Basic Concepts of Rubber

What is "Rubber"?

"Rubber" refers to elastomeric compounds that consist of various monomer units forming polymers that are heat cured (vulcanized). Polymers are long molecular chains and are derived from the Greek "poly" (many) and "meros" (parts). The base monomer or monomers is used to classify the type of rubber, for example: Nitrile, Silicone or Neoprene.

What is a Rubber Compound?

Rubber is composed of many different ingredients that include the base elastomer, vulcanization agents, fillers and plasticizers. For example, the addition of fillers can reinforce or modify properties, or additional plasticizer can increase elongation and lower durometer.

Why Does Rubber Act "Rubbery"?

Rubber is considered highly viscous liquid or an elastic solid. The polymeric chains in rubber tend to be very long and flexible by nature and can rotate about their axis, which results in an entangled mass of contorted chains.

When a deformation of the rubber occurs, these tangled chains uncoil and recoil when the force is released. Therefore, elastic rebound or rubbery behavior is possible due to contortions of long, flexible polymeric chains, which allow rubber to be so resilient.

How is Rubber Made?

The base polymer is the primary component of all rubber recipes and is selected in order to obtain specific chemical and physical properties in the final product. Processing aids and softeners, such as oils and plasticizers, modify rubber to aid in mixing or molding operations. Sulfur is one of the most widely used vulcanizing agents to promote crosslinking which is used in conjunction with accelerators and accelerator activators to reduce cure times and enhance physical properties. Carbon black is one of the most common fillers because it reinforces the molecular structure. Antidegradants, such as antioxidants and antiozonants, retard the deterioration of rubber products. Lubricants, colors or any other miscellaneous ingredients may also be added.

What is Vulcanization?

The long, flexible polymeric chains of rubber, when heated, react with vulcanizing agents to form three-dimensional structures. These vulcanizing agents (usually sulfur or peroxide) are necessary to facilitate chemical crosslinking of polymeric chains. Once the rubber has been vulcanized or "cured", physical properties are enhanced and the compound is more resistant to deterioration.

What is Compression Set?

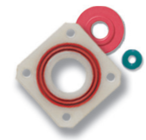
Elastic recovery is a measure of the elastomer's ability to return to its original shape once a compressive force has been removed. Failure of the seal to return to its original shape after compression is the condition termed "compression set" and all seals exhibit some degree of compression set. Determination of the amount of compression set is governed by ASTM designation D395 test procedure.

What is the difference between a Thermoset and Thermoplastic?

One classification method of polymeric materials is according to physical properties at elevated temperatures. Thermoset polymers become permanently "set" in the presence of heat and do not soften in the presence of subsequent heating. Conversely, a thermoplastic material will soften when heated (and eventually liquefy) and harden when cooled. This process is reversible and repeatable, as opposed to thermoset polymers where the process is irreversible. Also, thermoset polymers possess superior mechanical, thermal, and chemical properties as well as better dimensional stability than thermoplastic elastomers. This is why thermoset (rubber) parts are generally preferred for sealing applications.

This section contains descriptions of the elastomers used in seal applications. These elastomers form the base of a wide variety of compounds, designated for specific applications. Every compound has specific characteristics and many compounds have common attributes. Therefore, it is important to consider all aspects of the compound prior to use. Also, as compound availability is customer driven, lead time may vary.

Material Selection Guide



Chemical Compatibility Table

Please see the Seal Design Guide Online for the full "Chemical Compatibility" table.
www.applerubber.com/login/index.cfm

Buna-N (See Nitrile)

Butyl

Trade Name(s):
Exxon Butyl ... Exxon Chemical
Polysar Butyl ... Bayer Polymer

ASTM D1418 Designation: IIR

ASTM D2000/SAE J200 Type, Class: AA, BA

Apple Compound Designation: BU

Standard Color: Black

Description: An all-petroleum product, Butyl is a copolymer of isobutylene and isoprene and has largely been replaced by Ethylene Propylene since its introduction.

Key Use(s): Highly effective in vacuum sealing applications. Good seal for hydraulic systems.

Temperature Range: Standard Compound: -50°F to +250°F.

Hardness (Shore A): 30 to 90

Features: With outstanding low permeability to gases, Butyl is especially effective in vacuum sealing applications. It also features good to excellent resistance to ozone and sunlight aging.

Butyl further features excellent shock dampening capabilities. Only slightly affected by oxygenated solvents and other polar liquids, Butyl is often utilized in seals for hydraulic systems using synthetic fluids. It is good with MEK, and silicone fluids and greases.

Limitations: Because it is a petroleum product, Butyl has poor resistance to hydrocarbon solvents and oils, and diester-based lubricants. Halogenated butyl has been introduced to expand oil and chemical resistance to this polymer. Chlorobutyl and Bromobutyl have better resistance. These polymers have been accepted by the medical industry for stoppers and septumns for pharmaceutical applications.

Chloroprene (Neoprene)

Trade Name(s):
Neoprene ... DuPont Performance Elastomers
Baypren ... Bayer

ASTM D1418 Designation: CR

ASTM D2000/SAE J200 Type, Class: BC, BE

Apple Compound Designation: CR

Standard Color: Black

Description: One of the earliest of the synthetic materials to be developed as an oil-resistant substitute for Natural Rubber, Neoprene is a homopolymer of chloroprene (chlorobutadiene).

Key Use(s): Numerous component uses in the transportation field. Recommended for exposure to weathering. Preferred sealing material for refrigeration industry.

Temperature Range: Standard Compound: -40°F to +250°F. Special Compounds: -67°F to +250°F. (Dry Heat Only)

Hardness (Shore A): 40 to 90.

Features: Neoprene can be used in innumerable sealing applications due to its broad base of such desirable working properties as: good resistance to petroleum oils; good resistance to ozone, sunlight and oxygen aging; relatively low compression set; good resilience; outstanding physical toughness; and reasonable production cost.

Due to its excellent resistance to Freon® and ammonia, Neoprene is also widely accepted as a preferred material for refrigeration seals.

Limitations: Neoprene is generally attacked by strong oxidizing acids, esters, ketones, chlorinated, aromatic and nitro hydrocarbons.

Because Nitrile is economically competitive with Neoprene, and generally has superior performance characteristics in most situations, it has largely replaced Neoprene® in the O-rings of today.

Epichlorohydrin

Trade Name(s):
Hydrin ... Zeon

ASTM D1418 Designation: CO, ECO

ASTM D2000/SAE J2000 TYPE, CLASS: CH

Apple Compound Designation: EH

Standard Color: Black

Description: Available in homopolymer (CO), copolymer (ECO), and terpolymer (GECO) formats, Epichlorohydrins are oil resistant compounds.

Key Use(s): Ideal for fuel and air conditioning system components. Used in the petroleum industry where a little higher temperature capability than NBR is required.

Temperature Range: Standard Compound: -40°F to 275°F.

Hardness (Shore A): 50 to 90

Features: Epichlorohydrin features excellent resistance to hydrocarbon oils and fuels; low solvent and gas permeability; excellent resistance to ozone and weathering; and stable cycling from low to high temperature. Good replacement to butyl when gas permeability and oil resistance are needed.

Limitations: Compression set is only "fair" at elevated temperatures (250°F to 275°F). Epichlorohydrin is attacked by ketones; esters; aldehydes; chlorinated and nitro hydrocarbons; and is not recommended for exposure to brake fluids.

Ethylene/Acrylic (Vamac®)

Trade Name(s):
Vamac® ... DuPont Dow Elastomers

ASTM D1418 Designation: AEM

ASTM D2000/SAE J200 Type, Class: EE, EF, EG, EA

Apple Compound Designation: VA

Standard Color: Black

Description: A copolymer of ethylene and methyl acrylate, with a small amount of a third monomer added to provide a cure to active groups in the polymer chain, Vamac® exhibits properties similar to those of polyacrylate, but with an extended low temperature limit and better mechanicals.

Key Use(s): Seals for automotive applications, such as automatic transmissions and power steering systems.

Temperature Range: Standard Compound: -13°F to +338°F. (Dry Heat Only)

Hardness (Shore A): 50 to 90.

Features: Ideal for automotive sealing uses, Vamac® features excellent heat resistance, outstanding resistance to ozone and sunlight aging, moderate resistance to swelling in oils, and very low permeability to gases.

With a maximum reinforced tensile strength of 2,500 psi, Vamac®'s mechanical properties of adhesion to metals, tear resistance, flex life, abrasion resistance and compression set resistance are all rated as "good."

Resistance to water, engine coolant mixtures (glycols), dilute acids and alkalis is also good.

Limitations: Vamac® is not recommended for exposure to concentrated acids, aromatic hydrocarbons, gasoline, ketones, brake fluids and phosphate esters.

Ethylene-Propylene

Trade Name(s):
Nordel ... Dow Chemical
Kaltan ... DSM Elastomers
Royalene ... Chemtura Corporation

ASTM D1418 Designation: EPDM

ASTM D2000/SAE J200 Type, Class:
AA, BA, CA, DA

Apple Compound Designation: EP

Standard Color: Black

Description: A copolymer of ethylene and propylene (EPR), combined with a third comonomer adiene (EPDM), Ethylene Propylene has gained wide seal industry acceptance for its excellent ozone and chemical resistance characteristics.

Key Use(s): Outdoor weather resistant uses. Automotive brake systems. Automobile cooling systems. Water applications. Low torque drive belts.

Temperature Range: Standard Compound: -40°F to +275°F. Special Compound: -76°F to 302°F.

Hardness (Shore A): 40 to 95.

Features: When compounded using peroxide curing agents, high temperature service can reach +302°F. Good resistance to acids and solvents (i.e. MEK and Acetone).

Limitations: Have no resistance to hydrocarbon fluids.

> **Rule of Thumb**
> *When it is said that an elastomer is good for an application, it is meant that some compounds which include that elastomer are acceptable, not all. For instance, some compounds of EP are good for brake fluid applications, but most are not acceptable.*

Fluorocarbon (Viton®)

Trade Name(s):
Viton® ... DuPont Performance Elastomers
Fluorel ... 3M Company
Technoflon ... Solvey Solexis, USA

ASTM D1418 Designation: FKM

ASTM D2000/SAE Type, Class: HK

Apple Compound Designation: VT

Standard Color: Black

Description: Combining high temperature resistance with outstanding chemical resistance, Fluorocarbon-based compounds approach the ideal for a universal O-ring material.

Key Use(s): Seals for aircraft engines. Seals for automotive fuel handling systems. High temperature/ low compression set applications. Wide chemical exposure situations. Hard vacuum service.

Temperature Range: Standard Compound: -13°F to +446°F. Special Compounds: -40°F to +446°F.

Hardness (Shore A): 45 to 90.

Features: High fluorine grades offer higher resistance to swell in high octane and oxygenated fuel blends. This gives superior performance in Ethanol/Methanol blended gasoline. Base resistant grades offer improved resistance to amine based oil protectants found in new transmission oils. Also, improved resistant to steam for higher temperature services. Low temperature bases can improve performance to -40°F. New polymers being offered have improved chemical resistance and low temperature performance.

Viton® Extreme™ ETP offers similar chemical compatibility as Kalrez™ with temperature resistance to +446°F.

Special compounds, using new polymer technologies, provide improved low temperature performance with a TR(10) of -40°F and brittleness to -76°F.

Limitations: Fluorocarbons are not recommended for exposure to ketones, amines, low molecular weight esters and ethers, nitro hydrocarbons, hot hydrofluoric or chlorosulfonic acids, or Skydrol® fluids. They are also not recommended for situations requiring good low temperature flexibility.

Fluorosilicone

Trade Name(s):
Silastic LS ... Dow Corning Corporation
FSE ... Momentive Performance Materials

ASTM D1418 Designation: FVMQ

ASTM D2000/SAE J200 Type, Class: FK

Apple Compound Designation: FS

Standard Color: Blue

Description: Fluorosilicone combines the good high and low temperature stability of Silicones with the fuel, oil, and solvent resistance of Fluorocarbons.

Key Use(s): Aerospace fuel systems. Auto fuel emission control systems. Primarily for static sealing applications.

Temperature Range: Standard Compound: -75°F to +400°F.

Hardness (Shore A): 40 to 80.

Features: Fluorosilicone is most often used in aerospace applications for systems requiring fuel and/or diester-based lubricant resistance up to 400°F.

Although generally specified for aerospace use, due to its excellent fuel resistance and high temperature stability, Fluorosilicone is becoming an increasingly popular material for a wider range of sealing applications.

Featuring good compression set and resilience properties, fluorosilicone compounds are suitable for exposure to air, sunlight, ozone, chlorinated and aromatic hydrocarbons.

Limitations: Due to limited physical strength, poor abrasion resistance, and high friction characteristics, Fluorosilicone elastomers are not generally recommended for dynamic sealing. They are predominately designed for static sealing use. They are also not recommended for exposure to brake fluids, hydrazine, or ketones.

Liquid Silicone Rubber (LSR)

LSR is a low viscosity silicone elastomer intended for use in liquid injection molding (LIM) equipment. It offers high thermal stability and flexibility at low temperatures, high transparency and is easily colored. Also, self-lubricated and electrically conductive grades are available as well as FDA and medical compliant grades. Liquid silicone rubber is widely used to mold complex profiles because of its excellent flow characteristics.

Medical Grade Silicone

When properly prepared, possible benefits include fulfillment of USP Class VI and ISO 10993 requirements, embrittlement from gamma sterilization, sterilizable with EtO/steam. Also, this grade of silicone is generally transparent due to class requirements. Limited medical grade pigments are available.

Limitations: Generally, low abrasion and tear resistance, and high friction characteristics preclude silicones from effectively sealing some dynamic applications. Silicones are also highly permeable to gases and are generally not recommended for exposure to ketones (MEK, acetone) or concentrated acids.

Natural Rubber

ASTM D1418 Designation: NR

ASTM D2000/SAE J200 Type, Class: AA

Apple Compound Designation: NA

Standard Color: Black

Description: Natural Rubber is the vulcanized product of the juice of the Hevea tree (latex).

Key Use(s): Seals in food and beverage applications. Most popular material for non-hydraulic sealing applications. Mainly used for dampeners due to its ability to absorb vibration.

Temperature Range: Standard Compound: -58°F to +158°F. (Dry Heat Only)

Hardness (Shore A): 40 to 90.

Features: Natural Rubber features high tensile strength, high resilience, high abrasion and high tear resistance properties, with a good friction surface and excellent adhesion to metals. Until the invention of synthetic elastomers in the 1930's, Natural Rubber was the only polymer available for O-ring manufacture.

Natural Rubber features good resistance to organic acids and alcohols, with moderate resistance to aldehydes.

Limitations: Not widely used in sealing industry due to poor compression set performance and lack of resistance to many fluids.

Nitrile (Buna-N)

Trade Name(s):

Nipol ... Zeon
Nysyn ... DSM Elastomers
Krynac ... Bayer Polymer
Chemigum ... Eliokem

ASTM D1418 Designation: NBR

ASTM D2000/SAE J200 Type, Class:
BF, BG, BK, CH

Apple Compound Designation: BN

Standard Color: Black

Description: Presently, the seal industry's most widely used and economical elastomer, Nitrile combines excellent resistance to petroleum-based oils and fuels, silicone greases, hydraulic fluids, water and alcohols, with a good balance of such desirable working properties as low compression set, high tensile strength, and high abrasion resistance. Use of Carboxylated Nitrile can have superior abrasion resistance, while still having improved oil resistance.

Key Use(s): Oil resistant applications of all types Low temperature military uses. Off-road equipment. Automotive, marine, aircraft fuel systems. Can be compounded for FDA applications.

Temperature Range: Standard Compound: -40°F to +257°F. Special Compounds: -67°F to +275°F. (Dry Heat Only)

Hardness: (Shore A): 40 to 90.

Features: Comprised of the copolymer butadiene and acrylonitrile, in varying proportions. Use of Carboxylated Nitrile can have superior abrasion resistance, while still having improved oil resistance.

Limitations: Nitrile compounds are attacked by small amounts of Ozone. Phthalate type plasticizers are commonly used in compunding Nitrile rubber. These plasticizers can migrate out and cause problems with certain plastics. Also, new regulation on certain phthalates have limited their use.

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Nitrile, Hydrogenated (HNBR)

Trade Name(s):
Zetpol ... Zeon Co., Ltd.
Therban ... Bayer

ASTM D1418 Designation: HNBR

ASTM D2000/SAE J200 Type, Class: DH

Apple Compound Designation: NB

Standard Color: Black

Description: HNBR is the product of the hydrogenation of Nitrile, resulting in varying degrees of saturation of the polymeric chain, along with a range of enhanced physical strength and chemical resistance properties.

Key Use(s): ALL oil resistant applications, including exposure to such oil additives as detergents, anti-oxidants and anti-wear agents. Exposure to oil soured with metal sludge. Seals for oil well applications. Seals for automotive fuel handling systems. Seals for general industrial usage.

Temperature Range: Standard Compound: -30°F to +300°F. (Dry Heat Only) Special Compounds: -76°F to +347°F.

Hardness (Shore A): 50 to 90

Features: Like Nitrile, increasing acrylonitrile content improves oil resistance at a cost of reduced low temperature performance.

Limitations: Like Nitrile, HNBR is not recommended for exposure to ethers, esters, ketones, or chlorinated hydrocarbons.

Perfluoroelastomer

Trade Name(s):
Chemraz® ... Green, Tweed & Co.
Kalrez® ... DuPont Performance Elastomers
Tecnoflon PFR ... Solvay Solexis

ASTM D1418 Designation: FFKM

ASTM D2000/SAE J200 Type, Class:
No Designation at Time of Publication

Apple Compound Designation: KA

Standard Color: Black

Description: FFKM parts are made from a perfluoroelastomer possessing exceptional resistance to degradation by aggressive fluids and/or gases.

Key Use(s): Seals for use in the chemical and petroleum industries as well as for the manufacturing of semiconductors and analytical and process instruments. It is also used for high temperature applications and for paint and coating operations.

Temperature Range:
Standard Compound: -13°F to +600°F.

Hardness (Shore A): 65 to 90

Features: FFKM combines the toughness of an elastomeric material with the chemical inertness of Teflon®. It resists attack by nearly all chemical reagents and provides long-term service where corrosive additives can cause other elastomers to swell or degrade. In addition, FFKM parts are less likely to cold flow than Teflon seals.

Limitations: Withstanding degradation by virtually ALL chemicals, FFKM can swell significantly when exposed to some fluorinated solvents, fully halogenated freons and uranium hexafluoride. In addition, FFKM parts should not be exposed to molten or gaseous alkali metals.

As the thermal coefficient of expansion for FFKM is stated by the manufacturer to be “about 50% greater than for fluoroelastomers,” gland volume may have to be increased to allow for this expansion in elevated temperature situations.

Because of its high cost, FFKM is generally used when no other elastomer is appropriate.

Polyacrylate

Trade Name(s):
HyTemp ACM ... Zeon
Acralen A ... Bayer Polymer

ASTM D1418 Designation: ACM

ASTM D2000/SAE J200 Type, Class: DH; DF

Apple Compound Designation: PY

Standard Color: Black

Description: Polyacrylates are copolymers (ethyl acrylates) possessing outstanding resistance to petroleum fuels and oils.

Key Use(s): Sealing automatic transmissions & power steering systems. Sealing petroleum oils up to 300°F.

Temperature Range: Standard Compound: -25°F to +300°F.

Hardness (Shore A): 40 to 90.

Features: With excellent resistance to hot oil, automatic transmission and Type A power steering fluids, the greatest use for Polyacrylate is found in automobile manufacture, where O-rings of this material are employed to seal components of automatic transmission and power steering systems.

Highly resistant to sunlight and ozone degradation, Polyacrylate also features an enhanced ability to resist flex cracking.

Limitations: While resistance to hot air aging is superior to Nitrile, Polyacrylate strength, compression set, water resistance properties and low temperature capabilities are inferior to many other polymers.

Polyacrylates are also not generally recommended for exposure to alcohol, glycols, alkalis, brake fluids, or to chlorinated or aromatic hydrocarbons.

Polysulfide

Trade Name(s):
Thiokol® (types A, B, FA, ST) ... Thiokol Corp.

ASTM D1418 Designation: T

ASTM D2000/SAE J200 Type, Class: AK, BK

Apple Compound Designation: TH

Standard Color: Black

Description: Another of the early developed synthetic elastomers, Polysulfide offers a remarkable combination of solvent resistance, low temperature flexibility, flex crack resistance, oxygen and ozone resistance, and gas impermeability.

Key Use(s): Seals for paint and coatings and insecticide industry use.

Temperature Range: Standard Compound: -50°F to +225°F.

Hardness (Shore A): 50 to 80

Features: Resistant to a wide range of solvents, including ketones, ethers, and aromatic hydrocarbons. Polysulfide has gained wide acceptance as a seal material for paints and coatings, and insecticides.

Limitations: With poor heat resistance, poor mechanical strength and compression set properties, Polysulfides are not as versatile as other elastomers from a performance standpoint. They are also not recommended for exposure to mercaptans, esters, amines, chlorinated or nitro hydrocarbons.

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Polytetrafluoroethyne (Teflon®)

Trade Name(s):
Teflon® ... DuPont Dow Elastomers
TFM ... Dyneon

ASTM D1418 Designation: FEP

ASTM D2000/SAE J200 Type, Class:
No designation at time of publication.

Apple Compound Designation: TF

Standard Color: White

Description: Teflon® is a tough, chemically inert polymer possessing an incredible working temperature range.

Key Use(s): Seals for wide chemical exposure situations, with special emphasis on temperature extremes.

For static and SLOW INTERMITTENT dynamic situations.

Temperature Range: Standard Compound: -300°F to +450°F.

Hardness (Shore A): 98.

Features: Teflon® is inert to virtually all industrial chemicals, even at elevated temperatures. Seals fabricated from this material feature outstanding weather resistance, high resistance to ozone, and high resistance to the degrading effects of exposure to such solvents as acetone, MEK, and xylene. Possessing average elastomer characteristics of 2,500 to 3,500 psi tensile strength, and 300% elongation, they are tough, impact resistant, low friction, non-twisting performers over an extremely wide temperature range.

Limitations: Teflon® is hampered by very poor elastic memory at room, or low temperatures. This presents problems in O-ring installation, requiring extra care to be taken in control over O-ring I.D. stretch. Heating Teflon® in boiling water, or in a controlled oven, to 200°F is said to enable an O-ring stretch of 10 to 20% to be achieved, thereby assisting installation, and helping to assure a tight fit.

Because of its poor tear resistance, during O-ring installation particular care should be taken to avoid nicking or scratching Teflon®, as imperfections will cause O-ring leakage.

Finally, the tendency of virgin Teflon® to cold flow over time, when used in gasket type applications, may require special material compounding (with fillers) to control such "creep" in critical sealing situations.

Polyurethane, Cast

Trade Name(s):
Vibrathane ... Uniroyal
Cyanaprene ... American Cyanamid
Polathane ... Polaroid

ASTM D1418 Designation: No designation at time of publication.

ASTM D2000/SAE J200 Type, Class: No designation at time of publication.

Apple Compound Designation: CP

Standard Color: Amber

Description: Cast Polyurethane is outstanding over other O-ring elastomers in abrasion resistance and tensile strength. Additionally, Cast Polyurethane surpasses the performance of Millable Polyurethane in its higher tensile strength, greater elongation, wider temperature range, and lower compression set characteristics.

Key Use(s): Seals for high hydraulic pressures. Situations where highly stressed parts are subject to wear. Used for wheels, rolls, slurry parts, bumpers, couplers, and shock absorbers. Wiper seals for axially moving piston rods.

Temperature Range: Standard Compound: -30°F to +175°F.

Hardness (Shore A): 70 and 90.

Features: With tensile strength of up to 6,000 psi, elongation of 350 to 650%, compression sets of 10 to 25%, and exceedingly high abrasion resistance, the physical properties of Cast Polyurethane are among the best of all O-ring elastomers.

Although they swell slightly upon exposure, Cast Polyurethane compounds feature excellent resistance to mineral-based oils and petroleum products, aliphatic solvents, alcohols and ether. They are also compatible with hydraulic fluids, weak acids and bases, and mixtures containing less than 80% aromatic constituents.

Limitations: Cast Polyurethanes are not recommended for exposure to concentrated acids and bases, ketones, esters, very strong oxidizing agents, pure aromatic compounds and brake fluids. With the exception of special compounds, they are also not recommended for exposure to hot water or steam.

Polyurethane, Millable

Trade Name(s):
Millathane® ... TSE Industries Inc.

ASTM D1418 Designation: AU, EU

ASTM D2000/SAE J200 Type, Class: BG

Apple Compound Designation: MP

Standard Color: Black

Description: Millable Polyurethane is outstanding over most other O-ring elastomers in abrasion resistance and tensile strength.

Key Use(s): Seals for high hydraulic pressures. Situations where highly stressed parts are subject to wear.

Temperature Range: Standard Compound: -30°F to +175°F.

Hardness (Shore A): 40 to 90

Features: Millable Polyurethane offers superior seal performance in hydraulic situations, where high pressures, shock loads, or abrasive contamination is anticipated.

Millable Polyurethane possesses chemical compatibility similar to that of Nitrile, offering good resistance to petroleum-based oils, hydrocarbon fuels and hydraulic fluids, the oxidizing effects of ozone, and the aging effects of sunlight. It also has good tear resistance.

Limitations: Unless specially compounded, at elevated temperatures Millable Polyurethane begins to soften, losing its physical strength and chemical resistance advantages over other polymers.

Tending to rapidly deteriorate when exposed to concentrated acids, ketones, esters, chlorinated and nitro hydrocarbons, Millable Polyurethanes are also prone to hot water and steam degradation.

Silicone

Trade Name(s):
Elastosil ... Wacher
Silastic ... Dow Corning
Silplus ... Momentive Performance Materials

ASTM D1418 Designation: MQ, PMQ, VMQ, PVMQ

ASTM D2000/SAE J200 Type, Class: FC, FE, GE

Apple Compound Designation: SL

Standard Color: Red

Description: A group of elastomers, made from silicon, oxygen, hydrogen and carbon, Silicones are renowned for their retention of flexibility and low compression set characteristics, within one of the widest working temperature ranges for elastomers.

Key Use(s): Static seals in extreme temperature situations. Seals for medical devices, compatible with FDA regulations.

Temperature Range: Standard Compound: -85°F to +400°F. Special Compounds: -148°F to +400°F.

Hardness (Shore A): 5 to 80

Features: Phenyl (PVMQ) based silicones can perform to -148°F. New polymers can take short term to 600°F.

Rule of Thumb
Material cost does not correlate with performance, it depends on the application.

Styrene Butadiene

Trade Name(s):
Too numerous to list.

ASTM D1418 Designation: SBR

ASTM D2000/SAE J200 Type, Class: AA, BA

Apple Compound Designation: SB

Standard Color: Black

Description: Also known as Buna S, or GR-S (Government Rubber-Styrene), Styrene Butadiene was the elastomer substituted for Natural Rubber during World War II. Compounded properties are similar to those of Natural Rubber.

Key Use(s): Isolation dampeners.

Temperature Range: Standard Compound: -50°F to +212°F. (Dry Heat Only)

Hardness (Shore A): 40 to 90.

Features: The main use for Styrene Butadiene today is in the manufacture of automobile tires.

Limitations: SBR is not recommended for exposure to petroleum oils, most hydrocarbons, strong acids, or ozone.

This material is seldom used in modern sealing applications. It has been replaced by better performing materials.

Rule of Thumb *You must test all seals in their actual environment because every application is unique.*

Tetrafluoroethylene/Propylene (Aflas®)

Trade Name(s):
Aflas® ... Asahi Glass Co., Ltd.
TBR ... Dupont Performance Elastomers

ASTM D1418 Designation: FKM

ASTM D2000/SAE J200 Type, Class: HK

Apple Compound Designation: AF

Standard Color: Black

Description: A copolymer of tetrafluoroethylene/propylene, TFE/P can offer a combination of high temperature and chemical resistance.

Key Use(s): Seals for oil field, aerospace, chemical and general industrial environments.

Temperature Range: Standard Compound: +14°F to +446°F.

Hardness (Shore A): 60 to 90.

Features: Resistance to a wide range of chemicals, high temperature and electrical capabilities give broad application diversity. TFE/P have resistance to acids and bases, steam/hot water, corrosion inhibitors, oils and lubricants, and industrial solvents. TFE/P also offer improved low temperature properties over most fluoroelastomers.

Limitations: Tests have shown that other FKM elastomers are recommended for automotive fuels since they have less volume swell than TFE/P. Also, TFE/P has shown to have less than desirable results when exposed to toluene, ethers, ketones, and acetic acid.

Thermoplastic Elastomers

Description: Thermoplastic elastomers combine the processing advantages of plastics with the rubber-like performance of elastomers. Known as two-phase systems, these copolymers are comprised of both hard (plastic) and soft (elastomeric) molecular regions, with each region contributing advantages and limitations to the final material performance. Chemically, fully-cured thermoset rubber particles are dispersed throughout a continuous thermoplastic matrix. Examples of this class of material are Santoprene® and Geolast® from Advanced Elastomer System (AES) and Dynaflex™ from GLS Corporation.

Key Use(s): A broad range of applications that spans from bumpers to bellows, vibrational dampers, couplers, and grommets. Also used throughout the automotive, major and small appliances, and aerospace industries.

Features: In virtually all cases, the substitution of these materials for traditional thermosetting materials results in such benefits as significantly increased production speeds (via conventional plastic injection molding machines) and the ability to reuse clean scrap without a loss in physical properties. This results in a reduced part cost due to minimized scrap loss.

Also, they are available in a broad range of durometers and colors and, by adjusting the percentage of hard (plastic) segments in the copolymer matrix, the physical properties can be modified. For example, as styrene content is increased in polystyrene elastomer block copolymers, they change from weak rubber-like materials to strong elastomers, to leathery materials, to finally hard, glass-like products (with styrene content above 75%).

Limitations: The physical properties of thermoplastic elastomers are highly dependent upon the properties of the plastic and elastomeric regions of the copolymer. Consequently, as temperature changes, so does the behavior of the TPE. The low temperature limit is defined by the glass transition temperature of the rubber phase, below which the material is brittle. Likewise, the high temperature limit is defined by the melting point of the plastic phase, above which the material softens and begins to flow. This results in lowering the overall heat resistance of the copolymer.

Also, as temperature increases, compression set increases which limits the overall component size and complexity due to stack-up tolerances. Likewise, the chemical resistance of the thermoplastic is determined by the limits of BOTH materials comprising the system.

Please Note the Following:

The applications, suggestions and recommendations contained in this book are meant to be used as a professional guide only. Because no two situations or installations are the same, these comments, suggestions, and recommendations are necessarily general AND SHOULD NOT BE RELIED UPON BY ANY PURCHASER WITHOUT INDEPENDENT VERIFICATION BASED ON THE PARTICULAR INSTALLATION OR USE. We strongly recommend that the seal you select be rigorously tested in the actual application prior to production use.

General Properties Of O-Ring Elastomers

Elastomers	Apple Material Designation	ASTM D1418 Designation	ASTM D2000/SAE J200 Type, Class	Economy	Low/High Temp. Limits °F	Tensile Strength	Elongation Maximum (%)	Hardness Range Shore A	Resilience-Rebound	Compression Set	Adhesion To Metals	Abrasion Resistance	Tear Resistance	Weather Resistance	Ozone Resistance	Water Swell Resistance	Steam Resistance Under 300° F	Gas Impermeability	Acid Resistance, Conc.	Alkali Resistance, Conc.	Alcohols	Lubricating Oils Petroleum Based	Aliphatic Hydrocarbons	Aromatic Hydrocarbons	Halogenated Hydrocarbons	Phosphate Ester (Skydro®)	Polar Solvents (keytones)
Tetrafluoroethylene/ Propylene (Aflas®)	AF	FKM	HK	P	+14 to +446	F	400	60-90	F-G	F-G	F	G	F	E	E	G	E	G	G	E	G	G	F	F-G	F-P	G	F
Butyl	BU	IIR	AA; BA	F	-50 to +250	F-G	800	30-90	P	F-G	G	F-G	G	G-E	G-E	E	G	E	G	G-E	E	P	P	P	P	G	G
Chloroprene (Neoprene®)	CR	CR	BC; BE	G	-40 to +250	F	600	40-90	G-E	F-G	G-E	G-E	G	G-E	G-E	F-G	F	G-E	P	P	G-E	G	F	P	P	P	P
Epichlorohydrin	EH	CO; ECO	CH	F	-40 to +275	F	400	50-90	GG	G	F-G	G	E	G-E	G	F-G	P	E	F	F	E	G-E	G	E	P	P	P
Ethylene Acrylic (Vamac®)	VA	AEM	EE; EF; EG	F	-13 to +338	F	450	50-90	F	G	G	G	G	E	E	G	P	G-E	P-G	P-G	F	G	G	P	F-G	P	P
Ethylene-Propylene	EP	EPM; EPDM	AA; BA; CA; DA	E	-40 to +275	G	600	40-95	G	F-G	F-G	G	F-G	E	E	E	E	F	E	E	E	P	P	P	P	E	E
Fluorocarbon	VT	FKM	HK	F	-13 to +446	F	300	55-90	F-G	G	F-G	G	F-G	E	E	G	P	G-E	E	P	F-G	E	E	E	E	P	P
Fluorosilicone	FS	FVMQ	FK	P	-75 to +400	P	600	40-80	G	G-E	F-P	P	P-F	E	E	E	P	P	G	F-E	G	E	F-G	F-G	F-P	F-P	P
Natural Rubber	NA	NR	AA	G	-58 to +158	G-E	700	40-90	E	G-E	E	E	E	P	P	E	P	F-P	F-G	G-E	G	P	P	P	P	P	F-G
Nitrile (Buna-N)	BN	NBR; XNBR	BF; BG: BK; CH	E	-40 to +257	G	600	40-90	G	G	G-E	G-E	G	P-F	P	G	P	G-E	F-G	G	G-E	E	G-E	F	F-P	P	P
Nitrile, Hydrogenated	ZT	HNBR	DH	F	-30 to +300	G-E	340	50-90		G-E		G-E	G	G	G	G	P	G	F-G	P-G	E	E	G-E	F-P	P	P	P
Perfluoroelastome (Kalrez®, Chemraz®)	KA	FFKM	KK	P	-13 to +600	F-G	120 to 190	65-90	G	F	G-E	G-E	F	E	E	G	E	G-E	E	G	E	E	E	E	P	E	P
Polyacrylate	PY	ACM	DF; DH	F	-25 to +300	F	600	40-90	FF	G	F-G	F-G	E	E	P	P	P	P	P	P	E	F-G	E	F-P	P	P	P
Polysulfide	TH	T	AK; BK	P	-50 to +225	P	400	50-80	F	P	P	P	P	G-E	E	P	P	G-E	P	P	G-E	F	G-E	F-G	F-P	P	F-G
Polytetrafluoro-ethylene (Teflon®)	TF	FEP	▲	P	-300 to +450	F	300	98	P	G	P	P-G	P	E	E	E	E	G	E	F-E	E	E	E	E	G-E	P	E
Polyurethane, Cast	CP	▲	▲	P	-30 to +175	E	650	70&90	F-G	G-E	E	E	E	G	G	F-G	P	G-E	P-G	P	P	G	G	G	F-P	P	P
Polyurethane, Millable	MP	AU; EU	BG	F	-30 to +175	G-E	500	40-90	G-E	P-G	E	E	E	G	G	P	P	G-E	P	P	P	G	F	P	P	P	P
Silicone	SL	MQ; PMQ VMQ; PVMQ	FC; FE; GE	G	-85 to +400	P	800	5-80	F-G	G-E	G	P	P	E	E	E	F-P	P	F-G	F-G	G-E	P	P	P	P	F-P	P
Styrene Butadiene	SB	SBR	AA; BA EG	E	-50 to +212	G	600	40-90	P	G	G	P-G	F-G	G	G	E	P	F-G	F-G	F-G	G-E	P	P	P	P	P	F

E=Excellent **G**=Good **F**=Fair **P**=Poor ▲=No designation at time of publication **Blank**=Information not available or conflicting

Common Military Specifications

AMS (Aerospace Material Specifications)
AN (Air Force/Navy Specifications)
M;MIL;MS (Military Specifications)
NAS (National Aeronautical Specifications)

(1) Dash numbers correspond with the AS-568B dash numbers
(2) Dash numbers correspond with the 900 tube fitting series

Material Specification	Numbering Series	Durometer (+/-5)	Base Polymer	Temp. Range (°F)	Description
AMS3209	N/A	70	Neoprene	-40 to +225	Weather Resistant
AMS3301	N/A	40	Silicone	-85 to +400	General Purpose
AMS3302	N/A	50	Silicone	-85 to +400	General Purpose
AMS3303	N/A	60	Silicone	-85 to +400	General Purpose
AMS3304	MS9068 (1)	70	Silicone	-85 to +400	General Purpose
AMS3305	N/A	80	Silicone	-85 to +400	General Purpose
AMS7271	MS9020 (2) MS9021 (1)	65	Nitrile	-67 to +300	Phosphate Ester Resistant
AMS7277	N/A	70-85	Butyl	-85 to +400	General purpose
MIL-P-5315	MS29512 (2) MS29513 (1)	70	Nitrile	-65 to +200	Hydrocarbon Fuel Resistant
MIL-P-5510	MS28778 (2)	90	Nitrile	-65 to +212	For Hydraulic Fluid Systems
MIL-P-5516	AN6227 AN6230	70	Nitrile	-65 to +275	Hydraulic Fluids MIL-H-5606
MIL-R-7362	MS29561 (1) NAS617 (2)	70	Nitrile	-65 to +250	For MIL-L-7808 Fluids
MIL-P-25732	MS28775 (1)	70	Nitrile	-65 to +275	For Hydraulic Fluid Systems
MIL-R-83248 Type 1, Class 1	M83248/1 (1)	75	Fluorocarbon	-20 to +400	High Temperature, Fluid & Compression Set Resistance
Type 1, Class 2	M83248/2 (1)	90	Fluorocarbon	-20 to +400	
MIL-R-25988 Class 1, Grade 70	M25988/1 (1)	70	Fluorosilicone	-80 to +350	Oil & Fuel Resistant
Class 1, Grade 60	M25988/3 (1)	60	Fluorosilicone	-80 to +350	Oil & Fuel Resistant
Class 1, Grade 80	M25988/4 (1)	80	Fluorosilicone	-80 to +350	Oil & Fuel Resistant
ZZR-765B Class 1A & 1B Grade 40	N/A	40	Silicone	-80 to +437	High Temperature & Low Compression Set Resistant
Grade 50	N/A	50	Silicone	-103 to +437	High & Low Temperature Resistant & Low Compression Set Resistant
Grade 60	N/A	60	Silicone	-103 to +437	Same As Above
Grade 70	N/A	70	Silicone	-103 to +437	Low Temperature & Low Compression Set Resistant
ZZR-765B Class 2A & 2B Grade 40	N/A	40	Silicone	-80 to +437	High Temperature & Low Compression Set Resistant
Grade 50	N/A	50	Silicone	-103 to +437	High & Low Temperature Resistant & Low Compression Set Resistant
Grade 70	N/A	70	Silicone	-80 to +437	Low Temperature & Low Compression Set Resistant
Grade 80	N/A	80	Silicone	-80 to +437	Same As Above
ZZR-765B Class 2A Grade 60	N/A	60	Silicone	-103 to +437	High & Low Temperature Resistant & Low Compression Set Resistant
ZZR-765B Class 2B Grade 60	N/A	60	Silicone	-80 to +437	High Temperature Resistant & Low Compression Set Resistant
ZZR-765B Class 3B Grade 70	N/A	70	Silicone	-94 to +392	Tear & Flex Resistant
Grade 80	N/A	80	Silicone	-94 to +392	Same As Above

Note: For most current specifications, visit our website.

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