

Elastomers

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The information contained in this article represents a significant collection of technical information on elastomers. This information will help to achieve increased reliability at a decreased cost. Assemblage of this information will provide a single point of reference that might otherwise be time consuming to obtain. Most of information given in this article is mainly derived from the literature on the subject indicated in the references given at the end of this article. For more information, please refer them. All information contained in this article has been assembled with great care. However, the information is given for guidance purposes only. The ultimate responsibility for its use and any subsequent liability rests with the end user. Please see the disclaimer uploaded on <http://www.practicalmaintenance.net>.

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Elastomers

Elastomers are arguably the most versatile of engineering materials. They behave very differently from plastics and metals, particularly in the way they deform and recover under load. Unlike plastics and metals, all elastomers have the ability to deform substantially by stretching, compression or torsion and then return almost to their original shape after removal of the force causing the deformation. Elastomers are used in a vast range of sealing and non-sealing applications like O-rings, radial shaft seals (oil seals), gaskets, expansion joints, flexible hoses, coupling elements, belts for power transmission, conveyor belts, etc. Essential information about elastomers is given in this article.

History of Elastomers

Rubber was first brought to Europe in 1493 from the Americas by Columbus. However, it remained little more than a novelty for over 200 years. Interest eventually began to grow. In 1770 Joseph Priestley noted its ability to rub out pencil marks and it was named 'rubber'. This was followed by a rapid growth in technical developments and applications in the 19th century.

Charles Goodyear's discovery of vulcanization using sulfur increased the natural strength and durability of rubber by cross-linking the molecules of the soft gum rubber into a tougher material. Other technological advances included improved compounding techniques which enabled the use of anti-oxidants and accelerators, and the incorporation of carbon black to improve strength. This led to a vast increase in the number of applications. As the number of applications increased, demand for the raw material grew rapidly.

The period between World Wars I and II witnessed the first development of a true synthetic substitute for natural rubber, i.e., sodium polymerized butadiene, which was produced in Germany as Buna rubber and in the USSR as SK rubber. In the early 1960s production of natural rubber was surpassed by that of synthetic elastomers. By 1990, two-thirds of world rubber production consisted of synthetic varieties.

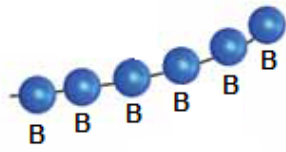
Polymers and Elastomers

A polymer is the "result of a chemical linking of molecules into a long chain-like structure." Both plastics and elastomers are classified as polymers. Polymers which have the property of elasticity are called elastomers.

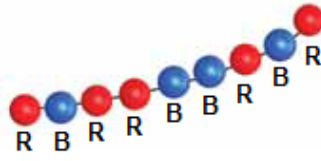
Elastomers are made up of long chains of atoms, mainly carbon, hydrogen and oxygen, which are having a cross-linking with their neighboring chains. It is these cross-linking bonds that pull the elastomer back into shape when the deforming force is removed.

The chains can typically consist of 300,000 or more monomer units. As shown in the following figure, they can be composed of repeated units of the same monomer, or made up of two or more different monomers. Polymers made up of two types of monomer are known as copolymers or dipolymers, while those made from three are called terpolymers.

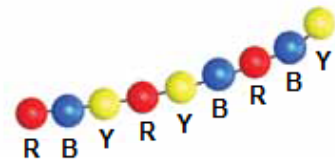
Legend: R – Red, Y – Yellow, B – Blue



**Single Monomer Units
Polymer**



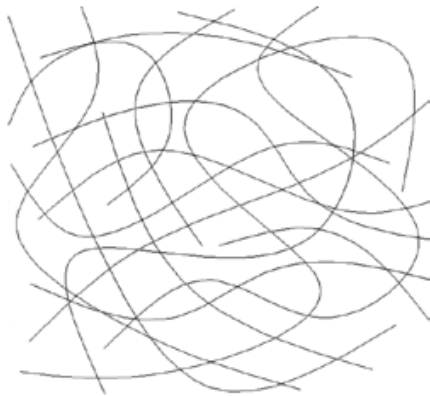
**Two Different Monomers
Copolymer (Dipolymer)**



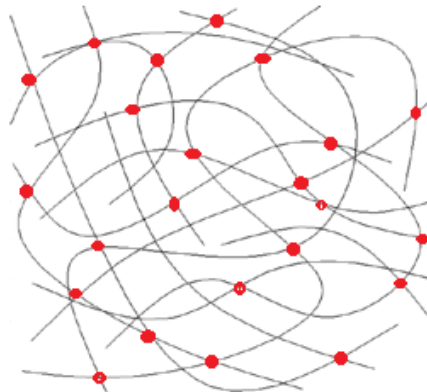
**Three Different Monomers
Terpolymer**

Polymerization of Monomer Units

Most types of elastomers are thermosets, which gain most of their strength after vulcanization - an irreversible cross-linking of their polymer chains that occurs when the compound is subjected to pressure and heat.



**No Cross-Links
Before Vulcanization**



**Cross-Linked
After Vulcanization**

Thermosets Elastomer Chains - Before and After Vulcanization

Thermoplastic elastomers, on the other hand, have weaker cross-linking and can be moulded, extruded and reused like plastic materials, while still having the typical elastic properties of elastomers.

Properties of Elastomers

Though “elastomer” is synonymous with “rubber,” it is formally defined as a “high molecular weight polymer that can be, or has been modified, to a state exhibiting little plastic flow and rapid, nearly complete recovery from an extending or compressing force.” In most instances we call such material before modification “uncured” or “unprocessed” rubber or polymer.

When the basic high molecular weight polymer, without the addition of plasticizers or other diluents, is converted by appropriate means to an essentially non-plastic state and tested at room temperature, it usually meets the following two requirements in order to be called an elastomer.

1. It must not break when stretched approximately 100%.
2. After being held for five minutes at 100% stretch, it must retract to within 10% of its original length within five minutes of release.

Note: Extremely high hardness/modulus materials generally do not exhibit above properties even though they are still considered elastomers.

The American Society for Testing and Materials (ASTM) uses above criteria to define the term “elastomer.”

Elasticity and resilience are the most important properties of an elastomer.

Elasticity

Elasticity is the ability of a material to return to its original shape and size after being stretched, compressed, twisted or bent. Elastic deformation (change of shape) lasts only as long as a deforming force is applied and disappears once the force is removed.

The elasticity of elastomers arises from the ability of their long polymer chains to reconfigure themselves under an applied stress. The cross-linkages between the chains ensure that the elastomer returns to its original configuration when the stress is removed. Elastomers can reversibly extend by approximately 200 to 1000% depending on the type of material.

Resilience

Resilience as applied to elastomers is essentially their ability to return quickly to their original shape after temporary deflection. In other words, it indicates the speed of recovery.

Most elastomers possess a number of other useful properties as under.

- Low permeability to air, gases, water and steam
- Good electrical and thermal insulation
- Good mechanical properties
- The ability to adhere to various fibres, metals and rigid plastics

ASTM D1418: Standard Practice for Rubber and Rubber Latices - Nomenclature

ASTM D1418 covers a system of general classification or nomenclature for the basic rubbers both in dry and latex forms. As per this practice, rubbers shall be coded from the chemical composition of the polymer chain using the classes: M, N, O, R, Q, T, U and Z. For more information on the classes, please see the standard.

Mixtures of rubbers are identified by using the class designations for the types of rubbers in the mixture, with the major component listed first if the composition is known and in alphabetical order if the rubbers are present in equal amounts.

The following table contains the nomenclature used for common elastomer types as per ASTM D1418 and ISO/DIN 1629.

Chemical Name	Abbreviation		Trade Name
	ASTM D1418	ISO/DIN 1629	
M-class (rubbers having a saturated chain of the polymethylene type)			
Polyacrylate Rubber	ACM	ACM	-
Ethylene Acrylate	AEM	-	Vamac®
Chlorosulfonated Polyethylene Rubber	CSM	CSM	-
Ethylene Propylene Diene Rubber	EPDM	EPDM	-
Ethylene Propylene Rubber	EPM	EPDM	-
Fluorocarbon Rubber	FKM	FPM	Viton®
Tetrafluorethylene Propylene Copolymer	FEPM	FEPM	-
Perfluorinated Elastomer	FFKM	-	Kalrez®
O-class (rubbers having oxygen in the polymer chain)			
Epichlorohydrin Rubber	CO	CO	-
Epichlorohydrin Copolymer Rubber	ECO	ECO	-
R-class (unsaturated hydrogen carbon chain)			
Butadiene Rubber	BR	BR	-
Chloroprene Rubber	CR	CR	Neoprene
Isobutene Isoprene Rubber (Butyl Rubber)	IIR	IIR	-
Isoprene Rubber / Natural Rubber	IR	IR	-
Nitrile Butadiene Rubber (BUNA-N)	NBR	NBR	-
Styrene Butadiene Rubber (BUNA-S)	SBR	SBR	-
Hydrogenated Nitrile	HNBR	-	-
Q-class (with Silicone in the main chain)			
Fluorosilicone Rubber	FVMQ	FMQ	-
Methyl Vinyl Silicone Rubber	VMQ	VMQ	-
U-class (with carbon, oxygen and nitrogen in the main chain)			
Polyester Urethane	AU	AU	-
Polyether Urethane	EU	EU	-

Elastomer Compounding and Quality

The basic properties of elastomers are highly dependent on the polymers used in their manufacture. However, these properties can be modified through the appropriate addition of compounding ingredients. A compound is a mixture of base polymer and other chemicals.

Some compounds are required to deliver the best performance in the end product, with cost being a secondary issue. In such case compounding requires the use of materials selected to give the required characteristics without the inclusion of non-essential ingredients which could compromise performance.

However, in some applications, compounds may be designed to minimize cost by addition of extenders and diluents to reduce the proportion of high priced components in the mix. Though this leads to compromises in the mechanical and other properties, it may be acceptable for those applications.

Other important factors that affect the quality of the resulting elastomer include the quality of the raw ingredients, the quality control in mixing and the vulcanization of the compounded material. As with all chemical reactions, temperature is responsible for the speed of vulcanization reaction. Hence, when the ideal process temperature is constant during the entire vulcanization time, the optimum degree of curing will be reached. For this reason, the conditions of vulcanization should be closely controlled and recorded as part of the quality assurance process.

Following are the important ingredients of a compound.

Polymers

The polymer, or mixture of polymers, is the fundamental component in determining the properties of the compound. It is selected to optimize service performance, processing requirements and cost consideration.

Fillers

Fillers are added primarily to provide reinforcement and secondly to reduce cost. They fall into two basic categories, reinforcing or semi-reinforcing and diluent (non-reinforcing, generally for cheapening).

The most popular reinforcing and semi-reinforcing fillers are carbon blacks, which are categorized primarily by means of particle size. Carbon blacks and nonblack fillers become more reinforcing as particle size decreases. Highly reinforcing fillers can make a compound tough, which can result in poor flow.

Diluent, or non-reinforcing, fillers have a large particle size and do not 'bond' to the polymer in the same way as reinforcing fillers. They are mainly added to reduce cost. Examples include soft clay, calcium carbonate and talc.

Fine-ground natural silica is used to provide dimensional stability, improved thermal conductivity and good electrical insulation properties at low cost.

Accelerators

These speed up the cure. Modifications in their levels can control the cure speed and elastomer properties.

Activators

In most sulfur-cured rubbers, zinc oxide and stearic acid are added to help initiate the cure. In other rubbers, different materials are added which assist the cure in an indirect way.

Bonding Promoters

Bonding agents are often added to the compound to increase the bond strength between the different components.

Extenders

Extenders are compounding ingredients that are added to the elastomer to reduce the cost of the compound.

Flame Retardants

Most elastomers support combustion and the resulting by-products can be extremely hazardous. To improve their flame resistance a number of products may be added to the compound, either inorganic or organic. They include antimony trioxide, zinc borate, aluminium hydroxide and chlorinated paraffin.

Plasticizers/process Aids

Plasticizers need to be compatible with the polymer. They reduce hardness with a given level of filler, and can help with filler incorporation and dispersion. They are normally added to improve processability.

Material and Product Testing

The following is an overview of important terms and methods for material and product testing.

Hardness

The hardness of an elastomer is measured using an indenter that is pushed into the sample with a known force. The indicating scale reads the hardness of the elastomer. If there is no penetration, the scale will read 100, as on a flat glass or steel surface. Two scales are in common use.

They are the Shore A type durometer scale and the IRHD (International Rubber Hardness Degrees) scale. The size and shape of the indenter used in IRHD readings is much smaller, thus allowing for more accurate measurements on curved surfaces such as an O-ring cross-section. Because of the limitations of the testing instruments, hardness is usually within ± 5 .

There is no direct correlation between the readings of Shore A and IRHD Scales. However, these scales are equivalent except at high hardness (>95) and low hardness (<40).

Tensile Strength

Tensile strength is the stress required in psi (pounds per square inch) or MPa (Mega Pascals) to rupture a standard test piece of a given elastomer material when stressed. Tensile strength is one quality assurance measurement used to insure compound uniformity. It is also useful as an indication of deterioration of the compound after it has been in contact with a fluid for long periods.

Tensile strength is not ordinarily used in design calculations. Most elastomers that have a tensile strength below 7 MPa are usually rather poor in most mechanical properties and those above 21 MPa have good mechanical properties. However, those elastomers that fall in between those numbers usually have adequate mechanical properties.

Elongation at Break

This refers to the elongation (percentage strain) measured at the point of rupture. A high value is important if substantial stretching is required during fitting, and also in applications where seals are energized across relatively large gaps.

Compression Set

A mechanically loaded elastomer exhibits time dependent relaxation. Hence they deform under load and rarely return completely to their original form. The difference between the initial and final dimensions is known as compression set or permanent set.

Compression set is widely used for assessing recovery. Standard methods require a compressed sample to be exposed for a fixed time, at a fixed temperature, and then allowed to recover (generally for 30 minutes) at room temperature. Compression set is expressed as

the percentage of the original deformation not recovered after this recovery period: 0 per cent indicating full recovery, 100 per cent indicating no recovery. The test is used primarily as a quality control tool.

High compression set is not conducive to long term sealability. Compression set is highest at the extremes of an elastomers operating capability: irreversible at high temperatures because of chemical degradation, and reversible at low temperatures because of physical stiffening and 'freezing'.

Compression Stress Relaxation (CSR) Testing

A compression stress relaxometer measures the residual sealing force of elastomer samples as they are held between parallel plates under a constant strain.

Fluid Resistance

Immersion of samples in various fluids at differing temperatures, followed by testing for volume change, tensile strength change, hardness change, etc., will give a reliable indication of how well the material will perform under similar service conditions. Due to complications arising from solubility parameters, this is an important test.

Tear Strength

Tear strength is a measure of the resistance of an elastomer to tearing. It is measured using a tensile test machine operating at a constant rate of traverse until the test piece breaks.

Abrasion Resistance

Abrasion damage can occur when there is dynamic motion against an abrasive counterface, or when the sealed environment is intrinsically abrasive and either passes across or impinges upon the seal.

Standard abrasion tests depend on producing relative motion between a rubber sample and an abrasive surface, pressed together by a predetermined force.

Air Ageing

Exposure to air or oxygen-rich environments at elevated temperatures can cause gradual loss of mechanical properties. Many of these changes occur at a molecular level and are irreversible.

For this test, samples (tensile, hardness, etc.) are placed in ovens at a controlled elevated temperature for a pre-determined time, removed, allowed to cool and then tested and compared against the original properties for the material at room temperature.

Chemical Compatibility

Many chemical species cause degradation to elastomeric compounds, either by attacking the polymer or some of its compounding ingredients.

After immersion in the test fluid under defined conditions of time, concentration and temperature, samples can be tested for hardness and swell. This may be followed by elongation at break testing.

Rapid Gas Decompression (RGD) Testing

Rapid gas decompression (RGD), also known as explosive decompression (ED), is generally found in the oil and gas industry. However, it can be experienced in any application where there is a rapid drop in gas pressure.

RGD damage consists of structural failure in the form of blistering, internal cracking and splits caused when the gas pressure, to which the seal is exposed, is rapidly reduced.

The elastomeric components of a system are, to a greater or lesser extent, susceptible to the permeation and diffusion of gases dissolving in their surface. With time, these components will become saturated with whatever gases are in the system. Under these conditions – as long as the internal gas pressure of the elastomer remains at equilibrium with the ambient pressure – there is minimal damage, if any, and no deterioration in performance of the elastomeric component occurs.

When the external gas pressure is removed or pressure fluctuations occur, large pressure gradients are created between the interior and the surface of the elastomeric component. This pressure differential may be balanced by the gas simply diffusing/permeating out of the elastomer. If the physical properties of the elastomeric compound cannot resist crack and blister growth during the permeation process, then it results in structural failure.

Testing is usually carried out on constrained O-rings which are placed in a test vessel. After purging the vessel with test gas to remove any air, the vessel is heated and pressurized with test gas to the chosen pressure and temperature and held for an exposure period.

Decompression is then performed at a predetermined rate while maintaining the test temperature as constant as possible. After a hold period at ambient pressure the pressure cycling is repeated for typically five to ten cycles.

The seals are then externally examined for visual appearance and cut into four radial sections. Magnification is used to examine the cross-sections for internal cracks, and the samples are rated for RGD damage according to the number and lengths of any cracks found.

Depending on application, elastomers are also tested for electrical properties, weathering and permeability.

Test Methods

ASTM and ISO standards to carry out various tests are as under.

Test	Standard	
	ASTM	ISO
Abrasion	D2228	4649
Air ageing	D573	188
Compression set	D395	815
Elongation	D412	37
Effect of liquid	D471	1817
Hardness, IRHD	D1415	48
Hardness, Shore	D2240	7619-1
Tear strength	D624	34-1
Tensile strength	D412	37

Material selection

When selecting elastomers for specific applications, a number of criteria need to be considered. The main criteria are as under.

Temperature: Continuous, minimum, maximum, thermal cycling, glass transition temperature shift.

Pressure: Continuous, maximum, fluctuations, rate of decompression.

Application: Static or dynamic, clearance gaps, surface finish.

Media: Chemical compatibility.

Cost: The guiding principle should be "value-in-use." When evaluating seal performance, seal life and maintenance costs must be included. Specifying the proper high performance seal can also prevent costly unscheduled downtime and dangerous leakage.

SAE J200 / ASTM D 2000 - Method for Specifying Elastomers

The purpose of ASTM D 2000: Standard Classification System for Rubber Products in Automotive Applications is to provide guidance to the engineer in the selection of practical, commercially available rubber materials, and further to provide a method for specifying these materials by the use of a simple "line call-out" designation.

This classification system tabulates the properties of vulcanized rubber materials (natural rubber, reclaimed rubber, synthetic rubbers, alone or in combination) that are intended for, but not limited to, use in rubber products for automotive applications.

This classification system is based on the premise that the properties of all rubber products can be arranged into characteristic material designations. These designations are determined by types, based on resistance to heat aging, and classes, based on resistance to swelling in oil. Basic levels are thus established which, together with values describing additional requirements, permit complete description of the quality of all elastomeric materials.

Type and Class

The prefix letter "M" shall be used to indicate that the classification system is based on SI units. Call outs not prefixed by the letter M refer to an earlier classification system based on inch-pound units. This was published in editions up to 1980.

Rubber materials shall be designated on the basis of type (heat resistance) and class (oil resistance). Type and class are indicated by letter designations as shown in the following tables (Table 1 and Table 2).

Type is based on changes in tensile strength of not more than $\pm 30\%$, elongation of not more than -50% , and hardness of not more than ± 15 points after heat aging for 70 h at an appropriate temperature. The temperatures at which these materials shall be tested for determining type are listed in the table given below (Table 1).

Basic Requirements for Establishing Type by Temperature (Table 1)	
Type	Test Temperature, °C
A	70
B	100
C	125
D	150
E	175
F	200
G	225
H	250
J	275
K	300

Class is based on the resistance of the material to swelling in ASTM Oil No. 3 after 70-h immersion at a temperature determined from Table 1, except that a maximum temperature of 150°C (the upper limit of oil stability) shall be used. Limits of swelling for each class are shown in the table given below (Table 2).

Basic Requirements for Establishing Class by Volume Swell (Table 2)	
Class	Volume Swell, max, %
A	no requirement
B	140
C	120
D	100
E	80
F	60
G	40
H	30
J	20
K	10

The letter designations shall always be followed by a three-digit number to specify the hardness and the tensile strength - for example, 505.

In above example, the first digit indicates durometer hardness, for example, 5 for 50 ± 5, 6 for 60 ± 5. The next two digits indicate the minimum tensile strength - for example, 05 for 5 MPa, 14 for 14 MPa.

Grade Numbers, Suffix Letters and Number

Grade Numbers

Since the basic requirements do not always describe sufficiently all the necessary qualities, provision is made for deviation or adding requirements through a system of prefix grade numbers. Grade No. 1 indicates that only the basic requirements are compulsory, and no suffix requirements are permitted. Grades other than No. 1 are used for expressing deviation or additional requirements and are listed as "Available Suffix Grade Numbers" in the last column under Basic Requirements in Table 6 of the standard (for more information, please see Table 6 of ASTM D 2000). A grade number is written as a material prefix preceding the letters for type and class.

Suffix Letters

The suffix letters that may be used, together with their meaning, appear in the following table (Table 3).

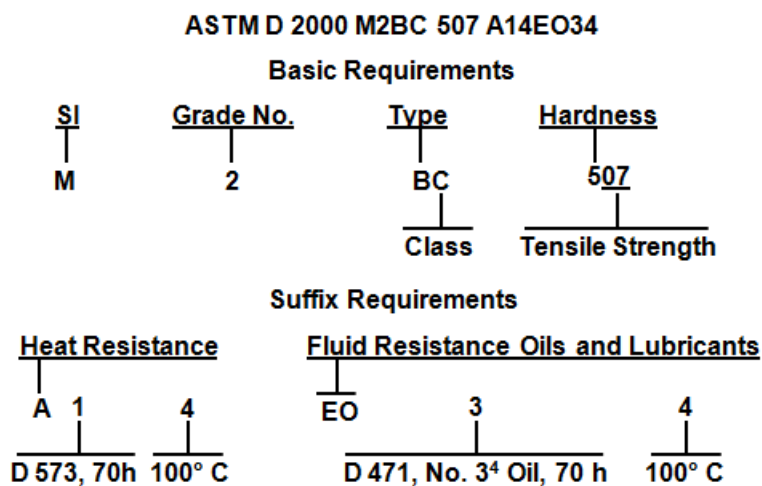
Meaning of Suffix Letters (Table 3)	
Suffix Letter	Test Required
A	Heat Resistance
B	Compression Set
C	Ozone or Weather Resistance
D	Compression-Deflection Resistance
EA	Fluid Resistance (Aqueous)
EF	Fluid Resistance (Fuels)
EO	Fluid Resistance (Oils and Lubricants)
F	Low-Temperature Resistance
G	Tear Resistance
H	Flex Resistance
J	Abrasion Resistance
K	Adhesion
M	Flammability Resistance
N	Impact Resistance
P	Staining Resistance
R	Resilience
Z	Any special requirement, which shall be specified in detail

Suffix Numbers

Each suffix letter should preferably be followed by two suffix numbers. The first suffix number always indicates the test method; time of test is part of the method and is taken from the listings in Table 4 of the standard. The second suffix number, if used, always indicates the temperature of test and is taken from Table 5 of the standard. Where three-digit numbers are required, they are separated by a dash - for example: -10; B4-10; F1-11.

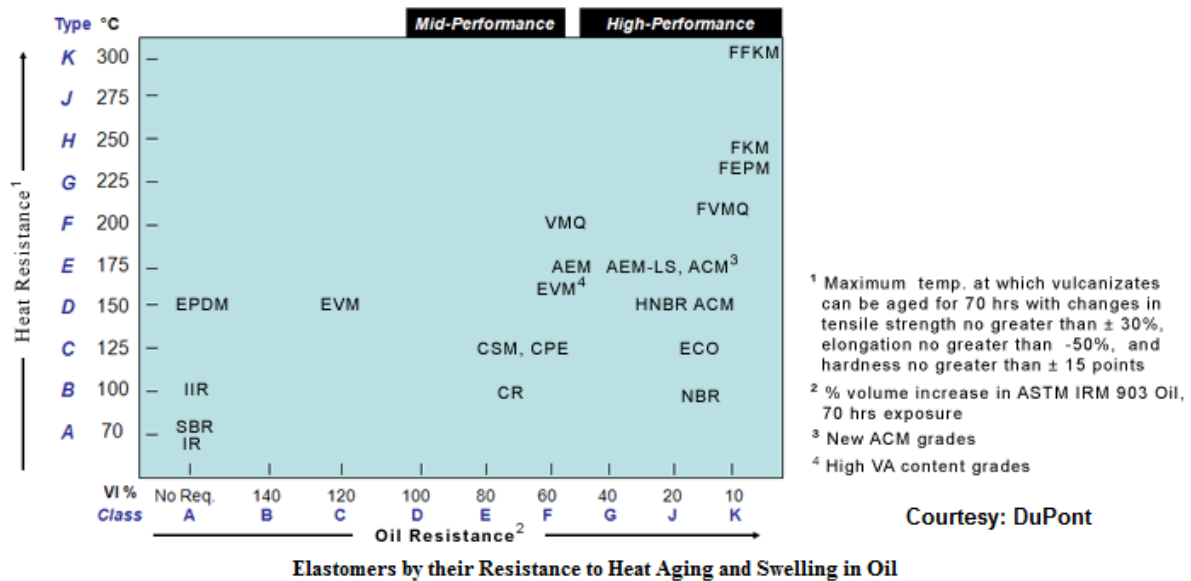
Line Call-Outs

A "line call-out," which is a specification, shall contain: the documents names, the prefix letter M, the grade number, the material designation (type and class), and the hardness and tensile strength, followed by the appropriate suffix requirements. The actual specification is required to fully interpret an ASTM D 2000 line call-out. Following is an example of a "line call-out" or specification for ASTM D 2000 M2BC 507 A14EO34.



Example of ASTM D 2000 Line Call-Out

The following chart positions elastomers by their resistance to heat aging and swelling in oil.



Elastomer Materials

Information about important elastomer materials is as under.

Butyl (IIR)

Service temperature range: -75°F(-60°C) to +250°F(+120°C)

Advantages:

Outstanding impermeability to gases and vapor, very good resistance to heat, oxygen, ozone, and sunlight; high energy absorption (dampening); excellent resistance to alkalis and oxygenated solvents; good hot tear strength; superior resistance to water and steam.

Limitations:

High compression set; poor resistance to oil; gasoline, and hydrocarbon solvents; low rebound elasticity; poor resilience.

Comments:

Butyl is unlike other synthetic elastomers or natural rubber in that it is inherently resistant to ozone and corrosive chemicals. On the negative side, butyl behaves like a plastic, in that it creeps, cold flows and has poor compression set.

Chlorosulfonated Polyethylene (CSM)

Service temperature range: -50°F(-60°C) to +250°F(+120°C)

Advantages:

Good flame retardance; good abrasion resistance; superior resistance to weather, ozone, sunlight and oxidation; excellent resistance to alcohols, alkalis and acids, very good color stability; moderate resistance to oils and gasoline.

Limitations:

Poor to fair resistance to aromatic solvents; limited flexibility at low temperature, fair resilience and compression set.

Comments:

CSM is a close match to neoprene, but it has improved resistance to acids, solvents, ozone and oxidation.

Epichlorohydrin (CO and ECO)

Service temperature range: -65°F(-55°C) to +250°F(+120°C)

Advantages:

Excellent resistance to oil and gasoline; superior impermeability to gases and vapor; very good resistance to weather, ozone, sunlight and oxidation; good resistance to petroleum-based fluids and solvents.

Limitations:

Inferior resistance to oxygenated solvents; poor resistance to steam and acids.

Comments:

Epichlorohydrin contains many of the desirable properties of neoprene and nitrile. Epichlorohydrin is available as a homopolymer (CO) and a copolymer (ECO) containing about 50 percent ethylene oxide. The homopolymer has superior ozone resistance and gas impermeability and the copolymer has better resilience and flexibility at low temperatures.

Ethylene Acrylic Elastomer (AEM, Vamac®)

Service temperature range: -40°C (-40°F) to +175°C (+347°F)

Advantages:

Excellent resistance to heat and oils especially engine oils and automatic transmission fluids. Very good balance of compression set, flex resistance, physical strength, low temperature flexibility, weather resistance properties, and resistance to acid condensates. Excellent vibration dampening over a broad temperature range. Can be formulated to produce non-halogen, flame resistant, low smoke generating compounds.

Limitations:

Not recommended for service in contact with aromatic hydrocarbons, esters, gasoline and ketones.

Comments:

Dipolymers are peroxide cured. Terpolymers contain cure site monomer and can be cured using amine-based cure system.

Ethylene Propylene (EPM, EPDM)

Service temperature range: -70°F(-57°C) to +300°F(+150°C)

Advantages:

EPM elastomers have excellent resistance to ozone, water and steam, alkalis and acids, salt solutions and oxygenated solvents. EPM and EPDM have very low temperature resiliency and excellent electrical properties.

Limitations:

Poor resistance to oil, gasoline, and hydrogenated solvents.

Comments:

EPM and EPDM are, respectively, co and ter-polymers of ethylene, propylene and a diene containing monomer (ter-polymer) to facilitate vulcanization. Monomer ratios are varied to provide specific characteristics and properties. Because of their unique combination of properties, they can be used in a broad range of products.

Fluoroelastomer (Viton®, FKM)

Service temperature range: -40°F(-40°C) to +500°F (+260°C)

Advantages:

Outstanding resistance to high heat; excellent resistance to oil, gasoline, hydraulic fluids and hydrocarbon solvents; very good impermeability to gases and vapor; very good resistance to weather, oxygen, ozone, and sunlight; good flame retardance.

Limitations:

Intermediate resistance to tear and cut growth, very little resistance to oxygenated solvents.

Comments:

There are many types of FKM's based upon the monomers used to create the elastomer's backbone. There are also three cure systems that offer different performance characteristics. These features define the product's performance. Select product and cure system which is more appropriate for your process.

Note:

DuPont have developed many types of Viton® to meet specific end-use and processing needs. There are differences between types of Viton® in terms of chemical resistance and mechanical properties.

Isoprene (Natural and Synthetic Natural Rubber, IR)

Service temperature range: -65°F(-55°C) to +175°F(+80°C)

Advantages:

Outstanding resilience; superior resistance to tear and abrasion; very good tensile strength; excellent rebound elasticity; good flexibility at low temperatures.

Limitations:

Poor resistance to heat, ozone, and sunlight; very little resistance to oil, gasoline, and hydrocarbon solvents.

Comments:

The chemical composition of isoprene is nearly identical to that of natural rubber. Therefore, the properties of these two elastomers are similar. Isoprene has slightly better weather resistance, and its properties are more consistent because of its purity and uniformity. It is somewhat inferior to natural rubber in tensile strength, tear resistance and compression set resistance.

Nitrile, Hydrogenated Nitrile (NBR, HNBR)

Service temperature range: -70°F(-57°C) to +250°F(+120°C)

Advantages:

Very good resistance to oil and gasoline: superior resistance to petroleum-based hydraulic fluids, wide range of service temperature, good resistance to hydrocarbon solvents, very good resistance to alkalis and solvents.

Limitations:

Inferior resistance to ozone, sunlight, and natural aging, poor resistance to oxygenated solvents.

Comments:

NBR are copolymers of butadiene (BD) and acrylonitrile (ACN). The monomer ratio may be varied over a broad range. NBR with Higher ACN offers improved oil resistance, fuel resistance and tensile at break. Most O-rings are made of this material due to its good physical and mechanical properties.

Hydrogenated Nitrile (HNBR) is a product family designed to overcome some of the deficiencies of nitriles. HNBR shows improved chemical resistance, higher service temperature, and lower brittle temperature than regular nitrile. HNBR polymers are reacted with hydrogen to hydrogenate a percentage of NBR's unsaturation to improve chemical compatibility to certain media, such as sour gas, ozone and some additive packages.

Perfluoroelastomer (Kalrez®, FFKM)

Service temperature range: -20°F(-29°C) to +620°F(+327°C)

Advantages:

The best combination of chemical and high temperature resistance of any elastomer. Thermal stability depends on the polymer and cure chemistry. Peroxide cure perfluoroelastomers have thermal resistance similar to FKM, while proprietary cure systems (as in Kalrez®) offer temperature resistance up to 620°F (327°C) with specific polymers.

Limitations:

Perfluoroelastomer performance is limited at lower temperatures.

Comments:

Perfluoroelastomers are high value-in-use products.

Polyacrylic (ACM)

Service temperature range: -5°F(-20°C) to +350°F(+177°C)

Advantages:

Outstanding resistance to heat and hot oil; excellent resistance to weather, ozone, sunlight, and oxidation; very good resistance to gasoline and oil, especially those that contain sulfur.

Limitations:

Poor resistance to alcohols, alkalis, solvents, and aromatic solvents; limited flexibility at low temperatures; inferior resistance to water and steam.

Comments:

Heat resistance of acrylic is superior to that of most elastomers, except silicone, fluorosilicone and fluorocarbon. It performs well in both hot air and hot oil for extended periods. Acrylic has moderate resistance to cut growth and flex cracking. Use of acrylic is limited by its inferior flexibility at low temperatures. However, some types of acrylic may have improved low-temperature flexibility at the expense of tensile strength and oil resistance.

Polychloroprene (Neoprene, CR)

Service temperature range: -65°F(-55°C) to +250°F(+120°C)

Advantages:

Good inherent flame resistance; moderate resistance to oil and gasoline; excellent adhesion to fabrics and metals; very good resistance to weather, ozone, and natural aging; good resistance to abrasion and flex cracking; very good resistance to alkalis and acids.

Limitations:

Poor to fair resistance to aromatic and oxygenated solvents; limited flexibility at low temperatures.

Comments:

Polychloroprene is an excellent general-purpose elastomer with an attractive balance of properties and few practical limitations. General-purpose types of neoprene are classified into two groups: sulfur-modified types and mercaptan-modified type. Sulfur-modified neoprenes have increased tear resistance and resiliency, whereas mercaptan-modified neoprenes are superior in resistance to heat and compression set.

Silicone, Fluorosilicone (VMQ, FVMQ)

Service temperature range: -150°F(-101°C) to +500°F(+260°C)

Advantages:

Outstanding resistance to high heat; excellent flexibility at low temperatures; low compression set; very good electrical insulation; excellent resistance to weather, ozone, sunlight, and oxidation; superior color stability.

Limitations:

Poor resistance to abrasion, tear and cut growth; low tensile strength; inferior resistance to oil, gasoline, and solvents; poor resistance to alkalis and acids.

Comments:

The most outstanding feature of silicone is its ability to retain rubbery properties through extremes in temperature. Service temperatures range from -150°F to 500°F. Silicones are normally used in applications requiring resistance to extreme temperature.

Fluorinated silicones (FVMQ) offer improved chemical resistance compared to silicones, especially oils and fuels. Fluorinated silicones have a more narrow temperature service range than silicones

Styrene Butadiene, Polybutadiene (SBR, BR)

Service temperature range: -70°F(-57°C) to +225°F(+107°C)

Advantages:

Very good resiliency, tensile strength, abrasion resistance, and flexibility at low temperatures.

Limitations:

Poor resistance to ozone and sunlight; very little resistance to oil, gasoline, and hydrocarbon solvents.

Comments:

SBR is similar to natural rubber in most of its properties and is the lowest-cost and highest-volume elastomer available. Although its physical properties are slightly poorer than those of natural rubber, SBR is tougher and slightly more resistant to heat and flex cracking and can be readily substituted for natural rubber in many applications. With the exception of silicone, butadiene has the lowest glass-transition temperature of all commercial elastomers and offers unusually good performance at temperatures as low as -80°F.

Tetrafluorethylene Propylene (FEPM)

Service temperature range: 32°F(0°C) to +482°F(+250°C)

Advantages:

Excellent resistance to amines and amine corrosion inhibitors, caustics and other high pH media, sour gas and oil, phosphate esters hydraulic fluid and glycol brake fluid.

Limitations:

Higher swelling in hydrocarbons, chlorinated solvents and esters than FKM's. More limited in low temperature applications than FKM's. Should not be used in aliphatic or aromatic hydrocarbon fluids.

Comments:

High value in use fluoroelastomer.

Polyester Urethane, Polyether Urethane (AU, EU)

Service temperature range: -40°F(-40°C) to +200°F(+93°C)

Advantages:

Outstanding resistance to abrasion and tear; very high tensile strength with good elongation; excellent resistance to weather, ozone, and sunlight; good resistance to oil and gasoline; excellent adhesion to fabrics and metals.

Limitations:

Poor resistance to alkalis, acids, and oxygenated solvents; inferior resistance to hot water.

Comments:

Polyurethane is notable for its combination of hardness with elasticity, outstanding abrasion resistance and high tear strength. It may be either ether or ester based. The ester-based polymer is superior in resistance to abrasion and heat; the ether-based polymer has better flexibility at low temperatures. Polyurethanes are available in both liquid and solid forms. Polyurethanes are used primarily in application requiring a combination of their outstanding properties; toughness, tear strength, and abrasion resistance.

Chemical Compatibility

Elastomers are rated for their compatibility to a variety of media including fluids, weather, ozone, etc. Elastomers in a fluid environment may absorb the liquid and swell, react chemically with the fluid and change the polymer structure, or solubles may be extracted from the elastomer causing an actual decrease in volume. In some cases, it is not the polymer itself which is adsorbing or desorbing, but the other ingredients that the compounder has used to make the part.

Most chemical resistance guides report the percentage of swelling to indicated part performance in a certain chemical, with below 5 to 10 percent swelling considered excellent. Although swelling is a key criterion for part compatibility and one that is generally accepted as a standard for compatibility, other properties should be measured as well. A knowledgeable supplier or part manufacturer can provide additional guidance.

For more information on chemical compatibility you may see website of DuPont (Chemical Resistance Guide by DuPont).

References

The content of this article is based on information from websites of DuPont (www.dupontelastomers.com) and James Walker (www.jameswalker.biz). For more information, please see their websites.