	**0.362**	**0.186**	**0.188**
-107	**0.103**	0.003	**0.206**	0.005	**0.230**	**0.404**	**0.406**	**0.394**	**0.218**	**0.220**
-108	**0.103**	0.003	**0.237**	0.005	**0.261**	**0.435**	**0.437**	**0.425**	**0.249**	**0.251**
-109	**0.103**	0.003	**0.299**	0.005	**0.323**	**0.497**	**0.499**	**0.487**	**0.311**	**0.313**
-110	**0.103**	0.003	**0.362**	0.005	**0.386**	**0.560**	**0.562**	**0.550**	**0.374**	**0.376**
-111	**0.103**	0.003	**0.424**	0.005	**0.448**	**0.622**	**0.624**	**0.612**	**0.436**	**0.438**
-112	**0.103**	0.003	**0.487**	0.005	**0.511**	**0.685**	**0.687**	**0.675**	**0.499**	**0.501**
-113	**0.103**	0.003	**0.549**	0.007	**0.573**	**0.747**	**0.749**	**0.737**	**0.561**	**0.563**
-114	**0.103**	0.003	**0.612**	0.009	**0.636**	**0.810**	**0.812**	**0.800**	**0.624**	**0.626**
-115	**0.103**	0.003	**0.674**	0.009	**0.698**	**0.872**	**0.874**	**0.862**	**0.686**	**0.688**
-116	**0.103**	0.003	**0.737**	0.009	**0.761**	**0.935**	**0.937**	**0.925**	**0.749**	**0.751**

Dimensions in inches.

Table 7-18: Standard Dynamic I.D./O.D. Sealing Diametrical Dimensions (continued)

A	B		C		D	E	F	G	H	I
Dash Size	O-Ring Cross-Section		O-Ring Diameter		O.D. Sealing Type			I.D. Sealing Type		
					Gland Dia	Piston Dia	Bore Dia	Gland Dia	Rod Dia	Bore Dia
	Nom	Tol +/-	Nom	Tol +/-	+.000 -.002	+.000 -.001	+.002 -.000	+.002 -.000	+.000 -.002	+.001 -.000
-201	0.139	0.004	0.171	0.005	0.195	0.434	0.437	0.427	0.185	0.188
-202	0.139	0.004	0.234	0.005	0.258	0.497	0.500	0.490	0.248	0.251
-203	0.139	0.004	0.296	0.005	0.320	0.559	0.562	0.552	0.310	0.313
-204	0.139	0.004	0.359	0.005	0.383	0.622	0.625	0.615	0.373	0.376
-205	0.139	0.004	0.421	0.005	0.445	0.684	0.687	0.677	0.435	0.438
-206	0.139	0.004	0.484	0.005	0.508	0.747	0.750	0.740	0.498	0.501
-207	0.139	0.004	0.546	0.007	0.570	0.809	0.812	0.802	0.560	0.563
-208	0.139	0.004	0.609	0.009	0.633	0.872	0.875	0.865	0.623	0.626
-209	0.139	0.004	0.671	0.009	0.695	0.934	0.937	0.927	0.685	0.688
-210	0.139	0.004	0.734	0.010	0.758	0.997	1.000	0.990	0.748	0.751
-211	0.139	0.004	0.796	0.010	0.820	1.059	1.062	1.052	0.810	0.813
-212	0.139	0.004	0.859	0.010	0.883	1.122	1.125	1.115	0.873	0.876
-213	0.139	0.004	0.921	0.010	0.945	1.184	1.187	1.177	0.935	0.938
-214	0.139	0.004	0.984	0.010	1.008	1.247	1.250	1.240	0.998	1.001
-215	0.139	0.004	1.046	0.010	1.070	1.309	1.312	1.302	1.060	1.063
-216	0.139	0.004	1.109	0.012	1.133	1.372	1.375	1.365	1.123	1.126
-217	0.139	0.004	1.171	0.012	1.195	1.434	1.437	1.427	1.185	1.188
-218	0.139	0.004	1.234	0.012	1.258	1.497	1.500	1.490	1.248	1.251
-219	0.139	0.004	1.296	0.012	1.320	1.559	1.562	1.552	1.310	1.313
-220	0.139	0.004	1.359	0.012	1.383	1.622	1.625	1.615	1.373	1.376
-221	0.139	0.004	1.421	0.012	1.445	1.684	1.687	1.677	1.435	1.438
-222	0.139	0.004	1.484	0.015	1.508	1.747	1.750	1.740	1.498	1.501

Dimensions in inches.

A	B		C		D	E	F	G	H	I
Dash Size	O-Ring Cross-Section		O-Ring Diameter		O.D. Sealing Type			I.D. Sealing Type		
					Gland Dia	Piston Dia	Bore Dia	Gland Dia	Rod Dia	Bore Dia
	Nom	Tol +/-	Nom	Tol +/-	+.000 -.002	+.000 -.001	+.002 -.000	+.002 -.000	+.000 -.002	+.001 -.000
-309	0.210	0.005	0.412	0.005	0.442	0.809	0.812	0.805	0.435	0.438
-310	0.210	0.005	0.475	0.005	0.505	0.872	0.875	0.868	0.498	0.501
-311	0.210	0.005	0.537	0.007	0.567	0.934	0.937	0.930	0.560	0.563
-312	0.210	0.005	0.600	0.009	0.630	0.997	1.000	0.993	0.623	0.626
-313	0.210	0.005	0.662	0.009	0.692	1.059	1.062	1.055	0.685	0.688
-314	0.210	0.005	0.725	0.010	0.755	1.122	1.125	1.118	0.748	0.751
-315	0.210	0.005	0.787	0.010	0.817	1.184	1.187	1.180	0.810	0.813
-316	0.210	0.005	0.850	0.010	0.880	1.247	1.250	1.243	0.873	0.876
-317	0.210	0.005	0.912	0.010	0.942	1.309	1.312	1.305	0.935	0.938
-318	0.210	0.005	0.975	0.010	1.005	1.372	1.375	1.368	0.998	1.001
-319	0.210	0.005	1.037	0.010	1.067	1.434	1.437	1.430	1.060	1.063
-320	0.210	0.005	1.100	0.012	1.130	1.497	1.500	1.493	1.123	1.126

Dimensions in inches.

Table 7-18: Standard Dynamic I.D./O.D. Sealing Diametrical Dimensions (continued)

A	B		C		D	E	F	G	H	I
Dash Size	O-Ring Cross-Section		O-Ring Diameter		O.D. Sealing Type			I.D. Sealing Type		
					Gland Dia	Piston Dia	Bore Dia	Gland Dia	Rod Dia	Bore Dia
	Nom	Tol +/-	Nom	Tol +/-	+.000 -.004	+.000 -.004	+.000 -.004	+.004 -.000	+.004 -.000	+.004 -.000
-321	0.210	0.005	1.162	0.012	1.192	1.559	1.562	1.555	1.185	1.188
-322	0.210	0.005	1.225	0.012	1.255	1.622	1.625	1.618	1.248	1.251
-323	0.210	0.005	1.287	0.012	1.317	1.684	1.687	1.680	1.310	1.313
-324	0.210	0.005	1.350	0.012	1.380	1.747	1.750	1.743	1.373	1.376
-325	0.210	0.005	1.475	0.015	1.505	1.872	1.875	1.868	1.498	1.501
-326	0.210	0.005	1.600	0.015	1.630	1.997	2.000	1.993	1.623	1.626
-327	0.210	0.005	1.725	0.015	1.755	2.122	2.125	2.118	1.748	1.751
-328	0.210	0.005	1.850	0.015	1.880	2.247	2.250	2.243	1.873	1.876
-329	0.210	0.005	1.975	0.018	2.005	2.372	2.375	2.368	1.998	2.001
-330	0.210	0.005	2.100	0.018	2.130	2.497	2.500	2.493	2.123	2.126
-331	0.210	0.005	2.225	0.018	2.255	2.622	2.625	2.618	2.248	2.251
-332	0.210	0.005	2.350	0.018	2.380	2.747	2.750	2.743	2.373	2.376
-333	0.210	0.005	2.475	0.020	2.505	2.872	2.875	2.868	2.498	2.501
-334	0.210	0.005	2.600	0.020	2.630	2.997	3.000	2.993	2.623	2.626
-335	0.210	0.005	2.725	0.020	2.755	3.122	3.125	3.118	2.748	2.751
-336	0.210	0.005	2.850	0.020	2.880	3.247	3.250	3.243	2.873	2.876
-337	0.210	0.005	2.975	0.024	3.005	3.372	3.375	3.368	2.998	3.001
-338	0.210	0.005	3.100	0.024	3.130	3.497	3.500	3.493	3.123	3.126
-339	0.210	0.005	3.225	0.024	3.255	3.622	3.625	3.618	3.248	3.251
-340	0.210	0.005	3.350	0.024	3.380	3.747	3.750	3.743	3.373	3.376
-341	0.210	0.005	3.475	0.024	3.505	3.872	3.875	3.868	3.498	3.501
-342	0.210	0.005	3.600	0.028	3.630	3.997	4.000	3.993	3.623	3.626
-343	0.210	0.005	3.725	0.028	3.755	4.122	4.125	4.118	3.748	3.751
-344	0.210	0.005	3.850	0.028	3.880	4.247	4.250	4.243	3.873	3.876
-345	0.210	0.005	3.975	0.028	4.005	4.372	4.375	4.368	3.998	4.001
-346	0.210	0.005	4.100	0.028	4.130	4.497	4.500	4.493	4.123	4.126
-347	0.210	0.005	4.225	0.030	4.255	4.622	4.625	4.618	4.248	4.251
-348	0.210	0.005	4.350	0.030	4.380	4.747	4.750	4.743	4.373	4.376
-349	0.210	0.005	4.475	0.030	4.505	4.872	4.875	4.868	4.498	4.501

Dimensions in inches.

Table 7-18: Standard Dynamic I.D./O.D. Sealing Diametrical Dimensions (continued)

A Dash Size	B O-Ring Cross-Section		C O-Ring Diameter		D O.D. Sealing Type Gland Dia	E O.D. Sealing Type Piston Dia	F O.D. Sealing Type Bore Dia	G I.D. Sealing Type Gland Dia	H I.D. Sealing Type Rod Dia	I I.D. Sealing Type Bore Dia
	Nom	Tol +/-	Nom	Tol +/-	+.000 -.004	+.000 -.001	+.002 -.000	+.004 -.000	+.000 -.002	+.001 -.000
-425	0.275	0.006	4.475	0.033	4.528	4.998	5.002	4.971	4.497	4.501
-426	0.275	0.006	4.600	0.033	4.653	5.123	5.127	5.096	4.622	4.626
-427	0.275	0.006	4.725	0.033	4.778	5.248	5.252	5.221	4.747	4.751
-428	0.275	0.006	4.850	0.033	4.903	5.373	5.377	5.346	4.872	4.876
-429	0.275	0.006	4.975	0.037	5.028	5.498	5.502	5.471	4.997	5.001
-430	0.275	0.006	5.100	0.037	5.153	5.623	5.627	5.596	5.122	5.126
-431	0.275	0.006	5.225	0.037	5.278	5.748	5.752	5.721	5.247	5.251
-432	0.275	0.006	5.350	0.037	5.403	5.873	5.877	5.846	5.372	5.376
-433	0.275	0.006	5.475	0.037	5.528	5.998	6.002	5.971	5.497	5.501
-434	0.275	0.006	5.600	0.037	5.653	6.123	6.127	6.096	5.622	5.626
-435	0.275	0.006	5.725	0.037	5.778	6.248	6.252	6.221	5.747	5.751
-436	0.275	0.006	5.850	0.037	5.903	6.373	6.377	6.346	5.872	5.876
-437	0.275	0.006	5.975	0.037	6.028	6.498	6.502	6.471	5.997	6.001
-438	0.275	0.006	6.225	0.040	6.278	6.748	6.752	6.721	6.247	6.251
-439	0.275	0.006	6.475	0.040	6.528	6.998	7.002	6.971	6.497	6.501
-440	0.275	0.006	6.725	0.040	6.778	7.248	7.252	7.221	6.747	6.751
-441	0.275	0.006	6.975	0.040	7.028	7.498	7.502	7.471	6.997	7.001
-442	0.275	0.006	7.225	0.045	7.278	7.748	7.752	7.721	7.247	7.251
-443	0.275	0.006	7.475	0.045	7.528	7.998	8.002	7.971	7.497	7.501
-444	0.275	0.006	7.725	0.045	7.778	8.248	8.252	8.221	7.747	7.751
-445	0.275	0.006	7.975	0.045	8.028	8.498	8.502	8.471	7.997	8.001
-446	0.275	0.006	8.475	0.055	8.528	8.998	9.002	8.971	8.497	8.501
-447	0.275	0.006	8.975	0.055	9.028	9.498	9.502	9.471	8.997	9.001
-448	0.275	0.006	9.475	0.055	9.528	9.998	10.002	9.971	9.497	9.501
-449	0.275	0.006	9.975	0.055	10.028	10.498	10.502	10.471	9.997	10.001
-450	0.275	0.006	10.475	0.060	10.528	10.998	11.002	10.971	10.497	10.501
-451	0.275	0.006	10.975	0.060	11.028	11.498	11.502	11.471	10.997	11.001
-452	0.275	0.006	11.475	0.060	11.528	11.998	12.002	11.971	11.497	11.501
-453	0.275	0.006	11.975	0.060	12.028	12.498	12.502	12.471	11.997	12.001
-454	0.275	0.006	12.475	0.060	12.528	12.998	13.002	12.971	12.497	12.501
-455	0.275	0.006	12.975	0.060	13.028	13.498	13.502	13.471	12.997	13.001
-456	0.275	0.006	13.475	0.070	13.528	13.998	14.002	13.971	13.497	13.501
-457	0.275	0.006	13.975	0.070	14.028	14.498	14.502	14.471	13.997	14.001
-458	0.275	0.006	14.475	0.070	14.528	14.998	15.002	14.971	14.497	14.501
-459	0.275	0.006	14.975	0.070	15.028	15.498	15.502	15.471	14.997	15.001
-460	0.275	0.006	15.475	0.070	15.528	15.998	16.002	15.971	15.497	15.501

Dimensions in inches.

GLOSSARY OF FLUID SEALING TERMS

Section A: General Definitions

fluid	Any gas or liquid.
gland	A cavity into which a seal is installed, including the groove and mating surface which confine the seal.
seal	Any device that prevents the passage of a fluid.

Section B: Seals and Related Components

anti-extrusion ring	Ring installed on the low pressure side of a seal to prevent extrusion into the clearance between the supporting metal parts.
backup ring	See *anti-extrusion ring*.
composite seal	Seal composed of two or more materials of differing flexibility or hardness, usually bonded together.
double-acting seal	Seal to prevent the passage of fluid from either direction relative to its axis.
dynamic seal	Seal designed to prevent leakage between adjacent surfaces which move relative to each other.
face seal	Device which seals by means of axial contact pressure, usually between two surfaces in a plane at right angles to the axis.
gasket	Static seal made from deformable material and compressed between plane surfaces.
lip seal	Seal having one or more axially extending flexible members which form the sealing surfaces.
O-ring seal	Ring of toroidal form, usually of elastomeric material.
O-ring seal, trapped	A type of seal using an O-ring with a special groove form. Typically a dovetail shape.
rectangular section	Ring of rectangular cross-section, usually of elastomeric seal material.
single-acting seal	A seal which prevents the passage of fluid from one direction only, relative to its axis.

static seal	A seal in which there is no relative motion between the adjacent surfaces being sealed.
toroidal seal	See *O-ring seal.*
U-ring seal	Seal of substantially "U" section having either flat or round base fitted with axially extending "lips" toward the pressure to be sealed.
wiper ring	A device to keep out dirt or other foreign matter.

Section C: Common Sealing Terms

axial interference	Difference in dimension between the axial width of a seal and the axial space into which it is installed.
break-away friction	Frictional force required to start a body in motion over a surface.
break-out friction	See *break-away friction.*
coefficient of friction	The force in the direction of motion required to move one surface with respect to another divided by the force normal to the two surfaces.
diametral interference	Difference between the I.D. (inside diameter) of the seal and the shaft diameter, or between the O.D. (outside diameter) of the seal and the housing diameter.
extrusion	Displacement of part of a seal into the extrusion gap under the action of fluid pressure or thermal expansion.
extrusion gap	The clearance on the low-pressure side between components which confine the seal.
heel	The part of a U-ring adjacent to the extrusion gap on the nonpressure side.
interference load	Pressure loading which arises at the surface to be sealed, caused by deformation of the seal material during assembly.
inter-seal pressure	Fluid pressure which may in some circumstances arise between two seals fitted to a double-acting piston.
kinetic friction	Minimum frictional force required to maintain a body in motion sliding over a surface.
lip	That part of a U-ring seal which forms the sealing surface.

radial interference Difference in dimension between the radial section of a seal and the radial space into which it is installed.

running friction See *kinetic friction*.

squeeze The deformation of a seal caused by the difference in dimension between the seal and the space into which it is installed.

static friction See *break-away friction*.

stick-slip The jerky motion of one surface when it is dragged across another surface.

stiction The increase in static friction which occurs with time of stationary contact of a seal.

Section D: Elastomeric Materials

aging Changes in rubber occurring with the passage of time. Qualification of this term is usually necessary, e.g., heat aging, light aging.

aging test, accelerated Test in which an attempt is made to produce and measure effects of natural aging in a shorter time.

air trap Unintentional void in a rubber molding.

antioxidant Compounding ingredient used to retard deterioration caused by oxidation.

antiozonant Compounding ingredient used to retard deterioration caused by ozone.

atmospheric or ozone cracking Cracks produced in the tensioned surface of rubber by exposure to the ozone of the atmosphere.

back-rinding Defect in which the rubber adjacent to the flash line shrinks below the level of the molding.

blister Bubble of air or gas indicated by a protrusion on the surface of a molded rubber part.

bloom Material which has diffused to the surface of rubber to give a cloudy or milky discoloration. It does not usually impair usefulness.

brittle point Temperature at which a material breaks under defined conditions of deformation.

butt joint	Joint made with the two ends cut at right angles to the length of material.
chalking	Formation of a powdery surface condition due to disintegration of surface binder or elastomer, caused by weathering or other destructive environments.
composition	Kinds and proportions of ingredients for or in a mix.
compound	Mixture of rubber with compounding ingredients; sometimes referred to as a mix.
compounding ingredients	Material or substance added to a rubber to form a mix.
compression molding	Molding process in which the blank is placed directly in the mold cavity and compressed to shape by closure of the mold.
compression set	The residual deformation of a material after removal of a compressive stress.
copolymer	A polymer in which the molecules are of two or more different kinds.
creep	A time dependent deformation of a material under load.
curatives	Chemicals such as sulfur which, generally with the application of heat, bring about cross-linkage of polymer molecules, usually termed Vulcanization or curing.
cure	Vulcanization; conditions necessary to produce a given state of vulcanization.
cure date	Date when rubber parts were molded.
curing agent	See *curatives*.
Durometer	An instrument for measuring the hardness of rubber. Measures resistance of the rubber surface to deformation by an indentor point.
durometer	A numerical scale of rubber hardness.
elasticity	The tendency of a body to return to its original size and shape after being deformed.
elastomer	Macromolecular material which can return rapidly to the approximate shape from which it has been substantially distorted by a weak stress. Elastic, rubber-like material.

elongation Increase in length caused by a tensile force and expressed numerically as a fraction or percentage of the initial length.

elongation, ultimate Increase (expressed as a percentage) in original length of a specimen when it reaches its breaking point. See *elongation.*

flash Excess material protruding from the surface of a molded part, appearing on a mold parting line or mold vent points.

flash line A raised ridge or "witness" produced on a molding by flow of material into the junction between separate parts of the mold.

flex cracking Surface cracking induced by repeated bending or flexing.

flow crack Surface imperfection due to improper flow and failure of the material to knit or blend with itself during the molding operation.

flow mark Mark or line on a molding, caused by imperfect fusion of flowing fronts.

fluoroelastomer A polymeric material which is partially fluorinated (some hydrogen positions replaced by fluorine) and which exhibits good chemical resistance.

formulation Kinds and proportions of ingredients for a mix, together with the method by which they are to be incorporated.

gas trap See *air trap.*

hardness A material's ability to resist a distorting force. Measured by the relative resistance of the material to an indentor point. See *durometer.*

hysteresis The energy lost in a complete cycle of deformation and retraction.

injection molding Molding process in which mix is forced into a closed heated mold from a separate chamber.

low-temperature effects Changes induced by low temperature are primarily physical and are reversible. When warmed, an elastomer will regain its original properties.

migration Transfer of ingredient from an elastomeric compound to a material with which it is in contact.

migration stain Stain caused by migration.

mismatch A defect produced from a mold whose parts are not in register. Generally a break or step in a supposedly continuous surface.

mix See *compound*.

modulus Tensile stress measured at a particular strain and expressed in psi. Normally defined at 50% or 100% strain.

mold mark Surface imperfection transferred to a molding from a corresponding mark in a mold.

molding shrinkage Decreased dimensions of a rubber molding, compared with mold cavity, arising from difference in coefficient of thermal expansion of the rubber material and the mold material and the chemical change produced by curing.

offset See *mismatch*.

parting line See *flash line*.

perfluoroelastomer A fully fluorinated (all hydrogen positions replaced by fluorine) polymeric material exhibiting high resistance to chemical attack.

permanent set Permanent distortion of an elastomer after deformation.

plasticizer Petroleum derivative or ester-type material added to a mix which increases the processibility, gives control over the hardness and plasticity, and strongly influences the low-temperature characteristics.

pockmark Shallow depression on the surface of a molding.

polymer (elastomeric) Result of a chemical linking of molecules into a long chain-like structure. Natural and synthetic rubbers and rubber-like materials are polymers.

reinforcing agent Compounding ingredient used to increase one or more of the three properties: abrasion resistance, tear resistance and tensile strength.

resilience Ratio of energy returned to energy input when rubber is made to undergo a single cycle of rapid deformation.

rubber Macromolecular material which has, or can be given, properties of:
(a) returning rapidly (at room temperature) to the approximate shape from which it has been substantially distorted by a weak stress, and
(b) not being easily remolded to a permanent shape by the application of heat and moderate pressure.
NOTE: The term “rubber” is also applied to articles made from rubber.

rubber, natural Rubber formed by a living plant.

rubber, synthetic Rubber other than natural rubber.

scarf joint	Joint made by cutting the ends of a length of material at an angle to correspond to each other and overlapping them.
scorch	Premature curing of an unvulcanized rubber as a result of subjecting it to an excessive amount of heat during processing.
spew	Excess material forced from a mold on closure under pressure.
stress relaxation	Decrease in stress occurring with lapse of time in a body in constant strain or deformation.
tear resistance	The ability of a material to resist the enlargement of a nick or cut, when tension is applied to the damaged specimen. Normally, this is expressed as "pounds per inch thickness."
tensile strength	Maximum tensile stress applied uniformly over the cross-section of the test piece in the course of stretching the test piece to rupture. By convention, calculated on the original cross-section.
tension set	Ratio of the residual lengthening of a test piece, after stretching and release, to the initial length after a given lapse of time.
thermoplasticity	Ability to exhibit plastic flow with rise of temperature and to revert to comparative rigidity on cooling and to repeat the cycle indefinitely.
TR-10	A test for approximating the low-temperature capabilities of an elastomer compression seal.
transfer molding	Molding process in which a quantity of mix is forced into a closed heated cavity or cavities from a heated chamber integral with the mold.
volume change	The change in a seal's volume resulting from immersion in a fluid. This is usually expressed in terms of a percentage of the original seal volume.
volume shrinkage	Decreased physical size caused by the extracting action of a fluid or by heat, expressed as a percent volume change.
volume swell	Increased physical size caused by the absorption of a fluid, expressed as a percent volume change.
Vulcanizate	Product of Vulcanization.
Vulcanization	Process of changing the chemical structure of rubber, converting it so that the elastomeric state exists over a greater range of temperature; in some cases the process is extended so that the substance becomes rigid.

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