THE SEAL MAN'S O-RING HANDBOOK™

- 13 O-Ring Materials
- Over 4,000 Sizes Listed
- Complete Design Information
- Every Metric & Inch Size O-Ring
- 2,073 Fluid Compatibility Listings

EPM, INC. The Seal Man™

EPM - TOUGH SEALS
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**47 Billion Seals in Stock!**

*Actually, that’s not true….it’s closer to 156 Billion….and we don’t really stock them, but - we can make any inch size up to nearly 60 inches outside or any metric size up to 1500 MM seal in a hurry!*

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<td>(SC, TC, SB &amp; TB) RUBBER O.D. WITH METAL MOLDED IN TO 30” / 760MM</td>
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“**These guys are GOOD!**”

Inside Sales - PT Distributor

“On a scale of 1 to 10, I rate EPM a 10. These guys are GOOD! They have very friendly and experienced inside sales people. I can recommend you call EPM when you need seals … especially odd ball, hard-to-find and METRICS!”

We make the seals!

Using our SEAL-MASTER Instant Seal Manufacturing Machine, we can ship Seals FAST!!!

ASK ABOUT OUR GUARANTEED SAME DAY SHIPPING

**METRICS NO PROBLEM FROM 1 PC TO 100,000**

SEND US THE SEALS - WE’LL IDENTIFY AND SIZE THEM FOR YOU

E-Mail Address - seals@epm.com  See us on the Internet http://www.epm.com

**EPM, INC.**

The Seal Capital of America

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SUITE G
STOCKBRIDGE (ATLANTA)
GA 30281 USA

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Phone: (800) 659-5050  Fax: (888) 353-7325  Web: www.epm.com
Who is The Seal Man™?

Introducing, Mr. Jerry Whitlock, The Seal Man™

There is an old marketing strategy which says, “become known by that which your customers call you.” Over 30 years ago, the customers of Jerry Whitlock began to call him “The Seal Man” because they realized that he was one of the most knowledgeable seal and gasket specialists in the entire world. Jerry’s experience has carried him around the world as a sought after business man, consultant, advisor, lecturer, training instructor and on-site trouble shooter. The Seal Man’s specialties include solutions for high pressure and high temperature sealing applications; large diameter seals and packings; rotating and reciprocating equipment sealing applications specialist; oil seals and any joint gasketing problem solving. To quote Jerry Whitlock - “There is NO international standard or special seal that we cannot provide - NONE. I can guarantee you, if I cannot supply you the seal or gasket you need, it probably does not exist.”

Jerry Whitlock:
• acts as a consultant to international seal and gasket firms.
• is available to companies outside the U.S. who need assistance establishing seal and gasket or industrial business in the U.S.
• has market studies available for the U.S. seal and gasket market.
• is a specialist in Internet marketing.
• has traveled extensively.

Mr. Whitlock is available for interviews for TV, radio, newspaper, and magazine.

Subjects of specialty:
• Cyber Executive
• Internet Marketing
• E-Commerce / Electronic Commerce
• Industrial Marketing
• Marketing
• Business Management
• Import / Export

• Seals & Gasket Marketing
• International Business
• Industrial Distribution in the U.S.
• Largemouth Bass Fishing
• Lake Oconee, GA
• Hybrid Bass Fishing
What Is An O-Ring?

O-Ring Description
An O-Ring is a torus, or doughnut-shaped object, generally made from an elastomer. O-Rings can also be made in PTFE and other plastic materials, and in metals, both hollow and solid. They are used primarily for sealing. Another use is for light duty drive belts.

Basic Principles
An O-Ring seal is a means for closing off a passageway preventing an unwanted escape or loss of fluid. The seal consists of an O-Ring installed in a gland and is exactly that - a circular run in which the elastomeric material has a section that is virtually circle. The gland is the cavity (usually within metal) into which the O-Ring is placed. The combination of these two elements comprises an O-Ring seal.

Use
O-Rings are used in two general design applications: static (non-moving) and dynamic (moving). Static applications may range from vacuum to over 60,000 psi for sealing flanges and O-Ring grooves. O-Ring seals with lobed cross sections were designed for both static and dynamic applications. The four and six lobed configurations resist spiral failure and also extrusion failure in applications with large clearance between parts. Of the some 20 different types of O-Ring seals available, the common round cross section O-Ring type is the most versatile. The conventional type of O-Ring may be used in almost any application if the gland to contain the seal is designd correctly and the right size and material is chosen.

Operation
All fluid-tight seals are characterized by the absence of any passage by which fluid might escape. Detail differences exist in the manner by which zero clearance is obtained - welding, brazing, soldering, ground or lapped fits or the yielding of a softer material wholly or partially confined between two harder and stiffer members of the structure. The O-Ring seal falls in the latter class. The rubber seal should be considered as an incompressible, viscous fluid having a very high surface tension. Now, whether by mechanical pressure from the surrounding structure or whether by pressure transmitted through hydraulic fluid, this extremely viscous fluid (the elastomeric O-Ring) is forced to flow in the gland to produce zero clearance or a positive block to the flow of the less viscous fluid being sealed. The rubber absorbs the stack-up of tolerances of the unit and its memory maintains a sealed condition.
How To Achieve Optimum Performance of An O-Ring

The successful use of O-Rings depends upon many factors:

A. **Surface Finish** - All metal surfaces over which the O-Ring moves should be held to a maximum finish of 16 RMS, although the groove finish can have a maximum of 32 RMS. There should be no nicks, burrs, or scratches.

B. **Metals** - All metals over which an O-Ring moves should have a hard surface such as steel, nickel-plated, or chrome-plated. Special attention should be given if you select soft metals such as aluminum, brass, or bronze.

C. **Excessive Metal Clearance** - Clearances should be held to the recommended maximum diametrical tolerance. Consideration must be given to the breathing of cylinder in your calculations - which is the possibility of the cylinder bore to expand or balloon out at its center.

D. **Concentricity** - It is important to hold eccentricity within the recommended practice and to design for sufficient bearing area to take care of side loads or off center loading.

E. **Cleanliness** - All systems should be kept clean and free from dirt, grit, chips, and any foreign materials. Any type of abrasive material will cut the O-Ring. When replacing a failed O-Ring, look for tiny metal chips embedded into the O-Ring, which could mean a pump problem.

F. **Squeeze (preload)** - For good sealing, the minimum diametrical squeeze should be observed. Where pressures are low and friction is critical, the amount of squeeze can be decreased but caution should be exercised.

G. **Lubrication** - When used in pneumatic systems, O-Rings should be lubricated. If permitted to run dry, then they will face abrasion and twisting.

H. **Groove Design** - Proper design is a most essential factor in the successful operation of O-Rings. The rectangular shaped groove is recommended except for special applications.
O-Ring Characteristics

An early and prominent user of O-Rings cites characteristics of O-Ring seals of interest to designers. The more general characteristics are:

A. The seals can be made perfectly leak-proof for cases of static pistons and cylinders for fluid pressures up to 5,000 psi (limit of test pressure). The pressure may be constant or variable.

B. The seals can be made to seal satisfactorily between reciprocating pistons and cylinders at any fluid pressure up to 5,000 psi. There may be slight running leakage (a few drops per hundred strokes) depending on the film forming ability of the hydraulic medium. O-Rings can be used between rotating members with similar results but in all cases the surface rubbing speed must be kept low.

C. A single O-Ring will seal with pressure applied alternately on one side and then on the other side. However, in cases of severe loading or usage under necessarily unfavorable conditions, seal life can be extended by designing the mechanism so that each seal is subjected to pressure in one direction only. Seals may be arranged in series as a safety measure, but the first seal exposed to pressure will take full load.

D. O-Ring seals must be radially compressed between the bottom of the seal groove and the cylinder wall for proper sealing action. This compression may cause the seal to roll slightly in its groove under certain conditions of piston motion, but the rolling action is not necessary for normal operation of the seals.

E. In either static or moving applications, when the O-Ring seal is under high pressure the primary cause of seal failure is extrusion of the seal material into the piston-cylinder clearance. The major factors affecting extrusion are fluid pressure, seal hardness and strength, and piston-cylinder clearance.

F. Moving seals may fail by abrasion against the cylinder or piston walls. Therefore, the contacting surfaces should be suitably finished for long seal life. Moving seals that pass over ports or surface irregularities, while under hydraulic pressure, are very quickly cut or worn to failure.

O-Ring Limitations

Although it has been stated that O-Rings offer a reasonable approach to the ideal hydraulic seal, they should not be considered the immediate solution to all sealing problems. It has been brought out in the forgoing discussion that there are certain definite limitations on their use, for example, high temperature, high rubbing speeds, cylinder ports over which seals must pass, and large clearances. Disregard for these limitations will result in poor seal performance. Piston rings, lip type seals, lapped fits, flat gaskets and pipe fitting all have their special places in hydraulic design, but where the design specifications permit the proper use of O-Rings, they will be found to give long and dependable service.²

While no claim is made that an O-Ring will serve best in all conditions, it merits consideration for most seal applications except:

A. Rotary speeds exceeding 1,500 feet per minute
B. An environment completely incompatible with any elastomeric material.
C. Just plain insufficient structure (for anything but a flat gasket).

O-Ring Life Cycle

1. Installation of O-Ring
2. Pressure Applied to O-Ring (Ideal)
3. Extrusion of O-Ring
4. Failure of O-Ring

Major Dynamic Sealing Problems

**FRICTION**

Friction is the rubbing force or resistance to motion between two surfaces that are touching each other.

Example: Seal material touching metal.

<table>
<thead>
<tr>
<th>Variable</th>
<th>To Reduce Friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Fluid pressure on seal</td>
<td>Reduce pressure (seldom practical).</td>
</tr>
<tr>
<td>B. Surface Finish</td>
<td>Smooth to 2µ - 4µ (10 microinches) RMS maximum.</td>
</tr>
<tr>
<td>C. Seal material hardness</td>
<td>Select softer material for squeeze seals; usually select a harder material for lip seals.</td>
</tr>
<tr>
<td>D. Seal material temperature</td>
<td>Cool the fluid and seal; if this is not possible, use smaller seal cross-section or larger groove to reduce hot squeeze.</td>
</tr>
<tr>
<td>E. Contact area between metal and seal</td>
<td>Reduce width of contact line of lip-type seal; increase width of line of squeeze-type seals (low pressure applications).</td>
</tr>
<tr>
<td>F. Lubricity of fluid</td>
<td>Select higher-lubricity fluid.</td>
</tr>
<tr>
<td>G. Coefficient of friction of seal material</td>
<td>Use low-coefficient compound if system must run dry; check dry lubricant additives and/or fiber reinforcement for retention of limited lubricant (if well lubricated, coefficient of dry seal compound has little relevance).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variable</th>
<th>To Reduce Friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>H. Shape of surface irregularities</td>
<td>No sharp angles; shallower angle to surface (seldom practical).</td>
</tr>
<tr>
<td>I. Fluid entrapment between seal and metal</td>
<td>Experiment with higher-viscosity fluid, lower contact force, lip shape, fiber reinforcement for lube “wicking.”</td>
</tr>
<tr>
<td>J. Orientation of surface irregularities</td>
<td>Hone linearly for axial orientation of tool marks (seldom practical due to increased leakage).</td>
</tr>
<tr>
<td>K. Time-at-rest between seal and metal</td>
<td>Reduce time between movements.</td>
</tr>
<tr>
<td>L. Speed of surface motion</td>
<td>Increase speed; this will increase hydroplaning and related leakage.</td>
</tr>
<tr>
<td>M. Compression forces on seal</td>
<td>Reduce squeeze on seal; avoid putting squeeze on heel of seals.</td>
</tr>
<tr>
<td>N. Direction of motion</td>
<td>Select seal shape less prone to wedging in critical direction.</td>
</tr>
<tr>
<td>O. Extrusion of seal into clearance gap (jamming)</td>
<td>Reduce clearance gap; use anti-extrusion device and/or extrusion resistant seal.</td>
</tr>
</tbody>
</table>
Major Dynamic Sealing Problems

WEAR

Wear - to diminish gradually by friction and rubbing motion.

Like a pencil eraser, an O-Ring is being worn away even though you may not see it until failure.
Major Dynamic Sealing Problems

SEALABILITY

Sealability is the ability of a material to conform to a surface to block the flow of a liquid.
Major Dynamic Sealing Problems

STABILITY

Stability is the ability of a seal to resist rolling, twisting and shifting in a groove.
Major Dynamic Sealing Problems

EXTRUSION

Extrusion is the flowing of the seal’s body into the clearance gap under pressure.
Conformability

Conformability is the ability of a seal compound to fill or dam the minute irregularities that are in the metal surface.
Why Do O-Rings Fail?

O-Rings, made of an elastomeric material, are unlike other materials. The reason for this is because in order for an O-Ring to function properly it has to deform. Once an O-Ring is installed into a gland it is then compressed resulting in zero clearance. It’s that zero clearance that seals the flow of fluids and gases. As the actuating pressure increases, so does the force acting on the surfaces, making a tighter seal and deforming the O-Ring. This sealing procedure works well for a lot of fluid-power systems. However, in order for it to work well it requires careful design, selection, and installation procedures.

The combined effects of different environmental factors usually result in a typical O-Ring failure. Some of the most common causes of an O-Ring failure are:

A. Incompatibility between the O-Ring material and the fluid it is to seal.  
   (See our Fluid Compatibility Guide on pages 44-103)
B. The wrong O-Ring size.
C. O-Ring not installed correctly.
D. Improper gland design. This allows for too much compression and too little compression, not enough room for displacement under compression, or tolerance stack-up.
E. Not enough O-Ring lubrication.
O-Ring Failure Analysis

COMPRESSION SET

Description of failure appearance:
This failure is common to both static and dynamic sealing applications. This type of failure produces flat surfaces on the sides of the O-Ring that were compressed, usually the top and bottom if sitting flat on a desk.

The sources of COMPRESSION SET failure:
• The O-Ring material used has poor compression set resistance
• The O-Ring material used has limited resistance to heat
• The O-Ring is swelling in the groove due to fluid incompatibility
• The O-Ring has too much squeeze in the groove

How to eliminate COMPRESSION SET failure:
• Use a higher quality, low compression set material
• Check the compatibility of the O-Ring material to the fluid
• Select a material good for heat produced in operation
• Double check the groove dimensions for proper squeeze
• Check existing O-Ring stock for physical properties
O-Ring Failure Analysis

ABRASION

Description of failure appearance:
This failure is most common in dynamic sealing applications - like reciprocating and rotating shafts. This type of failure produces a flattened surface on the side of the O-Ring body subjected to the movement.

The sources of ABRASION failure:
• The metal surfaces are too rough and are abrasive to the O-Ring
• The metal surfaces are too smooth, not allowing proper lubrication
• No lubrication in the design
• Operating temperatures are too high for the material
• The system fluid is contaminated with abrasive particles

How to eliminate ABRASION failure:
• Change surface finishes to recommended
• Arrange for better lubrication
• Use a material suitable for higher temperatures
• Eliminate any source of contamination
• Change to a more abrasion resistant O-Ring material
O-Ring Failure Analysis

INSTALLATION

Description of failure appearance:
This failure can occur in both static and dynamic O-Rings. Short nicks or scratches or peeling on the surface of the O-Ring can be noticed.

The sources of INSTALLATION failure:
• The use of sharp edged tools
• Sharp corners on the O-Ring groove
• Sharp threads that the O-Ring passes over
• No lead-in chamfer
• O-Ring was not lubricated
• O-Ring was twisted or trapped between metal surfaces
• Poor quality of the material

How to eliminate INSTALLATION failure:
• Cover all threads with masking tape
• Break all sharp edges
• Create a 15 to 20 degree lead-in chamfer
• Lubricate O-Ring during installation
• Use correct sized O-Ring
O-Ring Failure Analysis

EXPLOSIVE DECOMPRESSION

Description of failure appearance:
You will find random ruptures, crater-like pores and small slits, which have originated within the body of the O-Ring.

The sources of EXPLOSIVE DECOMPRESSION failure:
- Gases permeating the O-Ring material
- Rapid decompression of those gases
- Micro-explosions occurring as decompression takes place

How to eliminate EXPLOSIVE DECOMPRESSION failure:
- Slow system cycles down
- Increase time for decompression
- Replace with a harder material
- Select a smaller O-Ring cross section
O-Ring Failure Analysis

HEAT HARDENING AND OXIDATION

Description of failure appearance:
You will see this failure in both static and dynamic O-Rings. A flattened area will appear on the dynamic surface. Sometimes cracked, hardened and pitted areas can be seen throughout the entire body of the O-Ring.

The sources of HEAT HARDENING AND OXIDATION:
- Temperatures higher than recommended for the material
- Elastomers becoming dry and portions of the material evaporating
- Oxidation

How to eliminate HEAT HARDENING AND OXIDATION:
- Lower the operating temperatures of the system
- Use O-Rings rated for higher temperatures
O-Ring Failure Analysis

SPIRAL DAMAGE

Description of failure appearance:
The surface of the O-Ring appears to have been twisted, or to have rolled in its groove or against a reciprocating rod. It stays in this position when freed.

The sources of SPIRAL DAMAGE:
• Side loads causing excessive clearance
• Mis-fit components
• No suitable lubrication
• Material too soft
• Moving speed too slow
• Surfaces are uneven

How to eliminate SPIRAL DAMAGE:
• Decrease the clearances between components
• Check for roundness of fitting parts
• Machine surfaces to suitable finishes
• Provide lubrication
• Select a harder material
• Add a back-up ring
O-Ring Failure Analysis

EXTRUSION

Description of failure appearance:
You will see a ridge, nibbles and small missing pieces of the material along either the inner diameter or outer diameter due from the down-stream side of the O-Ring.

The sources of EXTRUSION:
- Excessive system pressures
- Too much clearance between mating parts
- Material too soft
- O-Ring body too large for the groove
- Improperly machined groove
- Attack by system fluid

How to eliminate EXTRUSION:
- Decrease or regulate system pressure
- Refit mating parts, machining back to proper, concentric fit
- Select a harder material
- Determine correct O-Ring cross section size
- Add back-up rings
- Re-machine groove to include clean, smooth groove edges
- Replace O-Ring with different type of seal
O-Ring Failure Analysis

EXCESSIVE SWELL

Description of failure appearance:
Identified by obvious dimension of the body of the O-Ring. Reduced physical properties, which causes improper fit. Heat and friction excelerates seal failure.

The source of EXCESSIVE SWELL:
• The material absorbs system fluids causing swelling
• An obvious chemical incompatibility

How to eliminate EXCESSIVE SWELL:
• Test material for fluid compatibility
• Consult a chemical compatability chart to determine suitable material
O-Ring Failure Analysis

WEATHERING OR OZONE CRACKING

Description of failure appearance:
Exposure of either static or dynamic sealing O-Ring to weather, atmosphere, polutions and ultra-violet light.

The source of WEATHERING OR OZONE CRACKING:
• Attack of the polymer chains, destruction of the material causing cracking

How to eliminate WEATHERING OR OZONE CRACKING:
• Select a material that resists ozone exposure
O-Ring Failure Analysis

NO APPARENT REASON FOR FAILURE

Description of failure appearance:
Difficult to pin-point due to non-obvious, unseen reasons

The source of NO APPARENT REASON FOR FAILURE:
- Combined tolerances of all components not correct
- Not enough squeeze
- Parts not fitting properly
- Components not round
- Too much flash, remaining rubber on O-Ring
- Improper groove shape

How to eliminate NO APPARENT REASON FOR FAILURE:
- Re-machine all parts for proper sizing tolerances
- Make sure the amount of squeeze is correct
- Double check the design
- Replace components not fitted correctly
- Select a different material or O-Ring source for clean ground outer diameters
- Check published data for groove shapes and sizing
Hydraulic cylinder seals cost the manufacturer pennies. They are usually purchased on a low bid basis. But, that simple, inexpensive seal can cost you thousands in downtime and loss of production if it fails. If you have a problem seal, focus on these four points to help determine the cause of failure.

1. Improper installation is a major cause of seal failure. The important things to be watched during seal installation are: (a) cleanliness, (b) protecting the seal from nicks and cuts, and (c) proper lubrication. Other problem areas are over tightening of the seal gland where there is an adjustable gland follower or folding over a seal lip during installation. Installing the seal upside down is a common occurrence, too. The solution to these problems is common sense and taking reasonable care during assembly.

2. System contamination is another major factor in hydraulic seal failure. It is usually caused by external elements such as dirt, grit, mud, dust even ice and internal contamination from circulating metal chips, break-down products of fluid, hoses or other degradable system components. As contamination can be prevented by a proper filtering of system fluid. Contamination is indicated by scored road and cylinder bore surfaces, excessive seal wear and leakage - and sometimes tiny pieces of metal imbedded in the seal.

3. Chemical breakdown of the seal material is most often the result of incorrect material selection in the first place or a change of hydraulic system fluid. Misapplication or use of non-compatible materials can lead to chemical attack on the seal by fluid additives, hydrolysis anoxidation reduction of seal elements. Chemical breakdown can result in loss of seal lip interface, softening of seal durometer, excessive swelling or shrinkage. Discoloration of the seal can also be an indicator of chemical attack.

continued on next page...
4. **Heat degradation** is to be suspected when the failed seal exhibits a hard, brittle appearance and/or shows a breaking away of parts of the seal lip or body. Heat degradation results in loss of sealing lip effectiveness through, excessive compression set and/or loss of seal material. Causes of their condition may be use of incorrect seal material, high dynamic friction, excessive lip loading, no heel clearance and proximity to outside heat source. Correction of heat degradation problems may involve reducing seal lip interference, increasing lubrication, or a change of the seal material. In borderline situations consider all upper temperature limits to be increased by 50 degrees Fahrenheit in hydraulic cylinder seals at the seal interface due to running friction caused by the sliding action of the lips.

Here’s a secret - it is not necessary to buy replacement seals from the original hydraulic cylinder manufacturer. Many seal suppliers have the same exact seals that are used in most hydraulic cylinders and can easily cross reference or match up a replacement. In many cases, if there is a recurring problem with a seal, our seal specialist can recommend a solution and increase the life of the seal.

Jerry Whitlock is known as The Seal Man™. He has over 30 years experience in the seal industry. Jerry owns and operates EPM, Inc. located in Atlanta, GA. His web site - [www.epm.com](http://www.epm.com) - is the largest and most visited web site for seals on the internet.

**More O-Ring Failure Information**
See our complete [O-Ring Failure Analysis](http://www.epm.com) section beginning on page 17 for more detailed information about O-Ring failures. Also, you can contact your EPM Customer Helper and ask about our Free Seal Failure Analysis.
Other Seal Types That Will Replace O-Rings

Any of the seal types below can be used in the place of an O-Ring.

EPM can supply any of these seals.
Material Selection Guide

Here is a list of available O-Ring materials. Material usage will depend upon the environment the O-Ring is to be used in. Various fluids, gases, temperatures, and other environmental properties will affect the material. Please review this guide and our Fluid Compatibility Guide on pages 44-103 to help you in your material selection.

*Note: This is to serve as a reference guide only. Please contact your EPM Customer Helper regarding any questions or for more information on any material.

<table>
<thead>
<tr>
<th>Seal Material</th>
<th>Hardness</th>
<th>Color</th>
<th>Temperature Limits</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPU Polyurethane</td>
<td>95</td>
<td>Red (could also be Natural Milky White or honey Colored)</td>
<td>-22 to 230°F</td>
<td>Use in: Hydraulic cylinders as rod seals and piston seals. This material is most commonly used as hydraulic u-cups, rod wipers and packings. Description: This is a high performance material with improved resistance to hot water (up to 200°F) makes it ideally suited for mining applications where water based hydraulic fluids are used. Can be used for pressures to 6000 psi. It is excellent in oil based hydraulic fluids. Great abrasion resistance. Resistant to most oils, fuels, and gases. Can be used successfully as a drive belt of various shapes. Characteristics: Plastic-like. Shiny surface finish. Difficult to stretch.</td>
</tr>
</tbody>
</table>

See page 37 for a hardness scale.
# Material Selection Guide

<table>
<thead>
<tr>
<th>Seal Material</th>
<th>Hardness Machined O-Ring</th>
<th>Molded O-Ring</th>
<th>Color</th>
<th>Temperature Limits</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NBR</strong> Nitrile Rubber</td>
<td>85</td>
<td>70 70FDA 70NSF 90</td>
<td>Black</td>
<td>-22 to 210°F</td>
<td><strong>Use in:</strong> Pneumatic seals, O-Rings, oil seal lips, gaskets, washers and low pressure hydraulic seals. Can be used with a back-up ring in higher pressure applications. This is the most popular O-Ring material. <strong>Description:</strong> General purpose elastomer for use as seal energizer or low pressure applications such as hydraulics and pneumatics. Resistant to oils, hydraulic fluids, water fuels, and gases. Not suited for use in brake fluids. Good abrasion resistance. Good resistance to compression set. High tensile strength. <strong>Characteristics:</strong> Rubber-like elastomer. Dull finish. Some NBR O-Rings have a very shiny surface.</td>
</tr>
<tr>
<td><strong>HNBR</strong> Highly Saturated Nitrile Rubber</td>
<td>85</td>
<td>70 90</td>
<td>Black</td>
<td>-13 to 302°F</td>
<td><strong>Use in:</strong> Seal and gasket application requiring additional resistance to chemicals and slightly higher temperatures than can be handled with NBR. O-Rings, washers, rod and piston seals, back-up rings, and gaskets. <strong>Description:</strong> HNBR is achieved by hydrogenated NBR. Greatly improved wear and extrusion resistance over standard NBR. Good chemical compatibility and can be used with oils which have aggressive additives. Has an extended high temperature range. <strong>Characteristics:</strong> Rubber-like elastomer. Dull finish</td>
</tr>
</tbody>
</table>

See page 37 for a hardness scale.
### Material Selection Guide

<table>
<thead>
<tr>
<th>Seal Material</th>
<th>Hardness</th>
<th>Color</th>
<th>Temperature Limits</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VIT</strong> Fluoroelastomer - Viton® -</td>
<td></td>
<td>Brown</td>
<td></td>
<td><strong>Use in:</strong> Tough sealing applications requiring extreme chemical resistance. O-Rings. Hydraulic seals. Pneumatic seals. <strong>Description:</strong> An excellent elastomer for use in high temperature applications. Also exhibits excellent chemical resistance for use in harsh environments such as phosphate esters. Widely used in applications dealing with extreme temperature and/or extreme chemicals. It is suitable to use with all chemicals (exception - Skydrol, certain esters and ethers) makes it a popular elastomer in chemical processing, paper/pulp mills, various chemical, acid and solvent applications. <strong>Characteristics:</strong> Rubber-like elastomer. Noticeably heavier than NBR. Dull, non-glossy finish. Smells like cinnamon.</td>
</tr>
<tr>
<td></td>
<td>Machined</td>
<td>Molded</td>
<td>-4 to 392°F</td>
<td></td>
</tr>
<tr>
<td></td>
<td>O-Ring</td>
<td>O-Ring</td>
<td>-20 to 200°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>85</td>
<td>75 (could also be Black, Green - molded O-Rings)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>90</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See page 37 for a hardness scale.

<table>
<thead>
<tr>
<th>Seal Material</th>
<th>Hardness</th>
<th>Color</th>
<th>Temperature Limits</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EPD</strong> EPDM Rubber</td>
<td></td>
<td>Black</td>
<td>-49 to 300°F</td>
<td><strong>Use in:</strong> Sealing lips of special oil seals, u-cups, wiper rings, O-Rings, gaskets, washers, and rollers. <strong>Description:</strong> For use in high temperature water, steam and brake fluids. This elastomer must not come in contact with mineral oils or grease. It is used in applications that deal with acids, weak alkalis. EPD is sometimes an acceptable FDA material. <strong>Characteristics:</strong> Rubber-like elastomer. Strong rubber smell.</td>
</tr>
<tr>
<td></td>
<td>Machined</td>
<td></td>
<td>-45 to 150°C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>O-Ring</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>85</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>70</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See page 37 for a hardness scale.
### Material Selection Guide

<table>
<thead>
<tr>
<th>Seal Material</th>
<th>Hardness Machined O-Ring</th>
<th>Hardness Molded O-Ring</th>
<th>Color</th>
<th>Temperature Limits</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SIL</strong> Silicone Rubber</td>
<td>85</td>
<td>70</td>
<td>Blue</td>
<td>-75 to 392°F, -60 to 200°C</td>
<td>Use in: O-Rings, special low pressure seals, gaskets.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>sometimes white</td>
<td></td>
<td>Description: An excellent material generally used for static seals with excellent low and high temperature stability and good resistance to aging. Generally not suited for dynamic applications due to poor tensile strength and abrasion resistance. Does exhibit excellent resistance to extreme temperature and is an acceptable FDA material. Typical use for silicone is in dry heat applications and food processing applications.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Orange</td>
<td></td>
<td>Characteristics: Very springy-like rubber-type material.</td>
</tr>
<tr>
<td><strong>TFV</strong> Virgin PTFE</td>
<td>Solid</td>
<td>Solid</td>
<td>White</td>
<td>-328 to 500°F, -200 to 260°C</td>
<td>Use in: Packings, gaskets, seals, washers, spacers, insulators, wheels, rollers, bearings, guide rings.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Description: An extremely low friction material which remains stable at both low and high temperatures. The chemical resistance of this material is outstanding. Can be used in applications with extreme temperatures, extreme pressures and extreme chemicals. Since Teflon® TFV has a tendency to cold flow and has no memory. It can be filled or mixed with glass, bronze, and nickel to enhance its properties.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Characteristics: Semi-rigid plastic material. Most of the time it is finished by machining.</td>
</tr>
</tbody>
</table>

See page 37 for a hardness scale.
### Material Selection Guide

<table>
<thead>
<tr>
<th>Seal Material</th>
<th>Hardness</th>
<th>Color</th>
<th>Temperature Limits</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Machined O-Ring</td>
<td>Molded O-Ring</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NEO Neoprene®</td>
<td>N/A</td>
<td>70</td>
<td>Black</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-65 to 250°F</td>
<td>Use in: Common applications include, refrigeration seals, freon/air conditioning, motor mounts, engine coolants. Use in: Common applications include, refrigeration seals, freon/air conditioning, motor mounts, engine coolants. Description: Good resistance to petroleum oils. Low compression set and good tear and abrasion strength. Good resistance to weathering, sunlight, and ozone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-54 to 121°C</td>
<td></td>
</tr>
<tr>
<td>PFR Perfluoro-lastomer</td>
<td>70</td>
<td>75</td>
<td>Black with Brown Hue</td>
<td>Use in: Most likely application environments are for aggressive acids, solvents, and steam. Could be suited for many non-oxidizing dry process chemicals. Description: Broad resistance to chemicals. Low compression set, strong tear resistance. Virtually indestructible. Above average outgassing performance in vacuums.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>90</td>
<td>White</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

See page 37 for a hardness scale.
## Material Selection Guide

<table>
<thead>
<tr>
<th>Seal Material</th>
<th>Hardness</th>
<th>Color</th>
<th>Temperature Limits</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FSI</strong> Fluorosilicone</td>
<td>Machined O-Ring: N/A</td>
<td>Molded O-Ring: 70</td>
<td>Blue</td>
<td><strong>Use in:</strong> Common applications include, aircraft fuel systems, jet fuel/gasoline, petroleum oils, synthetic jet oil. <strong>Description:</strong> Fluorosilicone is a mix of Fluorocarbon (Viton®) and Silicone. Wide range of fluid and chemical resistance. Large temperature range.</td>
</tr>
<tr>
<td>Also referred to as: Silastic L.S.®</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N/A</td>
<td>70</td>
<td>Blue</td>
<td><strong>Use in:</strong> Common applications include, aircraft fuel systems, jet fuel/gasoline, petroleum oils, synthetic jet oil. <strong>Description:</strong> Fluorosilicone is a mix of Fluorocarbon (Viton®) and Silicone. Wide range of fluid and chemical resistance. Large temperature range.</td>
</tr>
<tr>
<td><strong>AFL</strong> Aflas®</td>
<td>Machined O-Ring: Check with EPM for availability</td>
<td>Molded O-Ring: 75</td>
<td>Black</td>
<td><strong>Use in:</strong> Common applications include, O-Rings for various fluid seals. Not readily available in other seal forms. Petroleum fluids and steam, amines, brake fluids or phosphate esters. <strong>Description:</strong> Excellent resistance to petroleum products, steam, phosphate esters, amines and brake fluids. Broad range media resistance similar to EPDM and Viton®. Elastomeric form makes it low in gas permeability. <strong>Characteristics:</strong> Superior heat and wear resistance. Non-abrasive. <strong>Coef. Friction:</strong> .15</td>
</tr>
</tbody>
</table>
## Material Selection Guide

<table>
<thead>
<tr>
<th>Seal Material</th>
<th>Hardness</th>
<th>Color</th>
<th>Temperature Limits</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EOS Armor-O-Rings™ Silicone Core</strong>&lt;br&gt;Also referred to as: Teflon® Encapsulated Silicone O-Rings, PTFE Encapsulated Silicone O-Rings, PTFE-FEP Encapsulated Silicone O-Rings</td>
<td>Machined O-Ring: N/A&lt;br&gt;Molded O-Ring: 70 (core)</td>
<td>Orange with opaque shell</td>
<td>-40 to 205°C</td>
<td>Use in: To improve O-Ring performance in difficult applications where silicone O-Rings alone fail. Description: Armor-O-Rings™ EOS are produced using a thin PTFE shielded tubing fully encasing a silicone rubber core. The outer jacket protects the resilient silicone core from the fluids the O-Ring contacts. Characteristics: Semi-rigid PTFE-FEP tubing fully encapsulating the silicone core material. Material: PTFE-FEP jacket with a minimum thickness of .008” over a silicone core.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Seal Material</th>
<th>Hardness</th>
<th>Color</th>
<th>Temperature Limits</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EOV Armor-O-Rings™ Viton® Core</strong>&lt;br&gt;Also referred to as: Teflon® Encapsulated Viton® O-Rings, PTFE Encapsulated Viton® O-Rings, PTFE-FEP Encapsulated Viton® O-Rings</td>
<td>Machined O-Ring: N/A&lt;br&gt;Molded O-Ring: 75 (core)</td>
<td>Black with opaque shell</td>
<td>-99 to 401°F</td>
<td>Use in: To improve O-Ring performance in difficult applications where Viton® alone fails. Description: Armor-O-Rings™ EOV are produced using a thin PTFE shielded tubing fully encasing a Viton® elastomeric core. The outer jacket protects the resilient Viton® core from the fluids which the O-Ring contacts. Characteristics: Semi-rigid PTFE-FEP tubing fully encapsulating the Viton® core material. Endless. No joints. Material: PTFE-FEP jacket with a minimum thickness of .008” over a Viton® core.</td>
</tr>
</tbody>
</table>
The Shore A scale is used to measure the hardness of elastomers, rubber-like materials, and plastomer materials like polyurethane.

The higher the number the harder the material.

The unit of measure for all of these scales is called durometer.

Example:
A standard NBR O-Ring is 70 durometer Shore A.
O-Ring Material Rankings by Temperature Range

Table Legend
- Highest Recommended Temperature
- Lowest Recommended Temperature

Highest 500°F
450°F
400°F
350°F
300°F
250°F
200°F
150°F
100°F
50°F
0°F
-50°F
-100°F

Lowest -100°F

Neoprene®
Nitrile
EPDM Rubber
Fluoroelastomer Encapsulated
Teflon® Encapsulated
Viton® (Fluorocarbon)
Silicone
Kalrez® (Perfluorinated)
O-Ring Material Rankings by Surface Speed Limitation

<table>
<thead>
<tr>
<th>Material</th>
<th>FLI</th>
<th>SIL</th>
<th>VIT</th>
<th>NEO</th>
<th>EPD</th>
<th>NBR</th>
<th>TFC</th>
<th>PTFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feet Per Minute</td>
<td>Slow</td>
<td>Fast</td>
<td>Faster</td>
<td>Fastest</td>
<td>Faster</td>
<td>Fastest</td>
<td>Faster</td>
<td>Fastest</td>
</tr>
<tr>
<td>FLI</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>SIL</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>VIT (Fluorocarbon)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>NEO</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>EPDM Rubber</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrile Rubber</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teflon® Encapsulated</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>PTFE</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Caution: Outer layer can wear prematurely*
O-Ring Material Rankings by Oil Resistance

- EPDM Rubber
- Neoprene®
- Silicone
- Nitrile
- Fluorosilicone
- Viton® (Fluorocarbon)

- Good
- Not Recommended
- Better
- Best
- Best
O-Ring Material Rankings by Abrasion Resistance

1. VT - Fluorocarbon
2. Neoprene®
3. Nitrile
4. Fluorosilicone
5. EPDM Rubber
6. Silicone
7. TFV and Other PTFE Materials
8. Best

Least

TFV  SIL  EPD  FLI  NEO  NBR  VIT
O-Ring Material Rankings by Tear Resistance

(lb/inch of thickness)

Best

25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1

Least

SIL FLI VIT NEO EPD NBR

Silicone Fluorosilicone Viton® (Fluorocarbon) Neoprene® EPDM Rubber Nitrile
O-Ring Material Rankings by Relative Price

<table>
<thead>
<tr>
<th>Material</th>
<th>Relative Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBR</td>
<td>10</td>
</tr>
<tr>
<td>Neoprene®</td>
<td>9</td>
</tr>
<tr>
<td>EPDM Rubber</td>
<td>8</td>
</tr>
<tr>
<td>Silicone</td>
<td>7</td>
</tr>
<tr>
<td>Viton® (Fluorocarbon)</td>
<td>6</td>
</tr>
<tr>
<td>Fluorsilicone</td>
<td>5</td>
</tr>
<tr>
<td>Teflon® Encapsulated</td>
<td>4</td>
</tr>
<tr>
<td>Kalrez® (Perfluorinated)</td>
<td>3</td>
</tr>
</tbody>
</table>

NBR: Nitrile, NEO: Neoprene®