Minnesota Rubber and Plastics

Elastomers and Thermoplastics Engineering Design Guide

Minnesota Rubber & Plastics
Quadion Corporation

Table of Contents

Section 1
The Company Behind the Parts

Minneapolis, Minnesota

- Headquarters for Minnesota Rubber and Plastics, and Quadion Corporation
- Central technical support for Minnesota Rubber and Plastics engineering, design and materials R&D

Quadion Corporation

The Company Behind The Parts

Resources focused for your success.

Minnesota Rubber and Plastics are world leaders in the engineering design, compound development and manufacturing of custom molded elastomeric and thermoplastic components and assemblies. Our global reputation and resources, for producing "the tough parts," are matched by our commitment to quality, product performance and service support.

Expertise where it counts.

We have an advantage over many rubber and plastics manufacturers because we place a great deal of emphasis on research and development. Our technical support staff provides the resources to design, formulate, develop and test materials and parts.

What's more, we are uniquely positioned to offer both rubber and plastic combination parts, including sub-assemblies. This allows us to provide greater development and production efficiencies, thereby reducing development time and minimizing both short and long term costs.

From prototyping to final production, our state-of-the-art design engineering services provide timely answers to difficult design issues. Our CAD/CAM and FEA systems allow us to offer design alternatives quickly and precisely while our tool development and secondary press operations are second to none. Finally, prior to committing to production, our prototyping services provide you with production quality sample parts for final testing.

A global network on your side.

Across our worldwide operations, we demonstrate a commitment to excellence and performance by offering our customers greater value and quality in the products we sell. This commitment is fulfilled by the dedicated work force, including chemists, engineers and supporting technical personnel, working within our R&D centers and manufacturing facilities. Our global resources provide comprehensive service, support and sourcing options.

Talk to the experts.

When your rubber or plastic design requirements seem impossible, there's no one better to partner with than Minnesota Rubber and Plastics. We're here to make your designs a reality.

Minnesota Rubber and Plastics
1100 Xenium Lane North
Minneapolis, MN 55441-7000

(952) 927-1400
Fax (952) 927-1470

web site: www.mnrubber.com
e-mail: info@mnrubber.com

Custom molded rubber and plastic components.

Materials and Design Engineering Support For:

- Injection Molded Plastics
- Assemblies and Sub-assemblies
- Custom Seals and Shapes
- Insert Molding in Thermoplastics, Rubber and Silicone
- Injection, Transfer, Compression and LSR Molding
- Rotary Seal Rings and Thrust Washers
- Rubber to TPE Conversions
- Metal to Plastic Conversions
- Tool Design and Construction

Standard Products:

- Quad-Ring® Seals
  - Twice the Seal Surface
  - Lower Friction
  - Longer Life
  - Recessed Parting Line
  - Reduced Spiral Twist
- Quad® Brand O-Rings
- Quad® Brand Ground Rubber Balls
- Equi-Flex™ Rod Wiper/Scraper

Reduce Costs - Improve Performance

Markets and Applications:

- **Medical**
  - Pharmaceuticals
  - Surgical Tools
  - Drug Delivery
  - Prosthetics
  - Catheters
  - Leads

- **Food and Beverage**
  - Dispensing Valves
  - Bottling Equipment
- **Fluid Power**
  - Pneumatic and Hydraulic
  - Pumps
- **Plumbing and Water**
  - Faucets
  - Valves
  - Irrigation
  - Pumps

- **Automotive**
  - Bearings
  - Suspension
  - Fuel Systems
  - Transmissions
  - ABS

- **Appliance**
  - Water Valves
- **HVAC, Gas and Heating Controls**
  - Control Valves
- **Fire and Safety**
  - Fire Extinguishers
  - Hearing Protection

Liquid Silicone Rubber Molding:

- Robotic Automation
- Smaller Part Features
- Insert Molding
- Wasteless Production
- Reduced Post Processing
- Product Design and Prototyping

Working With Extremes:

- Medical and Contaminant Free Molding
- Bearing Grade and High Temperature Thermoplastics
  PEEK® / Torlon® / Aurum®
- Friction Modified Elastomers
- Fuel and Chemical Resistant Elastomers
- High and Low Temperature Elastomers
- Kevlar® and Specialty Filled Elastomers
- Thermoset Silicone and Fluorosilicone Elastomers

Reduce Costs - Improve Performance

Engineered to improve performance. Designed to reduce costs.

Facility Highlights

Litchfield, Minnesota

- 40,000 square feet/
  3,700 square meters
- Horizontal injection molding of black rubber
- Liquid silicone rubber molding
- Extensive automation
- Vision Systems
- Clean room finishing facilities
- Custom molded engineered shapes
- Thermoset silicone molding
- Insert Molding
- Standard products: ground rubber balls, o-rings & Quad-Ring® Seals
- Markets: automotive, medical, plumbing, industrial & consumer

Minnesota Rubber & Plastics
Quadion Corporation

Watertown, South Dakota

- 120,000 square feet/
  11,150 square meters
- Vertical injection molding
- Compression & transfer molding
- Short to medium production runs
- Insert molding
- Mixing facility for black rubber/colored stock/silicone
- Custom molded engineered shapes
- Wide range of markets

Minnesota Rubber & Plastics
Quadion Corporation

Mason City, Iowa

- 45,000 square feet/
  4,200 square meters
- Primary pre-forming, extrusion & mixing facility for Minnesota Rubber

Minnesota Rubber & Plastics
Quadion Corporation

Reynosa, Mexico

- 55,000 square feet/
  5,100 square meters
- Compression & transfer molding
- Secondary operations & assemblies
- Insert molding
- Thermoset silicone molding
- Custom molded engineered shapes
- Standard products: o-rings & Quad-Ring® Seals

Minnesota Rubber & Plastics
Quadion Corporation

Pacy-sur-Eure, France

- 50,000 square feet/
  4,650 square meters
- Distribution, sales and technical support facility
- Materials development & design engineering support
- Custom molded engineered shapes
- Prototyping services
- Regional and international sourcing.
- Markets: automotive, plumbing, medical, industrial, aerospace, agricultural & consumer

Minnesota Rubber & Plastics
Quadion Corporation

Fountain Valley, California

- 5,200 square feet/
  481 square meters
- Distribution facility
- Regional sales and international sourcing
- Standard and custom molded engineered shapes

Mar-Kell Seal
Global Express
Quadion Corporation

Suzhou, China

- 30,000 square feet/
  2,815 square meters
- Horizontal injection molding of black rubber
- Compression & transfer molding
- Secondary operations
- Insert molding
- Liquid Silicone Rubber (LSR) molding
- Custom molded engineered shapes
- Markets: automotive, medical, plumbing, industrial & consumer

Minnesota
Rubber & Plastics
Quadion Corporation

Singapore, Republic of Singapore

- 40,000 square feet/
  3,700 square meters
- Thermoset silicone molding
- Materials development & design engineering support
- Tool design & construction
- Insert molding, sub-assemblies
- Custom molded engineered shapes
- Prototyping services
- Vertical injection, compression & transfer molding
- Markets: automotive, plumbing, medical, industrial, aerospace, agricultural & consumer

Minnesota
Rubber & Plastics
Quadion Corporation

River Falls, Wisconsin

- 35,000 square feet/
  3,250 square meters
- Precision molded plastic components
- High performance thermoplastics & thermoplastic elastomers (TPE'S)
- Metal-to-plastic conversions
- Extensive range of molded engineering materials
- Insert molding
- Contract design, assemblies, & secondary operations
- Horizontal & vertical presses, 40 to 440 ton
- Prototyping services
- Markets: automotive, plumbing, industrial & consumer

Minnesota
Rubber & Plastics
Quadion Corporation

Minneapolis, Minnesota

- 60,000 square feet/
  5,575 square meters
- Precision molded plastic components
- Prototyping, tooling and decorative services
- Packaging and assembly services
- Class 10,000 and 100,000 clean rooms
- Insert molding
- Horizontal presses, 17 to 300 ton
- Markets: medical, electronics and industrial

Minnesota
Rubber & Plastics
Quadion Corporation

Section 2
Designing Rubber Components

Designing Rubber Components

Working Together

When a designer specifies rubber or plastic for a product or component, it's because no other material can duplicate the required performance characteristics. However, most design engineers do not have the time to become rubber and plastic experts.

The purpose of this Guide is to provide a better understanding of the processes, materials and technical considerations involved in the design and manufacture of custom-molded rubber and plastic parts. By understanding these considerations, you can better control costs while improving the performance of your product.

At Minnesota Rubber and Plastics we specialize in finding solutions to tough applications which require the molding and assembly of close tolerance components. Our capabilities allow us to offer unified technologies to assist in design recommendations and complete project management to accelerate time-to-market.

Engineering Design

Part design begins with answers to some basic questions about how the part will be used and the environment in which it must operate.

What will be the function of the part?

- Seal a fluid? (Impermeable to particular fluid?)
- Transmit a fluid?
- Transmit energy?
- Absorb energy?
- Provide structural support?

What is the environment in which it will function?

- Water, chemicals or solvents that could cause shrinkage of the part?
- Oxygen or ozone?
- Sunlight?
- Wet/dry situation?
- Constant pressure or pressure cycle?
- Dynamic stress, causing potential deformation?

How long must it perform correctly?

What properties must the part exhibit?

- Need to stretch without breaking (high ultimate elongation)?
- Resistance to deformation (high modulus)?
- Resistance to set under extensive load (high compression set)?
- Resistance to dimensional changes or embrittlement in the presence of heat or fluids?

Cost Effective Custom-Molded Seals

Engineers sometimes have the idea that custom parts are cost-prohibitive, so they design their products with less effective standard parts to avoid possible perceived added cost. However, in the long run, a well designed custom molded part can improve product performance, longevity and function, therefore reducing overall costs.

Avoiding Rubber Component Design Problems

The unique aspects of rubber product design require care to prevent unforeseen problems in the performance or manufacture of a part. The following is a list of common problems sometimes encountered when designing rubber parts, and some suggestions for avoiding them.

1. Attempting to compress rubber (or overfilling the groove)
2. Designing a rubber part which cannot be manufactured
3. Not providing installation tools and/or employee training
4. Failing to consider all possible chemicals/processes which may contact the rubber component
5. Not providing sufficient lubrication for a seal or other dynamic rubber part
6. Not allowing enough room for a seal or rubber part
7. Using too small a seal or rubber part
8. Using a seal as a bearing
9. Not considering rubber thermal effects
10. Not accounting for seal friction and power loss

Properties in Balance

Choosing the correct material always involves tradeoffs in performance, as illustrated in the following chart. The key then is to determine and prioritize your part's most critical performance characteristics.

An improvement in...	Usually improves...	But sacrifices...
Abrasion resistance	Hardness/Elongation	Resilience
Impact resistance	Elongation	Modulus
Creep resistance	Resilience	Flex resistance
Oil resistance	Tear resistance	Low temperature flex
Resilience	Creep resistance	Tear resistance
Tensile strength	Modulus	Elongation
Vibration damping	Impact resistance	Structural integrity

Selecting an Elastomeric Material

One of the most important aspects of designing a sealing system, or any other elastomeric component, is making a proper material selection. There are many different elastomeric materials from which to choose, and selecting the "best" material means balancing suitability for the application, performance, cost, and ease of manufacturing. Minnesota Rubber and Plastics manufactures and uses hundreds of different types of elastomeric materials. Contact us for assistance in selecting a material for your application.

1. How and where will the part actually be used? How will it be stored and transported? What will it be located next to?
2. What is the environment in which the seal or part is operating, including fluids, gases, contaminants, pressures, temperatures, etc.?
3. What are your performance objectives for the part, including life span and duty cycle?
4. What is your product worth in the marketplace, and are your performance objectives achievable at the market price?

When selecting a material for your application, consider the following:

- The primary fluid(s) to which the elastomer will be exposed.
- Secondary fluids to which the elastomer will be exposed, such as cleaning fluids or lubricants.
- Exposure to chloramines in water.
- The suitability of the material for the application's temperature extremes, both hot and cold.
- The presence of abrasive external contaminants.
- The presence of ozone from natural and artificial sources, such as electric motors, which can attack rubber.
- Exposure to processes such as sterilization by gas, autoclaving, or radiation.
- Exposure to ultraviolet light and sunlight, which can decompose rubber.
- The potential for outgassing in vacuum applications.
- Will the product come in contact with the human body, directly or indirectly, and if so, for how long a period?
- Does your part need to be a special or specific color?

Elastomer Hardness Selection

Elastomeric materials are available in a wide variety of hardnesses, from 20 Shore A to 90 Shore A for thermoset rubbers, to even harder materials (Shore D scale) for thermoplastic elastomers. The most common hardness range for materials is from 50 Shore A to 80 Shore A, with most sealing products being made from materials with a hardness of 70 Shore A. The actual hardness which will be selected depends upon your exact application.

There are some restrictions on the use of very hard and very soft materials in terms of manufacturing limitations. Parts with complex geometry or deep undercuts can be difficult to manufacture from very soft (< 30 Shore A) or very hard (> 80 Shore A) materials.

Application Type	Hardness Range (Shore A)
Sealing Applications (depending on pressure)	60 - 80
Flow Controllers	50 - 70
Umbrella/Duckbill Check Valves	50 - 60

Where to Start

Here are a few suggestions for beginning the process of material selection:

- If you are selecting a material for an O-Ring or Quad-Ring®, consider one of the two standard, "off-the-shelf" Minnesota Rubber and Plastics materials, 366Y, (a 70 Shore A nitrile rubber,) or 514AD, (a 70 Shore A fluoroelastomer rubber.) These are suitable for many industrial applications and are readily available.
- Nitrile rubber is a good general purpose rubber.
- If you are designing a potable water application, consider the use of an EP rubber, as long as the rubber will not come in contact with hydrocarbon based oils and greases, which will cause it to swell and degrade.
- If you are designing a medical application involving human contact or high cleanliness requirements, consider the use of a silicone rubber.
- If your application will experience temperatures greater than 300° F (150° C) in an industrial environment, a fluoroelastomer may be a good choice.

Corners and Edges

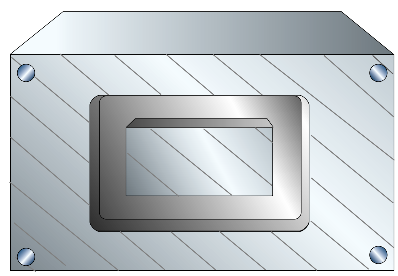
When designing rubber parts, sharp corners are generally undesirable. A part's corners should be broken with as gentle a radius as possible, preferably one greater than .050 inches, although radii as small as .010 inches are possible. A sharp corner increases the difficulty (and therefore the cost) of machining the mold and can potentially affect product quality by increasing the likelihood of certain types of molded defects.

It is preferred that a part's edges, where they coincide with a parting line, should be sharp. This simplifies the mold construction. Radii, when necessary or desired, however, can usually be added by relocating the part line.

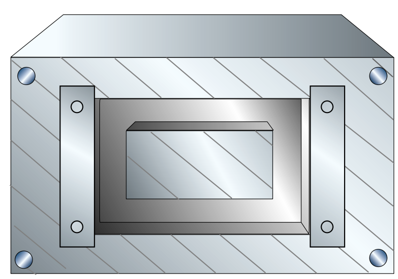
The preferred methods for designing corners and edges are illustrated in the following figures:

Corners: When viewed from the top, the part should display round corners.

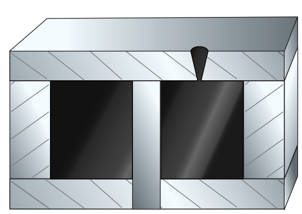
Edges: When seen from the side, the edges should be square.



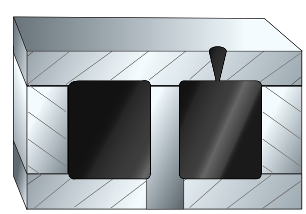
Correct



Incorrect



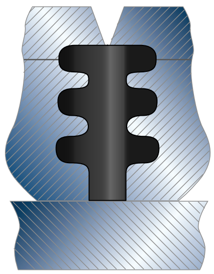
Preferred



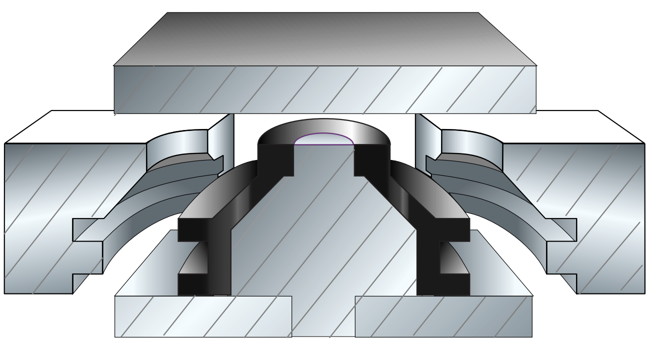
Least Preferred

Undercuts

An undercut feature of a part is one which projects back into the main body of the part. As the undercut becomes deeper, it results in a part that is difficult, or perhaps impossible, to remove from the mold. An extreme case of an undercut part is illustrated here, with the cross-section of a part in a mold. The mold, composed of three sections, opens vertically. In this example, it would not be possible to remove the part from the vertically opening mold.

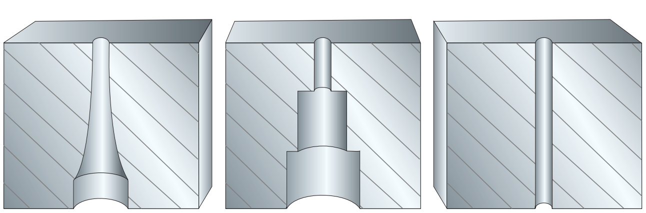


When an undercut feature is essential to the functionality of a part, it may be possible to design a mold that opens horizontally as well as vertically, as shown in the following illustration. When removing the part from this mold, the center plate separates and the part slides out, much easier than trying to pull the undercut feature through the center hole. These types of molds, however, are very costly to construct and operate and result in a relatively high part cost.



Holes

When designing a hole in a rubber part, there are a few design requirements to consider. The hole in the part is created by inserting a pin in the mold cavity. During molding, cavity pressures can be quite high (in excess of 7000 psi (500 Bar)), so substantial forces can be exerted on the pin,



Preferred **Alternate** **Least Preferred**

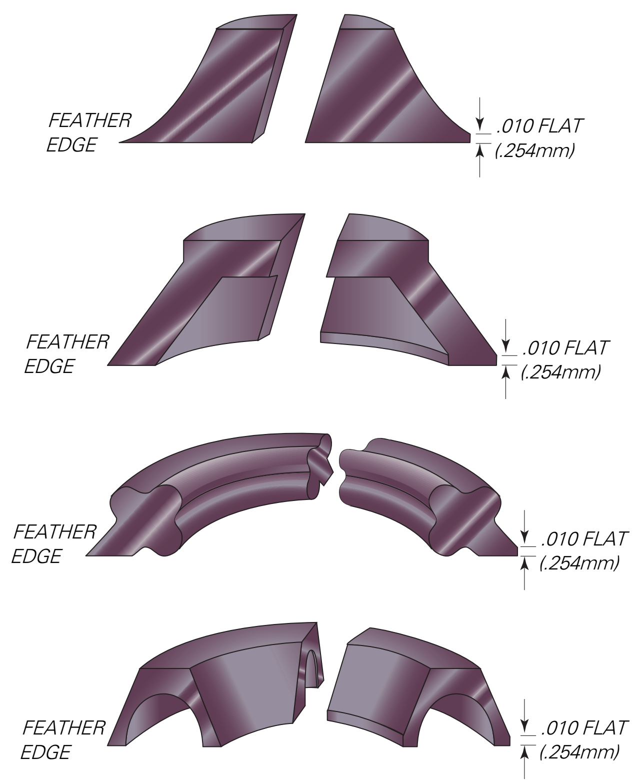
potentially deflecting it and creating an inconsistent hole. The size of the core pin, and thus the diameter of the hole, should therefore be maximized whenever possible, particularly at the base, to prevent bending or breaking of the core pin. A couple of useful "rules of thumb" to remember are:

- The height of the hole should not be more than twice its diameter.
- The minimum diameter of a hole should be about .050 in (1.27 mm).

Sharp Edges

Wiper seals, lip seals, and similar parts are frequently designed with a sharp edge, referred to as a knife edge or feather edge. It is difficult to hold such a thin edge in the molding process, as these edges tend to tear during removal from the mold. Normal deflashing can also chip a sharp edge.

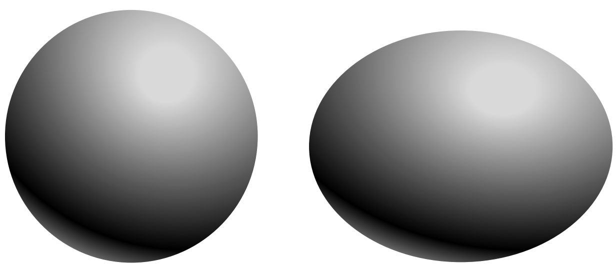
Unless a sharp edge is absolutely necessary, we recommend squaring off edges [.010 in (0.25 mm) minimum flat] to ensure clean surfaces on the finished product.



Circularity

A rubber ball provides an effective and efficient seal in check valve type applications. The ball's effectiveness in sealing, however, is dependent on its roundness. Circularity tolerances normally range from .006-.008 (0.15 - 0.20 mm) for molded-only parts.

Parts with diameters of .093 - 1.000 (2.36 - 25.40 mm) can be put through a centerless grinder to remove gates and parting lines, reducing the variation to .003-.004 (0.08 - 0.10 mm).

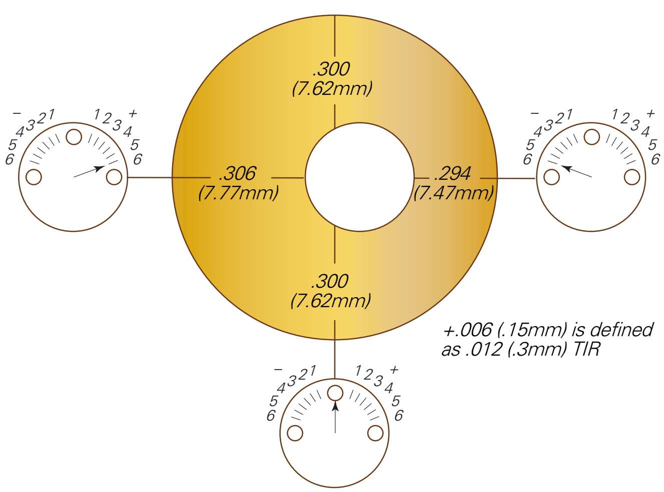


Correct **Incorrect**

Total Indicator Reading

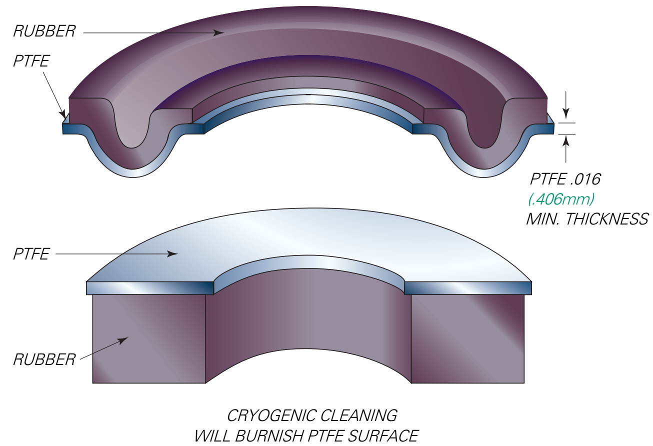
Total Indicator Reading (TIR) measures roundness in relationship to a center line. TIR is expressed in total diametric deviation. Example: +/- .004 (0.10mm) deviation is defined as .008 (0.20mm) TIR.

TIR is the total lateral distance traveled by the indicator needle resting against the O.D. of a round part as the part is turned one full revolution.



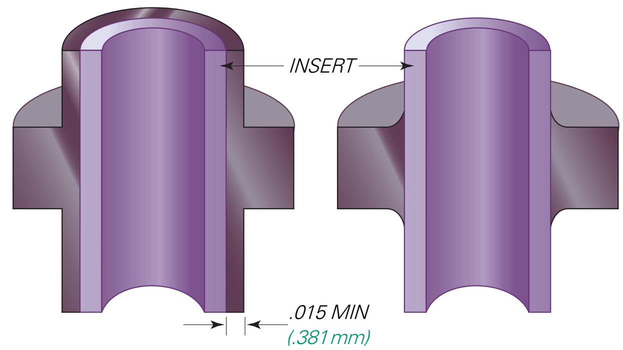
Rubber Over-Molding

Steel, brass, aluminum, or plastic subcomponents are often incorporated into overmolded rubber parts. These subcomponents are commonly termed inserts, as they are "inserted into the mold." Typical metal inserts include screw machine parts, metal stampings, and powdered metal shapes.



When designing rubber overmolded parts, keep in mind the following design principles:

1. Encapsulate as much of the surface of the insert in rubber as possible, with a minimum specified rubber thickness of .020 in (0.51 mm). This coverage helps to ensure maximum bonding and control flash formation.
2. Avoid shutting rubber flow off on vertical surfaces and provide proper lands (steps).
3. The rubber can be molded to the insert by means of mechanical or chemical bonding. Mechanical bonding involves the incorporation of holes, depressions or projections in the insert itself. The rubber flows around or through the insert during the molding process to create a bond.

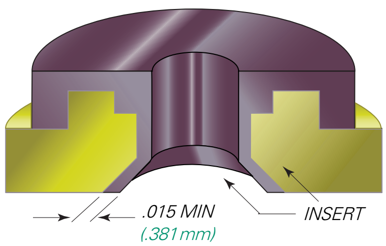


Correct **Incorrect**

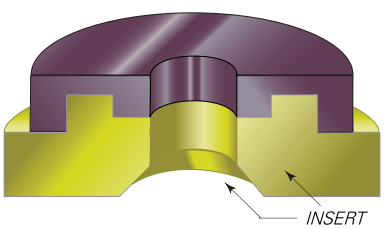
Special adhesives can be applied to the insert prior to molding to create a strong chemical bond.

Inserts designed for use in demanding applications are often attached to the rubber part using a combination of mechanical and chemical bonding.

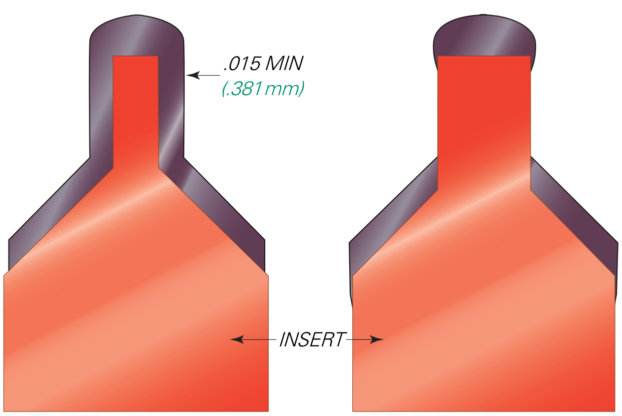
The production of molded rubber parts containing inserts typically involves considerable preparation before and after molding. Steps may include cleaning and etching of the insert surfaces, masking and unmasking, application of adhesives, and deflashing. Careful design of the insert can help to ensure a durable finished part while minimizing production costs.



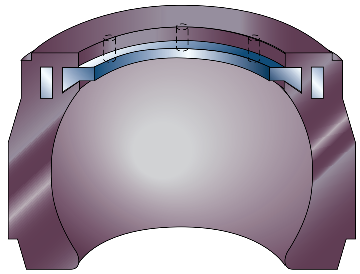
Correct



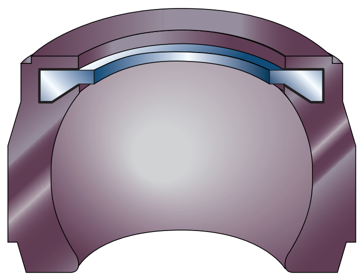
Incorrect



Correct **Incorrect**



Mechanical Bond



Chemical Bond

Minnesota Rubber and Plastics Standard Tolerance Chart

The following tolerance information is for reference purposes only and is intended to provide an indication of the types of tolerances which can be achieved with a molded part. This chart does not represent a guarantee of the tolerances which can be achieved in all cases. In many instances, specific part geometry will affect the precision of the tolerances which can be achieved. Please contact our Customer Service Group if you need a tolerance assessment conducted for a specific product.

Recommended Tolerances

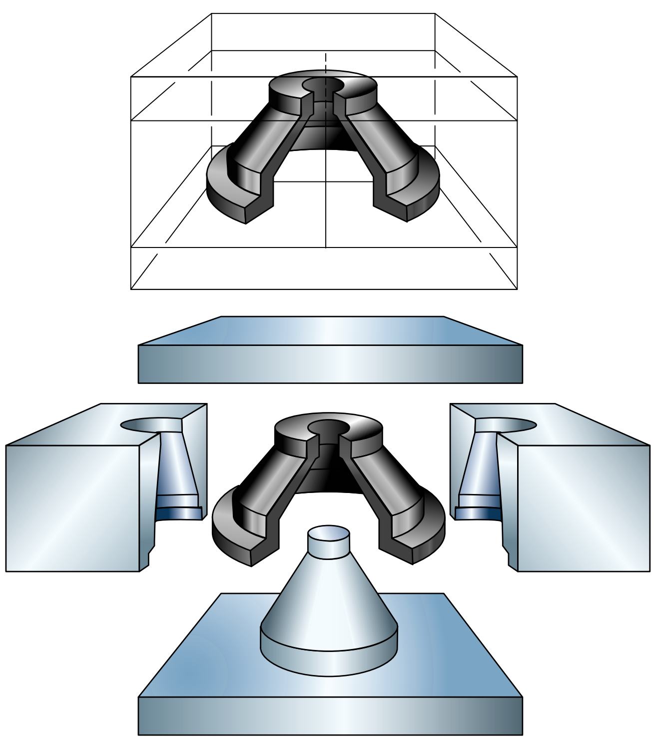
Dimension		Fixed Dimension Tolerance		Closure Dimension Tolerance	
(in)	(mm)	(in)	(mm)	(in)	(mm)
.001 - .250	.0254 - 6.350	±.004	±.102	±.005	±.127
.251 - .500	6.375 - 12.700	±.004	±.102	±.005	±.127
.501 - .625	12.725 - 15.875	±.005	±.127	±.006	±.152
.626 - .750	15.900 - 19.050	±.006	±.152	±.008	±.203
.751 - 1.000	19.075 - 25.400	±.006	±.152	±.008	±.203
1.001 - 1.500	25.425 - 38.100	±.008	±.203	±.010	±.254
1.501 - 2.000	38.125 - 50.800	±.010	±.254	±.013	±.330
2.001 - 2.500	50.825 - 63.500	±.010	±.254	±.013	±.330
2.501 - 3.000	63.525 - 76.200	±.014	±.355	±.015	±.381
3.001 - 3.500	76.225 - 88.900	±.017	±.432	±.018	±.457
3.501 - 4.000	88.925 - 101.600	±.020	±.508	±.020	±.508
4.001 - 5.000	101.625 - 127.000	±.025	±.635	±.025	±.635
5.001 - 7.000	127.025 - 177.800	±.035	±.890	±.035	±.890
7.001 - 8.000	177.825 - 203.200	±.040	±1.016	±.040	±1.016
8.001 - 9.000	203.225 - 228.600	±.045	±1.143	±.045	±1.143
9.001 - 10.000	228.625 - 254.000	±.050	±1.270	±.050	±1.270
10.001 - 11.000	254.025 - 279.400	±.055	±1.397	±.055	±1.397
11.001 - 13.000	279.425 - 330.200	±.065	±1.651	±.065	±1.651
13.001 - 14.000	330.225 - 355.600	±.075	±1.905	±.075	±1.905
14.001 - 15.000	355.625 - 381.000	±.090	±2.286	±.090	±2.286

Rubber Molding Considerations

The manufacturing of rubber parts is accomplished in one of three ways: transfer molding, compression molding or injection molding. (Each is described later in more detail.) The choice of process depends on a number of factors, including the size, shape and function of the part, anticipated quantity, type and cost of the raw material. The three methods, however, share certain basic characteristics that are important to understand when designing custom molded rubber parts.

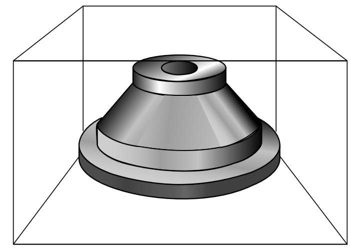
Building the Mold

The custom molding process begins with design and construction of a precision machined steel mold. This mold, or tool, consists of two or more custom tooled steel plates carefully registered to ensure consistent close tolerances and appropriate surface finish. After the rubber compound is placed or injected in the mold, the plates are exposed to heat and pressure to cure the part. The exact mix of time, temperature and pressure depends on the molding process and material.

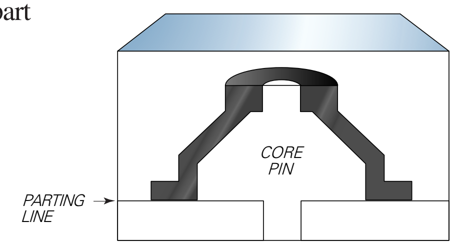


NOTE: Rubber is a thermoset material; once the rubber has been cured, it cannot be remolded. The curing process is irreversible.

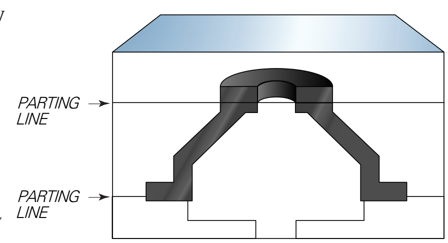
A molded rubber part, such as the simple rubber bushing shown, begins in the designers mind as a cavity in a solid steel block.



In order to get at the part, the block is "sliced" into plates. A tool steel pin called a core pin is inserted into one of the plates to form the interior dimensions of the part. The line on the surface of the part where the plates meet is the parting line. An excess amount of rubber is necessary in the cavity to ensure complete cavity fill and proper density. When pressure is applied, a small amount of this material is forced out of the cavity along the parting line to form a thin ridge of material known as flash. Removal of this flash from the part (deflashing), is accomplished in a number of different ways, described on page 2-11 and 7-3.

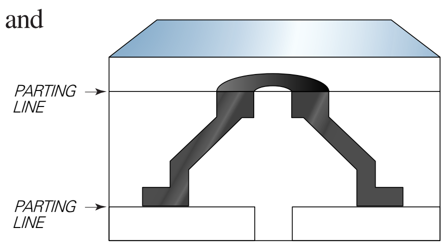


Sometimes the presence of a parting line is objectionable to the designer for functional or aesthetic reasons. This condition can be prevented by shifting the parting line from the top or bottom to the middle of the part.



A molded part may be too delicate, too small or too firm to be removed by hand from the cavity of a two-plate mold. Depending on the viscosity of the raw rubber, air may be trapped under the material, resulting in air pockets or weak sections in the finished part.

A common solution to both of these problems is a three-plate mold, as shown. When the molding process is complete, the plates are separated and the part is pushed out by hand or blown out with air.



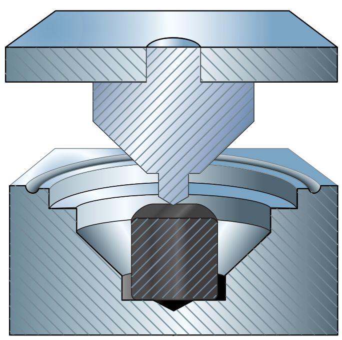
Molding Processes

Minnesota Rubber and Plastics' custom-molding capabilities encompass all three processes – transfer, compression and injection molding. We select from among these methods based on a number of key factors, including: the size and shape of the part, the hardness, flow and cost of the material, and the anticipated number of parts to be produced.

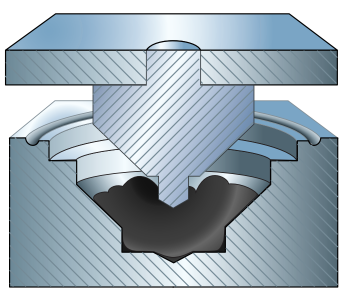
Compression Molding

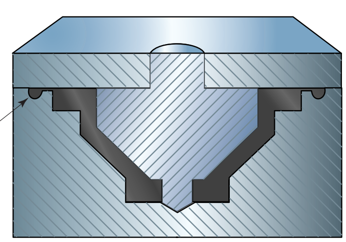
The compression molding process is not unlike making a waffle. A surplus of material must be placed in the cavity to ensure total cavity fill. Heat and pressure are applied, causing the compound to flow, filling the cavity and spilling out into overflow grooves.

Compression molding is often chosen for medium hardness compounds – in high volume production, or applications requiring particularly expensive materials.



The overflow, or flash, created by larger diameter parts is of particular concern when using the more expensive compounds. Compression molding helps to minimize the amount of overflow. The pre-load, however, can be difficult to insert in a compression mold of more complex design, and the compression molding process does not lend itself to the material flow requirement of harder rubber compounds.

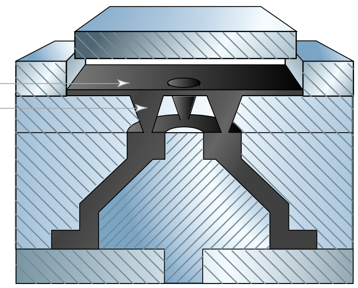




Applications range from simple o-ring drive belts to complex brake diaphragms with diameter of more than 10.000 inches (254.0mm).

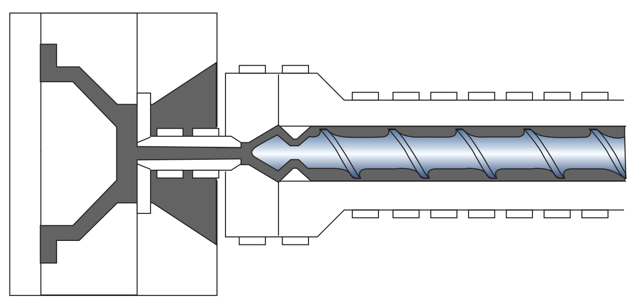
Transfer Molding

Transfer molding differs from compression molding in that the material is placed in a pot, located between the top plate and plunger. The material is squeezed from the pot into the cavity through one or more orifices called gates, or sprues.



Injection Molding

Injection molding is normally the most automated of the molding processes. The material is heated to a flowing state and injected under pressure from the heating chamber through a series of runners or sprues into the mold. Injection molding is ideal for the high volume production of molded rubber parts of relatively simple configuration.



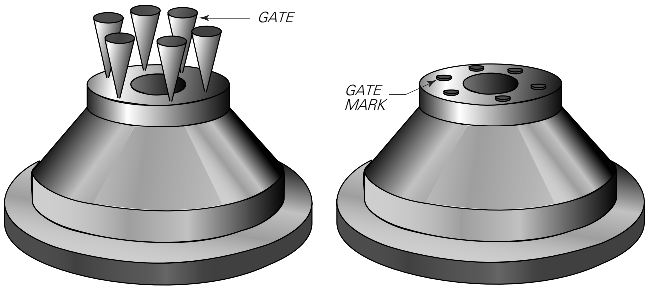
NOTE: There are some restrictions in the choice of material for injection molding.

Deflashing

Removal of the waste edge, or flash, from a molded rubber part is accomplished in a number of ways, depending on the material, part size, tolerance and quantity. Common deflashing methods include manual tear trimming, cryogenic processing, tumbling, and precision grinding.

Gates

Transfer and injection molds typically feature multiple gates to ensure even flow of the material into the cavity. These gates range in diameter from .010 - .150 (.254 – 3.81mm), placed at intervals along the circumference of the cavity. Gate diameter and location are determined by our Engineering Department in conjunction with the customer so as not to hinder part function.



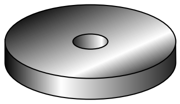
A raised spot or small depression, called a gate mark or sprue mark, can be seen on the surface of the finished part where the gates interface with the cavity.

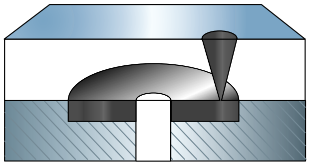
Material Durometer	Typical depression or projection from surface of part
less than 50	.015 (.381 mm)
50 or more	.007 (.178 mm)

Feed Examples

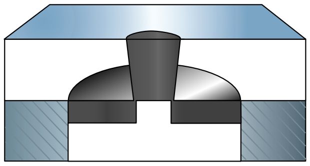
The number, size and location of gates in even the simplest mold design can vary greatly depending on the molding process, hardness of the material, dimensional tolerances, cosmetic consideration, and other customer requirements or specifications.

Illustrated here are 5 of the most common mold configurations:

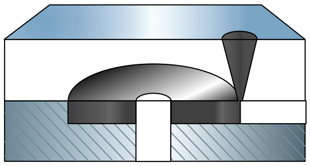




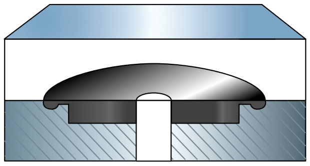
Body Feed



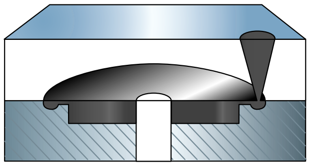
Flush Pin Feed



Edge Feed



Compression



Parting Line Feed

Building a Prototype

The building and testing of prototype parts allow for detailed analysis of the part design and material selection. What's more, these parts can be tested under actual operating conditions before committing to production. In many cases, this involves the molding of the same part from several different materials, each one chosen for its ability to perform within a specific operating environment.

The endless combination of variables related to part function and production requirements makes every new part a unique challenge. The prototyping process also provides us the opportunity to learn the critical features of your part so that we can recommend the right combination of materials, mold design and production procedures.

We understand that your R&D projects typically run on a very tight schedule, so we make every effort to expedite the prototype-building process and respond quickly to your prototyping needs.

In the end you will receive molded articles produced to your specifications, identical in material and dimensional tolerances to those you would receive in normal volume production. All before committing to a production tool.

Selecting the Mold

The recommended mold configuration and molding process depend on the size and complexity of the part, anticipated production volumes, type(s) of material involved, part function, and quantity requirements.

The key is to select the mold design and process that most closely approximates actual production conditions and cost requirements. The more demanding the part design, the more critical it becomes that we build the prototype cavity just as we would a production cavity. The upfront investment in a more costly mold may pay for itself very quickly through lower material costs or more improved handling procedures.

A two-part, single-cavity mold is typical for prototype quantities of up to 200 pieces, though two-to nine-cavity molds are not uncommon. The real advantage of a single-cavity mold is that it lets you change part design or material at minimal cost before committing to production.

For more information on mold design and process selection, see page 2-10, "The Molding Process."

Parts Assembly and Prototype Testing

In some cases, instead of building a single, complex mold, we may recommend the use of several parts of simpler configuration which can be molded and assembled to produce the finished prototype.

In order to reduce costs or improve lead times on plastic parts, we may begin with a standard shape and modify it to specification using various machining techniques such as drilling, turning, and/or milling.

Specifying Metal Parts

Based on our experience in both rubber and plastics molding and metals purchasing, we can specify and purchase for you any metal parts required for assembly of your prototype and production parts.

CAD Data Interchange Capabilities

Native CAD File Formats

We maintain current versions (and often previous versions) of the following CAD applications.

EDS (SDRC) I-DEAS®*	Unigraphics®
ProEngineer®	AutoCAD LT®
SolidWorks®	

** Preferred CAD system*

Standardized File Formats

We also maintain the capability to view and import the following standardized file formats

3-D IGES	VRML	STEP
DXF	HPGL	VDA
STL	PDF	DWG

Email is the preferred method of delivery, but any contemporary media may be used. Files may be sent to your usual contact at Minnesota Rubber and Plastics.

Writing Your Rubber Component Specifications

(For plastic components, see our "Writing Your Plastic Component Specifications" in Section 4.)

Contact: ________ **Date:** ________

Company name: ________ **Phone:** ________ **Fax:** ________

Address: ________ **e-mail:** ________

Part name: ________ **Part number/Rev.** ________

Basic description and function of part in application: ________

Elastomer type requested: ________ Hardness/Durometer ________

- Material Specifications (A) ________ (B) ________
- Maximum swell and/or shrinkage permitted ________

Media to be sealed: ________ (Both sides of seal) ________

- Specification ________
- Viscosity ________
- Concentration ________ %
- Aniline point ________
- Continual immersion or subject to dry out ________

Application: (A) Static ________ (B) Dynamic ________

Temperature limit: (A) High ________ (B) Low ________ (C) Normal operation ________

- Continuous ________
- Intermittent ________

Pressure or vacuum conditions: Normal operation ________ PSI

- Maximum ________ PSI
- Minimum ________ PSI
- Constant pressure ________
- Pulsating pressure ________
- Unidirectional ________
- Bidirectional ________

Shaft motion: • Continuous ________

- Intermittent ________
- Rotating ________
- Reciprocating ________
- Oscillating ________
- RPM/FPM ________
- Stroke length ________
- Degree ________

Finish of sealing surface: ________ micro inch RMS

- Material ________
- Hardness ________

Operating clearances: Maximum ________ total Minimum ________ total

- Bore eccentricity, shaft runout, TIR (Total Indicator Reading) ________

Friction tolerance: Breakaway ________ Running ________

continued on reverse

Lubrication of seal: By fluid sealed ______ External ______ None ______

Life expectancy of seal: ______ Leakage tolerance ______

Visual/Functional Attributes:

- Esthetic value of part ______ If yes, what area ______
- Where and how much parting line flash can be tolerated? ______
- Where and how much gate extension or depression can be tolerated? ______
- Is surface finish critical? ______ Better than 32 micro? ______
- If so, what area? ______
- Critical sealing surfaces ______
- Critical dimensions ______
- Engraving of part ______

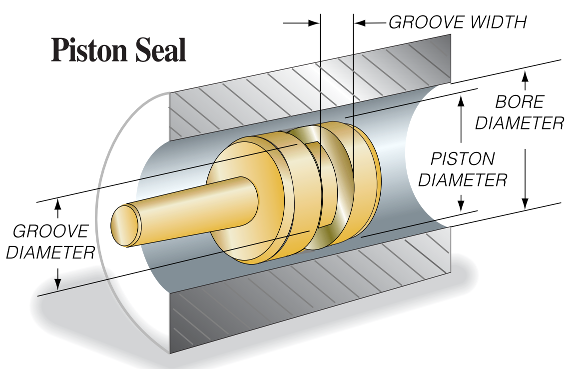
Quality Related:

- Anticipated AQL ______
- Cleanliness factor ______
- Special controls: Batch control ______ Lot control ______
- Special packaging ______
- SPC requirements ______
- FDA ______
- UL ______
- NSF ______
- Medical ______

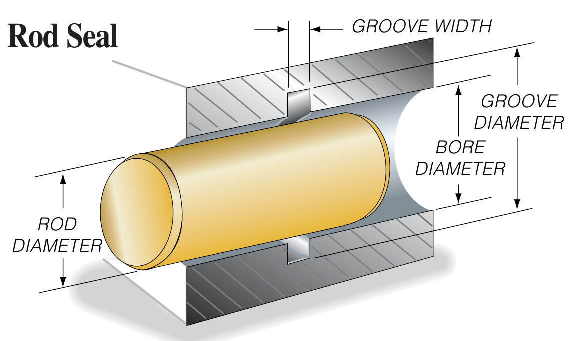
Business Related Criteria:

- Number of protoype samples needed ______ Date needed by ______
- Number of production parts needed ______ Date needed by ______
- Target price ______
- Estimated Annual Usage (EAU) ______

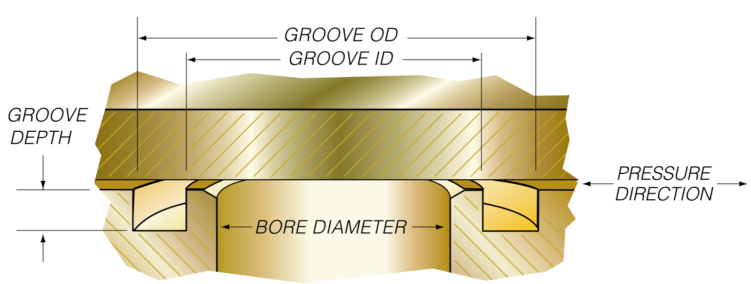
Piston Seal



Rod Seal

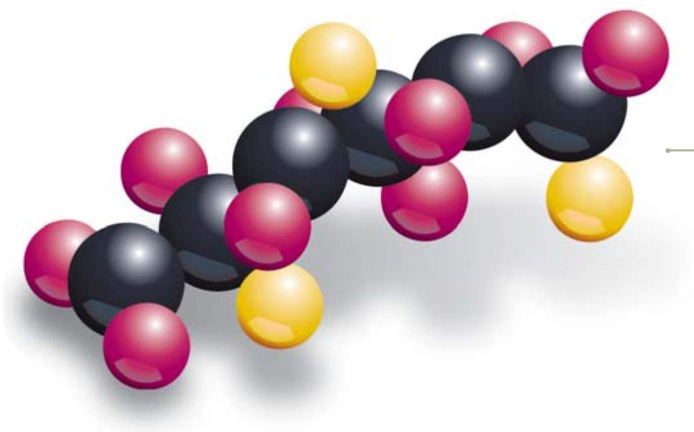


Face Seal



Additional comments or sketch: Make a sketch or attach a print showing the seal area, clamp area, etc., or any of the above which may be easier to illustrate than to describe.

Section 3
Elastomers/Materials



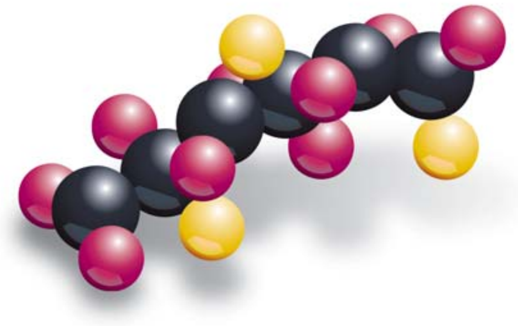
Elastomers/Materials

Chemical Terms, Abbreviations and Trade Names

Chemical Term	ASTM Designated Abbreviation	Polymer Trade Names
Acrylonitrile Butadiene	NBR, XNBR	Nipol®, Krynac®, Paracril®
Chlorinated Polyethylene	CM	Tyrin®
Chlorosulfonated Polyethylene	CSM	Hypalon®
Epichlorohydrin	CO, ECO	Hydrin®
Ethylene Acrylic	AEM	Vamac®
Ethylene Propylene Diene Monomer	EPDM	Buna-EP®, Nordel®, Royalene®, Vistalon®
Fluorocarbon	FKM, FFKM	Dyneon Fluoroelastomer®, Viton®
Fluorosilicone	FVMQ	
Highly Saturated Nitrile	HNBR	Therban®, Zetpol®
Isobutylene Isoprene	IIR / XIIR	Butyl
Polyacrylate	ACM	HyTemp®
Polybutadiene	BR	Budene®, Taktene®
Polychloroprene	CR	Neoprene, Baypren®
Polyisoprene:		
■ **Natural**	NR	SMR®, Pale Crepe, Smoked Sheet,
■ **Synthetic**	IR	Natsyn®
Silicone	VMQ, PMQ, PVMQ	Silastic®, Elastosil®
Styrene Butadiene	SBR	Plioflex®, Stereon®
Urethane (Polyester or Polyether)	AU or EU	Adiprene®, Millathane®, Vibrathane®

All polymer trade names are registered trademarks of their respective companies and are not affiliated with Minnesota Rubber and Plastics.

Polymer Types



Acrylonitrile / Butadiene (NBR)

NBR, Buna-N, and nitrile all represent the same elastomer based on a butadiene and acrylonitrile copolymer. Nitrile is inherently resistant to hydraulic fluids, lubricating oils, transmission fluids and other non-polar petroleum based products due to the polar structure of this elastomer. Nitriles are also resistant to air and water environments.

Utilizing the variety of nitrile polymers and compounding ingredients, Minnesota Rubber and Plastics has derived nitrile compounds to withstand environments that require low compression set, abrasion resistance, low temperature flex, gas permeation resistance, ozone resistance and/or stress-stain properties.

By hydrogenation, carboxylic acid addition, or PVC blending, the nitrile polymer can meet a broader range of physical or chemical requirements.

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)	Oil Aging Volume Swell (Change %) 70hr at 100°C/212°F ASTM #1	Oil Aging Volume Swell (Change %) 70hr at 100°C/212°F IRM 903
366Y	70	14.1	2050	320	-4	+10
525K	70	17.2	2500	330	-1	+16
431T	70	14.6	2100	340	-13	-5
523HW	70	13.8	2000	330	-9	+19
372FX	50	10.0	1450	400	-10	+20

Compound 366Y

- Excellent petroleum fluid and water resistance
- Outstanding oil resistance to aniline point oils of 130°F to 255°F (55°C to 124°C)
- Good compression set resistance

Compound 372FX

- Good oil and water resistance
- Good compression set resistance
- Low durometer and modulus
- Low temperature resistance

Compound 431 T

- Low swell to petroleum oils and fuels
- Outstanding oil resistance - aniline point oils below 130ºF (55ºC)
- Low temperature properties to -30ºF (-34ºC)
- High tensile strength and good abrasion resistance
- Good heat aging

Compound 523HW

- Excellent low temperature performance at -70ºF (-57ºC)

Compound 525K

- Excellent abrasion and wear resistance
- Good heat resistance and compression set resistance
- Frequently used for ground ball applications
- Excellent contact compatibility properties with plastics

Polymer Types-continued

Highly Saturated Nitrile (HNBR)

HNBR has been developed to withstand continuous temperatures of up to 302ºF (150ºC) while retaining resistance to petroleum oils. Obtained by hydrogenerating the nitrile copolymer, HNBR fills the gap left by NBR and FKM elastomers when high temperature conditions require high tensile strength while maintaining excellent resistance to motor oil, ATF, sour gas, amine/oil mixtures, oxidized fuels and lubricating oils.

Compound	Hardness Shore A	Tensile		Elongation (%)	Oil Aging Volume Swell (Change %) 70hr at 100°C/212°F	
		MPa	psi		ASTM #1	IRM 903
574GY	70	15.2	2200	250	+1	+18

Compound 574GY

- Saturated nitrile compound
- High temperature operations to 300ºF (150ºC)
- Excellent oil and fuel resistance

Nitrile/PVC Resin Blends (NBR/PVC)

PVC resins are blended with nitrile polymers to provide increased resistance to ozone and abrasion. The PVC also provides a significant improvement in solvent resistance yet maintains similar chemical and physical properties, commonly noted among nitrile elastomers. In non-black compounds the addition of the PVC resins also provides a greater pigment-carrying capacity that allows better retention of pastel and bright colors.

Compound	Hardness Shore A	Tensile		Elongation (%)
		MPa	psi	
567A	60	13.8	2000	400
567FG	65	17.2	2500	500
567B	80	10.0	1455	400
477B	90	14.5	2100	150

Fluorocarbon (FKM)

Fluorocarbon elastomers are highly fluorinated, carbon backboned polymers used in applications to resist harsh chemical and ozone attack with a thermal stability to 500°F (262°C). Fluorocarbons also offer low compression set and excellent aging characteristics. FKM elastomers provide excellent service in oil, gasoline, hydraulic fluids, hydrocarbon solvents and extended fuels.

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)	Oil Aging Volume Swell (Change %) 70hr at 150°C/302°F IRM 901	IRM 903	Fuel Aging Volume Swell (Change %) 70hr at 23°C/73°F Ref fuel B	Ref fuel C
514QN	55	6.9	1000	300	+0	+3	+4	+9
514WT	60	8.3	1200	280	+2	+4	+2	+6
514AD	70	10.3	1500	200	+1	+4	+2	+3
514AQ	80	11.4	1650	180	+2	+4	+2	+4
514VN	90	10.3	1500	160	+2	+3	+2	+4
514GJ	70	14.5	2100	250	+0	+3	+2	+2
514TS	70	12.4	1800	150	+1	+2	+6	+8
514VJ	75	11.0	1600	120	0	+2	+4	-
514UE	80	11.0	1600	200	-	-	-	-

The fluorine on the elastomer backbone provides the relative inertness of FKM elastomer. Generally speaking, with increasing fluorine content, resistance to chemical attack is improved while low temperature characteristics are diminished. There are, however, a few specialty grade fluorocarbons that can provide high fluorine content with low temperature properties.

Compound 514GJ

- Superior fluid resistance as compared to general purpose fluorocarbons
- Excellent performance with herbicides, pesticides, gasoline and alcohol extended fuels

Compound 514VJ

- Provides good low temperature flexibility for -13°F (-25°C)

Compound 514BC

- Provides the best low temperature flexibility for -40°F (-40°C)

Perfluoroelastomers (FFKM, see page 3-20)

Compound 514QN, 514WT, 514AD, 514AQ, 514VN

- Minnesota Rubber and Plastics' general purpose FKM compound series
- Hardness range 55-90 Shore A
- Outstanding corrosive fluid resistance
- Low compression set
- Excellent seal compounds
- Low outgassing

Compound 514TS

- Low temperature service FKM -4°F (-20°C)
- Excellent extended fluid resistance and general fluids resistance

Compound 514UE

- A very chemically resistant fluorocarbon material
- Exhibits broad resistance to bases, amines, and polar solvents

Polymer Types-continued

Ethylene Propylene Diene Monomer (EPDM)

EPDM elastomers provide excellent resistance to heat, water, steam, ozone and UV light (color stability) while providing very good low temperature flexibility properties. These compounds also withstand the affects of brake fluids, alkali, mild acidic and oxygenated solvent environments. EPDM compounds are not recommended for gasoline, petroleum oil and greases, and hydrocarbon solvent environments.

EPDM's are very effective for outdoor functions requiring long term weathering properties. EPDM elastomers are also suitable for use in hot water and steam environments. EPDM's are especially suited to high temperature brake fluid applications.

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)
559N	70	12.4	1800	320
560CD	60	14.5	2100	250
560CF	60	11.0	1600	200
560ND	70	14.5	2100	220
559PE	70	12.4	1800	135
560VH	80	13.1	1900	190
560YH	70	13.8	2000	200
559GT	90	12.4	1800	100

Compound 559N

- Specially formulated for steam and hot water applications
- Extremely low volume swell in water
- Good tensile strength and compression set properties
- A good general purpose EPDM elastomer

Compound 560CD

- Excellent tensile strength and flex fatigue resistance
- Temperature operation up to 302ºF (150ºC)

Compound 560ND

- Tailored for use in automotive brake applications
- Exceptional resistance to brake fluid
- Outstanding temperature and compression set resistance
- Superior low temperature properties

Compound 559PE, 559GT

- Exceptionally good in chloraminated and chlorinated water. Very low compression set. NSF, KTW, and WRAS certified.
- Certified throughout the world for drinking water contact including: NSF, WRAS, KTW and ACS.

Compound 560VH, 560CF

- Similar to 559N physical and chemical properties

Compound 560YH

- Low extractables – minimal taste and odor transfer to food and beverage products

Compound 558BP

- The most chloramine resistant 70 Shore A EPDM compound available world wide.

Styrene Butadiene (SBR)

Styrene butadiene is a low cost, general-purpose elastomer. Known as Buna-S, it was originally developed to replace natural rubber in tires. SBR exhibits very good flex fatigue resistance and is resistant to many polar type chemicals such as alcohols and ketones. It is also widely accepted for use in automotive brake fluids. SBR, however, is not resistant to petroleum based fluids.

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)
480E	70	14.5	2100	340
480DR	65	19.7	2850	340
448AP	60	15.8	2300	280
508A	50	10.3	1500	400

Compound 480E

- Good general purpose compound
- Specified for static sealing applications

Compound 480DR

- High strength
- Excellent flex and abrasion resistance

Compound 448AP

- Developed for automotive brake applications
- Upper temperature limit of 250ºF (121ºC)

Compound 508A

- Excellent weather resistant compound
- 50 Shore A hardness

Polychloroprene (CR)

Neoprene is a commercial name for polymers comprised of chloroprene. Polychloroprene's overall physical characteristics classify it as a general-purpose elastomer. Excellent aging characteristics in ozone and weather environments, along with abrasion and flex cracking resistance, justify the general-purpose categorization.

Polychloroprene is alkali and acid resistant, flame retardant, and suitable for petroleum based oils. Animal and vegetable fats and greases also provide a highly stable environment for this polymer. Polychloroprene is noted for good compression set resistance, excellent flex fatigue resistance, and resistance to weather and ozone. Its excellent adhesion to metals makes polychloroprene ideal for molding with metal inserts.

Polychloroprene is not effective in aromatic and oxygenated solvent environments.

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)	Oil Aging Volume Swell (Change %) 70hr at 100°C/212°F ASTM #1	IRM 903
486CT	70	13.0	1880	200	-2	+41
482BJ	70	18.3	2650	350	+5	+63
337Z	50	10.3	1500	500	-5	+60
323AR	60	11.0	1600	450	+1	+58
405A	80	13.8	2000	220	-2	+48
386AE	70	10.3	1500	500	+1	+84
368GF	75	20.7	3000	250	-3	+58
405DY	90	12.4	1800	100	-1	+35

Compound 482BJ

- High tensile and tear strength
- Excellent flex fatigue resistance
- Excellent serviceability in repeated distortion applications (o-ring drive belts)
- Good for refrigerants

Compound 337Z, 323AR, 405A, 405DY

- General purpose neoprene compounds in a range of hardnesses
- Good weather, ozone, and flex fatigue resistance
- Moderate resistance to petroleum oils and chemicals

Compound 386AE

- Good electrical resistance properties

Compound 368GF

- Excellent flex characteristics
- Excellent impeller compound

Compound 486CT

- Excellent aging characteristics
- Proven in a variety of gasket and washer applications

Isobutylene Isoprene Rubber (IIR)

Butyl is a common term used for the isobutylene isoprene elastomer. As the name implies, butyl is comprised of isobutylene with a small amount of isoprene. It is known for its excellent resistance to water, steam, alkalis, and oxygenated solvents. Another outstanding characteristic is low gas permeation. Butyl is capable of providing high-energy absorption (dampening) and good hot tear strength.

Good resistance to heat, abrasion, oxygen, ozone and sunlight are dependent upon the butyl polymer saturation level. Butyl however, displays poor resistance to petroleum oil, gasoline and hydrocarbon solvents.

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)
359CY	50	11.0	1600	650
359DQ	60	8.3	1200	400
501C	70	13.8	2000	320
359DN	80	8.3	1200	370
487KC	40	9.0	1300	850
487KD	50	9.0	1300	650
487KE	60	9.7	1400	420
487KF	70	8.3	1200	300

Compounds 487KC, 487KD, 487KE, 487KF

- Very low outgassing
- Excellent vibration dampening compounds
- Low extractables

Compounds 359CY, 359DQ, 501C, 359DN

- Good acid and base resistance
- Weather and high temperature resistant

Polymer Types-continued

Silicones (VMQ, PMQ, PVMQ)

Extreme temperature range stability and low temperature flexibility are characteristics of silicone compounds. Silicones provide outstanding resistance to compression set, sunlight, ozone, oxygen, and moisture. They are very clean and are used in many food and medical applications because they do not impart odor or taste.

Silicone can be compounded to be electrically resistant, conductive or flame retardant.

3-8

Compound 71417C

- Minnesota Rubber's most versatile silicone compound
- Excellent compression set properties
- Heat resistance to 450ºF (232ºC)

Compound 71115B

- Recommended for diaphragms and similar dynamic parts
- Heat resistant to 450ºF (232ºC)

Compound 74115

- High strength at low temperatures
- Performs well and remains flexible to -150ºF (-101ºC)
- High tensile strength and excellent tear resistance over a wide temperature range

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)
71417C	70	6.0	870	200
71115B	50	8.3	1200	420
73117A	70	4.8	700	170
74115	55	8.3	1200	450

As well as millable grade silicones, Minnesota Rubber and Plastics offers Liquid Silicone Rubber (LSR) molding. The LSR process offers design, cost and end-use options that complement and extend beyond the capabilities of millable grade materials. Minnesota Rubber and Plastics offers LSR compounds with hardness from 20 to 80 Shore A in different colors.

LSR Compound (RED)	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)
76112	20	6.9	1000	300
76113	30	6.9	1000	300
76114	40	8.3	1200	300
76115	50	8.3	1200	300
76116	60	8.3	1200	300
76117	70	8.3	1200	300
76118	80	6.9	1000	300

Fluorosilicone (FVMQ)

Fluorinated silicones provide chemical properties similar to those of fluorinated organic elastomers. This property provides excellent resistance to hydrocarbon fuels, petroleum oils and silicone fluids.

Fluorosilicones provide a much wider operational temperature range than fluorocarbon (FKM) elastomers -70ºF to 400ºF (-57ºC to 205ºC). Many applications for fluorosilicones are in synthetic oils, gasoline and even extended fuels since its low temperature performance is much better than that of FKM's.

Compound	Hardness Shore A	Tensile		Elongation (%)	Oil Aging Volume Swell (Change %) 70hr at 150°C/302°F		Fuel Aging Volume Swell (Change %) 70hr at 23°C/73°F
		MPa	psi		ASTM #1	IRM 903	Ref fuel C
70154	40	6.9	1000	300	-1	+3	+19
70155	50	6.9	1000	450	+1	+3	+21
70156A	60	6.9	1000	170	-1	+2	+15
70157A	70	5.5	800	150	-1	+2	+19
70158A	80	6.9	1000	130	-1	+3	+20

Compound 70154, 70155, 70156A, 70157A, 70158A

- Good oil and compression set resistance
- Low temperature operation
- Good fuel and extended (alcohol) fuel resistance

Polyacrylate (ACM)

Polyacrylate (ACM) compounds are designed to withstand high heat while retaining oil resistance. Specially designed for sulfur bearing oil applications, ACM elastomers are suitable for high temperature, differential and bearing environments. ACM elastomers are also resistant to oxidation, ozone, aliphatic solvents, sunlight, weathering and gas permeation. ACM's are capable of withstanding high temperatures up to 302ºF (150ºC), but their low temperature properties are relatively poor.

Compound	Hardness Shore A	Tensile		Elongation (%)	Oil Aging Volume Swell (Change %) 70hr at 150°C/302°F	
		MPa	psi		ASTM #1	IRM 903
335LW	60	8.7	1300	200	-7	+7
335GA	70	10.4	1500	250	+2	+15

Compound 335LW, 335GA

- Excellent oil and ozone resistance under high heat conditions

Ethylene Acrylic (AEM)/Vamac®

Ethylene acrylic compounds provide excellent high heat aging resistance to 347ºF (175ºC) while providing good physical properties. A high degree of oil, ozone, UV, and weather resistance along with good low temperature flexibility are also ethylene acrylic attributes.

Compound	Hardness Shore A	Tensile		Elongation (%)	Oil Aging Volume Swell (Change %) 70hr at 150°C/302°F	
		MPa	psi		ASTM #1	IRM 903
572K	60	13.8	2000	450	+6	+60
572BJ	70	13.8	2000	400	+7	+60

Compound 572K, 572BJ

- Excellent vibration dampening
- Excellent heat aging characteristics
- Moderate petroleum oil resistance
- Good dynamic property retention over a wide temperature range

Chlorosulfonated Polyethylene (CSM)/Hypalon®

Chlorosulfonated polyethylene is the base polymer for CSM synthetic rubbers.

Chlorosulfonated polyethylene compounds provide excellent ozone, oxidation, sunlight (color degradation), and weather resistance. They are also capable of providing excellent resistance to alkalis and acids.

Compound	Hardness Shore A	Tensile		Elongation (%)
		MPa	psi	
399BN	50	16.9	2450	450
399ES	60	12.4	1800	400
399BL	70	13.8	2000	300

Compound 399BN, 399ES, 399BL

- Acid resistant, "general purpose" type elastomers
- Oil resistance similar to polychloroprene while operating at higher temperatures

Polymer Types-continued

Chloropolyethylene (CM)

CM compounds are based on the highly saturated chloropolyethylene polymer which provides outstanding resistance to ozone, weather, oil and heat. CM elastomers also have excellent flex fatigue characteristics, abrasion resistance and resistance to refrigerant chemicals at high temperatures. CM elastomers are capable of operating at temperatures from -40 to 302ºF (-40 to 150ºC) and are flame resistant.

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)	Oil Aging Volume Swell (Change %) 70hr at 150°C/302°F ASTM #1	Oil Aging IRM 903
569Z	70	17.2	2500	400	+0	+48

Compound 569Z

- Excellent flex and abrasion characteristics
- A tough vibration dampening compound
- Weather, heat, and oil resistant
- Wide temperature operating range

Epichlorohydrin (ECO/CO)

ECO's are noted for their superior gas impermeability and physical properties over a wide temperature range -40ºF to 275ºF (-40ºC to 135ºC); while maintaining excellent resistance to petroleum oils. Ozone, oxidation, weathering, and sunlight resistance are other typical ECO/CO qualities.

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)	Oil Aging Volume Swell (Change %) 70hr at 150°C/302°F ASTM #1	Oil Aging IRM 903	Fuel Aging Volume Swell (Change %) 70hr at 23°C/73°F Ref fuel B
571AG	50	9.7	1400	400	-3	+19	+23
571P	70	11.0	1600	260	-5	+4	+15

Compound 571P, 571AG

- Excellent general purpose physical characteristics
- Good impermeability to air and nitrogen
- Good petroleum oil resistance

Polyisoprene Natural (NR) and Synthetic (IR)

Polyisoprenes, both natural (from trees) and synthetic, are noted for outstanding resilience, resistance to tear and abrasion, excellent elasticity, and flex fatigue resistance.

Polyisoprenes also have excellent tensile strength characteristics and are operable in low temperature -65ºF (-54ºC) environments. Polyisoprenes are not recommended for high heat, ozone, sunlight, petroleum, or hydrocarbon environments.

The two isoprenes differ slightly; the purity of synthetic polyisoprene provides more consistent dynamic properties with better weather resistance. Synthetic polyisoprene's lack of "tree" organics also gives a relatively odorless rubber. Natural rubber, when compared to synthetic, provides slightly better properties in tensile strength, tear resistance, compression set, and flex fatigue resistance.

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)
352AP	40	10.3	1500	500
352DG	50	17.2	2500	550
352CV	60	21.1	3050	460
326W	70	17.9	2600	330

Compounds 352AP, 352DG, 352CV, 326W

- "General purpose" isoprene compounds
- Excellent tear and abrasion resistance
- Excellent vibration isolating material
- Outstanding resilience and flex fatigue resistance

Polyurethane (EU/AU)

Polyurethanes are noted for outstanding resistance to abrasion and tear. Polyurethanes provide the highest available tensile strength among all elastomers while providing good elongation characteristics. Ozone, oxidation, sunlight, weather, oil and incidental gasoline exposure are environments suited for urethane applications. Polyether based polyurethanes (EU) are directed toward low temperature flexibility applications. The polyester based polyurethanes (AU) provide improved abrasion, heat and oil swell resistance.

Polyurethanes are not recommended for alkalis, acids and oxygenated solvents. Polyester based polyurethanes are not typically recommended for hot water, steam and high humidity applications, but can be formulated to improve resistance to these properties.

Compound	Hardness Shore A	Tensile MPa	Tensile psi	Elongation (%)	Oil Aging Volume Swell (Change %) 70hr at 100°C/212°F ASTM #1	IRM 903
522GN	60	18.1	2530	670	-11	-7
522MD	75	22.8	3300	280	-3	+4
522FX	70	24.8	3600	320	-2	+4
522NR	90	23.4	3400	125	+4	+0
512AJ	70	24.1	3500	480	+0	+26
512AC	80	26.2	3800	430	-5	+14

Compounds 522GN, 522MD, 522FX, 522NR

- Superior tensile strength compounds
- Excellent abrasion resistance
- Low temperature operation to -40ºF (-40ºC)

Compounds 512AJ, 512AC

- Excellent tensile and elongation properties
- Low temperature properties to -70ºF (-57ºC)

Polybutadiene (BR)

Polybutadiene provides excellent low temperature flexibility (-80ºF/-62ºC) and exceptionally high resilience (bounce). Resistance to abrasion, cut growth and flex cracking are also outstanding characteristics of butadiene.

Butadiene is not resistant to oil, gasoline or hydrocarbon solvent. Minnesota Rubber uses butadiene in blending with other polymers to take advantage of the outstanding low temperature, resilience and toughness characteristics polybutadiene is noted for.

Chemical and Physical Tables

Polymer	Tensile Strength (MPa)	Tensile Modulus at 100% (MPa)	Hardness Durometer (shoreA)	Enlongation (%)	Compression Set Rating	Low Temp Range °F	Low TempRange °C	High Temp Range °F	High Temp Range °C	Heat Aging at 212°F (100°C)	Steam Resistance	Flame Resistance	Weather Resistance	Sunlight Resistance	Ozone Resistance
NBR	6.9-27.6	2.0-15	20-100	100-650	Good-Exc.	-70 to 0	-57 to -18	210 to 250	99 to 121	Good	Fair-Good	Poor	Fair-Good	Poor-Good	Fair-Good
HNBR	31.0-10.0	1.7-20.7	30-95	90-450	Good-Exc.	-50 to 0	-46 to -18	250 to 300	121 to 149	Exc.	Fair-Good	Poor	Good-Exc.	Good-Exc.	Good-Exc.
FKM	3.4-20.7	1.4-13.8	50-95	100-500	Good-Exc.	-50 to 0	-46 to -18	400 to 500	200 to 260	Exc.	Poor-Good	Good-Exc.	Exc.	Good-Exc.	Exc.
EP	2.1-24.1	0.7-20.7	30-90	100-700	Poor-Exc.	-75 to -40	-59 to -40	220 to 300	104 to 149	Good-Exc.	Exc.	Poor	Exc.	Exc.	Good-Exc.
SBR	3.4-24.1	2.1-10.3	30-100	450-600	Good-Exc.	-75 to -55	-59 to -48	210 to 250	99 to 121	Good	Fair-Good	Poor	Fair-Good	Poor	Poor
CR	3.4-27.6	0.7-20.7	15-95	100-800	Poor-Good	-70 to -30	-57 to -34	200 to 250	93 to 121	Good-Exc.	Fair-Good	Good-Exc.	Fair-Good	Good-Exc.	Good-Exc.
IIR	13.8-20.7	0.3-3.4	30-80	300-850	Poor-Good	-70 to -40	-57 to -40	250 to 300	121 to 149	Good-Exc.	Good-Exc.	Poor	Exc.	Exc.	Exc.
VMQ, Si, PMQ, PVMQ	1.4-10.3	6.2	20-90	100-900	Good-Exc.	-178 to -90	-117 to -68	400 to 500	204 to 260	Exc.	Fair-Good	Fair-Exc.	Exc.	Exc.	Exc.
FVMQ	3.4-9.7	3.1-3.4	35-80	100-480	Fair-Good	-112 to -90	-80 to -68	400 to 450	204 to 232	Exc.	Fair	Exc.	Exc.	Exc.	Exc.
ACM	8.6 17.2	0.7-10.3	40-90	100-450	Poor-Good	-30 to 0	-34 to -18	250 to 350	121 to 177	Exc.	Poor	Poor	Exc.	Good-Exc.	Good-Exc.
EA	6.9-20.7	0.7-10.3	35-95	200-650	Poor-Good	-55 to -30	-48 to -34	250 to 350	121 to 177	Exc.	Poor-Fair	Poor	Exc.	Exc.	Exc.
CSM	3-15	0.2-10	40-100	100-700	Poor-Fair	-60 to -40	-51 to -40	225 to 270	107 to 132	Good-Exc.	Poor-Good	Good-Exc.	Exc.	Exc.	Exc.
ECO	10-15	1-10	30-95	200-800	Good-Exc.	-60 to -15	-51 to -26	225 to 275	107 to 135	Good-Exc.	Fair-Good	Poor-Good	Good	Good	Good-Exc.
NR, IR	3.4-34.5	0.5-0.8	20-100	300-900	Exc.	-70 to -40	-57 to -40	180 to 220	82 to 104	Fair-Good	Fair-Good	Poor	Poor-Fair	Poor	Poor
AU, EU	6.9-69.0	0.2-34.5	10-100	250-900	Poor-Good	-65 to -40	-54 to -40	180 to 220	82 to 104	Fair-Good	Poor	Poor-Good	Exc.	Good-Exc.	Exc.

Radiation Resistance	Oxidization Resistance (AIR)	Water Resistance	Gas Permeability Rating	Odor	Taste Retention	Adhesion to Metals	Colorability	RMA Color Code	Resilience or Rebound Rating	Vibration Dampening	Flex Cracking Resistance	Tear Resistance	Abrasion Resistance	Vacuum Weight Loss
Fair-Good	Good	Good-Exc.	Fair-Exc.	Good	Fair-Good	Exc.	Exc.	Black	Good	Fair-Good	Good	Good-Exc.	Good-Exc.	Good
Fair-Good	Exc.	Exc.	Fair-Exc.	Good	Fair-Good	Exc.	Exc.	—	Good	Good-Exc.	Good	Good-Exc.	Good-Exc.	Good
Fair-Good	Exc.	Exc.	Good-Exc.	Good	Fair-Good	Good-Exc.	Good-Exc.	Brown	Fair-Exc.	Fair-Good	Good	Fair-Good	Good	Exc.
Good-Exc.	Exc.	Exc.	Fair-Good	Good	Good-Exc.	Good-Exc.	Good-Exc.	Purple	Fair-Good	Fair-Good	Good	Fair-Good	Good	Exc.
Poor-Good	Fair-Exc.	Good-Exc.	Fair	Good	Fair-Good	Exc.	Good	—	Fair-Exc.	Fair-Good	Good-Exc.	Fair-Exc.	Good-Exc.	Poor
Fair-Good	Good-Exc.	Fair-Good	Fair-Good	Fair-Good	Fair-Good	Exc.	Fair	Red	Fair-Good	Good-Exc.	Good	Good-Exc.	Good-Exc.	Fair
Poor-Good	Exc.	Good-Exc.	Good	Good	Fair-Good	Good	Good	—	Poor-Good	Exc.	Good-Exc.	Good	Fair-Good	Exc.
Poor-Good	Exc.	Exc.	Poor-Fair	Good	Good-Exc.	Good-Exc.	Exc.	Rust	Good-Exc.	Fair-Good	Poor-Good	Poor-Good	Poor-Good	Exc.
Fair-Exc.	Exc.	Exc.	Poor-Good	Good	Good	Good-Exc.	Good-Exc.	Blue	Exc.	Good	Poor-Good	Poor-Exc.	Poor	Exc.
Poor-Good	Exc.	Poor-Fair	Good-Exc.	Fair-Good	Fair-Good	Good	Good	—	Fair-Good	Good-Exc.	Fair-Good	Poor-Good	Fair-Good	Good
Good	Exc.	Good-Exc.	Exc.	Good	Fair-Good	Good	Good	—	Poor-Fair	Good	Good	Good-Exc.	Good-Exc.	Fair-Good
Poor-Good	Exc.	Good	Good-Exc.	Good	Fair-Good	Exc.	Exc.	—	Fair-Good	Fair-Good	Fair-Good	Fair-Good	Good-Exc.	Fair
Poor	Good-Exc.	Good	Exc.	Good	Good	Fair-Good	Good	—	Good	Good	Good	Fair-Exc.	Fair-Good	Good
Fair-Good	Good	Exc.	Fair-Good	Good-Exc.	Fair-Good	Exc.	Poor	—	Exc.	Good-Exc.	Exc.	Good-Exc.	Good-Exc.	Poor
Good-Exc.	Good-Exc.	Poor-Good	Good-Exc.	Exc.	Fair-Good	Exc.	Good-Exc.	—	Poor-Good	Fair-Good	Good-Exc.	Exc.	Exc.	Good

Chemical and Physical Tables-continued

Polymer	Acids (dilute)	Acids (concentrated)	Acid, Organic (dilute)	Acid, Organic (concentrated)	Alcohols (C1 thru C4)	Aldehydes (C1 thru C6)	Alkalies (dilute)	Alkalies (concentrated)	Amines	Animal & Vegetable Oils	Brake Fluid; Dot 3,4&5	Diester Oils	Esters, Alkyl Phosphate
NBR	Good	Poor-Fair	Good	Poor	Fair-Good	Poor-Fair	Good	Poor-Good	Poor	Good-Exc.	Poor	Fair-Good	Poor
HNBR	Good	Fair-Good	Good	Fair-Good	Good Exc.	Fair-Good	Good	Poor-Good	Good	Good-Exc.	Fair	Good	Poor
FKM	Good-Exc.	Good-Exc.	Fair-Good	Poor-Good-	Fair-Exc.	Poor	Fair-Good	Poor	Poor	Exc.	Poor-Fair	Good-Exc.	Poor
EP	Exc.	Exc.	Exc.	Fair-Good	Good-Exc.	Good-Exc.	Exc.	Exc.	Fair-Good	Good	Good-Exc.	Poor	Exc.
SBR	Fair-Good	Poor-Fair	Good	Poor-Good	Good	Poor-Fair	Fair-Good	Fair-Good	Poor-Good	Poor-Good	Poor-Good	Poor	Poor
CR	Exc.	Poor	Good-Exc.	Poor-Good	Exc.	Poor-Fair	Good	Poor	Poor-Good	Good	Fair	Poor	Poor
IIR	Good-Exc.	Fair-Exc.	Good	Fair-Good	Good-Exc.	Good	Good-Exc.	Good-Exc.	Good	Good-Exc.	Good	Poor-Good	Good-Exc.
VMQ, Si, PMQ, PVMQ	Fair-Good	Poor-Fair	Good	Fair	Fair-Good	Good	Poor-Fair	Poor-Exc.	Good	Good-Exc.	Good.	Poor-Fair	Good
FVMQ	Exc.	Good	Good	Fair	Fair-Exc.	Poor	Exc.	Good	Poor	Exc.	Poor	Good-Exc.	Poor-Fair
ACM	Fair	Poor-Fair	Poor	Poor	Poor	Poor	Fair	Fair	Poor	Good	Poor	Good	Poor
EA	Good	Poor-Fair	Good-Exc.	Poor-Exc.	Good-Exc.	Fair-Good	Good-Exc.	Poor	Good	Good	Poor	Poor	Poor
CSM	Exc.	Good-Exc.	Exc.	Good	Exc.	Poor-Fair	Good-Exc.	Good-Exc.	Poor	Good	Fair	Poor	Poor
ECO	Good	Poor-Fair	Fair	Poor	Fair-Good	Poor	Fair-Good	Poor-Fair	Poor-Good	Exc.	Poor	Poor-Good	Poor
NR, IR	Fair-Exc.	Poor-Good	Good	Fair-Good	Good Exc.	Good	Fair-Exc.	Fair-Good	Poor-Fair	Poor-Good	Good	Poor	Poor
AU, EU	Fair-Good	Poor	Fair	Poor	Good	Poor	Poor-Exc.	Poor	Poor-Fair	Fair-Exc.	Poor	Poor-Good	Poor

Esters, Aryl Phosphate	Ethers	Fuel, Aliphatic Hydrocarbon	Fuel, Aromatic Hydrocarbon	Fuel, Extended (Oxygenated)	Halogenated Solvents	Ketones	Lacquer Solvents	L. P. Gases & Fuel Oils	Petroleum Aromatic-Low Aniline	Petroleum Aliphatic-High Aniline	Refrigerant Ammonia	Silicone Oils
Poor-Fair	Poor	Good-Exc.	Fair-Good	Fair-Good	Poor	Poor	Fair	Exc.	Good-Exc.	Exc.	Good	Good
Poor-Fair	Poor-Fair	Exc.	Fair-Good	Good-Exc.	Poor-Fair	Poor	Fair	Exc.	Good-Exc.	Exc.	Good	Good-Exc.
Exc.	Poor	Exc.	Exc.	Exc.	Good-Exc.	Poor	Poor	Exc.	Exc.	Exc.	Poor	Exc.
Exc.	Fair	Poor	Poor	Poor	Poor	Good-Exc.	Poor	Poor	Poor	Poor	Good	Exc.
Poor	Poor	Poor	Poor	Poor	Poor	Poor-Good	Poor	Poor	Poor	Poor	Good	Poor
Poor-Fair	Poor	Poor-Good	Poor-Fair	Fair	Poor	Poor-Fair	Poor	Good	Good	Good	Exc.	Fair-Exc.
Exc.	Poor-Fair	Poor	Poor	Poor	Poor	Poor-Exc.	Fair-Good	Poor	Poor	Poor	Good	Poor
Good	Poor	Poor-Fair	Poor	Poor	Poor	Poor	Poor	Fair	Poor	Good	Exc.	Poor-Fair
Good-Exc.	Fair	Exc.	Good-Exc.	Exc.	Good-Exc.	Poor	Poor	Exc.	Good	Good	Exc.	Exc.
Poor	Poor-Fair	Exc.	Poor-Good	Fair-Good	Poor-Good	Poor	Poor	Good	Fair	Poor	Fair	Exc.
Poor	Poor	Good	Poor-Fair	Fair	Poor-Good	Poor	Poor	Poor	Poor	Poor	Poor-Good	Good-Exc.
Fair	Poor	Fair-Good	Fair	Fair	Poor	Poor	Poor	Good	Poor	Fair	Good	Exc.
Poor	Good	Good-Exc.	Good-Exc.	Fair-Good	Poor	Fair	Fair	Exc.	Good-Exc.	Poor	Poor	Good-Exc.
Poor	Poor	Poor	Poor	Poor	Poor	Fair-Good	Poor	Poor	Poor	Poor	Good	Good
Poor	Fair	Good-Exc.	Poor-Fair	Fair-Good	Poor-Good	Poor	Poor	Fair-Good	Good	Good	Poor	Exc.

NOTE: The chart data herein provides general elastomer base properties. In many design applications, special compounds are required. Minnesota Rubber and Plastics strongly recommends MR Lab approval in such cases. Minnesota Rubber and Plastics, therefore, will not be responsible for the usage of this chart in any manner.

Special Compounds and Certifications

Wear Resistant and Lubricated Compounds

There are a variety of techniques to enhance the wear resistance of a rubber component. A common technique includes the introduction of low friction fillers, such as PTFE, molybdenum disulfide or graphite into the compound during mixing. These wear resistant compounds have proven to provide longer life in applications involving frequent reciprocation.

A unique method used by Minnesota Rubber and Plastics to provide friction reduction is the addition of lubrication chemicals into the elastomer mixture. These chemicals modify the surface of the part to provide an "internally lubricated" compound which greatly reduces surface friction. (See table.) The mechanism of the lubricant does not affect the long-term physical properties of the rubber part. The internally lubricated compounds are designed for intermittent or slow cycling type applications. It is recommended that designs with long idle times make use of these compounds to assure minimum startup friction.

Coefficient of Friction Comparisons

Hardness Shore A	Polymer	Compound	Type	Coefficient of Friction Static	Dynamic
70	EPDM	559N	STANDARD	0.57	0.64
		560RJ	LUBRICATED	0.18	0.17
90	EPDM	559GT	STANDARD	0.55	0.54
		561NA	LUBRICATED	0.30	0.15
70	NBR	366Y	STANDARD	1.10	1.02
		366HA	LUBRICATED	0.17	0.17
70	NBR	525K	STANDARD	2.10	2.33
		525EX	LUBRICATED	0.15	0.09

F-Treat

Minnesota Rubber and Plastics uses a proprietary technology to provide ultra-low friction and low stiction of FKM compounds. This process is called “F-Treat” and provides a permanent chemical modification to the surface of the elastomer, which cannot be removed. The F-Treat process has minimal effect upon the elastomer’s original and aged properties.

Static Coefficient of Friction Comparison, FKM

Hardness Shore A	Compound	Type	Coefficient of Friction Initial	After 1 hr. of loading
55	514QN	UNTREATED	1.19	5.0
		F-TREATED	0.28	0.35
70	515AJ	UNTREATED	0.92	1.3
		F-TREATED	0.37	0.43
90	514ZD	UNTREATED	0.75	1.2
		F-TREATED	0.33	0.48
70	514GJ	UNTREATED	0.76	0.92
		F-TREATED	0.37	0.42

FDA Regulations / Food & Beverage Applications

The United States Government regulates the ingredients in rubber products that are intended for use in food contact applications. The controlling agency is the Food and Drug Administration (FDA), whose guidelines are stated through the Code of Federal Regulations (CFR). The regulations covering rubber articles are contained in CFR Title 21, Chapter 1, Subchapter B, Part 177, Subpart C, and Paragraph 2600.

The FDA provides two categories for individual food types with rubber compatibility. The Class I category designates foods, including edible oils, butter, milk and milk based products and cooking oils. Rubber compounds that meet these requirements are also compliant with foods in Class II. The second category, Class II, pertains to foods that do not contain edible oils or milk products. Water, soft drinks, alcoholic beverages and other aqueous solutions are typical Class II environments. Minnesota Rubber and Plastics has a large selection of compounds with physical property ranges to meet your application needs. The following tables give a listing of recommendations as a starting point.

FDA - Food, Drug and Cosmetic Act CFR 21, Chapter 1, Sub ch. B, Part 177, Subpart C, Section 177.2600

	For foods containing milk and edible oils as well as aqueous beverages		For aqueous-based foods and beverages only	
Hardness Shore A	NBR	FKM	NBR*	EP
50	536DS	-----	372FX	565CZ
60	536AB	514ZR	445A	559PN
70	536X	514YP	525K	559PE, 560YH, 559TM
80	536AQ	514ZM	446A	559PM
90	----	514ZC	309BK	559GT

*These NBR elastomers will provide superior heat and compression set resistance as compared to the 536 series NBR elastomers.

Most Minnesota Rubber and Plastics silicones meet the above requirements. The following compounds are examples of the unique features available in silicone elastomers:

71417C	General purpose; very versatile, excellent compression set properties, heat resistant.
73117A	Ultra low temperatures.
74115	High strength at low temperatures, high tensile strength.
74115C	Tear resistant and high strength for good mechanical durability.

Minnesota Rubber and Plastics has also worked extensively with a wide variety of soft drinks and has data available.

UL Listed Compounds

Underwriters Laboratories® (UL) is a non-profit organization that operates laboratories to examine and test devices, systems and materials manufactured by non-affiliated industries. UL provides a rating on how these products correspond to hazards affecting part life and properties. Products that maintain UL designated safety limits are approved and given the UL trademark label.

In order for a product to carry a UL label, a series of rigorous tests must be passed annually, insuring that the product will withstand conditions beyond those normally encountered. UL has provided the elastomer industry with set standards for compounds in different working environments.

While Minnesota Rubber and Plastics no longer separately certifies our compounds to individual standards, we continue to work with customers in their UL certification process by providing compliant materials.

Special Compounds and Certifications

NSF International® - Potable Water Applications (ANSI / NSF Standard 61)

NSF International is an independent third party certifier that acts as a neutral agency among the interests of business, government and the public. Products certified and carrying the NSF mark signify that they have been proven safe for contacting products intended for human consumption. NSF is particularly known for its food related and potable water standards. Like the UL label, the NSF mark is given to the finished consumer product. Minnesota Rubber and Plastics will assist any customer in their quest to comply with any NSF standard. Minnesota Rubber and Plastics has the largest number of ANSI/NSF Standard 61 certified compounds available today. Approved material can be used in a wide variety of water applications and other NSF standards. By choosing a Standard 61 certified compound, customers realize large savings in product testing and time to certification for their product.

Minnesota Rubber and Plastics ANSI / NSF Standard 61 Listed Materials. Certified materials for the water industry.

Compound	Hardness Shore A	Elastomer	Agency	Water Contact Temperature	Specialty
561NY	40	EPDM	NSF	Cold (23°C)	▪ Ultra low hardness and modulus applications ▪ High elongation
565CZ	50	EPDM	NSF	Hot (82°C)	▪ Low hardness ▪ High elongation ▪ Listed in KTW recommendations
560CF	60	EPDM	NSF	Cold (23°C)	▪ Flow controls ▪ Intermediate hardness
560YH	70	EPDM	NSF	Hot (82°C)	▪ Low taste and odor ▪ Low extractables
559N	70	EPDM	NSF	Hot (82°C)	▪ Dynamic applications
559PE	70	EPDM	NSF	Hot (82°C)	▪ Chloramine resistant ▪ Compression set resistant ▪ Static applications ▪ KTW and WRc listed to BS6920
560RJ	70	EPDM	NSF	Hot (82°C)	▪ Self-lubricating ▪ Dynamic and static applications
559TM	70	EPDM	NSF	Hot (82°C)	▪ Self-lubricating
561NZ	80	EPDM	NSF	Cold (23°C)	▪ Chloramine resistant ▪ Compression set resistant ▪ Higher hardness and modulus applications
561TX	80	EPDM	NSF	Cold (30°C)	▪ Self-lubricating ▪ Chloramine resistant ▪ Compression set resistant ▪ Higher hardness and modulus applications
559GT	90	EPDM	NSF	Cold (23°C)	▪ Chloramine resistant ▪ Compression set resistant ▪ Ultra high hardness and modulus applications ▪ High pressure applications ▪ KTW and WRc listed to BS6920
366SM	70	NBR	NSF	Hot (82°C)	▪ Oil and abrasion resistant
534HC	70	NBR	UL	Cold (23°C)	▪ Self-lubricating ▪ Oil and abrasion resistant
71105B	50	SIL	UL	Cold (23°C)	▪ Low hardness and modulus applications ▪ Tear resistant
559YU	90	EPDM	NSF	Cold (30°C)	▪ Self-lubricating ▪ Compression set and chloramine resistant ▪ High pressure applications
76155	50	LSR	NSF	Cold (23°C)	▪ Low modulus and cracking pressure applications ▪ Chloramine resistant
558BM	70	EPDM	NSF	Cold (23°C)	▪ Self-lubricating ▪ Wear resistant
534DF	65	NBR	NSF	Cold (23°C)	▪ Self-lubricating ▪ Oil and abrasion resistant
C2528KF	70	EPDM	NSF	Cold (23°C)	▪ Green in color
212N	70	EPDM	NSF	Hot (82°C)	▪ Chloramine resistant ▪ Low cost alternative } O-Rings only
210N	70	NBR	NSF	Cold (23°C)	▪ Oil resistant ▪ Low cost alternative } O-Rings only

Notes:
- All EPDM compounds are designed to have low water swell.
- All compounds are available in our standard o-ring and most Quad-Ring® Brand seal products.
- Most compounds are available in ground balls.
- Compound 559GT is not available in some small Quad-Ring® Brand seal sizes.

International Certifications - Potable Water

Minnesota Rubber and Plastics has the most extensive domestic and international potable water certified elastomers list in the world today. Compounds 559PE (EP, 70) and 559GT (EP, 90) feature the latest in chloramine resistant technology and are certified for potable water use throughout the world.

Drinking Water

Compound	Hardness Shore A	Elastomer	
Great Britain WRAS: British std. BS6920-1990			
558BW	50	EP	For hot and cold water.
559PE	70	EP	For cold water.
559GT	90	EP	For cold water.
565LJ	80	EP	For cold water.
C2528JW	70	EP	For cold water. Color: royal blue
C2512FW	60	Butyl	For cold water. Color: orange
212N	70	EP	For hot and cold water. O-Rings only
210N	70	NBR	For hot and cold water. O-Rings only
Germany KTW:			
559PE	70	EP	
366SN	70	NBR	
565CZ	50	EP	
559GT	90	EP	
212N	70	EP	O-Rings only
210N	70	NBR	O-Rings only
France ACS:			
559PE	70	EP	
559GT	90	EP	
366SM	70	NBR	
565CZ	50	EP	
534HZ	50	NBR	
309DP	80	NBR	

Chloramines and Other Water Treatment Chemicals

For several years there has been a strong trend for water municipalities to add ammonia and chlorine to water in order to form disinfecting chloramines. It has been well documented that chloraminated water is much more aggressive to rubber products than water containing the conventional free chlorine. We also know that chloramine disinfecting will continue to increase due to the rules set forth by the U.S. EPA Safe Drinking Water Act.

Minnesota Rubber and Plastics has done extensive research on formulating rubber compounds to be chloramine resistant and we offer the most free chlorine and chloramine resistant elastomers available. We are recognized industry leaders in both chloramine resistant and ANSI/NSF Standard 61 certified compounds.

Minnesota Rubber and Plastics is also capable of formulating compounds with specific properties that will be used in potable water systems. See chart on previous page labeled ANSI/NSF Standard 61 Listed Materials for specific compounds to fit your needs.

Special Compounds and Certifications -continued

Perfluoroelastomers

Perfluoroelastomers, (FFKM), are fully fluorinated hydrocarbons whose key trait is the ability to withstand exposure to almost any chemical. Minnesota Rubber and Plastics has developed 70 and 80 Shore A perfluoroelastomers with high temperature performance to 450°F (230°C). Perfluoroelastomers remain flexible to 30°F (0°C).

Relative to other elastomers, perfluoroelastomers generally exhibit higher compression set values and are the most expensive of all elastomers. In addition, FFKM elastomers are difficult to process. Compression molding is most often preferred.

Properties - FFKM Compound 610B	
Tensile, (psi)	(1998)
Elongation, %	204
Modulus, 100% (psi)	(620)
Hardness, Shore A	73
Specific Gravity	2.08
Air Aged (70 hrs @ 250°C (518°F)	
Tensile, change %	-3.2%
Elongation, change %	+8.3%
Hardness change, Shore A	0
Compression Set, 70 hrs @ 200°C (392°F)	
Buttons	21
O-Rings	34

Medical and Laboratory Requirements

"Medical grade" is a term used to designate compounds that will be put to use in diagnostic devices and medical equipment. "Medical grade" compounds can be thought of as "non-contaminating" to the surrounding media.

Many elastomeric materials can be designed to be medically acceptable using the proper ingredients. Silicone elastomers are generally the first choice for a medical part. Silicone's inertness to body fluids and ability to meet USP Class VI regulations make it a very feasible medical grade material (this includes LSR). Polyisoprene is also widely used for medical grade components. Natural rubber is noted for its compatibility with insulin. Butyl, nitrile, ethylene propylene, urethane, fluorocarbon, epichlorohydrin, polychloroprene and CSM elastomers provide serviceable parts to medical applications in non-critical areas.

Although the responsibility for medical specification compliance lies with the device manufacturer, it is necessary for us to have complete details as to the media to be encountered and the environmental conditions expected when designing parts for use in medical applications (i.e.: gases, solutions, vaccines, serums, sterilization, freezing, immersion, as well as any applicable standards and cleanliness requirements.) This information will enable us to accurately recommend a specific rubber formulation for the part application.

We are a type 3 (packaging) drug master file holder and maintain FDA compliant compounds.

Taste and Odor Specifications

Minnesota Rubber and Plastics has considerable experience with materials that will not impart a taste or odor into products they contact. We can provide further information about these applications upon request. Minnesota Rubber and Plastics currently participates in many such food/beverage and drinking water applications worldwide.

FKM Compounds for Fuel and Chemical Industries

Minnesota Rubber and Plastics offers a wide range of materials to meet the needs of fuel and chemical sealing applications. These compounds include a variety of FKM (fluorocarbon) materials, some of which offer more chemical resistance, improved cold temperature performance or heat resistance.

Explanation of fuel/chemical resistance for FKM compounds		
514AD	70 duro FKM	Gasoline/Diesel Fuel
515AS	70 duro FKM	Base/Amine Resistance
514GJ	70 duro FKM	Extended Fuels
514TS	70 duro FKM	Extended Fuels/Low Temperature
514VJ	70 duro FKM	Low Temperature Resistance
514BC	70 duro FKM	Low Temperature Resistance
514UE	80 duro FKM	*Specialty Chemicals/Blends
514UG	70 duro FKM	*Specialty Chemicals/Blends

*Specialty chemicals include these oxygenated fuel extenders and solvents, but are not limited to: MTBE, TAME, ETBE, MeOH, EtOH, MEK and Toluene.

Compound	Type	Polymer	%Fluorine	Service Temp.	Application
514AD	Dipolymer	VDF/HFP	66	-15°C to 230°C	Low cost, general-purpose chemical
515AS	Terpolymer	TFE/Propylene/VDF	59	0°C to 200°C	Base resistant FKM
514GJ	Tetrapolymer	VDF/HFP/TFE/CSM	70	0°C to 230°C	Specialty chemical extended fuel
514TS	Tetrapolymer	VDF/PMVE/TFE/CSM	67	-20°C to 230°C	Specialty low temp., extended fuel
514BC	Tetrapolymer	TFE/VDF/VE/CSM	67	-40°C to 230°C	Specialty low temp., extended fuel
514VJ	Tetrapolymer	VDF/PMVE/TFE/CSM	66	-25°C to 230°C	Specialty low temp., general chemical
514UE	Terpolymer	TFE/PMVE/Ethylene	66	-5°C to 230°C	Ultra-specialty chemical
Kalrez®	Dipolymer	TFE/PMVE	73	0°C to 260°C	Ultra-specialty chemical

VDF - Vinylidene Fluoride, **HFP** - Hexafluoropropylene, **TFE** - Tetrafluoroethylene , **PMVE** - Perfluoro (Methyl Vinyl Ether), **CSM** - Cure Site Monomer, **VE** - Vinyl Ether

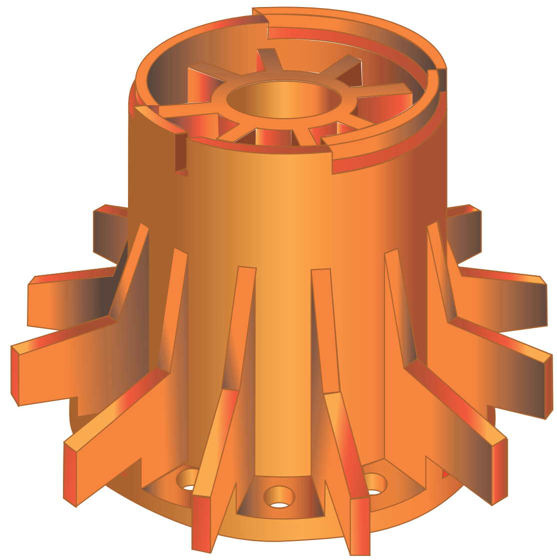
Computer Applications

Minnesota Rubber and Plastics makes rubber compounds that are ideal for vibration control and "perfect sealing" component requirements of the computer industry. A number of elastomers have been designed at Minnesota Rubber and Plastics that are suited to withstand varying degrees of vibration through the absorption of mechanical energy by the rubber component. Bumper pads or shock mounts and crash stops are typical components encountered.

Certain electrical areas of computer design require separation from contaminating environments. Minnesota Rubber and Plastics' low outgassing and low extractable compounds, especially the 487 butyl compound series, are good choices for these applications.

Section 4
Designing Plastic Components

Designing Plastic Components



Plastics Technologies and Services

Minneota Rubber and Plastics offers a wide range of technical services and production capabilities for producing close tolerance components. Our specialty processes and services include:

- Hotplate, rotational and ultrasonic welding
- Adhesive bonding, hot stamping and machining
- Bonding for plastic to metal, plastic to rubber and plastic to plastic

Assemblies

Our experience in applications for high performance materials and thermoplastic elastomers allows us to view a new design or re-design criteria objectively. As the components we produce are typically part of a larger assembly, many customers have benefited from our part consolidation recommendations that allow us to design, develop, manufacture, test, package and ship their completed assembly.

In order to meet critical time-to-market requirements we provide creative solutions for assembly programs. Whether it is a simple two component sub-assembly or a complex, multi-component rubber and plastic assembly that incorporates inserts and hotplate welding, we offer cost-effective engineered solutions.

What's more, we know how to maintain the integrity of your basic design while taking into consideration factors such as shrink distortion and parting lines; this helps avoid surprises when it comes time to manufacture, assemble and use the end product.

As the relationship between materials, parts and end-use performance needs to be addressed, we also know how to solve problems arising from torque values and sealing contacts. We then ensure that the rubber and plastic materials complement each other's tolerance capabilities.

Once the design is complete, we can follow up with testing through the use of tools, such as FEA, where benefits like increased strength, reduced material use and reduced costs can be realized.

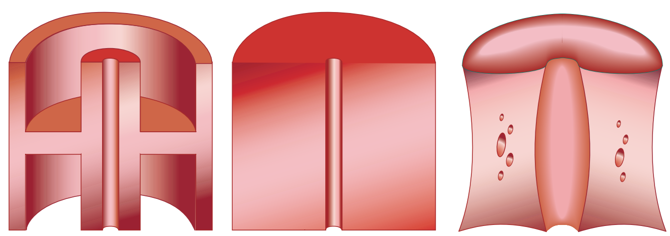
Plastic Design Issues

Injection molded plastic parts offer an important combination of flexibility, toughness, and chemical resistance for cost effective, long-term performance in a wide range of applications. However, not every plastic part design can be efficiently injection molded. So working with us early in the design process is important. With our experience in plastics materials and molding, we can help you design parts that are both functional and within budget.

Shrinkage

Thermoplastic materials are heated in the barrel and injected into the mold cavity. As the part cools in the mold, it shrinks. Thick cross-section areas cool at a substantially lower rate than thin cross-sections, and press cycle time is based on the cooling rate of the thickest cross-section.

Therefore, even one relatively thick cross-section area will increase the press cycle time, thereby reducing the number of parts per hour and increasing the cost per part.



Correct **Incorrect** **Distortion and Sink**

The uneven rate of cooling of these thick and thin cross-sections is also likely to result in distortion of the part after it has been removed from the mold. This distortion is often severe enough to prevent the part from meeting specifications.

A thick cross-section is also likely to result in a depression on the surface called a sink mark, particularly if the cross-section is of varying widths.

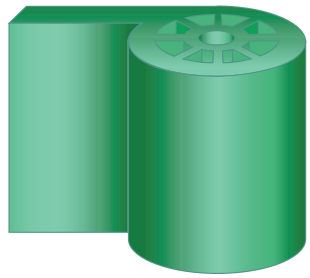
A good rule of thumb is to design all part cross-sections as thinly and uniformly as possible. The use of ribs is an effective way of achieving rigidity and strength while avoiding cross-sectional thickness.

In cases where it is impossible to avoid a thick cross-section, ribs may also help to minimize the distortion that can occur during post-cure. Very complex shapes that must combine thick and thin cross-section should be reviewed in advance so as to determine dimensional stability and tolerance changes that will occur during and after molding.

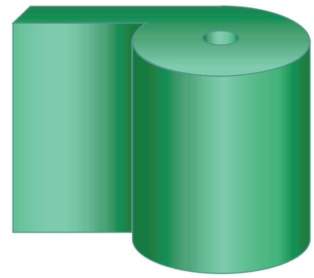
Wall Thickness

Uniform wall thickness is critical in part design for an injection molded part. Non-uniform wall thickness causes dimensional control problems, warpage and other part integrity issues.

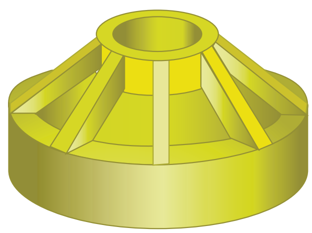
Production techniques on thin walls become quite complicated. For efficient, high volume production, we recommend a minimum wall thickness of .025-.030 (.635-.762mm) on small parts, .040-.050 (1.02-1.27mm) on larger parts.



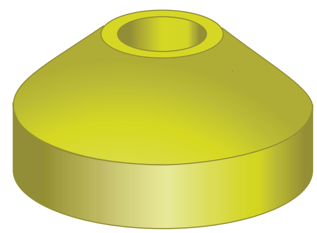
Correct



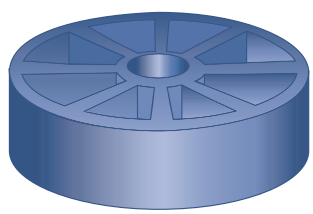
Incorrect



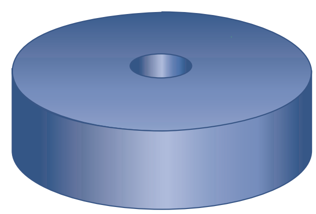
Correct



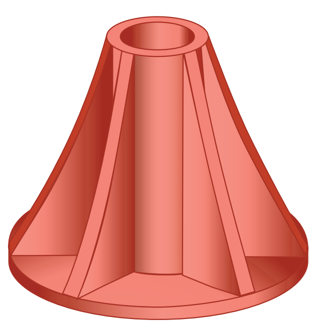
Incorrect



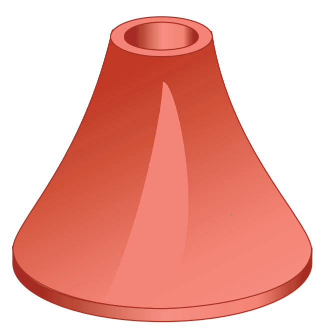
Correct



Incorrect



Correct

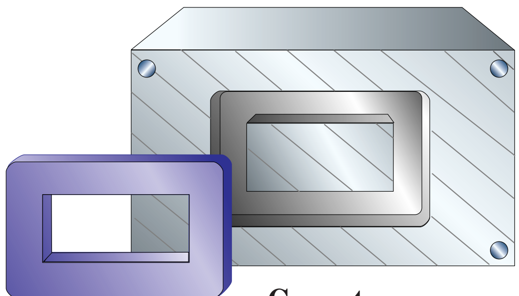


Incorrect

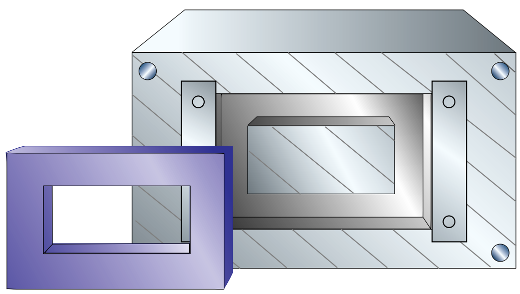
Corners

Two key points to keep in mind when designing part corners: the mold is machined from steel, and it's easier to machine a radius than a square corner.

Therefore, whenever possible, the part should display round corners when viewed from the top. When viewed from the side, the edges should be square.

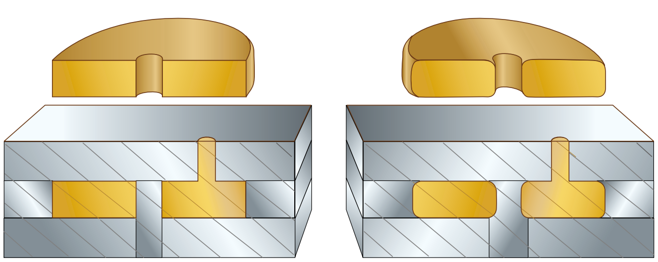


Correct



Incorrect

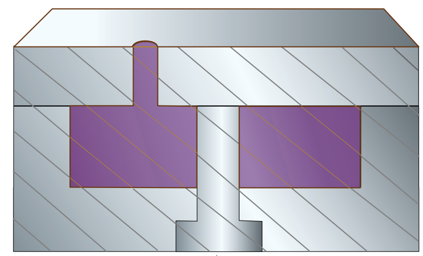
Also, due to the flow characteristics of the molten material during the molding process, square corners tend to be weaker than rounded corners. To ensure dimensional stability, we recommend a minimum radius of .010 (.254mm).



Incorrect **Correct**

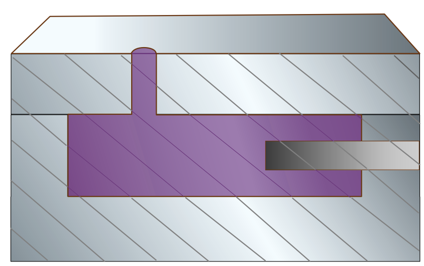
Holes

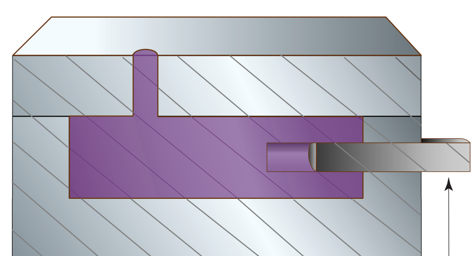
A hole or I.D. is created in a part by inserting a core pin in the cavity. Holes at a right angle to the mold parting line are relatively easy to produce since the core pin is parallel to the injection path. The normal shrinkage process, however, can cause the part to cling to the core as it cools in the mold. In order to facilitate ejection of the part from the mold, a draft should be incorporated along the length of the hole.



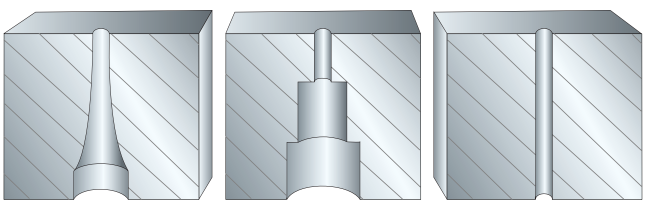
Holes that are parallel to the mold parting line call for the use of a sliding core that automatically retracts from the part as the mold opens. The use of sliding cores adds to the cost and complexity of tool design and construction.

If a hole does pass completely through a part, or if the part contains holes on more than one side, the mold must be designed to hold the part on a specific side of the open mold to facilitate automatic parts unloading.





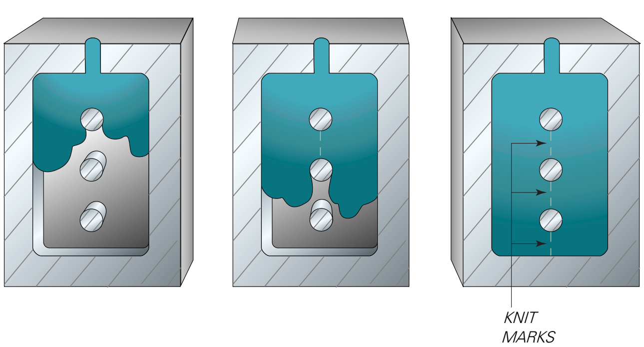
Long, fragile cores tend to warp or break under continuous use due to the heat and pressure of their operating environment. The size of the core pin, and thus the diameter of the hole, should therefore be maximized whenever possible, particularly at the base, to ensure the stability of the pin. A useful rule of thumb to remember when designing part holes is the “2.1 rule”: The height of the hole should not be more than twice its diameter.



Preferred **Alternate** **Least Preferred**

Knit Marks

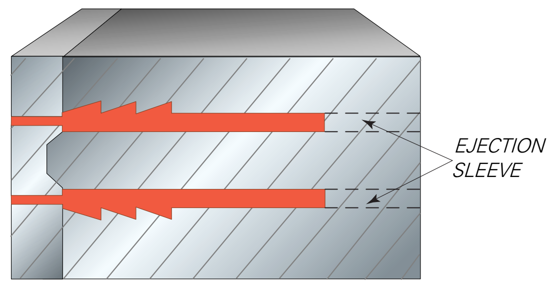
A core pin blocks the normal path of the molten material as it enters the mold. A weak point called a knit mark can be created on the “back side” of the pin where the material flows together. These weak points can be eliminated by proper placement of the gate, or material entry point. It is therefore critical that you call out areas where knit marks cannot be tolerated so that potential problems can be eliminated in the mold design stage.

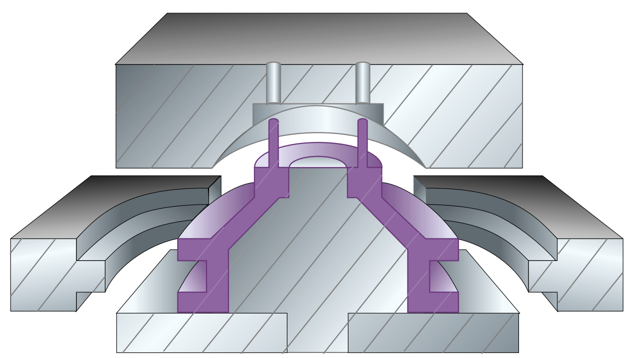


Undercuts

The ease with which a plastic part is removed from the mold is affected in large part by the presence and depth of undercuts, the cross-section thickness, and the flexibility of the thermoplastic material. The undercut must be shallow or the material must have considerable “give” in order to allow the core pin to be “snapped” from the molded part.

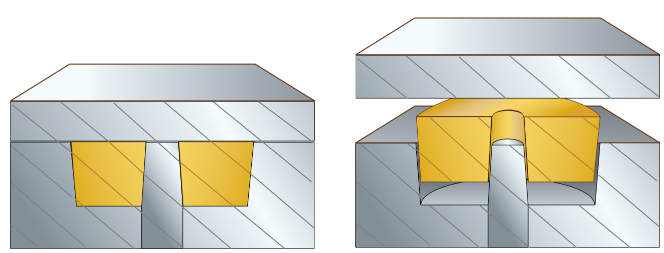
Parts featuring an undercut on the O.D. are often molded by a split-shell process. Deeper undercuts on the O.D. may require the use of a more expensive sliding core mold.





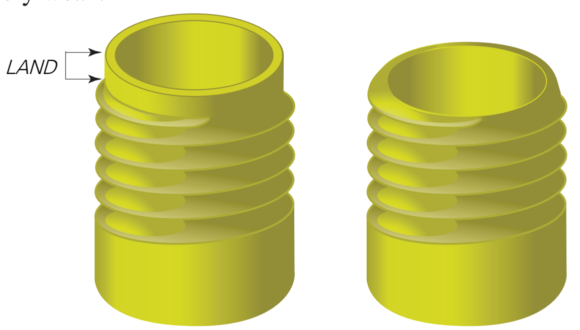
Taper

Part surfaces should be tapered slightly to facilitate ejection of the part from the mold, especially in high speed, high volume production applications. Surfaces to be tapered include holes, cavities and internal grooves, as well as the O.D.



Threads

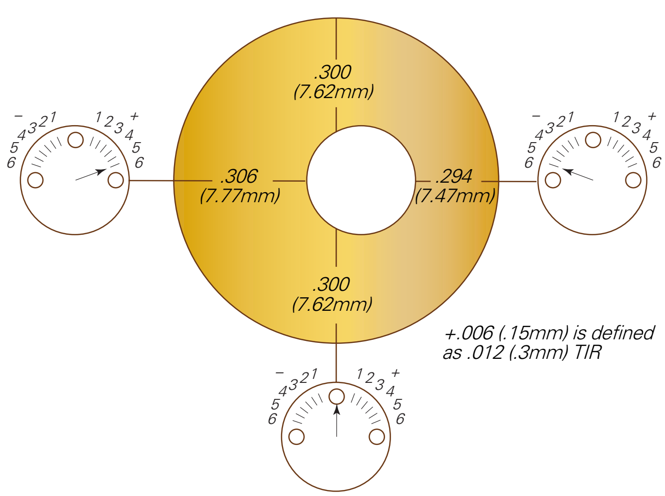
Threads can be molded into your plastic part on either the I.D. or O.D. surface. An O.D. thread design must include a non-threaded surface, or land, extending from one end of the thread approximately one and one-half times the thickness of the thread. I.D. threads should be a maximum of .050 (1.27mm) long, and no finer than 32 threads per inch (12 threads/cm), as fine threads molded in plastic tend to be very weak.



Correct **Incorrect**

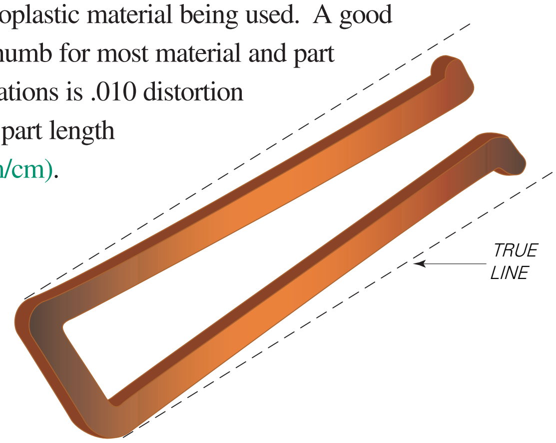
Total Indicator Reading

Total Indicator Reading (TIR) measures roundness in relationship to a center line. TIR is expressed in total diametric deviation: ±.004 (.102mm) deviation is defined as ± .008 (.203mm) TIR. Roundness tolerances for molded plastic parts should not exceed ± .007 per inch diameter (.07mm/cm), with a minimum TIR of ±.005 (.127mm).



Warpage

Some warpage can be expected with any molded plastic part. The amount of warpage will vary with the type of thermoplastic material being used. A good rule of thumb for most material and part configurations is .010 distortion per 3.00 part length (.033mm/cm).



Surface Finish

Molded plastic parts may be designed with a variety of surface finishes, from glossy polish to a rough texture. The choice of surface finish is normally based on cosmetic considerations. A glossy finish can enhance the appearance of a part, while a textured surface may help to mask sink marks or parting lines.

Surface finish should be specified so as not to interfere with ejection of the part from the mold. The smoother the finish, the more easily the part will be removed from the mold. An extremely rough surface may function much like an O.D. undercut, preventing the part from slipping easily from the mold.

When not otherwise specified, we adhere to the surface finish standards of the Society of Plastic Engineers and the Society of Plastic Industries.

Color Coding

Molded plastic parts are easily produced in a wide range of colors. Some plastic formulations, however, do include strongly colored fillers whose color is not easily altered by the addition of other pigments. The proportion of pigments to plastic is small, so as to have very little effect on the performance of the part.

Coloring agents do, however affect the shrinkage characteristics of the plastic. Thus, parts of different colors produced from the same material in the same mold will have different dimensions.

The addition of color pigments does not delay the production process, since color mixing is done in our facility as part of the material formulation process.

Finished parts can also be hot-stamped with part numbers and company designations.

Inserts

Steel, brass, or aluminum components are commonly inserted into plastic parts during or after the molding process. A knurled, ribbed or abraded surface on the metal part helps to ensure a strong, permanent bond between metal and plastic. Our design engineers can provide you with more information and assistance in designing your inserts.

Secondary Operations

Most parts are shipped "as molded." Some parts however require minor cleaning, normally accomplished using one of several types of tumblers. Gate marks can also be removed by buffing, grinding or trimming.

Tapping, drilling, insertion, assembly, bonding, decorating or other secondary operations are sometimes used to facilitate the production process. In order to decrease mold complexity or improve production throughout, for example, a part feature might be more easily added after molding.

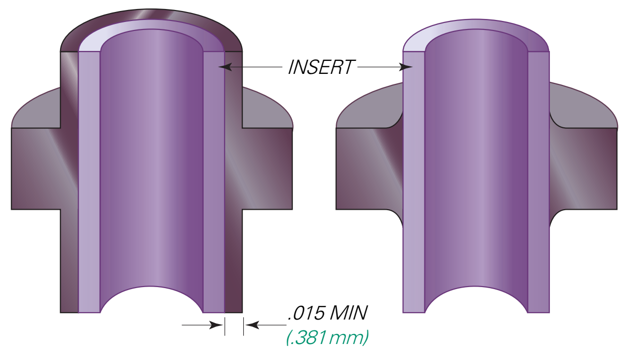
Plastic Over-Molding

Over-molding onto plastic inserts can solve many design problems. The flexibility, toughness, solvent and chemical resistance of rubber is combined with rigidity, light weight, and cost savings of plastic.

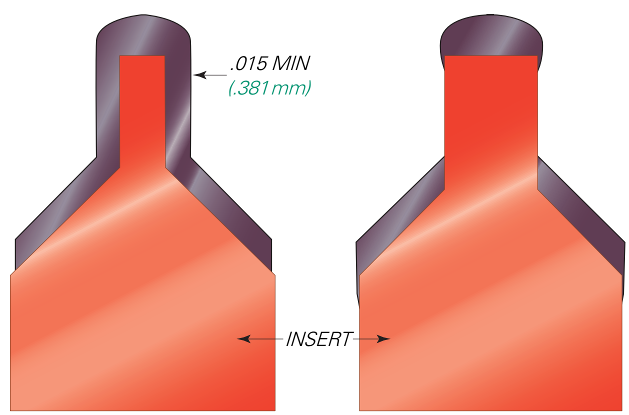
Material with a heat deflection temperature of less than 400°F (204°C) should normally be avoided for rubber-to-plastic molding, as the intense heat and pressure of the rubber molding press may cause the plastic part to reflow and distort.

Plastic materials commonly used in the bonding process include nylon, polycarbonate, modified PPO, polysulfone, and polyphyenylene sulfide.

Even these ideal materials will experience some shrinkage. We recommend a starting tolerance of +.005 inch (.127mm). This tolerance would increase, however, for diameters of more than .250 inch (6.35mm).



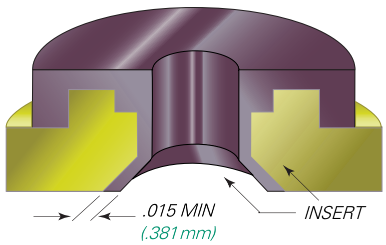
Correct **Incorrect**



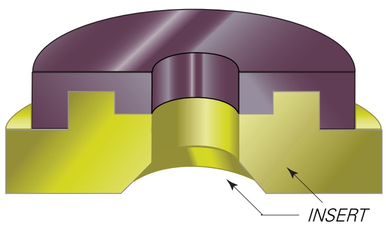
Correct **Incorrect**

The heat and pressure of the rubber flow tends to warp or crush plastic threads, as well. Even if the threads are located away from the rubber flow, shrinkage due to heating is likely. In order to avoid this problem, we recommend that plastic threads be ground after the rubber molding process.

Undercuts are subject to the same stresses and may collapse or shrink to some extent. The tolerance on undercuts, however, is usually more forgiving and predictable. Envelop as much of the plastic insert in rubber as possible. This simplifies insert design and eliminates tedious flash removal. This technique also improves bonding by increasing surface-to-surface contact and/or by supplementing the chemical bond with a mechanical bond.

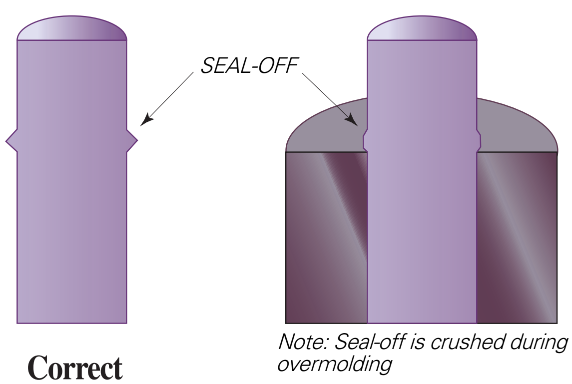


Correct

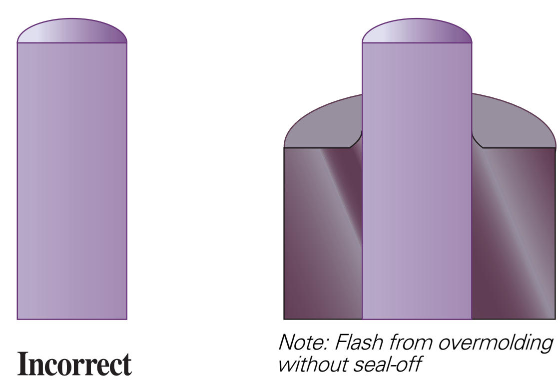


Incorrect

In cases where the rubber cannot be allowed to cover the entire surface of the insert, a mechanical barrier, called a seal-off, must be incorporated into the insert design.



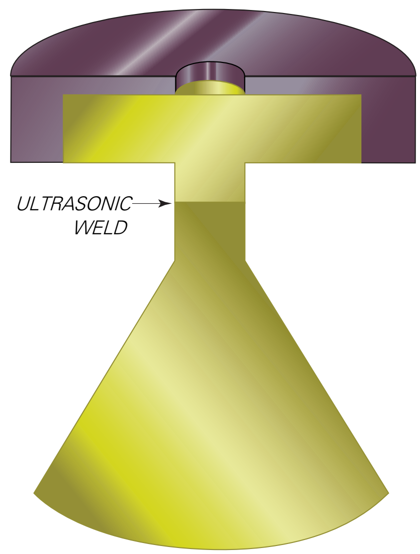
Correct



Incorrect

Unsupported areas of a part, such as large, flat surfaces not covered by rubber, are especially prone to warping. Such areas may be supported by the tool itself; more often, however, this support must be incorporated into the part design.

Providing this support is not always simple. A part such as the one shown below may have to be produced in two stages. A sliding core would be required in the rubber mold to support the part. In this case, it may be simpler to ultrasonically weld the flat insert to the funnel-shaped section after the rubber molding process. The insert must still be supported by pins on one side so that the rubber can flow over the horizontal surface of the insert.



Sliding pins often leave marks on the part surface, which may be a concern in cases where appearance is critical. Also, the part surface may be discolored by the adhesive that is applied to the part prior to molding. Further discoloration usually occurs during molding and deflashing.

If color and appearance are important, the part should be designed so that the rubber completely covers the plastic insert. Silicone rubbers can be specified in a variety of bright hues, whereas other rubber materials are generally available in only dark or dull colors.

Writing Your Plastic Component Specifications

(For rubber components, see our "Writing Your Rubber Component Specifications" in Section 2)

Contact: ______ **Date:** ______

Company name: ______ **Phone:** ______ **Fax:** ______

Address: ______ **e-mail:** ______

Part name: ______ **Part number:** ______

Basic description and function of part in application: ______

Estimated annual usage (EAU): ______

Target price: ______ **Cost of present part:** ______

Life expectancy: ______

Material: ______ **Color:** ______

Part data base available? ☐ Yes ☐ No **Prototypes available?** ☐ Yes ☐ No

Describe assembly operation: ______

Assembly methods and equipment currently used: ______

Can assembly be simplified? ☐ Yes ☐ No

Temperature conditions:
- Minimum ______
- Maximum ______
- Continuous ______
- Intermittent ______

Testing Requirement: ______

Operating environment part is exposed to (i.e.: fluids, chemicals, solids)**:** ______

Significance of media contact (i.e: splash, submersion, mist, fumes, subject to dry)**:** ______

continued on reverse

Describe performance requirements (i.e.: structural, torque, tension)**:** ____________________

Load frequency (i.e.: static dynamic, cycling, impact, RPM, interference, FPM, stroke length)**:** __________

Does plastic come in contact with rubber parts? ☐ Yes ☐ No

If so, what type of rubber compound? ____________________

Material and surface contact points of mating parts: ____________________

Anticipated Q.A. requirements: ____________________

Aesthetic requirements (i.e.: weld lines, parting lines, gate location)**:** ____________________

Gate extension: ▪ Minimum __________ ▪ Maximum __________

Critical features of functional requirements: ____________________

Are tolerances correct and applicable? ☐ Yes ☐ No

Can multiple parts or functions be combined? ☐ Yes ☐ No

Is special packaging required? ☐ Yes ☐ No

Additional comments: ____________________

Make a sketch or attach a print if the part is easier to illustrate than to describe:

Section 5
Plastic & Thermoplastic Elastomer Materials

Plastic & Thermoplastic Elastomer Materials

Minnesota Rubber and Plastics specializes in the design and molding of close tolerance, high performance thermoplastics and thermoplastic elastomers. We also work with engineered plastics and specialize in finding the most efficient and innovative means of reducing costs while improving product performance.

Our specialty services include hot plate welding, two shot molding, product testing, assembly and packaging. In addition, our unified project management system accelerates product launch and time-to-market.

High Performance Plastics

Not every plastics molder can produce high quality components from high performance materials. Even fewer offer the range of high performance / high temperature materials found at Minnesota Rubber and Plastics. These materials, and our hot manifold and hot runner systems, represent our core business. And our customers have come to rely on our ability to develop, design and produce their components and assemblies, cost-effectively, from a wide range of material offerings.

High performance materials have extensive performance ranges and unique property attributes. As manufacturers require higher levels of performance and lower costs from materials, we continue to meet their needs for a wide range of markets from aerospace and automotive to consumer and off-road.

High Temperature Resistant Thermoplastics:

Abbreviation	Polymer	Continuous Use Temp	Glass Transition Temp	HDT @ 264 psi	HDT @ 66 psi
Torlon® PAI	**Polyamide Imide**	**482°F (250°C)**	**527°F (275°C)**	**534°F (279°C)**	–
Aurum® PI	**Polyimide**	**550°F (288°C)**	**482°F (250°C)**	**475°F (246°C)**	–
PES	Polyethersulfone	350-400°F (177-204°C)	435°F (224°C)	400-460°F (204-238°C)	420-460°F (216-238°C)
PEI	Polyetherimide	350-400°F (177-204°C)	415°F (213°C)	390-420°F (199-216°C)	400-440°F (204-227°C)
PSO-PSU	Polysulfone	300-340°F (149-171°C)	374°F (190°C)	340-360°F (171-182°C)	350-370°F (177-188°C)
PEEK® PK	**Polyetheretherketone**	**400-450°F (204-232°C)**	**290°F (143°C)**	**350-610°F (177-321°C)**	**500-640°F (227-338°C)**
PPA	Polyphthalamide	400-450°F (204-232°C)	274°F (134°C)	530-545°F (277-285°C)	560-574°F (293-301°C)
PPS	Polyphenylene Sulfide	400-450°F (204-232°C)	198°F (92°C)	300-550°F (149-288°C)	400-500°F (204-260°C)

Superior Performance

For applications that include unique or demanding requirements, a high performance polymer often provides an effective material and design solution.

From mechanical to unique thermal properties, high performance polymers provide design engineers with valuable design and end use options.

Performance Attributes Include:

- Chemical resistance
- Conformability
- Dimensional stability
- Flexibility
- Injection moldable
- Lightweight
- Metal replacement
- Noise reducing
- Self lubricating
- Temperature extremes

End Use Applications Include:

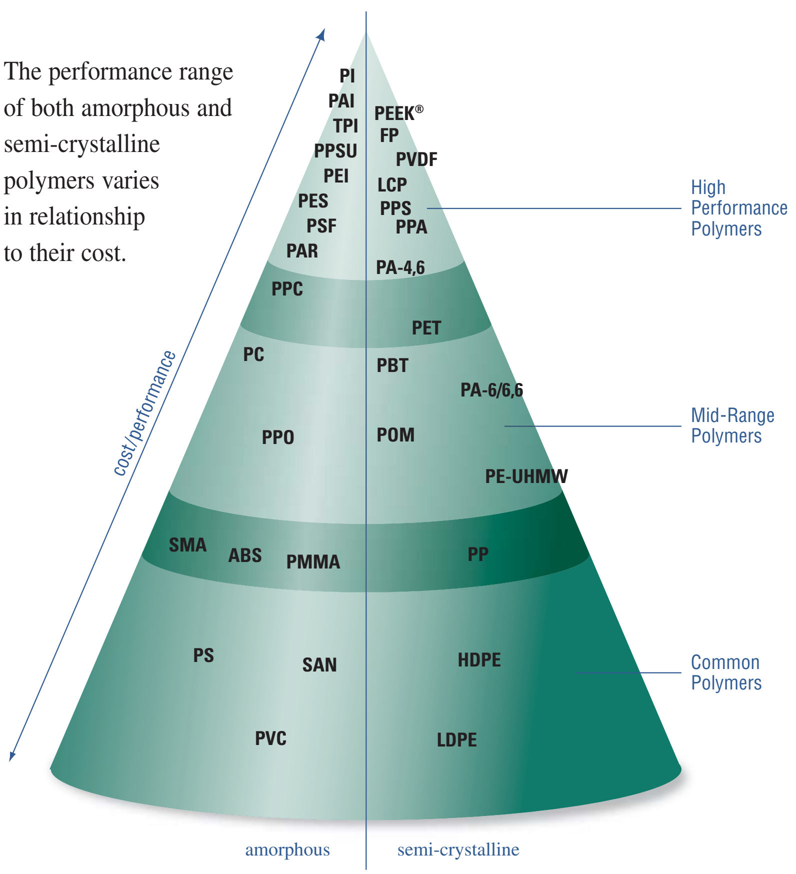
- Bearings
- Bushings
- Retainers
- Thrust plates
- Thrust washers
- Rotary seal rings
- Gears
- Poppets

Application Environments Include:

- Valves
- Pumps
- Compressors
- Fuel systems
- Transmission
- Steering systems
- Suspension systems
- Torque converters

This performance and cost illustration is a partial list depicting the spectrum of low-end to high-end performance materials.

The performance range of both amorphous and semi-crystalline polymers varies in relationship to their cost.



Abbreviation	
ABS	acrylonitrilebutadienestyrene
FP	fluoropolymers
HDPE	high density polyethylene
LCP	liquid crystal polymers
LDPE	low density polyethylene
PA-4,6	polyamide-4,6
PA-6/6,6	polyamide-6/6,6
PAI	**polyamideimide (Torlon®)**
PAR	polyarylate
PBT	polybutylene terephthalate
PC	polycarbonate
PE-UHMW	ultrahigh molecular weight polyethylene
PEEK®	**polyetheretherketone**
PEI	polyetherimide
PES	polyethersulfone
PET	polyethylene terephthalate
PI	**polyimide (Aurum®)**
PMMA	polymethyl methacrylate
POM	polyoxymethylene (also polyacetal)
PP	polypropylene
PPA	polyphthalamide
PPC	polyphthalate carbonate
PPO	polyphenylene oxide
PPS	polyphenylene sulfide
PPSU	polyphenylsulfone
PS	polystyrene
PSF	polysulfone
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
SAN	styrene acrylonitrile
SMA	styrene maleic anhydride
TPI	thermoplastic polyimide

Thermoset Plastics vs Thermoplastics

When classified by chemical structure, there are two generally recognized classes of plastic materials: Thermosets, having cross-linked molecular chains, and Thermoplastics, which are made up of linear molecular chains.

Thermoset polymers require a two-stage polymerization process. The first is done by the material supplier, which results in a linear chain polymer with partially reacted portions. The second is done by the molder, who controls final cross-linking. Short chains with many cross-links form rigid thermosets, while longer chains with fewer cross-links form more flexible thermosets. With all thermosets, the polymerization is permanent and irreversible.

Thermoplastic polymers require no further chemical processing before molding. There are two types of thermoplastic polymers: Crystalline and Amorphous. The pyramid graphic on page 5-3 identifies many of our common thermoplastic materials.

Crystalline Polymers:

1. Have a relatively sharp melting point.
2. Have an ordered arrangement of molecule chains.
3. Generally require higher temperatures to flow well when compared to Amorphous.
4. Reinforcement with fibers increases the load-bearing capabilities considerably.
5. Shrink more than Amorphous, causing a greater tendency for warpage.
6. Fiber reinforcement significantly decreases warpage.
7. Usually produce opaque parts due to their molecular structure.

Amorphous Polymers:

1. Have no true melting point and soften gradually.
2. Have a random orientation of molecules; chains can lie in any direction.
3. Do not flow as easily in a mold as Crystalline Polymers.
4. Shrink less than Crystalline Polymers.
5, Generally yield transparent, water-clear parts.

Long Glass and Short Glass

How long is long?

Long glass is typically 11mm long x .3mm in diameter. Normally the glass fibers lay parallel within the strand.

Short glass is usually 3mm long x .3mm in diameter.

Normally when we make reference to "Glass Filled" we are referring to short glass unless otherwise specified.

Temperature Resistance of Thermoplastics

There are many ways to measure the heat resistance of thermoplastics. These include heat deflection temperatures (HDT) which are normally measured under a load of 264 or 66 psi, melt temperatures, and glass transition temperature (Tg).

However, over time it has been determined that one of the most useful physical properties of a high temperature resistant thermoplastic is that of the glass transition temperature. (Tg is the temperature at which a material begins to soften.)

Temperature Resistance of Thermoplastics

Abbreviation	Polymer	Tg
PAI	Polyamideimide (Torlon®)	527°F (275°C)
PI	Polyimide (Aurum®)	482°F (250°C)
PES	Polyethersulfone	435°F (224°C)
PEI	Polyetherimide	415°F (213°C)
PSO	Polysulfone	374°F (190°C)
PC	Polycarbonate	302°F (150°C)
PEEK®	Polyetheretherketone	290°F (143°C)
PPA	Polyphthalamide	274°F (134°C)
PTFE	Polytetrafluoroethylene	266°F (130°C)
PS	Polystyrene	219°F (104°C)
ABS	Acrylonitrilebutadienestyrene	219°F (104°C)
PPS	Polyphenylene Sulfide	198°F (92°C)
PVC	Polyvinyl Chloride	176°F (80°C)
PA	Polyamide 6/6,6	167°F (75°C)
PA	Polyamide 4,6	133°F (56°C)

By means of independent tests, Minnesota Rubber and Plastics has published performance results that demonstrate continuous use temperature above the Tg. The same is true for heat deflection temperatures. However, it is important to remember that performance ultimately depends upon the application. Normally, a material is in danger of failure when it begins to soften (Tg). Therefore, as a general guide, the Tg must be a major consideration when selecting a high temperature resistant thermoplastic.

A material listing helps to clarify and place into perspective common thermoplastic materials showing the Tg of several high performance materials.

Thermoplastic Elastomers

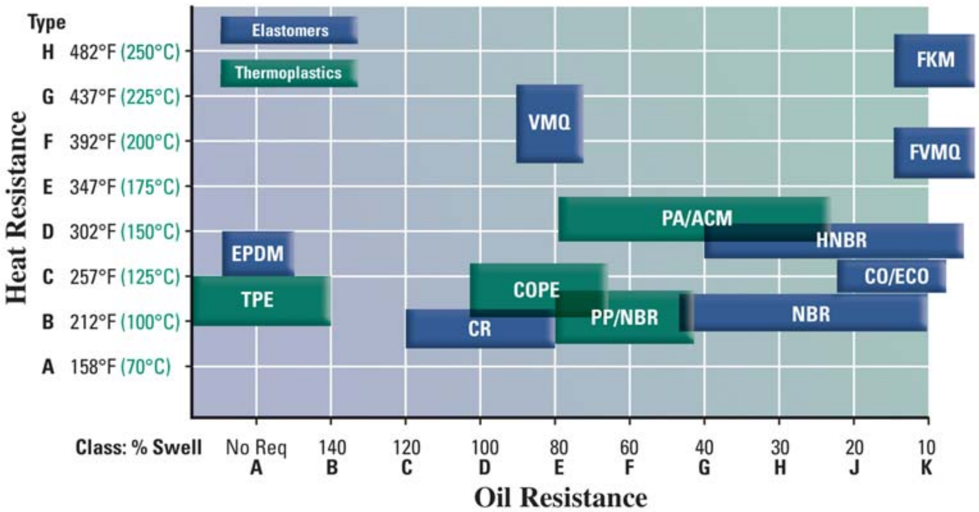
Engineered thermoplastic elastomers (TPE's), are one of the most versatile plastics available today. Our wide range of TPE's combine many of the performance properties of thermoset rubber with the processing ease of plastic thereby providing design options and greater cost-reduction opportunities. Minnesota Rubber and Plastics has pioneered the molding of TPE's in part by converting thermoset rubber parts to lower cost TPE components.

TPE's offer a wide range of performance attributes including: heat and oil resistance, improved adhesion, tear resistance, surface appearance and low permeability. And our experience allows us to know when to recommend a TPE over thermoset rubber. In addition, TPE's are colorable and can be specified in a variety of hardness grades.

Process and design flexibility are important features and advantages TPE's offer over thermoset rubber. They can be processed with the speed, efficiency and economy of thermoplastics and can be insert molded with other olefin-based materials, such as polypropylene, without the use of adhesives. With other substrates like polyamides, (nylon), or acrylonitrile butadiene styrene (ABS), mechanical interlocks can be designed into the part to ensure a tight fit.

Thermoplastic elastomers serve a wide range of markets:
- Agriculture & Off Road
- Appliance
- Automotive & Transportation
- Consumer
- Electrical & Industrial Controls
- Food & Beverage
- Hydraulics & Pneumatics
- Marine
- Medical & Safety
- Plumbing & Irrigation

Heat & Oil Resistance Comparison



Abbreviation	
COPE	Copolyester
CO/ECO	Epichlorohydrin
EPDM	Ethylene-propylene terpolymer
FKM	Fluorocarbon
FVMQ	Fluorosilicone
HNBR	Highly saturated Nitrile Butadiene Rubber
NBR	Nitrile Butadiene Rubber
PA/ACM	Nylon PolyAcrylic
CR	Polychloroprene (Neoprene)
PP/NBR	Polypropylene & Nitrile Butadiene Rubber
VMQ	Silicone
TPE	Thermoplastic Elastomer

Thermoplastics and Materials List

Generic Type	Aliphatic Hydro-carbons	Aromatic Hydro-carbons	Oils, Fats, Waxes	Full Halo genated Hydrocarbons	Partly Halo genated Hydrocarbons	Alcohols Mono Hydric	Alcohols PolyHydric	Phenols	Ketones	Esters	Ethers
ABS	Fair	Poor	Good	Poor	Poor	Fair	Good	Poor	Poor	Poor	Poor
Acetal	Good	Good	Good	Good	Fair-Good	Good	Good	Poor	Good	Good	Good
Acrylic	Good	Poor	Good	Poor	Poor	Poor	Good	Good	Poor	Poor	Poor
Polyamide (Nylon)	Good	Fair	Good	Fair	Poor	Good	Good	Poor	Good	Fair	Good
Polycarbonate	Poor-Fair	Poor	Poor-Fair	Good-Fair	Poor	Good	Good	Poor	Poor	Poor	Poor
Polyester	Good	Poor-Fair	Unknown	Poor-Good	Poor	Good-Exc.	Exc.	Poor	Poor	Poor-Fair	Poor
Polyetheretherketone (PEEK®)	Exc.	Fair	Exc.	Fair	Fair	Good	Exc.	Fair-Good	Good	Fair	Good
Polyether Sulfone	Exc.	Poor	Exc.	Poor	Poor	Good	Fair	Poor	Good	Poor	Good
Polyethlyene	Fair	Fair	Exc.	Poor	Poor	Fair	Good	Exc.	Good	Good	Good
Polyamideimide	Exc.	Exc.	Exc.	Exc.	Exc.	Exc.	Exc.	Good	Exc.	Exc.	Exc.
Polyphenylene Oxide	Good	Good	Exc.	Good	Good	Exc.	Exc.	Good	Good	Good	Exc.
Polyphenylene Sulfide	Exc.	Good	Unknown	Fair	Poor	Exc.	Exc.	Good	Good	Exc.	Good
Polyproplylene	Fair	Fair	Good	Poor	Poor-Fair	Good	Exc.	Good	Good	Good	Fair
Polystyrene	Fair-Poor	Poor	Poor	Poor	Poor	Good	Good	Poor	Poor	Poor	Poor
Polysulfone	Poor	Poor	Fair	Poor	Poor	Poor-Fair	Good	Poor	Poor	Poor	Poor
Polyurethane	Fair	Poor	Good	Poor	Poor	Poor	Fair-Good	Poor	Poor	Poor	Poor
Styrene Acrylonitrile	Good	Poor	Good	Poor	Poor	Fair	Good	Poor	Poor	Poor	Poor

Inorganic Acids (Conc.)	Inorganic Acids (Dilute)	Bases (Conc.)	Bases (Dilute)	Salts (Acid)	Salts (Neutral)	Basic	Organic Acids (Conc.)	Organic Acids (Dilute)	Oxidising Acids (Conc.)	Oxidising Acids (Dilute)	Sunlight & Weathering
Good	Good	Good	Good	Good	Exc.	Good	Poor	Fair-Poor	Poor	Good	Fair-Good
Poor	Poor	Poor	Poor	Fair	Good	Good	Poor	Fair	Poor	Poor	Fair-Good
Poor	Good	Fair-Poor	Good	Good	Good	Good	Poor	Fair	Poor	Fair	Good
Poor	Good	Good	Exc.	Poor	Good	Fair	Poor	Fair	Poor	Poor	Fair-Good
Fair	Good	Poor	Poor	Good	Exc.	Fair	Fair	Fair	Poor	Good	Good
Good-Fair	Good	Poor	Poor-Fair	Good	Good	Poor-Fair	Poor-Fair	Good	Poor	Fair-Poor	Good
Dissolves	Poor	Good	Poor	Good	Good	Good	Fair-Good	Fair-Good	Poor	Exc.	Good
Dissolves	Poor-Good	Good	Poor	Fair	Fair	Fair	Fair-Good	Fair-Good	Dissolves	Fair	Good
Good-Exc.	Exc.	Good	Good	Exc.	Exc.	Exc.	Exc.	Exc.	Poor	Good	Poor
Fair	Good	Poor	Fair	Good	Good	Poor	Good	Exc.	Poor	Good	Exc,
Good	Exc.	Good	Exc.	Exc.	Exc.	Exc.	Good	Exc.	Good	Exc.	Exc.
Good	Good	Good	Exc.	Good	Good	Good	Good	Good	Poor	Fair	Good
Exc.	Exc.	Exc.	Exc.	Exc.	Exc.	Exc.	Good	Exc.	Poor	Good	Poor
Fair	Good	Fair	Exc.	Good	Exc.	Good	Poor	Fair	Poor	Fair	Fair
Good	Good	Good	Exc.	Good	Exc.	Good	Fair	Good	Poor	Good	Good-Exc.
Poor	Fair	Good	Good	Good	Exc.	Exc.	Poor	Fair	Poor	Poor	Fair
Good	Good	Good	Exc.	Good	Exc.	Good	Fair	Good	Poor	Good	Fair

Section 6
Rubber/Standard Products

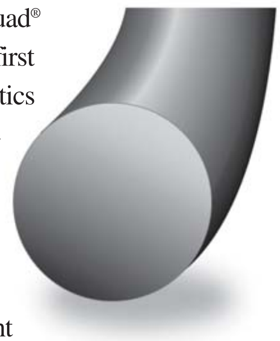
Rubber/Standard Products

The Quad® Brand Seal Family

Standard Products and Common Configurations

Minnesota Rubber and Plastics produces a complete family of Standard O-Ring, Quad-Rings® Brand and custom seals to provide the optimum seal for a wide range of applications. Our original four-lobed Quad-Ring® Brand seal design has been expanded into a complete line of custom seals, some patented, with unique features to handle the most difficult sealing requirements.

Quad® Brand O-Rings (standard and custom molded)



For general sealing applications, Quad® Brand O-Rings usually are a good first choice. Minnesota Rubber and Plastics offers a full range of sizes in Nitrile and Fluoroelastomer materials as standard products (p 6-22). If your application requires other elastomers, Minnesota Rubber and Plastics will help you select the right material and custom mold it to the required specifications.

Quad-Ring® Brand Seals (standard and custom molded)

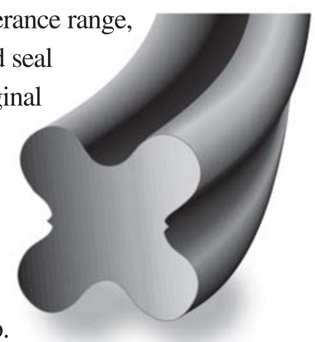
Providing excellent sealing characteristics in a broad range of applications, Minnesota Rubber and Plastics' original four-lobed designed seals are available in a full range of s tandard sizes, in Nitrile and Fluoroelastomer materials (p 6-22). Should your application require other elastomers, Minnesota Rubber and Plastics will help you select the right material and custom mold it to the required specifications.

Quad-Ring® Brand Seal Advantages over standard O-Rings:

1. Twice the Sealing Surface. Quad-Ring® Brand seals have a unique multiple point seal contact design. With two sealing surfaces, there is greater seal protection when used as an ID seal, OD seal, or face seal.
2. Lower Friction because of the Quad-Ring® Brand seals' multiple point seal contact design, less squeeze is required to maintain an effective seal. This lower squeeze results in lower friction, an important consideration for dynamic sealing applications.
3. Longer life because of reduced squeeze. Quad-Ring® Brand seals last longer and promote system "uptime." Equipment operates longer and requires less maintenance.
4. Seal surface free from parting line insures no leakage across the parting line. Parting line is in the valley not on the sealing surface like conventional O-Rings.

5) No spiral twist. Four lobe shaped Quad-Ring® Brand seals eliminate spiral twist which causes conventional O-Rings to rupture.

Modified Quad-Ring® Brand Seals (custom molded)



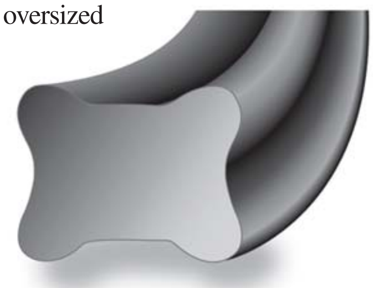
For sealing across a broader tolerance range, the Modified Quad-Ring® Brand seal has a deeper valley than the original Quad-Ring® Brand seal design, thereby producing a lower deflection force. In OEM applications such as plastic housings, this seal design has reduced load with less creep. Designed for pressures less than 120 psi (8.1 bar). Modified Quad-Ring® Brand seals recently were granted a new patent.

The Quad® Brand Seal Family - continued

Quad-O-Dyn® Brand Seals (custom molded)

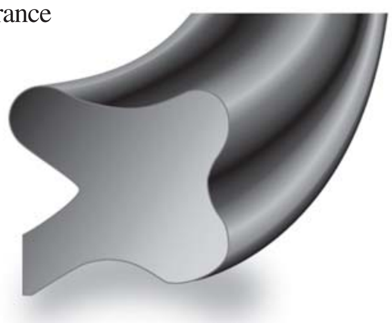
For dynamic sealing applications providing near zero leakage at pressures to 2000 psi (138 bar) and higher. This six-lobed configuration, designed with two primary and four backup sealing surfaces, has excellent sealing features in very difficult applications. It can be used with standard O-Ring grooves.

Quad-Bon® Brand Seals (custom molded)



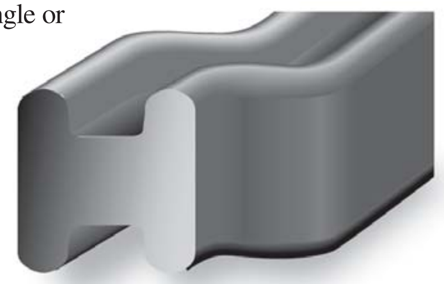
Ideal for applications with oversized grooves, strong spiraling pressures and as a retrofit for existing O-Ring applications. This four-lobed configuration has the widest valley in our custom cross section product line. It provides excellent sealing features.

Quad-Kup® Brand Seals (custom molded)



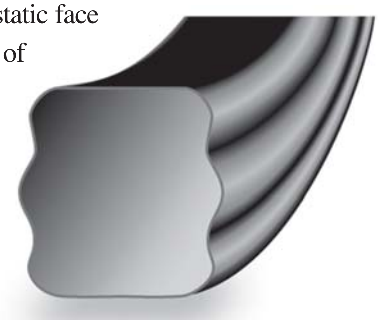
For high diameteric clearance applications and those requiring low operating friction. Provides low-pressure seal up to 150 psi (10.3 bar) in reciprocating and rotary applications. The combination lobed/cup configuration can be designed with the lip on any of the four surfaces, top or bottom, on the ID or OD.

H-Seals (custom molded)



Ideal for intricate single or multiple groove configurations in static face seal applications. With the deepest valley of all Minnesota Rubber and Plastics product designs, this configuration has superior sealing features in difficult applications.

Quad®-O-Stat Brand Seals (custom molded)



Designed specifically for static face sealing applications. Each of the six lobes serves as an individual seal with the corner lobes functioning as seal backups to the central lobes. If one lobe fails, the remaining lobes provide zero leakage sealing. Can be installed in standard O-Ring grooves.

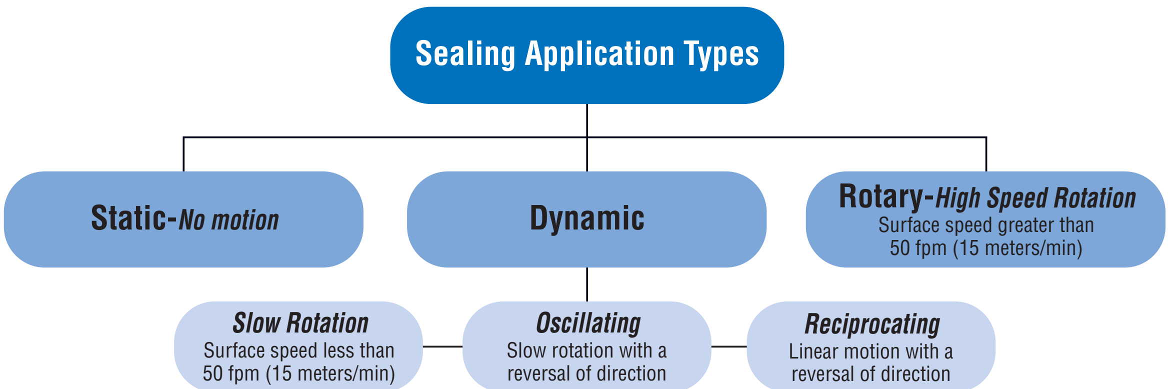
Quad® P.E. Plus Brand Seals (custom molded)

This dual-function seal forms a self-lubricating seal and an elastomeric spring for both rotary and reciprocating applications. Newly patented, this seal design combines injection moldable thermoplastic bearing material with a Quad-Ring® Brand seal. This seal is not intended for zero leakage applications.

Identifying A Sealing Application Type

Although sealing applications can be classified in many different ways, a common method for classifying sealing applications is by the type of motion experienced by the application. The common application types are depicted below.

General sealing principles common to all of the seal types are discussed on the following pages.



Sealing Tips

- Provide detailed seal installation and assembly instructions, especially if the unit could be serviced by the end-user of the product. When appropriate or required, specify the use of OEM sealing parts.
- Within reason, the larger the cross-section, the more effective the seal.
- Do not seal axially and radially at the same time with the same O-Ring or Quad-Ring® Brand Seal.
- Don't use a seal as a bearing to support a load or center a shaft. This will eventually cause seal failure.
- Lubricate the seal and mating components with an appropriate lubricant before assembling the unit.
- Keep the seal stationary in its groove - don't let it spin with the rotating member.
- When using back-up rings, increase the groove width by the maximum thickness of the back-up ring.
- With a face seal, don't try to seal around a square corner. Corners must have a minimum radius of 4 times the seal cross-section.

Selecting the Seal Material

When selecting the seal material for the application, carefully consider:

- The primary fluids which the O-Ring or Quad-Ring® Brand will be sealing
- Other fluids to which the seal will be exposed, such as cleaning fluids or lubricants
- The suitability of the material for the application's temperature extremes - hot and cold
- The presence of abrasive external contaminants
- The presence of ozone from natural sources and electric motors, which can attack rubber
- Exposure to processes such as sterilization by gas, autoclaving, or radiation
- Exposure to ultraviolet light and sunlight, which can decompose rubber
- The potential for out-gassing in vacuum applications
- Don't forget about water - it covers two-thirds of the Earth's surface

Defining Factors In Sealing Applications

While small in cost, seals are often one of the most important components in a product. Seals must be carefully designed and produced to ensure superior performance of the product in which they are used. This section provides a review of the issues that need to be considered when making sealing decisions.

All sealing applications fall into one of three categories: (1) those in which there is no movement, (2) those in which there is linear motion or relatively slow rotation, or (3) those involving high speed rotation.

A sealing application in which there is no movement is termed a static seal. Examples include the face seal in an end cap, seals in a split connector, and enclosure cover seals.

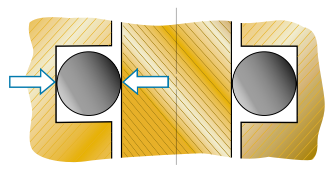
A sealing application in which there is linear motion (reciprocation) or relatively slow rotation or oscillation, is termed a dynamic seal. Applications involving slow rotation or oscillation are classified as a dynamic application if the surface speed is less than 50 fpm (15 meters/min).

Finally, a sealing application in which there is high speed rotation, is termed a rotary seal. Applications are classified as a rotary application if the surface speed is greater than 50 fpm (15 meters/min). It should be noted that both the seals and grooves used for dynamic and rotary applications are different in design and specification. These differences are explained in the following sections.

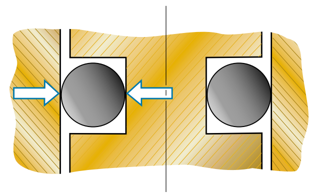
Seal Orientation and Type

Quad-Ring® Brand and O-Ring seals can be oriented such that the seal compression, and therefore the sealing, is occurring in either a radial or axial direction. This is illustrated above. In the case of a radial seal, the primary sealing surface can occur at either the ID or the OD of the seal, with the common names for these seals being a rod seal and a piston seal respectively. An axial seal is commonly referred to as a face seal. Each of these seal types can be either a static, dynamic, or rotary seal, with the exception of a piston seal which is generally not recommended for a rotary application.

Radial Sealing Applications

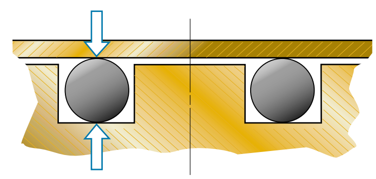


Rod Seal



Piston (Bore) Seal

Axial Sealing Applications



Face Seal

Surface Finish

Shorter than expected seal life is usually the result of too fine a finish on either the rod or the cylinder bore. A highly polished (non-porous) metal surface does not retain the lubricant necessary to control friction, whereas a rough or jagged surface will abrade the seal and lead to early seal failure.

To avoid these problems, we recommend an ideal surface finish of 20-24 µin (.5-.6 µm) Ra, with an acceptable range of 20-32 µin (.5-.81 µm) Ra. The surface finish should never be finer than 16 µin (.4 µm) Ra.

Pressure Energized Seals

It is more difficult to seal at low pressures than at high pressures. As pressure acts against a seal, the rubber material is deformed. With proper seal design, deformation can improve the seal. This concept is used in many seal designs. By adding seal beads or pressure intensification details to the seal, sealing improvements can be made to custom designs. For very low pressure or vacuum applications we recommend using a Quad-Ring® Brand seal over an O-Ring.

Defining Factors In Sealing Applications - continued

Friction

The functional life of a seal is affected by the level of friction to which it is exposed. Factors contributing to friction include seal design, lubrication, rubber hardness (the standard rubber hardness for most sealing applications is 70 durometer Shore A), surface finish, temperature extremes, high pressure and the amount of squeeze placed on the seal.

The use of "slippery rubber" compounds can help lessen friction and improve seal life. Surface coatings and seal treatments such as PTFE and molybdenum disulfide are also used to reduce seal friction.

It is difficult to accurately predict the seal friction which will be present in an application, given the many variables involved. When designing an application which will be sensitive to seal friction, testing will probably be required to determine the effect of seal friction.

Component Concentricity and Roundness

When evaluating an application, remember that components are not perfectly concentric or round. Concentricity and roundness can also change with changes in pressure and temperature. When sizing a seal, consider the worst case scenario for your application and make sure that the seal system you select will work in the worst case scenario.

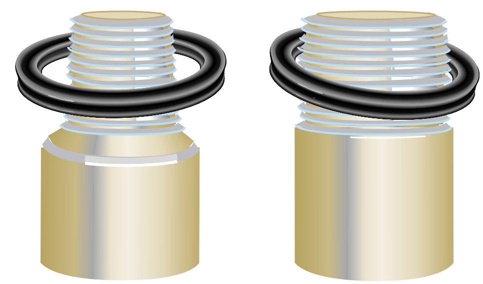
If, after reviewing the calculations on your application, you find that seal integrity may be compromised when dimensions approach a worst case scenario, consider making the following adjustments before recalculating:

1. Reduce the clearance between components.
2. Reduce the tolerances of the components.
3. Use a larger cross section seal to absorb the extra tolerance.
4. Increase the seal squeeze (which will also increase friction).
5. Improve component alignment and support to reduce the eccentricity.

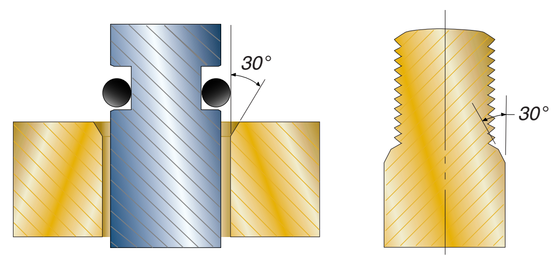
Seal Installation – Avoiding Damage

Seals can be easily damaged during installation. For example, a seal is often inserted onto a shaft by sliding it over a threaded surface. To avoid seal damage reduce the rod diameter in the threaded region. Also include a lead in chamfer for the seal and avoid sharp corners on grooves.

Easy Installation **Potential For Damage**



Use Lead-In Chamfer:



Peripheral Compression

In certain applications, such as with a rotary seal, the seal size is selected and the seal groove is designed such that the free-state diameter of the seal ring is larger than the groove diameter. Upon installation, the seal will be compressed by the groove to a smaller diameter. This is called "placing the seal under peripheral compression", or simply "peripheral compression."

Peripheral compressed seals are used in rotary applications to prevent heat-induced failure of the seal due to material contraction. They are also used in face seal applications when sealing a positive internal pressure. It should be noted that a peripherally compressed seal does not experience installed stretch, since the seal is being compressed rather than stretched during installation.

Percentage Gland Fill

Since rubber can generally be regarded as an incompressible material, there must always be sufficient space in the seal gland for the seal. When there is insufficient space for the seal, application problems including high assembly forces and seal and unit failure can occur. The ratio of seal volume to gland volume, which is frequently termed "gland fill" or less formally as "groove fill", is usually expressed as a percentage of the gland which is occupied by the seal. It is always desired to keep this percentage less than 100% under all application conditions and extremes of tolerance. To allow for a margin of safety, a good practice is to design to a maximum gland fill of 90% or less.

The gland fill can be easily determined by calculating the cross-sectional area of the seal and dividing it by the cross-sectional area of the gland. The cross-sectional area of the gland is its height times its width. The equations for the cross-sectional areas of an O-Ring and a Quad-Ring® Brand can be found on Page 6-8. When calculating the maximum gland fill, always use the worst-case tolerance situation which results in the smallest gland and largest seal.

Cross Section Size

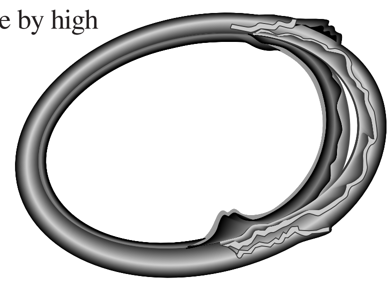
In applications in which the area to contain the seal is small, it is important to remember that smaller cross-section seals require much tighter tolerances on mating parts. Small cross-section seals cannot handle the large variation in part sizes, imperfections like scratches, and high pressure.

Installed Seal Stretch and Cross-sectional Reduction

Installed seal stretch is defined as the stretch experienced by a seal ring following installation into the seal groove. As a seal ring is stretched, there is a resulting reduction in the seal's cross-section. This reduction in cross-section will reduce the squeeze on a seal, which has the potential to create sealing problems, especially when using smaller diameter seal rings. To minimize the occurrence of cross-sectional reduction, a general "rule of thumb" to follow is to keep the installed seal stretch less than 3%. It should be noted that with standard seal sizes smaller than an -025 seal, the installed seal stretch will frequently be higher than 3%, even with a properly designed groove. In these situations, care should be taken to properly control component tolerances to prevent insufficient seal squeeze from occurring at the extremes of component tolerance. If necessary, component tolerances should be tightened to ensure an acceptable seal is obtained.

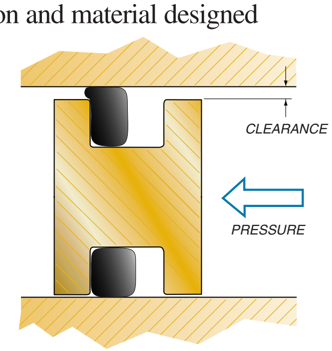
Seal Extrusion

Extrusion is a common source of seal failure in both static and dynamic applications. The O-Ring illustrated failed when it was extruded from the groove. Part or all of the seal is forced from the groove by high continuous or pulsating pressure on the seal. If left uncorrected, the entire cross-section will eventually disintegrate.



Follow these easy rules to minimize the risk of seal extrusion:

1. Choose a seal configuration and material designed to withstand the anticipated pressure.



2. Make sure the clearance between adjacent surfaces is appropriate for the hardness of the material. Clearance should be minimized and must not exceed recommended limits for the rubber hardness.

Defining Factors In Sealing Applications - continued

Anti-Extrusion (Back-up) Rings

The use of a back-up ring with an O-Ring or Quad-Ring® Brand seal can minimize or prevent the occurrence of seal extrusion in applications with higher pressure or higher than desirable clearance. Spiral-wound or washer-shaped back-up rings are installed next to the seal opposite the pressure side of the application. Back-up rings are recommended for applications with pressures in excess of 1500 psi.

Although back-up rings can be made from any material which is softer than the shaft, they are commonly made from poly-tetrafluoroethylene (PTFE), which provides low friction. PTFE back-up rings are available as solid rings, single-layer split rings, and two-layer spiral-wound split rings. Two-layer spiral-wound PTFE rings provide easy installation, protect the seal from damage, and are the recommended type. When using a back-up ring, always increase the seal groove width to account for the thickness of the back-up ring.

Seal Groove Design Equations

The equations on this page are used to calculate the different parameters of a seal groove. They are used in the explanations and the examples on the following pages.

Installed Seal Stretch

Equation 1

Percent Stretch = ((Installed Seal ID - Original Seal ID)/ Original Seal ID) x 100

Seal Cross-sectional Compression (Squeeze)

Equation 2

Percent Compression = (1 - (Gland Radial Width/Seal Cross-Section)) x 100

Equation 3

Max Percent Compression = (1 - (Min Gland Radial Width/Max Seal Cross-Section)) x 100

Equation 4

Min Percent Compression = (1 - (Max Gland Radial Width/Min Seal Cross-Section)) x 100

Seal Percent Gland Fill

Equation 5

Percent Gland Fill = (Seal Cross-sectional Area/(Gland Depth X Groove Width)) x 100

Equation 6

Max Percent Gland Fill = (Max Seal Cross-sectional Area/(Min Gland Depth X Min Groove Width)) x 100

Seal Cross-sectional Area

Equation 7

O-Ring Cross-sectional Area = (O-Ring Cross-section/2)^2 x 3.1415

Equation 8

Quad-Ring® Brand, Cross-sectional Area = (Quad-Ring® Brand Cross-section)^2 x .8215

(Note the intentional absence of the division term in the Quad-Ring® Brand formula)

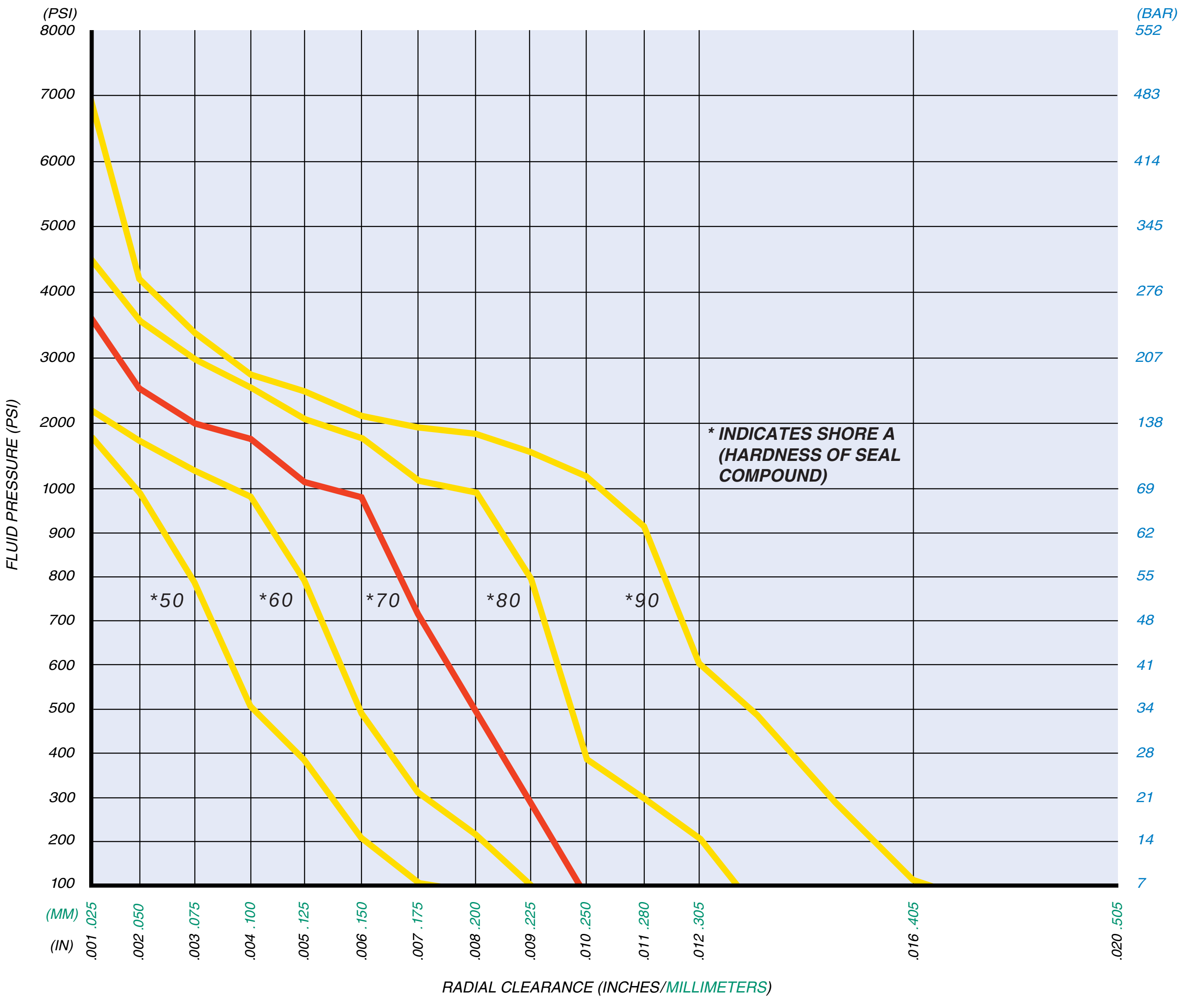
The maximum value for seal cross-sectional area can be obtained by using the maximum seal cross-section size (nominal size + tolerance) in Equations 7 and 8.

The following table provides the nominal and maximum seal cross-sectional areas for the standard seal cross-section sizes. This table can be used for quickly computing the percent gland fill.

Seal Cross-section	O-Ring Cross-sectional Area (in^2)		Quad-Ring® Brand Cross-sectional Area (in^2)	
	Nominal (in^2)	Maximum	Nominal	Maximum
.070±.003	.00385	0.00419	0.00403	0.00438
.103 ±.003	.00833	0.00882	0.00872	0.00923
.139 ±.004	.01517	0.01606	0.01587	0.01680
.210 ±.005	.03464	0.03631	0.03623	0.03797
.275 ±.006	.05940	0.06202	0.06213	0.06487

Recommended Radial Sealing Clearances for Quad-Ring® Brand and O-Ring Seals

This chart indicates the maximum permissible radial clearance as a function of application pressure and the seal rubber hardness.



Notes

1. This chart has been developed for seal cross-sections of .139" and larger. Smaller cross-section seals require less (tighter) clearance.
2. This chart is for applications in which the piston and bore are concentric. Radial clearance must be reduced in those applications with severe side loading or eccentric movement.
3. The data in this chart are for seals which are not using anti-extrusion back-up rings.
4. The data in this chart are for seals at room temperature. Since rubber becomes softer as temperature increases, clearances must be reduced when using seals at elevated temperatures.
5. The maximum permissible radial clearance would include any cylinder expansion due to pressure.

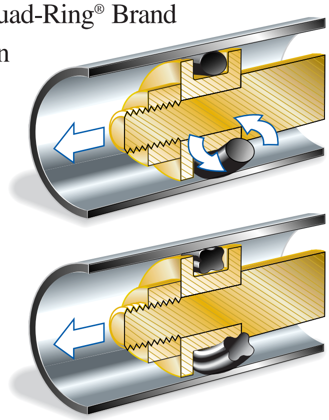
Quad-Ring® Brand Seals

Minnesota Rubber and Plastics pioneered the design and production of four-lobed seals with the Quad-Ring® Brand seal design. These seals are used today around the world for a wide variety of static and dynamic sealing applications.

Avoiding Spiral Twist

To minimize breakaway friction, an O-Ring groove must be wide enough to allow rolling or twisting of the seal. In the long stroke of a reciprocating seal application, this twisting action can strain and eventually tear the rubber, causing a failure mode known as spiral twist.

To prevent spiral twist, the Quad-Ring® Brand seal's four-lobed configuration is designed to withstand the distortion and extrusion often caused by high or pulsating pressure. To accommodate these forces, a Quad-Ring® Brand seal uses a narrower groove than a comparable O-Ring seal.

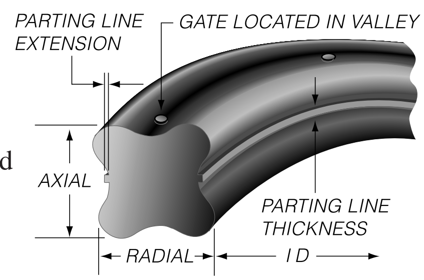


Longer Seal Life

Because less squeeze means less friction with the four-lobe design, seals last longer. Therefore, equipment in which the Quad-Ring® Brand seal is installed will operate longer and require less maintenance.

No Parting Line on Sealing Surface

Unlike O-Rings, where parting lines are on the sealing surface, Quad-Ring® Brand seals' parting lines lie between the lobes, away from the sealing surface. This design eliminates the problems of leakage resulting from a parting line's irregular surface.



Groove Design: Quad-Ring® Brand Seals for Static and Non-Rotary Dynamic Applications

1. **Cross-section.** Select a Quad-Ring® Brand cross-section size from the available standard sizes. If you are unsure what cross-section size to use, see the discussion on Page 6-7.
2. **Clearance.** Determine the maximum clearance present in your application. For a radial seal, subtract the minimum rod (shaft) diameter from the maximum bore diameter. For a face seal, subtract the distance between the sealing surface and the mating surface.
3. **Check the Clearance.** Determine if the clearance is acceptable for the application pressures and the material hardness being used by checking the graph on Page 6-9. Minnesota Rubber and Plastics standard-line products are made from materials having a hardness of 70 Shore A. If the clearance is unacceptable, component tolerance will have to be tightened, a harder material will have to be special ordered, or a back-up ring will have to be used. **Note:** The graph provides clearance values as radial values, so divide the number obtained in the preceding step by 2 to obtain your radial clearance.

Groove Design: Quad-Ring® Brand Seals for Static and Non-Rotary Dynamic Applications - continued

Recommended Starting Dimensions

RING SIZE	CROSS-SECTION (in)	CROSS-SECTION (mm)	DYNAMIC RECOMMENDED GLAND DEPTH "C" (in)	DYNAMIC RECOMMENDED GLAND DEPTH "C" (mm)	STATIC RECOMMENDED GLAND DEPTH "C" (in)	STATIC RECOMMENDED GLAND DEPTH "C" (mm)	AXIAL GROOVE WIDTH "D" (in) +.005/-.000	AXIAL GROOVE WIDTH "D" (mm) +0.13/0-.00	GROOVE ECCENTRICITY (TIR) (in)	GROOVE ECCENTRICITY (TIR) (mm)
Q4004 - Q4050	.070 ±.003	1.78 ±0.08	.061	1.55	.056	1.42	.080	2.03	.002	0.05
Q4102 - Q4178	.103 ±.003	2.62 ±0.08	.094	2.39	.089	2.26	.115	2.92	.002	0.05
Q4201 - Q4284	.139 ±.004	3.53 ±0.10	.128	3.25	.122	3.10	.155	3.94	.003	0.08
Q4309 - Q4395	.210 ±.005	5.33 ±0.13	.196	4.98	.188	4.78	.240	6.10	.004	0.10
Q4425 - Q4475	.275 ±.006	6.99 ±0.15	.256	6.50	.244	6.20	.310	7.87	.005	0.13

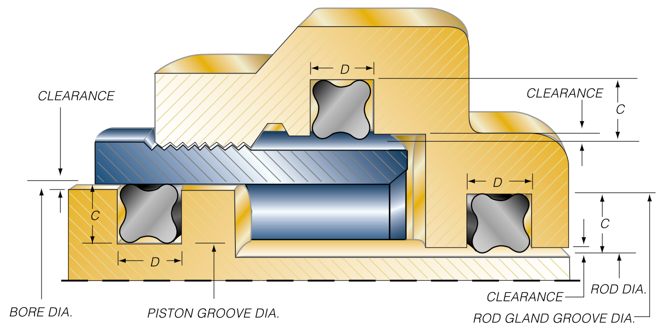
4. **Calculate the Quad-Ring® Brand groove dimensions.** Using the table above, determine the maximum recommended gland depth for your application. Then, calculate the Quad-Ring® Brand groove diameter as follows:
   a. For a rod (shaft) seal:
      Quad-Ring® Brand Groove Diameter = Min Shaft Diameter + (2 X Recommended Gland Depth)
   b. For a bore (piston) seal:
      Quad-Ring® Brand Groove Diameter = Max Bore Diameter - (2 X Recommended Gland Depth)
   c. For a face seal:
      Quad-Ring® Brand Groove Depth = Recommended Gland Depth - Application Clearance

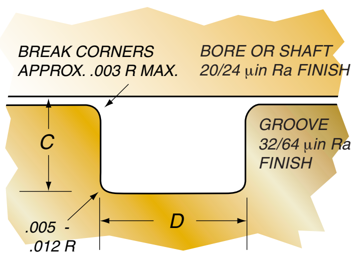
   With a face seal, if the two surfaces to be sealed are in direct contact (such as with a cover), the seal groove depth is simply the Recommended Gland Depth

5. **Groove Width.** Refer to the table above to determine the groove width for the Quad-Ring® Brand cross-section size you have selected. If you are using a back-up ring in your application, increase the groove width by the maximum thickness of the back-up ring.

6. **Percent Gland Fill.** Determine the maximum percent gland fill using Equation 6 from Page 4-8. If the gland fill exceeds 100%, the groove will have to be redesigned. A good "rule-of-thumb" is to not exceed about 90% gland fill.

7. **Calculate the Seal Squeeze.** Using Equations 3 and 4 (Page 6-8), calculate the minimum and maximum seal cross-sectional compression (squeeze). The recommended gland values in the table above have been developed to create a proper range of squeeze for many applications involving oil, hydraulic fluid, or normal lubricants, providing component tolerances are sufficiently controlled. In applications involving high pressure, large component tolerances, the need for very low frictional forces, or other types of fluids, the seal and groove design should be verified through an acceptable method, such as testing or engineering analysis.



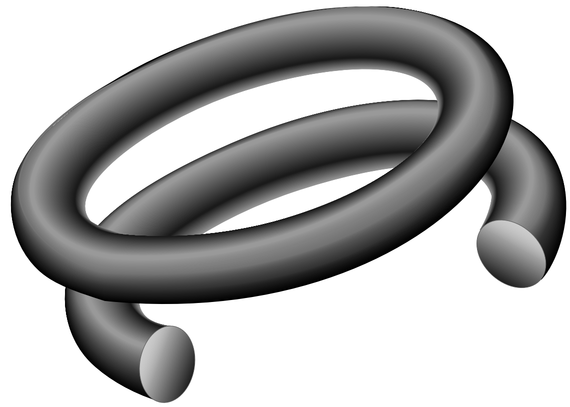


8. **Select the Seal.** Select the proper Quad-Ring® Brand size from the Standard Size table beginning on Page 6-22. Start by turning to the section of the table for the cross-section size you have selected, and then finding the Quad-Ring® Brand for the proper size bore or rod (shaft) you are sealing. If the bore or shaft size you are using is not listed, select the Quad-Ring® Brand with an inside diameter just smaller than the shaft you are using. If you are designing a face seal, select the Quad-Ring® Brand with an inside diameter which will position the Quad-Ring® Brand on the side of the groove opposite the pressure. See Page 6-16 for more information on face seal groove design. Note the Quad-Ring® Brand inside diameter for the next step.

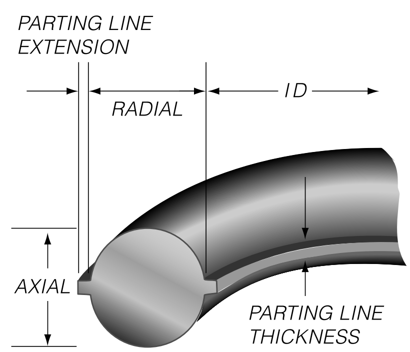
9. **Calculate the Seal Stretch.** Using Equation 1 (Page 6-8), calculate the installed seal stretch. If the installed seal stretch is greater than about 3%, you may have to select the next larger Quad-Ring® Brand size or require a custom Quad-Ring® Brand for your application. If you are using a Quad-Ring® Brand size less than a number -025, See Page 6-7 for more information.

10. **Detail the Groove.** Complete the groove design by specifying the proper radii and finish as indicated in the figure above.

Quad® Brand O-Ring Seals



The O-Ring is usually the designer's first choice when a sealing application is encountered. Properly engineered to the application, an O-Ring will provide long-term performance in a variety of seal applications. O-Rings are well suited for use as static, reciprocal and oscillating seals in low speed and low pressure applications.



The O-Ring is a good general purpose seal in both air and gas systems, as well as in hydraulic applications. Air and gas system designs must include adequate lubrication of the O-Ring in order to prevent damage to the sealing surface.

The popular O-Ring cross-section is configured in a variety of shapes as a stand alone seal, or incorporated into other rubber sealing components such as gaskets and diaphragms. O-Ring cross-sections are molded or bonded to metal or plastic parts such as valve stems, quick-disconnect poppets and spool valve cylinders.

Groove Design: O-Ring Seals for Static and Non-Rotary Dynamic Applications

1. **Cross-section.** Select an O-Ring cross-section size from the available standard sizes. If you are unsure what cross-section size to use, see the discussion on Page 6-7.

2. **Clearance.** Determine the maximum clearance present in your application. For a radial seal, subtract the minimum rod (shaft) diameter from the maximum bore diameter. For a face seal, subtract the distance between the sealing surface and the mating surface.

3. **Check the Clearance.** Determine if the clearance is acceptable for the application pressures and the material hardness being used by checking the graph on Page 6-9. Minnesota Rubber and Plastics standard-line products are made from materials having a hardness of 70 Shore A. If the clearance is unacceptable, component tolerance will have to be tightened, a harder material will have to be special ordered, or a back-up ring will have to be used. **Note:** The graph provides clearance values as radial values, so divide the number obtained in the preceding step by 2 to obtain your radial clearance.

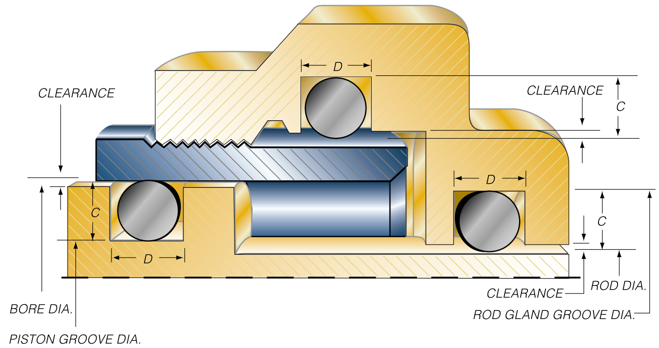
Groove Design: O-Ring Seals for Static and Non-Rotary Dynamic Applications - continued

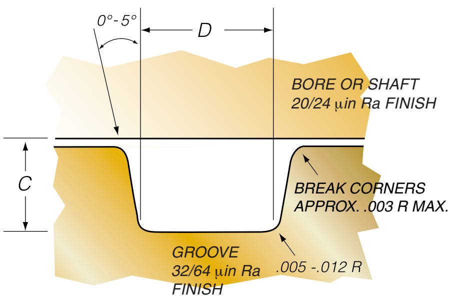
Recommended Starting Dimensions

RING SIZE	CROSS-SECTION (in)	CROSS-SECTION (mm)	DYNAMIC RECOMMENDED GLAND DEPTH "C" (in)	(mm)	STATIC RECOMMENDED GLAND DEPTH "C" (in)	(mm)	DYNAMIC AXIAL GROOVE WIDTH "D" (in) +.005/-.000	(mm) +0.13/-0.00	STATIC AXIAL GROOVE WIDTH "D" (in) +.005/-.000	(mm) +0.13/-0.00
Q8004 - Q8050	.070 ±.003	1.78 ±0.08	.056	1.42	.051	1.30	.094	2.39	.080	2.03
Q8102 - Q8178	.103 ±.003	2.62 ±0.08	.089	2.26	.082	2.08	.141	3.58	.115	2.92
Q8201 - Q8284	.139 ±.004	3.53 ±0.10	.122	3.10	.112	2.85	.188	4.78	.155	3.94
Q8309 - Q8395	.210 ±.005	5.33 ±0.13	.187	4.75	.172	4.37	.281	7.14	.240	6.10
Q8425 - Q8475	.275 ±.006	6.99 ±0.15	.239	6.07	.219	5.56	.375	9.53	.310	7.87

4. **Calculate the O-Ring groove dimensions.** Using the table above, determine the maximum recommended gland depth for your application. Then, calculate the O-Ring groove diameter as follows:
   a. For a rod (shaft) seal:
      O-Ring Max Groove Diameter = Min Shaft Diameter + (2 x Recommended Gland Depth)
   b. For a bore (piston) seal:
      O-Ring Min Groove Diameter = Max Bore Diameter - (2 x Recommended Gland Depth)
   c. For a face seal:
      O-Ring Max Groove Depth = Recommended Gland Depth - Application Clearance

   With a face seal, if the two surfaces to be sealed are in direct contact (such as with a cover), the seal groove depth is simply the Recommended Gland Depth
5. **Groove Width.** Refer to the table above to determine the groove width for the O-Ring cross-section size you have selected. If you are using a back-up ring in your application, increase the groove width by the maximum thickness of the back-up ring.
6. **Percent Gland Fill.** Determine the maximum percent gland fill using Equation 6 from Page 6-8. If the gland fill exceeds 100%, the groove will have to be redesigned. A good "rule-of-thumb" is to not exceed about 90% gland fill.
7. **Calculate the Seal Squeeze.** Using Equations 3 and 4 (Page 6-8), calculate the minimum and maximum seal cross-sectional compression (squeeze). The recommended gland values in the table above have been developed to create a proper range of squeeze for many applications involving oil, hydraulic fluid, or normal lubricants, providing component tolerances are sufficiently controlled. In applications involving high pressure, large component tolerances, the need for very low frictional forces, or other types of fluids, the seal and groove design should be verified through an acceptable method, such as testing or engineering analysis.

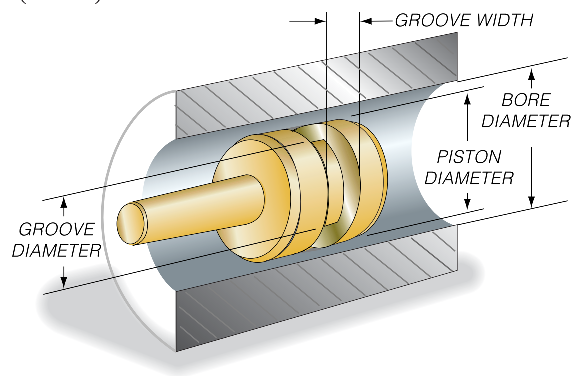




8. **Select the Seal.** Select the proper O-Ring size from the Standard Size table beginning on Page 6-22. Start by turning to the section of the table for the cross-section size you have selected, and then finding the O-Ring for the proper size bore or rod (shaft) you are sealing. If the bore or shaft size you are using is not listed, select the O-Ring with an inside diameter just smaller than the shaft you are using. If you are designing a face seal, select the O-Ring with an inside diameter which will position the O-Ring on the side of the groove opposite the pressure. See Page 6-16 for more information on face seal groove design. Note the O-Ring inside diameter for the next step.
9. **Calculate the Seal Stretch.** Using Equation 1 (Page 6-8), calculate the installed seal stretch. If the installed seal stretch is greater than about 3%, you may have to select the next larger O-Ring or require a custom O-Ring for your application. If you are using an O-Ring size less than a number -025, See Page 6-7 for more information.
10. **Detail the Groove.** Complete the groove design by specifying the proper radii and finish as indicated in the figure above.

Application Example: Piston Quad-Ring® Brand Seal

Application description: Hydraulic Cylinder, U. S. Customary Units (inches)



- 5" dynamic stroke
- Piston diameter: 2.992" ±.002
- Bore diameter: 3.000" ±.002
- 200 psi maximum pressure
- .103" cross-section Quad-Ring® Brand seal
- No side loading or eccentricity

RING SIZE	CROSS-SECTION	DYNAMIC RECOMMENDED GLAND DEPTH "C"	STATIC RECOMMENDED GLAND DEPTH "C"	AXIAL GROOVE WIDTH "D" +.005/-.000
Q4102 - Q4178	.103 ±.003	.094	.089	.115

1. Calculate the Seal Groove Diameter:

Groove Diameter
= Maximum Bore Diameter - (2 x Dynamic Gland Depth)
= 3.002 - (2 x .094)
= 2.814 -.000/+ .002

(Recall the gland depth values in the chart are given as radial values)

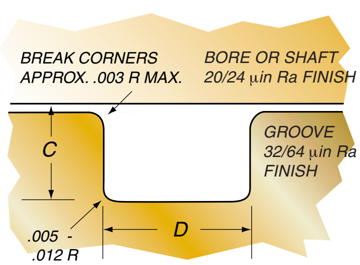
2. From the chart, the groove width is .115 -.000/+.005

3. Calculate the Minimum Gland Volume:

Minimum Gland Volume
= ((Min Bore Dia. - Max Groove Dia./ 2) x Min Groove Width
= ((2.998 - 2.816)/2) X .115
= .0105 in^2

4. Calculate the Maximum Quad-Ring® Brand Seal Volume:

Maximum Quad-Ring® Brand Volume
= (Max Quad-Ring® Brand Cross-section)^2 X .8215
= (.106)^2 X .8215
= .0092 in^2



5. Compare the Minimum Gland Volume to the Maximum Quad-Ring® Brand Volume

In this application the maximum seal volume is less than the minimum gland volume, so the seal should function satisfactorily.

6. Calculate the Minimum and Maximum Seal Squeeze

a. Max Seal Squeeze = 1 - (Min Gland Depth / Max Seal Cross-section)
Min Gland Depth = (Min Bore Dia. - Max Groove Dia.) / 2
= (2.998 - 2.816) / 2
= .091
Max Seal Squeeze = 1 - (.091/.106)
= .141
= 14.1%

b. Min Seal Squeeze = 1 - (Max Gland Depth / Min Seal Cross-section)
Max Gland Depth = (Max Bore Dia. - Min Groove Dia.) / 2
= (3.002 - 2.814) / 2
= .094
Min Seal Squeeze = 1 - (.094/.100)
= .06
= 6%

Therefore, sufficient squeeze should exist to seal this application.

7. Calculate the Maximum Clearance and evaluate possible extrusion problems

Max Radial Clearance = (Max Bore Dia. - Min Piston Dia.) / 2
= (3.002 - 2.990) /2
= .006

From the Clearance Chart on Page 6-9, the recommended max clearance for a Quad-Ring® Brand with a hardness of 70 Shore A at 200 psi is .009. The seal should function properly.

8. Select the Seal Size

Refer to the Selection Guide beginning on page 6-22 and turn to the section which lists the seals having a .103 cross-section. Since in this application the sealing is occurring on the bore, use the Bore column to look up the seal size for a 3.000" bore. The correct seal is a number 4 -149 (with the 4 prefix signifying a Quad-Ring® Brand seal). Note the seal inside diameter, which is 2.800 ±.022. This will be used below.

9. Calculate the Installed Seal Stretch

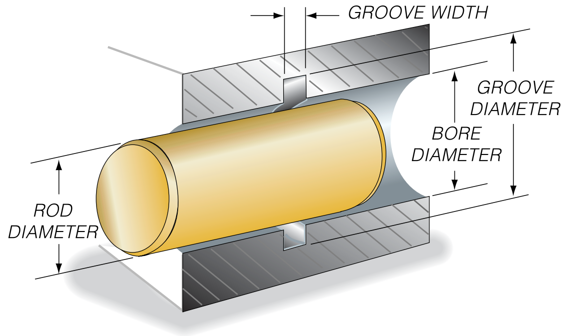
Stretch % = ((Installed Seal ID - Original Seal Inside Diameter) / Original Seal Diameter) x 100
= ((Groove Diameter - Original Seal Inside Diameter) / Original Seal Diameter) x 100
= ((2.814 - 2.800) / 2.800) x 100
= (.014 / 2.800) * 100 = .5 %

This stretch is low and will not cause significant cross-sectional reduction.

Application Example: Rod Quad-Ring® Brand Seal

Application description: Water faucet valve, U. S. Customary Units (inches)

- .25" dynamic stroke
- Rod (shaft) diameter: .374" ±.003
- Bore diameter: .385" ±.003
- 150 psi maximum pressure
- .070" cross-section Quad-Ring® Brand seal
- No side loading



RING SIZE	CROSS-SECTION	DYNAMIC RECOMMENDED GLAND DEPTH "C"	STATIC RECOMMENDED GLAND DEPTH "C"	AXIAL GROOVE WIDTH "D" +.005/-.000
Q4004 - Q4050	.070 ±.003	.061	.056	.080

1. Calculate the Seal Groove Diameter:

   Groove Diameter
   = Min Shaft Diameter + (2 X Dynamic Gland Depth)
   = .371 + (2 X .061)
   = .493 +.000 / -.002
   (Recall the gland depth values in the chart are given as radial values)

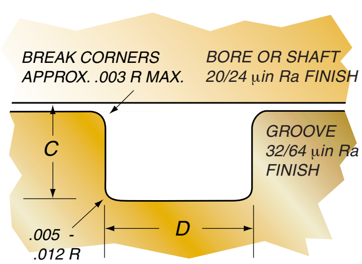
2. From the chart, the groove width is .080 -.000/+.005

3. Calculate the Minimum Gland Volume:

   Minimum Gland Volume
   = ((Min Groove Dia - Max Rod Dia. / 2) X Min Groove Width
   = ((.491 - .377) / 2) X .080
   = .00456 in^2

4. Calculate the Maximum Quad-Ring® Brand Seal, Volume:

   Maximum Quad-Ring® Brand Seal Volume
   = (Max Quad-Ring® Brand Cross-section)^2 X .8215
   = (.073)^2 X .8215
   = .0044 in^2



5. Compare the Minimum Gland Volume to the Maximum Quad-Ring® Brand Volume

   In this application the maximum seal volume is less than the minimum gland volume, so the seal should function satisfactorily.

6. Calculate the Minimum and Maximum Seal Squeeze

   a. Max Seal Squeeze = 1 - (Min Gland Depth / Max Seal Cross-section)
   Min Gland Depth = (Min Groove Dia. - Max Rod Dia.) / 2
   = (.491 - .377) / 2
   = .057
   Max Seal Squeeze = 1 - (.057 /.073)
   = .219
   = 21.9 %

   b. Min Seal Squeeze = 1 - (Max Gland Depth / Min Seal Cross-section)
   Max Gland Depth = (Max Groove Dia. - Min Rod Dia.)
   = (.493 - .371) / 2
   = .061
   Min Seal Squeeze = 1 - (.061/.067)
   = .09
   = 9.0%
   Therefore, sufficient squeeze should exist to seal this application.

7. Calculate the Maximum Clearance and evaluate possible extrusion problems

   Max Radial Clearance = (Max Bore Dia. - Min Rod Dia.) / 2
   = (.388 - .371) / 2
   = .0085
   From the Clearance Chart on Page 6-9, the recommended maximum radial clearance for a Quad-Ring® Brand seal with a hardness of 70 Shore A at 150 psi is slightly greater than .009 inches. The seal should work in this application.

8. Select the Seal Size

   Refer to the Selection Guide beginning on page 6-22 and turn to the section which lists the seals having a .070 cross-section. This example's rod size of .374 is very close to the standard size of .375, so the standard seal for a .375 rod will probably work. Since in this application the sealing is occurring on the rod, use the Rod column to look up the seal size for a .375 rod. The correct seal is a number 4 -012 (with the 4 prefix signifying a Quad-Ring® Brand seal). Note the seal inside diameter, which is .364 ± .005. This will be used below.

9. Calculate the Installed Seal Stretch

   Stretch % = ((Installed Seal ID - Original Seal Inside Diameter) / Original Seal Inside Diameter) x 100
   = ((Rod Diameter - Original Seal Inside Diameter) / Original Seal Inside Diameter) x 100
   = ((.374 - .364) / .364) x 100
   = (.010 / .364) x 100 = 2.7 %

Quad-Ring® Brand and O-Ring Seals for Face Seal Applications

Quad-Rings® Brand and O-Rings seals are routinely used for face seal applications, which can be either static or dynamic applications.

General Considerations

The seal should be selected and the groove should be designed so the seal is always positioned against the side of the groove opposite the pressure. This prevents the applied pressure (or vacuum) from moving the seal which can lead to seal failure. When selecting the seal and designing the groove, use the groove and seal size tolerance conditions which will result in the seal always being positioned against the side of the groove opposite the applied pressure.

When designing face seal grooves, be careful to distinguish between the axial groove depth, which is the depth of the slot machined into the components for the seal, and the axial gland depth, which is the total axial space allowed for the seal (see opposite page). If necessary, refer to the glossary for a more detailed description of the two terms.

The groove diameters for a face seal are usually established based upon one of the following:

- A predetermined groove ID or OD has been selected based upon other design criteria (size of the unit, minimum amount of wall thickness necessary, etc). The groove width "D", taken from the O-Ring or Quad-Ring® Brand seal table, for the selected seal cross-section size is then used to calculate the groove diameters by either adding or subtracting twice its value from the predetermined groove dimension. The seal size is then selected to position it properly as described above.
- A particular seal has been pre-selected or is already available.

    Internal Pressure: The minimum seal OD is calculated and then the groove OD is established so the seal is always seated against it. The groove ID is calculated by subtracting twice the appropriate groove width.

    External Pressure: The maximum seal ID is calculated and then the groove ID is established so the seal is always seated against it. The groove OD is calculated by adding twice the appropriate groove width.

The recommended gland depths for Quad-Ring® Brand seal and O-Ring face seal applications are the same as for radial applications. Recommended gland depths can be found in the tables on Page 6-11 for a Quad-Ring® Brand seal and Page 6-13 for an O-Ring. However, the orientation of a face seal groove is axial instead of radial.

In an application where there is direct contact between the mating surfaces, such as with a cover, the groove depth is simply the recommended gland depth. In an application where there is clearance between the mating surfaces, the groove depth is calculated by subtracting the appropriate static or dynamic recommended gland depth from the absolute position of the sealing surface.

Groove Design for Face Seal Applications

1. **Cross-section.** Select a seal cross-section size from the available standard sizes. If you are unsure what cross-section size to use, see the discussion on Page 6-7.
2. **Clearance.** Determine the maximum clearance present in your application. In a direct contact application, consider the potential for variations in the surface flatness.
3. **Check the Clearance.** Determine if the clearance is acceptable for the application pressures and the material hardness being used by checking the graph on Page 6-9. Minnesota Rubber and Plastics standard-line products are made from materials having a hardness of 70 Shore A. If the clearance is unacceptable, component tolerance will have to be tightened or a harder seal material will have to be special ordered. For a face seal, use the clearance determined in Step 2 and read its value directly from the graph.
4. **Calculate the seal groove dimensions.** Using either the Quad-Ring® Brand table (Page 6-11) or the O-Ring table (Page 6-13), determine the groove width "D" for the seal cross-section size you have selected. Determine the seal groove diameter as described in the paragraph above.
5. **Groove Depth.** Using either the Quad-Ring® Brand seal table (Page 6-11) or the O-Ring table (Page 6-13), select the recommended gland depth for a static or dynamic application.
6. **Percent Gland Fill.** Determine the maximum percent gland fill. If the gland fill exceeds 100%, the groove will have to be redesigned. A good "rule-of-thumb" is to not exceed about 90% gland fill.
7. **Calculate the Seal Squeeze.** Calculate the minimum and maximum seal cross-sectional compression (squeeze). The recommended gland values in the seal tables have been developed to create a proper range of squeeze for many applications. In applications involving high pressure, large component tolerances, or other extreme conditions, the seal and groove design should be verified through an acceptable method, such as testing or engineering analysis.

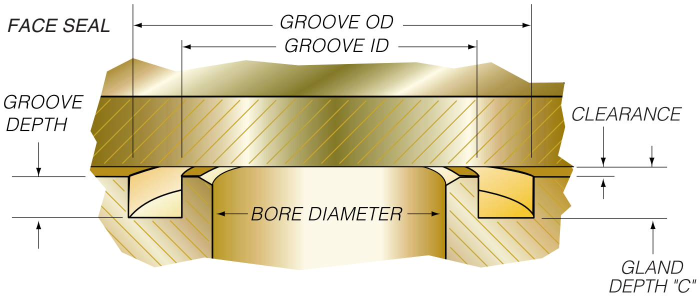
    Maximum Percent Compression = (1 - (Min Gland Depth/ Max Seal Cross-Section)) x 100

    Minimum Percent Compression = (1 - (Max Gland Depth/ Min Seal Cross-Section)) x 100
8. **Select the Seal.** Select the Quad-Ring® Brand seal with an inside diameter which will position the Quad-Ring® Brand seal on the side of the groove opposite the pressure.
9. **Detail the Groove.** Complete the groove design by specifying the proper radii and finish as indicated in the appropriate figure on page 6-11 or 6-13.

Application Example: Quad-Ring® Brand Face Seal

Application description: Cover for a Static Pressure Vessel, U. S. Customary Units (inches)

- Inside pressure of 50 psi
- Bore diameter .500" ±.005
- Desired Maximum groove OD of .750" -.005/+.000
- .103" cross-section Quad-Ring® Brand seal
- Cover is flat



RING SIZE	CROSS-SECTION	AXIAL STATIC RECOMMENDED GLAND DEPTH "C"	RADIAL STATIC SQUEEZE GROOVE WIDTH "D" +.005/-.000
Q4102 - Q4178	.103 ±.003	.089	.115

1. Determine the groove depth:
   Since the cover is flat, the groove depth is simply the gland depth. For this static application, the recommended gland depth from the table is .089.
   Groove Depth = Gland Depth = .089 -.002/+.000
   For the purpose of this example, a tolerance on this dimension of -.002/+.000 is assumed.

2. Calculate the groove inside diameter.
   From the table, the groove width for a .103 cross-section seal is .115 -.000/+.005.
   Groove I.D. = Minimum Groove O.D. - (2 x Groove Width)
   = .745 - (2 X .115)
   = .515 -.005/+.000
   For the purpose of this example, a tolerance on this dimension of -.000/+.005 is assumed.

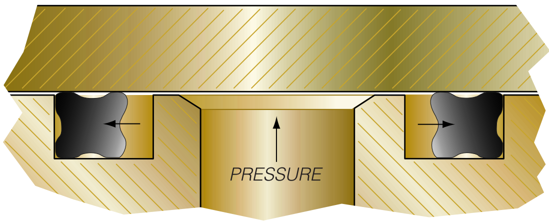
3. Calculate the Minimum Gland Volume:
   Minimum Gland Volume = ((Min Groove O.D. - Max Groove I.D.) / 2) x Min Gland Depth
   = ((.745 - .515)/2) X .087
   = .010 in^2

4. Calculate the Maximum Quad-Ring® Brand Seal Volume:
   Maximum Quad-Ring® Brand Seal Volume = (Max Quad-Ring® Brand Cross-section)^2 X .8215
   = (.106)^2 X .8215
   = .00923 in^2

5. Compare the Minimum Gland Volume to the Maximum Quad-Ring® Brand Seal Volume
   In this application the maximum seal volume is less than the minimum gland volume, so the seal should function satisfactorily.

6. Calculate the Minimum and Maximum Seal Squeeze
   a. Max Seal Squeeze = 1 - (Min Gland Depth / Max Seal Cross-section
   = 1 - (.087 / .106)
   = .179 = 17.9%
   b. Min Seal Squeeze = 1 - (Max Gland Depth / Min Seal Cross-section)
   = 1 - (.089/.100)
   = .11 = 11%
   Therefore, sufficient squeeze should exist to seal this application.

8. Select the Seal Size
   Refer to the Selection Guide beginning on page 6-22 and turn to the section which lists the seals having a .103 cross-section. Since this is an internal pressure application, the seal OD should always be seated against the groove OD, which has a maximum size of .750. Since the Selection Guide Table provides seal ID information, determine the minimum required ID by subtracting the minimum seal cross-section:
   Min ID= .750 - 2 x Min seal Cross-section = .750 X (2 X .100) = .550
   A 4114 seal would always have a minimum ID greater than .550.



Rotary Seals

Rotary Seal Considerations

Rotary seal applications offer unique challenges to seal manufacturers. Friction produced heat can quickly exceed the materials' maximum temperature if careful consideration is not made to minimize friction. Consider the following issues with rotary seal applications.

Heat Dissipation

The most common failure mode for a rotary seal is heat failure of the material. The most effective method of reducing heat build up is to reduce friction. This can be accomplished in many ways. Consider the chart below.

Difficult to Seal	Easy to Seal
■ High shaft speed	■ Low shaft speed
■ Non-lubricating seal medium	■ Lubricating seal medium
■ Loose component tolerances	■ Tight component tolerances
■ Incorrect shaft surface finish	■ Correct surface finish
■ Insulating materials	■ Conductive materials
■ High temperature	■ Lower temperature
■ Pressure less than 10 psi	■ Pressure between 10 and 750 psi
■ Pressure greater than 750 psi	

Mating Part Tolerance

To maintain a good seal with minimum friction, rotary applications require mating parts to be manufactured with tight tolerances. The shaft and bore should have a tolerance of ±.001 or better. Using tight tolerances reduces the amount of squeeze needed to seal in the worst case tolerance stackup.

Select Cross-section Size

When specifying a seal, choose the largest cross-section possible. The greater the cross-section, the more effective the seal and the longer the service life.

Shaft Speed

Whenever a choice exists, seal on the smallest diameter of the shaft to minimize friction and reduce surface speed. Shaft speeds of 900 FPM (274.3 m/min) are possible in pressure lubricated hydraulic applications. For shaft speeds of less than 20 FPM (15.2 m/min) and greater than 900 FPM (274.3 m/min) please contact our engineering department for technical assistance.

Feet / Minute (FPM) =
Shaft diameter (in inches) x 3.1415 x RPM) / 12

Meters / Minute (m/min) =
Shaft diameter (in meters) x 3.1415 x RPM

Seal Lubrication

Because heat related failure is the most common rotary seal failure mode, seal lubrication is extremely important. As friction increases so does heat buildup, decreasing seal life. Every application is different, but with increased surface speed lubrication is increasingly important. Also consider it takes lubrication pressure to get the lubrication forced into the dynamic seal interface. This pressure needs to be a minimum of 10 psi. When sealing non-lubricating fluids (milk, water, air, etc.) the seal life will be reduced significantly.

Surface Finish and Hardness

To reduce friction, the surface finish of the shaft should ideally be 20-24 μin Ra (.5-.6 μm) to improve its lubrication holding ability; 20-32 μin Ra (.5-.7 μm) is acceptable. Having a surface finish that is too smooth stops lubrication from getting to the sealing surface. Surface finish in the groove should be 63-85 μin Ra (1.6-2.1 μm) to prevent the seal from rotating in the groove. The minimum recommended hardness for the shaft material is 35 Rc.

Peripheral Compression

In a rotary application, the inside diameter of a free, uninstalled, Quad-Ring® Brand seal should always be larger than the OD of the shaft. After installation, the inside diameter will be peripherally compressed to be small enough to provide the squeeze necessary for sealing. This holds the seal in the groove and makes the dynamic surface between the seal and the shaft, not between the seal and the groove.

Seal Movement

Placing the groove in the housing, peripherally compressing the seal into the groove, and maximizing component concentricity maximizes seal life. Component eccentricity in rotary applications will cause the seal to act as a pump, causing the seal to leak.

Materials

Our compounds 525LP and 525L are recommended for rotary applications. These carboxylated nitrile formulations offer excellent abrasion resistance and are compatible for use with most hydraulic fluids. Compound 525LP is generally used in applications to 300 psi (20.7 bar), while 525L is preferred for pressures of 300-750 psi (20.7-51.7 bar).

Avoiding Seal Installation Damage

Seals can be easily damaged during installation. For example, a seal is often inserted onto a shaft by sliding it over a threaded or splined surface. To avoid seal damage, reduce the shaft diameter in the threaded region. Also include a lead-in chamfer for the seal and avoid sharp corners on grooves.When possible, consider using a cone-shaped installation tool to help install the seal.

Sealing Systems for the Rotary Application

Quad-Ring® Brand Seals (standard and custom molded)

If applied correctly, standard Quad-Ring® Brand seals can be excellent rotary seals as compared to more expensive alternatives. They offer low friction for long life in hydraulic systems with speeds up to 900 FPM (4.5 M/Sec) and a maximum pressure of 750 psi (52 bar). Refer to the table on the following page for correct sizing of Quad-Ring® Brand seals for your application.

Quad-Kup® Brand Seals (custom molded)

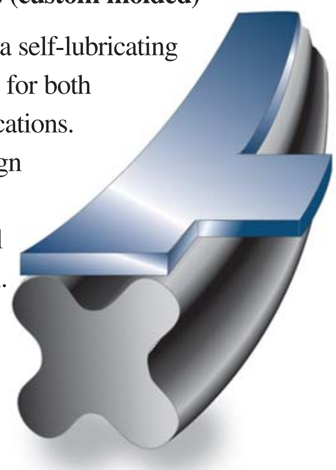
For high diametrical clearance applications and those requiring low operating friction. Provides low-pressure seal up to 150 psi (10.3 bar) in reciprocating and rotary applications. The combination lobed/cup configuration can be designed with the lip on any of the four surfaces, top or bottom, on the ID or OD.

Modified Quad-Ring® Brand Seals (custom molded)

This modified Quad-Ring® Brand seal has a deeper valley than the original Quad-Ring® Brand seal design, thereby producing lower deflection force value and reduced friction. Using Modified Quad-Ring® Brand seals will extend the seal life of rotary applications with pressures less than 100 psi.

Quad® P.E Plus Brand Seals (custom molded)

This dual-function seal forms a self-lubricating seal and an elastomeric spring for both rotary and reciprocating applications. Newly patented, this seal design combines injection moldable thermoplastic bearing material with a Quad-Ring® Brand seal. This seal is not intended for zero leakage applications.



Specialized Seals for Demanding Applications

Each rotary application is unique, often involving media other than oil or extreme conditions of temperature, pressure, or friction. Special seals are available to meet these demanding requirements.

Quad-Ring® Brand Seals for Rotary Applications With Oil

Quad-Ring® Brand seals offer low friction for long life in hydraulic systems with surface speeds up to 900 FPM (4.5 m/sec)

Quad-Ring® Brand seals should operate in a seal groove with a maximum diametral clearance of .004 in (0.10 mm) and a maximum pressure of 750 psi (52 bar). There must be a minimum of 10 psi oil pressure to properly lubricate the seal.

The table below contains groove dimensions for some common shaft sizes. The example on the opposite page illustrates how to calculate the groove dimensions for other shaft sizes. To calculate the proper groove diameter, select a Quad-Ring® Brand seal from the Standard Size Seal Table on Page 6-22 with the desired cross-section having an ID slightly larger than the maximum shaft diameter (shaft diameter at the high end of its tolerance). The rotary seal groove diameter is calculated as:

Maximum Groove Diameter = Minimum Shaft Diameter + (2 x Minimum Seal Cross-section) - .004 inches [0.10 mm]

Tip: To quickly locate the proper rotary seal Quad-Ring® Brand size in the Standard Size Seal Table on Page 6-22, turn to the section of the table for the seal cross-section size you have chosen. Then, using the Rod (shaft) size column, find the seal number for the shaft size you are using, as listed in the table. Move down one row in the table and check the seal ID for the next larger seal size. This will usually be the correct seal for a rotary application. Remember that as explained on page 6-19, for a rotary seal application the uninstalled Quad-Ring® Brand seal inside diameter should always be larger than the shaft diameter.

Recommended Initial Groove Design Dimensions for Rotary Applications

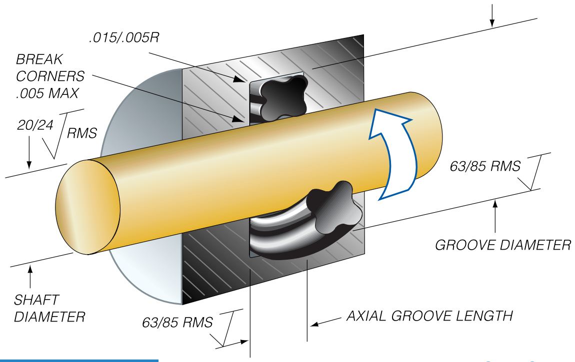
Note: This table is for use with rotary applications only.

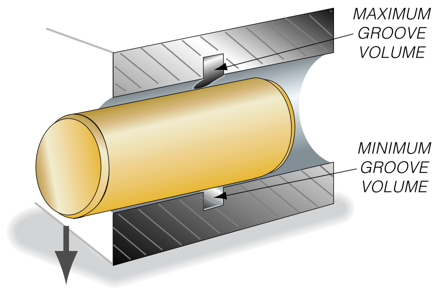
ROTARY SEAL QUAD-RING® BRAND SIZE	SHAFT DIA. (in)	SHAFT DIA. (mm)	SEAL CROSS-SECTION (in)	SEAL CROSS-SECTION (mm)	GROOVE DIA. (in) +.001/-.001	GROOVE DIA. (mm) +0.03/-0.03	AXIAL GROOVE WIDTH (in) +.005/-.000	AXIAL GROOVE WIDTH (mm) +0.13/-0.00
Q4007	.125	3.18	.070 ±.003	1.78 ±0.08	.255	6.48	.080	2.03
Q4008	.156	3.96	.070 ±.003	1.78 ±0.08	.286	7.26	.080	2.03
Q4009	.188	4.78	.070 ±.003	1.78 ±0.08	.318	8.08	.080	2.03
Q4010	.218	5.54	.070 ±.003	1.78 ±0.08	.348	8.84	.080	2.03
Q4011	.250	6.35	.070 ±.003	1.78 ±0.08	.380	9.65	.080	2.03
Q4011	.281	7.14	.070 ±.003	1.78 ±0.08	.411	10.44	.080	2.03
Q4110	.312	7.92	.103 ±.003	2.62 ±0.08	.508	12.90	.110	2.79
Q4111	.375	9.53	.103 ±.003	2.62 ±0.08	.571	14.50	.110	2.79
Q4112	.437	11.10	.103 ±.003	2.62 ±0.08	.633	16.08	.110	2.79
Q4113	.500	12.70	.103 ±.003	2.62 ±0.08	.696	17.68	.110	2.79
Q4114	.562	14.27	.103 ±.003	2.62 ±0.08	.758	19.25	.110	2.79
Q4115	.625	15.88	.103 ±.003	2.62 ±0.08	.821	20.85	.110	2.79
Q4117	.750	19.05	.103 ±.003	2.62 ±0.08	.946	24.03	.110	2.79
Q4118	.812	20.62	.103 ±.003	2.62 ±0.08	1.008	25.60	.110	2.79
Q4119	.875	22.23	.103 ±.003	2.62 ±0.08	1.071	27.20	.110	2.79
Q4120	.937	23.80	.103 ±.003	2.62 ±0.08	1.133	28.78	.110	2.79
Q4121	1.000	25.40	.103 ±.003	2.62 ±0.08	1.196	30.38	.110	2.79
Q4122	1.062	26.97	.103 ±.003	2.62 ±0.08	1.258	31.95	.110	2.79
Q4123	1.125	28.58	.103 ±.003	2.62 ±0.08	1.321	33.55	.110	2.79
Q4124	1.187	30.15	.103 ±.003	2.62 ±0.08	1.383	35.13	.110	2.79
Q4125	1.250	31.75	.103 ±.003	2.62 ±0.08	1.446	36.73	.110	2.79
Q4126	1.312	33.32	.103 ±.003	2.62 ±0.08	1.508	38.30	.110	2.79
Q4127	1.375	34.93	.103 ±.003	2.62 ±0.08	1.571	39.90	.110	2.79
Q4129	1.500	38.10	.103 ±.003	2.62 ±0.08	1.696	43.08	.110	2.79
Q4133	1.750	44.45	.103 ±.003	2.62 ±0.08	1.946	49.43	.110	2.79
Q4137	2.000	50.80	.103 ±.003	2.62 ±0.08	2.196	55.78	.110	2.79

Application Example: Quad-Ring® Brand Rotary Seal

Application description: Hydraulic Pump

- Shaft diameter .750" ±.001
- Bore diameter OD .753" ±.001
- 150 psi Hydraulic oil
- .103" cross-section Quad-Ring® Brand seal





RING SIZE	CROSS-SECTION	AXIAL GROOVE WIDTH "D" +.005/-.000
Q4102 - Q4178	.103 ±.003	.110

1. Calculate groove dimensions

   Groove Diameter = Minimum Shaft Diameter + (2 x Min Cross-Section) - .004"
   Groove Diameter = .749 + (2 x .100) - .004
   Groove Diameter = .945 in ± .001

2. Groove width = .110" -.000/+.005 - see chart on page 4-20

3. Calculate Minimum Groove Volume

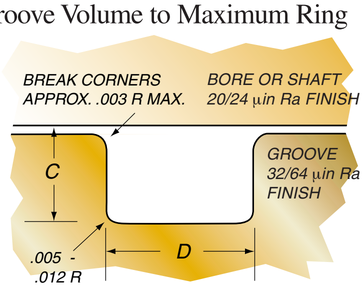
   Minimum Groove Volume = ((Min Groove Dia. - Max. Bore Dia.)/2) x Groove Width
   Minimum Groove Volume = ((.944 - .754)/2) x .115
   Minimum Groove Volume = .0109 in^2

4. Calculate Maximum Quad-Ring® Brand Seal Volume

   Maximum Quad-Ring® Brand Volume = (Maximum Cross-Section)^2 x .8215
   Maximum Quad-Ring® Brand Volume = .106^2 x .8215
   Maximum Quad-Ring® Brand Volume = .0092 in^2

5. Compare Minimum Groove Volume to Maximum Ring Volume

   In this application the Maximum Ring Volume is less than the Minimum Groove Volume; everything appears to be OK.



6. Calculate Minimum and Maximum seal squeeze

   These calculations look at both ends of the worst case stack up tolerance, including rod shift, to determine the maximum and minimum ring squeeze.

   Maximum Seal Squeeze =
   1 - (Minimum Groove Depth / Maximum Ring Cross-Section)
   Minimum Groove Depth = (Minimum Groove diameter – Maximum Bore)/2
   Minimum Groove Depth = (.944 - .754)/2
   Minimum Groove Depth = .095
   Maximum Seal Squeeze = 1 - (.095 / .106)
   Maximum Seal Squeeze = 10.3%

   Minimum Seal Squeeze =
   1 - (Maximum Groove Depth / Minimum Ring Cross-Section)
   Maximum Groove Depth = ((Max. Groove Diameter. – Max Bore)/2) + (Max Bore – Min. Rod)
   Maximum Groove Depth = ((.946 - .754)/2) + (.754 - .749)
   Maximum Groove Depth = .096 + .005
   Maximum Groove Depth = .101
   Minimum Seal Squeeze = 1 – (.101 / .100)
   Minimum Seal Squeeze = -1.0%

   In this application, if every dimension went to the worst side of the tolerance and the piston was side loaded, the seal would leak. To avoid these problems:

   1. *Reduce the clearance between the bore and piston.*
   2. *Reduce the tolerances of the bore and piston.*
   3. *Use a larger cross section Quad-Ring® Brand seal to absorb the extra tolerance.*
   4. *Support the piston so that it can not move off center.*

7. Calculate Maximum Clearance and Evaluate Possible Extrusion Issues

   Maximum Clearance = Maximum Bore – Minimum Rod
   Maximum Clearance = .754 – .749
   Maximum Clearance = .005" (.0025" Radial)

   This application has a max clearance of .0025" and must withstand 150 PSI without extruding the Quad-Ring® Brand seal. Refer to the clearance chart on page 6-9. A 70 Shore A material at 150 PSI can withstand a maximum clearance of .009, so a 70 Shore A material will work. Making improvements to the Minimum Seal Squeeze issues in Step 6 will also reduce any possible issues with seal extrusion.

8. Select seal size

   For all rotary rod seal applications select a Quad-Ring® Brand seal that has an ID larger than the maximum shaft diameter.
   Part ID >= .751"
   Quad-Ring® Brand Seal Size = 4117

Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals

Our standard Quad-Ring® Brand and O-Ring Seals are available from stock, in compound 366Y, a 70 Shore A nitrile and 514AD, a 70 Shore A fluorocarbon material.

For applications requiring other materials, Minnesota Rubber and Plastics can recommend one of our existing compounds or customize a special material to meet your needs. These parts are all manufactured in standard tools.

Tolerances

Our standard Quad-Ring® Brand and O-Ring seal tooling is designed to the shrinkage characteristics of our popular 366Y, a 70 durometer nitrile formulation. Because every rubber formulation has its own shrinkage characteristics, slight deviations in dimensions will occur when standard seal tooling is used with materials other than our 366Y. The majority of the cases we encounter involve rubber compounds with a higher shrinkage factor, resulting in seals with undersized cross-sections and undersized inside diameters. This increase in shrinkage is most pronounced when using silicone, fluorosilicone and flourocarbon elastomer materials. Because of the decrease in cross-sectional size, groove dimensions may need to decrease to maintain a good seal. Parts produced in materials other than 366Y may not conform to the dimensional specifications as stated in AS-568A or the following table.

Understanding Our Part Numbers

Seal Configuration Quad-Ring® Brand Seal | Ring Size | Rubber Compound

4 210-366Y

Part Number

Seal Configuration Quad® Brand O-Ring Seal | Ring Size AS-568A Dimensions | Rubber Compound

8 210-366Y

Part Number

Note: The Rod and Bore columns listed in the following table do NOT indicate a rod/bore combination for a specific seal number. To use the table, first determine the proper seal size by locating the rod or the bore size on which you are sealing. The seal groove diameter can then be calculated as indicated, starting on page 6-10.

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
001	.031	.093	1/32	1/32	.029 ±.004	0.74 ±0.10	.040 ±.003	1.02 ±0.08
002	.046	.125	3/64	3/64	.042 ±.004	1.07 ±0.10	.050 ±.003	1.27 ±0.08
003	.062	.156	1/16	1/16	.056 ±.004	1.42 ±0.10	.060 ±.003	1.52 ±0.08
003 1/2	.078	.141	1/16	1/32	.070 ±.004	1.78 ±0.10	.040 ±.003	1.02 ±0.08
004	.078	.203	5/64	1/16	.070 ±.005	1.78 ±0.13	.070 ±.003	1.78 ±0.08
005	.109	.234	3/32	1/16	.101 ±.005	2.57 ±0.13	.070 ±.003	1.78 ±0.08
006	.125	.250	1/8	1/16	.114 ±.005	2.90 ±0.13	.070 ±.003	1.78 ±0.08
007	.156	.281	5/32	1/16	.145 ±.005	3.68 ±0.13	.070 ±.003	1.78 ±0.08
008	.187	.312	3/16	1/16	.176 ±.005	4.47 ±0.13	.070 ±.003	1.78 ±0.08
009	.218	.343	7/32	1/16	.208 ±.005	5.28 ±0.13	.070 ±.003	1.78 ±0.08
010	.250	.375	1/4	1/16	.239 ±.005	6.07 ±0.13	.070 ±.003	1.78 ±0.08
011	.312	.437	5/16	1/16	.301 ±.005	7.65 ±0.13	.070 ±.003	1.78 ±0.08
012	.375	.500	3/8	1/16	.364 ±.005	9.25 ±0.13	.070 ±.003	1.78 ±0.08
013	.437	.562	7/16	1/16	.426 ±.005	10.82 ±0.13	.070 ±.003	1.78 ±0.08
014	.500	.625	1/2	1/16	.489 ±.005	12.42 ±0.13	.070 ±.003	1.78 ±0.08
015	.562	.687	9/16	1/16	.551 ±.007	14.00 ±0.18	.070 ±.003	1.78 ±0.08
016	.625	.750	5/8	1/16	.614 ±.009	15.60 ±0.23	.070 ±.003	1.78 ±0.08
017	.687	.812	11/16	1/16	.676 ±.009	17.17 ±0.23	.070 ±.003	1.78 ±0.08

Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals - continued

RING SIZE	ROD (in)	BORE (in)	NOMINAL		INSIDE DIAMETER		CROSS-SECTION	
			ID (in)	C/S (in)	(in)	(mm)	(in)	(mm)
018	.750	.875	3/4	1/16	.739 ±.009	18.77 ±0.23	.070 ±.003	1.78 ±0.08
019	.812	.937	13/16	1/16	.801 ±.009	20.35 ±0.23	.070 ±.003	1.78 ±0.08
020	.875	1.000	7/8	1/16	.864 ±.009	21.95 ±0.23	.070 ±.003	1.78 ±0.08
021	.937	1.062	15/16	1/16	.926 ±.009	23.52 ±0.23	.070 ±.003	1.78 ±0.08
022	1.000	1.125	1	1/16	.989 ±.010	25.12 ±0.25	.070 ±.003	1.78 ±0.08
023	1.062	1.187	1 1/16	1/16	1.051 ±.010	26.70 ±0.25	.070 ±.003	1.78 ±0.08
024	1.125	1.250	1 1/8	1/16	1.114 ±.010	28.30 ±0.25	.070 ±.003	1.78 ±0.08
025	1.187	1.312	1 3/16	1/16	1.176 ±.011	29.87 ±0.28	.070 ±.003	1.78 ±0.08
026	1.250	1.375	1 1/4	1/16	1.239 ±.011	31.47 ±0.28	.070 ±.003	1.78 ±0.08
027	1.312	1.437	1 5/16	1/16	1.301 ±.011	33.05 ±0.28	.070 ±.003	1.78 ±0.08
028	1.375	1.500	1 3/8	1/16	1.364 ±.013	34.65 ±0.33	.070 ±.003	1.78 ±0.08
029	1.500	1.625	1 1/2	1/16	1.489 ±.013	37.82 ±0.33	.070 ±.003	1.78 ±0.08
030	1.625	1.750	1 5/8	1/16	1.614 ±.013	41.00 ±0.33	.070 ±.003	1.78 ±0.08
031	1.750	1.875	1 3/4	1/16	1.739 ±.015	44.17 ±0.38	.070 ±.003	1.78 ±0.08
032	1.875	2.000	1 7/8	1/16	1.864 ±.015	47.35 ±0.38	.070 ±.003	1.78 ±0.08
033	2.000	2.125	2	1/16	1.989 ±.018	50.52 ±0.46	.070 ±.003	1.78 ±0.08
034	2.125	2.250	2 1/8	1/16	2.114 ±.018	53.70 ±0.46	.070 ±.003	1.78 ±0.08
035	2.250	2.375	2 1/4	1/16	2.239 ±.018	56.87 ±0.46	.070 ±.003	1.78 ±0.08
036	2.375	2.500	2 3/8	1/16	2.364 ±.018	60.05 ±0.46	.070 ±.003	1.78 ±0.08
037	2.500	2.625	2 1/2	1/16	2.489 ±.018	63.22 ±0.46	.070 ±.003	1.78 ±0.08
038	2.625	2.750	2 5/8	1/16	2.614 ±.020	66.40 ±0.51	.070 ±.003	1.78 ±0.08
039	2.750	2.875	2 3/4	1/16	2.739 ±.020	69.57 ±0.51	.070 ±.003	1.78 ±0.08
040	2.875	3.000	2 7/8	1/16	2.864 ±.020	72.75 ±0.51	.070 ±.003	1.78 ±0.08
041	3.000	3.125	3	1/16	2.989 ±.024	75.92 ±0.61	.070 ±.003	1.78 ±0.08
042	3.250	3.375	3 1/4	1/16	3.239 ±.024	82.27 ±0.61	.070 ±.003	1.78 ±0.08
043	3.500	3.625	3 1/2	1/16	3.489 ±.024	88.62 ±0.61	.070 ±.003	1.78 ±0.08
044	3.750	3.875	3 3/4	1/16	3.739 ±.027	94.97 ±0.69	.070 ±.003	1.78 ±0.08
045	4.000	4.125	4	1/16	3.989 ±.027	101.32 ±0.69	.070 ±.003	1.78 ±0.08
046	4.250	4.375	4 1/4	1/16	4.239 ±.030	107.67 ±0.76	.070 ±.003	1.78 ±0.08
047	4.500	4.625	4 1/2	1/16	4.489 ±.030	114.02 ±0.76	.070 ±.003	1.78 ±0.08
048	4.750	4.875	4 3/4	1/16	4.739 ±.030	120.37 ±0.76	.070 ±.003	1.78 ±0.08
049	5.000	5.125	5	1/16	4.989 ±.037	126.72 ±0.94	.070 ±.003	1.78 ±0.08
050	5.250	5.375	5 1/4	1/16	5.239 ±.037	133.07 ±0.94	.070 ±.003	1.78 ±0.08
051 THROUGH 101 SIZES NOT ASSIGNED								
102	.062	.250	1/16	3/32	.049 ±.005	1.24 ±0.13	.103 ±.003	2.62 ±0.08
103	.094	.281	3/32	3/32	.081 ±.005	2.06 ±0.13	.103 ±.003	2.62 ±0.08
104	.125	.312	1/8	3/32	.112 ±.005	2.84 ±0.13	.103 ±.003	2.62 ±0.08
105	.156	.343	5/32	3/32	.143 ±.005	3.63 ±0.13	.103 ±.003	2.62 ±0.08
106	.187	.375	3/16	3/32	.174 ±.005	4.42 ±0.13	.103 ±.003	2.62 ±0.08
107	.219	.406	7/32	3/32	.206 ±.005	5.23 ±0.13	.103 ±.003	2.62 ±0.08

Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals - continued

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
108	.250	.437	$\frac{1}{4}$	$\frac{3}{32}$	.237 ±.005	6.02 ±0.13	.103 ±.003	2.62 ±0.08
109	.312	.500	$\frac{5}{16}$	$\frac{3}{32}$	.299 ±.005	7.59 ±0.13	.103 ±.003	2.62 ±0.08
110	.375	.562	$\frac{3}{8}$	$\frac{3}{32}$	.362 ±.005	9.19 ±0.13	.103 ±.003	2.62 ±0.08
111	.437	.625	$\frac{7}{16}$	$\frac{3}{32}$	.424 ±.005	10.77 ±0.13	.103 ±.003	2.62 ±0.08
112	.500	.687	$\frac{1}{2}$	$\frac{3}{32}$	.487 ±.005	12.37 ±0.13	.103 ±.003	2.62 ±0.08
113	.562	.750	$\frac{9}{16}$	$\frac{3}{32}$	.549 ±.007	13.94 ±0.18	.103 ±.003	2.62 ±0.08
114	.625	.812	$\frac{5}{8}$	$\frac{3}{32}$	.612 ±.009	15.54 ±0.23	.103 ±.003	2.62 ±0.08
115	.687	.875	$\frac{11}{16}$	$\frac{3}{32}$	.674 ±.009	17.12 ±0.23	.103 ±.003	2.62 ±0.08
116	.750	.937	$\frac{3}{4}$	$\frac{3}{32}$	.737 ±.009	18.72 ±0.23	.103 ±.003	2.62 ±0.08
117	.812	1.000	$\frac{13}{16}$	$\frac{3}{32}$	.799 ±.010	20.29 ±0.25	.103 ±.003	2.62 ±0.08
118	.875	1.062	$\frac{7}{8}$	$\frac{3}{32}$	.862 ±.010	21.89 ±0.25	.103 ±.003	2.62 ±0.08
119	.937	1.125	$\frac{15}{16}$	$\frac{3}{32}$	.924 ±.010	23.47 ±0.25	.103 ±.003	2.62 ±0.08
120	1.000	1.187	1	$\frac{3}{32}$	.987 ±.010	25.07 ±0.25	.103 ±.003	2.62 ±0.08
121	1.062	1.250	$1\frac{1}{16}$	$\frac{3}{32}$	1.049 ±.010	26.64 ±0.25	.103 ±.003	2.62 ±0.08
122	1.125	1.312	$1\frac{1}{8}$	$\frac{3}{32}$	1.112 ±.010	28.24 ±0.25	.103 ±.003	2.62 ±0.08
123	1.187	1.375	$1\frac{3}{16}$	$\frac{3}{32}$	1.174 ±.012	29.82 ±0.30	.103 ±.003	2.62 ±0.08
124	1.250	1.437	$1\frac{1}{4}$	$\frac{3}{32}$	1.237 ±.012	31.42 ±0.30	.103 ±.003	2.62 ±0.08
125	1.312	1.500	$1\frac{5}{16}$	$\frac{3}{32}$	1.299 ±.012	32.99 ±0.30	.103 ±.003	2.62 ±0.08
126	1.375	1.562	$1\frac{3}{8}$	$\frac{3}{32}$	1.362 ±.012	34.59 ±0.30	.103 ±.003	2.62 ±0.08
127	1.437	1.625	$1\frac{7}{16}$	$\frac{3}{32}$	1.424 ±.012	36.17 ±0.30	.103 ±.003	2.62 ±0.08
128	1.500	1.687	$1\frac{1}{2}$	$\frac{3}{32}$	1.487 ±.012	37.77 ±0.30	.103 ±.003	2.62 ±0.08
129	1.562	1.750	$1\frac{9}{16}$	$\frac{3}{32}$	1.549 ±.015	39.34 ±0.38	.103 ±.003	2.62 ±0.08
130	1.625	1.812	$1\frac{5}{8}$	$\frac{3}{32}$	1.612 ±.015	40.94 ±0.38	.103 ±.003	2.62 ±0.08
131	1.687	1.875	$1\frac{11}{16}$	$\frac{3}{32}$	1.674 ±.015	42.52 ±0.38	.103 ±.003	2.62 ±0.08
132	1.750	1.937	$1\frac{3}{4}$	$\frac{3}{32}$	1.737 ±.015	44.12 ±0.38	.103 ±.003	2.62 ±0.08
133	1.812	2.000	$1\frac{13}{16}$	$\frac{3}{32}$	1.799 ±.015	45.69 ±0.38	.103 ±.003	2.62 ±0.08
134	1.875	2.062	$1\frac{7}{8}$	$\frac{3}{32}$	1.862 ±.015	47.29 ±0.38	.103 ±.003	2.62 ±0.08
135	1.938	2.125	$1\frac{15}{16}$	$\frac{3}{32}$	1.925 ±.017	48.90 ±0.43	.103 ±.003	2.62 ±0.08
136	2.000	2.187	2	$\frac{3}{32}$	1.987 ±.017	50.47 ±0.43	.103 ±.003	2.62 ±0.08
137	2.063	2.250	$2\frac{1}{16}$	$\frac{3}{32}$	2.050 ±.017	52.07 ±0.43	.103 ±.003	2.62 ±0.08
138	2.125	2.312	$2\frac{1}{8}$	$\frac{3}{32}$	2.112 ±.017	53.64 ±0.43	.103 ±.003	2.62 ±0.08
139	2.188	2.375	$2\frac{3}{16}$	$\frac{3}{32}$	2.175 ±.017	55.25 ±0.43	.103 ±.003	2.62 ±0.08
140	2.250	2.437	$2\frac{1}{4}$	$\frac{3}{32}$	2.237 ±.017	56.82 ±0.43	.103 ±.003	2.62 ±0.08
141	2.313	2.500	$2\frac{5}{16}$	$\frac{3}{32}$	2.300 ±.020	58.42 ±0.51	.103 ±.003	2.62 ±0.08
142	2.375	2.562	$2\frac{3}{8}$	$\frac{3}{32}$	2.362 ±.020	59.99 ±0.51	.103 ±.003	2.62 ±0.08
143	2.438	2.625	$2\frac{7}{16}$	$\frac{3}{32}$	2.425 ±.020	61.60 ±0.51	.103 ±.003	2.62 ±0.08
144	2.500	2.687	$2\frac{1}{2}$	$\frac{3}{32}$	2.487 ±.020	63.17 ±0.51	.103 ±.003	2.62 ±0.08
145	2.563	2.750	$2\frac{9}{16}$	$\frac{3}{32}$	2.550 ±.020	64.77 ±0.51	.103 ±.003	2.62 ±0.08
146	2.625	2.812	$2\frac{5}{8}$	$\frac{3}{32}$	2.612 ±.020	66.34 ±0.51	.103 ±.003	2.62 ±0.08
147	2.688	2.875	$2\frac{11}{16}$	$\frac{3}{32}$	2.675 ±.022	67.95 ±0.56	.103 ±.003	2.62 ±0.08

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
148	2.750	2.937	2 3/4	3/32	2.737 ±.022	69.52 ±0.56	.103 ±.003	2.62 ±0.08
149	2.813	3.000	2 13/16	3/32	2.800 ±.022	71.12 ±0.56	.103 ±.003	2.62 ±0.08
150	2.875	3.062	2 7/8	3/32	2.862 ±.022	72.69 ±0.56	.103 ±.003	2.62 ±0.08
151	3.000	3.187	3	3/32	2.987 ±.024	75.87 ±0.61	.103 ±.003	2.62 ±0.08
152	3.250	3.437	3 1/4	3/32	3.237 ±.024	82.22 ±0.61	.103 ±.003	2.62 ±0.08
153	3.500	3.687	3 1/2	3/32	3.487 ±.024	88.57 ±0.61	.103 ±.003	2.62 ±0.08
154	3.750	3.937	3 3/4	3/32	3.737 ±.028	94.92 ±0.71	.103 ±.003	2.62 ±0.08
155	4.000	4.187	4	3/32	3.987 ±.028	101.27 ±0.71	.103 ±.003	2.62 ±0.08
156	4.250	4.437	4 1/4	3/32	4.237 ±.030	107.62 ±0.76	.103 ±.003	2.62 ±0.08
157	4.500	4.687	4 1/2	3/32	4.487 ±.030	113.97 ±0.76	.103 ±.003	2.62 ±0.08
158	4.750	4.937	4 3/4	3/32	4.737 ±.030	120.32 ±0.76	.103 ±.003	2.62 ±0.08
159	5.000	5.187	5	3/32	4.987 ±.035	126.67 ±0.89	.103 ±.003	2.62 ±0.08
160	5.250	5.437	5 1/4	3/32	5.237 ±.035	133.02 ±0.89	.103 ±.003	2.62 ±0.08
161	5.500	5.687	5 1/2	3/32	5.487 ±.035	139.37 ±0.89	.103 ±.003	2.62 ±0.08
162	5.750	5.937	5 3/4	3/32	5.737 ±.035	145.72 ±0.89	.103 ±.003	2.62 ±0.08
163	6.000	6.187	6	3/32	5.987 ±.035	152.07 ±0.89	.103 ±.003	2.62 ±0.08
164	6.250	6.437	6 1/4	3/32	6.237 ±.040	158.42 ±1.02	.103 ±.003	2.62 ±0.08
165	6.500	6.687	6 1/2	3/32	6.487 ±.040	164.77 ±1.02	.103 ±.003	2.62 ±0.08
166	6.750	6.937	6 3/4	3/32	6.737 ±.040	171.12 ±1.02	.103 ±.003	2.62 ±0.08
167	7.000	7.187	7	3/32	6.987 ±.040	177.47 ±1.02	.103 ±.003	2.62 ±0.08
168	7.250	7.437	7 1/4	3/32	7.237 ±.045	183.82 ±1.14	.103 ±.003	2.62 ±0.08
169	7.500	7.687	7 1/2	3/32	7.487 ±.045	190.17 ±1.14	.103 ±.003	2.62 ±0.08
170	7.750	7.937	7 3/4	3/32	7.737 ±.045	196.52 ±1.14	.103 ±.003	2.62 ±0.08
171	8.000	8.187	8	3/32	7.987 ±.045	202.87 ±1.14	.103 ±.003	2.62 ±0.08
172	8.250	8.437	8 1/4	3/32	8.237 ±.050	209.22 ±1.27	.103 ±.003	2.62 ±0.08
173	8.500	8.687	8 1/2	3/32	8.487 ±.050	215.57 ±1.27	.103 ±.003	2.62 ±0.08
174	8.750	8.937	8 3/4	3/32	8.737 ±.050	221.92 ±1.27	.103 ±.003	2.62 ±0.08
175	9.000	9.187	9	3/32	8.987 ±.050	228.27 ±1.27	.103 ±.003	2.62 ±0.08
176	9.250	9.437	9 1/4	3/32	9.237 ±.055	234.62 ±1.40	.103 ±.003	2.62 ±0.08
177	9.500	9.687	9 1/2	3/32	9.487 ±.055	240.97 ±1.40	.103 ±.003	2.62 ±0.08
178	9.750	9.937	9 3/4	3/32	9.737 ±.055	247.32 ±1.40	.103 ±.003	2.62 ±0.08
179 THROUGH 201 SIZES NOT ASSIGNED								
201	.187	.437	3/16	1/8	.171 ±.005	4.34 ±0.13	.139 ±.004	3.53 ±0.10
202	.250	.500	1/4	1/8	.234 ±.005	5.94 ±0.13	.139 ±.004	3.53 ±0.10
203	.312	.562	5/16	1/8	.296 ±.005	7.52 ±0.13	.139 ±.004	3.53 ±0.10
204	.375	.625	3/8	1/8	.359 ±.005	9.12 ±0.13	.139 ±.004	3.53 ±0.10
205	.437	.687	7/16	1/8	.421 ±.005	10.69 ±0.13	.139 ±.004	3.53 ±0.10
206	.500	.750	1/2	1/8	.484 ±.005	12.29 ±0.13	.139 ±.004	3.53 ±0.10
207	.562	.812	9/16	1/8	.546 ±.007	13.87 ±0.18	.139 ±.004	3.53 ±0.10
208	.625	.875	5/8	1/8	.609 ±.009	15.47 ±0.23	.139 ±.004	3.53 ±0.10

Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals-continued

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
209	.687	.937	$\frac{11}{16}$	$\frac{1}{8}$	.671 ±.009	17.04 ±0.23	.139 ±.004	3.53 ±0.10
210	.750	1.000	$\frac{3}{4}$	$\frac{1}{8}$	.734 ±.010	18.64 ±0.25	.139 ±.004	3.53 ±0.10
211	.812	1.062	$\frac{13}{16}$	$\frac{1}{8}$	.796 ±.010	20.22 ±0.25	.139 ±.004	3.53 ±0.10
212	.875	1.125	$\frac{7}{8}$	$\frac{1}{8}$	.859 ±.010	21.82 ±0.25	.139 ±.004	3.53 ±0.10
213	.937	1.187	$\frac{15}{16}$	$\frac{1}{8}$	.921 ±.010	23.39 ±0.25	.139 ±.004	3.53 ±0.10
214	1.000	1.250	1	$\frac{1}{8}$	.984 ±.010	24.99 ±0.25	.139 ±.004	3.53 ±0.10
215	1.062	1.312	$1\frac{1}{16}$	$\frac{1}{8}$	1.046 ±.010	26.57 ±0.25	.139 ±.004	3.53 ±0.10
216	1.125	1.375	$1\frac{1}{8}$	$\frac{1}{8}$	1.109 ±.012	28.17 ±0.30	.139 ±.004	3.53 ±0.10
217	1.187	1.437	$1\frac{3}{16}$	$\frac{1}{8}$	1.171 ±.012	29.74 ±0.30	.139 ±.004	3.53 ±0.10
218	1.250	1.500	$1\frac{1}{4}$	$\frac{1}{8}$	1.234 ±.012	31.34 ±0.30	.139 ±.004	3.53 ±0.10
219	1.312	1.562	$1\frac{5}{16}$	$\frac{1}{8}$	1.296 ±.012	32.92 ±0.30	.139 ±.004	3.53 ±0.10
220	1.375	1.625	$1\frac{3}{8}$	$\frac{1}{8}$	1.359 ±.012	34.52 ±0.30	.139 ±.004	3.53 ±0.10
221	1.437	1.687	$1\frac{7}{16}$	$\frac{1}{8}$	1.421 ±.012	36.09 ±0.30	.139 ±.004	3.53 ±0.10
222	1.500	1.750	$1\frac{1}{2}$	$\frac{1}{8}$	1.484 ±.015	37.69 ±0.38	.139 ±.004	3.53 ±0.10
223	1.625	1.875	$1\frac{5}{8}$	$\frac{1}{8}$	1.609 ±.015	40.87 ±0.38	.139 ±.004	3.53 ±0.10
224	1.750	2.000	$1\frac{3}{4}$	$\frac{1}{8}$	1.734 ±.015	44.04 ±0.38	.139 ±.004	3.53 ±0.10
225	1.875	2.125	$1\frac{7}{8}$	$\frac{1}{8}$	1.859 ±.018	47.22 ±0.46	.139 ±.004	3.53 ±0.10
226	2.000	2.250	2	$\frac{1}{8}$	1.984 ±.018	50.39 ±0.46	.139 ±.004	3.53 ±0.10
227	2.125	2.375	$2\frac{1}{8}$	$\frac{1}{8}$	2.109 ±.018	53.57 ±0.46	.139 ±.004	3.53 ±0.10
228	2.250	2.500	$2\frac{1}{4}$	$\frac{1}{8}$	2.234 ±.020	56.74 ±0.51	.139 ±.004	3.53 ±0.10
229	2.375	2.625	$2\frac{3}{8}$	$\frac{1}{8}$	2.359 ±.020	59.92 ±0.51	.139 ±.004	3.53 ±0.10
230	2.500	2.750	$2\frac{1}{2}$	$\frac{1}{8}$	2.484 ±.020	63.09 ±0.51	.139 ±.004	3.53 ±0.10
231	2.625	2.875	$2\frac{5}{8}$	$\frac{1}{8}$	2.609 ±.020	66.27 ±0.51	.139 ±.004	3.53 ±0.10
232	2.750	3.000	$2\frac{3}{4}$	$\frac{1}{8}$	2.734 ±.024	69.44 ±0.61	.139 ±.004	3.53 ±0.10
233	2.875	3.125	$2\frac{7}{8}$	$\frac{1}{8}$	2.859 ±.024	72.62 ±0.61	.139 ±.004	3.53 ±0.10
234	3.000	3.250	3	$\frac{1}{8}$	2.984 ±.024	75.79 ±0.61	.139 ±.004	3.53 ±0.10
235	3.125	3.375	$3\frac{1}{8}$	$\frac{1}{8}$	3.109 ±.024	78.97 ±0.61	.139 ±.004	3.53 ±0.10
236	3.250	3.500	$3\frac{1}{4}$	$\frac{1}{8}$	3.234 ±.024	82.14 ±0.61	.139 ±.004	3.53 ±0.10
237	3.375	3.625	$3\frac{3}{8}$	$\frac{1}{8}$	3.359 ±.024	85.32 ±0.61	.139 ±.004	3.53 ±0.10
238	3.500	3.750	$3\frac{1}{2}$	$\frac{1}{8}$	3.484 ±.024	88.49 ±0.61	.139 ±.004	3.53 ±0.10
239	3.625	3.875	$3\frac{5}{8}$	$\frac{1}{8}$	3.609 ±.028	91.67 ±0.71	.139 ±.004	3.53 ±0.10
240	3.750	4.000	$3\frac{3}{4}$	$\frac{1}{8}$	3.734 ±.028	94.84 ±0.71	.139 ±.004	3.53 ±0.10
241	3.875	4.125	$3\frac{7}{8}$	$\frac{1}{8}$	3.859 ±.028	98.02 ±0.71	.139 ±.004	3.53 ±0.10
242	4.000	4.250	4	$\frac{1}{8}$	3.984 ±.028	101.19 ±0.71	.139 ±.004	3.53 ±0.10
243	4.125	4.375	$4\frac{1}{8}$	$\frac{1}{8}$	4.109 ±.028	104.37 ±0.71	.139 ±.004	3.53 ±0.10
244	4.250	4.500	$4\frac{1}{4}$	$\frac{1}{8}$	4.234 ±.030	107.54 ±0.76	.139 ±.004	3.53 ±0.10
245	4.375	4.625	$4\frac{3}{8}$	$\frac{1}{8}$	4.359 ±.030	110.72 ±0.76	.139 ±.004	3.53 ±0.10
246	4.500	4.750	$4\frac{1}{2}$	$\frac{1}{8}$	4.484 ±.030	113.89 ±0.76	.139 ±.004	3.53 ±0.10
247	4.625	4.875	$4\frac{5}{8}$	$\frac{1}{8}$	4.609 ±.030	117.07 ±0.76	.139 ±.004	3.53 ±0.10
248	4.750	5.000	$4\frac{3}{4}$	$\frac{1}{8}$	4.734 ±.030	120.24 ±0.76	.139 ±.004	3.53 ±0.10

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
249	4.875	5.125	$4\frac{7}{8}$	$\frac{1}{8}$	4.859 ±.035	123.42 ±0.89	.139 ±.004	3.53 ±0.10
250	5.000	5.250	5	$\frac{1}{8}$	4.984 ±.035	126.59 ±0.89	.139 ±.004	3.53 ±0.10
251	5.125	5.375	$5\frac{1}{8}$	$\frac{1}{8}$	5.109 ±.035	129.77 ±0.89	.139 ±.004	3.53 ±0.10
252	5.250	5.500	$5\frac{1}{4}$	$\frac{1}{8}$	5.234 ±.035	132.94 ±0.89	.139 ±.004	3.53 ±0.10
253	5.375	5.625	$5\frac{3}{8}$	$\frac{1}{8}$	5.359 ±.035	136.12 ±0.89	.139 ±.004	3.53 ±0.10
254	5.500	5.750	$5\frac{1}{2}$	$\frac{1}{8}$	5.484 ±.035	139.29 ±0.89	.139 ±.004	3.53 ±0.10
255	5.625	5.875	$5\frac{5}{8}$	$\frac{1}{8}$	5.609 ±.035	142.47 ±0.89	.139 ±.004	3.53 ±0.10
256	5.750	6.000	$5\frac{3}{4}$	$\frac{1}{8}$	5.734 ±.035	145.64 ±0.89	.139 ±.004	3.53 ±0.10
257	5.875	6.125	$5\frac{7}{8}$	$\frac{1}{8}$	5.859 ±.035	148.82 ±0.89	.139 ±.004	3.53 ±0.10
258	6.000	6.250	6	$\frac{1}{8}$	5.984 ±.035	151.99 ±0.89	.139 ±.004	3.53 ±0.10
259	6.250	6.500	$6\frac{1}{4}$	$\frac{1}{8}$	6.234 ±.040	158.34 ±1.02	.139 ±.004	3.53 ±0.10
260	6.500	6.750	$6\frac{1}{2}$	$\frac{1}{8}$	6.484 ±.040	164.69 ±1.02	.139 ±.004	3.53 ±0.10
261	6.750	7.000	$6\frac{3}{4}$	$\frac{1}{8}$	6.734 ±.040	171.04 ±1.02	.139 ±.004	3.53 ±0.10
262	7.000	7.250	7	$\frac{1}{8}$	6.984 ±.040	177.39 ±1.02	.139 ±.004	3.53 ±0.10
263	7.250	7.500	$7\frac{1}{4}$	$\frac{1}{8}$	7.234 ±.045	183.74 ±1.14	.139 ±.004	3.53 ±0.10
264	7.500	7.750	$7\frac{1}{2}$	$\frac{1}{8}$	7.484 ±.045	190.09 ±1.14	.139 ±.004	3.53 ±0.10
265	7.750	8.000	$7\frac{3}{4}$	$\frac{1}{8}$	7.734 ±.045	196.44 ±1.14	.139 ±.004	3.53 ±0.10
266	8.000	8.250	8	$\frac{1}{8}$	7.984 ±.045	202.79 ±1.14	.139 ±.004	3.53 ±0.10
267	8.250	8.500	$8\frac{1}{4}$	$\frac{1}{8}$	8.234 ±.050	209.14 ±1.27	.139 ±.004	3.53 ±0.10
268	8.500	8.750	$8\frac{1}{2}$	$\frac{1}{8}$	8.484 ±.050	215.49 ±1.27	.139 ±.004	3.53 ±0.10
269	8.750	9.000	$8\frac{3}{4}$	$\frac{1}{8}$	8.734 ±.050	221.84 ±1.27	.139 ±.004	3.53 ±0.10
270	9.000	9.250	9	$\frac{1}{8}$	8.984 ±.050	228.19 ±1.27	.139 ±.004	3.53 ±0.10
271	9.250	9.500	$9\frac{1}{4}$	$\frac{1}{8}$	9.234 ±.055	234.54 ±1.40	.139 ±.004	3.53 ±0.10
272	9.500	9.750	$9\frac{1}{2}$	$\frac{1}{8}$	9.484 ±.055	240.89 ±1.40	.139 ±.004	3.53 ±0.10
273	9.750	10.000	$9\frac{3}{4}$	$\frac{1}{8}$	9.734 ±.055	247.24 ±1.40	.139 ±.004	3.53 ±0.10
274	10.000	10.250	10	$\frac{1}{8}$	9.984 ±.055	253.59 ±1.40	.139 ±.004	3.53 ±0.10
275	10.500	10.750	$10\frac{1}{2}$	$\frac{1}{8}$	10.484 ±.055	266.29 ±1.40	.139 ±.004	3.53 ±0.10
276	11.000	11.250	11	$\frac{1}{8}$	10.984 ±.065	278.99 ±1.65	.139 ±.004	3.53 ±0.10
277	11.500	11.750	$11\frac{1}{2}$	$\frac{1}{8}$	11.484 ±.065	291.69 ±1.65	.139 ±.004	3.53 ±0.10
278	12.000	12.250	12	$\frac{1}{8}$	11.984 ±.065	304.39 ±1.65	.139 ±.004	3.53 ±0.10
279	13.000	13.250	13	$\frac{1}{8}$	12.984 ±.065	329.79 ±1.65	.139 ±.004	3.53 ±0.10
280	14.000	14.250	14	$\frac{1}{8}$	13.984 ±.065	355.19 ±1.65	.139 ±.004	3.53 ±0.10
281	15.000	15.250	15	$\frac{1}{8}$	14.984 ±.065	380.59 ±1.65	.139 ±.004	3.53 ±0.10
282	16.000	16.250	16	$\frac{1}{8}$	15.955 ±.075	405.26 ±1.91	.139 ±.004	3.53 ±0.10
283	17.000	17.250	17	$\frac{1}{8}$	16.955 ±.080	430.66 ±2.03	.139 ±.004	3.53 ±0.10
284	18.000	18.250	18	$\frac{1}{8}$	17.955 ±.085	456.06 ±2.16	.139 ±.004	3.53 ±0.10
285 THROUGH 308 SIZES NOT ASSIGNED								
309	.437	.812	$\frac{7}{16}$	$\frac{3}{16}$	.412 ±.005	10.46 ±0.13	.210 ±.005	5.33 ±0.13
310	.500	.875	$\frac{1}{2}$	$\frac{3}{16}$	.475 ±.005	12.07 ±0.13	.210 ±.005	5.33 ±0.13
311	.562	.937	$\frac{9}{16}$	$\frac{3}{16}$	.537 ±.007	13.64 ±0.18	.210 ±.005	5.33 ±0.13

Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals - continued

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
312	.625	1.000	$\frac{5}{8}$	$\frac{3}{16}$	.600 ±.009	15.24 ±0.23	.210 ±.005	5.33 ±0.13
313	.687	1.062	$\frac{11}{16}$	$\frac{3}{16}$	.662 ±.009	16.81 ±0.23	.210 ±.005	5.33 ±0.13
314	.750	1.125	$\frac{3}{4}$	$\frac{3}{16}$	.725 ±.010	18.42 ±0.25	.210 ±.005	5.33 ±0.13
315	.812	1.187	$\frac{13}{16}$	$\frac{3}{16}$	.787 ±.010	19.99 ±0.25	.210 ±.005	5.33 ±0.13
316	.875	1.250	$\frac{7}{8}$	$\frac{3}{16}$	.850 ±.010	21.59 ±0.25	.210 ±.005	5.33 ±0.13
317	.937	1.312	$\frac{15}{16}$	$\frac{3}{16}$	.912 ±.010	23.16 ±0.25	.210 ±.005	5.33 ±0.13
318	1.000	1.375	1	$\frac{3}{16}$	.975 ±.010	24.77 ±0.25	.210 ±.005	5.33 ±0.13
319	1.062	1.437	$1\frac{1}{16}$	$\frac{3}{16}$	1.037 ±.010	26.34 ±0.25	.210 ±.005	5.33 ±0.13
320	1.125	1.500	$1\frac{1}{8}$	$\frac{3}{16}$	1.100 ±.012	27.94 ±0.30	.210 ±.005	5.33 ±0.13
321	1.187	1.562	$1\frac{3}{16}$	$\frac{3}{16}$	1.162 ±.012	29.51 ±0.30	.210 ±.005	5.33 ±0.13
322	1.250	1.625	$1\frac{1}{4}$	$\frac{3}{16}$	1.225 ±.012	31.12 ±0.30	.210 ±.005	5.33 ±0.13
323	1.312	1.687	$1\frac{5}{16}$	$\frac{3}{16}$	1.287 ±.012	32.69 ±0.30	.210 ±.005	5.33 ±0.13
324	1.375	1.750	$1\frac{3}{8}$	$\frac{3}{16}$	1.350 ±.012	34.29 ±0.30	.210 ±.005	5.33 ±0.13
325	1.500	1.875	$1\frac{1}{2}$	$\frac{3}{16}$	1.475 ±.015	37.47 ±0.38	.210 ±.005	5.33 ±0.13
326	1.625	2.000	$1\frac{5}{8}$	$\frac{3}{16}$	1.600 ±.015	40.64 ±0.38	.210 ±.005	5.33 ±0.13
327	1.750	2.125	$1\frac{3}{4}$	$\frac{3}{16}$	1.725 ±.015	43.82 ±0.38	.210 ±.005	5.33 ±0.13
328	1.875	2.250	$1\frac{7}{8}$	$\frac{3}{16}$	1.850 ±.015	46.99 ±0.38	.210 ±.005	5.33 ±0.13
329	2.000	2.375	2	$\frac{3}{16}$	1.975 ±.018	50.17 ±0.46	.210 ±.005	5.33 ±0.13
330	2.125	2.500	$2\frac{1}{8}$	$\frac{3}{16}$	2.100 ±.018	53.34 ±0.46	.210 ±.005	5.33 ±0.13
331	2.250	2.625	$2\frac{1}{4}$	$\frac{3}{16}$	2.225 ±.018	56.52 ±0.46	.210 ±.005	5.33 ±0.13
332	2.375	2.750	$2\frac{3}{8}$	$\frac{3}{16}$	2.350 ±.018	59.69 ±0.46	.210 ±.005	5.33 ±0.13
333	2.500	2.875	$2\frac{1}{2}$	$\frac{3}{16}$	2.475 ±.020	62.87 ±0.51	.210 ±.005	5.33 ±0.13
334	2.625	3.000	$2\frac{5}{8}$	$\frac{3}{16}$	2.600 ±.020	66.04 ±0.51	.210 ±.005	5.33 ±0.13
335	2.750	3.125	$2\frac{3}{4}$	$\frac{3}{16}$	2.725 ±.020	69.22 ±0.51	.210 ±.005	5.33 ±0.13
336	2.875	3.250	$2\frac{7}{8}$	$\frac{3}{16}$	2.850 ±.020	72.39 ±0.51	.210 ±.005	5.33 ±0.13
337	3.000	3.375	3	$\frac{3}{16}$	2.975 ±.024	75.57 ±0.61	.210 ±.005	5.33 ±0.13
338	3.125	3.500	$3\frac{1}{8}$	$\frac{3}{16}$	3.100 ±.024	78.74 ±0.61	.210 ±.005	5.33 ±0.13
339	3.250	3.625	$3\frac{1}{4}$	$\frac{3}{16}$	3.225 ±.024	81.92 ±0.61	.210 ±.005	5.33 ±0.13
340	3.375	3.750	$3\frac{3}{8}$	$\frac{3}{16}$	3.350 ±.024	85.09 ±0.61	.210 ±.005	5.33 ±0.13
341	3.500	3.875	$3\frac{1}{2}$	$\frac{3}{16}$	3.475 ±.024	88.27 ±0.61	.210 ±.005	5.33 ±0.13
342	3.625	4.000	$3\frac{5}{8}$	$\frac{3}{16}$	3.600 ±.028	91.44 ±0.71	.210 ±.005	5.33 ±0.13
343	3.750	4.125	$3\frac{3}{4}$	$\frac{3}{16}$	3.725 ±.028	94.62 ±0.71	.210 ±.005	5.33 ±0.13
344	3.875	4.250	$3\frac{7}{8}$	$\frac{3}{16}$	3.850 ±.028	97.79 ±0.71	.210 ±.005	5.33 ±0.13
345	4.000	4.375	4	$\frac{3}{16}$	3.975 ±.028	100.97 ±0.71	.210 ±.005	5.33 ±0.13
346	4.125	4.500	$4\frac{1}{8}$	$\frac{3}{16}$	4.100 ±.028	104.14 ±0.71	.210 ±.005	5.33 ±0.13
347	4.250	4.625	$4\frac{1}{4}$	$\frac{3}{16}$	4.225 ±.030	107.32 ±0.76	.210 ±.005	5.33 ±0.13
348	4.375	4.750	$4\frac{3}{8}$	$\frac{3}{16}$	4.350 ±.030	110.49 ±0.76	.210 ±.005	5.33 ±0.13
349	4.500	4.875	$4\frac{1}{2}$	$\frac{3}{16}$	4.475 ±.030	113.67 ±0.76	.210 ±.005	5.33 ±0.13
350	4.625	5.000	$4\frac{5}{8}$	$\frac{3}{16}$	4.600 ±.030	116.84 ±0.76	.210 ±.005	5.33 ±0.13
351	4.750	5.125	$4\frac{3}{4}$	$\frac{3}{16}$	4.725 ±.030	120.02 ±0.76	.210 ±.005	5.33 ±0.13

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
352	4.875	5.250	4 7/8	3/16	4.850 ±.030	123.19 ±0.76	.210 ±.005	5.33 ±0.13
353	5.000	5.375	5	3/16	4.975 ±.037	126.37 ±0.94	.210 ±.005	5.33 ±0.13
354	5.125	5.500	5 1/8	3/16	5.100 ±.037	129.54 ±0.94	.210 ±.005	5.33 ±0.13
355	5.250	5.625	5 1/4	3/16	5.225 ±.037	132.72 ±0.94	.210 ±.005	5.33 ±0.13
356	5.375	5.750	5 3/8	3/16	5.350 ±.037	135.89 ±0.94	.210 ±.005	5.33 ±0.13
357	5.500	5.875	5 1/2	3/16	5.475 ±.037	139.07 ±0.94	.210 ±.005	5.33 ±0.13
358	5.625	6.000	5 5/8	3/16	5.600 ±.037	142.24 ±0.94	.210 ±.005	5.33 ±0.13
359	5.750	6.125	5 3/4	3/16	5.725 ±.037	145.42 ±0.94	.210 ±.005	5.33 ±0.13
360	5.875	6.250	5 7/8	3/16	5.850 ±.037	148.59 ±0.94	.210 ±.005	5.33 ±0.13
361	6.000	6.375	6	3/16	5.975 ±.037	151.77 ±0.94	.210 ±.005	5.33 ±0.13
362	6.250	6.625	6 1/4	3/16	6.225 ±.040	158.12 ±1.02	.210 ±.005	5.33 ±0.13
363	6.500	6.875	6 1/2	3/16	6.475 ±.040	164.47 ±1.02	.210 ±.005	5.33 ±0.13
364	6.750	7.125	6 3/4	3/16	6.725 ±.040	170.82 ±1.02	.210 ±.005	5.33 ±0.13
365	7.000	7.375	7	3/16	6.975 ±.040	177.17 ±1.02	.210 ±.005	5.33 ±0.13
366	7.250	7.625	7 1/4	3/16	7.225 ±.045	183.52 ±1.14	.210 ±.005	5.33 ±0.13
367	7.500	7.875	7 1/2	3/16	7.475 ±.045	189.87 ±1.14	.210 ±.005	5.33 ±0.13
368	7.750	8.125	7 3/4	3/16	7.725 ±.045	196.22 ±1.14	.210 ±.005	5.33 ±0.13
369	8.000	8.375	8	3/16	7.975 ±.045	202.57 ±1.14	.210 ±.005	5.33 ±0.13
370	8.250	8.625	8 1/4	3/16	8.225 ±.050	208.92 ±1.27	.210 ±.005	5.33 ±0.13
371	8.500	8.875	8 1/2	3/16	8.475 ±.050	215.27 ±1.27	.210 ±.005	5.33 ±0.13
372	8.750	9.125	8 3/4	3/16	8.725 ±.050	221.62 ±1.27	.210 ±.005	5.33 ±0.13
373	9.000	9.375	9	3/16	8.975 ±.050	227.97 ±1.27	.210 ±.005	5.33 ±0.13
374	9.250	9.625	9 1/4	3/16	9.225 ±.055	234.32 ±1.40	.210 ±.005	5.33 ±0.13
375	9.500	9.875	9 1/2	3/16	9.475 ±.055	240.67 ±1.40	.210 ±.005	5.33 ±0.13
376	9.750	10.125	9 3/4	3/16	9.725 ±.055	247.02 ±1.40	.210 ±.005	5.33 ±0.13
377	10.000	10.375	10	3/16	9.975 ±.055	253.37 ±1.40	.210 ±.005	5.33 ±0.13
378	10.500	10.875	10 1/2	3/16	10.475 ±.060	266.07 ±1.52	.210 ±.005	5.33 ±0.13
379	11.000	11.375	11	3/16	10.975 ±.060	278.77 ±1.52	.210 ±.005	5.33 ±0.13
380	11.500	11.875	11 1/2	3/16	11.475 ±.065	291.47 ±1.65	.210 ±.005	5.33 ±0.13
381	12.000	12.375	12	3/16	11.975 ±.065	304.17 ±1.65	.210 ±.005	5.33 ±0.13
382	13.000	13.375	13	3/16	12.975 ±.065	329.57 ±1.65	.210 ±.005	5.33 ±0.13
383	14.000	14.375	14	3/16	13.975 ±.070	354.97 ±1.78	.210 ±.005	5.33 ±0.13
384	15.000	15.375	15	3/16	14.975 ±.070	380.37 ±1.78	.210 ±.005	5.33 ±0.13
385	16.000	16.375	16	3/16	15.955 ±.075	405.26 ±1.91	.210 ±.005	5.33 ±0.13
386	17.000	17.375	17	3/16	16.955 ±.080	430.66 ±2.03	.210 ±.005	5.33 ±0.13
387	18.000	18.375	18	3/16	17.955 ±.085	456.06 ±2.16	.210 ±.005	5.33 ±0.13
388	19.000	19.375	19	3/16	18.955 ±.090	481.46 ±2.29	.210 ±.005	5.33 ±0.13
389	20.000	20.375	20	3/16	19.955 ±.095	506.86 ±2.41	.210 ±.005	5.33 ±0.13
390	21.000	21.375	21	3/16	20.955 ±.095	532.26 ±2.41	.210 ±.005	5.33 ±0.13
391	22.000	22.375	22	3/16	21.955 ±.100	557.66 ±2.54	.210 ±.005	5.33 ±0.13

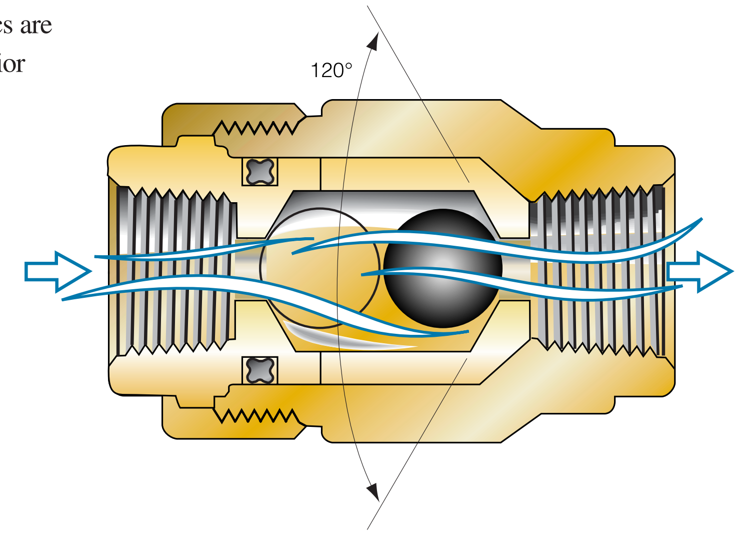
Selection Guide for Standard Size Quad-Ring® Brand Seals and Quad® Brand O-Ring Seals - continued

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)	INSIDE DIAMETER (mm)	CROSS-SECTION (in)	CROSS-SECTION (mm)
392	23.000	23.375	23	$\frac{3}{16}$	22.940 ±.105	582.68 ±2.67	.210 ±.005	5.33 ±0.13
393	24.000	24.375	24	$\frac{3}{16}$	23.940 ±.110	608.08 ±2.79	.210 ±.005	5.33 ±0.13
394	25.000	25.375	25	$\frac{3}{16}$	24.940 ±.115	633.48 ±2.92	.210 ±.005	5.33 ±0.13
395	26.000	26.375	26	$\frac{3}{16}$	25.940 ±.120	658.88 ±3.05	.210 ±.005	5.33 ±0.13
396 THROUGH 424 SIZES NOT ASSIGNED								
425	4.500	5.000	$4\frac{1}{2}$	$\frac{1}{4}$	4.475 ±.033	113.67 ±0.84	.275 ±.006	6.99 ±0.15
426	4.625	5.125	$4\frac{5}{8}$	$\frac{1}{4}$	4.600 ±.033	116.84 ±0.84	.275 ±.006	6.99 ±0.15
427	4.750	5.250	$4\frac{3}{4}$	$\frac{1}{4}$	4.725 ±.033	120.02 ±0.84	.275 ±.006	6.99 ±0.15
428	4.875	5.375	$4\frac{7}{8}$	$\frac{1}{4}$	4.850 ±.033	123.19 ±0.84	.275 ±.006	6.99 ±0.15
429	5.000	5.500	5	$\frac{1}{4}$	4.975 ±.037	126.37 ±0.94	.275 ±.006	6.99 ±0.15
430	5.125	5.625	$5\frac{1}{8}$	$\frac{1}{4}$	5.100 ±.037	129.54 ±0.94	.275 ±.006	6.99 ±0.15
431	5.250	5.750	$5\frac{1}{4}$	$\frac{1}{4}$	5.225 ±.037	132.72 ±0.94	.275 ±.006	6.99 ±0.15
432	5.375	5.875	$5\frac{3}{8}$	$\frac{1}{4}$	5.350 ±.037	135.89 ±0.94	.275 ±.006	6.99 ±0.15
433	5.500	6.000	$5\frac{1}{2}$	$\frac{1}{4}$	5.475 ±.037	139.07 ±0.94	.275 ±.006	6.99 ±0.15
434	5.625	6.125	$5\frac{5}{8}$	$\frac{1}{4}$	5.600 ±.037	142.24 ±0.94	.275 ±.006	6.99 ±0.15
435	5.750	6.250	$5\frac{3}{4}$	$\frac{1}{4}$	5.725 ±.037	145.42 ±0.94	.275 ±.006	6.99 ±0.15
436	5.875	6.375	$5\frac{7}{8}$	$\frac{1}{4}$	5.850 ±.037	148.59 ±0.94	.275 ±.006	6.99 ±0.15
437	6.000	6.500	6	$\frac{1}{4}$	5.975 ±.037	151.77 ±0.94	.275 ±.006	6.99 ±0.15
438	6.250	6.750	$6\frac{1}{4}$	$\frac{1}{4}$	6.225 ±.040	158.12 ±1.02	.275 ±.006	6.99 ±0.15
439	6.500	7.000	$6\frac{1}{2}$	$\frac{1}{4}$	6.475 ±.040	164.47 ±1.02	.275 ±.006	6.99 ±0.15
440	6.750	7.250	$6\frac{3}{4}$	$\frac{1}{4}$	6.725 ±.040	170.82 ±1.02	.275 ±.006	6.99 ±0.15
441	7.000	7.500	7	$\frac{1}{4}$	6.975 ±.040	177.17 ±1.02	.275 ±.006	6.99 ±0.15
442	7.250	7.750	$7\frac{1}{4}$	$\frac{1}{4}$	7.225 ±.045	183.52 ±1.14	.275 ±.006	6.99 ±0.15
443	7.500	8.000	$7\frac{1}{2}$	$\frac{1}{4}$	7.475 ±.045	189.87 ±1.14	.275 ±.006	6.99 ±0.15
444	7.750	8.250	$7\frac{3}{4}$	$\frac{1}{4}$	7.725 ±.045	196.22 ±1.14	.275 ±.006	6.99 ±0.15
445	8.000	8.500	8	$\frac{1}{4}$	7.975 ±.045	202.57 ±1.14	.275 ±.006	6.99 ±0.15
446	8.500	9.000	$8\frac{1}{2}$	$\frac{1}{4}$	8.475 ±.055	215.27 ±1.40	.275 ±.006	6.99 ±0.15
447	9.000	9.500	9	$\frac{1}{4}$	8.975 ±.055	227.97 ±1.40	.275 ±.006	6.99 ±0.15
448	9.500	10.000	$9\frac{1}{2}$	$\frac{1}{4}$	9.475 ±.055	240.67 ±1.40	.275 ±.006	6.99 ±0.15
449	10.000	10.500	10	$\frac{1}{4}$	9.975 ±.055	253.37 ±1.40	.275 ±.006	6.99 ±0.15
450	10.500	11.000	$10\frac{1}{2}$	$\frac{1}{4}$	10.475 ±.060	266.07 ±1.52	.275 ±.006	6.99 ±0.15
451	11.000	11.500	11	$\frac{1}{4}$	10.975 ±.060	278.77 ±1.52	.275 ±.006	6.99 ±0.15
452	11.500	12.000	$11\frac{1}{2}$	$\frac{1}{4}$	11.475 ±.060	291.47 ±1.52	.275 ±.006	6.99 ±0.15
453	12.000	12.500	12	$\frac{1}{4}$	11.975 ±.060	304.17 ±1.52	.275 ±.006	6.99 ±0.15
454	12.500	13.000	$12\frac{1}{2}$	$\frac{1}{4}$	12.475 ±.060	316.87 ±1.52	.275 ±.006	6.99 ±0.15
455	13.000	13.500	13	$\frac{1}{4}$	12.975 ±.060	329.57 ±1.52	.275 ±.006	6.99 ±0.15
456	13.500	14.000	$13\frac{1}{2}$	$\frac{1}{4}$	13.475 ±.070	342.27 ±1.78	.275 ±.006	6.99 ±0.15
457	14.000	14.500	14	$\frac{1}{4}$	13.975 ±.070	354.97 ±1.78	.275 ±.006	6.99 ±0.15
458	14.500	15.000	$14\frac{1}{2}$	$\frac{1}{4}$	14.475 ±.070	367.67 ±1.78	.275 ±.006	6.99 ±0.15
459	15.000	15.500	15	$\frac{1}{4}$	14.975 ±.070	380.37 ±1.78	.275 ±.006	6.99 ±0.15

RING SIZE	ROD (in)	BORE (in)	NOMINAL ID (in)	NOMINAL C/S (in)	INSIDE DIAMETER (in)		INSIDE DIAMETER (mm)		CROSS-SECTION (in)		CROSS-SECTION (mm)	
460	15.500	16.000	15 1/2	1/4	15.475	±.070	393.07	±1.78	.275	±.006	6.99	±0.15
461	16.000	16.500	16	1/4	15.955	±.075	405.26	±1.91	.275	±.006	6.99	±0.15
462	16.500	17.000	16 1/2	1/4	16.455	±.075	417.96	±1.91	.275	±.006	6.99	±0.15
463	17.000	17.500	17	1/4	16.955	±.080	430.66	±2.03	.275	±.006	6.99	±0.15
464	17.500	18.000	17 1/2	1/4	17.455	±.085	443.36	±2.16	.275	±.006	6.99	±0.15
465	18.000	18.500	18	1/4	17.955	±.085	456.06	±2.16	.275	±.006	6.99	±0.15
466	18.500	19.000	18 1/2	1/4	18.455	±.085	468.76	±2.16	.275	±.006	6.99	±0.15
467	19.000	19.500	19	1/4	18.955	±.090	481.46	±2.29	.275	±.006	6.99	±0.15
468	19.500	20.000	19 1/2	1/4	19.455	±.090	494.16	±2.29	.275	±.006	6.99	±0.15
469	20.000	20.500	20	1/4	19.955	±.095	506.86	±2.41	.275	±.006	6.99	±0.15
470	21.000	21.500	21	1/4	20.955	±.095	532.26	±2.41	.275	±.006	6.99	±0.15
471	22.000	22.500	22	1/4	21.955	±.100	557.66	±2.54	.275	±.006	6.99	±0.15
472	23.000	23.500	23	1/4	22.940	±.105	582.68	±2.67	.275	±.006	6.99	±0.15
473	24.000	24.500	24	1/4	23.940	±.110	608.08	±2.79	.275	±.006	6.99	±0.15
474	25.00	25.500	25	1/4	24.940	±.115	633.48	±2.92	.275	±.006	6.99	±0.15
475	26.000	26.500	26	1/4	25.940	±.120	658.88	±3.05	.275	±.006	6.99	±0.15

Quad® Brand Ground Rubber Balls

Rubber balls from Minnesota Rubber and Plastics are carefully molded and precision ground for superior performance in the most critical applications.



Material

Our standard rubber balls are molded from a 70 Shore A nitrile compound specially formulated for grinding. Our compound 525K is recommended for most typical pneumatic, hydraulic or water applications.

Other elastomeric compounds are also available for more demanding situations such as steam, high temperatures or corrosive fluids. Compounds with a hardness lower than 70 Shore A are difficult to grind. Harder materials are also available.

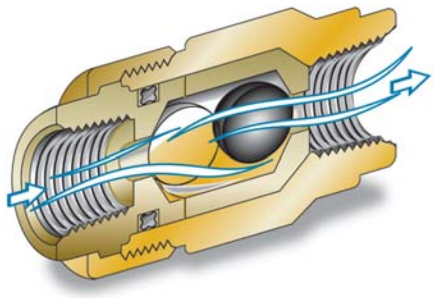
Sphericity

High speed centerless grinding combined with automatic gauging/measuring equipment assures you of a consistent, close tolerance on both spherical and diametric dimensions. The resulting uniform finish also ensures consistent sealing performance regardless of how the ball seats.

Variety of Sizes

Select from our standard sizes below, or take advantage of our custom molding facilities for your specialized ball applications.

PART NO.	COMPOUND	DIAMETER Nominal	DIAMETER (in)	DIAMETER (mm)
B130093	525K	3/32	.093 ±.003 dia., .003sph. Total	2.36 ±0.08 dia., 0.08sph. Total
B130125	525K	1/8	.125 ±.003 dia., .003sph. Total	3.18 ±0.08 dia., 0.08sph. Total
B130156	525K	5/32	.156 ±.003 dia., .003sph. Total	3.96 ±0.08 dia., 0.08sph. Total
B130187	525K	3/16	.187 ±.003 dia., .003sph. Total	4.75 ±0.08 dia., 0.08sph. Total
B130218	525K	7/32	.218 ±.003 dia., .003sph. Total	5.54 ±0.08 dia., 0.08sph. Total
B130250	525K	1/4	.250 ±.003 dia., .003sph. Total	6.35 ±0.08 dia., 0.08sph. Total
B130312	525K	5/16	.312 ±.003 dia., .003sph. Total	7.93 ±0.08 dia., 0.08sph. Total
B130375	525K	3/8	.375 ±.003 dia., .003sph. Total	9.53 ±0.08 dia., 0.08sph. Total
B130437	525K	7/16	.437 ±.004 dia., .005sph. Total	11.10 ±0.10 dia., 0.13sph. Total
B130500	525K	1/2	.500 ±.004 dia., .005sph. Total	12.70 ±0.10 dia., 0.13sph. Total
B130562	525K	9/16	.562 ±.004 dia., .005sph. Total	14.28 ±0.10 dia., 0.13sph. Total
B130625	525K	5/8	.625 ±.004 dia., .005sph. Total	15.88 ±0.10 dia., 0.13sph. Total
B130750	525K	3/4	.750 ±.004 dia., .005sph. Total	19.05 ±0.10 dia., 0.13sph. Total
B131000	525K	1	1.000 ±.004 dia., .005sph. Total	25.40 ±0.10 dia., 0.13sph. Total

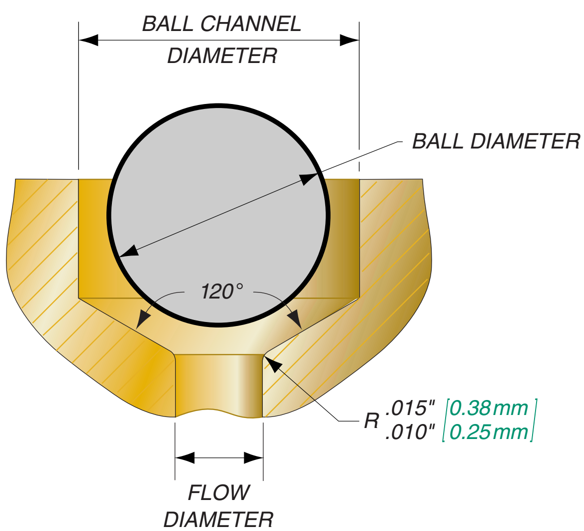


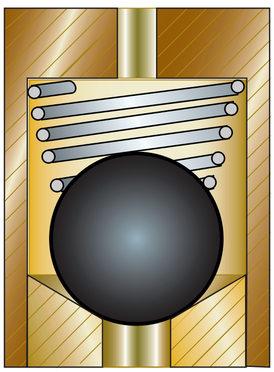
Ground Ball Tip Sheet

- Solid, non-reinforced core ground balls are generally used as check devices for pressures less than 120 psi.
- When designing an application to incorporate a check ball, the differential area between the projected ball area and the area of the ball channel should be slightly greater than that of the main flow area. This will minimize flow disruption due to the presence of the ball in the flow stream.
- The ball seat should have an included angle of 120° and have a .010"-.015" radius where the seat and the flow channel meet. For liquids, the ball seat should have a surface finish of 20µin RMS or better. For air or vacuum applications, the ball seat should have a surface finish of 10µin RMS or better.
- At pressures greater than 120 psi, there is a tendency for ground balls to become stuck in the ball seat (checking orifice). If this occurs often, it can damage the ball, eventually causing the ball to extrude through the orifice.
- As a "rule-of-thumb," the diameter of a check ball should be at least three times the diameter of the flow orifice. The larger the ball-to-orifice ratio, the lower the likelihood of ball extrusion.
- Standard tolerances for ground balls are indicated in the following table:

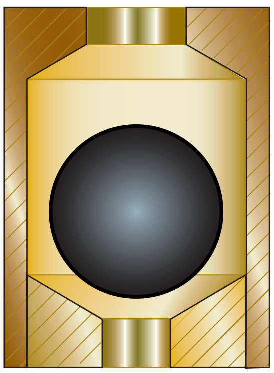
BALL DIAMETER	DIAMETER TOLERANCE	SPHERICITY
<= .375"	±.003	.003 Total
> .375"	±.004	.005 Total

Typical Applications



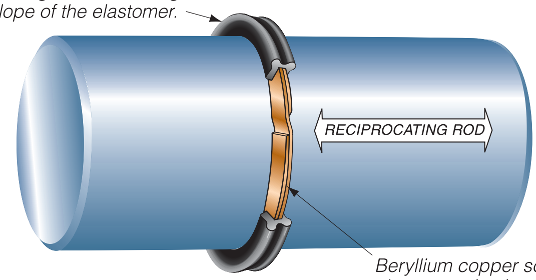


Spring Loaded



Double Seat

Equi-Flex™ Rod Wiper/Scraper



What is Equi-Flex™?

Equi-Flex™ rod wiper/scrapers effectively wipe and scrape the full 360º circumference of a reciprocating rod. They are designed to remove road dust, dirt, ice, mud, weld flash, paint and many other particulates from the rod surface. They prevent damage to bearings, seals, packings, and rods, thereby reducing or eliminating contamination of fluids in hydraulic systems.

Equi-Flex™ rod wiper/scrapers consist of a honed, double-spiral wiping element of age-hardened beryllium copper (Rockwell C 40 hardness) surrounded by a synthetic rubber elastomer. It is designed so that the beryllium copper element is distended from the final rod diameter. It is precision honed to an inner-diameter tolerance of +/- 0.0005". The honing process guarantees a true circle on the ring inside diameter and provides a highly polished and knife-sharp edge. In operation, the beryllium copper ring polishes the rod without damage to the rod's finish. It is self-sharpening and does not oval, curve, or feather.

Equi-Flex™ rod wiper/scrapers are found wherever hydraulic or pneumatic cylinders are used. They have demonstrated their effectiveness on fork lifts, resistance welders, off-road machinery, farm equipment, hydraulic presses, foundry machines, and aircraft landing gear.

Why Use Equi-Flex™?

Equi-Flex™ rod wiper/scrapers provide the following benefits:

Feature	Advantage	Benefit
360° contact	No gap eliminates clogging and bypass contamination	Longer primary seal life means more up-time
Spring action scraper	Greater rod tolerance	No precision machining of rods
Low friction/low wear	Longer scraper life	More up-time & lower equipment maintenance cost
Self-sharpening	Continuous and consistent performance	More up-time & lower equipment maintenance cost
Occupies a minimum amount of space	Greater design freedom	Smaller package
MS28776-R2 compatible gland	Use existing components	No modification required
Product availability	Readily available from stock	Reduces design cycle time. Shortens leadtimes resulting in less purchasing and planning
Large selection of sizes	Greater design freedom	No non-recurring engineering charges. No custom tooling

Selecting Equi-Flex™ Rod Wiper/ Scraper Elastomeric Compounds.

Standard Equi-Flex™ rod wiper/scraper elastomers are compounded of a nitrile material which is compatible with most mineral-based oils and other commercial hydraulic fluids within a temperature range of -65°F to 212°F (-54°C to 100°C). However, a wide variety of other elastomers are available to meet special application requirements.

LetterSuffix	MN Rubber Compound	Shore A Hardness	Compatible With:	Temperature Range
A	Nitrile 523EU Date Coded	70	MIL-H-5606 Petroleum Fluids Auto Transmission Fluids Water	-65°F to 212°F (-54°C to 100°C)
I	FKM 514AD	70	Fuel Oil, Chemicals Petroleum Fluids Other Corrosive Fluids	-25°F to 400°F (-32°C to 204°C)
P	Ethylene Propylene 559N	70	Ozone Aqueous Chemicals Acid or Alkali Phosphate Esters (Skydrol) Auto Brake Fluids	-70°F to 300°F (-57°C to 149°C)
None	Nitrile 523EU	70	Petroleum Hydraulic Fluids Auto Transmission Fluids Water	-65°F to 212°F (-54°C to 100°C)

Mounting Principle and Methods

When distended around a rod and mounted in an appropriate recess of proper diameter and depth (Figure A, confined view), the elastomer deforms, surrounds and seals the beryllium copper element in a cushioned suspension. The elastomer prevents solids from migrating through the sealing cavity and reaching the rod bearing or primary seal. It exerts a uniform peripheral squeeze on the wiping element to provide 360° contact with the rod. This squeeze, and the spring characteristics of the beryllium copper element, provide exceptionally good wear resistance for both the scraper element and the reciprocating rod. The elastomer also allows a cushioned float of the scraper element to compensate for normal misalignments.

To obtain the best performance, Equi-Flex™ rod wiper/scrapers should be installed with consideration of the following:

1. Equi-Flex™ rod wiper/scrapers should be assembled on the rod in a free state and then confined (Figure A) using gland dimensions from the Housing Recesses Tables on the following pages.
2. To prevent damage to the honed inner-diameter of the Equi-Flex™ scraper ring; A) chamfer the rod ends a minimum of 5° and a maximum of 20°, or B) use a distention sleeve to insert the rod into the Equi-Flex™ scraper. A properly inserted Equi-Flex™ scraper can then be mounted in the housing using any of several mounting methods (including those shown in Figure B).
3. Refer to the selection criteria listed on the opposite page to assure compatibility of the elastomer with the fluids used in your application.

Figure A

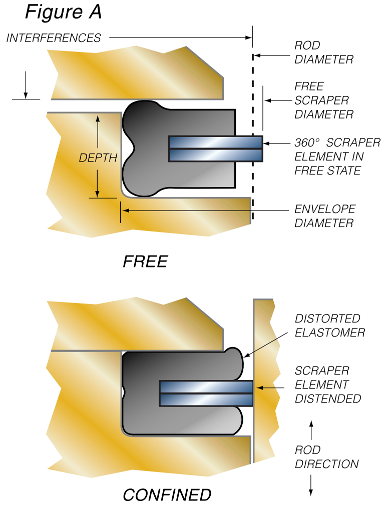
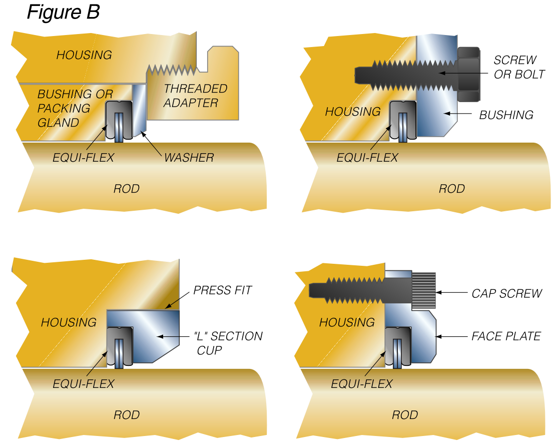


Figure B



Note: Always use a rigid metallic adapter or washer between Equi-Flex and packing or seal.

Application Specifications

To assist you in selecting the right materials and part size for your application, include the following information:

1. A description of the application including rod length, speed of travel, and materials to be wiped from the rod.
2. The type, brand name, product number, etc. for any liquids that may contact the Equi-Flex™ rod wiper/scraper.
3. The exact decimal rod size.
4. The rod finish and hardness (Rockwell C scale).
5. The operational temperature range.
6. The service requirements (number of cycles per minute, hour, day, etc.).

Rod Diameters

Equi-Flex™ rod wiper/scrapers are distended on an arbor and honed to .005" under the normal rod diameter. They may be applied without modification to rods that are .003" larger or smaller than their nominal diameter. If a rod diameter exceeds the honed diameter of an Equi-Flex™ wiper by more than +/-.003", special honing may be required to ensure effective 360º wiping performance.

Friction

The friction experienced by an Equi-Flex™ rod wiper/scraper is primarily determined by the diameter and depth of the elastomer retaining cavity. Standard cavity dimensions ensure tight wiper contact with the rod while maintaining relatively low friction. If an application demands a minimum of drag force, the cavity dimensions can be modified and we can add a special polishing procedure.

Rod Finish and Hardness

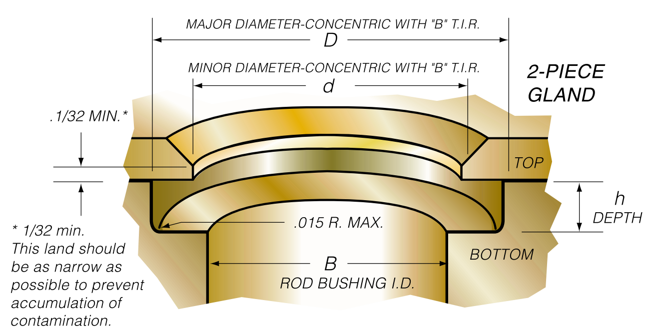
Standard Equi-Flex™ rod wiper/scrapers function best on rods having a surface finish of 25 micro inches RMS or better. The rod should be chrome-plated or hardened to Rockwell C 45 or harder.

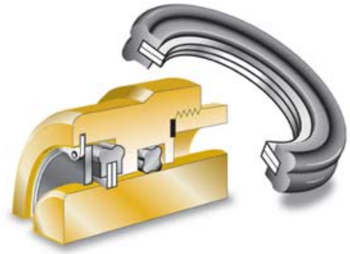
Elastomer Compounds

Standard Equi-Flex™ rod wiper/scrapers consist of elastomers made from a 70 Shore A nitrile material. This material is compatible with most mineral-based oils and other commercial hydraulic fluids. A wide variety of custom elastomer materials is available to meet special application requirements. Commonly used materials and associated physical properties are shown in the table on the proceeding page.

Housing Recess Specifications - Standard Industrial

E/F NUMBER (See Note 1)	ROD DIAMETER NOMINAL	ROD DIAMETER ACTUAL +/-.003 (See Note 2)	ROD BORE ID "B" MAXIMUM	GROOVE DIMENSIONS MAJOR DIA."D" +.005/-.000 (See Note 3)	GROOVE DIMENSIONS DEPTH "h" +.003/-.000 (See Note 3)	GROOVE DIMENSIONS MINOR DIA."d" +.005/-.000 (See Note 3)
109000	1/4	.245	.254	.498	.100	.280
110000	5/16	.307	.316	.562	.100	.342
120000	3/8	.370	.379	.624	.100	.405
130000	7/16	.432	.441	.686	.104	.467
201000	1/2	.495	.504	.769	.104	.530
202000	9/16	.557	.566	.831	.104	.592
203000	5/8	.620	.629	.894	.104	.655
204000	11/16	.682	.691	.956	.104	.717
205000	3/4	.745	.754	1.019	.104	.780
306000	13/16	.807	.820	1.095	.104	.843
307000	7/8	.870	.879	1.157	.104	.905
308000	15/16	.932	.941	1.219	.104	.967
309000	1	.995	1.004	1.282	.104	1.030
310000	1 1/16	1.057	1.066	1.344	.104	1.092
311000	1 1/8	1.120	1.129	1.407	.104	1.155
312000	1 3/16	1.182	1.191	1.469	.104	1.217
313000	1 1/4	1.245	1.254	1.532	.104	1.208
414000	1 5/16	1.307	1.316	1.623	.104	1.342
415000	1 3/8	1.370	1.379	1.686	.104	1.405
417000	1 1/2	1.495	1.504	1.811	.104	1.530
418000	1 5/8	1.620	1.629	1.934	.104	1.655
419000	1 3/4	1.745	1.754	2.061	.104	1.780
420000	1 7/8	1.870	1.879	2.186	.104	1.905
421000	2	1.995	2.004	2.311	.104	2.030
422000	2 1/8	2.120	2.129	2.436	.104	2.155
423000	2 1/4	2.245	2.254	2.561	.104	2.280
424000	2 3/8	2.370	2.379	2.686	.104	2.405
425000	2 1/2	2.495	2.504	2.811	.104	2.530
526000	2 5/8	2.620	2.629	3.000	.119	2.675
527000	2 3/4	2.745	2.754	3.125	.119	2.800
528000	2 7/8	2.870	2.879	3.250	.119	2.925
529000	3	2.995	3.004	3.375	.119	3.050
530000	3 1/8	3.120	3.129	3.500	.119	3.175
531000	3 1/4	3.245	3.254	3.625	.119	3.300
532000	3 3/8	3.370	3.379	3.750	.119	3.425





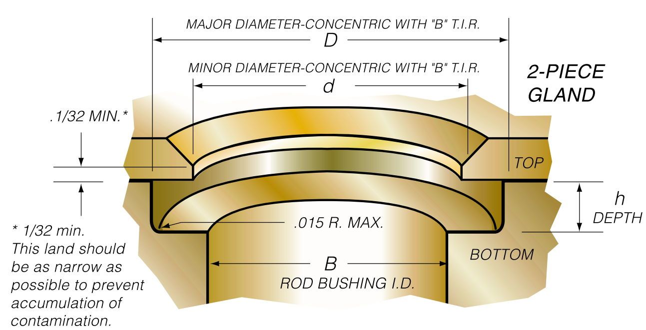
E/F NUMBER (See Note 1)	ROD DIAMETER NOMINAL	ROD DIAMETER ACTUAL +/-.003 (See Note 2)	ROD BORE ID "B" MAXIMUM	GROOVE DIMENSIONS MAJOR DIA."D" +.005/-.000 (See Note 3)	GROOVE DIMENSIONS DEPTH "h" +.003/-.000 (See Note 3)	GROOVE DIMENSIONS MINOR DIA."d" +.005/-.000 (See Note 3)
533000	$3^1/_2$	3.495	3.504	3.875	.119	3.550
534000	$3^5/_8$	3.620	3.629	4.000	.119	3.675
535000	$3^3/_4$	3.745	3.754	4.125	.119	3.800
536000	$3^7/_8$	3.870	3.879	4.250	.119	3.925
637000	4	3.995	4.006	4.439	.135	4.060
638000	$4^1/_8$	4.120	4.018	4.564	.135	4.180
639000	$4^1/_4$	4.245	4.256	4.689	.135	4.310
640000	$4^3/_8$	4.370	4.381	4.814	.135	4.440
641000	$4^1/_2$	4.495	4.506	4.939	.135	4.560
642000	$4^5/_8$	4.920	4.631	5.064	.135	4.680
643000	$4^3/_4$	4.745	4.756	5.189	.135	4.810
644000	$4^7/_8$	4.870	4.881	5.314	.135	4.940
645000	5	4.995	5.006	5.439	.135	5.060
646000	$5^1/_8$	5.120	5.131	5.564	.135	5.185
647000	$5^1/_4$	5.245	5.256	5.689	.135	5.310
648000	$5^3/_8$	5.370	5.381	5.814	.135	5.440
649000	$5^1/_2$	5.495	5.506	5.939	.135	5.560
751000	$5^3/_4$	5.745	5.756	6.251	.151	5.810
753000	6	5.995	6.006	6.501	.151	6.060
754000	$6^1/_4$	6.245	6.256	6.751	.151	6.310
755000	$6^1/_2$	6.495	6.506	7.000	.151	6.560
756000	$6^3/_4$	6.745	6.756	7.250	.151	6.810
757000	7	6.995	7.008	7.500	.151	7.060
758000	$7^1/_4$	7.245	7.258	7.750	.151	7.310
759000	$7^1/_2$	7.495	7.508	8.00	.151	7.560
760000	$7^3/_4$	7.745	7.758	8.250	.151	7.810
761000	8	7.995	8.008	8.500	.151	8.060
762000	$8^1/_2$	8.495	8.508	9.000	.151	8.560
763000	9	8.995	9.008	9.500	.151	9.060
764000	$9^1/_2$	9.495	9.508	10.000	.151	9.560
765000	10	9.995	10.008	10.500	.151	10.060
766000	$10^1/_2$	10.495	10.508	11.000	.151	10.560
767000	11	10.995	11.008	11.500	.166	11.060
869000	12	11.995	12.008	12.500	.166	12.060

Notes:

1. Equi-Flex™ numbers without a letter suffix indicate the standard 70 Shore A nitrile elastomer. It is suitable for most industrial applications. This material is compatible with most mineral-based fluids when used within a temperature range of -65°F to 212°F (-54°C to 100°C).
2. Rod diameters beyond listed dimensions and tolerances may require special honing of the beryllium copper component in the Equi-Flex™ rod wiper/scraper.
3. Any mounting method can be employed, provided the major diameter D, minor diameter d, and depth h, are maintained within specified tolerances. Examples of recommended mounting methods are shown in section 6-35.

Housing Recess Specifications - Aircraft

E/F NUMBER (See Note 1)	ROD DIAMETER NOMINAL	ROD DIAMETER ACTUAL +/-.003 (See Note 2)	ROD BORE ID "B" MAXIMUM	GROOVE DIMENSIONS MAJOR DIA."D" +.005/-.000 (See Note 3 & 4)	GROOVE DIMENSIONS DEPTH "h" +.003/-.000 (See Note 3 & 4)	GROOVE DIMENSIONS MINOR DIA."d" +.005/-.000 (See Note 3 & 4)
109000-A	1/4	.245	.254	.498	.100	.280
110000-A	5/16	.307	.316	.562	.100	.342
120000-A	3/8	.370	.379	.624	.100	.405
130000-A	7/16	.432	.441	.686	.104	.467
201000-A	1/2	.495	.504	.760	.104	.548
202000-A	9/16	.557	.566	.823	.104	.610
203000-A	5/8	.620	.629	.885	.104	.673
204000-A	11/16	.682	.691	.948	.104	.735
205000-A	3/4	.745	.754	1.010	.104	.798
306000-A	13/16	.807	.820	1.086	.104	.866
307000-A	7/8	.870	.879	1.148	.104	.930
308000-A	15/16	.932	.941	1.210	.104	.991
309000-A	1	.995	1.004	1.273	.104	1.054
310000-A	1 1/16	1.057	1.066	1.335	.104	1.116
311000-A	1 1/8	1.120	1.129	1.398	.104	1.179
312000-A	1 3/16	1.182	1.191	1.460	.104	1.241
313000-A	1 1/4	1.245	1.254	1.523	.104	1.304
414000-A	1 5/16	1.307	1.316	1.614	.104	1.375
415000-A	1 3/8	1.370	1.379	1.677	.104	1.438
417000-A	1 1/2	1.495	1.504	1.802	.104	1.563
418000-A	1 5/8	1.620	1.629	1.927	.104	1.688
419000-A	1 3/4	1.745	1.754	2.052	.104	1.813
420000-A	1 7/8	1.870	1.879	2.177	.104	1.938
421000-A	2	1.995	2.004	2.302	.104	2.063
422000-A	2 1/8	2.120	2.129	2.427	.104	2.188
423000-A	2 1/4	2.245	2.254	2.552	.104	2.313
424000-A	2 3/8	2.370	2.379	2.677	.104	2.438
425000-A	2 1/2	2.495	2.504	2.802	.104	2.563
526000-A	2 5/8	2.620	2.629	2.989	.119	2.703
527000-A	2 3/4	2.745	2.754	3.114	.119	2.828
528000-A	2 7/8	2.870	2.879	3.239	.119	2.953
529000-A	3	2.995	3.004	3.364	.119	3.077
530000-A	3 1/8	3.120	3.129	3.489	.119	3.202
531000-A	3 1/4	3.245	3.254	3.614	.119	3.327
532000-A	3 3/8	3.370	3.379	3.739	.119	3.452



E/F NUMBER (See Note 1)	ROD DIAMETER NOMINAL	ROD DIAMETER ACTUAL +/-.003 (See Note 2)	ROD BORE ID "B" MAXIMUM	GROOVE DIMENSIONS MAJOR DIA."D" +.005/-.000 (See Note 3 & 4)	GROOVE DIMENSIONS DEPTH "h" +.003/-.000 (See Note 3 & 4)	GROOVE DIMENSIONS MINOR DIA."d" +.005/-.000 (See Note 3 & 4)
533000-A	$3\frac{1}{2}$	3.495	3.504	3.864	.119	3.577
534000-A	$3\frac{5}{8}$	3.620	3.629	3.989	.119	3.702
535000-A	$3\frac{3}{4}$	3.745	3.754	4.114	.119	3.827
536000-A	$3\frac{7}{8}$	3.870	3.879	4.239	.119	3.952
637000-A	4	3.995	4.006	4.427	.135	4.092
638000-A	$4\frac{1}{8}$	4.120	4.018	4.552	.135	4.217
639000-A	$4\frac{1}{4}$	4.245	4.256	4.677	.135	4.342
640000-A	$4\frac{3}{8}$	4.370	4.381	4.802	.135	4.467
641000-A	$4\frac{1}{2}$	4.495	4.506	4.927	.135	4.592
642000-A	$4\frac{5}{8}$	4.920	4.631	5.052	.135	4.717
643000-A	$4\frac{3}{4}$	4.745	4.756	5.177	.135	4.842
644000-A	$4\frac{7}{8}$	4.870	4.881	5.302	.135	4.967
645000-A	5	4.995	5.006	5.427	.135	5.092
646000-A	$5\frac{1}{8}$	5.120	5.131	5.552	.135	5.217
647000-A	$5\frac{1}{4}$	5.245	5.256	5.677	.135	5.342
648000-A	$5\frac{3}{8}$	5.370	5.381	5.802	.135	5.467
649000-A	$5\frac{1}{2}$	5.495	5.506	5.927	.135	5.592
751000-A	$5\frac{3}{4}$	5.745	5.756	6.239	.151	5.858
753000-A	6	5.995	6.006	6.489	.151	6.108
754000-A	$6\frac{1}{4}$	6.245	6.256	6.739	.151	6.358
755000-A	$6\frac{1}{2}$	6.495	6.506	6.989	.151	6.608
756000-A	$6\frac{3}{4}$	6.745	6.756	7.239	.151	6.858
757000-A	7	6.995	7.008	7.489	.151	7.108
758000-A	$7\frac{1}{4}$	7.245	7.258	7.739	.151	7.354
759000-A	$7\frac{1}{2}$	7.495	7.508	7.989	.151	7.608
760000-A	$7\frac{3}{4}$	7.745	7.758	8.239	.151	7.858
761000-A	8	7.995	8.008	8.489	.151	8.117
762000-A	$8\frac{1}{2}$	8.495	8.508	8.989	.151	8.617
763000-A	9	8.995	9.008	9.489	.151	9.117
764000-A	$9\frac{1}{2}$	9.495	9.508	9.989	.151	9.617
765000-A	10	9.995	10.008	10.489	.151	10.117
766000-A	$10\frac{1}{2}$	10.495	10.508	10.989	.151	10.617
767000-A	11	10.995	11.008	11.489	.166	11.117
869000-A	12	11.995	12.008	12.489	.166	12.117

Notes:

1. Equi-Flex™ numbers with the letter "A" suffix indicate a date coded 70 Shore A nitrile elastomer suitable for aircraft applications. This material is compatible with MIL-H-5606 petroleum-based fluids when used within a temperature range of -65°F to 212°F (-54°C to 100°C).
2. Rod diameters beyond listed dimensions and tolerances may require special honing of the beryllium copper component in the Equi-Flex™ rod wiper/scraper.
3. Listed housing recesses will accommodate MS-28776 of corresponding nominal sizes with modification of only minor diameter d.
4. Second and third digits of Equi-Flex™ numbers, 201000 and up, conform to MS-28776 dash numbers of corresponding sizes.
5. Major diameter D and depth h must be held strictly within indicated dimensions and tolerances.

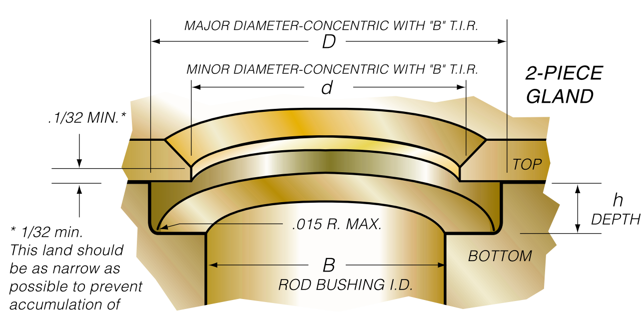
Housing Recess Specifications - Metric

E/F NUMBER (See Note 1 & 2)	ROD DIAMETER +0.00/-0.15mm (See Note 3)	ROD BORE ID "B" MAXIMUM	GROOVE DIMENSIONS MAJOR DIA."D" +0.10/-0.15mm (See Note 4)	DEPTH "h" +0.08mm/-0.00mm (See Note 4)	MINOR DIA."d" +0.13/-0.00mm (See Note 4)
60080	8.00	8.10	14.30	2.54	8.90
60120	12.00	12.10	18.20	2.54	12.90
60160	16.00	16.10	22.70	2.64	16.90
60200	20.00	20.10	26.80	2.64	20.90
60220	22.00	22.10	29.20	2.64	22.90
60250	25.00	25.10	32.00	2.64	25.90
60280	28.00	28.10	35.00	2.64	28.90
60300	30.00	30.10	37.20	2.64	30.90
60320	32.00	32.10	39.00	2.64	32.90
60350	35.00	35.10	42.80	2.64	35.90
60360	36.00	36.10	43.90	2.64	36.90
60400	40.00	40.10	47.90	2.64	40.90
60450	45.00	45.10	53.00	2.64	45.90
60500	50.00	50.10	58.10	2.64	50.90
60550	55.00	55.10	62.80	2.64	55.90
60560	56.00	56.10	63.80	2.64	56.90
60620	62.00	62.10	70.10	2.64	62.90
60630	63.00	63.00	71.10	3.02	63.90
60700	70.00	70.00	79.20	3.02	71.40
60800	80.00	80.00	89.60	3.02	81.40
60900	90.00	90.00	99.70	3.02	91.40
61000	100.00	100.15	109.60	3.43	101.40
61100	110.00	110.15	119.80	3.43	111.40
61250	125.00	125.15	134.80	3.43	126.40
61400	140.00	140.15	150.00	3.83	141.40
61600	160.00	160.15	172.80	3.83	161.60
61800	180.00	180.20	192.80	3.83	181.60
62000	200.00	200.20	212.90	3.83	201.60
62240	224.00	224.20	236.80	3.83	225.60

Notes:

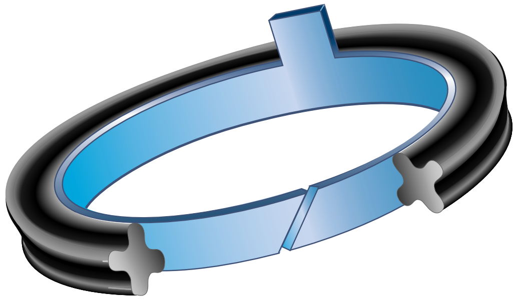
1. Equi-Flex™ numbers without a letter "A" suffix indicate a standard 70 Shore A nitrile elastomer suitable for industrial applications. The 523EU material is compatible with most mineral-based fluids when used within a temperature range of -65°F to 212°F (-54°C to 100°C).
2. Not shown in the table, but also available, are metric Equi-Flex™ rod wiper/scrapers with the letter "A" suffix. The suffix indicates a date coded 70 Shore A nitrile elastomer suitable for industrial applications.

   The date coded 523EU material is compatible with MIL-H-5606 petroleum-based fluids when used within a temperature range of -65°F to 212°F (-54°C to 100°C).



3. Rod diameters beyond listed dimensions and tolerances may require special honing of the beryllium copper component in the Equi-Flex™ rod wiper/scraper.
4. Any mounting method can be employed, providing the major diameter D, minor diameter d, and depth h, are maintained within the specified tolerances. Examples of recommended mounting methods are shown on page 6-35.

Quad® P.E. Plus Brand Plastic Exclusion Seals



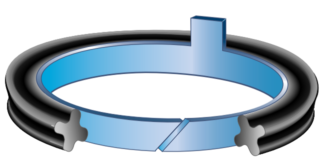
The Quad® P.E. Plus Brand is a patented seal design that combines an injection-molded thermoplastic bearing material with a Quad-Ring® Brand seal, O-ring, or custom seal to form a self-lubricating seal for both rotary and reciprocating seal applications. This seal can be used in applications where some leakage is permissible.

A tab on the thermoplastic ring locks it into the housing or shaft to prevent independent movement of the seal assembly. The ring is split to allow for thermal expansion of the shaft or cylinder.

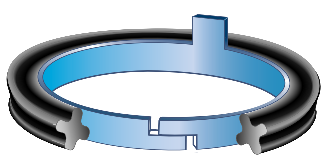
Materials used for the custom-molded Quad® P.E. Plus Brand seal can be specified from a wide range of rubber compounds and high performance thermoplastics.

The characteristically high pressure-velocity values and low coefficients of friction of thermoplastic bearing materials make them ideal for high velocity applications. These thermoplastics are also self-lubricating, which means that a Quad® P.E. Plus Brand seal can be used in continuous applications without external lubrication, a condition that would cause other seals to either burn up quickly, or destroy the surface of the cylinder or shaft it was meant to protect. Versions of the Quad® P.E. Plus Brand seal can be designed to operate in:

- Nonlubricated rotary applications with up to 1200 fpm (457.2 M/min) surface speeds
- Pressure lubricated rotary applications with up to 6500 fpm (1981.2 M/min) surface speeds
- Continuous temperature up to 450°F (232°C)
- Nonlubricated reciprocating applications with an operating life of more than 15 million cycles.



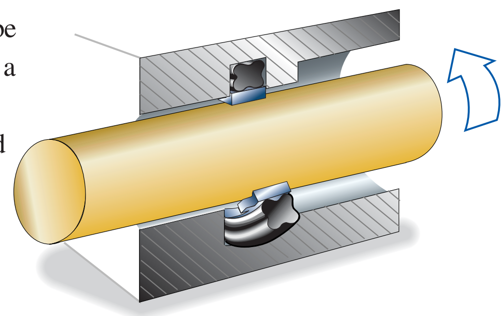
Angle Cut
For thermal expansion



Step-Cut
Minimizes fluid bypass

For rotating shafts

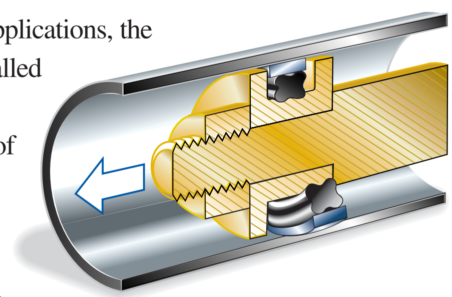
For rotary applications, the thermoplastic ring is split at an angle to allow for thermo-expansion of the metal surface. The thermoplastic ring can also be designed with a step-cut to minimize fluid bypass.



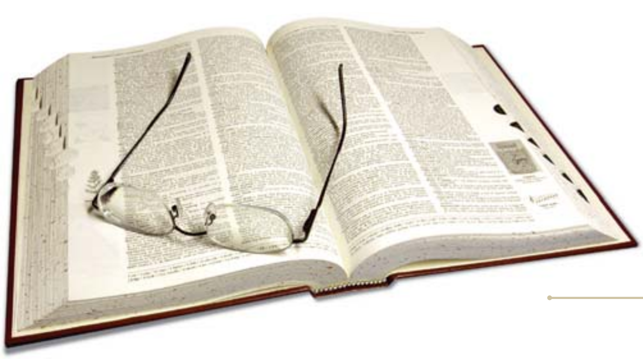
Placed in the housing or on the shaft, the rubber seal squeezes the thermoplastic ring snugly against the sealing surface. The tab on the thermoplastic ring fits into a slot in the groove and prevents the seal from rotating.

Reciprocating Applications

In reciprocating applications, the rubber seal is installed in a groove on the piston (on the ID of the thermoplastic ring) and presses the thermoplastic ring firmly against the cylinder wall. The ring is split to compensate for thermal expansion.



Section 7
Glossary



Glossary

Abrasion: Surface wear caused by relative motion between contacting objects

Age Protection, Active: The use of a chemical additive in a rubber compound which is preferentially attacked by oxygen or ozone thereby sacrificially protecting the rubber.

Age Protection, Passive: The use of a chemical additive in a rubber that will migrate to the surface of a rubber part to form a protective physical barrier.

Aging: The change in physical and chemical characteristics of a rubber compound that has been exposed to a particular environment over time.

Axial: Directed along, or parallel to, an axis. With a seal ring, the axial direction is perpendicular to the plane of the seal, and would be described as the "up and down" direction if the seal ring were to be placed flat upon a desktop.

Backup washer: A washer made from certain material that will add strength or support when installed next to the seal. This prevents the seal from being pinched and evenly distributes the load.

Bore: A hole in a component which permits the passage of a shaft.

Bore Seal: A sealing system, usually in a radial orientation, in which the primary sealing surface is between the O.D. of a seal ring and the I.D. of a bore.

Cavity: The features of a mold which are directly responsible for forming the final shape of a molded part. Mold cavities are formed from two or more mating components of a mold.

Chemical bonding: A method for bonding rubber to secondary parts by applying special adhesives to the part prior to molding.

Circularity: The form tolerance of the surface of a molded or ground ball in reference to a perfect sphere. Also referred to as "roundness."

Clearance (in a sealing system): The space between components in a mechanical system which is present to allow for manufacturing, thermal, and dynamic variations in the size and position of the components. As measured, it is equal to the distance between the sealing surface and the entrance to the seal groove. In a radial sealing system, this will be the space between the O.D. of the shaft or piston and the I.D. of the bore. As the clearance in a system increases, the tendency of the seal to dislodge from the groove and enter into the clearance space also increases, especially in applications where pressure is present. Care should be taken in radial applications to note whether clearances are being stated as radial clearances or as diametral clearances.

Closure Dimension: Any dimension assigned to a feature of a molded part which is parallel to the direction of mold travel and formed by mating cavity components carried on two or more separate mold plates. A closure dimension, by this definition, always spans or references a mold parting line. Closure dimensions typically have larger associated tolerances because of the additional accumulated tolerance due to the creation of the feature from separate, movable, parts of the mold.

Coating: A uniform layer of chemical primers or adhesives applied to a surface to produce a chemical bond between the rubber and substrate. May also refer to special surface treatments that can be applied to rubber to achieve desired properties.

Cold Deck: A component of a mold which is responsible for cooling a cold runner system.

Cold Runner: A molding system whereby material being transferred through the mold's runner is cooled to prevent it from vulcanizing prior to entrance into the mold cavity. This reduces material usage by eliminating the waste of the material which would otherwise vulcanize inside the runner.

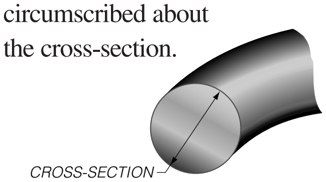
Compound: A mixture of a polymer and associated chemical ingredients necessary to produce a finished rubber material. The term is commonly used when referring to a specific rubber formulation.

Compression Molding: A molding process in which the uncured rubber compound is placed directly into the mold cavity, and compressed to its final shape by the closure of the mold.

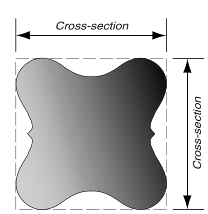
Compression Set: The amount of permanent deformation experienced by a rubber material when compressed for a period of time. The term is commonly used in reference to a test conducted under specific conditions wherein the permanent deformation, expressed as a percentage of the original deflection, is measured after a prescribed period of time. A low compression set is desirable in molded rubber parts such as seals and gaskets, which must retain their dimensions to maintain an effective seal. Compression set is the "end-product" of the process of stress relaxation.

Cross-linking Agents: A chemical or chemicals that bond the polymer chains of a rubber together during the molding process.

Cross-section (of a seal): The axial thickness or radial width of an O-Ring or Quad-Ring® seal. For an O-Ring, this will be the circular diameter of its cross-section. For a Quad-Ring®, this will be the length of a side of a square circumscribed about the cross-section.



O-Ring Cross-section



Quad-Ring® Cross-section

Cross-sectional Reduction (of a seal): The reduction in thickness of a seal's cross-section as a result of material displacement caused by an applied stretch to the seal. *(See also Necking)*

Cross-sectional Compression, Percent (of a seal): The deformation placed on a rubber part to affect a seal. It is expressed as a percentage of the seal's original (undeformed) cross-section. *(See also Squeeze)*

Crush Bead: A deformable feature, normally taking the form of a continuous, small, hemispherical radius, on an insert which is used to help control which surfaces of the part will be covered by rubber during the molding process. During the molding process as the mold closes on the insert, the crush bead is deformed, creating a tight seal which confines rubber to the desired area of the part.

Crush Ring: *See Crush Bead*

Curing: An informal (slang) term for the vulcanizing process that cross-links a rubber to form its characteristic elastic properties. *(See also Vulcanization)*

Damping: The ability of an elastomer to absorb forced vibrational energy.

Deflashing: Any of various processes used to remove extraneous rubber from a molded rubber part.

Durometer: Standard rubber industry term for hardness, which uses an indenter to measure the hardness of molded rubber. While other scales are available, the hardness of rubber is most commonly reported by a durometer using the Shore A scale.

Dynamic Seal: A seal used in an environment that subjects it or a mating surface to movement.

Ejector Pin: A moving pin or set of pins used to remove, normally by pushing, a finished part from a mold cavity at the conclusion of the molding cycle.

Elasticity: A rubber's ability to return to its original size and shape after removal of the stress causing deformation such as stretching, compression, or torsion. It is the opposite of plasticity. The term elasticity is often loosely employed to signify the "stretchiness" of rubber.

Elastomer: Any of various polymers having the elastic properties of rubber.

Extrusion: When part or all of a component is forced from its groove by high continuous or pulsating pressure.

Face Seal: A sealing system in which the sealing occurs in the axial direction of the seal. If the seal ring were to be placed flat upon a desktop, the seal compression would occur between the top and bottom of the seal.

Feather Edge: The sharp, thin edge on parts such as wiper seals and cups. Also called a "knife edge."

Filler: An ingredient added to a rubber formulation. Carbon black and silica are common fillers used in rubber compounds.

Fixed Dimension: Any dimension assigned to a feature of a molded part which is formed from a part of the mold which is machined into a single mold cavity component. Fixed dimensions, since there are fewer variables affecting the formation of the part's feature, typically have smaller associated tolerances than closure dimensions.

Flash: Extraneous material protruding from the surface of a molded part. Flash is generally found on a molded part at the parting line locations.

Flexural strength: The ability of a material to flex without permanent distortion or breaking.

Flow: The movement of heated plastic or uncured rubber to travel in the mold and runner systems during the molding process.

Flow Line: A disturbance in the homogeneous structure of a molded part generally caused when material knitted or blended with itself during the molding operation.

Gasket: A seal used in a static application, where the seal is effected by clamping the gasket between two rigid, flat surfaces. Gaskets can be made from many different types of materials, including paper, plastic, cork, rubber, metal, or a combination thereof.

Gates: The openings in an injection or transfer mold whereby material enters the mold cavity.

Gate Mark: A raised spot or small depression on the surface of an injection or transfer molded part where the gates interface the cavity. *(See also Sprue Mark)*

Gland: The space in a mechanical system into which a seal is installed. The gland consists of the seal groove and any additional space required to achieve the proper compression of the seal. Care should be taken to distinguish between the terms gland and groove, which are separate but related concepts

Gland Depth: The gland depth (pictorially depicted and described as Dimension "C" throughout this book) is the distance from the sealing surface to the seal groove surface. The gland depth determines how much the seal is compressed and therefore how much cross-sectional compression (squeeze) is applied to the seal. In a radial sealing application, the gland depth is used to calculate the seal groove diameter by either adding or subtracting (depending on the type of seal) twice its value from the diameter of the sealing surface. In an axial (face) sealing application, the gland depth equals the groove depth when it is a zero clearance application (two directly contacting surfaces, such as a cover) or, when clearance is present, it is the distance from the sealing surface to the seal groove surface (such as in a rotary face seal application). It should be noted that the Gland depth and the Clearance are separate sealing system parameters and a change in one of these parameters does not result in a change to the other. For example, if the clearance in a system needed to be increased, the required gland depth to achieve the desired seal compression would remain the same, but the seal groove diameter would need to be adjusted to achieve the desired gland depth. Care should also be taken to distinguish between the terms gland depth and groove depth, which are separate but related concepts See the Application section of this publication for more information on calculations involving Gland Depth.

Groove Depth: The measured depth of a feature, frequently a slot, machined or otherwise created in a mechanical system to physically locate and constrain a seal. Care should be taken to distinguish between the terms Gland Depth and Groove Depth, which are separate but related concepts.

Hardness: A measurement of the resistance to penetration of a rubber or TPE sample by an indenter. High values indicate harder materials while low values indicate softer materials. *(See also Durometer, IRHD, and Shore A.)*

Heat Deflection Temperature: The temperature at which a standard plastic test bar deflects 0.010 in. (.254mm) under a stated load of either 66 or 264 psi (4.55 or 18.2 Bar).

Honing: A machining process that sharpens, enlarges, and smoothes material through the use of a fine-grit stone.

Hot Manifold: A mold construction that directs the melted plastic internally within the mold base directly to the cavity thus reducing or eliminating the runner. Also known as "Runnerless molding."

Hot Runner: A mold design that maintains the raw material in a molten state up to or very near the mold cavity.

I.D. (Inner Diameter): The innermost (smallest diameter) surface of a circular object, such as a bore or a round seal. The term I.D. is frequently used to indicate both the circumferential surface itself as well as the measured diameter of that surface.

I.R.H.D. (International Rubber Hardness Degrees): A system of characterizing an elastomer by its resistance to penetration of a known geometry indenter by a known force. The microtechnique is reproducible on irregular as well as flat surfaces and on cross sections as small as 1mm in thickness (.04"). Measurements taken using the IRHD scale are similar, but not identical, to those obtained using the Shore A scale.

Injection Molding: A molding method in which a rubber or plastic material is heated and forced under pressure into the mold cavity.

Insert: A term referring to a metal or plastic component, placed ("inserted") into a mold cavity prior to the start of the molding cycle, to which rubber or plastic is chemically and/or physically bonded during the molding process.

Internally Lubricated Rubber: A rubber formulation containing lubricating materials. An internally lubricated rubber is designed to slowly release the lubricant to the surface of the molded part over time.

Joule Effect: A phenomenon characteristic of rubber where rubber which is in tension, when heated, contracts rather than expanding. This effect only occurs when rubber is subject to strain while being heated - unstrained rubber will expand as it is heated (like most materials). This effect has serious consequences for the design of a high speed, rotary shaft seal using a Quad-Ring® (or o-ring). In order to function correctly, in a free state the seal inside diameter must be larger than the outside diameter of the shaft. The seal groove is then designed such that when the Quad-Ring® is placed in the groove, it is compressed onto the shaft. This prevents the frictional heat and the resulting contraction of the seal due to the Joule effect from initiating a cycle (frictional heat causes contraction, causing more friction, generating more heat, leading to more contraction, etc.) causing rapid seal failure.

Knit Mark: A witness mark on a molded part, often occurring at the midpoint between two transfer or injection sprue locations. It is caused by the incomplete joining of the uncured rubber or plastic from each sprue during the molding process.

Knock outs: Normally pins or blades that, when activated internally to the mold, eject the part from the mold. (Also called "ejector pins.")

Land: A feature of an insert, normally flat, that is pinched against a corresponding mold surface to restrict the flow of rubber and thereby control which surfaces of the insert are covered with rubber and which are not. Occasionally termed a "seal-off."

Mechanical bond: A method of creating a molded part where the rubber is mechanically attached to an overmolded insert through the use of holes, depressions or projections on the insert.

Microhardness: A measurement of rubber hardness for specimens below .25 inches (6.35mm) in thickness. Microhardness, like Shore A durometer, is also a measurement of indentation.

Modulus: A measure of the resistance of a material to deformation. It is measured by the force required to reach a predetermined compression or extension.

Necking: An informal (slang) term for seal cross-sectional reduction.

Non-fill: An unintentional void or absence of material in the rubber structure of a part.

O.D. (Outer Diameter): The outermost (largest diameter) surface of a circular object, such as a shaft or a round seal. The term O.D. is frequently used to indicate both the circumferential surface itself as well as the measured diameter of that surface.

Outgassing: The release of volatile chemical components in the form of a gas from an elastomer when it is placed in a vacuum. These volatile components can have the potential to cause undesirable effects, such as fogging optical system components, interfering with the proper functioning of sensitive electronic circuitry or micromechanical systems, or causing corrosion on components. Certain elastomer formulations are more susceptible to outgassing than others, depending on their ingredients.

Overflow Groove: A groove around the periphery of a mold cavity used to accept any excess material from the cavity during molding. Additional material beyond that which is required to fill the cavity is usually introduced into the cavity to ensure that the part is completely formed and to minimize the presence of entrapped air and voids.

Parting Line: The witness line on the surface of a molded part corresponding to the location where the mold plates were in contact.

Permeation: The diffusion of a medium (generally a gas) through a rubber or plastic material.

Piston Seal: A bore seal in which the seal is mounted in a groove machined into a piston. The term piston seal usually implies an application involving linear reciprocating motion.

Plunger: The ram which applies pressure in the process of injection or transfer molding, forcing the material into the mold cavities. Also called an "injection ram."

Post-curing: The process of baking or autoclaving parts after molding. This process is used to improve the heat and compression set resistance of certain specific elastomers.

Pot: The chamber in a transfer or injection mold where raw material is placed before it is transferred into the cavity.

Primary Sealing Interface: *See Primary Sealing Surface*

Primary Sealing Surface: The primary location in a sealing system where a seal and a mating surface come in contact with the intention of forming a barrier to prevent the passage of some type of medium, such as a fluid or a gas. The Primary Sealing Surface is usually distinguished from other sealing surfaces by the presence of relative motion in the case of a dynamic seal, or by the interface of assembled components in the case of a static seal. This term is often used interchangeably with the more generic term Sealing Surface

Radial: Directed along a radius. With a seal ring, the radial direction is in the plane of the seal, and would be parallel to the desktop were the seal ring to be placed flat upon a desktop. The radial direction is perpendicular to the seal axis.

Reciprocating Seal: A seal used in a linear motion application which experiences a repeated reversal of direction of travel.

Regrind: The re-use of material which has previously been processed in a molding operation.

Reinforcing Agent: An ingredient added to a rubber formulation which enhances the material's mechanical properties. Carbon black is a common reinforcing agent used in rubber.

Resilience: The ability of an elastomer to return to original size and shape after deforming forces are removed.

Rod: *See Shaft*

Rod Seal: A sealing system, usually in a radial orientation, in which the primary sealing surface is between the I.D. of a seal ring and the O.D. of a shaft.

Rotary seal: A seal such as an O-ring or a Quad-Ring® seal, exposed on either the I.D. or O.D. sealing surface to a rotating component (e.g. shaft seals). Minnesota Rubber defines a rotating seal as a "rotary" seal if the rotational surface speed is greater than 20 feet/min.

Runner: The system of passages in an injection mold which carries rubber or plastic materials to the cavity gate.

Seal Groove: A feature, frequently a slot, machined or otherwise created in a mechanical system to physically locate and constrain a seal. Care should be taken to distinguish between the terms Gland and Groove, which are separate but related concepts.

Sealing Interface: *See Sealing Surface*

Sealing Surface: Any location where a seal and a mating surface come in contact with the intention of forming a barrier to prevent the passage of some type of medium, such as a fluid or a gas. This term is often used interchangeably with the more specific term Primary Sealing Surface.

Sealing System: The components and attributes which compose the sealing environment, including the seal, the components being sealed, the medium or media being sealed, and the environmental conditions such as temperature, pressure, and motion.

Seal-off: *See Land*

Shaft: A load-bearing and/or power-transmitting member of a mechanical system which is generally cylindrical in shape and frequently rotates or reciprocates.

Glossary-continued

Shore A: A hardness scale used to measure the hardness of molded rubber and TPE's. The Shore A scale is most effectively used to measure rubber with a hardness from 10 to 95 Shore A. For materials harder than 90 to 95 Shore A, the Shore D scale is recommended. *(See also Durometer)*

Shore M: A durometer hardness instrument using a microindicator, designed for the purpose of measuring o-ring hardness.

Short shot: A condition where there is insufficient material introduced into a mold cavity to completely fill the cavity, resulting in a partially formed part.

Shrinkage: The linear contraction upon cooling of a molded rubber or thermoplastic part.

Sliding Core: A component in a mold that automatically retracts when the mold opens.

Specific Gravity: The ratio of the mass of a unit volume of a material to that of the same volume of water at a specified temperature.

Sphericity: Term formerly used to denote Circularity

Spiral Twist: A type of seal failure in reciprocating applications that results from a twisting action that strains or ruptures the rubber.

Sprue: The primary feed channel that runs from the outer face of an injection or transfer mold to the mold gate in a single cavity mold or to runners in a multiple-cavity mold.

Sprue Mark: A small raised spot or depression left on the surface of an injection or transfer molded part. The sprues are the locations at which the elastomer enters into the mold cavity. Also called "gate mark."

Squeeze: An informal (slang) term for the deformation placed on a rubber part to affect a seal. Although it is usually expressed as a percentage of a seal's original (undeformed) cross-section, it is also occasionally expressed as an absolute value of the deformation. *(See also Cross-sectional Compression, Percent)*

Static Seal: A seal that, except for pulsations caused by cycle pressure, does not move in its environment.

Statistical Process Control (SPC): The use of statistical techniques on processes and their output to establish process stability and increase capabilities.

Strain: The deformation caused by an applied stress.

Stress: Force per original cross section that is applied to a specimen.

Stress Relaxation: Decreasing stress with constant strain over a given time interval (viscoelastic response).

Surface Finish: A term usually used in reference to the roughness parameter of a surface's texture, generally expressed in units of microinches (μin) or micrometers (μm).

Swell: The linear or volumetric change of a material resulting from immersion in a particular liquid for a specified period of time. Swell is a general indicator of the compatibility of a material for use in a particular environment.

Tear Strength: The force required to rupture a sample of stated geometry.

Tensile Strength: The extension force per cross-sectional area required to fracture a material specimen.

Thermoplastic: A material which when thermally processed undergoes a reversible phase change to become plastic and capable of being molded to a desired shape. Upon cooling, the material reverts to its original properties.

Thermoplastic Elastomer (TPE): A material which combines the processing characteristics of a plastic but displays rubber-like properties upon completion of processing.

Thermoset: A material, either an elastomer or plastic, which when thermally processed undergoes an irreversible chemical reaction to achieve its final material state.

Total Indicator Reading (TIR): A term used to indicate how the measurement of the roundness of a part, as rotated about its center-line, should be interpreted.

Transfer Molding: A method of molding in which material is placed in a pot located between the top plate and plunger and squeezed from the pot through sprues into the mold cavity.

Ultimate Elongation: Expressed as a percentage of its original length, a measure of how far a material will stretch before breaking.

Undercut: A feature on a part which has a corresponding feature in the part's mold which is perpendicular to the direction of mold movement. An undercut complicates the manufacture of a molded part by making it difficult to remove the finished part from the mold.

Viscosity: The measurement of the resistance of a material to flow under stress.

Volume Change: The measure of the swell or shrinkage of a material resulting from immersion in a particular media (usually a liquid) for a specified period of time at a specified temperature.

Vulcanization: The thermally initiated, irreversible process whereby polymer chains are cross-linked to form the final physical and chemical state of a rubber.

Weathering: The detrimental effect upon an elastomer or plastic after outdoor exposure.

Important Notice:

All statements, technical information and recommendations herein are based on tests we believe to be reliable, but the accuracy or completeness thereof is not guaranteed. NEITHER SELLER NOR MANUFACTURER SHALL BE LIABLE EITHER IN TORT OR IN CONTRACT FOR ANY LOSS OR DAMAGE, DIRECT, INCIDENTAL, OR CONSEQUENTIAL, ARISING OUT OF THE USE OF OR THE INABILITY TO USE THE PRODUCT. No statement or recommendation not contained herein shall have any force or effect unless in an agreement signed by officers of seller and manufacturer.

Minnesota Rubber & Plastics
Quadion Corporation

1100 Xenium Lane North
Minneapolis, MN 55441-7000
(952) 927-1400
Fax (952) 927-1470
www.mnrubber.com

Mar-Kell Seal Global Express
Quadion Corporation

11233 Condor Avenue
Fountain Valley, CA 92708
(714) 546-0994
Fax (714) 546-7614
www.mnrubber.com

Minnesota Rubber & Plastics
Quadion Corporation

Unit C, 5/Floor,
ZAO FONG UNIVERSE BUILDING
No 1800, Zhongshan West Road
Shanghai, 200235
P.R. China
China: 86 (21) 6440 1282
U.S.: 952-927-1400
e-mail: jshen@mnrubber.com
www.mnrubber.com

Minnesota Rubber & Plastics
Quadion Corporation

13 Tuas Avenue 10
Singapore 639137
Tel: (65) 6 861.4111
Fax: (65) 6 861.8277
e-mail: mrap@mnrubber.com
www.mnrubber.com

Minnesota Rubber & Plastics
Quadion Corporation

155 Route de Paris
27120 Pacy-sur-Eure
FRANCE
Tel: +33 (0) 2 32 22 24 26
INDIGO +33 (0) 820 320 751
Fax: +33 (0) 2 32 22 24 27
e-mail: commercial@mnrubber.com
www.mrerubber.com

70-8-3200-30

Minnesota Rubber & Plastics
Quadion Corporation

Engineered to improve performance.
Designed to reduce costs.