7 Special Elastomer Applications

Optimum sealing performance has proven troublesome in certain sealing environments. Therefore, for the following O-ring applications, specific elastomers and actions are recommended.

In some cases, a variety of elastomers may be "acceptable" in a given application. The final material choice may be guided by the secondary operating conditions of the systems; or in the case of "equal" performance, by considerations of cost and availability. We are using the O-ring as an example, but much of this information applies to other seal types.

Friction

Standard methods employed for minimizing the effects of O-ring friction include reducing seal squeeze; increasing compound hardness; specifying a low friction compound, such as Teflon®; surface treatment with a low friction coating; and reducing the O-ring's cross section to reduce the amount of contact area (being conscious of avoiding spiral failure).

Internal Lubrication

The use of internally lubricated compounds has proven especially effective in applications requiring low friction performance without the reduction of squeeze.

Best Choice(s)

To date, homogeneously dispersed lubrication in the form of Erucanides (natural fatty acids), Teflon®, Paraffin waxes, petroleum and molybdenum disulfide have been successfully incorporated into Ethylene Propylene, Nitrile, Neoprene™, Fluorocarbon, and Silicone.

External Lubrication

Surface treatment of O-rings with lubricants helps to protect against abrasion, pinching, or cutting during installation in parts assembly. External lubrication helps seat the O-rings into grooves with minimum twisting and maximum assembly speed.

In hydraulic systems where lubricating fluids are nearly always present, surface treatment of O-rings is less essential.

IN PNEUMATIC OR VACUUM APPLICATIONS WHERE SYSTEM FLUIDS ARE PREDOMINANTLY ABSENT, O-RING SURFACE LUBRICATION IS MANDATORY FOR EFFECTIVE, LOW FRICTION OPERATION AND THE PREVENTION OF SEAL LEAKAGE. O-ring surface lubricants help prevent leakage from around the seal by filling the micropores of both the O-ring and surrounding metal surfaces.

A final benefit of O-ring lubrication is the protection it offers some elastomers from the degrading effects of exposure to oxygen and ozone. In this regard, O-ring surface lubrication acts as a barrier, helping to prevent premature seal aging and extending O-ring service life.

PRECAUTIONARY NOTES: In ALL cases requiring O-ring lubrication, make certain to select a lubricant that is compatible with both the O-ring compound and the system chemicals being used. The lubricant, or additive which it contains, SHOULD NOT cause excessive shrinkage or swelling of the O-ring compound.

Also, check the recommended temperature range for the lubricant of choice, making certain to operate within stated limits.

Finally, if system filtration is being employed, check to see that the lubricant is capable of passing through filters prior to use with the system O-rings.

As a general guide, Table H (O-ring Lubricant Guide), at the end of this section, lists a number of lubricants used with specific O-ring compounds in the application shown.

Rule of Thumb	*Do **not** use a lubricant composed of the same material as the O-ring because "like" will dissolve "like." For example, a silicone lubricant should **not** be used with a silicone O-ring.*

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Rotary Applications

In rotary applications, a turning shaft protrudes through the I.D. of the O-ring, continuously exposing the inside surface of the O-ring to friction-generated heat from the rotating shaft.

Elastomers are poor thermal conductors: if heat is generated faster than it can be dissipated, O-ring failure may result.

To help minimize O-ring heat buildup, especially in applications with shaft rotating speeds in excess of 180 surface feet per minute, the following mechanical design safeguards should be considered where applicable:

- Reduce squeeze to as little as .002" to minimize friction.
- Provide ample diametrical clearance to increase fluid flow and dissipate heat.
- Select an O-ring made of a hard, self-lubricating compound.
- Maintain a system pressure not greater than 250 psi.
- Avoid applications requiring lower than -40°F, or higher than +250°F operating temperatures.
- Locate the gland as close as possible to the lubricating fluid and as far away as possible from the shaft support bearings.
- Assure that relative motion occurs only between the O-ring I.D. and the rotating shaft... NOT between the O-ring outside diameter and the gland. This can be accomplished by minimizing eccentric shaft rotation (machining shafts concentric to within 0.0005" TIR), finishing shaft surfaces to 16 RMS for smooth, non-abrasive running; and machining gland surfaces to rougher than 32 RMS to discourage O-ring movement within the gland.

Best Choice(s)

In rotary applications, polymer selection is based upon abrasion resistance, heat resistance, and the other environmental considerations mentioned above. For related polymer performance properties, refer to the "Material Selection Guide" in Section 6.

Extreme High Temperature Situations

Exposure of O-ring elastomers to extreme high temperatures can cause physical and/or chemical deterioration. When exposed to extremely high temperatures, the O-ring will initially soften and swell within the gland, which causes increased friction in dynamic applications.

High pressure applications are especially prone to failure here because room temperature tests may provide inaccurate results. Over time, irreversible chemical changes occur that increase seal hardness as well as induce compression set and volumetric changes.

In the case of thermoplastic materials, prolonged exposure to high temperatures may cause partial reversion back to basic components. This occurs because thermoplastics are a class of polymers that are composed of individual molecules that are linear in structure and held together and crosslinked by weak, intermolecular forces which can be broken by heat and pressure. Any rubber compound has a point of heat failure which must be individually addressed. (See Temperature Graph 5.4 in Section 5)

Conversely, thermosets are cross-linked by stronger bonds more resistant to heat and pressure.

Best Choice(s)

A number of special compounds have been developed to provide dependable O-ring sealing performance in high temperature situations. These include Fluorocarbon (Viton®), Aflas®, Perfluoro-elastomers (Kalrez®, Chemraz®), Silicone, Fluoro-silicone, and Teflon®. These compounds feature heat resistance to at least 400°F, with some Perfluoro-elastomers rated to 600°F (for short periods of time).

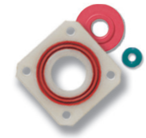
An additional number of O-ring materials feature temperature resistance to 300°F, with special resistances to particular fluids or environmental factors. Ethylene propylene, for example, features excellent resistance to steam. Polyacrylate is resistant to hot oil.

Rule of Thumb

Resistance of elastomers to chemical attack is greatly reduced at elevated temperatures.

7

Special Elastomer Applications



Low Temperature Situations

Low temperature performance is one of the most overlooked properties in seal performance. Exposure to low temperature can contract elastomeric materials, resulting in decreased compression and possible leakage. When seal materials are exposed to lower temperature than their designed limit, seals become less flexible and brittle. Seals can fail by two modes under low temperature: (1.) the seal material will harden when the low temperature limit is reached and resist deformation to pressure causing leak paths; (2.) the seal will undergo a compression set, so when heated above the low temperature, this allows for leak. Material selection is key for the low temperature seal performance.

Low Temperature Testing

Three standard low temperature tests are performed to measure material performance. Brittleness (ASTM D2137) measures the ability of a material to withstand breaking when bent at a given temperature for a period of time. Temperature Retraction (ASTM D1329) measures the temperature at which a material returns from an elongated state. Torsional Stiffness Ratio (ASTM D1053) measures the ratio from when a material is twisted, first at room temperature and then at a given low temperature. These tests give some idea of low temperature performance, but have limited value for seal applications. One example is that a material might not break at -40°C, but the material could be stiff enough to allow leak paths.

A good indicator for seal performance is Compression Set at Low Temperature (ASTM D1229). This test measures set at 3 min. after exposure to a given temperature and at 30 min. This gives a clear indication of what will happen to a material when exposed to low temperature and allowed to return to higher temperatures. A quick indicator is the Glass Transition Temperature (Tg). This shows the temperature at which the material becomes hard.

Best Choice(s)

Vinyl Silicone (VMQ) is considered the general polymer. These types of polymers have brittle points to -80°F as tested in A-A-59588 (ZZ-r-765 Class 2B). Phenyl Silicone (PVMQ) is an extreme low temperature polymer with brittle points down to -130°F as tested in A-A-59588 Class 3B. Drawbacks with Silicone use are excessive swelling in aliphatic and aromatic hydrocarbon fuels and many lubricating oils.

Fluorosilicone (FVMQ) can be used to -104°F in oil and fuel applications. The addition of the Fluorine group to the polymer chain gives the polymer swell resistance. Many aircraft applications use Fluorosilicone because of low temperatures at higher altitudes and contact with JP-4, de-icing agents and hydraulic oils.

General polymers can be used, but service temperatures need to be watched. Many EP polymers work at -85°F. Nitrile (Buna-N) compounds when formulated correctly can withstand -40°F to -85°F. With Nitrile, the better the low temperature performance, the more swell you will have in oils and fuels. Fluorocarbons (Viton®) can be used from -13°F to -40°F. To reach the lower limit, low temperature polymers must be used. This normally costs more than standard polymers but must be used for this type of service.

Teflon® is outstanding in low temperature service. With good resistance to gas permeation, Teflon® is capable of sealing to -300°F. Teflon®'s drawback is poor elastic memory and a tendency to "creep" when not confined. Addition of fillers and energizers can help limit some of these drawbacks.

Abrasion Resistance

Applications involving oscillation, reciprocation, or rotation induce friction and typically generate wear regions on one surface of the seal. This leads to premature seal failure, system contamination, and eventually system malfunction. When feasible, the use of lubricants, improved surface finishes, or system filtration reduces the effect from friction. However, proper compound selection is essential for extended seal utility.

Best Choice(s)

Carboxilated Nitrile (XNBR) has superior wear resistance properties, when compared to that of the base compound Nitrile, through the addition of carbon in the crosslinking organization. Polyurethane also has outstanding resistance to abrasion and is typically employed in high-pressure applications.

FDA Food Applications

Seals proposed for use by the food processing field are often required by law to be comprised of only the compound ingredients determined by the U.S. Food and Drug Administration (FDA) to be safe for food contact.

Such O-ring compounds must consist exclusively of the ingredients listed in the FDA's "White List" located in the Code of Federal Regulations (Title 21) Section Number 177.2600. It is the responsibility of the O-ring manufacturer to utilize food grade materials only from the "white list" of FDA-sanctioned ingredients. These compounds tend to have a high compression set due to the limit of cures allowed.

Best Choice(s)

Food service O-rings that have thus far met FDA "White List" requirements have been produced primarily from the elastomers Ethylene Propylene, Fluorocarbon, Chloroprene (Neoprene), Nitrile and Silicone.

Medical Applications

Medical equipment seal applications, and/or applications involving implantation of devices within the human body require strict compliance with FDA and ISO-imposed regulations.

Regarding ALL medical O-ring applications, please contact your Apple Rubber representative from the initial stages of product design and we will work with you step-by-step to meet all applicable governmental requirements.

Best Choice(s)

Since all medical devices are unique by their nature, the best choice will be different for each application. Normally, materials that comply to USP Class VI or ISO10993 are used.

NSF Applications

The National Sanitation Foundation (NSF) is recognized for its health related specifications and is available for certification of rubber compounds used in the drinking water industry. Prior to NSF certification, extensive testing, such as a water extraction analysis, must be performed on the submitted rubber compound. Please contact Apple Rubber for specific application requirements regarding NSF material certification.

Best Choice(s)

Because each compound must be individually submitted for NSF approval, there is no relative superior compound selection.

Underwriters Laboratories Recognized Compounds

The Underwriters Laboratories is a non-profit organization and has established standards for elastomeric compounds in specific service environments. In order to display the UL trademark label, annual tests must be performed to ensure that the compounds will exceed the conditions they normally encounter.

Apple Rubber has a variety of compounds listed by UL for applications such as propane, natural gas and heating oils. Apple Rubber routinely submits new compounds for UL approval in different service environments.

If you want a UL-registered compound, you must be sure to specify it.

Water and Steam Sterilization

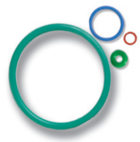
Immersion in water adversely affects many elastomers by inducing considerable compound swell. As increased swell means increased O-ring volume and friction, excessive water swell precludes the use of a number of elastomers in dynamic (moving) situations.

As water is converted to steam, O-ring elastomers are exposed to the degrading effects of heat, in addition to water swell. If heat ranges are exceeded, O-ring materials may assume the condition of a sponge, soaking up gases and fluids, leading to a partial or total loss of sealing properties.

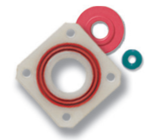
Best Choice(s)

Silicone, Ethylene Propylene, Aflas®, and Hydrogenated Nitrile, for example, are good performers in water and steam.

Perfluoroelastomers are excellent performers in both water and steam, especially at elevated temperatures.



Special Elastomer Applications



Gamma Sterilization

Gamma radiation affects polymers by either breaking the intermolecular bonds (which promotes embrittlement) or increasing the degree of cross linking (which increases compression set). Both of these reactions occur simultaneously, with one being predominant, depending on the elastomer and additives used. Additionally, radiation may affect physical properties such as tensile strength, elongation and discoloration of certain elastomers.

Best Choice(s)

Due to low levels of radiation used in sterilization, Silicone, peroxide cured EP, or Viton® can be used.

ETO Sterilization

Low dosage of ethylene oxide is used. Ethylene oxide can swell most seal materials.

Best Choice(s)

Peroxide cured EP and Silicones can be used since low exposure to Ethylene oxide is normal for the sterilization process.

Automotive Fuels

Gasoline is a varying blend of aromatic and aliphatic hydrocarbons with alcohols at varying levels being used to decrease oil consumption. Alcohols are very oxidizing and can cause swell.

Assurance of desired O-ring resistance to gasoline, therefore, requires an elastomer that is resistant to a minimum of three chemical agents, with additional consideration being given to the temperature range(s) routinely encountered in automobile operation.

Best Choice(s)

A check of the "General Properties of O-ring Elastomers" chart in Section 6 shows that Teflon®, Fluorocarbon and Epichlorohydrin possess enhanced resistance of exposure to aromatics, aliphatics and alcohols, over a working temperature range suitable for automotive use.

Additionally, Nitriles, specially compounded to reduce swelling in gasoline, are sometimes employed for automotive use.

Brake Fluid Applications

Contact with brake fluid inevitably causes either seal swelling or shrinkage to some degree, depending on the elastomeric compound. This results in excessive or insufficient compression and leads to seal failure. Swell or increase in volume is also usually accompanied by a decrease in hardness, which causes a reduction in abrasion and tear resistance and may allow seal extrusion under high pressure. Also, seal failure due to swelling is accelerated in dynamic applications because of the heat generated from friction.

Best Choice(s)

Ethylene-Propylene, when specifically compounded for brake fluid service, is the elastomeric compound of choice. It allows a relatively nominal amount of swell while attaining service temperatures to 250°F. With the addition of different types of brake fluid, please contact Apple Rubber for assistance in the matching of elastomer compound to service fluid. Some automobiles use mineral oil-based brake fluids which can attack EP rubber.

Contact with Plastic Surfaces

With the increasing use of plastic parts in many areas of modern manufacturing, it has become mandatory for O-rings to effectively seal against an ever-widening variety of plastic as well as metal surfaces.

The problem encountered with O-ring contact with plastics is the adverse effect of compound ingredients, such as plasticizers, inducing surface cracking ("crazing") in plastics. This crazing may eventually lead to physical weakness and/or failure of the plastic structure.

Best Choice(s)

Ethylene-Propylene, Fluorocarbon and Silicones; special formulated Nitriles can be used. Normal Nitriles use the same plasticizers that soften most plastics, therefore, it is very important to identify when a seal material is going to be used with plastics.

NOTE: THE ABOVE LISTED INFORMATION IS INTENDED TO BE USED AS A GENERAL GUIDE ONLY. PLEASE CONTACT US FOR SPECIFIC APPLICATION INFORMATION.

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Face Seal Applications (Non-Round)

Some face seal applications may require a rectangular groove configuration. In order to use a standard round O-ring, the inside corner radius of the groove should not be less than three times (3X) the O-ring cross-section diameter.

Use the recommended gland design for static seals from Table A in Section 4. The length of the O-ring centerline should be equal to the length of the groove centerline. Following is an equation to assist in determining the O-ring inside diameter.

O-ring ID = (Groove CL length / 3.14) – O-ring CS

If a standard round O-ring cannot be applied to your face seal application, then contact Apple Rubber for assistance with designing a custom molded gasket solution.

Low Permeability

To some degree ALL elastomers are permeable to gases. The rate of gas permeation through an O-ring varies by material compounding; material hardness; degree of squeeze; presence or absence of lubrication; size of O-ring cross section; and the pressure, temperature and type of gas being sealed.

Typically, harder compounds containing more carbon black feature lower diffusion rates.

In the case of Nitriles, increasing acrylonitrile content results in decreased permeability.

Laboratory tests indicate that lubricated O-rings are significantly less permeable than unlubricated rings. These same tests further demonstrate that increased seal squeeze results in decreased permeability in unlubricated situations.

Best Choice(s)

In general, Butyl is best for low permeability applications.

Note: Fluorosilicone and Silicone provide the LEAST resistance to gas permeation.

Vacuum Applications

To make effective vacuum seals, O-rings must be comprised of elastomeric materials featuring low gas permeability, low weight loss under vacuum, and good compression set characteristics.

Best Choice(s)

Butyl excels as the most impermeable performer, followed by several other elastomers including Fluorocarbon, offering good to excellent resistance to gas permeation and low weight loss in vacuum applications.

As an added measure of leak prevention, lubrication of O-rings with vacuum grease helps to fill the microscopic pores of surrounding glandular surfaces which have been machined to the recommended 16 to 32 RMS finish.

Outgassing

Most rubber compounds contain small quantities of oil and other ingredients that will become volatile under vacuum conditions. Evidence of this “outgassing” is apparent as a thin film deposited on surrounding surfaces. Optical and electrical contact applications are of special concern in this situation as they incorporate sensitive surfaces that must remain uncontaminated. Other compounds exhibit some degree of weight loss in the form of water vapor which may act as a contaminant in some applications. While this process is inevitable, it is accelerated at elevated temperatures and in high vacuum situations.

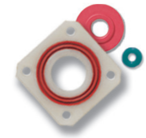
Best Choice(s)

“Postcuring” elastomeric compounds such as Viton®, Fluorosilicone, and Silicone prior to service removes many of the unwanted volatiles and improves physical properties by increasing the degree of crosslinking. Other compounds, such as Nitrile and Natural Rubber, do not usually benefit as much from this process as the previous compounds.

Compression Set Resistance

The final requirement for effective vacuum sealing involves the specification of O-ring elastomers with good compression set characteristics. Employing a seal squeeze of up to 40% inhibits media flow through the seal. This squeeze also forces the O-ring to conform to the surface irregularities of the gland, helping to further prevent leakage. Keep in mind, however, that because of the decreased groove depth, increased groove width is essential.

Special Elastomer Applications



Best Choice(s)

In terms of compression set resistance, Fluorocarbon is rated as "good to excellent," followed by Chloroprene (Neoprene) at "fair to excellent," and Butyl at "fair to good."

Drive Belt Applications

O-rings provide excellent service in low power drive belt assemblies because they are inexpensive, easy to install, and the use of tensioning devices are not required.

When using O-rings as drive belts, certain design considerations should be observed such as maintaining between 8% to 12% stretch on the inside diameter. Also, the pulley grooves should be round and match the O-ring's cross section in depth and width while ensuring that the pulley diameter at the bottom of the groove is no less than 4 times the O-ring cross section.

Best Choice(s)

Ethylene propylene (EP)(peroxide cured) is the primary elastomeric choice because of the low stress relaxation, good flex life, abrasion resistance, and high temperature resistance. However, poor resistance to petroleum-based lubricating oil limits its application range.

Polyurethane, unlike EP, demonstrates excellent resistance to petroleum-based lubricating oils while maintaining high abrasion resistance, tensile strength, and flex life. Stress relaxation (loss of tension), however, is relatively higher and the service temperature limit (to 130°F) is somewhat lower, when compared to EP.

Neoprene is generally specified when service temperatures exceed the limit of Polyurethane (to 180°F) and possible contact with petroleum fluids. Abrasion resistance is good, but EP displays superior flex life and stress relaxation properties. HNBRs are now being used for their superior tensile strength and oil resistance.

Age Control/Shelf Life

As it relates to the internal chemical degradation of elastomer performance properties over time, the term "aging" is misleading. In fact, it is the exposure of O-ring elastomers to stressful environmental factors during storage that ultimately causes changes in performance properties over time.

For the maintenance of optimum O-ring properties during storage, the following conditions are recommended:

1. Ambient temperature not exceeding 120°F.
2. Exclusion of air (oxygen).
3. Exclusion of contamination.
4. Exclusion of light (especially ultra-violet).
5. Exclusion of ozone-generating electrical devices.
6. Exclusion of radiation.
7. Storage of O-rings in sealed polyethylene bags, inside cardboard containers helps assure maximum shelf life.

Note: The MIL-STD-1523A ("Age Controls of Age-Sensitive Elastomeric Material") which relates to "cure dating" for seals was canceled on January 30, 1995. When a seal is stored properly, age is no longer considered a factor in seal failure.

Compound Colorization

In non-silicone O-ring performance applications, it must be remembered that partial or total replacement of carbon black with tinted, non-black fillers WILL result in some modifications of physical properties.

IN ALL CASES OF COMPOUND COLORIZATION, THEREFORE, IT IS ESSENTIAL THAT COLORIZED O-RING SAMPLES BE TESTED IN THE ACTUAL APPLICATION UNDER CONSIDERATION, PRIOR TO INCLUSION IN THE MANUFACTURING PROCESS.

Automatic Assembly

The increasing use of automatic equipment for the feeding and installation of O-rings requires greater emphasis on the dimensional quality of the O-ring and its packaging. With automatic installation, there are two environments that must be addressed: the environment of the application, and the environment of the automatic assembly process. Each of these applications will require separate dimensional and material considerations. Of course, the installation considerations must always remain secondary to the requirements of the application environment.

Some of the factors that must be considered when automatically installing O-rings are distortion, coating, and foreign matter. Failure to consider one of these factors may cause an unacceptable frequency of downtime.

Concentrated Acids at Elevated Temperatures

A number of elastomers possess good resistance when exposed to dilute acids at room temperature.

These materials include Aflas®, Butyl, Epichlorohydrin, Ethylene Propylene, Fluorocarbon, Fluorosilicone, Perfluoroelastomer, Natural Rubber, Chloroprene (Neoprene), Nitrile, and Teflon®.

THE ACID RESISTANCE OF THESE COMPOUNDS, HOWEVER, SIGNIFICANTLY LESSENS WITH BOTH INCREASING ACID CONCENTRATIONS AND RISING TEMPERATURES.

Best Choice(s)

As temperatures and concentrations of nitric and hydrochloric acids rise, Perfluoroelastomers such as Kalrez® or Chemraz® have demonstrated good performance in lab tests.

As temperatures rise above 158°F, only the chemical inertness of Teflon® can be relied upon for maintenance of a seal exposed to hydrochlolic or nitric acids.

Note: Teflon® has been laboratory tested (by DuPont) for 168 hours of exposure to 37% hydro-chloric acid, at 248°F, with only 0.03% of observed weight gain. It has further been tested for 12 months of exposure to 10% nitric acid, at 158°F, with 0.1% weight gain. Teflon® has also been shown by DuPont to undergo ONLY SLOW OXIDATIVE ATTACK by 70% nitric acid, under pressure, at 480°F.

EMI Shielding

Electromagnetic interference (EMI) is composed of both electric and magnetic components, and either can be the source of interference. Often, it is critical to shield electronic devices from EMI, which is done via either reflection or absorption. By the suspension of conductive fillers such as silver or nickel in the elastomer binder, a compound suited for shielding or grounding is available for service.

Table H O-Ring Lubricant Guide

Elastomer	Apple Rubber Material Designation	Applications	Lubricants: Optimum	Lubricants: Temperature Range °F	Lubricants: Manufacturer
Nitrile	BN	Hydraulic Oils & Fuels Extreme Service Pneumatic Vacuum	Petrolatum Barium Grease DC-55 Celvacene®	-20 to 180 -20 to 300 -65 to 275 -40 to 200	Various Various Dow Corning Co. CVC
Chloroprene (Neoprene)	CR	Hydraulic Oils & Freon® Vacuum	Petrolatum Celvacene®	-20 to 180 -40 to 200	Various CVC
Ethylene-Propylene	EP	Skydrol® Steam & Hot Water	MCS-352* DC4, DC7, DC55	-65 to 300 +32 to 350	Aviation F.S. Co. Dow Corning Co.
Styrene Butadiene	SB	Brake Fluids	DC4 or DC7	-40 to 250	Dow Corning Co.
Polyurethane, Cast	CP	Oils & Fuels Heavy Duty	Petrolatum Barium Grease	-24 to 180 -20 to 300	Various Various
Butyl	BU	Skydrol® Vacuum	MCS-352* Celvacene®	-65 to 300 -40 to 200	Aviation F.S. Co. CVC
Polysulfide	TH	Solvents	Petrolatum	-20 to 180	Various
Silicone	SL	General High Temp	Petrolatum FS 1292	-20 to 300 -20 to 400	Various Dow Corning Co.
Fluorosilicone	FS	Oil or Fuel High Temp	Petrolatum DC4 or DC7	-20 to 180 +32 to 350	Various Dow Corning Co.
Fluorocarbon	VT	Hydraulic Vacuum & High Temp	Petrolatum DC55	-20 to 180 -65 to 400	Various Dow Corning Co.

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