Section X – Appendix

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Appendix

10.1. O-Ring Failure Modes

Like any device subject to judgment in design or to human error during installation, O-ring seals are susceptible to failure. The following brief summary of O-ring failure patterns is intended to give the designer/engineer a brief overview of the more common types of failure and a listing of recommended corrective actions. While there are a number of different types and causes of seal failure, we intend to cover only the types encountered most frequently. For a more complete listing of O-ring failure modes, Parker suggests the engineer obtain a copy of Publication AIR1707, Patterns of O-Ring Failure, available from:

SAE Inc.
400 Commonwealth Drive
Warrendale, PA 15095
www.sae.org

AIR1707, Patterns of O-Ring Failure, contains extensive material and some excellent photographs and will be most helpful for identifying the less common modes of O-ring failure not covered in this guide.

10.1.1 Why an O-Ring Fails Prematurely

The premature failure of an O-ring in service can usually be attributed to a combination of causes and not merely a single failure mode. It is important to maximize sealing life and reliability by reducing the probability of seal failure at the onset by the use of good design practices, proper compound selection, pre-production testing, and continued education and training of assembly personnel.

10.1.1.1 Compression Set

Probably the most common cause of O-ring failure is compression set. An effective O-ring seal requires a continuous "seal line" between the sealed surfaces. The establishment of this "seal line" is a function of gland design and seal cross-section which determines the correct amount of squeeze (compression) on the O-ring to maintain seal integrity without excessive deformation of the seal element. (See Section II, Basic O-Ring Elastomers, for an in-depth discussion of compression set and Section IV, Static O-Ring Sealing, for information on correct gland design.)

There are a number of factors that can contribute to compression set failure of an O-ring seal. They are listed below. Figure 10-1 provides an illustration of characteristic compression set. See Table 10-1 for a failure analysis and corrective action discussion.

Figure 10-1: Characteristic compression set — high deformation -seen as flattening on all contact surfaces.

Compression Set

Failure Analysis

In general, Compression Set is caused by one or more of the following conditions:

1. Selection of O-ring material with inherently poor compression set properties.
2. Improper gland design.
3. Excessive temperature developed causing the O-ring to harden and lose its elastic properties. (High temperatures may be caused by system fluids, external environmental factors, or frictional heat build-up.)
4. Volume swell of the O-ring due to system fluid.
5. Excessive squeeze due to over tightening of adjustable glands.
6. Incomplete curing (vulcanization) of O-ring material during production.
7. Introduction of fluid incompatible with O-ring material.

Prevention/Correction

Suggested solutions to the causes of compression set are:

1. Use "Low-Set" O-ring material whenever possible.
2. Select O-ring material compatible with intended service conditions.
3. Reduce system operating temperature.
4. Check frictional heat build-up at seal interface and reduce if excessive.
5. Inspect incoming O-ring shipments for correct physical properties. (Requesting the Parker C.B.I. number will be of great assistance in this area. For a complete discussion of this exclusive Parker service, look later in this section.)

Identification of Compression Set Failure

A typical example of classic O-ring compression set in simplistic terms: the O-ring ceases to be "O" shaped and is permanently deformed into a flat sided oval, the flat sides of which were the original seal interface under compression before failure.

Table 10-1: Compression Set Failure Analysis

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10.1.1.2 Extrusion and Nibbling

Extrusion and nibbling of the O-ring is a primary cause of seal failure in dynamic applications such as hydraulic rod and piston seals. This form of failure may also be found from time to time in static applications subject to high pressure pulsing which causes the clearance gap of the mating flanges to open and close, trapping the O-ring between the mating surfaces. See Table 10-2 for a failure analysis and corrective action discussion. Figure 10-2 shows an example of an extruded and "nibbled" O-ring.

Figure 10-2: Extruded O-Ring

Extrusion and Nibbling

Failure Analysis

In general, extrusion and nibbling are caused by one or more of the following conditions:

1. Excessive clearances.
2. High pressure (in excess of system design or high pressure excursions).
3. O-ring material too soft.
4. Degradation (swelling, softening, shrinking, cracking, etc.) of O-ring material by system fluid.
5. Irregular clearance gaps caused by eccentricity.
6. Increase in clearance gaps due to excessive system pressure.
7. Improper machining of O-ring gland (sharp edges).
8. Improper size (too large) O-ring installed causing excessive filling of groove.

Prevention/Correction

Suggested solutions to the causes of Extrusion and Nibbling listed above are:

1. Decrease clearance by reducing machining tolerances.
2. Use back-up devices. (See Section VI, ParBack Back-Up Rings, for information on Parker Parbak anti-extrusion devices.)
3. Check O-ring material compatibility with system fluid.
4. Increase rigidity of metal components.
5. Replace current O-ring with a harder O-ring.
6. Break sharp edges of gland to a minimum radius 0.005 inches.
7. Insure installation of proper size O-rings.
8. Use alternative seal shape, for example, in some long stroke piston or rod applications, the Parker T-Seal, with its built-in back-up rings, may prevent extrusion and spiral failure.

Identification of Extrusion Failure

A typical example of O-ring extrusion is when edges of the ring on the low pressure or downstream side of the gland exhibit a "chewed" or "chipped" appearance. In an O-ring that has failed due to nibbling, it may have the appearance that many small pieces have been removed from the low pressure side. In some forms of extrusion, more than 50% of the O-ring may be destroyed before catastrophic leakage is observed.

Table 10-2: Extrusion and Nibbling Failure Analysis

10.1.1.3 Spiral Failure

Spiral failure of an O-ring is often found on long stroke hydraulic piston seals and to a lesser degree on rod seals. This type of O-ring failure is caused when the seal becomes "hung-up" at one point on its diameter (against the cylinder wall) and slides and rolls at the same time. The resultant twisting of the O-ring as the sealed device is cycled finally causes the seal to develop a series of deep spiral cuts (usually at a 45° angle) on the surface of the seal. (For more complete discussion on spiral failure, see Section IV, Static O-Ring Sealing).

Table 10-3 provides a discussion of spiral failure analysis. Figure 10-3 illustrates spiral failures.

Spiral Failure

Failure Analysis

As stated above, spiral failure is generally caused by an O-ring both sliding and rolling at the same time. Conditions which may cause this to occur are:

1. Eccentric components.
2. Wide clearance combined with side loads.
3. Uneven surface finishes.
4. Inadequate or improper lubrication.
5. O-ring too soft.
6. Stroke speed (usually too slow).
7. Improper installation (O-ring pinched or rolled).

Prevention/Correction

Suggested solutions to the causes of spiral failure are as follows:

1. Improve surface finish of sealed assembly at dynamic interface (Cylinder Bore, Piston Rod).
2. Check for out-of-round components (Cylinder Bores especially).
3. Provide proper lubrication. Consider the use of internally lubed O-rings.
4. Replace with a harder O-ring.
5. Consider use of alternate seal shapes. for example, the Parker T-seal is specifically designed to prevent spiral failure and its use will allow for increased tolerances because of built-in anti-extrusion back-up rings. Parker T-Seals are available to fit a number of standard AS568 O-ring grooves and may directly interchange with O-rings in most cases.

Identification of Spiral Failure

You will see the typical cuts that gave this type of O-ring failure its name.

Table 10-3: Spiral Analysis

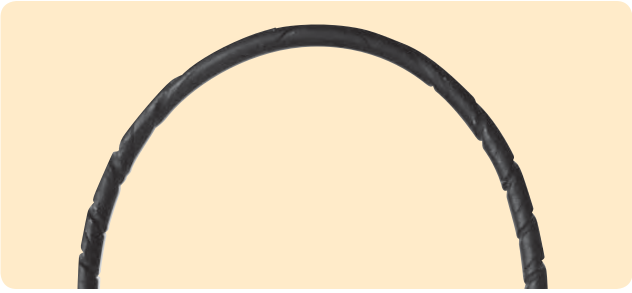

Figure 10-3: Twisted O-ring with spiral marking, or with spiral cuts in surface

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10.1.1.4 Explosive Decompression

As system pressures increase we are seeing this type of O-ring failure with more frequency. It might be termed O-ring embolism, in that after a period of service under high pressure gas, when the pressure is reduced too rapidly, the gas trapped within the internal structure of the O-ring expands rapidly, causing small ruptures or embolisms on the O-ring surface.

Table 10-4 provides a failure analysis discussion. Figure 10-4 illustrates an O-ring damaged by explosive decompression.

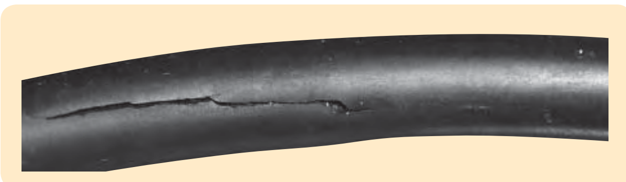

Figure 10-4: O-Ring Damaged by Explosive Decompression

Explosive Decompression

Failure Analysis

Explosive decompression or gas expansion rupture is caused by high pressure gas trapped within the internal structure of the elastomeric seal element. Rapid decrease in system pressure causes the trapped gas to expand to match the external pressure and this expansion causes blisters and ruptures on the seal surface. If the volume of trapped gas is small, the blisters may recede as the pressure is equalized with little effect on seal integrity. Excessive trapped gas may cause total destruction of the seal. (Refer to Section III, O-Ring Applications, for more information on this problem.)

Prevention/Correction

Suggested solutions to explosive decompression are:

1. Increase decompression time to allow trapped gas to work out of seal material.
2. Choose a seal material with good resistance to explosive decompression.
3. If problem persists and pressures are very high, consider use of Parker Metal Seals.

Identification of Explosive Decompression Failure

The seal subjected to explosive decompression will often exhibit small pits or blisters on its surface. In severe cases, examination of the internal structure of the O-ring will reveal other splits and fissures.

Table 10-4 Explosive Decompression Failure Analysis

10.1.1.5 Abrasion

Another rather common type of O-ring failure is abrasion. This usually is found only in dynamic seals subject either to reciprocating, oscillating, or rotary motion. Possible causes of O-ring abrasion are listed in Table 10-5. Figure 10-5 shows wear on an O-ring.

Abrasion

Failure Analysis

In general, abrasion of O-ring seals is caused by one or more of the following:

1. Improper finish of the surface in dynamic contact with the O-ring. This surface finish may be too rough, acting as an abrasive, or too smooth, causing inadequate lubrication due to inability of surface to hold lubricant.
2. Improper lubrication provided by system fluid.
3. Excessive temperatures.
4. Contamination of system fluid by abrasive particles.

Prevention/Correction

Suggested solutions to problems caused by abrasion are:

1. Use proper surface finish (see surface finish in Dynamic Seals section).
2. Provide adequate lubrication by use of proper system fluid.
3. Consider use of internally lubricated O-rings to reduce friction and wear.
4. Check for contamination of fluid and eliminate source. Install filters if necessary.
5. Consider changing to an O-ring material with improved abrasion resistance.

Table 10-5: Abrasion Failure Analysis

Figure 10-5: Wear is Seen as Flattening of O-ring on One Side

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10.1.1.6 Installation Damage

Many O-ring failures can be directly attributed to improper installation. In spite of its simple appearance, the O-ring is a precision device requiring care during installation. Some of the more frequent causes of O-ring failure due to careless handling are listed in Table 10-6.

Installation Damage

Failure Analysis

Damage to an O-ring during installation can occur when:

1. There are sharp corners on mating metal components such as the O-ring gland or threads over which the O-ring must pass during assembly.
2. Insufficient lead-in chamfer.
3. Blind grooves in multi-port valves.
4. Oversize O-ring on piston seal application.
5. Undersize O-ring on rod application.
6. O-ring twisted/pinched during installation.
7. O-ring not properly lubricated before installation.
8. O-ring dirty upon installation.
9. O-ring gland and/or other surfaces over which O-ring must pass during assembly contaminated with metal particles.
10. General Carelessness.

Prevention/Correction

Probably the best way to prevent damage to O-rings during installation is the use of good old-fashioned "Common Sense." There are some specific solutions which are listed below:

1. Break all sharp edges on metal components.
2. Provide a 20° lead-in chamfer.
3. Check all components for cleanliness before installation.
4. Tape all threads over which the O-ring will pass.
5. Use an O-ring lubricant such as Parker O-Lube or Parker Super O-Lube if its use will not contaminate system.
6. Double check O-ring to ensure correct size and material.
7. Be CAREFUL.

Table 10-6: Installation Damage Failure Analysis

10.1.1.7 Other Causes of O-Ring Failure

Damages to O-rings can be caused by compounding of the causes described in paragraphs 10.1.2.1 through 10.1.2.6. Upon failure of an O-ring check all causes mentioned above.

Although not illustrated here, there are several other possible causes of O-ring failure. They are:

1. Weather and ozone degradation
2. Heat aging and oxidation
3. Loss of plasticizer(s)

If you encounter an unusual type of O-ring failure or are unable to identify a particular failure mode, please feel free to contact the O-Ring Division Applications Engineering Department for assistance. In most cases these experienced engineers will be able to offer both an identification of the problem and a number of possible solutions.

10.1.2 Assembly Hints

Leak-free seals are achieved only when a proper sealing material is selected in the right size and sufficiently deformed. Correct deformation depends on observance of machine element tolerances and surface finishes. In practical terms all factors influencing the seal must be considered. Inadequate or improper assembly will lead to high servicing costs and subsequent downtime.

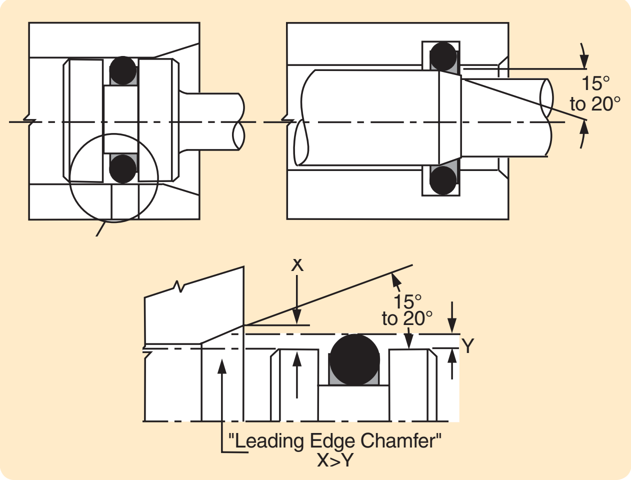

Figure 10-6: Chamfers

10.1.2.1 Chamfers

To prevent damaging of seals during assembly, chamfers are necessary on all leading edges. All edges must be free from burrs and sharp edges bevelled.

Figure 10-6 shows the leading edge chamfer and an O-ring before deformation. The dimension X should be greater than dimension Y to ensure a trouble-free assembly operation.

10.1.2.2 Traversing of Cross-Drilled Ports

An O-ring can be sheared when a spool or rod moves in a bore broken by cross-drilled ports. The deformed O-ring returns to its original round cross-section as it enters the port and is sheared as it leaves the drilled area. To avoid this, connection holes should be repositioned. If repositioning is not possible, an internal chamfer is recommended.

Optimal solution is the relief of the bore on complete circumference which allows the O-ring to return to a round cross-section before being compressed again. See Figure 10-7.

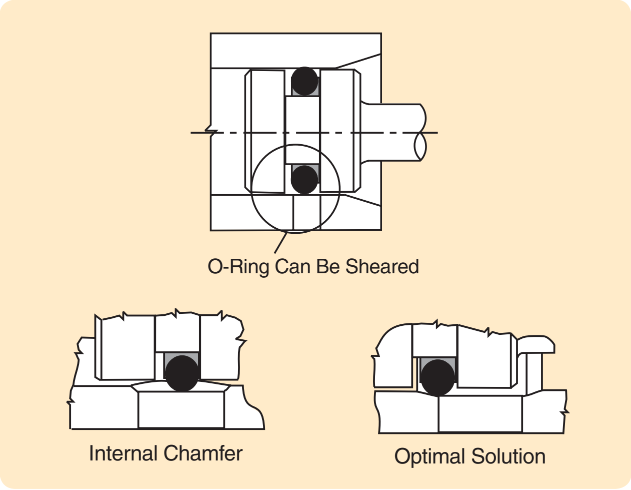

Figure 10-7: Drilled Port Assembly

Appendix

10.1.2.3 Cleanliness and Cleaning Materials

Lack of cleanliness of O-ring glands leads to leakage. To ensure protection from foreign particles of sealing faces during working life it is necessary to use filters or to plan maintenance cycles.

Cleaning material must also be a medium which is compatible with the elastomer. Also grease used to ease assembly must be compatible.

10.1.2.4 Stretching for Assembly

O-rings or back-up rings can be stretched during assembly by 50% of their inner diameters. With small inner diameters the percentage can be significantly greater eventually becoming critical.

It therefore is important to ensure that the stretch remains less than elongation at break given in compound data sheets. If an O-ring is stretched to near its elastic limit it will still return to its original size after a short delay.

10.1.2.5 Rolling

O-rings of large inner diameters and small cross-sections tend to roll during assembly. An O-ring rolled during fitting can be prone to spiral failure (cf. paragraph 10.1.2.3) or tend to leak. See Figure 10-8.

10.1.2.6 Sharp Edges

O-rings should not be forced over sharp edges, threads, slits, bores, glands, splines, etc. Such sharp edges must be removed or covered. Fitting aids assist assembly and thus avoid sharp edges. See Figures 10-9 and 10-10.

10.1.3 Failure Mode and Effects Analysis for Customers

Parker Seal has a wide network of people who are trained to analyze your requirements and assist in suggesting intelligent solutions to specific problems during all stages…design…prototype…testing…qualification…specification writing…and purchasing. All these services can be supplied by a trained Parker Territory Sales Manager or Parker Distributor.

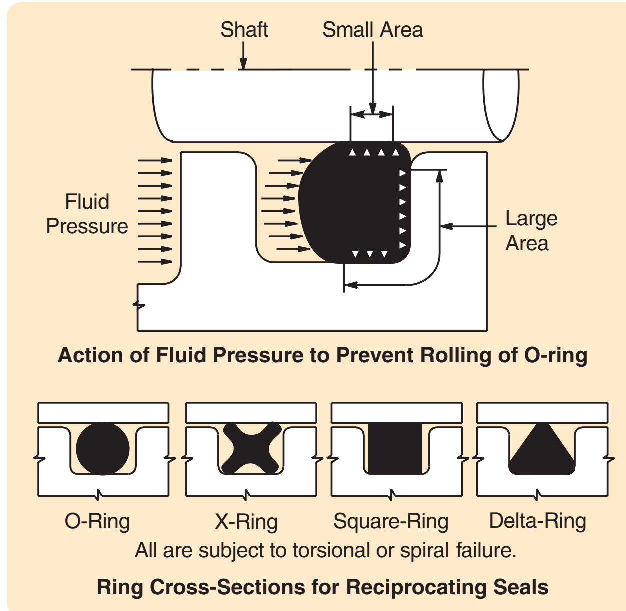

Figure 10-8: Rolling of O-ring

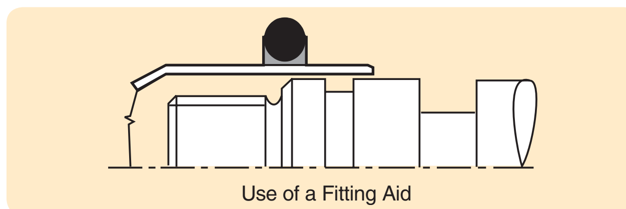

Figure 10-9: Use of a Fitting Aid

Parker Territory Sales Managers serving customers in the field are trained to recognize undesirable or uneconomical proposed applications in favor of those that are logical and cost efficient. You can count on your Parker Territory Sales Manager and your Parker Distributor to give you good counsel. They can help you in many ways — preparation of preliminary sketches, submission of working samples for test and evaluation, and even during qualification of a component or entire assembly.

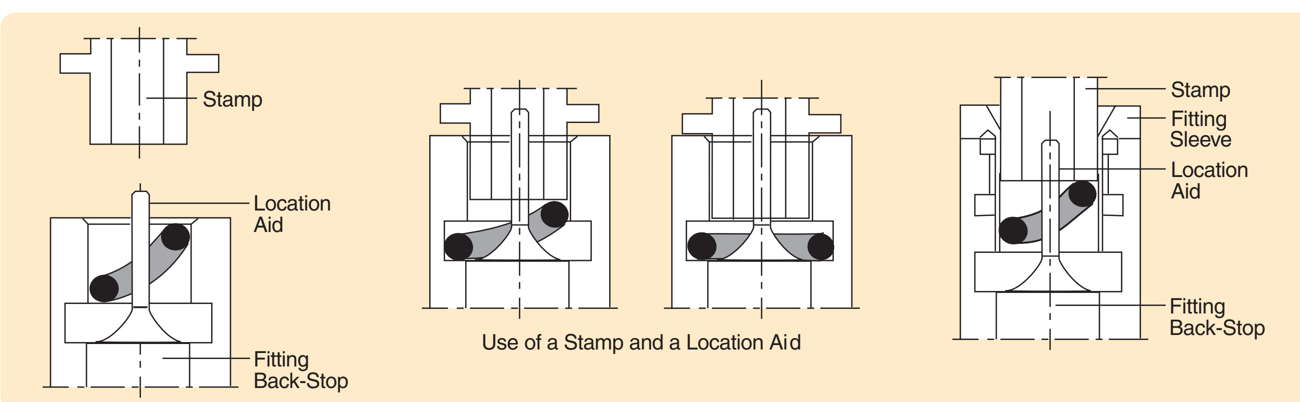

Figure 10-10: Use of a Stamp and a Location Aid

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Parker Seal also has the capability to analyze seals and their behavior in proposed applications through Finite Element Analysis (FEA). FEA is a powerful tool which allows the designer and the engineer to design complex parts and then verify with FEA mathematical models whether the design will perform under actual conditions. If the proposed design shows shortcomings under this modeling analysis, changes can easily be made in the design until acceptable performance is predicted by the model. All this can be done in a matter of days without investment in tooling, prototype parts, or physical testing. Parker engineers are available to help you with your sealing questions and all are fully qualified to recommend solutions to your sealing problems and how these problems can be corrected to prevent future failure. At Parker Seal, customer satisfaction is our goal. Our internal and field personnel are ready to help you with all your sealing needs, and your Authorized Parker Seal Distributor is a sealing expert who can assure you fast service and the kind of reliable seals you need, when you need them.

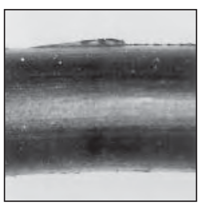
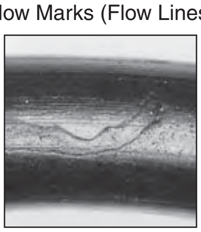
10.2 Molded Elastomeric O-Ring Quality Pass/Fail Limits

This section is intended to provide visual references regarding the standard published visual defect tolerances, which are dependant upon the actual cross section size of the subject O-ring. This information is based upon the industry standard MIL-STD-413C, which has subsequently been cancelled but is still in common use.

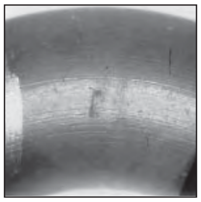
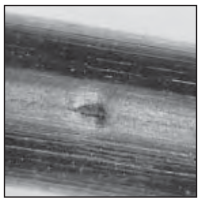
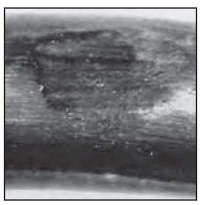
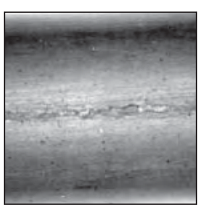
The pictures displayed do not necessarily represent an acceptable or defective product. They are intended to display examples of how a given defect may appear. Several of the noted defects may vary in actual physical representation as it relates to size and shape.

The use of other defect tolerance documents may apply if requested by the customer, and agreed upon at the time of quote. Unless requested otherwise, the requirements of MIL-STD-413C are utilized during the processing and inspection of Parker Seals O-Rings.

O-Ring Defect Description: MIL-STD-413C

Description	Definition	Cause	Tolerances for:
Excess Flash or Parting Line Projection 	Parting Line Projection: A continuous ridge of material on the parting line at the ID and/or OD. Flash: A film-like material which extends from the parting line on the ID, and/or OD, and may be super-imposed on the parting line projection	Parting Line Projection: Enlarged corner radii due to mold wear (triangular formation). Excessive Flash: Mold plate separation or inadequate trim and deflash	Flash and/or Projection: Cross Section / Depth .070 / .003 .103 / .003 .139 / .004 .210 / .005 .275 / .006
Flow Marks (Flow Lines) 	A thread-like recess, usually curved, of very slight depth with normal surface texture and radial edge.	Incomplete flow and knit of the material.	Flow Marks: Cross Section / Depth / Length .070 / .002 / .060 .103 / .002 / .060 .139 / .002 / .180 .210 / .002 / .180 .275 / .002 / .180
Foreign Material 	Any extraneous, imbedded matter, or depression formed by its removal.	Dirt, contamination, undispersed pigment, etc.	Foreign Material: No "protruding" foreign material is acceptable on any cross section. For depression formed by foreign material removal revert to Mold Deposit. Width is measured at widest direction. Cross section / Depth / Width .070 / None / None .103 / .003 / .005 .139 / .004 / .007 .210 / .005 / .010 .275 / .006 / .015

O-Ring Defect Description: MIL-STD-413C (Continued)

Description	Definition	Cause	Tolerances for:
Mold Deposit (Dirty Mold) 	Surface indentations, irregular in shape, with a rough surface texture.	A build-up of hardened deposits adhering to the mold cavity.	Mold Deposit (Dirty Mold): Cross section / Depth / Width .070 / .003 / .010 .103 / .003 / .015 .139 / .004 / .020 .210 / .004 / .025 .275 / .005 / .030
Nicks or Parting Line Indentation 	A shallow, saucer-like recess, sometimes triangular in shape, located on the parting line at the ID or OD, and usually divided by the parting line. The edges are smoothly flared into the O-ring surface and have similar texture.	A deformity in the \mold cavity edge at the parting line.	Nicks or Parting Line Indentations: Cross Section / Depth / Width .070 / .003 / .010 .103 / .003 / .015 .139 / .004 / .020 .210 / .005 / .025 .275 / .006 / .030
Non- Fill or Void 	A randomly spaced, irregularly shaped, surface indentation having a coarser texture than the normal O-ring surface. It may have molded edges which may or may not join.	Mold cavities not being completely filled with material.	Non-Fills or Voids: Cross Section / Depth / Width .070 / None allowed / None allowed .103 / .002 / .010 .139 / .003 / .015 .210 / .003 / .025 .275 / .003 / .040
Off-Register and Mismatch 	Off-Register: Misaligned O-ring halves. Mismatch: Cross section of each half are different sizes.	Off-Register: Relative lateral shift of mold plates. Mismatch: Dimensional differences in the mold halves	Off-Register and/or Mismatch: Cross Section / Maximum Allowed .070 / .003 .103 / .004 .139 / .005 .210 / .006 .275 / .006
Backrind 	A longitudinal recess of wide angle "U-like" or "W-like" cross sections orientated circumferentially and located only at parting lines.	Thermal expansion over a sharp mold edge or by premature cure.	Backrind: Edges, though smoothly faired into ring surface are irregular and can be present on full circumference on OD and/or ID within the following limits Cross Section / Depth / Width .070 / None / None .103 / .003 / .005 .139 / .004 / .006 .210 / .004 / .006 .275 / .005 / .010

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10.3 Glossary of Seal and Rubber Terms

— A —

Abrasion: The wearing away of a surface in service by mechanical action such as rubbing, scrap ing or erosion.

Abrasion Resistance: The ability of a rubber compound to resist mechanical wear.

Absorption: The physical mechanism by which one substance attracts and takes up another substance (liquid, gas, or vapor) into its INTERIOR.

Accelerated Life Test: Any set of test conditions designed to reproduce in a short time the deteriorating effect obtained under normal service conditions.

Accelerated Service Test: A service or bench test in which some service condition, such as speed, or temperature, or continuity of operation, is exaggerated in order to obtain a result in shorter time.

Accelerator: A substance which hastens the vulcanization of an elastomer causing it to take place in a shorter time or at a lower temperature.

Acid Resistant: Withstands the action of acids.

Adhere: To cling or stick together.

Adhesion: Tendency of rubber to bond or cling to a contact surface.

Adsorption: The physical mechanism by which one substance attracts another substance (either solid, liquid, gas, or vapor) to its SURFACE and through molecular forces causes the incident substance to adhere thereon.

Aging: To undergo changes in physical properties with age or lapse of time.

Aging, Oxygen Bomb: A means of accelerating the change in physical properties of rubber compounds by exposing them to the action of oxygen at an elevated temperature and pressure.

Air Bomb: Similar to an oxygen bomb but used with air. Used for accelerated aging test.

Air Checks: Surface markings or depressions due to trapping air between the material being cured and the mold or press surface.

Air Curing: The vulcanization of a rubber product in air as distinguished from vulcanizing in a press or steam vulcanizer.

Alpha (α) Particles: Positively charged particles composed of two protons and neutrons (often referred to simply as helium atom nuclei) and characterized by limited penetration.

Ambient Temperature: The surrounding temperature relative to a given point of application.
Note: Ambient temperature is not necessarily the same as atmospheric temperature.

Aniline Point: The lowest temperature at which equal volumes of pure, fresh aniline and an oil will completely dissolve in one another.

Antioxidant: An organic substance which inhibits or retards oxidation.

Antiozonant: A substance that retards or prevents the appearance of cracks from the action of ozone when the elastomer is exposed under tension, either statically or dynamically, to air containing ozone.

Antirad: A material which inhibits radiation damage.

Atmospheric Cracking: Cracks produced in surface of rubber articles by exposure to atmospheric conditions.

— B —

Backrind: Distortion at the parting line usually in the form of a ragged indentation.

Back-Up Ring: (Anti-extrusion device) a ring of relatively hard and tough material placed in the gland between the O-ring and groove side walls, to prevent extrusion of the O-ring.

Bake-Out: A process whereby a vacuum system is heated for a given time at some predetermined temperature to degas all the components, i.e. gauges, fittings, valves, seals, etc.

Banbury Mixer: A specific type of internal mixer used to blend fillers and other ingredients with an elastomer.

Bench Test: A modified service test in which the service conditions are approximated, but the equipment is conventional laboratory equipment and not necessarily identical with that in which the product will be employed.

Beta (β) Particles: Negatively charged particles or electrons, characterized by limited penetration.

Bleeding: Migration to the surface of plasticizers, waxes, or similar materials to form a film or beads.

Blemish: A mark, deformity, or injury that impairs the appearance.

Blisters: A raised spot in the surface or a separation between layers usually forming a void or air-filled space in the vulcanized article.

Bloom: A dusty or milky looking deposit that sometimes appears on the surface of an O-ring after molding and storage, caused by migration of a liquid or solid to the surface. Not to be confused with dust from external sources.

Bond: The term commonly used to denote the attachment of a given elastomer to some other member. Bonds may be classified by type as follows:

(a) Mechanical Bond — purely physical attachment accomplished by such means as “through” holes interlocking fingers, envelope design, riveting etc.

(b) “Cold” Bond — adhesion of previously vulcanized elastomer to another member through use of suitable contact cements.

(c) “Vulcanized” Bond — adhesion of an elastomer to a previously primed surface using heat and pressure thus vulcanizing the elastomer at the same time.

Break: A separation or discontinuity in any part of an article.

Break-Out: Force to initiate sliding. Expressed in same terms as friction. An excessive break-out value is taken as an indication of the development of adhesion.

Brittleness: Tendency to crack when deformed.

Buna-N: Same as *nitrile* rubber.

Buna-S: A general term for the copolymers of butadiene and styrene. Also known as SBR and GRS.

Butt Joint: Joining two ends of a seal whereby the junction is perpendicular to the mold parting line.

Butyl: A copolymer of isobutylene with small amounts of isoprene.

— C —

Calender: A machine used to form sheets of rubber between steel rollers.

Coefficient of Thermal Expansion: Average expansion per degree over a stated temperature range expressed as a fraction of initial dimension. May be linear or volumetric.

Cold Flexibility: Flexibility following exposure to a predetermined low temperature for a predetermined time.

Cold Flow: Continued deformation under stress.

Cold Resistant: Able to withstand the effects of cold or low temperatures without loss of serviceability.

Commercially Smooth: Degree of smoothness of the surface of an article that is acceptable for use.

Compound: A term applied to a mixture of polymers and other ingredients, to produce a usable rubber material.

Compression Modulus: The ratio of the compressive stress to the resulting compressive strain (the latter expressed as a fraction of the original height or thickness in the direction of the force). Compression modulus may be either static or dynamic.

Compression Set: The amount by which a rubber specimen fails to return to original shape after release of compressive load.

Conductive Rubber: A rubber capable of conducting electricity. Most generally applied to rubber products used to conduct static electricity.

Copolymer: A polymer consisting of two different monomers chemically combined.

Corrosion (Packing): Corrosion of rigid member (usually metal) where it contacts packing. The actual corroding agent is fluid medium trapped in the interface.

Corrosive (Packing): A property of packing whereby it is assumed often incorrectly, to promote corrosion of the rigid member by the trapped fluid.

Cracking: A sharp break or fissure in the surface. Generally due to excessive strain.

Creep: The progressive relaxation of a given rubber material while it is under stress. This relaxation eventually results in permanent deformation or "set."

Cross-Section: A seal as viewed if cut at right angles to the mold parting line showing internal structure.

Cure: See Vulcanization.

Cure Date: Date when O-ring was molded; i.e., 2Q94 means second quarter 1994.

Curing Temperature: The temperature at which the rubber product is vulcanized.

Cylinder: Chamber in which piston, plunger, ram, rod, or shaft is driven by or against the system fluid.

— D —

Degassing: The intentional **but controlled** OUTGAS of a rubber substance or other material.

Diffusion: The mixing of two or more substances (solids, liquids, gases, or combinations thereof) due to the intermingling motion of their individual molecules. Gases diffuse more readily than liquids; similarly, liquids diffuse more readily than solids.

Durometer:
(a) An instrument for measuring the hardness of rubber. Measures the resistance to the penetration of an indentor point into the surface of rubber.
(b) Numerical scale of rubber hardness.

Dynamic: An application in which the seal is subject to movement, or moving parts contact the seal.

Dynamic Packing: A packing employed in a joint whose members are in relative motion.

Dynamic Seal: A seal required to prevent leakage past parts which are in relative motion.

— E —

Elasticity: The property of an article which tends to return it to its original shape after deformation.

Elastomer: Any synthetic or natural material with resilience or memory sufficient to return to its original shape after major or minor distortion.

Electron Volt: Unit of energy in atom calculations equal to 1.602 E -12 ergs.

Elongation: Generally means "ultimate elongation" or percent increase in original length of a specimen when it breaks.

ERG: Unit of energy (C.G.S.) equal to one dyne centimeter or approximately equal to the work done by a force of 1 gram causing a movement of 1 centimeter.

Evaporation: The direct conversion from liquid state to vapor state of a given fluid.

Explosive Decompression: Rupturing of the substructure caused by the rapid removal of pressure from an elastomer containing dissolved gases. The result is a blistering or swelling of the material. Some elastomeric compounds are quite resistant to explosive decompression.

Extrusion: Distortion or flow, under pressure, of portion of seal into clearance between mating metal parts.

— F —

Face Seal: A seal between two flat surfaces.

Filler: Chemically inert, finely divided material added to the elastomer to aid in processing and improve physical properties, i.e., abrasion resistance and strength — giving it varying degrees of hardness.

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

Flex Cracking: A surface cracking induced by repeated bending or flexing.

Flex Resistance: The relative ability of a rubber article to withstand dynamic bending stresses.

Flock: Fibrous filler sometimes used in rubber compounding.

Flow Cracks: Surface imperfections due to improper flow and failure of stock to knit or blend with itself during the molding operation.

Fluid: A liquid or a gas.

Friction: Resistance to motion due to the contact of surfaces.

Friction (Breakout): Friction developed during initial or starting motion.

Friction (Running): Constant friction developed during operation of a dynamic O-ring.

Fuel (Aromatic): Fuel which contains benzene or aromatic hydrocarbons. Causes high swell of rubber.

Fuel (Nonaromatic): Fuel which is composed of straight chain hydrocarbons. Causes little swell of rubber.

— G —

Gamma (γ) Radiation: Electromagnetic disturbance (photons) emanating from an atom nucleus. This type of radiation travels in wave form much like X-rays or light, but has a shorter wave length (approx. 1 A° or 10 E -07 mm). It is very penetrating.

Gasket: A device used to retain fluids under pressure or seal out foreign matter. Normally refers to a static seal.

Gland: Cavity into which O-ring is installed. Includes the groove and mating surface of second part which together confine the O-ring.

— H —

Hardness: Resistance to a distorting force. Measured by the relative resistance of the material to an indentor point of any one of a number of standard hardness testing instruments.

Hardness Shore A: The rubber durometer hardness as measured on a Shore "A" gauge. Higher numbers indicate harder material. 35 Shore "A" durometer reading is considered soft. 90 is considered hard.

Hermetic Seal: An airtight seal evidencing no detectable leakage.

Homogeneous:
(a) General - a material of uniform composition throughout.
(b) In seals - a rubber seal without fabric or metal reinforcement.

Hypalon: DuPont trade name for chlorosulphonated polyethylene, an elastomer.

— I —

Identification: Colored dots or stripes on seals for identification purposes.

Immediate Set: The deformation found by measurement immediately after removal of the load causing the deformation.

Immersion: Placing an article into a fluid, generally so it is completely covered.

Impact: The single, instantaneous stroke or contact of a moving body with another, either moving or at rest, such as a large lump of material dropping on a conveyor belt.

— L —

Leakage Rate: The rate at which a fluid (either gas or liquid) passes a barrier. Total Leakage Rate includes the amounts that diffuse or permeate through the material of the barrier as well as the amount that escapes around it.

Life Test: A laboratory procedure used to determine the amount and duration of resistance of an article to a specific set of destructive forces or conditions.

Linear Expansion: Expansion in any one linear dimension or the average of all linear dimensions.

Logy: Sluggish, low snap or recovery of a material.

Low Temperature Flexibility: The ability of a rubber product to be flexed, bent or bowed at low temperatures without cracking.

— M —

mm Hg: Millimeters of mercury. In vacuum work, this is a measure of absolute pressure, being the height of a column of mercury that the air or other gas will support. Standard atmospheric pressure will support a mercury column 760 millimeters high (760 mm Hg.) Any value less than this represents some degree of vacuum.

Memory: Tendency of a material to return to original shape after deformation.

Mirror Finish: A bright, polished surface.

Mismatch: Unsymmetrical seal caused by dissimilar cavities in mating mold sections.

Modulus: Tensile stress at a specified elongation. (Usually 100% elongation for elastomers).

Modulus of Elasticity: One of the several measurements of stiffness or resistance to deformation, but often incorrectly used to indicate specifically static tension modulus.

Mold Cavity: Hollow space or cavity in the mold which is used to impart the desired form to the product being molded.

Mold Finish: The uninterrupted surface produced by intimate contact of rubber with the surface of the mold at vulcanization.

Mold Lubricant: A material usually sprayed onto the mold cavity surface prior to the introduction of the uncured rubber, to facilitate the easy removal of the molded rubber parts.

Mold Marks: Indentations or ridges embossed into the skin of the molded product by irregularities in the mold cavity surface.

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Mold Register: Accuracy of alignment or fit of mold sections.

Mooney Scorch: The measurement of the rate at which a rubber compound will cure or set up by means of the Mooney Viscometer test instrument.

Mooney Viscosity: The measurement of the plasticity or viscosity of an uncompounded or compounded, unvulcanized, elastomeric seal material by means of the Mooney Shearing Disk Viscometer.

— N —

Nitrile: (Buna-N) The most commonly used elastomer for O-rings because of its resistance to petroleum fluids, good physical properties and useful temperature range.

Nominal Dimension: Nearest fractional equivalent to actual decimal dimension.

Non-Blooming: The absence of bloom.

— O —

Occlusion:

(a) The mechanical process by which vapors, gases, liquids, or solids are entrapped within the folds of a given substance during working or solidification.

(b) The materials so trapped.

Off-Register: Misalignment of mold halves causing out-of-round O-ring cross section.

Oil Resistant: Ability of a vulcanized rubber to resist the swelling and deteriorating effects of various type oils.

Oil Swell: The change in volume of a rubber article due to absorption of oil or other or other fluid.

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

O-Ring Seal: The combination of a gland and an O-ring providing a fluid-tight closure. (Some designs may permit momentary or minimum leakage.)
Moving (dynamic) — O-ring seal in which there is relative motion between some gland parts and the O-ring — oscillating, reciprocating, or rotary motion.
Non-moving (static) — O-ring seal in which there is no relative motion between any part of the gland and the O-ring (distortion from fluid pressure or swell from fluid immersion is excluded).

Optimum Cure: State of vulcanization at which the most desirable combination of properties is attained.

Outgassing: A vacuum phenomenon wherein a substance spontaneously releases volatile constituents in the form of vapors or gases. In rubber compounds, these constituents may include water vapor, plasticizers, air, inhibitors, etc.

Over Cure: A degree of cure greater than the optimum causing some desirable properties to be degraded.

Oxidation: The reaction of oxygen on a compound usual detected by a change in the appearance or feel of the surface, or by a change in physical properties or both.

Oxygen Bomb: A chamber capable of holding oxygen at an elevated pressure which can be heated to an elevated temperature. Used for an accelerated aging test.

Ozone Resistance: Ability to withstand the deteriorating effect of ozone (which generally causes cracking).

— P —

Packing: A flexible device used to retain fluids under pressure or seal out foreign matter. Normally refers to a dynamic seal.

Permanent Set: The deformation remaining after a specimen has been stressed in tension for a definite period and released for a definite period.

Permeability: The rate at which a liquid or gas under pressure passes through a solid material by diffusion and solution. In rubber terminology, it is the rate of gas flow expressed in atmospheric cubic centimeters per second through an elastomeric material one centimeter square and one centimeter thick (atm $cc/cm^2/cm$ sec).

Pit or Pock Mark: A circular depression, usually small.

Plasticizer: A substance, usually a viscous liquid, added to an elastomer to decrease stiffness, improve low temperature properties, and improve processing.

Plastometer: An instrument for measuring the plasticity of raw or unvulcanized compounded rubber.

Pock Mark: See "Pit or Pock Mark".

Polymer: A material formed by the joining together of many (poly) individual units (mer) of one or more monomers; synonymous with elastomer.

Porosity: Quality or state of being porous.

Post Cure: The second step in the vulcanization process for the more exotic elastomers. Provides stabilization of parts and drives off decomposition products resulting from the vulcanization process.

— R —

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

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

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

Radiation Damage: A measure of the loss in certain physical properties of organic substances such as elastomers, due principally to ionization of the long chain molecule. It is believed that this ionization process (i e. electron loss) results in redundant cross-linking and possible scission of the molecule. This effect is **cumulative**.

Radiation Dosage: The total amount of radiation energy absorbed by a substance. This value is usually expressed in ergs per gram, and is denoted by the following units:

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

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(b) **REP** (Roentgen equivalent-physical) - a quantity of ionizing radiation that causes an energy absorption of approximately 83 to 93 ergs per gram of tissue.

(c) **REM** (Roentgen equivalent-man)—similar to REP except used to denote biological effects.

(d) **RAD** - the unit of dosage related to elastomers. It is independent of type of radiation or specimen, and denotes an energy absorption level of 100 ergs per gram (of elastomer). The RAD is approximately equal to 1.2 Roentgens.

Register, Off or Uneven: See Off-register.

Reinforcing Agent: Material dispersed in an elastomer to improve compression, shear or other stress properties.

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

Resilient: Capable of returning to original size and shape after deformation.

Roentgen: See Radiation Dosage.

Rough Trim: Removal of superfluous material by pulling or picking. Usually the removal of a small portion of the flash or sprue which remains attached to the product.

Rubber: Same as elastomer.

Rubber, Natural: Raw or crude rubber obtained from plant sources.

Rubber, Synthetic: Manufactured or man-made elastomers.

Runout (Shaft): Same as gyration; when expressed in inches alone or accompanied by abbreviation “T.I.R.” (total indicator reading), it refers to twice the radial distance between shaft axis and axis of rotation.

— S —

Scorching: Premature curing or setting up of raw compound during processing.

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

Service: Operating conditions to be met.

Shaft: Reciprocating or rotating member usually within cylinder; not in contact with walls.

Shelf-Aging: The change in a material’s properties which occurs in storage with time.

Shore A Hardness: See Hardness and Durometer.

Shrinkage: a) Decreased volume of seal, usually caused by extraction of soluble constituents by fluids followed by air drying. b) Difference between finished part dimensions and mold cavity used to make the part.

Silicone Rubber: Elastomer that retains good properties through extra wide temperature range.

Size, Actual: Actual dimensions of the O-ring or other seal, including tolerance limits.

Size, Nominal: Approximate size of part in fractional dimensions. May also indicate the actual size of the groove into which a nominal size seal fits.

Size Number: Number assigned to indicate inside and cross section diameters of an O-ring. Sizes established in SAE standard AS 568A have been adopted by the military and industry.

Sorption: The term used to denote the combination of absorption and adsorption processes in the same substance.

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

Sprue Marks: Marks left on the surface of a rubber part, usually elevated, after removal of the sprue or cured compound in the gate through which the compound is injected or transfer molded.

Squeeze: Cross section diametral compression of O-ring between surface of the groove bottom and surface of other mating metal part in the gland assembly.

Static Seal: Part designed to seal between parts having no relative motion. See Gasket.

Strain: Deflection due to a force.

Stress: Force per unit of original cross section area.

Sublimation: The direct conversion of a substance from **solid** state to **vapor** state without passing through a transitory liquid state. The **vapor,** upon recondensing, reforms into the **solid** state with no intervening liquid phase.

Sun Checking: Surface cracks, checks or crazing caused by exposure to direct or indirect sunlight.

Swell: Increased volume of a specimen caused by immersion in a fluid (usually a liquid).

— T —

Tear Resistance: Resistance to growth of a cut or nick when tension is applied to the cut specimen Commonly expressed as pounds per inch thickness.

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

Tensile Strength: Force in pounds per square inch required to cause the rupture of a specimen of a rubber material.

Terpolymer: A polymer consisting of three different monomers chemically combined.

Thermal Expansion: Expansion caused by increase in temperature. May be linear or volumetric.

Threshold: The maximum tolerance of an elastomer to radiation dosage expressed as a total number of ergs per gram (or rads) beyond which the physical properties are significantly degraded. This is generally an arbitrary value, depending on function and environment.

Torque: The turning force of a shaft.

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Torr: The unit of pressure used in vacuum measurement. It is equal to 1/760 of a standard atmosphere, and for all practical purposes is equivalent to one millimeter of mercury (mm Hg).

Example:
25 mm Hg = 25 torr
1 x 10^{-3} mm Hg = 10^{-3} torr (millitorr)
1 X 10^{-6} mm Hg = 10^{-6} torr (microtorr)

Torsional Strength: Ability of rubber to withstand twisting.

TR-10: (10% Temperature retraction) A measure of the low temperature capability of an elastomer, being the temperature at which a stretched and frozen specimen has retracted by 10% of the stretched amount. (ASTM method D1329)

Trapped Air: Air which is trapped in a product or a mold during cure. Usually causes a loose ply or cover, or a surface mark, depression or void.

Trim: The process involving removal of mold flash.

Trim Cut: Damage to mold skin or finish by too close trimming.

— U —

Under-Cure: Degree of cure less than optimum. May be evidenced by tackiness, loginess, or inferior physical properties.

Ultimate Elongation: See Elongation.

— V —

Vacuum: The term denoting a given space that is occupied by a gas at less than atmospheric pressure. For degrees of vacuum; see vacuum level.

Vacuum Level: The term used to denote the degree of vacuum evidenced by its pressure in torr (or mm Hg).
(a) **Rough** vacuum — 760 torr to 1 torr
(b) Medium vacuum — 1 torr to 10^{-3} torr
(c) High vacuum — 10^{-3} torr to 10^{-6} torr
(d) Very high (hard) vacuum — 10^{-6} torr to 10^{-9} torr
(e) Ultra **high** (ultra hard) vacuum — Below 10^{-9} torr

Vapor: The gaseous state of a fluid that normally exists as a liquid under atmospheric conditions, i.e. a gas whose temperature is below its critical temperature.

Vapor Pressure: The maximum pressure exerted by a liquid (or solid) heated to a given temperature in a closed container.

Virtual Leak: An “apparent” leak in a vacuum system that is traceable, in fact, to some internal (and often accidental) release of occluded and/or sorbed gases.

Example:
An undetected blister in a fused joint may eventually break down in a vacuum and suddenly (or slowly) release its entrapped air, thereby indicating a “leak.”

Viscosity: The property of fluids and plastic solids by which they resist an instantaneous change of shape, i.e., resistance to flow.

Void: The absence of material or an area devoid of materials where not intended.

Volatilization: The transition of either a liquid or a solid directly into the vapor state. In the case of a liquid, this transition is called evaporation, whereas in the case of a solid, it is termed sublimation.

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

Volume Swell: Increase in physical size caused by the swelling action of a liquid.

Vulcanization: A thermo-setting reaction involving the use of heat and pressure, resulting in greatly increased strength and elasticity of rubber-like materials.

Vulcanizing Agent: A material which produces vulcanization of an elastomer.

— W —

Width: Seal cross section or thickness.

Wiper Ring: A ring employed to remove excess fluid, mud, etc., from a reciprocating member before it reaches the packings.

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Appendix

10.4 Abbreviations

ACM	Polyacrylate Rubber
AF	Air Force
AFML	Air Force Material Laboratory
AMS	Aerospace Material Specification
AN	(1) Army-Navy; (2) Air Force-Navy
ANA	Air Force-Navy Aeronautical Bulletin
AND	Air Force-Navy Design
AQL	Acceptable Quality Level
ARP	Aerospace Recommended Practice
AS	Aerospace Standard
ASTM	American Society for Testing and Materials
atm	Atmosphere (atmospheric)
AU	Polyurethane Rubber
BR	Butadiene Rubber
C or °C	Degrees Centigrade
cc	Cubic centimeter
C.G.S.	Centimeter-Gram-Second; system of units for length, mass, and time
CO	Epichlorohydrin Rubber
cpm	Cycles per minute
CR	Chloroprene (Neoprene)
cs	Cross Section
CSM	Hypalon Rubber
Dia	Diameter
ECO	Epichlorohydrin Rubber
EP, EPM	Ethylene-Propylene Rubber
EPDM	Ethylene-Propylene Rubber
EU	Polyurethane Rubber
F or °F	Degrees Fahrenheit
FED	Federal Specification
FKM	(also FPM) Fluorocarbon Rubber
F.P.S.	Foot-Pound-Second; system of units for length, weight and time
FVMQ	Fluorosilicone Rubber
HNBR	Hydrogenated Nitrile Rubber
GRS	"Government Rubber Styrene"; now SBR
ID	Inside Diameter
IIR	Butyl Rubber
in.	Inch
IR	Isoprene Rubber
JAN	Joint Army-Navy
JIC	Joint Industry Conference on Hydraulic Standards for Industrial Equipment
K	Degrees Kelvin (Absolute) — (°C +273)
Max	Maximum
MIL	Military Specification
Min	Minimum
MS	Military Standard
MVQ	Silicone Rubber
NAS	National Aerospace Standard (also National Aircraft Standards [older meaning])
NASA	National Aeronautics and Space Administration
NBR	Nitrile or Buna-N Rubber
No	Number
NR	Natural Rubber
OD	Outside Diameter
psi	Pounds per square inch
PVMQ	Phenyl Silicone Rubber
QPL	Military Qualified Products List
R or °R	Degrees Rankine (Absolute) — (°F +460)
Rad	Radius
RMA	Rubber Manufacturers Association
RMS	Root-Mean-Square; average value of surface roughness measured in microinches
rpm	Revolutions per minute
SAE	Society of Automotive Engineers, Inc.
SBR	Styrene Butadiene Rubber
sfm	Surface Feet per minute
Spec	Specification
T	Polysulfide Rubber
Temp.	Temperature
TFE/P	AFLAS
USAF	United States Air Force
VMQ	Silicone Rubber
W	Width (seal cross section)
WPAFB	Wright-Patterson Air Force Base

Appendix

10.5 Standard Shrinkage

All rubber materials shrink during molding, resulting in finished parts that are smaller than the mold cavity dimensions. "Standard" mold shrinkage is called "AN" shrinkage. Compounds that are manufactured from unusual formulations or polymers will have different shrinkage rates associated with them. Some materials shrink LESS than the standard (AN) nitrile would in the same mold. These materials have been given an arbitrary CLASS(-1) shrinkage designation. Still other materials have shrinkage rates that are greater than the standard (AN) shrink rate. These progressively larger shrinkage rates have been arbitrarily called CLASS I through CLASS VI.

Table 10-7 lists the shrinkage class for some of our more popular compounds. Table 10-8 lists all the possibilities for dimensions for Parker's 2-xxx and 3-xxx series O-ring sizes depending upon the shrinkage of the material that is chosen.

In applications that require materials with shrinkage more or less than the standard (AN) rate, the O-ring gland dimensions may have to be modified to provide the desired squeeze. If the assembled inside diameter of the O-ring is fixed, a high-shrink compound will be stretched more than a standard material, and this will reduce the O-ring cross-section further. See Figure 3-3 to observe the effect of this stretch on the "W" Dimension. When O-rings of a high-shrink compound are required for use in standard (AN) or special dimensions, molds can be made to compensate for the shrinkage, but at special mold costs.

It should be noted that many factors affect the shrinkage of rubber compounds, including method (injection, compression, transfer), time, temperature, and/or pressure, to name a few. As new manufacturing techniques for O-rings are developed, there will be the possibility that shrinkage rates of our compounds will change (or shift) correspondingly. For this reason, consultation with the factory is imperative prior to specifying a particular Parker compound.

10.5.1 Procedure for O-Rings Molded of Compounds Having Non-Standard Shrinkage Rates

Determine the Finished Dimension and Tolerances as Follows:

2- and 3- Sizes

1. Locate the compound in Table 10-7 and note the shrinkage class listed.
2. Use this shrinkage class and the O-ring size number to find the dimensions and tolerances in Table 10-8.

   Example: O-ring size 2-150, Compound S0355-75
   (1) Shrinkage Class IV (Table 10-7)
   (2) Dimensions and Tolerances
   2.816" ± .032" I.D. X .101" ±.004 W. (Table 10-8)

5- Sizes

1. Locate the compound in Table 10-7, and note the shrinkage class listed.
2. Find the standard AN dimensions and tolerances in Table 9-3. (If the I.D. is not known, refer to Table 9-4 first.)
3. Find the actual I.D. and cross-section by multiplying the standard I.D. and W. dimensions by the dimension factor from Table 10-10.
4. Find the I.D. tolerance by multiplying the standard I.D. by the tolerance factor from Table 10-10 and adding the result to the standard tolerance.
5. Find the actual cross-section tolerance in Table 10-9.

   Example: O-ring Size 5-547, Compound S0355-75
   (1) Shrinkage Class III (Table 10-7)
   (2) Standard I.D. = 21.564 ± .100 W. = .139 ± .004
   (3) Actual I.D. = 21.564 X .984 = 21.219
   Actual W. = .139 X .984 = .137
   (4) I.D. Tolerance = 21.564 X .0036 + .100 = ± .178
   (5) W. Tolerance ± .005
   Actual Dimensions and Tolerance =
   21.219" ± .178" I.D. X .137" ± .005" W.

Note: Follow the procedure given for the 5-series to find dimensions and tolerances for special sizes for which standard shrinkage tooling exists.

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Compound Shrinkage Class

Compound Number	Shrinkage Class	Compound Number	Shrinkage Class	Compound Number	Shrinkage Class
47-071	AN	N0545-40	I	C0873-70	AN
N0103-70	AN	N0552-90	-1	V0884-75*	III
C0267-50	AN	C0557-70	AN	E0893-80	AN
N0287-70	AN	S0595-50	II	V0894-90*	II
N0299-50	I	N0602-70	AN	C0944-70	-1
N0304-75	AN	E0603-70	AN	N0951-75	AN
S0317-60	II	S0604-70	I	E0962-90	3
S0355-75	IV	B0612-70	I	E1028-70	AN
S0383-70	II	S0613-60	AN	N1090-85	I
N0406-60	I	S0614-80	AN	LM159-70	IV
S0455-70	V	P0642-70	2	C1124-70	AN
S0469-40	III	E0652-90	-1	LM158-60	IV
N0497-70	-1	E0667-70	I	LM160-80	II
N0506-65	I	N0674-70	AN	L1186-80	II
N0507-90	-1	V0680-70*	II	V1164-75*	III
N0508-75	-1	E0692-75	AN	V1226-75*	III
E0515-80	AN	V0709-90*	III	VM835-75	III
C0518-60	AN	E0740-75	AN	V1289-75	III
N0525-60	AN	V0747-75*	III		
E0540-80	AN	E0803-70	I		

* Fluorocarbon compounds that have CLASS III shrinkage are manufactured using special compensated molds that will give nominal dimensions equivalent to the corresponding standard AN size. However, the tolerance spread will be that of a CLASS III shrinkage material unless otherwise specified.

** Run on Compensated Tooling.

Note: The O-Ring Division is constantly developing new materials to solve customer needs. For the most up-to-date information, contact the O-Ring Division directly.

Table 10-7: Compound Shrinkage Class

Parker Hannifin Corporation • O-Ring Division
2360 Palumbo Drive, Lexington, KY 40509
Phone: (859) 269-2351 • Fax: (859) 335-5128
www.parkerorings.com

Appendix

Dimensions From Standard Tooling

The following are the anticipated dimensions and tolerances for O-rings from compounds having various shrinkage rates when molded in standard tooling (tooling produced to allow for the average or AN shrinkage rate). The shrinkage classes of a number of popular Parker Compounds are listed in Table 10-7.

Dimensions From Standard Tooling

Parker Size Number	Class -1				Class AN				Class I				Class II			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-001	.029	.004	.040	.003	.029	.004	.040	.003	.029	.004	.040	.004	.029	.004	.040	.004
2-002	.042	.004	.050		.042	.004	.050		.042	.004	.050		.042	.004	.049	
2-003	.056	.004	.060		.056	.004	.060		.056	.004	.060		.055	.004	.059	
2-004	.070	.005	.070		.070	.005	.070		.070	.005	.070		.069	.005	.069	
2-005	.102				.101				.100				.100			
2-006	.115				.114				.113				.113			
2-007	.146				.145				.144				.143			
2-008	.177				.176				.175				.174			
2-009	.209				.208				.207				.206	.005		
2-010	.240				.239				.238				.236	.006		
2-011	.303				.301				.299				.298			
2-012	.366				.364				.362	.005			.360			
2-013	.429				.426				.423	.006			.421	.006		
2-014	.492	.005			.489	.005			.486	.006			.484	.006		
2-015	.554	.007			.551	.007			.548	.008			.545	.008		
2-016	.618	.009			.614	.009			.610	.010			.607	.010		
2-017	.680	.009			.676	.009			.672	.010			.669	.011		
2-018	.743	.009			.739	.009			.735	.010			.731	.011		
2-019	.806	.009			.801	.009			.796	.010			.792	.011		
2-020	.869	.009			.864	.009			.859	.010			.854	.011		
2-021	.932	.009			.926	.009			.920	.010			.916	.011		
2-022	.995	.010			.989	.010			.983	.011			.978	.012		
2-023	1.057	.010			1.051	.010			1.045	.011			1.039	.013		
2-024	1.121	.010			1.114	.010			1.107	.011			1.102	.013		
2-025	1.183	.011			1.176	.011			1.169	.012			1.163	.014		
2-026	1.246	.011			1.239	.011			1.232	.012			1.225	.014		
2-027	1.309	.011			1.301	.011			1.293	.013			1.287	.014		
2-028	1.372	.013			1.364	.013			1.356	.015			1.349	.016		
2-029	1.498	.013			1.489	.013			1.480	.015			1.473	.017		
2-030	1.624	.013			1.614	.013			1.604	.015			1.596	.017		
2-031	1.749	.015			1.739	.015			1.729	.017			1.720	.019		
2-032	1.875	.015			1.864	.015			1.853	.017			1.843	.019		
2-033	2.001	.018			1.989	.018			1.977	.020			1.967	.023		
2-034	2.127	.018			2.114	.018			2.101	.021			2.091	.023		
2-035	2.252	.018			2.239	.018			2.226	.021			2.214	.023		
2-036	2.378	.018			2.364	.018			2.350	.021			2.338	.024		
2-037	2.504	.018			2.489	.018			2.474	.021			2.462	.024		
2-038	2.630	.020			2.614	.020			2.598	.023			2.585	.026		
2-039	2.755	.020			2.739	.020			2.723	.023			2.709	.027		
2-040	2.881	.020			2.864	.020			2.847	.023			2.832	.027		
2-041	3.007	.024			2.989	.024			2.971	.028			2.956	.031		
2-042	3.258	.024			3.239	.024			3.220	.028			3.203	.032		
2-043	3.510	.024			3.489	.024			3.468	.028			3.451	.032		
2-044	3.761	.027			3.739	.027			3.717	.031			3.698	.036		
2-045	4.013	.027			3.989	.027			3.965	.032			3.945	.037		
2-046	4.264	.030			4.239	.030			4.214	.035			4.192	.040		
2-047	4.516	.030			4.489	.030			4.462	.035			4.440	.041		
2-048	4.767	.030			4.739	.030			4.711	.036			4.687	.041		
2-049	5.019	.037			4.989	.037			4.959	.043			4.934	.049		
2-050	5.270	.037	070	.003	5.239	.037	.070	.003	5.208	.043	.070	.004	5.181	.050	.069	.004

Table 10-8: Dimensions From Standard Tooling

Parker Hannifin Corporation • O-Ring Division
2360 Palumbo Drive, Lexington, KY 40509
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www.parkerorings.com

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class III				Class IV				Class V				Class VI			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-001	.029	.004	.039	.004	.028	.004	.039	.004	.028	.004	.039	.004	.028	.004	.039	.004
2-002	.041	.004	.049		.041	.004	.049		.041	.004	.049		.041	.004	.048	
2-003	.055	.004	.059		.055	.004	.059		.055	.004	.058		.054	.004	.058	
2-004	.069	.005	.069		.069	.005	.069		.068	.005	.068		.068	.006	.068	
2-005	.099	.005			.099	.005			.098	.006			.098	.006		
2-006	.112	.005			.112	.006			.111	.006			.110	.006		
2-007	.143	.006			.142	.006			.141	.006			.141	.006		
2-008	.173	.006			.172	.006			.171	.006			.171	.006		
2-009	.205	.006			.204	.006			.203	.006			.202	.006		
2-010	.235	.006			.234	.006			.233	.006			.232	.007		
2-011	.296	.006			.295	.006			.293	.007			.292	.007		
2-012	.358	.006			.356	.007			.355	.007			.353	.008		
2-013	.419	.007			.417	.007			.415	.008			.413	.008		
2-014	.481	.007			.479	.007			.476	.008			.474	.009		
2-015	.542	.009			.539	.010			.537	.010			.534	.011		
2-016	.604	.011			.601	.012			.598	.013			.595	.013		
2-017	.665	.011			.662	.012			.658	.013			.655	.014		
2-018	.727	.012			.723	.013			.720	.013			.716	.014		
2-019	.788	.012			.784	.013			.780	.014			.776	.015		
2-020	.850	.012			.846	.013			.842	.014			.837	.015		
2-021	.911	.012			.907	.013			.902	.015			.897	.016		
2-022	.973	.014			.968	.015			.963	.016			.958	.017		
2-023	1.034	.014			1.029	.015			1.024	.016			1.018	.018		
2-024	1.096	.014			1.091	.015			1.085	.017			1.079	.018		
2-025	1.157	.015			1.151	.017			1.145	.018			1.140	.019		
2-026	1.219	.015			1.213	.017			1.207	.018			1.201	.020		
2-027	1.280	.016			1.274	.017			1.267	.019			1.261	.020		
2-028	1.342	.018			1.335	.020			1.329	.021			1.322	.023		
2-029	1.465	.018			1.458	.020			1.450	.022			1.443	.024		
2-030	1.588	.019			1.580	.021			1.572	.023			1.564	.025		
2-031	1.711	.021			1.702	.023			1.694	.025			1.685	.028		
2-032	1.834	.022			1.825	.024			1.816	.026			1.806	.028		
2-033	1.957	.025			1.947	.028			1.937	.030			1.927	.032		
2-034	2.080	.026			2.070	.028			2.059	.031			2.048	.033		
2-035	2.203	.026			2.192	.029			2.181	.031			2.170	.034		
2-036	2.326	.027			2.314	.029			2.303	.032			2.291	.035		
2-037	2.449	.027			2.437	.030			2.424	.033			2.412	.036		
2-038	2.572	.029			2.559	.033			2.546	.036			2.533	.039		
2-039	2.695	.030			2.681	.033			2.668	.036			2.654	.040		
2-040	2.818	.030			2.804	.034			2.790	.037			2.775	.041		
2-041	2.941	.035			2.926	.038			2.911	.042			2.896	.046		
2-042	3.187	.036			3.171	.040			3.155	.043			3.139	.047		
2-043	3.433	.037			3.416	.041			3.398	.045			3.381	.049		
2-044	3.679	.040			3.660	.045			3.642	.049			3.623	.054		
2-045	3.925	.041			3.905	.046			3.885	.051			3.865	.056		
2-046	4.171	.045			4.150	.050			4.129	.055			4.108	.061		
2-047	4.417	.046			4.395	.052			4.372	.057			4.350	.062		
2-048	4.663	.047			4.639	.053			4.616	.058			4.592	.064		
2-049	4.909	.055			4.884	.061			4.859	.067			4.834	.073		
2-050	5.155	.056	.069	.004	5.129	.062	.069	.004	5.103	.068	.068	.004	5.077	.075	.068	.004

Table 10-8: Dimensions From Standard Tooling

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Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class -1				Class AN				Class I				Class II			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-102	.049	.005	.104	.003	.049	.005	.103	.003	.049	.005	.102	.004	.048	.005	.102	.004
2-103	.081				.081				.081				.080			
2-104	.113				.112				.111				.111			
2-105	.144				.143				.142				.141			
2-106	.175				.174				.173				.172			
2-107	.207				.206				.205				.204			
2-108	.238				.237				.236				.234	.006		
2-109	.301				.299				.297				.296	.006		
2-110	.364				.362				.360				.358	.006		
2-111	.427				.424				.421	.006			.419	.006		
2-112	.490	.005			.487				.484	.007			.482	.006		
2-113	.552	.007			.549	.007			.546	.008			.543	.008		
2-114	.616	.009			.612	.009			.608	.010			.605	.010		
2-115	.678	.009			.674	.009			.670	.010			.667	.011		
2-116	.741	.009			.737	.009			.733	.010			.729	.011		
2-117	.804	.010			.799	.010			.794	.011			.790	.012		
2-118	.867	.010			.862	.010			.857	.011			.853	.012		
2-119	.930	.010			.924	.010			.918	.011			.914	.012		
2-120	.993	.010			.987	.010			.981	.011			.976	.012		
2-121	1.055	.010			1.049	.010			1.043	.011			1.037	.013		
2-122	1.119	.010			1.112	.010			1.105	.011			1.100	.013		
2-123	1.181	.012			1.174	.012			1.167	.013			1.161	.015		
2-124	1.244	.012			1.237	.012			1.230	.013			1.223	.015		
2-125	1.307	.012			1.299	.012			1.291	.014			1.285	.015		
2-126	1.370	.012			1.362	.012			1.354	.014			1.347	.015		
2-127	1.433	.012			1.424	.012			1.415	.014			1.408	.015		
2-128	1.496	.012			1.487	.012			1.478	.014			1.471	.016		
2-129	1.558	.015			1.549	.015			1.540	.017			1.532	.019		
2-130	1.622	.015			1.612	.015			1.602	.017			1.594	.019		
2-131	1.684	.015			1.674	.015			1.664	.017			1.656	.019		
2-132	1.747	.015			1.737	.015			1.727	.017			1.718	.019		
2-133	1.810	.015			1.799	.015			1.788	.017			1.779	.019		
2-134	1.873	.015			1.862	.015			1.851	.017			1.842	.019		
2-135	1.937	.017			1.925	.017			1.913	.019			1.904	.022		
2-136	1.999	.017			1.987	.017			1.975	.019			1.965	.022		
2-137	2.062	.017			2.050	.017			2.038	.020			2.027	.022		
2-138	2.125	.017			2.112	.017			2.099	.020			2.089	.022		
2-139	2.188	.017			2.175	.017			2.162	.020			2.151	.022		
2-140	2.250	.017			2.237	.017			2.224	.020			2.212	.022		
2-141	2.314	.020			2.300	.020			2.286	.023			2.275	.026		
2-142	2.376	.020			2.362	.020			2.348	.023			2.336	.026		
2-143	2.440	.020			2.425	.020			2.410	.023			2.398	.026		
2-144	2.502	.020			2.487	.020			2.472	.023			2.460	.026		
2-145	2.565	.020			2.550	.020			2.535	.023			2.522	.026		
2-146	2.628	.020			2.612	.020			2.596	.023			2.583	.026		
2-147	2.691	.022			2.675	.022			2.659	.025			2.646	.028		
2-148	2.753	.022			2.737	.022			2.721	.025			2.707	.029		
2-149	2.817	.022			2.800	.022			2.783	.025			2.769	.029		
2-150	2.879	.022			2.862	.022			2.845	.025			2.831	.029		
2-151	3.005	.024			2.987	.024			2.969	.028			2.954	.031		
2-152	3.256	.024			3.237	.024			3.218	.028			3.201	.032		
2-153	3.508	.024			3.487	.024			3.466	.028			3.449	.032		
2-154	3.759	.028			3.737	.028			3.715	.032			3.696	.037		
2-155	4.011	.028			3.987	.028			3.963	.033			3.943	.038		
2-156	4.262	.030	.104	.003	4.237	.030	.103	.003	4.212	.035	.102	.004	4.190	.040	.102	.004

Table 10-8: Dimensions From Standard Tooling

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Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class III				Class IV				Class V				Class VI			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-102	.048	.005	.101	.004	.048	.005	.101	.004	.048	.005	.100	.005	.047	.005	.100	.005
2-103	.080	.005			.079	.005			.079	.005			.078	.006		
2-104	.110	.005			.110	.006			.109	.006			.109	.006		
2-105	.141	.006			.140	.006			.139	.006			.139	.006		
2-106	.171	.006			.170	.006			.169	.006			.169	.006		
2-107	.203	.006			.202	.006			.201	.006			.200	.006		
2-108	.233	.006			.232	.006			.231	.006			.230	.007		
2-109	.294	.006			.293	.006			.291	.007			.290	.007		
2-110	.356	.006			.354	.007			.353	.007			.351	.008		
2-111	.417	.007			.415	.007			.413	.008			.411	.008		
2-112	.479	.007			.477	.007			.474	.008			.472	.009		
2-113	.540	.009			.537	.010			.535	.010			.532	.011		
2-114	.602	.011			.599	.012			.596	.013			.593	.013		
2-115	.663	.011			.660	.012			.656	.013			.653	.014		
2-116	.725	.012			.722	.013			.718	.013			.714	.014		
2-117	.786	.013			.782	.014			.778	.015			.774	.016		
2-118	.848	.013			.844	.014			.840	.015			.835	.016		
2-119	.909	.013			.905	.014			.900	.016			.895	.017		
2-120	.971	.014			.966	.015			.961	.016			.956	.017		
2-121	1.032	.014			1.027	.015			1.022	.016			1.016	.018		
2-122	1.094	.014			1.089	.015			1.083	.017			1.078	.018		
2-123	1.155	.016			1.149	.018			1.143	.019			1.138	.020		
2-124	1.217	.016			1.211	.018			1.205	.019			1.199	.021		
2-125	1.278	.017			1.272	.018			1.265	.020			1.259	.021		
2-126	1.340	.017			1.333	.019			1.327	.020			1.320	.022		
2-127	1.401	.017			1.394	.019			1.387	.021			1.380	.022		
2-128	1.463	.017			1.456	.019			1.448	.021			1.441	.023		
2-129	1.524	.021			1.516	.022			1.509	.024			1.501	.026		
2-130	1.586	.021			1.578	.023			1.570	.025			1.562	.027		
2-131	1.647	.021			1.639	.023			1.630	.025			1.622	.027		
2-132	1.709	.021			1.701	.023			1.692	.025			1.683	.028		
2-133	1.770	.021			1.761	.024			1.752	.026			1.743	.028		
2-134	1.832	.022			1.823	.024			1.814	.026			1.804	.028		
2-135	1.894	.024			1.885	.026			1.875	.029			1.865	.031		
2-136	1.955	.024			1.945	.027			1.935	.029			1.925	.031		
2-137	2.017	.024			2.007	.027			1.997	.029			1.986	.032		
2-138	2.078	.025			2.068	.027			2.057	.030			2.047	.032		
2-139	2.140	.025			2.129	.027			2.118	.030			2.108	.033		
2-140	2.201	.025			2.190	.028			2.179	.030			2.168	.033		
2-141	2.263	.028			2.252	.031			2.240	.034			2.229	.037		
2-142	2.324	.029			2.312	.031			2.301	.034			2.289	.037		
2-143	2.386	.029			2.374	.032			2.362	.035			2.350	.037		
2-144	2.447	.029			2.435	.032			2.422	.035			2.410	.038		
2-145	2.509	.029			2.496	.032			2.484	.035			2.471	.038		
2-146	2.570	.029			2.557	.033			2.544	.036			2.531	.039		
2-147	2.632	.032			2.619	.035			2.605	.038			2.592	.041		
2-148	2.693	.032			2.680	.035			2.666	.038			2.652	.042		
2-149	2.755	.032			2.741	.035			2.727	.039			2.713	.042		
2-150	2.816	.032			2.802	.036			2.788	.039			2.773	.043		
2-151	2.939	.035			2.924	.038			2.909	.042			2.894	.046		
2-152	3.185	.036			3.169	.040			3.153	.043			3.137	.047		
2-153	3.431	.037			3.414	.041			3.396	.045			3.379	.049		
2-154	3.677	.041			3.659	.046			3.640	.050			3.621	.055		
2-155	3.923	.042			3.903	.047			3.883	.052			3.863	.057		
2-156	4.169	.045	.101	.004	4.148	.050	.101	.004	4.127	.055	.100	.005	4.106	.061	.100	.005

Table 10-8: Dimensions From Standard Tooling

Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class -1				Class AN				Class I				Class II			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-157	4.514	.030	.104	.003	4.487	.030	.103	.003	4.460	.035	.102	.004	4.438	.041	.102	.004
2-158	4.765	.030			4.737	.030			4.709	.036			4.685	.041		
2-159	5.017	.035			4.987	.035			4.957	.041			4.932	.047		
2-160	5.268	.035			5.237	.035			5.206	.041			5.179	.048		
2-161	5.520	.035			5.487	.035			5.454	.042			5.427	.048		
2-162	5.771	.035			5.737	.035			5.703	.042			5.674	.049		
2-163	6.023	.035			5.987	.035			5.951	.042			5.921	.049		
2-164	6.274	.040			6.237	.040			6.200	.047			6.168	.055		
2-165	6.526	.040			6.487	.040			6.448	.048			6.416	.056		
2-166	6.777	.040			6.737	.040			6.697	.048			6.663	.056		
2-167	7.029	.040			6.987	.040			6.945	.048			6.910	.057		
2-168	7.280	.045			7.237	.045			7.194	.054			7.157	.062		
2-169	7.532	.045			7.487	.045			7.442	.054			7.405	.063		
2-170	7.783	.045			7.737	.045			7.691	.054			7.652	.064		
2-171	8.035	.045			7.987	.045			7.939	.055			7.899	.064		
2-172	8.286	.050			8.237	.050			8.188	.060			8.146	.070		
2-173	8.538	.050			8.487	.050			8.436	.060			8.394	.070		
2-174	8.789	.050			8.737	.050			8.685	.060			8.641	.071		
2-175	9.041	.050			8.987	.050			8.933	.061			8.888	.072		
2-176	8.292	.055			9.237	.055			9.182	.066			9.135	.077		
2-177	9.544	.055			9.487	.055			9.430	.066			9.383	.078		
2-178	9.795	.055			9.737	.055			9.679	.067			9.630	.078		
2-201	.172	.005	.140	.004	.171	.005	.139	.004	.170	.005	.138	.005	.169	.005	.137	.005
2-202	.235	.005			.234	.005			.233	.005			.231	.006		
2-203	.298	.005			.296	.005			.294	.005			.293	.006		
2-204	.361	.005			.359	.005			.357	.005			.355	.006		
2-205	.424	.005			.421	.005			.418	.006			.416	.006		
2-206	.487	.005			.484	.005			.481	.006			.479	.007		
2-207	.549	.007			.546	.007			.543	.008			.540	.008		
2-208	.613	.009			.609	.009			.605	.010			.602	.010		
2-209	.675	.009			.671	.009			.667	.010			.664	.011		
2-210	.738	.010			.734	.010			.730	.011			.726	.012		
2-211	.801	.010			.796	.010			.791	.011			.787	.012		
2-212	.864	.010			.859	.010			.854	.011			.850	.012		
2-213	.927	.010			.921	.010			.915	.011			.911	.012		
2-214	.990	.010			.984	.010			.978	.011			.973	.012		
2-215	1.052	.010			1.046	.010			1.040	.011			1.034	.013		
2-216	1.116	.012			1.109	.012			1.102	.013			1.097	.015		
2-217	1.178	.012			1.171	.012			1.164	.013			1.158	.015		
2-218	1.241	.012			1.234	.012			1.227	.013			1.220	.015		
2-219	1.304	.012			1.296	.012			1.288	.014			1.282	.015		
2-220	1.367	.012			1.359	.012			1.351	.014			1.344	.015		
2-221	1.430	.012			1.421	.012			1.412	.014			1.405	.015		
2-222	1.493	.015			1.484	.015			1.475	.017			1.468	.019		
2-223	1.619	.015			1.609	.015			1.599	.017			1.591	.019		
2-224	1.744	.015			1.734	.015			1.724	.017			1.715	.019		
2-225	1.870	.018			1.859	.018			1.848	.020			1.839	.022		
2-226	1.996	.018			1.984	.018			1.972	.020			1.962	.023		
2-227	2.122	.018			2.109	.018			2.096	.021			2.086	.023		
2-228	2.247	.020			2.234	.020			2.221	.023			2.209	.025		
2-229	2.373	.020			2.359	.020			2.345	.023			2.333	.026		
2-230	2.499	.020			2.484	.020			2.469	.023			2.457	.026		
2-231	2.625	.020			2.609	.020			2.593	.023			2.580	.026		
2-232	2.750	.024			2.734	.024			2.718	.027			2.704	.031		
2-233	2.876	.024	.140	.004	2.859	.024	.139	.004	2.842	.027	.138	.005	2.828	.031	.137	.005

Table 10-8: Dimensions From Standard Tooling

Parker

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Dimensions From Standard Tooling (Continued)

Parker Size Number	Class III				Class IV				Class V				Class VI			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-157	4.415	.046	.101	.004	4.393	.052	.101	.004	4.370	.057	.100	.005	4.348	.062	.100	.005
2-158	4.661	.047			4.638	.053			4.614	.058			4.590	.064		
2-159	4.907	.053			4.882	.059			4.857	.065			4.832	.071		
2-160	5.153	.054			5.127	.060			5.101	.066			5.075	.073		
2-161	5.399	.055			5.372	.061			5.344	.068			5.317	.075		
2-162	5.645	.056			5.617	.063			5.588	.069			5.559	.076		
2-163	5.891	.057			5.861	.064			5.831	.071			5.801	.078		
2-164	6.137	.062			6.106	.070			6.075	.077			6.044	.085		
2-165	6.383	.063			6.351	.071			6.318	.079			6.286	.087		
2-166	6.629	.064			6.596	.072			6.562	.080			6.528	.089		
2-167	6.875	.065			6.840	.074			6.805	.082			6.770	.090		
2-168	7.121	.071			7.085	.080			7.049	.088			7.013	.097		
2-169	7.367	.072			7.330	.081			7.292	.090			7.255	.099		
2-170	7.613	.073			7.575	.082			7.536	.091			7.497	.101		
2-171	7.859	.074			7.819	.083			7.779	.093			7.739	.103		
2-172	8.105	.080			8.064	.090			8.023	.099			7.982	.109		
2-173	8.351	.081			8.309	.091			8.266	.101			8.224	.111		
2-174	8.597	.081			8.554	.092			8.510	.102			8.466	.113		
2-175	8.843	.082			8.798	.093			8.753	.104			8.708	.115		
2-176	9.089	.088			9.043	.099			8.997	.110			8.951	.122		
2-177	9.335	.089			9.288	.101			9.240	.112			9.193	.123		
2-178	9.581	.090			9.533	.102			9.484	.113			9.435	.125		
2-201	.168	.006	.137	.005	.167	.006	.136	.006	.167	.006	.135	.006	.166	.006	.135	.006
2-202	.230	.006			.229	.006			.228	.006			.227	.007		
2-203	.291	.006			.290	.006			.288	.007			.287	.007		
2-204	.353	.006			.351	.007			.350	.007			.348	.008		
2-205	.414	.007			.412	.007			.410	.008			.408	.008		
2-206	.476	.007			.474	.007			.471	.008			.469	.008		
2-207	.537	.009			.535	.010			.532	.010			.529	.011		
2-208	.599	.011			.596	.012			.593	.013			.590	.013		
2-209	.660	.011			.657	.012			.654	.013			.650	.014		
2-210	.722	.013			.719	.014			.715	.014			.711	.015		
2-211	.783	.013			.779	.014			.775	.015			.771	.016		
2-212	.845	.013			.841	.014			.837	.015			.832	.016		
2-213	.906	.013			.902	.014			.897	.016			.892	.017		
2-214	.968	.014			.963	.015			.958	.016			.953	.017		
2-215	1.029	.014			1.024	.015			1.019	.016			1.014	.018		
2-216	1.091	.016			1.086	.017			1.080	.019			1.075	.020		
2-217	1.152	.016			1.146	.018			1.141	.019			1.135	.020		
2-218	1.214	.016			1.208	.018			1.202	.019			1.196	.021		
2-219	1.275	.017			1.269	.018			1.262	.020			1.256	.021		
2-220	1.337	.017			1.330	.019			1.324	.020			1.317	.022		
2-221	1.398	.017			1.391	.019			1.384	.021			1.377	.022		
2-222	1.460	.020			1.453	.022			1.445	.024			1.438	.026		
2-223	1.583	.021			1.575	.023			1.567	.025			1.559	.027		
2-224	1.706	.021			1.698	.023			1.689	.025			1.680	.027		
2-225	1.829	.025			1.820	.027			1.811	.029			1.801	.031		
2-226	1.952	.025			1.942	.028			1.932	.030			1.922	.032		
2-227	2.075	.026			2.065	.028			2.054	.031			2.044	.033		
2-228	2.198	.028			2.187	.031			2.176	.033			2.165	.036		
2-229	2.321	.028			2.309	.031			2.298	.034			2.286	.037		
2-230	2.444	.029			2.432	.032			2.419	.035			2.407	.038		
2-231	2.567	.029			2.554	.033			2.541	.036			2.528	.039		
2-232	2.690	.034			2.677	.037			2.663	.040			2.649	.044		
2-233	2.813	.034	.137	.005	2.799	.038	.136	.006	2.785	.041	.135	.006	2.770	.045	.135	.006

Table 10-8: Dimensions From Standard Tooling

Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class -1				Class AN				Class I				Class II			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-234	3.002	.024	.140	.004	2.984	.024	.139	.004	2.966	.028	.138	.005	2.951	.031	.137	.005
2-235	3.128	.024			3.109	.024			3.090	.028			3.075	.031		
2-236	3.253	.024			3.234	.024			3.215	.028			3.198	.032		
2-237	3.379	.024			3.359	.024			3.339	.028			3.322	.032		
2-238	3.505	.024			3.484	.024			3.463	.028			3.446	.032		
2-239	3.631	.028			3.609	.028			3.587	.032			3.569	.037		
2-240	3.756	.028			3.734	.028			3.712	.032			3.693	.037		
2-241	3.882	.028			3.859	.028			3.836	.033			3.817	.037		
2-242	4.008	.028			3.984	.028			3.960	.033			3.940	.038		
2-243	4.134	.028			4.109	.028			4.084	.033			4.064	.038		
2-244	4.259	.030			4.234	.030			4.209	.035			4.187	.040		
2-245	4.385	.030			4.359	.030			4.333	.035			4.311	.040		
2-246	4.511	.030			4.484	.030			4.457	.035			4.435	.041		
2-247	4.637	.030			4.609	.030			4.581	.036			4.558	.041		
2-248	4.762	.030			4.734	.030			4.706	.036			4.682	.041		
2-249	4.888	.035			4.859	.035			4.830	.041			4.806	.047		
2-250	5.014	.035			4.984	.035			4.954	.041			4.929	.047		
2-251	5.140	.035			5.109	.035			5.078	.041			5.053	.047		
2-252	5.265	.035			5.234	.035			5.203	.041			5.176	.048		
2-253	5.391	.035			5.359	.035			5.327	.041			5.300	.048		
2-254	5.517	.035			5.484	.035			5.451	.042			5.424	.048		
2-255	5.643	.035			5.609	.035			5.575	.042			5.547	.048		
2-256	5.768	.035			5.734	.035			5.700	.042			5.671	.049		
2-257	5.894	.035			5.859	.035			5.824	.042			5.795	.049		
2-258	6.020	.035			5.984	.035			5.948	.042			5.918	.049		
2-259	6.271	.040			6.234	.040			6.197	.047			6.165	.055		
2-260	6.523	.040			6.484	.040			6.445	.048			6.413	.056		
2-261	6.774	.040			6.734	.040			6.694	.048			6.660	.056		
2-262	7.026	.040			6.984	.040			6.942	.048			6.907	.057		
2-263	7.277	.045			7.234	.045			7.191	.054			7.154	.062		
2-264	7.529	.045			7.484	.045			7.439	.054			7.402	.063		
2-265	7.780	.045			7.734	.045			7.688	.054			7.649	.064		
2-266	8.032	.045			7.984	.045			7.936	.055			7.896	.064		
2-267	8.283	.050			8.234	.050			8.185	.060			8.143	.070		
2-268	8.535	.050			8.484	.050			8.433	.060			8.391	.070		
2-269	8.786	.050			8.734	.050			8.682	.060			8.638	.071		
2-270	9.038	.050			8.984	.050			8.930	.061			8.885	.072		
2-271	9.289	.055			9.234	.055			9.179	.066			9.132	.077		
2-272	9.541	.055			9.484	.055			9.427	.066			9.380	.078		
2-273	9.792	.055			9.734	.055			9.676	.067			9.627	.078		
2-274	10.044	.055			9.984	.055			9.924	.067			9.874	.079		
2-275	10.547	.055			10.484	.055			10.421	.068			10.369	.080		
2-276	11.050	.065			10.984	.065			10.918	.078			10.863	.091		
2-277	11.553	.065			11.484	.065			11.415	.079			11.358	.093		
2-278	12.056	.065			11.984	.065			11.912	.079			11.852	.094		
2-279	13.062	.065			12.984	.065			12.906	.081			12.841	.096		
2-280	14.068	.065			13.984	.065			13.900	.082			13.830	.099		
2-281	15.074	.065			14.984	.065			14.894	.083			14.819	.101		
2-282	16.051	.075			15.955	.075			15.859	.094			15.779	.113		
2-283	17.057	.080			16.955	.080			16.853	.100			16.768	.121		
2-284	18.063	.085			17.955	.085			17.847	.107			17.757	.128		
2-309	.414	.005	.211	.005	.412	.005	.210	.005	.410	.005	.209	.006	.407	.006	.208	.007
2-310	.478	.005			.475	.005			.472	.006			.470	.006		
2-311	.540	.007			.537	.007			.534	.008			.531	.008		
2-312	.604	.009	.211	.005	.600	.009	.210	.005	.596	.010	.209	.006	.593	.010	.208	.007

Table 10-8: Dimensions From Standard Tooling

Parker

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Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class III				Class IV				Class V				Class VI			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-234	2.936	.035	.137	.005	2.921	.038	.136	.006	2.906	.042	.135	.006	2.891	.045	.135	.006
2-235	3.059	.035			3.044	.039			3.028	.043			3.013	.046		
2-236	3.182	.036			3.166	.040			3.150	.043			3.134	.047		
2-237	3.305	.036			3.288	.040			3.272	.044			3.255	.048		
2-238	3.428	.037			3.411	.041			3.393	.045			3.376	.049		
2-239	3.551	.041			3.533	.045			3.515	.050			3.497	.054		
2-240	3.674	.041			3.656	.046			3.637	.050			3.618	.055		
2-241	3.797	.042			3.778	.047			3.759	.051			3.739	.056		
2-242	3.920	.042			3.900	.047			3.880	.052			3.860	.057		
2-243	4.043	.043			4.023	.048			4.002	.053			3.982	.058		
2-244	4.166	.045			4.145	.050			4.124	.055			4.103	.060		
2-245	4.289	.046			4.267	.051			4.246	.056			4.224	.061		
2-246	4.412	.046			4.390	.052			4.367	.057			4.345	.062		
2-247	4.535	.047			4.512	.052			4.489	.058			4.466	.063		
2-248	4.658	.047			4.635	.053			4.611	.058			4.587	.064		
2-249	4.781	.052			4.757	.058			4.733	.064			4.708	.070		
2-250	4.904	.053			4.879	.059			4.854	.065			4.829	.071		
2-251	5.027	.053			5.002	.060			4.976	.066			4.951	.072		
2-252	5.150	.054			5.124	.060			5.098	.066			5.072	.073		
2-253	5.273	.054			5.246	.061			5.220	.067			5.193	.074		
2-254	5.396	.055			5.369	.061			5.341	.068			5.314	.074		
2-255	5.519	.055			5.491	.062			5.463	.069			5.435	.075		
2-256	5.642	.056			5.614	.063			5.585	.069			5.556	.076		
2-257	5.765	.056			5.736	.063			5.707	.070			5.677	.077		
2-258	5.888	.057			5.858	.064			5.828	.071			5.798	.078		
2-259	6.134	.062			6.103	.070			6.072	.077			6.041	.085		
2-260	6.380	.063			6.348	.071			6.315	.079			6.283	.087		
2-261	6.626	.064			6.593	.072			6.559	.080			6.525	.088		
2-262	6.872	.065			6.837	.074			6.802	.082			6.767	.090		
2-263	7.118	.071			7.082	.080			7.046	.088			7.010	.097		
2-264	7.364	.072			7.327	.081			7.289	.090			7.252	.099		
2-265	7.610	.073			7.572	.082			7.533	.091			7.494	.101		
2-266	7.856	.074			7.816	.083			7.776	.093			7.736	.102		
2-267	8.102	.080			8.061	.090			8.020	.099			7.979	.109		
2-268	8.348	.081			8.306	.091			8.263	.101			8.221	.111		
2-269	8.594	.081			8.551	.092			8.507	.102			8.463	.113		
2-270	8.840	.082			8.795	.093			8.750	.104			8.705	.115		
2-271	9.086	.088			9.040	.099			8.994	.110			8.948	.121		
2-272	9.332	.089			9.285	.101			9.237	.112			9.190	.123		
2-273	9.578	.090			9.530	.102			9.481	.113			9.432	.125		
2-274	9.824	.091			9.774	.103			9.724	.115			9.674	.127		
2-275	10.316	.093			10.264	.105			10.211	.118			10.159	.130		
2-276	10.808	.105			10.753	.118			10.698	.131			10.643	.144		
2-277	11.300	.106			11.243	.120			11.185	.134			11.128	.148		
2-278	11.792	.108			11.732	.123			11.672	.137			11.612	.151		
2-279	12.776	.112			12.711	.127			12.646	.143			12.581	.158		
2-280	13.760	.115			13.690	.132			13.620	.149			13.550	.166		
2-281	14.744	.119			14.669	.137			14.594	.155			14.519	.173		
2-282	15.700	.132			15.620	.152			15.540	.171			15.460	.190		
2-283	16.684	.141			16.599	.161			16.514	.182			16.429	.202		
2-284	17.668	.150			17.578	.171			17.488	.193			17.398	.214		
2-309	.405	.006	.207	.007	.403	.007	.206	.007	.401	.007	.205	.008	.399	.008	.203	.008
2-310	.467	.007			.465	.007			.463	.008			.460	.008		
2-311	.528	.009			.526	.010			.523	.010			.520	.011		
2-312	.590	.011	.207	.007	.587	.012	.206	.007	.584	.013	.205	.008	.581	.013	.203	.008

Table 10-8: Dimensions From Standard Tooling

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Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class -1				Class AN				Class I				Class II			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-313	.666	.009	.211	.005	.662	.009	.210	.005	.658	.010	.209	.006	.655	.011	.208	.007
2-314	.729	.010			.725	.010			.721	.011			.717	.012		
2-315	.792	.010			.787	.010			.782	.011			.778	.012		
2-316	.855	.010			.850	.010			.845	.011			.841	.012		
2-317	.917	.010			.912	.010			.907	.011			.902	.012		
2-318	.981	.010			.975	.010			.969	.011			.964	.012		
2-319	1.043	.010			1.037	.010			1.031	.011			1.026	.012		
2-320	1.107	.012			1.100	.012			1.093	.013			1.088	.015		
2-321	1.169	.012			1.162	.012			1.155	.013			1.149	.015		
2-322	1.232	.012			1.225	.012			1.218	.013			1.212	.015		
2-323	1.295	.012			1.287	.012			1.279	.014			1.273	.015		
2-324	1.358	.012			1.350	.012			1.342	.014			1.335	.015		
2-325	1.484	.015			1.475	.015			1.466	.017			1.459	.019		
2-326	1.610	.015			1.600	.015			1.590	.017			1.582	.019		
2-327	1.735	.015			1.725	.015			1.715	.017			1.706	.019		
2-328	1.861	.015			1.850	.015			1.839	.017			1.830	.019		
2-329	1.987	.018			1.975	.018			1.963	.020			1.953	.023		
2-330	2.113	.018			2.100	.018			2.087	.021			2.077	.023		
2-331	2.238	.018			2.225	.018			2.212	.021			2.201	.023		
2-332	2.364	.018			2.350	.018			2.336	.021			2.324	.024		
2-333	2.490	.020			2.475	.020			2.460	.023			2.448	.026		
2-334	2.616	.020			2.600	.020			2.584	.023			2.571	.026		
2-335	2.741	.020			2.725	.020			2.709	.023			2.695	.027		
2-336	2.867	.020			2.850	.020			2.833	.023			2.819	.027		
2-337	2.993	.024			2.975	.024			2.957	.028			2.942	.031		
2-338	3.119	.024			3.100	.024			3.081	.028			3.066	.031		
2-339	3.244	.024			3.225	.024			3.206	.028			3.190	.032		
2-340	3.370	.024			3.350	.024			3.330	.028			3.313	.032		
2-341	3.496	.024			3.475	.024			3.454	.028			3.437	.032		
2-342	3.622	.028			3.600	.028			3.578	.032			3.560	.037		
2-343	3.747	.028			3.725	.028			3.703	.032			3.684	.037		
2-344	3.873	.028			3.850	.028			3.827	.033			3.808	.037		
2-345	3.999	.028			3.975	.028			3.951	.033			3.931	.038		
2-346	4.125	.028			4.100	.028			4.075	.033			4.055	.038		
2-347	4.250	.030			4.225	.030			4.200	.035			4.179	.040		
2-348	4.376	.030			4.350	.030			4.324	.035			4.302	.040		
2-349	4.502	.030			4.475	.030			4.448	.035			4.426	.041		
2-350	4.628	.030			4.600	.030			4.572	.036			4.549	.041		
2-351	4.753	.030			4.725	.030			4.697	.036			4.673	.041		
2-352	4.879	.030			4.850	.030			4.821	.036			4.797	.042		
2-353	5.005	.037			4.975	.037			4.945	.043			4.920	.049		
2-354	5.131	.037			5.100	.037			5.069	.043			5.044	.049		
2-355	5.256	.037			5.225	.037			5.194	.043			5.168	.050		
2-356	5.382	.037			5.350	.037			5.318	.043			5.291	.050		
2-357	5.508	.037			5.475	.037			5.442	.044			5.415	.050		
2-358	5.634	.037			5.600	.037			5.566	.044			5.538	.050		
2-359	5.759	.037			5.725	.037			5.691	.044			5.662	.051		
2-360	5.885	.037			5.850	.037			5.815	.044			5.786	.051		
2-361	6.011	.037			5.975	.037			5.939	.044			5.909	.051		
2-362	6.262	.040			6.225	.040			6.188	.047			6.157	.055		
2-363	6.514	.040			6.475	.040			6.436	.048			6.404	.056		
2-364	6.765	.040			6.725	.040			6.685	.048			6.651	.056		
2-365	7.017	.040			6.975	.040			6.933	.048			6.898	.057		
2-366	7.268	.045			7.225	.045			7.182	.054			7.146	.062		
2-367	7.520	.045	.211	.005	7.475	.045	.210	.005	7.430	.054	.209	.006	7.393	.063	.208	.007

Table 10-8: Dimensions From Standard Tooling

Parker

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Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class III				Class IV				Class V				Class VI			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-313	.651	.011	.207	.007	.648	.012	.206	.007	.645	.013	.205	.008	.641	.014	.203	.008
2-314	.713	.013			.710	.013			.706	.014			.703	.015		
2-315	.774	.013			.770	.014			.767	.015			.763	.016		
2-316	.836	.013			.832	.014			.828	.015			.824	.016		
2-317	.897	.013			.893	.014			.888	.015			.884	.017		
2-318	.959	.014			.955	.015			.950	.016			.945	.017		
2-319	1.020	.014			1.015	.015			1.010	.016			1.005	.017		
2-320	1.082	.016			1.077	.017			1.071	.019			1.066	.020		
2-321	1.143	.016			1.138	.018			1.132	.019			1.126	.020		
2-322	1.205	.016			1.199	.018			1.193	.019			1.187	.021		
2-323	1.266	.017			1.260	.018			1.254	.020			1.247	.021		
2-324	1.328	.017			1.322	.018			1.315	.020			1.308	.022		
2-325	1.451	.020			1.444	.022			1.437	.024			1.429	.026		
2-326	1.574	.021			1.566	.023			1.558	.025			1.550	.027		
2-327	1.697	.021			1.689	.023			1.680	.025			1.672	.027		
2-328	1.820	.022			1.811	.024			1.802	.026			1.793	.028		
2-329	1.943	.025			1.934	.027			1.924	.030			1.914	.032		
2-330	2.066	.026			2.056	.028			2.045	.031			2.035	.033		
2-331	2.189	.026			2.178	.029			2.167	.031			2.156	.034		
2-332	2.312	.026			2.301	.029			2.289	.032			2.277	.035		
2-333	2.435	.029			2.423	.032			2.411	.035			2.398	.038		
2-334	2.558	.029			2.545	.032			2.532	.036			2.519	.039		
2-335	2.681	.030			2.668	.033			2.654	.036			2.641	.040		
2-336	2.804	.030			2.790	.034			2.776	.037			2.762	.041		
2-337	2.927	.035			2.913	.038			2.898	.042			2.883	.045		
2-338	3.050	.035			3.035	.039			3.019	.043			3.004	.046		
2-339	3.173	.036			3.157	.039			3.141	.043			3.125	.047		
2-340	3.296	.036			3.280	.040			3.263	.044			3.246	.048		
2-341	3.419	.037			3.402	.041			3.385	.045			3.367	.049		
2-342	3.542	.041			3.524	.045			3.506	.050			3.488	.054		
2-343	3.665	.041			3.647	.046			3.628	.050			3.610	.055		
2-344	3.788	.042			3.769	.046			3.750	.051			3.731	.056		
2-345	3.911	.042			3.892	.047			3.872	.052			3.852	.057		
2-346	4.034	.043			4.014	.048			3.993	.053			3.973	.058		
2-347	4.157	.045			4.136	.050			4.115	.055			4.094	.060		
2-348	4.280	.046			4.259	.051			4.237	.056			4.215	.061		
2-349	4.403	.046			4.381	.051			4.359	.057			4.336	.062		
2-350	4.526	.047			4.503	.052			4.480	.058			4.457	.063		
2-351	4.649	.047			4.626	.053			4.602	.058			4.579	.064		
2-352	4.772	.047			4.748	.053			4.724	.059			4.700	.065		
2-353	4.895	.055			4.871	.061			4.846	.067			4.821	.073		
2-354	5.018	.055			4.993	.061			4.967	.068			4.942	.074		
2-355	5.141	.056			5.115	.062			5.089	.068			5.063	.075		
2-356	5.264	.056			5.238	.063			5.211	.069			5.184	.076		
2-357	5.387	.057			5.360	.063			5.333	.070			5.305	.076		
2-358	5.510	.057			5.482	.064			5.454	.071			5.426	.077		
2-359	5.633	.058			5.605	.064			5.576	.071			5.548	.078		
2-360	5.756	.058			5.727	.065			5.698	.072			5.669	.079		
2-361	5.879	.059			5.850	.066			5.820	.073			5.790	.080		
2-362	6.125	.062			6.094	.070			6.063	.077			6.032	.085		
2-363	6.371	.063			6.339	.071			6.307	.079			6.274	.087		
2-364	6.617	.064			6.584	.072			6.550	.080			6.517	.088		
2-365	6.863	.065			6.829	.073			6.794	.082			6.759	.090		
2-366	7.109	.071			7.073	.080			7.037	.088			7.001	.097		
2-367	7.355	.072	.207	.007	7.318	.081	.206	.007	7.281	.090	.205	.008	7.243	.099	.203	.008

Table 10-8: Dimensions From Standard Tooling

Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class -1				Class AN				Class I				Class II			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-368	7.771	.045	.211	.005	7.725	.045	.210	.005	7.679	.054	.209	.006	7.640	.064	.208	.007
2-369	8.023	.045			7.975	.045			7.927	.055			7.887	.064		
2-370	8.274	.050			8.225	.050			8.176	.060			8.135	.070		
2-371	8.526	.050			8.475	.050			8.424	.060			8.382	.070		
2-372	8.777	.050			8.725	.050			8.673	.060			8.629	.071		
2-373	9.029	.050			8.975	.050			8.921	.061			8.876	.072		
2-374	9.280	.055			9.225	.055			9.170	.066			9.124	.077		
2-375	9.532	.055			9.475	.055			9.418	.066			9.371	.078		
2-376	9.783	.055			9.725	.055			9.667	.067			9.618	.078		
2-377	10.035	.055			9.975	.055			9.915	.067			9.865	.079		
2-378	10.538	.060			10.475	.060			10.412	.073			10.360	.085		
2-379	11.041	.060			10.975	.060			10.909	.073			10.854	.086		
2-380	11.544	.065			11.475	.065			11.406	.079			11.349	.093		
2-381	12.047	.065			11.975	.065			11.903	.079			11.843	.094		
2-382	13.053	.065			12.975	.065			12.897	.081			12.832	.096		
2-383	14.059	.070			13.975	.070			13.891	.087			13.821	.104		
2-384	15.065	.070			14.975	.070			14.885	.088			14.810	.106		
2-385	16.051	.075			15.955	.075			15.859	.094			15.779	.113		
2-386	17.057	.080			16.955	.080			16.853	.100			16.768	.121		
2-387	18.063	.085			17.955	.085			17.847	.107			17.757	.128		
2-388	19.069	.090			18.955	.090			18.841	.113			18.746	.135		
2-389	20.075	.095			19.955	.095			19.835	.119			19.735	.143		
2-390	21.081	.095			20.955	.095			20.829	.120			20.724	.145		
2-391	22.087	.100			21.955	.100			21.823	.126			21.713	.153		
2-392	23.078	.105			22.940	.105			22.802	.133			22.688	.160		
2-393	24.084	.110			23.940	.110			23.796	.139			23.677	.167		
2-394	25.090	.115			24.940	.115			24.790	.145			24.666	.175		
2-395	26.096	.120			25.940	.120			25.784	.151			25.655	.182		
2-425	4.502	.033	.277	.006	4.475	.033	.275	.006	4.448	.038	.273	.007	4.426	.044	.272	.008
2-426	4.628	.033			4.600	.033			4.572	.039			4.549	.044		
2-427	4.753	.033			4.725	.033			4.697	.039			4.673	.044		
2-428	4.879	.033			4.850	.033			4.821	.039			4.797	.045		
2-429	5.005	.037			4.975	.037			4.945	.043			4.920	.049		
2-430	5.131	.037			5.100	.037			5.069	.043			5.044	.049		
2-431	5.256	.037			5.225	.037			5.194	.043			5.168	.050		
2-432	5.382	.037			5.350	.037			5.318	.043			5.291	.050		
2-433	5.508	.037			5.475	.037			5.442	.044			5.415	.050		
2-434	5.634	.037			5.600	.037			5.566	.044			5.538	.050		
2-435	5.759	.037			5.725	.037			5.691	.044			5.662	.050		
2-436	5.885	.037			5.850	.037			5.815	.044			5.786	.051		
2-437	6.011	.037			5.975	.037			5.939	.044			5.909	.051		
2-438	6.262	.040			6.225	.040			6.188	.047			6.157	.055		
2-439	6.514	.040			6.475	.040			6.436	.048			6.404	.056		
2-440	6.765	.040			6.725	.040			6.685	.048			6.651	.056		
2-441	7.017	.040			6.975	.040			6.933	.048			6.898	.057		
2-442	7.268	.045			7.225	.045			7.182	.054			7.146	.062		
2-443	7.520	.045			7.475	.045			7.430	.054			7.393	.063		
2-444	7.771	.045			7.725	.045			7.679	.054			7.640	.064		
2-445	8.023	.045			7.975	.045			7.927	.055			7.887	.064		
2-446	8.526	.055			8.475	.055			8.424	.065			8.382	.075		
2-447	9.029	.055			8.975	.055			8.921	.066			8.876	.077		
2-448	9.532	.055			9.475	.055			9.418	.066			9.371	.078		
2-449	10.035	.055			9.975	.055			9.915	.067			9.865	.079		
2-450	10.538	.060			10.475	.060			10.412	.073			10.360	.085		
2-451	11.041	.060	.277	.006	10.975	.060	.275	.006	10.909	.073	.273	.007	10.854	.086	.272	.008

Table 10-8: Dimensions From Standard Tooling

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Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class III				Class IV				Class V				Class VI			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-368	7.601	.073	.207	.007	7.563	.082	.206	.007	7.524	.091	.205	.008	7.486	.101	.203	.008
2-369	7.847	.074			7.808	.083			7.768	.093			7.728	.102		
2-370	8.093	.080			8.052	.089			8.011	.099			7.970	.109		
2-371	8.339	.081			8.297	.091			8.255	.101			8.212	.111		
2-372	8.585	.081			8.542	.092			8.498	.102			8.455	.133		
2-373	8.831	.082			8.787	.093			8.742	.104			8.697	.115		
2-374	9.077	.088			9.031	.099			8.985	.110			8.939	.121		
2-375	9.323	.089			9.276	.100			9.229	.112			9.181	.123		
2-376	9.569	.090			9.521	.102			9.472	.113			9.424	.125		
2-377	9.815	.091			9.766	.103			9.716	.115			9.666	.127		
2-378	10.307	.098			10.255	.110			10.203	.123			10.150	.135		
2-379	10.799	.100			10.745	.113			10.690	.126			10.635	.139		
2-380	11.291	.106			11.234	.120			11.177	.134			11.119	.148		
2-381	11.783	.108			11.724	.122			11.664	.137			11.604	.151		
2-382	12.767	.112			12.703	.127			12.638	.143			12.573	.158		
2-383	13.751	.120			13.682	.137			13.612	.154			13.542	.171		
2-384	14.735	.124			14.661	.142			14.586	.160			14.511	.178		
2-385	15.700	.132			15.620	.152			15.540	.171			15.460	.190		
2-386	16.684	.141			16.599	.161			16.514	.182			16.429	.202		
2-387	17.668	.150			17.578	.171			17.488	.193			17.398	.214		
2-388	18.652	.158			18.557	.181			18.462	.204			18.367	.226		
2-389	19.636	.167			19.536	.191			19.436	.215			19.336	.239		
2-390	20.620	.170			20.515	.196			20.410	.221			20.305	.246		
2-391	21.604	.179			21.494	.205			21.384	.232			21.274	.258		
2-392	22.573	.188			22.458	.215			22.344	.243			22.229	.270		
2-393	23.557	.196			23.437	.225			23.318	.254			23.198	.282		
2-934	24.541	.205			24.416	.235			24.292	.265			24.167	.295		
2-395	25.525	.213	.207	.007	25.395	.245	.206	.007	25.266	.276	.205	.008	25.136	.307	.203	.008
2-425	4.403	.049	.271	.008	4.381	.054	.269	.009	4.359	.060	.268	.010	4.336	.065	.266	.010
2-426	4.526	.050			4.503	.055			4.480	.061			4.457	.066		
2-427	4.649	.050			4.626	.056			4.602	.061			4.579	.067		
2-428	4.772	.050			4.748	.056			4.724	.062			4.700	.068		
2-429	4.895	.055			4.871	.061			4.846	.067			4.821	.073		
2-430	5.018	.055			4.993	.061			4.967	.068			4.942	.074		
2-431	5.141	.056			5.115	.062			5.089	.068			5.063	.075		
2-432	5.264	.056			5.238	.063			5.211	.069			5.184	.076		
2-433	5.387	.057			5.360	.063			5.333	.070			5.305	.076		
2-434	5.510	.057			5.482	.064			5.454	.071			5.426	.077		
2-435	5.633	.058			5.605	.064			5.576	.071			5.548	.078		
2-436	5.756	.058			5.727	.065			5.698	.072			5.669	.079		
2-437	5.879	.059			5.850	.066			5.820	.073			5.790	.080		
2-438	6.125	.062			6.094	.070			6.063	.077			6.032	.085		
2-439	6.371	.063			6.339	.071			6.307	.079			6.274	.087		
2-440	6.617	.064			6.584	.072			6.550	.080			6.517	.088		
2-441	6.863	.065			6.829	.073			6.794	.082			6.759	.090		
2-442	7.109	.071			7.073	.080			7.037	.088			7.001	.097		
2-443	7.355	.072			7.318	.081			7.281	.090			7.243	.099		
2-444	7.601	.073			7.563	.082			7.524	.091			7.486	.101		
2-445	7.847	.074			7.808	.083			7.768	.093			7.728	.102		
2-446	8.339	.086			8.297	.096			8.255	.106			8.212	.116		
2-447	8.831	.087			8.787	.098			8.742	.109			8.697	.120		
2-448	9.323	.089			9.276	.100			9.229	.112			9.181	.123		
2-449	9.815	.091			9.766	.103			9.716	.115			9.666	.127		
2-450	10.307	.098			10.255	.110			10.203	.123			10.150	.135		
2-451	10.799	.100	.271	.008	10.745	.113	.269	.009	10.690	.126	.268	.010	10.635	.139	.266	.010

Table 10-8: Dimensions From Standard Tooling

Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class -1				Class AN				Class I				Class II			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-452	11.544	.060	.277	.006	11.475	.060	.275	.006	11.406	.074	.273	.007	11.349	.088	.272	.008
2-453	12.047	.060			11.975	.060			11.903	.074			11.843	.089		
2-454	12.550	.060			12.475	.060			12.400	.075			12.338	.090		
2-455	13.053	.060			12.975	.060			12.897	.076			12.832	.091		
2-456	13.556	.070			13.475	.070			13.394	.086			13.327	.102		
2-457	14.059	.070			13.975	.070			13.891	.087			13.821	.104		
2-458	14.562	.070			14.475	.070			14.388	.087			14.316	.105		
2-459	15.065	.070			14.975	.070			14.885	.088			14.810	.106		
2-460	15.568	.070			15.475	.070			15.382	.089			15.305	.107		
2-461	16.051	.075			15.955	.075			15.859	.094			15.779	.113		
2-462	16.554	.075			16.455	.075			16.356	.095			16.274	.114		
2-463	17.057	.080			16.955	.080			16.853	.100			16.768	.121		
2-464	17.560	.085			17.455	.085			17.350	.106			17.263	.127		
2-465	18.063	.085			17.955	.085			17.847	.107			17.757	.128		
2-466	18.566	.085			18.455	.085			18.344	.107			18.252	.129		
2-467	19.069	.090			18.955	.090			18.841	.113			18.746	.135		
2-468	19.572	.090			19.455	.090			19.338	.113			19.241	.137		
2-469	20.075	.095			19.955	.095			19.835	.119			19.735	.143		
2-470	21.081	.095			20.955	.095			20.829	.120			20.724	.145		
2-471	22.087	.100			21.955	.100			21.823	.126			21.713	.153		
2-472	23.078	.105			22.940	.105			22.802	.133			22.688	.160		
2-473	24.084	.110			23.940	.110			23.796	.139			23.677	.167		
2-474	25.090	.115			24.940	.115			24.790	.145			24.666	.175		
2-475	26.096	.120	.277	.006	25.940	.120	.275	.006	25.784	.151	.273	.007	25.655	.182	.272	.008

Parker Size Number	Class -1				Class AN				Class I				Class II			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
3-901	.186	.005	.056	.003	.185	.005	.056	.003	.184	.005	.056	.004	.183	.005	.055	.004
3-902	.240	.005	.064		.239	.005	.064		.238	.005	.064		.236	.006	.063	
3-903	.303	.005	.064		.301	.005	.064		.299	.005	.064		.298	.006	.063	
3-904	.353	.005	.072		.351	.005	.072		.349	.005	.072		.347	.006	.071	
3-905	.416	.005	.072		.414	.005	.072		.412	.005	.072		.409	.006	.071	
3-906	.471	.005	.078		.468	.005	.078		.465	.006	.078		.463	.006	.077	
3-907	.533	.007	.082		.530	.007	.082		.527	.008	.082		.524	.008	.081	
3-908	.648	.009	.088		.644	.009	.087		.640	.010	.086		.637	.011	.086	
3-909	.710	.009	.098		.706	.009	.097		.702	.010	.096		.698	.011	.096	
3-910	.760	.009	.098		.755	.009	.097		.750	.010	.096		.747	.011	.096	
3-911	.868	.009	.117		.863	.009	.116		.858	.010	.115		.854	.011	.115	
3-912	.930	.009	.117		.924	.009	.116		.918	.010	.115		.914	.011	.115	
3-913	.992	.010	.117		.986	.010	.116		.980	.011	.115		.975	.012	.115	
3-914	1.053	.010	.117		1.047	.010	.116		1.041	.011	.115		1.035	.013	.115	
3-916	1.178	.010	.117		1.171	.010	.116		1.164	.011	.115		1.158	.013	.115	
3-918	1.363	.012	.117		1.355	.012	.116		1.347	.014	.115		1.340	.015	.115	
3-920	1.484	.014	.119		1.475	.014	.118		1.466	.016	.117		1.459	.018	.117	
3-924	1.730	.014	.119		1.720	.014	.118		1.710	.016	.117		1.701	.018	.117	
3-928	2.103	.018	.119		2.090	.018	.118		2.077	.021	.117		2.067	.023	.117	
3-932	2.351	.018	.119	.004	2.337	.018	.118	.004	2.323	.021	.117	.005	2.311	.024	.117	.005

Table 10-8: Dimensions From Standard Tooling

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Appendix

Dimensions From Standard Tooling (Continued)

Parker Size Number	Class III				Class IV				Class V				Class VI			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
2-452	11.291	.101	.271	.008	11.234	.115	.269	.009	11.177	.129	.268	.010	11.119	.143	.266	.010
2-453	11.783	.103			11.724	.117			11.664	.132			11.604	.146		
2-454	12.275	.105			12.213	.120			12.151	.135			12.088	.150		
2-455	12.767	.107			12.703	.122			12.638	.138			12.573	.153		
2-456	13.259	.119			13.192	.135			13.125	.151			13.057	.167		
2-457	13.751	.120			13.682	.137			13.612	.154			13.542	.171		
2-458	14.243	.122			14.171	.139			14.099	.157			14.026	.174		
2-459	14.735	.124			14.661	.142			14.586	.160			14.511	.178		
2-460	15.227	.126			15.150	.144			15.073	.163			14.995	.181		
2-461	15.700	.132			15.620	.152			15.540	.171			15.460	.190		
2-462	16.192	.134			16.109	.154			16.027	.174			15.945	.193		
2-463	16.684	.141			16.599	.161			16.514	.182			16.429	.202		
2-464	17.176	.148			17.088	.169			17.001	.190			16.914	.211		
2-465	17.668	.150			17.578	.171			17.488	.193			17.398	.214		
2-466	18.160	.151			18.067	.174			17.975	.196			17.883	.218		
2-467	18.652	.158			18.557	.181			18.462	.204			18.367	.226		
2-468	19.144	.160			19.046	.183			18.949	.207			18.852	.230		
2-469	19.636	.167			19.536	.191			19.436	.215			19.336	.239		
2-470	20.620	.170			20.515	.196			20.410	.221			20.305	.246		
2-471	21.604	.179			21.494	.205			21.384	.232			21.274	.258		
2-472	22.573	.188			22.458	.215			22.344	.243			22.229	.270		
2-473	23.557	.196			23.437	.225			23.318	.254			23.198	.282		
2-474	23.541	.205			24.416	.235			24.292	.265			24.167	.295		
2-475	25.525	.213	.271	.008	25.395	.245	.269	.009	25.266	.276	.268	.010	25.136	.307	.266	.010

Parker Size Number	Class III				Class IV				Class V				Class VI			
	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±	ID	Tol ±	W	Tol ±
3-901	.182	.006	.055	.004	.181	.006	.055	.004	.180	.006	.055	.004	.179	.006	.054	.004
3-902	.235	.006	.063		.234	.006	.063		.233	.006	.062		.232	.007	.063	
3-903	.296	.006	.063		.295	.006	.063		.293	.007	.062		.292	.007	.062	
3-904	.345	.006	.071		.344	.007	.070		.342	.007	.070		.340	.008	.070	
3-905	.407	.006	.071		.405	.007	.070		.403	.007	.070		.401	.008	.070	
3-906	.461	.007	.077		.458	.007	.076		.456	.008	.076		.453	.008	.076	
3-907	.522	.009	.081		.519	.010	.080		.516	.010	.080		.514	.011	.079	
3-908	.634	.011	.086		.630	.012	.085		.627	.013	.085		.624	.014	.084	
3-909	.695	.012	.095		.691	.012	.095		.688	.013	.094		.684	.014	.094	
3-910	.743	.012	.095	.004	.739	.013	.095	.004	.735	.014	.094	.004	.732	.014	.094	.004
3-911	.849	.012	.114	.005	.845	.013	.114	.005	.841	.014	.113	.006	.836	.015	.112	.006
3-912	.909	.012	.114		.905	.013	.114		.900	.015	.113		.895	.016	.112	
3-913	.970	.014	.114		.965	.015	.114		.960	.016	.113		.955	.017	.112	
3-914	1.030	.014	.114		1.025	.015	.114		1.020	.016	.113		1.015	.018	.112	
3-916	1.152	.014	.114		1.146	.016	.114		1.141	.017	.113		1.135	.018	.112	
3-918	1.333	.017	.114		1.327	.019	.114		1.320	.020	.113		1.313	.022	.113	
3-920	1.451	.019	.116		1.444	.021	.116		1.437	.023	.115		1.429	.025	.114	
3-924	1.692	.020	.116		1.684	.022	.116		1.675	.024	.115		1.667	.026	.114	
3-928	2.057	.026	.116		2.046	.028	.116		2.036	.031	.115		2.025	.033	.114	
3-932	2.300	.026	.116	.005	2.288	.029	.116	.005	2.276	.032	.115	.006	2.265	.035	.114	.006

Table 10-8: Dimensions From Standard Tooling

Tolerances for Special O-Rings with Standard Shrinkage Rates

Inside Dia. (in.)			Tol. (in.)	Inside Dia. (mm)			Tol. (mm)	Inside Dia. (in.)			Tol. (in.)	Inside Dia. (mm)			Tol. (mm)
.027	–	.060	.004	.68	–	1.53	.10	4.001	–	4.620	.030	101.62	–	117.36	.76
.061	–	.490	.005	1.54	–	11.69	.13	4.621	–	5.560	.035	117.37	–	141.23	.89
.491	–	.530	.006	11.70	–	14.49	.15	5.561	–	6.550	.040	141.24	–	166.39	1.02
.531	–	.690	.007	14.50	–	17.54	.18	6.551	–	7.560	.045	166.40	–	192.03	1.14
.691	–	.810	.008	17.55	–	20.59	.20	7.561	–	8.610	.050	192.04	–	218.70	1.27
.811	–	.940	.009	20.60	–	23.89	.23	8.611	–	9.975	.055	218.71	–	246.39	1.40
.941	–	1.130	.010	23.90	–	28.71	.25	9.976	–	11.400	.060	246.40	–	289.57	1.52
1.131	–	1.400	.012	28.72	–	35.57	.30	11.401	–	13.700	.070	289.58	–	347.99	1.78
1.401	–	1.700	.014	35.58	–	43.17	.36	13.701	–	16.100	.080	348.00	–	408.95	2.03
1.701	–	2.000	.016	43.20	–	50.81	.41	16.101	–	18.600	.090	408.96	–	472.45	2.29
2.001	–	2.300	.018	50.82	–	58.43	.46	18.601	–	22.500	.100	472.46	–	571.51	2.54
2.301	–	2.620	.020	58.44	–	66.56	.51	22.501	–	28.000	.120	571.52	–	711.21	3.05
2.621	–	2.950	.022	66.57	–	74.94	.56	28.001	–	33.700	.140	711.22	–	855.99	3.56
2.951	–	3.290	.024	74.95	–	83.57	.61	33.701	–	39.600	.160	856.00	–	1005.85	4.06
3.291	–	3.630	.026	83.58	–	92.21	.66	39.601	–	45.800	.180	1005.86	–	1163.66	4.57
3.631	–	4.000	.028	92.22	–	101.61	.71	45.801	–	52.000	.200	1163.34	–	1320.80	5.08

Table 10-11: Tolerances for Special O-Rings with Standard Shrinkage Rates

Appendix

Cross Section Tolerances

W Cross Section Range – in.	Shrinkage Class Tolerance ± inches							
	-1	AN	+I	+II	+III	+IV	+V	+VI
.025 – .097	.003	.003	.004	.004	.004	.004	.004	.004
.098 – .104	.003	.003	.004	.004	.004	.004	.005	.005
.105 – .129	.004	.004	.005	.005	.005	.005	.006	.006
.130 – .149	.004	.004	.005	.005	.005	.006	.006	.006
.150 – .174	.005	.005	.006	.006	.007	.007	.007	.008
.175 – .220	.005	.005	.006	.007	.007	.007	.008	.008
.221 – .250	.006	.006	.007	.008	.008	.009	.009	.009
.251 – .300	.006	.006	.007	.008	.008	.009	.010	.010
.301 – .340	.007	.007	.008	.010	.010	.010	.011	.011
.341 – .375	.007	.007	.008	.010	.010	.011	.011	.011

W Cross Section Range – mm.	Shrinkage Class Tolerance ± millimeters							
	-1	AN	+I	+II	+III	+IV	+V	+VI
.63 – 2.47	.08	.08	.10	.10	.10	.10	.10	.10
2.48 – 2.65	.08	.08	.10	.10	.10	.10	.13	.13
2.60 – 3.29	.10	.10	.13	.13	.13	.13	.15	.15
3.30 – 3.80	.10	.10	.13	.13	.13	.15	.15	.15
3.81 – 4.43	.13	.13	.15	.15	.18	.18	.18	.20
4.44 – 5.60	.13	.13	.15	.18	.18	.18	.20	.20
5.61 – 6.36	.15	.15	.18	.20	.20	.23	.23	.23
6.37 – 7.64	.15	.15	.18	.20	.20	.23	.25	.25
7.65 – 8.65	.18	.18	.20	.25	.25	.25	.28	.28
8.66 – 9.55	.18	.18	.20	.25	.25	.28	.28	.28

Table 10-9: Cross Section Tolerances

Shrinkage Class Factors

Shrinkage Class	Dimension Factor	Tolerance Factor
-1	1.006	0
AN	1.000	0
+I	.994	.0012
+II	.989	.0024
+III	.984	.0036
+IV	.979	.0048
+V	.974	.0060
+VI	.969	.0072

Table 10-10: Shrinkage Class Factors

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