Seven versatile sealing materials

These polymers are the materials of choice for most seals and gaskets.

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Parts molded from natural rubber, EPDM, and SBR handle a range of automotive applications.

Designing the right seal involves several key criteria, including physical and mechanical characteristics, shape and cross section, as well as processing methods and how the seal attaches to mating parts. But, undoubtedly, a critical factor is the choice of material.

Engineers commonly rely on extruded and molded polymers to seal fluids and protect sensitive equipment from harsh environments. However, with literally thousands of compounds, blends, and formulations to choose from, selecting the best material can be a daunting prospect. To simplify the task, here's a look at seven of the most versatile polymers.

VERSATILE POLYMERS

The following list is by no means all-inclusive. But these widely used materials meet most sealing requirements.

Silicone (polysiloxane) is the elastomer of choice for a broad range of high-performance seals. It is flexible at low temperatures, has outstanding heat resistance, low compression set, and is a good electrical insulator.

Silicone maintains rubberlike properties through a wide range of temperatures, performing for extended periods at –150 to 500°F. Actual service life at a given temperature varies with demands such as continuous flexing or shrinkage restrictions.

It generally does not have high tensile strength. However, silicone retains much of its inherent tensile strength at high temperatures. The material resists radiation, ozone and other gases, water, sunlight, and oxidation, and is color stable. In fact, silicone seals exposed to outdoor weather for more than 15 years often show no significant loss of physical properties.

It can also be easily formulated to be either conductive or nonconductive. And, when properly fabricated, silicone does not stain, corrode, or in any way damage the materials it contacts.

Conventional silicones are classified as slow burning. They contain nonhalogen flame retardants that do not produce corrosive or toxic by-products. Consequently, they generate significantly less smoke during combustion than that given off by most organic elastomers.

Pound for pound, silicone tends to be pricier than many other sealing materials. But longer service life, along with less maintenance and repair over the seal's life span, frequently makes silicone rubber lower in total cost than competing materials.

However, it is not suited for applications that require abrasion, tear, and cut-growth resistance, or high-tensile strength. It is also not recommended for exposure to oil, gasoline, solvents, alkalis, and acids. Fluoroelastomer-coated silicone, EPDM, and nitrile can overcome these limitations.

EPDM (ethylene-propylene-di-

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ene monomer) is well known for strongly resisting ozone, weathering, and aging. It stands up to water and steam, stays flexible at low temperatures, is compatible with alkalis, acids, and oxygenated solvents, and is color stable. But it is generally not recommended for use with oil, gasoline, and hydrocarbon solvents.

EPDM is suited for a wide range of applications, including outdoor use. For instance, products made with rubber-thermoset EPDM, or EPDM-based thermoplastics, are used as primary and secondary door seals, seals for trunk lids, sunroof seals, "gimps" or gap fillers, boot covers, hose insulators, and seals for lights and HVAC systems. EPDM is often the material of choice because it offers superior weathering protection and operates in temperatures from –50 to 330°F.

Neoprene (polychloroprene) is generally considered an all-purpose elastomer with a solid balance of properties and few limitations. Neoprene moderately resists oils and gasoline. It features good flame resistance, weathers well, and resists abrasion, flex cracking, alkalis, and acids. However, expect poor performance with aromatic and oxygenated solvents and limited flexibility at low temperatures.

Nitrile (acrylonitrile-butadiene) stands up well to oil and gasoline, has good permeability, and resists heat and abrasion. Resistance to alkalis and acids increases with a compound's nitrile content. And it can be compounded to withstand ozone, sunlight, and natural aging. Nitrile is superior to neoprene in oil and solvent resistance, but is not recommended for applications where it faces severe weathering or exposure to oxygenated solvents.

Fluoroelastomers provide premium performance and long-term reliability in harsh and corrosive environments. Their exceptional resistance to heat, aging, and a broad range of fuels, solvents, and chemicals makes them ideal for many demanding aerospace, automotive, and industrial applications. Fluoroelastomers also of-

Pinpointing the right material

To select the best elastomer for a seal, engineers must determine physical, mechanical, and chemical-resistance requirements. Unless material specifications are predesignated, gathering information about the seal's functional requirements and end use helps ensure the material maintains its physical properties despite temperature swings, environmental exposure, physical wear and tear, and time.

The best way to start is by taking a close look at the application. For replacement products, examine the properties and service conditions of the original material. For new products, the properties of materials used in similar applications can provide valuable information.

The following checklist denotes a number of characteristics to consider when specifying a seal material.

Physical properties
- Tensile strength and, for dense materials, elongation
- Hardness range (for dense materials) or compression deflection (cellular materials)
- Compression set at room and operating temperatures
- UV, ozone, heat, and storage requirements
- Color, if pigmenting is necessary
- Aesthetics

Mechanical properties
- Speed of recovery from deflection
- Flexibility
- Tear resistance
- Abrasion resistance
- Permeability to gases

Chemical-resistance properties
- Acids or caustics
- Hydrocarbon solvents
- Oxygenated solvents
- Flame or temperature extremes.

Extruded and molded polymer parts handle a wide range of sealing applications.

fer excellent resistance to weather, ozone, oxygen, and sunlight, and are inherently more flame retardant than hydrocarbon rubbers.

On the downside, they tend to be among the most-expensive sealing materials. And fluoroelastomers have poor resistance to ketones, esters, ethers, amines, and aqueous bases such as ammonia and sodium hydroxide.

SBR (styrene-butadiene rubber) has excellent impact strength, good resilience, tensile strength, and abrasion resistance, and stays flexible at low temperatures. However, it is not the polymer of choice for applications requiring resistance to oil, gasoline, and hydrocarbon solvents.

SBR is also unsuitable for exposure to the outside elements, such as UV and ozone. In addition to seals and gaskets, SBR can be found in tire treads, conveyor belt covers, mats, and even shoe soles.

TPE (thermoplastic elastomer) is a collective name for several families of elastomers that differ in composition and molecular structure. TPE materials have properties and performance comparable to rubber but are processed like other thermoplastics.

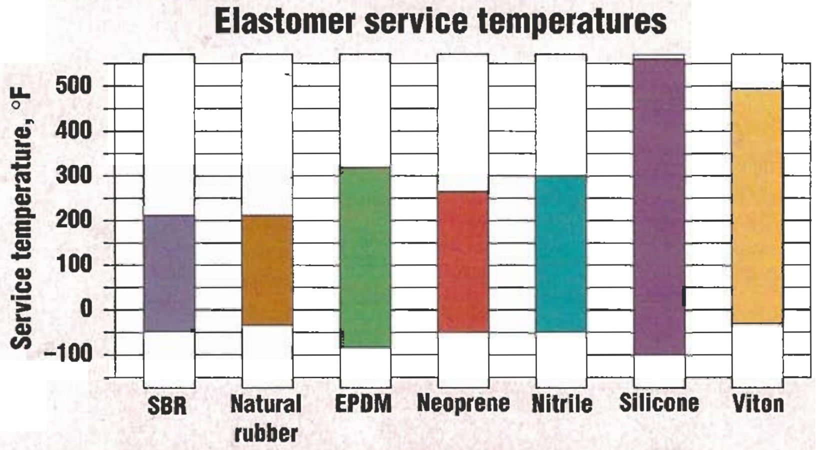
Performance is similar to conventional thermosets such as natural rubber, SBR, EPDM, and neoprene except for some tempera-

COMPARING ELASTOMER PROPERTIES

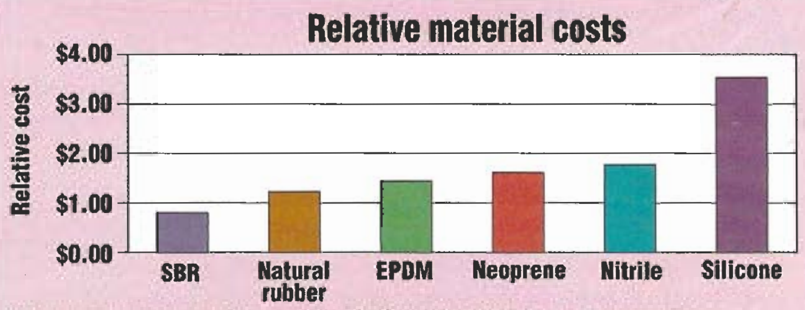
Chemical name	NATURAL RUBBER Polyisoprene	SBR Styrene butadiene	EPDM Ethylene propylene	NEOPRENE Chloroprene	NITRILE Acrylonitrile butadiene	SILICONE Polysiloxane	FKM Fluorinated hydrocarbon
Physical properties							
Specific gravity	0.93	0.94	0.86	1.23	1.00	0.95 to 1.20	1.4 to 1.95
Durometer range	30 to 100	40 to 100	30 to 90	40 to 95	30 to 90	25 to 90	55 to 90
Tensile strength	E	F-G	VG	VG	VG	F-G	VG
Elongation	VG-E	G	G	G	G	VG-E	F-G
Compression set	G	G	G	F-G	G	G-E	G-E
Heat resistance	F	F-G	VG-E	F-G	G	E	E
Resilience or rebound	E	F-G	G	VG	F-G	G	F
Impact resistance	E	E	G	G	F	P-G	E
Abrasion resistance	E	G-E	G-E	G-E	G-E	P-F	F-G
Tear resistance	E	F	F-G	F-G	F-G	P-F	F
Cut growth	E	G	G	G	G	P-F	P-F
Flame resistance	P	P	P	G	P	F-G	VG-E
Gas impermeability	F	F	F-G	F-G	G	F-G	E
Weathering resistance	P-F	F	E	VG	F-G	E	E
Low-temperature limit, °F	–10 to –50	0 to –50	–20 to –60	–10 to –50	–10 to –30	–65 to –100	+10 to –40
High-temperature limit, °F	170 to 225	170 to 225	300 to 350	225	250	400 to 550	400 to 450
Chemical resistance							
Acid	F-G	F-G	G	G	G	F	G
Alcohols	G	G	F-G	VG	F-G	G	F-E
Aliphatic hydrocarbon solvents	P	P	P	G	E	P-F	E
Alkali	F	F	VG	E	VG	P	F-G
Animal and vegetable oils	F	F	G	G	VG	G	E
Aromatic hydrocarbon solvents	P	P	P	P-F	F-G	P-F	E
Oil and gasoline	P	P	P	F-G	G-E	P-F	E
Oxygenated solvents	G	G	VG	P-F	P	F	P
Water	E	G-E	E	G	G-E	G-E	G

Key: E = excellent, VG = very good, G = good, F = fair, and P = poor.

The information presented is intentionally general in nature, as it represents a consensus based on input from many sources. Selecting the best elastomer for an application isn't always easy or clear cut. Temperature and other environmental factors can affect long-term physical properties of a compound. The best course is to seek a balance of properties from the lowest-cost material.



The temperature range for a given polymer may vary with specific formulations. It is often possible to raise or lower some ratings through creative compounding.



Price comparisons shown are relative and should only be used for estimating purposes, as prices tend to fluctuate. Approximate costs are per extrudable pound. Unique polymers, such as DuPont's Viton, tend to be much more expensive and can range up to $20 to $25/lb.

ture limitations. Important features include flame and ozone resistance, excellent flex fatigue, and compatibility with alcohol. TPEs, however, are limited by poor resistance to aliphatic and aromatic hydrocarbon solvents, as well as oil and gasoline.

TPE-V, otherwise known as TPV, is dynamically vulcanized and is flexible, elastic, recyclable, and can be colored. TPE-O, also known as TPO, is a mixture that is not vulcanized. It has better rebound characteristics but is less effective for compression set, compared with other TPEs. TPOs resist fluid and heat and work well in nondynamic applications.

THE RIGHT COMPOUND

Most virgin elastomers have limited commercial value. Therefore, seal suppliers must formulate a "recipe" that enhances an elastomer's inherent physical and chemical characteristics. The recipe also aims to ensure efficient molding or extruding and meet industrial specifications such as UL, ASTM, SAE, and Mil Standards.

The range of properties compounders can develop for a given polymer is limited by the material itself. All properties of a particular class are not found in a single compound. However, it is often possible to raise or lower ratings to acceptable levels through creative compounding.

Manufacturers have a wide variety of ingredients at their disposal, including:

Processing aids that modify the compound during mixing and processing and improve extrusion or molding efficiency.

Vulcanizing agents, or cure agents, to convert formless rubber compounds, when heated, into permanent extruded or molded shapes.

Accelerators that increase the vulcanization or cure rate and, in many instances, improve the final product's physical properties.

Accelerator activators work with accelerators to reduce vulcanization or cure time and improve a compound's final characteristics.

Age resistors such as antioxidants and antiozonants slow the deterioration of rubber products due to exposure to light, heat, oxygen, radiation, and ozone.

Fillers can reduce costs, reinforce materials, alter physical properties, or facilitate final processing.

Softeners/plasticizers make polymers more elastic, aid mixing, increase tack, and extend or replace a portion of a polymer's hydrocarbon content.

Miscellaneous ingredients include color pigments, blowing agents, odorants, retarders, abrasives, and dusting agents that impart specific characteristics to a compound.

Even after compounders determine the final formulation, the order in which ingredients are added, the mixing time, temperature conditions, and other processing factors are critical to creating compounds that repeatedly meet desired specifications. Because processing conditions tend to vary from one formulation to another, mixing equipment must be versatile and equipped with controls that ensure batch-to-batch consistency. **MD**

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