

LOCTITE®

LOCTITE®

Design Guide for Bonding Rubber and Thermoplastic Elastomers

Volume 3

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Design Guide for Bonding Rubber and Thermoplastic Elastomers

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Section 1

Why Bond Elastomers With Loctite® Brand Adhesives?

Advantages Over Other Assembly Methods

Adhesives offer an array of benefits to the manufacturer who needs to join elastomeric substrates to other substrates in the manufacturing process. These benefits are best understood by comparing adhesive joining processes with the other options a manufacturing engineer can consider.

Advantages Versus Mechanical Fasteners

Mechanical fasteners are quick and easy to use, but have a number of significant drawbacks.

- They create stresses in the elastomer, which may lead to distortion or ripping of the part; adhesives do not.
- There are extra components which must be purchased and inventoried. Adhesives require no extra components.
- They require altering the design of the product to include bosses and holes. Adhesives require no special features.
- Their appearance often interferes with the styling of the product. Adhesives are invisible inside a bonded joint.
- They concentrate all of the holding power at the fastener location, causing the applied load to be carried by a small area of elastomer. Adhesives spread the load evenly over the entire joint area.

Advantages Versus Ultrasonic Welding

Ultrasonic welding can be an excellent method for certain types of assemblies. There are, however, a number of factors which limit its usefulness.

- The dampening characteristics of most elastomers can make them poor candidates for ultrasonic welding. Adhesives are not limited in this fashion.
- Ultrasonic welding is not usable for thermoset rubbers. Adhesives are.
- Joining of elastomers to metal, glass or other materials is not feasible in most cases. Adhesives do this easily.

- The design of joints is restricted to geometries which are favorable to the process. Ideally, they should have a small, uniform contact area to concentrate the ultrasonic energy. Adhesives can accommodate irregular bond lines.
- The capability of joining different thermoplastic elastomers in the same assembly is limited to those which are chemically compatible and have similar melting points. Adhesives are not restricted in this way.
- Ultrasonic welding requires investment in machinery as well as special tooling for each part. Adhesives require no machinery or tooling.

Advantages Versus Solvent Welding

Solvent welding can be a useful, low-cost method of bonding elastomers. However, its usefulness is limited by a number of disadvantages.

- Solvent welding cannot be used with dissimilar materials such as metals or glass. Adhesives do the job.
- Solvents will not work with thermoset rubbers. Adhesives will.
- Solvents are more likely to cause stress cracking than are adhesives.
- The time between application of the solvent and joining the parts is critical. The joints are weak if too much solvent remains in the bond area or if too much solvent has flashed off prior to assembly. Adhesives have a much less critical open time.
- Solvent cementing is not capable of joining parts with significant gaps between them. Adhesives tolerate much larger gaps.

Section 2

How to Use This Guide

Selecting the proper adhesive for an application demands a consideration of the processing and performance characteristics of the adhesive. This guide has been designed to provide this information in a format that will allow the end-users to rapidly identify the best adhesive option for evaluation in their application.

Performance Characteristics

When selecting an adhesive for an application, it is important to consider whether the adhesive's processing characteristics will be compatible with the assembly production process. The processing characteristics of greatest interest to the end-user typically revolve around the dispensing and curing properties of the adhesive. Information about these characteristics is important because it will help the end-user answer questions such as:

- What types of dispensing equipment will be required for the adhesive? Is the adhesive easily dispensed using automated or manual methods?
- Will special curing equipment, such as ovens or UV light sources, be required?
- How will environmental factors, such as relative humidity, affect the curing rate of the adhesive?
- How long will it take the adhesive to develop sufficient strength for the assembly to proceed to the next step in the assembly process?
- Will racking of parts during cure be required? Will special fixtures be needed to hold the assembly while the adhesive is curing? How much floor space will be required for the racked parts?

To gain an understanding of the processing characteristics of the adhesives in this guide, see:

Section 4: Adhesive Review provides an overview of the dispensing and curing characteristics of each family of adhesives.

Section 5: Factors Affecting Activator Selection provides detailed information on the effect that activator selection has on the processing and performance characteristics of two-step acrylic products.

Section 6: Heat Cure Parameters for Two-Step Acrylic Adhesives provides information on the times and temperatures needed to heat cure these products when an activator cannot be used.

Section 7: Hot Strength Curves for Adhesives provides curves of shear strength versus temperature for each of the adhesives evaluated in the guide.

Section 8: Metal Bonding Chapters provides detailed shear strength data for the adhesives evaluated in this guide on aluminum, anodized aluminum, stainless steel, steel, zinc dichromated steel, zinc galvanized steel, nickel plated steel and copper. Bond strengths are evaluated at ambient conditions and after exposure to high temperatures as well as high humidity and corrosive environments. For aluminum, steel, stainless steel and copper, the effect of surface roughening on bond strength is also evaluated.

Section 3

Adhesive Joint Design

Introduction

In this section, the terms and concepts related to joint design are divided into three categories which include:

- Types of Joints.
- Joint Stress Distribution.
- Design Guidelines.

Before looking at different types of joints, a few terms need to be explained:

Joint: A joint is the location where an adhesive joins two substrates.

Joint Geometry: Joint geometry refers to the general shape of an adhesive bond. Is the shape of the bond long and narrow, short and wide, thick or thin?

Types of Joints

The specific types of joints which will be examined in this section include:

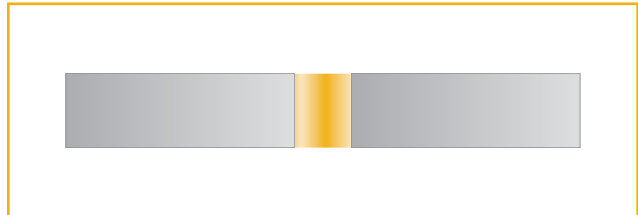
- Lap/Overlap.
- Scarf.
- Offset.
- Strap/Double Strap.
- Butt.
- Cylindrical.



LAP/OVERLAP JOINT: A lap joint, also called an overlap joint, is formed by placing one substrate partially over another substrate.



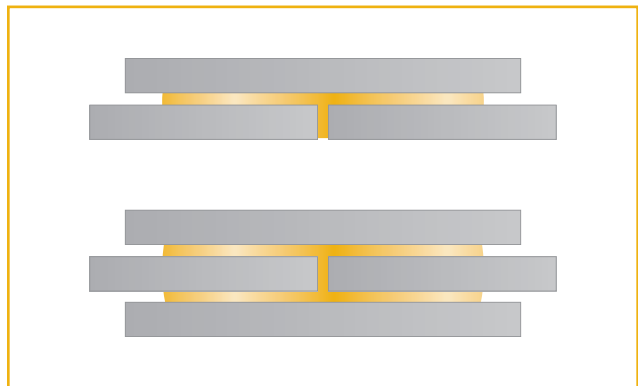
OFFSET JOINT: The offset joint is very similar to the lap joint.



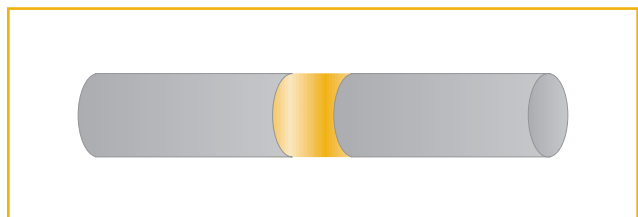
BUTT JOINT: A butt joint is formed by bonding two objects end-to-end.



SCARF JOINT: A scarf joint is an angular butt joint. Cutting the joint at an angle increases the surface area.



STRAP JOINT (SINGLE OR DOUBLE): A strap joint is a combination overlap joint with a butt joint.



CYLINDRICAL JOINT: A cylindrical joint uses a butt joint to join two cylindrical objects.

Joint Stress Distribution

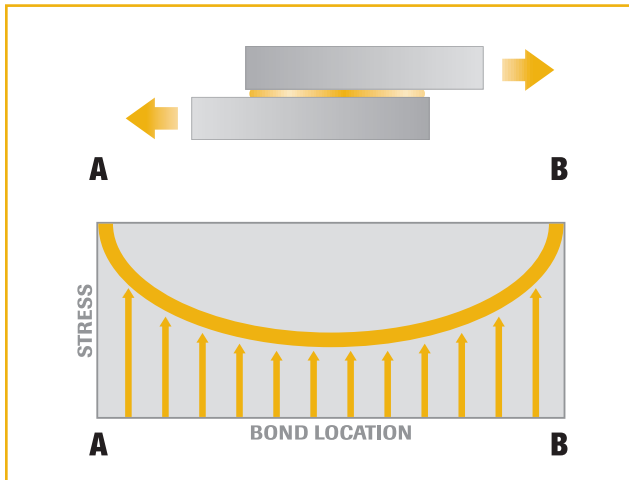
Joint stress distribution is the location of stresses within a bond.

Stress: Usually expressed as Newtons per square meter (N/M²), which is equivalent to a Pascal (Pa). In the English system, stress is normally expressed in pounds per square inch (psi).

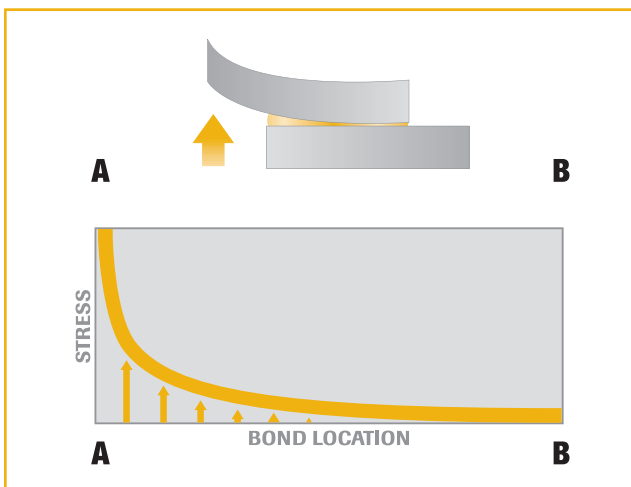
Types of Stresses

There are several types of stresses commonly found in adhesive bonds which include:

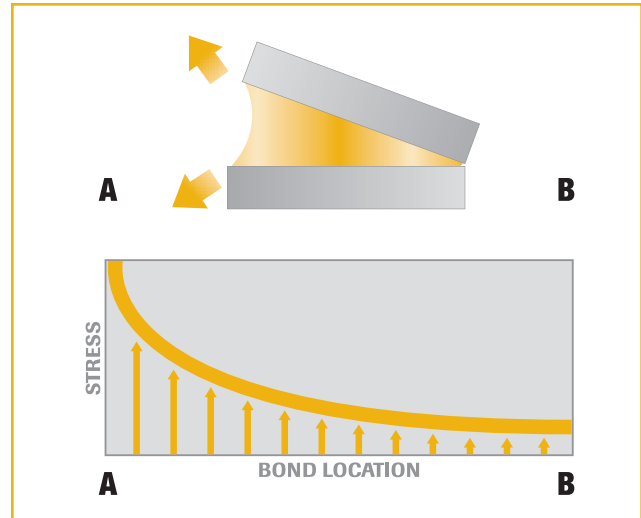
- Shear.
- Tensile.
- Compressive.
- Peel.
- Cleavage.



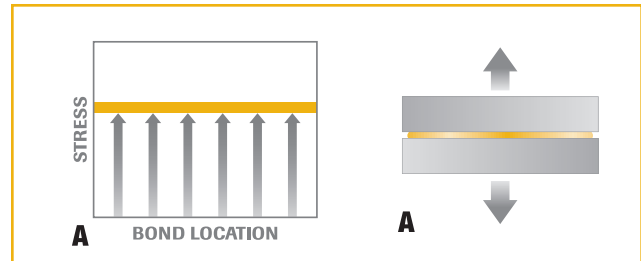
SHEAR STRESS: A shear stress results in two surfaces sliding over one another.



PEEL STRESS: A peel stress occurs when a flexible substrate is being lifted or peeled from the other substrate. *NOTE: The stress is concentrated at one end.*



CLEAVAGE STRESS: A cleavage stress occurs when rigid substrates are being opened at one end. *NOTE: The stress is concentrated at one end.*



TENSION STRESS DISTRIBUTION: When a bond experiences a tensile stress, the joint stress distribution is illustrated as a straight line. The stress is evenly distributed across the entire bond. Tensile stress also tends to elongate an object.



COMPRESSION STRESS DISTRIBUTION: When a bond experiences a compressive stress, the joint stress distribution is illustrated as a straight line. The stress is evenly distributed across the entire bond.

Design Guidelines

Engineers must have a good understanding of how stress is distributed across a joint which is under an applied force. There are several design guidelines which should be considered when designing an adhesive joint.

- **Maximize Shear/Minimize Peel and Cleavage.**

Note, from the stress distribution curve for cleavage and peel, that these bonds do not resist stress very well. The stress is located at one end of the bond line. Whereas, in the case of shear, both ends of the bond resist the stress.

- **Maximize Compression/Minimize Tensile.**

Note, from the stress distribution curve for compression and tension, that stress was uniformly distributed across the bond. In most adhesive films, the compressive strength is greater than the tensile strength. An adhesive joint which is feeling a compressive force is less likely to fail than a joint undergoing tension.

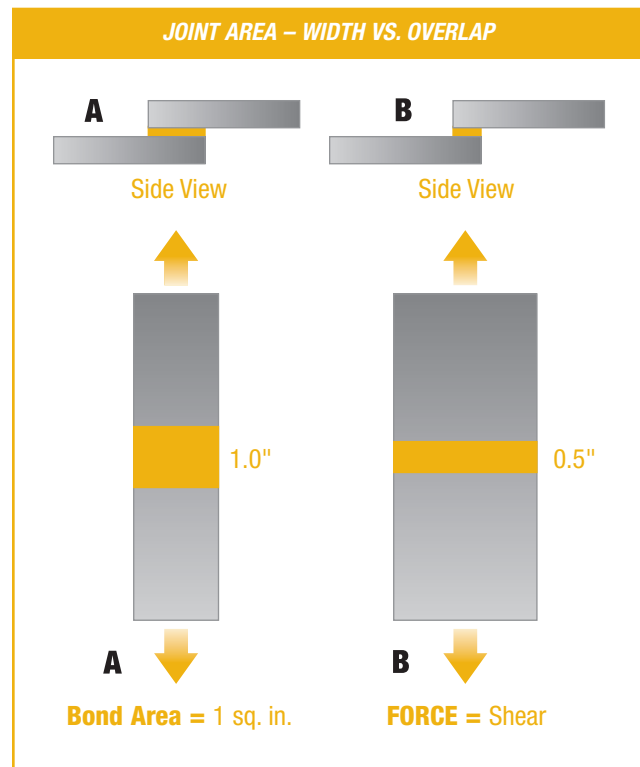
- **Joint Width More Important Than Overlap.**

Note, from the shear stress distribution curve, that the ends of the bond receives a greater amount of stress than does the middle of the bond. If the width of the bond is increased, stress will be reduced at each end and the overall result is a stronger joint.

In this same overlap joint, if the overlapping length is greatly increased, there is little, if any, change in the bond strength. The contribution of the ends is not increased. The geometry of the ends has not changed; thus, their contribution to the bond strength has not changed.

- **Bond Shear Strength Width vs Overlap.**

As a general rule, increase the joint width rather than the overlap area (“wider is better”).



Section 4

Adhesive Review Acrylics, Two-Step

Advantages

- Fast fixture speed.
- Room temperature cure.
- No mixing required.
- High peel and impact strength.
- Good environmental resistance.
- Bonds to lightly contaminated surfaces.
- Cure can be accelerated with heat.

Considerations

- Limited cure-through depth (0.040 in.).
- Activator may contain solvents.
- Activator requires controlled dispensing process.
- Adhesive may have strong odor.

General Description

Two-step acrylic adhesives consist of a resin and an activator. The resin component is a solvent-free, high viscosity liquid typically in the range of 10,000 to 100,000 cP. The activator is a low viscosity liquid catalyst typically in the range of 2 to 50 cP. The activator is available either as a solvent dispersion or pure (also called “solventless”).

When the resin and activator contact each other, the resin begins to cure very rapidly, fixturing in 15 seconds to several minutes depending on the specific adhesive used and gap being cured through. The resin can also be cured with light or heat. Light cure can be used to fully cure resin that light can reach fillets, for example. While the fixture time depends on many factors, 15 to 30 seconds is typical.

A typical heat cure cycle is 10 to 20 minutes at 300°F (149°C). Heat curing normally offers higher bond strengths, improved thermal resistance, and better chemical resistance, and achieves complete cure faster. Heat cure is sometimes also used to eliminate any residual odor of the acrylic adhesive from the cured assembly.

Process Notes

Use the activator specified for the adhesive in the datasheet. All activators are not compatible with all adhesives.

Do not over-apply. When using solventless activators, such as Loctite® 7380™, 7090™ or 7091™, do not over-apply them. The target quantity is normally 4-8 mg/in². Solventless activators generally require automated dispensing via a rotor spray or atomized spray valve.

Allow time for the carrier solvent to evaporate. If using a solvent-based activator, such as Loctite® 7387™ or 7075™, allow sufficient time for the carrier solvent to evaporate after applying the activator before mating the two assemblies. This is normally 30 to 60 seconds but can be longer, based on the specific activator used.

Do not apply the activator and adhesive to the same part, unless they are assembled immediately after dispensing. The adhesive will start curing in as little as 5 to 15 seconds.

Do not apply the activator to porous surfaces, such as a ferrite magnet. The porous surface may absorb the activator, taking it away from the adhesive joint.

Be sure to assemble the parts before the activator open time expires. After that time, the adhesive may not cure properly. Activator open times range widely from an hour to 30 days, so refer to the technical data sheet to determine the open time for the activator you are using.

Protect activators from air exposure. Depending upon their specific chemistry, some activators may oxidize readily upon exposure to air. Always close containers after use. Use nitrogen blanket if necessary to lessen air contact.

Acrylics, Two-Part

Advantages

- High cure-through depth.
- Room temperature cure.
- High peel and impact strength.
- Good environmental resistance.
- Bonds to moderately contaminated surfaces.
- Cure can be accelerated with heat.

Considerations

- Slow fixture times (5-30 minutes).
- Waste associated with static mix process.
- May have strong odor.

General Description

Two-part acrylic adhesives consist of a resin and an activator, both of which are normally high-viscosity liquids typically in the range of 5,000 to 100,000 cP. While the activator is chemically similar to that of a two-step acrylic, it is delivered as a high viscosity liquid that is normally similar in viscosity to the resin. The two components are mixed just prior to dispensing at mix ratios ranging from 1:1 and 10:1 by volume. By mixing the activator and resin, two-part acrylics have much larger cure-through depths than two-step acrylics that only have the activator applied to the surface.

To maintain the ratio of the resin and activator, equipment is required. For small to moderate volume applications, the adhesive is packaged in a dual cartridge that sets the ratio. For high volume applications, meter mix dispense equipment is used.

The resin and activator are mixed by passing them through a static mix tip which allows the material to be dispensed as a homogenous one-part material. Since the mixed adhesive is curing in the mix tip, there will be trade-off between the open time and the fixture time. Faster curing products will require that mix tips be changed after shorter idle times.

Two-part acrylics can also be accelerated with heat, but care must be taken when determining the cure temperature.

Process Notes

Properly prime the mix tip by dispensing a small amount before attaching the mix tip (also called “bumping”) to ensure both sides are flowing, then dispensing several grams after attaching the tip to prime the mix tip before creating production parts.

Audit to ensure proper mixing. Many two-part acrylics are color-coded to allow for visual inspection of the mixing. For example, a blue resin and yellow activator would result in a green product. There should not be pockets of unmixed (i.e., yellow or blue) product that can be visually observed.

Use equipment designed for two-part acrylics.

Two-part acrylics are very reactive systems that may cure when contacting active metals such as steel, copper or brass. When dispensing from a meter-mix dispense system, two-part acrylics must be dispensed from inactive systems such as stainless steel. Care should be taken not to replace fitting during maintenance with active metals.

Evaluate peak exotherm for large volume

applications. Two-part acrylics cure very rapidly via an exothermic reaction that releases heat. When curing large volumes, the heat can be sufficient to warp plastic parts or degrade the adhesive.

Cyanoacrylates

Advantages

- One part, solvent-free.
- Rapid room temperature cure.
- Excellent adhesion to most substrates.
- Wide range of viscosities available.
- Primers available for polyolefins and difficult to bond plastics.
- Light cure versions available.

Considerations

- Poor peel strength.
- Limited gap cure.
- Poor durability on glass.
- Poor solvent resistance.
- Low temperature resistance.
- Bonds skin rapidly.
- May stress crack some plastics.

General Description

Cyanoacrylates are one-part, room-temperature curing adhesives that are available in viscosities ranging from water-thin liquids to thixotropic gels. When pressed into a thin film between two surfaces, the moisture present on the bonding surfaces neutralizes the acid stabilizer present in the cyanoacrylate formulation, causing the adhesive to cure rapidly to form rigid thermoplastics with excellent adhesion to most substrates. Typical fixture times are 5 to 30 seconds.

In addition to standard cyanoacrylates, there are many specialty formulations with enhanced performance properties.

Rubber toughened grades offer high peel strength and impact resistance.

Thermally resistant cyanoacrylates are available which offer excellent bond strength retention after exposure to temperatures as high as 250°F for thousands of hours.

Surface-insensitive cyanoacrylates offer rapid fixture times and cure speeds on acidic surfaces, such as wood or dichromated metals, which could slow the cure of a standard cyanoacrylate.

Low Odor/Low Bloom grades minimize the potential for a white haze to occur around the bondline.

Light curing cyanoacrylates utilize proprietary photoinitiators to cure cyanoacrylates in seconds when exposed to light of the appropriate wavelength.

Accelerators such as Loctite® 712™, 7109™, 7113™, 7452™ and 7453™ can be used to speed the cure of cyanoacrylate adhesives, and are primarily used to reduce fixture times and to cure excess adhesive.

Primers such as Loctite® 770™ and 793™ dramatically increase the strength achieved on hard to bond plastics such as polypropylene, polyethylene and DELRIN (acetal).

Process Notes

A controlled environment is necessary for consistent fixture times. Temperature and, more importantly, relative humidity have a significant effect on cure speed. The optimum relative humidity is 40-60%. Hot and moist environments will result in faster cure speed, while cold and dry environments will slow cure.

Proper storage is critical. Cyanoacrylates should be stored refrigerated. If cyanoacrylates are exposed to high temperature during storage, their viscosity will rise and their cure speed will slow. Once a bottle is opened, it must not be returned to refrigerated storage.

Use equipment designed for cyanoacrylates. Because cyanoacrylates are so reactive, only equipment that has been tested for compatibility, such as the Loctite® Cyanoacrylate Dispense Valve (item number 98013), should be used.

Ensure that dry air is used for reservoirs. When dispensing cyanoacrylates from pressure reservoirs, dryers should be used to remove moisture from the supply air, otherwise, the moisture could cause the cyanoacrylate to cure.

Ventilation may be required in some instances to minimize odor.

Epoxies

Advantages

- Wide variety of formulations available.
- High adhesion to many substrates.
- Good toughness.
- Cure can be accelerated with heat.
- Excellent depth of cure.
- Superior environmental resistance.

Considerations

- Two-part systems require mixing.
- One-part systems require heat cure.
- Long cure and fixture times.

General Description

Epoxy adhesives are supplied as one and two-part systems with viscosities that range from a few thousand centipoise to thixotropic pastes. Upon cure, epoxies typically form tough, rigid thermoset polymers with high adhesion to a wide variety of substrates and superior environmental resistance. A major advantage of epoxies is that there are a wide variety of commercially available resins, hardeners and fillers for epoxies that allows the performance characteristics of epoxies to be tailored to the needs of almost any application.

When using a one-part heat-cure system, the resin and a latent hardener are supplied already mixed and typically need to be stored refrigerated or frozen. By heating the system, the latent hardener is activated causing cure to initiate. The epoxy will normally start to cure rapidly at temperatures of 100° to 125°C (212° to 257°F) and cure times of 30 to 60 minutes are typical. Heat curing also generally improves bond strengths, thermal resistance and chemical resistance.

When using a two-part system, the resin and hardener are packaged separately and are mixed just prior to use. This allows more active hardeners to be used so that the two-part epoxies will rapidly cure at ambient conditions.

Two-part system are normally mixed by passing them through a static mix tip. This allows the two-part material to be dispensed as a single homogenous liquid where it exits the mix tip.

Since the mixed adhesive is curing in the mix tip, the adhesive's viscosity and performance change during idle times, and the mix tip must be changed after the idle time exceeds the adhesive's open time. This creates a trade-off between fixture time and open time. Faster curing products will require that mix tips be changed after shorter idle times.

To maintain the ratio of the resin and activator, equipment is required. For small to moderate volume applications, the adhesive is normally packaged in a dual cartridge that sets the ratio. For high volume applications, meter mix dispense equipment is recommended.

Process Notes

Properly prime the mix tip by dispensing a small amount before attaching the mix tip (also called "bumping") to ensure both sides are flowing, then dispensing several grams after attaching the tip to prime the mix tip before creating production parts.

Significant exotherms can occur for large volume applications. The curing reaction of the epoxy can release a great deal of heat (exotherm) and can result in a significant temperature rise in the adhesive.

Ensure that meter mix systems are on-ratio and air-free. To maintain consistent performance when using a meter mix dispense system, it is critical that the equipment is at the required mix ratio. This should be audited periodically with QC tests. Air in the equipment is a frequent cause of the equipment becoming off ratio. Care should be taken not to introduce air in the equipment when changing packages.

Induction curing typically offers the fastest heat cures. Induction heats ferrous components much faster than convection or infrared ovens.

Hot Melts

Advantages

- One-part, solvent-free.
- Fast fixturing.
- High adhesion to plastics.
- Wide variety of formulations available.
- Low volumetric cost.

Considerations

- Hot dispense point.
- Poor adhesion on metals.
- Cools quickly.
- Equipment is required.
- Thermoplastic parts may deform.
- Charring in reservoir.
- Moisture sensitivity.

General Description

Hot melt adhesives are one-part, solvent-free thermoplastic adhesives that are solid at room temperature and a low to medium viscosity (750 to 10,000 cP) adhesive at dispense temperatures (typically greater than 175°C). After dispense, hot melt adhesives rapidly cool to form a strong bond. In the cured or cooled state, hot melt adhesives can vary in physical properties from soft, rubbery and very tacky to hard and rigid. Hot melts have excellent long-term durability and resistance to moisture, chemicals, oils, and temperature extremes.

The performance of hot melts varies widely based on their chemistry:

Ethylene vinyl acetate (EVA) hot melts are the “original” hot melt. They have good adhesive to many substrates, the lowest cost and a wide range of open times, but typically have the poorest temperature resistance.

Polyamide hot melts are a higher cost, higher performing adhesive with excellent high temperature resistance (up to 300°F). Specialty formulations are available that carry a UL-94 V-0 flammability rating.

Polyolefin hot melts are specially formulated for adhesion to polyolefins such as polypropylene and polyethylene plastics. Compared to other chemistries, they have longer open times and they have excellent resistance against polar solvents.

Reactive polyurethanes (PUR) are supplied as an urethane prepolymer, which behaves much like a standard hot melt until it cools. Once the PUR cools, it reacts with moisture over time (a few days) to crosslink into a tough thermoset polyurethane. PURs offers lower dispense temperatures, higher adhesion to metals and improved thermal resistance.

Process Notes

Operators should wear protective gloves to avoid burns. Cotton gloves are recommended.

Dispense equipment is required to heat the hot melt. Sticks are used in handheld guns for low to medium volume applications and pellets are loaded into large tanks for bulk hot melt dispensers.

Bonding metals with hot melts. Hot melt adhesives cool very rapidly on metals due to their high heat capacity. If this results in low strengths, the strength can be increased by using a longer open time hot melt, the metal can be heated before or after assembly, or a reactive polyurethane, which inherently has excellent adhesion on metals, can be used.

Polyamides and PURs must be handled carefully. Polyamides absorb water rapidly if not stored properly. This is generally not a problem for bulk dispensers that heat the product well above the boiling point of water in the tank, but can cause bubbles when dispensing sticks. Sticks should be stored in their original packages and packages should be sealed during storage. PUR hot melts cure when exposed to ambient humidity, so dispense tips must be protected from air during idle times.

Tanks must be maintained for bulk dispensers. All hot melts will char over time in the melt tank for bulk dispensers, so the tanks should be maintained periodically. To minimize charring, one can put a nitrogen blanket over the tank, program the tank to cool down for long idle time or dispense at lower temperatures.

Light Cure

Advantages

- One part, solvent-free.
- Fast cure time (seconds).
- High cure-through depths (>0.5 in.).
- Wide range of viscosities available.
- Wide range of physical properties.

Considerations

- Light must be able to reach bondline.
- Oxygen can inhibit cure at the surface.
- Equipment expense for light source.
- If a high intensity light source is used, ozone must be vented.

General Description

Light cure adhesives “cure on demand,” eliminating the normal trade-off between open time and cure speed. At ambient conditions, all but the fastest light curing adhesives remain unaffected by ambient light for hours, allowing for almost infinite part adjustment time. Upon exposure to light of the proper intensity and spectral output, the photoinitiator in the adhesive initiates cure, rapidly yielding a cured polymer. While cure times depend on many factors, 10-to-30 second exposure times to achieve full cure are typical and cure depths in excess of 0.5 in. (13 mm) are possible. Light curing adhesives are available with physical properties ranging from very rigid glass-like materials to soft, flexible elastomers.

While light cure acrylic adhesives are the most well-known and commonly used type of light curing adhesive, four other chemistries that can be cured with light

are anaerobics, cyanoacrylates, epoxies and silicones. Significant development has occurred on these light curing adhesives in the last five years and they may offer improved performance when compared to light cure acrylics in many motor applications. The key benefits of each of these technologies are:

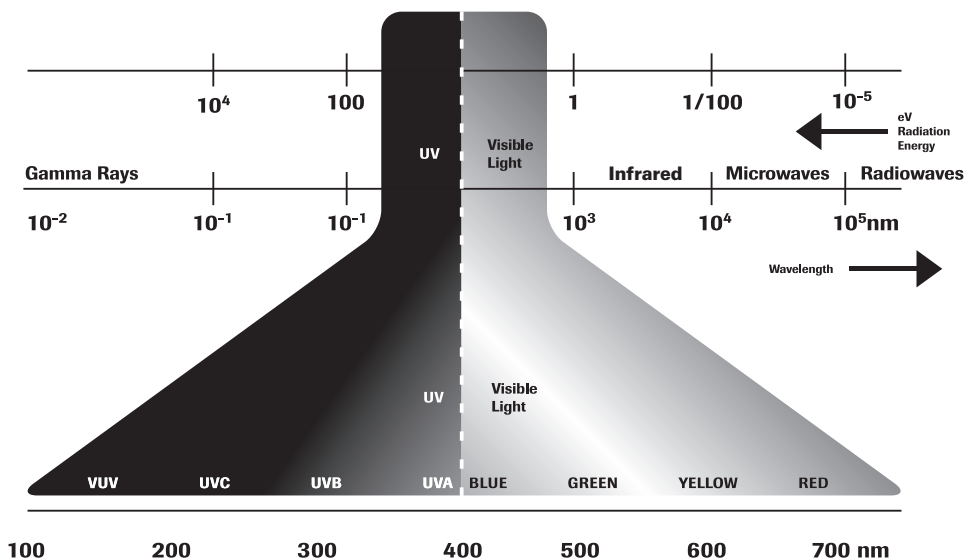
Chemistry	Typical Use
Acrylics	General-purpose
Anaerobic	Curing fillets when retaining cylindrical metal assemblies
Cyanoacrylate	Adhesion to plastics Cyanoacrylate shadow cure
Epoxy	Temperature resistance Chemical resistance Two-part for deep potting
Silicone	Highest temperature resistance Flexibility

Process Notes

Audit the light source using a radiometer. To ensure consistent curing, a radiometer should be regularly used to audit the output of the light source.

Use opaque (black) feedlines. Prolonged exposure to ambient light can thicken or cure the faster curing light cure adhesives.

The Electromagnetic Spectrum



Polyurethanes

Advantages

- Extremely tough.
- Good resistance to solvents.
- High cohesive strength.
- Good impact resistance.
- Good abrasion resistance.

Considerations

- Mixing required for two-part polyurethanes.
- Limited depth of cure for one-part polyurethanes.
- Primer may be needed for adhesion to some substrates.
- Limited high temperature use.

General Description

Polyurethane adhesives are supplied as one- and two-part systems which range in viscosity from self-leveling liquids to non-slumping pastes. They cure to form thermoset polymers with good solvent and chemical resistance. They are extremely versatile and can range in cured form from extremely soft elastomers to rigid, extremely hard plastics. Polyurethanes offer a good blend of cohesive strength and flexibility that makes them very tough, durable adhesives. They bond well to most unconditioned substrates, but may require the use of solvent-based primers to achieve high bond strengths. They offer good toughness at low temperatures, but typically degrade in strength after long-term exposure over 302°F (150°C).

Since the cure of one-part, moisture-curing polyurethanes is dependent on moisture diffusing through the polymer, the maximum depth of cure that can be achieved in a reasonable time is limited at approximately 0.375 in. (9.5 mm). Two-part systems, on the other hand, offer unlimited depth of cure.

Two-part systems are normally mixed by passing them through a static mix tip. This allows the two-part material to be dispensed as a single homogenous liquid where it exits the mix tip. Since the mixed adhesive is curing in the mix tip, the adhesive's viscosity and performance change during idle times, and the mix tip must be changed after the idle time exceeds the adhesive's open time. This creates a trade-off between fixture time and open time. Faster curing products will require that mix tips be changed after shorter idle times.

To maintain the ratio of the resin and activator, equipment is required. For small to moderate volume applications, the adhesive is packaged in a dual cartridge that sets the ratio. For high volume applications, meter mix dispense equipment is used.

Process Notes

Properly prime the mix tip. 1. Before attaching the mix nozzle to the cartridge, dispense adhesive from the cartridge until product flows from both sides of the cartridge (also called “bumping.”) This will ensure that the product mixes properly. 2. After attaching the mix nozzle to the cartridge, but before creating production parts, dispense several grams of adhesive through the tip to the cartridge. This will properly prime the mix tip.

Audit to ensure proper mixing. When setting up a new process, the mix tip should be evaluated in application representative conditions, including planned downtimes to ensure proper mixing. This should be audited periodically.

Significant exotherms can occur for large volume applications. The curing reaction of the epoxy can release a great deal of heat (exotherm) and can result in a significant temperature rise in the adhesive.

Protect the adhesive from moisture. Polyurethanes will absorb moisture from the ambient atmosphere which may cause premature gelling or bubbling of the adhesive. As a result, bulk system must be designed with dryers to prevent this.

Elastomers

Advantages

- One-part or two-part solvent-free.
- Room temperature cure.
- Excellent adhesion to many substrates.
- Extremely flexible.
- Superior thermal resistance.
- Light curing formulations available.

Considerations

- Poor cohesive strength.
- Moisture cure systems have limited depth of cure.
- May be swelled by non-polar solvents.

General Description

Elastomeric adhesives, specifically silane-modified polymers (SMP) and silicones, are available in one-part moisture curing systems as well as two-part static mix systems that range in viscosity from self-leveling liquids to non-slumping pastes. They cure to soft thermoset elastomers with excellent property retention over a wide temperature range. SMPs and silicones have good primerless adhesion to many substrates, but are limited in their utility as structural adhesives by their low cohesive strength. Elastomeric adhesives are typically cured via reaction with ambient humidity, although formulations are also available which can be cured by heat, mixing of two components, or exposure to ultraviolet light.

Since the cure of moisture-curing elastomers is dependent on moisture diffusing through the elastomeric matrix, the cure rate is strongly affected by the ambient relative humidity and the maximum depth of cure is limited to 0.375 in. to 0.500 in. At 50% relative humidity, moisture cure elastomers will generally cure to a tack-free surface in five to 60 minutes. Complete cure-through thick sections of product can take up to 72 hours. It should be noted that adhesive strength may continue to develop for one-to-two weeks after the product has been applied. This occurs because the reaction between the reactive groups on the polymer and the reactive groups on the substrate surface is slower than the cross-linking reaction of the products' groups with themselves.

The by-product given off as they react with moisture categorizes moisture-curing elastomers:

Acetoxy are general-purpose silicones. Their largest limitation is the potential for the by-product, acetic acid, to promote corrosion.

Alkoxy have alcohol by-products so they are noncorrosive. SMPs fall into this category, which makes them well suited for electronic and medical applications where acetic acid could be a problem.

Oxime are noncorrosive, fast curing and have excellent adhesion. There are also grades available with improved chemical resistance.

Light curing silicones generally also have a secondary moisture cure mechanism to ensure that any silicone that is not irradiated with ultraviolet light will still cure. Upon exposure to ultraviolet light of the proper wavelength and intensity, they will form a tack-free surface and cure to a polymer with up to 80% of its ultimate physical strength in less than a minute. Initial adhesion can be good, but because ultimate bond strength is dependent on the moisture cure mechanism of the silicone, full bond strength can take up to a week to develop. Silicones with a secondary acetoxy cure show good bond strength while those with a secondary alkoxy cure are lower.

Process Notes

A controlled environment is necessary for consistent fixture times. Temperature and, more importantly, relative humidity have a significant effect on cure speed. The optimum relative humidity is 40-60%. Hot and moist environments will result in faster cure speed, while cold and dry environments will prolong cure.

Use equipment designed for elastomers. Because SMPs and silicones moisture cure, the system must be designed to prevent moisture from penetrating the system. To that end, moisture-lock hoses and dryers should be used to remove moisture from supply air that could cause the product to cure.

Section 5

Elastomer Bonding Chapters

How to Use the Rubber and TPE Bonding

A Trade Names

Lists common suppliers of each elastomer and the trade names of their products.

B Typical Applications

Lists common markets where the elastomer is used and specific applications.

C General Description

Provides information concerning the chemical structure, types available and cure method used (if appropriate).

D Relative Adhesive Performance

Provides relative ranking of bond strengths achieved with adhesives tested.

E General Properties

Describes the key characteristics of each elastomer.

F Effects of Formulation and Processing

Highlights formulation or elastomer processing changes that had a significant effect on adhesive performance.

G Surface Treatments

Summarizes the effect of Loctite® 770™ Prism® Primer on cyanoacrylate adhesive performance.

Styrene-Butadiene Rubber (SBR) thermoset rubber

A Trade Names

Trade Names	Manufacturer
• AFPOL	CAL Polymers
• BUNA	Bayer
• COPEFLEX	Coperbo
• DURADENE	Firestone
• EUROPRENE	Enichem
• KRATON	Shell Chemical
• PLIOFLEX	Goodyear
• PLIOLITE	Goodyear
• SOLPRENE	Housmex
• STEREON	Firestone

Manufacturer

B Typical Applications

Automotive	Tires, hoses, belts
Industrial	Foamed products, extruded goods
Consumer	Shoe soles, waterproof materials
Miscellaneous	Adhesives, asphalt

D Relative Adhesive Performance

High	Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive Surface Insensitive CA - Loctite® 401™ Prism™ Instant Adhesive Primer - Loctite® 401™ Prism™ Instant Adhesive with Loctite® 770™ Prism™ Primer Rubber Toughened CA - Loctite® 480™ Prism™ Instant Adhesive Rubber Toughened CA - Loctite® 4204™ Prism™ Instant Adhesive
Medium	Oxime Silicone - Loctite® 5900™ Flange Sealant, Heavy Body Two-Part No-Mix Acrylic - Loctite® 330™ Depend™ Adhesive Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
Low	Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant

C General Description

SBR is formed via the copolymerization of styrene and butadiene. This can be performed as an emulsion or solution polymerization. In emulsion polymerizations, the monomer is emulsified in a medium, such as water, using an emulsifying agent, such as soap. This can be performed as a hot process at 122°F (50°C) or a cold process at 41° to 50°F (5° to 10°C). Solution polymerizations typically occur in a hydrocarbon solution with an alkyl lithium catalyst. Solution polymerizations offer improved properties due to the increased control of molecular weight and stereospecificity. In addition, emulsion SBR typically contains 4 to 7% of non-rubber emulsifier residues which solution SBR does not.

E General Properties

Approximately 75% of the SBR produced in the US is used in tires. This is due to the superior abrasion resistance and traction of SBR. For tire applications, the glass transition temperature (T_g) is critical. If the T_g is too high, the tires will become brittle in cold conditions. If the T_g is too low, the tire traction is compromised. Consequently, any rubber with a T_g which is not between -58° and -94°F (-50° and -70°C) must be mixed with at least one other rubber for tire applications. NR and SBR have T_gs which allow them to be used as the sole elastomer in a tire compound. The processing temperature of SBR has a large effect on the resulting properties of the material. Cold SBR has better abrasion resistance and dynamic properties, as well as a higher capacity to be extended, than hot SBR. Therefore, hot SBR is no longer used for tire applications. Due to the increased control of solution SBR, improved abrasion resistance, traction and hysteretic properties have been realized. Consequently, solution SBR is rapidly replacing emulsion SBR for tire production. The addition of carbon black has many advantageous effects on the properties of SBR. In particular, it increases the strength properties, hardness and dimensional stability of SBR. In addition, it can provide electrical and thermal conductivity, all while lowering cost.

F Effects of Formulation and Processing

Additives	High Styrene - Increase Carbon Black - Increase Clay - Increase Silica - Increase Styrene Resin - Increase Aromatic Oil - Decrease Processing Aid - Increase Antioxidant - Increase
T₈₀ Cure	No Trend Apparent

G Surface Treatments

Loctite® 770™ Prism™ Primer - No Trend Apparent

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The Loctite® Design Guide for Bonding Rubbers and TPEs, Volume 3

How to Use the Adhesive Shear Strength Table

A Control

The control is an unfilled elastomer that was used as the base resin for all compounded formulations. It is listed at the top of the table and is indicated as the “control.” Each formulation of elastomer was produced by compounding the unfilled elastomer with a single additive or filler. That formulation was then compared to the control to determine statistically significant effects within 95% confidence limits. In some cases, a change in the process or the chemical composition was evaluated. In these cases, that specific formulation may not have been compounded using the control elastomers but was compared to the control to determine the effect of the change.

B T₈₀ Cure

Stopping the polymerization process before completion could theoretically increase its bondability for two reasons. The first reason is that the lower cross-link density of the polymer allows for increased diffusion of the adhesive into the rubber. The second reason is that the active species that were not utilized during vulcanization can now react with the adhesive. In this testing, the polymerization was stopped when the modulus was 80% of the modulus at full cure.

C Elastomer Description

The elastomer formulations were selected in two ways. For five of the 25 elastomers evaluated, commercially available grades were selected to represent each of the major categories of that elastomer. The 20 remaining elastomers were specifically compounded for the purpose of determining the effect of individual additives and fillers on the bondability of that material.

- **Commercially Available Grades**

If commercially available grades were evaluated, then the specific grades which were tested were listed in the left-hand column of this table.

- **Specialty Formulations**

If special formulations were compounded, then the additive, filler, processing change or change in chemical structure was indicated, as well as the specific concentration and product used, in the left-hand column of this table.

D Notes

This section explains the superscripts and shading used in the table.

E Shading

When the cell is shaded dark yellow, the addition of the indicated additive or filler, the processing change or the change in the chemical makeup of the polymer resulted in a statistically significant increase in bondability when compared to the control. A statistically significant decrease is denoted by light yellow shading. If there is a change in the failure mode, the cell is also shaded accordingly.

F Single Line

A single line in the table indicates that the elastomer evaluated below the line was formulated from a control and compared back to that control to determine the effect of an additive, filler, processing change or change in chemistry. To determine the control, move up the table from the single line until a row has a double line on top of the table. That row will be the control and is often denoted as the “control.”

G Double Line

A double line in the table indicates that the elastomer evaluated below the line was not compared to a control to determine the effect of a filler, additive, processing change or change in the polymer chemistry.

Adhesive Shear Strength

SAMPLE

(psi)
(MPa)

Locite® Brand Adhesives	Locite® 496™ Super Bonder® Instant Adhesive	Locite® 401™ Prism® Instant Adhesive	Locite® 401™ Prism® Instant Adhesive with Locite® 770™ Prism® Primer	Locite® 480™ Prism® Instant Adhesive	Locite® 420A™ Prism® Instant Adhesive	Locite® Superflex® RTV Silicone Adhesive Sealant	Locite® 5900® Flange Sealant, Heavy Body	Locite® 330™ Depenq® Adhesive	Locite® 3105™ Light Cure Adhesive
Control: Plioflex 1502 <i>Cold Emulsion Polymer, 23.5% Styrene</i> 100 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>190Δ >1.31Δ	60 0.41	60 0.41	60 0.41	110 0.76
T₉₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> Plioflex 1502 100 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>110Δ >0.76Δ	60 0.41	100 0.69	40 0.28	110 0.76
Cold Solution Polymer <i>Firestone SBR 710</i> 100 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>110Δ >0.76Δ	50 0.34	100 0.69	60 0.41	70 0.48
High Styrene Content <i>Cold Emulsion Polymer, 40% Styrene</i> Plioflex 1513 100 phr	>310Δ >2.14Δ	>340Δ >2.34Δ	>260Δ >1.79Δ	>270Δ >1.86Δ	>290Δ >2.00Δ	60 0.41	90 0.62	130 0.90	110 0.76
Carbon Black <i>Plioflex 1513 FEF N-550</i> 100 phr 15 phr	>550Δ >3.79Δ	>560Δ >3.86Δ	>530Δ >3.65Δ	>360Δ >2.48Δ	>350Δ >2.41Δ	60 0.41	140 0.97	110 0.76	110 0.76
Calcium Carbonate <i>Plioflex 1502 Calcium Carbonate</i> 100 phr 60 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>190Δ >1.31Δ	80 0.55	140 0.97	140 0.97	110 0.76
Clay <i>Plioflex 1502 Dixie Clay</i> 100 phr 60 phr	>410Δ >2.83Δ	>460Δ >3.17Δ	>390Δ >2.69Δ	270 1.86	270 1.86	60 0.41	150 1.03	170 1.17	210 1.45
Silica <i>Plioflex 1502 Hi Sil 233</i> 100 phr 15 phr	460 3.17	>510Δ >3.52Δ	>570Δ >3.93Δ	300 2.07	>330Δ >2.28Δ	80 0.55	130 0.90	60 0.41	110 0.76
Processing Aid <i>Plioflex 1502 Struktol WB212</i> 100 phr 4 phr	>220Δ >1.52Δ	>310Δ >2.14Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>240Δ >1.65Δ	60 0.41	90 0.62	80 0.55	110 0.76
Antioxidant <i>Plioflex 1502 DMQ</i> 100 phr 3 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>250Δ >1.72Δ	>250Δ >1.72Δ	60 0.41	90 0.62	80 0.55	110 0.76
Antistatic <i>Plioflex 1502 Armostat 550</i> 100 phr 5 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>270Δ >1.86Δ	60 0.41	120 0.83	60 0.41	110 0.76
Alcryn 1070 BK 100 phr	80 0.55	>680Δ >4.69Δ	>700Δ >4.83Δ	180 1.24	250 1.72	40 0.28	140 0.97	150 1.03	130 0.90
Alcryn 2070 BK 100 phr	60 0.41	>400Δ >2.76Δ	320 2.21	240 1.65	180 1.24	<10 <0.07	150 1.03	120 0.83	350 2.41

A

B

C

E

F

G

D

NOTES:

- = The addition of the indicated additive (or processing change) caused a statistically significant increase in the bond strength within 95% confidence limits.
- = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
- Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System and Reinforcement Used in All Formulations

Stearic Acid 1.00 phr
Zinc Oxide 5.00 phr
Sulfur 2.50 phr
MBTS 1.50 phr
TMTD 0.10 phr
Carbon Black FEF N-550 10.00 phr

Butyl Rubber (IIR)

thermoset rubber

Trade Names

- EXXON BUTYL
- POLYSAR BUTYL

Manufacturer

ExxonMobil Chemical
Bayer

General Description

Butyl rubber is poly(methylpropene-co-2-methyl-1,3-butadiene) or poly(isobutylene-co-isoprene). The rubber gum stock is produced through the cationic polymerization of isobutylene with 1-3% isoprene. The isoprene is incorporated into the polymer structure to provide unsaturated sites which can be utilized to form cured rubber from the gum stock. Butyl rubber is typically cross-linked using sulfur; however, two other methods are also available. The first method is to react the butyl gum stock with phenol-formaldehyde resin. The other involves reacting it with p-quinone dioxime, or p-quinone dioxime dibenzoate, in conjunction with lead oxide. The cross-link density and ultimate properties of the cured rubber can be controlled by varying the amount of unsaturation in the base polymer. The properties of the base polymer are also controlled by varying the molecular weight of the polymer and the degree of branching in the gum stock. Halogenation of these rubbers has been used to produce the family of halogenated butyl rubbers which are discussed in a separate chapter.

General Properties

The saturation of the polymer backbone and lack of reactive groups result in a combination of valuable properties that have made butyl polymers one of the most widely used synthetic elastomers. The aliphatic nature of the polymer gives it good resistance to ozone, UV light, moisture and mineral acids. This also contributes to its thermal resistance, which is limited more by the type of cross-link system used than the stability of the polymer backbone. Butyl rubber formulations cured using sulfur tend to degrade after long-term exposure to temperatures above 302°F (150°C). Formulations which utilize the phenol formaldehyde resin cure system offer much better thermal resistance. Butyl rubber is attacked by non-polar solvents, such as hydrocarbon oils, greases and fuels. Alternatively, butyl rubbers have good resistance to polar liquids such as oxygenated solvents, ester type plasticizers, vegetable oils and synthetic hydraulic fluids. The lack of bulky pendant groups on the polymer chains allows them to pack closely and give a vulcanizate with extremely low gas permeability. This has resulted in the widespread use of butyl rubber in inner tubes and other industrial gas bladders. Butyl compounds have good damping and shock absorption characteristics which has led to their use in automotive body mounts.

Typical Applications

- Automotive** Tire inner liners, inner tubes, radiator hose, belts
- Electronics** Electrical insulation
- Industrial** Conveyor belts, curing bladders, membranes, freezer gaskets, tank linings, steam hose, diaphragms
- Miscellaneous** Dock fenders

Relative Adhesive Performance

- High**
 - Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
 - Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
 - Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
- Medium**
 - Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
 - Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
 - Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Low**
 - Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
 - Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
 - Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Effects of Formulation and Processing

- Additives**
 - Carbon Black - Increase
 - Clay - Increase
 - Silica - Increase
 - Paraffinic Oil - Decrease
 - Processing Aid - Decrease
 - Antistat - Increase CA
- T₈₀ Cure** No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer - Increase

Adhesive Shear Strength

Butyl Rubber

BUTYL RUBBER by ExxonMobil Chemical

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Butyl 165 1.2% Unsaturation 100 phr	>90Δ >0.62Δ	>110Δ >0.76Δ	>140Δ >0.97Δ	100 0.69	>110Δ >0.76Δ	<10 <10	60 0.41	60 0.41	90 0.62
T₈₀ Cure Cured to 80% of Modulus at Full Cure Butyl 165 100 phr	>110Δ >0.76Δ	>130Δ >0.90Δ	>140Δ >0.97Δ	80 0.55	110 0.76	30 0.21	60 0.41	60 0.41	60 0.41
Low Unsaturation 0.8% Unsaturation Butyl 065 100 phr	>110Δ >0.76Δ	>140Δ >0.97Δ	>140Δ >0.97Δ	100 0.69	110 0.76	20 0.14	40 0.28	80 0.55	80 0.55
High Unsaturation 1.6% Unsaturation Butyl 268 100 phr	>100Δ >0.69Δ	>110Δ >0.76Δ	>140Δ >0.97Δ	>100Δ >0.69Δ	>100Δ >0.69Δ	30 0.21	60 0.41	60 0.41	90 0.62
Carbon Black Butyl 165 100 phr N-550 40 phr	430 2.97	>490Δ >3.38Δ	>640Δ >4.41Δ	170 1.17	340 2.34	80 0.55	130 0.90	170 1.17	300 2.07
Clay Butyl 165 100 phr Dixie Clay 100 phr	>210Δ >1.45Δ	>270Δ >1.86Δ	>230Δ >1.59Δ	150 1.03	150 1.03	60 0.41	100 0.69	140 0.97	160 1.10
Silica Butyl 165 100 phr Hi Sil 233 20 phr	>210Δ >1.45Δ	>330Δ >2.28Δ	>360Δ >2.48Δ	160 1.10	200 1.38	50 0.34	70 0.48	90 0.62	120 0.83
Paraffinic Oil Butyl 165 100 phr Paraffinic Oil 20 phr	>80Δ >0.55Δ	>110Δ >0.76Δ	>100Δ >0.69Δ	60 0.41	70 0.48	20 0.14	30 0.21	30 0.21	60 0.41
Processing Aid Butyl 165 100 phr Petrolatum 4 phr	80 0.55	>110Δ >0.76Δ	>140Δ >0.97Δ	70 0.48	80 0.55	30 0.21	20 0.14	60 0.41	60 0.41
Antiozonant Butyl 165 100 phr Vanox NBC 3.5 phr	>120Δ >0.83Δ	>110Δ >0.76Δ	>140Δ >0.97Δ	>140Δ >0.97Δ	>110Δ >0.76Δ	20 0.14	40 0.28	60 0.41	90 0.62
Antistatic Butyl 165 100 phr Armostat 550 5 phr	>120Δ >0.83Δ	>140Δ >0.97Δ	>140Δ >0.97Δ	>130Δ >0.90Δ	>160Δ >1.10Δ	40 0.28	40 0.28	60 0.41	70 0.48

NOTES:

- = The addition of the indicated additive (or processing change) caused a statistically significant increase in the bond strength within 95% confidence limits.
- = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
- Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System Used in All Formulations

Stearic Acid	1.00 phr
Zinc Oxide	5.00 phr
Sulfur	2.00 phr
MBT	0.50 phr
TMTD	1.00 phr

Chlorosulfonated Polyethylene (CSM)

thermoset rubber

Trade Names

- HYPALON

Manufacturer

DuPont Performance Elastomers

General Description

Chlorosulfonated polyethylene (CSM) is produced via the simultaneous chlorination and chlorosulfonation of polyethylene in an inert solvent. The addition of the chlorine groups increases the molecular irregularity of the CSM which contributes to its flexibility. The pendant chlorine groups also increase chemical resistance and flame retardance, while the sulfonyl groups provide cross-linking sites. The sulfur content of CSM is normally maintained at approximately 1%, while the chlorine content varies over a wide range. Low chlorine content formulations retain some of the stiffer mechanical properties of PE due to their partial crystallinity. Increasing the chlorine content improves oil resistance and flame resistance.

General Properties

The most notable properties of CSM are its chemical resistance (especially to oxygen, oil and ozone), tensile properties and low temperature properties. The chemical resistance of CSM is much better than that of neoprene and nitrile rubbers. The extremely polar nature of the polymer's backbone makes it especially well suited for non-polar service environments. The ozone resistance of CSM is such that antiozonants are not normally used. CSM is tougher than silicone and EPDM. This is illustrated by the high tensile strengths that are achieved by CSM without high filler levels. The properties of CSM are very dependent on the chlorine content. As the chlorine content increases, the heat resistance, low temperature flexibility and electrical resistance decrease. The ozone resistance also decreases, but the effect is much lower in magnitude than that of the aforementioned properties. On the other hand, as the chlorine content increases, the flame resistance and oil resistance increase. The electrical properties of CSM are better than most elastomers, but not as good as EPDM. Compounds of CSM can be formulated with excellent abrasion resistance and brittle temperatures as low as -76°F (-60°C). Other noteworthy properties of CSM are its excellent radiation resistance and color stability.

Typical Applications

Automotive	Hoses, spark plug boots
Industrial	Hoses, coatings
Consumer	Pond liners, roof membranes

Relative Adhesive Performance

High	Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
Medium	Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
Low	Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Effects of Formulation and Processing

Additives	Low Chlorine - Increase High Chlorine - Increase Carbon Black - Increase Calcium Carbonate - Increase Clay - Increase Silica - Increase Titanium Dioxide - Increase Antistatic - Increase
T₈₀ Cure	No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer – Increase

Adhesive Shear Strength

Chlorosulfonated Polyethylene

HYPALON by DuPont Dow Elastomers

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Hypalon 40 35% Chlorine 100 phr	>510Δ >3.52Δ	>610Δ >4.21Δ	>550Δ >3.79Δ	190 1.31	270 1.86	60 0.41	120 0.83	160 1.10	250 1.72
T₈₀ Cure Cured to 80% of Modulus at Full Cure Hypalon 40 100 phr	>510Δ >3.52Δ	>610Δ >4.21Δ	>550Δ >3.79Δ	80 1.31	190 1.86	270 0.34	120 0.83	110 0.76	180 1.24
Low Chlorine 24% Chlorine Hypalon 45 100 phr	>660Δ >4.55Δ	>870Δ >6.00Δ	>550Δ >3.79Δ	410 2.83	>520Δ >3.59Δ	90 0.62	240 1.66	360 2.48	400 2.76
High Chlorine 43% Chlorine Hypalon 48 100 phr	>510Δ 3.52Δ	>610Δ >4.21Δ	700 4.83	260 1.79	270 1.86	80 0.55	150 1.03	240 1.66	480 3.31
Carbon Black Hypalon 40 100 phr N-990 100 phr	>850Δ >5.86Δ	>1010Δ >6.97Δ	>870Δ >6.00Δ	540 3.72	840 5.79	100 0.69	240 1.66	830 5.72	1030 7.10
Calcium Carbonate Hypalon 40 100 phr Calcium Carbonate 100 phr	>400Δ >2.76Δ	>450Δ >3.10Δ	>410Δ >2.83Δ	390 2.69	>390Δ >2.69Δ	120 0.83	210 1.45	330 2.28	>700Δ >4.83Δ
Clay Hypalon 40 100 phr Dixie Clay 50 phr	>510Δ >3.52Δ	>610Δ >4.21Δ	>550Δ >3.79Δ	190 1.31	390 2.69	100 0.69	120 0.83	200 1.38	930 6.41
Silica Hypalon 40 100 phr Hi Sil 233 50 phr	>540Δ >3.72Δ	>1000Δ >6.90Δ	>550Δ >3.79Δ	510 3.52	720 4.97	60 0.41	210 1.45	540 3.72	860 5.93
Titanium Dioxide Hypalon 40 100 phr Titanium Dioxide 40 phr	>510Δ >3.52Δ	>800Δ >5.52Δ	>750Δ >5.17Δ	260 1.79	270 1.86	60 0.41	150 1.03	230 1.59	1050 7.24
Aromatic Oil Hypalon 40 100 phr Sundex 790 75 phr	160 1.10	>610Δ >4.21Δ	>550Δ >3.79Δ	>190Δ >1.31Δ	>270Δ >1.86Δ	<10 <0.07	50 0.34	80 0.55	90 0.62
Naphthenic Oil Hypalon 40 100 phr Calsol 8240 30 phr	>990Δ >6.83Δ	>940Δ >6.48Δ	>960Δ >6.62Δ	190 1.31	270 1.86	40 0.28	120 0.83	160 1.10	250 1.72
Polyethylene Wax Hypalon 40 100 phr AC617A 10 phr	>510Δ >3.52Δ	>410Δ >2.83Δ	>550Δ >3.79Δ	120 0.83	270 1.86	120 0.83	50 0.34	200 1.38	250 1.72
Antistatic Hypalon 40 100 phr Armostat 550 5 phr	>510Δ >3.52Δ	>610Δ >4.21Δ	>550Δ >3.79Δ	430 2.97	>360Δ >2.48Δ	60 0.41	140 0.97	250 1.72	550 3.79

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 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System Used in All Formulations

Magnesium Oxide	4.00 phr
TMTD	2.00 phr
Rubber Maker's Sulfur	1.00 phr

Copolyester TPE

thermoplastic elastomer

Trade Names

- ECDEL
- HYTREL
- LOMOD
- RITEFLEX

Manufacturer

Eastman
DuPont
GE
Hoescht Celanese

General Description

Copolyester TPE is composed of alternating hard poly-1,4-butanediol terephthalate and soft long-chain polyalkylene ether terephthalate block copolymers connected by ester and ether linkages. Copolyester has an -A-B-A-B- structure. However, the performance of copolyester TPE is analogous to that of three block copolymers such as styrenic TPEs.

General Properties

The cost of copolyester TPE is above average, but the performance is also above average. They have two to 15 times the strength of conventional rubbers. This means that replacing a thermoset rubber with a copolyester TPE can result in a significant decrease in the part volume and weight. Consequently, the option of reducing the required size of the part while achieving the original mechanical and strength properties can significantly offset the higher cost of copolyester TPE. Copolyester TPE has very good resistance to organic solvents and aqueous solutions. However, they have poor resistance to halogenated solvents, acids and bases. They have moderate thermal resistance with recommended service temperatures ranging from -67° to 285°F (-55° to 140°C). Below their elastic limit, copolyester TPE has excellent physical properties. Tensile strength ranges from 3,000 to 8,000 psi (20.7 to 55.2 MPa). The elastic limit of copolyester TPE is only 25%, which is low for an elastomer. Above this elongation, the polymer will be permanently deformed. The low elongation is accompanied by an unusually high hardness. The hardness typically ranges from 40 to 75 Shore D. Plasticizer is not used when compounding copolyester TPEs. This makes copolyester TPE purer than most other TPEs which, consequently, makes them especially well suited for medical and food applications.

Typical Applications

- Automotive** Fuel tanks, gear wheels, boots, drive belts
- Consumer** Ski boots
- Industrial** Gears, belts, bellows, boots, coil tubing and cables

Relative Adhesive Performance

- High** Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Medium** Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
- Low** Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body

Surface Treatments

Loctite® 770™ Prism® Primer – Decrease

Adhesive Shear Strength

Copolyester TPE

HYTREL by DuPont

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Hytrell G5544 <i>100 phr</i>	330 2.28	1570 10.83	1510 10.41	510 3.52	560 3.86	20 0.14	170 1.17	350 2.41	1220 8.41
Hytrell 7246 <i>100 phr</i>	1180 8.14	1020 7.03	650 4.48	400 2.76	470 3.24	120 0.83	120 0.83	470 3.24	1170 8.07

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Cure System Used in All Formulations

None Required

Epichlorohydrin Rubber (CO, ECO, GCO, GECO)

thermoset rubber

Trade Names

- HYDRIN

Manufacturer

Zeon

General Description

Epichlorohydrin polymers are available as a homopolymer (CO) of epichlorohydrin, epichlorohydrin/ethylene oxide copolymer (ECO), epichlorohydrin/allyl glycidyl ether copolymer (GCO) and epichlorohydrin/ethylene oxide/allyl glycidyl ether terpolymer (GECO). The ethylene oxide content varies from zero in the homopolymer, to 32% to 35% for terpolymers and up to 50% for copolymers. As ethylene oxide content increases, the halogen content and polarity of the polymer decreases. Blends of the various rubber types are used to obtain specific properties. The allyl glycidyl ether provides a cure site on the polymer backbone. This permits the use of other cure systems, such as peroxides, rather than the sulfur-based systems which are typically used for CO and ECO.

General Properties

All epichlorohydrin polymers offer low temperature flexibility; resistance to oils, fuel and common solvents; low gas permeability; good weatherability and good dynamic properties. The specific degree to which these properties are manifested varies with each type of epichlorohydrin polymer. Because all epichlorohydrin polymers have a completely saturated backbone, they all have good resistance to UV, ozone and thermal degradation. For the lowest gas permeability, the homopolymer is the polymer of choice. The lower halogen content in the copolymers and terpolymer imparts a higher degree of flexibility to the backbone and results in improved low temperature performance of the material. This improvement is gained at the expense of an increase in permeability. If the ECO copolymer is difficult to cure, or the properties that result from the sulfur-based cure systems are unacceptable, copolymer or terpolymer containing the allyl glycidyl ether monomer can be used. The unsaturated site opens the door to cure by a peroxide system. This yields improved high temperature properties and compression set resistance over sulfur cured systems. The copolymers and terpolymer have a lower halogen content than the pure homopolymer. Consequently, the resistance to non-polar solvents, such as fuels and oils, is decreased. Aqueous and non-aqueous electrolytes rapidly degrade the polar epichlorohydrin polymer.

Typical Applications

Automotive	Fuel pump diaphragms, hoses, motor mounts, boots, seals, o-rings, air conditioning system components
Industrial	Gaskets, rolls, belts, bladders
Medical	Oxygen mask hoses

Relative Adhesive Performance

High	Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
Medium	Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
Low	Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body

Effects of Formulation and Processing

Additives	Hydrin C - Increase CA Hydrin T - Increase CA Carbon Black - Increase Plasticizer - Decrease
T₈₀ Cure	Increase CA

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Epichlorohydrin Rubber

HYDRIN by Zeon Chemical Corporation

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Hydrin H <i>Homopolymer</i> 100 phr	>120Δ >0.83Δ	>110Δ >0.76Δ	>140Δ >0.97Δ	>100Δ >0.69Δ	>120Δ >0.83Δ	60 0.41	60 0.41	100 0.69	>160Δ >1.10Δ
T₈₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> Hydrin H 100 phr	>150Δ >1.03Δ	>160Δ >1.10Δ	>140Δ >0.97Δ	>130Δ >0.90Δ	>120Δ >0.83Δ	40 0.28	60 0.41	100 0.69	>200Δ >1.38Δ
Hydrin C <i>ECO copolymer</i> Hydrin C 100 phr	>310Δ >2.14Δ	>150Δ >1.03Δ	>160Δ >1.10Δ	>120Δ >0.83Δ	>120Δ >0.83Δ	60 0.41	60 0.41	80 0.55	160 1.10
Hydrin T <i>GEEO Terpolymer</i> Hydrin T 100 phr	>140Δ >0.97Δ	>150Δ >1.03Δ	>140Δ >0.97Δ	>100Δ >0.69Δ	>110Δ >0.76Δ	40 0.28	70 0.48	>60Δ >0.41Δ	>160Δ >1.10Δ
Carbon Black Hydrin H 100 phr N-550 25 phr	>750Δ >5.17Δ	>870Δ >6.00Δ	>480Δ >3.31Δ	330 2.28	290 2.00	90 0.62	140 0.97	140 0.97	160 1.10
Calcium Carbonate Hypalon H 100 phr Calcium Carbonate 50 phr	>110Δ >0.76Δ	>130Δ >0.90Δ	>140Δ >0.97Δ	>120Δ >0.83Δ	>120Δ >0.83Δ	30 0.21	60 0.41	100 0.69	>160Δ >1.10Δ
Plasticizer Hydrin H 100 phr Diocetyl Phthalate 10 phr	>90Δ >0.62Δ	>110Δ >0.76Δ	>100Δ >0.69Δ	>80Δ >0.55Δ	>90Δ >0.62Δ	30 0.21	50 0.34	70 0.48	>130Δ >0.90Δ

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Cure System Used in All Formulations

Zinc Oxide	3.00 phr
ZO-9	2.00 phr
Ethylene Thiurea	2.00 phr

Ethylene Acrylic Rubber (EEA)

thermoset rubber

Trade Names

- VAMAC

Manufacturer

DuPont

General Description

Ethylene acrylic rubber is manufactured exclusively by DuPont under the trade name Vamac. Vamac is a terpolymer of ethylene, methacrylate and a small quantity of a third monomer which contributes a carboxylate cure site. Raising the level of methacrylate monomer in the terpolymer blend improves oil resistance, at the expense of low temperature flexibility. Ester plasticizers are used to improve low temperature properties, but can be lost in heat aging or extracted by solvents at high temperatures. These rubbers tend to stick to processing equipment and generally contain processing aids such as release agents. These products can be cured with peroxide cure systems, although superior properties generally result from the use of multivalent diamine cure systems. Ethylene acrylic rubber is commonly reinforced with carbon black to obtain best performance properties.

General Properties

Ethylene acrylic rubbers have better heat resistance and low temperature flexibility than polyacrylate rubbers. Ethylene acrylic rubber also offers excellent resistance to water. This, coupled with its resistance to UV and ozone, give it excellent weathering resistance. These improvements are gained while offering equivalent oil resistance to polyacrylate rubber. Other less notable improvements include the improved oxidative, alkali and acid resistance of Vamac over polyacrylate rubbers. Ethylene acrylic rubber offers poor resistance to non-mineral oil brake fluid, esters or ketones. They do, however, offer excellent resistance to diesel fuel, kerosene, ethylene glycol and water. Vamac has combustion products that are have a very low smoke density, toxicity and corrosivity.

Typical Applications

Automotive Automotive fluid seals, gaskets, boots, grommets, vibration mounts, pads, cam covers, filters, o-rings, door seals, hose covers

Electrical Wire and cable insulation

Relative Adhesive Performance

High Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive

Medium Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive

Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive

Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive

Low Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant

Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body

Effects of Formulation and Processing

Additives Carbon Black - Increase
Clay - Increase
Silica - Increase
Antistatic - Increase

T₈₀ Cure Increase

Surface Treatments

Loctite® 770™ Prism® Primer - Increase

Adhesive Shear Strength

Ethylene Acrylic Rubber

VAMAC by DuPont

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Vamac B-124 <i>100 phr</i>	130 0.90	>330Δ >2.28Δ	>420Δ >2.90Δ	130 0.90	140 0.97	30 0.21	110 0.76	170 1.17	190 1.31
T₈₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> <i>Vamac B-124 100 phr</i>	>400Δ >2.76Δ	>330Δ >2.28Δ	>420Δ >2.90Δ	200 1.38	>370Δ >2.55Δ	<10 <0.07	110 0.76	100 0.69	190 1.31
Carbon Black <i>Vamac B-124 100 phr</i> <i>N-550 25 phr</i>	470 3.24	>810Δ >5.59Δ	>970Δ >6.69Δ	360 2.48	>740Δ >5.10Δ	60 0.41	170 1.17	300 2.07	290 2.00
Clay <i>Vamac B-124 100 phr</i> <i>Dixie Clay 50 phr</i>	260 1.79	330 2.28	420 2.90	>320Δ >2.21Δ	470 3.24	<10 <0.07	150 1.03	280 1.93	>710Δ >4.90Δ
Silica <i>Vamac B-124 100 phr</i> <i>Hi Sil 233 15 phr</i>	>420Δ >2.90Δ	>790Δ >5.45Δ	>860Δ >5.93Δ	330 2.28	>600Δ >4.14Δ	<10 <0.07	150 1.03	170 1.17	330 2.28
Calcium Carbonate <i>Hypalon H 100 phr</i> <i>Calcium Carbonate 50 phr</i>	>110Δ >0.76Δ	>130Δ >0.90Δ	>140Δ >0.97Δ	>120Δ >0.83Δ	>120Δ >0.83Δ	30 0.21	60 0.41	100 0.69	>160Δ >1.10Δ
Antistatic <i>Vamac B-124 100 phr</i> <i>Armostat 550 5 phr</i>	>320Δ >2.21Δ	>410Δ >2.83Δ	>420Δ >2.90Δ	>360Δ >2.48Δ	>360Δ >2.48Δ	110 0.76	110 0.76	120 0.83	190 1.31

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Cure System Used in All Formulations

Armeen 18D	0.50 phr
HVA-2	1.00 phr
Diak #1 (All Except Grade G)	1.25 phr
Vulcup R (Grade G only)	1.50 phr

Ethylene Propylene Rubber (EPM, EPDM)

thermoset rubber

Trade Names

- NORDEL
- POLYSAR EPDM
- ROYALENE
- VISTALON

Manufacturer

DuPont
Bayer
Uniroyal
ExxonMobil Chemical

Typical Applications

- Automotive** Hoses, belts, cable insulation, boots, seals, weatherstrip
- Consumer** Garden hose, roof sheeting, ditch liners, coated fabrics
- Electronic** Cable covers, underground wire, power cable insulation

General Description

EPDM is formed via the copolymerization of ethylene, propylene and a third comonomer in slurry or solution. The ethylene content of EPDM is typically 45% to 75%. The third comonomer is a non-conjugated diene. The three most prevalent in industry are dicyclopentadiene (DCPD), ethylidene norbornene (ENB) and 1,4 hexadiene (1,4 HD); the most commonly used being ENB. The polymerization of EPDM is catalyzed with a vanadium halide, halogenated aluminum alkyl and, in some cases, an activator. Due to the poor mechanical properties of unfilled EPDM, it typically requires reinforcing filler levels greater than 70 phr to be of practical value.

General Properties

EPDM is known for its superior resistance to ozone and oxidation as well as its relatively low cost. The low cost of compounded EPDM stems from its potential for high loading with low cost fillers. The aliphatic nature of the backbone results in the excellent weatherability of EPDM and also makes it extremely stable in color. Due to its non-polarity, EPDM has poor resistance to non-polar chemicals, such as aliphatic, aromatic and chlorinated hydrocarbons, and high resistance to polar solvents, such as ketones and alcohols. EPDM also exhibits good electrical properties due to the non-polar backbone and the amorphous regions of the polymer. EPDM responds well to loading, developing high tensile, tear and abrasion properties, and is frequently filled in high amounts (up to 700 phr). The most prevalent filler is carbon black. Other fillers that are commonly used are silicas, clays, talcs and ground whittings. EPDM has favorable thermal properties. Heat resistance of 300°F (149°C) can be achieved with sulfur accelerated cure systems, while 350°F (177°C) can be achieved using peroxide cure systems. In addition, peroxide cure systems result in EPDM rubbers with better compression set properties.

Relative Adhesive Performance

- High** Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
Prism Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
- Medium** Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
- Low** Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive

Effects of Formulation and Processing

- Additives** Clay - Increase
Naphthenic Oil - Decrease
Paraffinic Oil - Decrease
- T₈₀ Cure** Increase

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Ethylene Propylene Rubber

VISTALON 2504 by ExxonMobil Chemical,
NORDEL by DuPont, ROYALENE by Uniroyal

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Vistalon 2504 EPDM, ENB Terpolymer 100 phr	270 1.86	>680Δ >4.69Δ	>580Δ >4.00Δ	230 1.59	240 1.66	80 0.55	140 0.97	130 0.90	110 0.76
T₈₀ Cure Cured to 80% of Modulus at Full Cure Vistalon 2504 100 phr	>270Δ >1.86Δ	>680Δ >4.69Δ	>680Δ >4.69Δ	>230Δ >1.59Δ	>500Δ >3.45Δ	<10 <0.07	190 1.31	160 1.1	110 0.76
Vistalon 404 EP Copolymer 100 phr	>270Δ >1.86Δ	>360Δ >2.48Δ	>350Δ >2.41Δ	80 0.55	140 0.97	60 0.41	140 0.97	80 0.55	110 0.76
Nordel 1040 EPDM, HD Terpolymer 100 phr	>390Δ >2.69Δ	>440Δ >3.03Δ	>490Δ >3.38Δ	230 1.59	>350Δ >2.41Δ	80 0.55	170 1.17	220 1.52	340 2.34
Royalene 301-T EPDM, DCPD Terpolymer 100 phr	>270Δ >1.86Δ	>210Δ >1.45Δ	>250Δ >1.72Δ	230 1.59	>240Δ >1.66Δ	80 0.55	40 0.28	130 0.90	110 0.76
Vistalon 3708 EPDM, High Ethylene 100 phr	190 1.31	410 2.83	>580Δ >4.00Δ	230 1.59	340 2.34	50 0.34	70 0.48	130 0.90	110 0.76
Carbon Black Vistalon 2504 100 phr N-550 65 phr	510 3.52	>680Δ >4.69Δ	>410Δ >2.83Δ	230 1.59	>540Δ >3.72Δ	60 0.41	230 1.59	110 0.76	210 1.45
Clay Vistalon 2504 100 phr Dixie Clay 200 phr	>290Δ >2.00Δ	>270Δ >1.86Δ	>250Δ >1.72Δ	>280Δ >1.93Δ	>220Δ >1.52Δ	80 0.55	240 1.66	250 1.72	>290Δ >2.00Δ
Silica Vistalon 2504 100 phr Hi Sil 233 20 phr	270 1.86	>530Δ >3.66Δ	>580Δ >3.66Δ	230 1.59	240 1.66	<10 <0.07	190 1.31	130 0.90	110 0.76
Naphthenic Oil Vistalon 2504 100 phr Naphthenic Oil 25 phr	>380Δ >2.62Δ	>510Δ >3.52Δ	>580Δ >4.00Δ	120 0.83	160 1.10	40 0.28	100 0.69	80 0.55	110 0.76
Paraffinic Oil Vistalon 2504 100 phr Paraffinic Oil 25 phr	>990Δ >6.83Δ	>940Δ >6.48Δ	>960Δ >6.62Δ	190 1.31	270 1.86	40 0.28	120 0.83	160 1.10	250 1.72
Antistatic Vistalon 2504 100 phr Armostat 550 5 phr	>470Δ >3.24Δ	>400Δ >2.76Δ	>390Δ >2.69Δ	>400Δ >2.76Δ	>420Δ >2.90Δ	50 0.34	110 0.76	130 0.90	110 0.76

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Cure System and Reinforcements Used in Vistalon 404

N-550	25.00 phr
Zinc Oxide	5.00 phr
VAROX DBPH-50	5.00 phr
VANAX MBM	1.50 phr
Zinc Stearate	1.00 phr

Cure System and Reinforcements Used in All Other Formulations

N-550	25.00 phr
Zinc Oxide	5.00 phr
CAPTAX	1.50 phr
Methyl TUADSO	.80 phr
Stearic Acid	1.00 phr

Ethylene-Vinyl Acetate Copolymer (EVA)

thermoset rubber or thermoplastic elastomer

Trade Names

- ELVAX
- ESCORENE
- EVAZOTE
- ULTRATHENE

Manufacturer

DuPont
ExxonMobil Chemical
B.P. Chemicals
Quantum Chemicals

Typical Applications

Appliances	Freezer door gaskets, convoluted tube for vacuum cleaners
Electrical	Foams for static-sensitive devices
Industrial	Hoses, tubes
Packaging	Shrink wrap film
Medical	Disposable gloves, anesthesia face masks and hoses
Miscellaneous	Adhesives, coatings, sealants, solar cell encapsulants, baby bottle nipples

General Description

Ethylene-vinyl acetate copolymer is formed through the copolymerization of ethylene and vinyl acetate by continuous bulk polymerization or solution polymerization. Since bulk polymerization produces polymer too low in molecular weight to be useful in the rubber industry, solution polymerization is predominately used. Common grades have vinyl acetate contents ranging from 2% to 50%. As the vinyl acetate content changes, the crystallinity of the polymer decreases from 60% to 10%, respectively. Since EVA is a thermoplastic, it can be processed by methods common to thermoplastics such as extrusion, injection molding, blow molding, calendaring and rotational molding. Subsequent cross-linking with a peroxide cure system can yield thermoset EVA.

General Properties

The properties of ethylene-vinyl acetate copolymer vary depending primarily on the level of vinyl acetate in the copolymer. At lower levels of vinyl acetate, the copolymer is a thermoplastic with properties similar to low density polyethylene. As the vinyl acetate content is increased, the copolymer takes on the performance characteristics of a thermoplastic elastomer until the crystallinity drops so low that the copolymer forms a soft rubbery material with minimal physical strength. The copolymer containing high levels of vinyl acetate is primarily used as a component in adhesives and coatings but can be vulcanized to obtain useful physical properties. As vinyl acetate content increases, polymer flexibility, toughness, solubility in organic solvents and clarity increase. The lowered crystallinity caused by the addition of the vinyl acetate contributes to good durability at lower temperatures and environmental stress cracking resistance. The enhanced flexibility is accompanied by lower softening point temperatures as the vinyl acetate content increases, which limits the upper service temperatures of these materials. EVA has good resistance to salt water and bases, but is not compatible with strong oxidizers. Grades offering good resistance to hydrocarbon greases are available, but EVA copolymers are generally readily soluble in a wide range of aliphatic, aromatic and chlorinated solvents. Grades offering good resistance to UV degradation and ozone are also available.

Relative Adhesive Performance

High	Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
Medium	Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
Low	Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body

Effects of Formulation and Processing

Additives	Antistatic - Increase High Vinyl Acetate - Decrease Low Vinyl Acetate - Increase
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Surface Treatments

Loctite® 770™ Prism® Primer - Increase

Adhesive Shear Strength

Ethylene-Vinyl Acetate Copolymer

ELVAX by DuPont

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Elvax 560 15% Vinyl Acetate 100 phr	360 2.48	430 2.97	>470Δ >3.24Δ	240 1.66	300 2.07	50 0.34	50 0.34	360 2.48	780 5.38
Antistatic Elvax 560 100 phr Armostat 550 5 phr	510 3.52	550 3.79	>830Δ >5.72Δ	530 3.66	>580Δ >4.00Δ	10 0.07	10 0.07	220 1.52	780 5.38
Elvax 150 32% Vinyl Acetate 100 phr	300 2.07	320 2.21	>830Δ >5.72Δ	220 1.52	290 2.00	10 0.07	70 0.48	290 2.00	670 4.62
Elvax 760 9.3% Vinyl Acetate 100 phr	250 1.72	>870Δ >5.72Δ	>660Δ >4.55Δ	360 2.48	>410Δ >2.83Δ	10 0.07	50 0.34	410 2.83	780 5.38

- NOTES:**
- = The addition of the indicated additive (or processing change) caused a statistically significant increase in the bond strength within 95% confidence limits.
 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System Used in All Formulations
None Used

Fluorocarbon Rubber (FKM)

thermoset rubber

Trade Names

- DAI-EL
- FLUOREL
- KALREZ
- TECNOFLON
- VITON

Manufacturer

Daikin
3M
DuPont
Ausimont
DuPont Performance
Elastomers

General Description

Fluoroelastomers are produced by the polymerization of various fluorine containing monomers. Commonly used monomers include vinylidene fluoride, hexafluoropropylene, per fluoro (methyl vinyl ether) and tetrafluoroethylene. Generally, these monomers are used in conjunction with other non-fluorine containing monomers which contribute cure sites and help alter the fluorine content. The primary factors that influence the cured performance characteristics are the fluorine content and the cure system used. Fluoroelastomers of varying fluorine content are divided into the following groups: A-66%; B-68%; F-70% and a fourth group of specialty grades. The fluorine content of the rubber is controlled by monomer type and monomer ratio. Cure systems commonly used with fluoroelastomers include diamines, bisphenol and peroxide types.

General Properties

Fluoroelastomers are known for their outstanding thermal and chemical resistance. They are generally capable of long-term service at temperatures of 392°F (200°C). It has been reported that some grades can withstand intermittent exposure to temperatures as high as 644°F (340°C). These properties stem from the high polarity of the fluorine group, the high bond energy of the fluorine-carbon bond and the complete saturation of the fluorocarbon backbone. The physical properties of fluorocarbon elastomers are dependent on the ionic attraction between adjacent fluorine and hydrogen atoms. This attraction leads to brittle point temperatures as high as -13°F (-25°C). This tendency towards poor flexibility at low temperatures increases as the fluorine content of the polymer increases. Fluorosilicones or specialty grades of fluorocarbon elastomers are generally used where good low temperature flexibility is required. Fluoroelastomers show very good resistance to hydrocarbons, acids and chlorinated solvents. To improve the oil resistance of fluoro-elastomers, the fluorine content can be increased. Increasing the fluorine content will decrease its resistance to polar solvents due to the increased polarity of the polymer. Fluoroelastomers can also be attacked by bases and amines. To address these limitations, specialty formulations are available with improved

chemical resistance.

Typical Applications

- Aerospace** Fuel seals, manifold gaskets, fuel tank bladders, firewall seals
- Appliances** Copier fuser rolls
- Automotive** Shaft seals, fuel lines and seals, carburetor parts, gaskets
- Electronics** Electrical connectors, wire and cable insulation
- Industrial** Flue ducts, gaskets, hoses, oil well seals, pump linings

Relative Adhesive Performance

- High**
 - Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
 - Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
 - Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
 - Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
 - Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
 - Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Low**
 - Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
 - Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
 - Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Effects of Formulation and Processing

- Additives**
 - Carbon Black - Increase
 - Barium Sulfate - Increase
 - Silica - Increase
 - Processing Aid - Decrease
 - Antistat - Decrease

T₈₀ Cure No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Fluorocarbon Rubber

VITON by DuPont Performance Elastomers and FLUOREL by 3M

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Viton E-60C Group A: Dipolymer, 66% Fluorine 100 phr	>300Δ >2.07Δ	>300Δ >2.07Δ	280 1.93	>330Δ >2.28Δ	>270Δ >1.86Δ	70 0.48	120 0.83	130 0.90	>510Δ >3.52Δ
T₈₀ Cure Cured to 80% of Modulus at Full Cure Viton E-60C 100 phr	>300Δ >2.07Δ	>300Δ >2.07Δ	280 1.93	>330Δ >2.28Δ	270 1.86	70 0.48	120 0.83	130 0.90	>510Δ >3.52Δ
Viton B Group B: Terpolymer, 68% Fluorine 100 phr	>300Δ >2.07Δ	>300Δ >2.07Δ	>280Δ >1.93Δ	200 1.38	>210Δ >1.45Δ	70 0.48	110 0.76	130 0.90	>400Δ >2.76Δ
Fluorel 5730Q Group F: High Fluorine, 70% Fluorine SMR-5 100 phr	>280Δ >2.93Δ	>350Δ >2.41Δ	>280Δ >1.93Δ	230 1.59	>270Δ >1.86Δ	40 0.28	80 0.55	80 0.55	>510Δ >3.52Δ
Carbon Black Viton E-60C 100 phr MT N990 30 phr	>440Δ >3.03Δ	>530Δ >3.66Δ	>520Δ >3.59Δ	>520Δ >3.59Δ	>560Δ >3.86Δ	70 0.48	190 1.31	240 1.66	>830Δ >5.72Δ
Barium Sulfate Viton E-60C 100 phr Barium Sulfate 50 phr	>240Δ >1.66Δ	>300Δ >2.07Δ	>280Δ >1.93Δ	>330Δ >2.28Δ	>270Δ >1.86Δ	100 0.69	170 1.17	200 1.38	>510Δ >3.52Δ
Silica Polyethylene Glycol 2.5 phr Viton E-60C 100 phr Hi Sil 233 15 phr	>660Δ >4.55Δ	>750Δ >5.17Δ	>730Δ >5.03Δ	>690Δ >4.76Δ	>790Δ >5.45Δ	70 0.48	210 1.45	310 2.14	>1060Δ >7.31Δ
Processing Aid Viton E-60C 100 phr Carnauba Wax 5 phr	>250Δ >1.72Δ	>300Δ >2.07Δ	>280Δ >1.93Δ	>330Δ >2.28Δ	>270Δ >1.86Δ	70 0.48	120 0.83	130 0.90	>410Δ >2.83Δ
Processing Aid Viton E-60C 100 phr Dynamar PPA-790 5 phr	>120Δ >0.83Δ	>140Δ >0.97Δ	>150Δ >1.03Δ	>110Δ >0.76Δ	>140Δ >0.97Δ	70 0.48	120 0.83	150 1.03	>170Δ >1.17Δ
Antistatic Viton E-60C 100 phr Armostat 550 5 phr	>150Δ >1.03Δ	>200Δ >1.38Δ	>180Δ >1.24Δ	>160Δ >1.10Δ	>270Δ >1.86Δ	50 0.34	100 0.69	>170Δ >1.17Δ	>360Δ >2.48Δ

- NOTES:**
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 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System Used in All Formulations

MAGLITE D 3.00 phr
Calcium Hydroxide 6.00 phr

Fluorosilicone Rubber (FVMQ)

thermoset rubber

Trade Names

- FE
- FSE
- LS

Manufacturer

Shinetsu Chemical Company
General Electric
Dow Corning

General Description

Fluorosilicone rubber (FVMQ) has an inorganic silicone backbone, comprised of siloxane linkages (silicon-oxygen bonds). This, coupled with the highly polar pendant trifluoropropyl groups, give fluorosilicones a unique combination of properties. The siloxane backbone provides superior flexibility at low temperatures compared to other fluoroelastomers. The pendant trifluoropropyl groups make the elastomer extremely polar which increases its resistance to non-polar solvents. Silicone elastomers have one pendant methyl group and one pendant trifluoropropyl group for 40-90 mole % of the silicon atoms on the backbone depending on the fluorine content of the monomers selected. A small percent of silicon atoms with a pendant vinyl group will be incorporated into the polymer chain to serve as cross-link sites. Typically, it is required for fluorosilicones to be reinforced with silica to obtain useful physical properties.

General Properties

Fluorosilicones are renowned for their fuel resistance and utility in extreme temperature service environments. The siloxane backbone results in a polymer with excellent UV, ozone and thermal resistance. The maximum recommended service temperature is in excess of 392°F (200°C) for most grades with brittle points as low as -85°F (-65°C). This results in better flexibility at low temperatures than fluorocarbon elastomers can offer. The polarity of the fluorosilicone elastomer results in very good resistance to non-polar solvents such as aliphatic and aromatic hydrocarbons commonly used in fuels. In comparison to silicone rubbers, the primary advantage of fluorosilicone rubbers is their exceptional resistance to non-polar solvents which would normally cause severe swelling of the PMVQ rubbers. On the other hand, the fluorosilicone will have less resistance to polar solvents than PMVQ rubbers.

Typical Applications

Automotive O-rings, seals
Industrial Shaft seals, gaskets, molded goods, duct hoses
Electronics Wire and cable insulation

Relative Adhesive Performance

High Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer

Medium Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive

Low Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Effects of Formulation and Processing

Additives Carbon Black - Increase
Calcium Carbonate - Increase
Fluorosilicone Oil - Decrease

T₈₀ Cure No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer - Increase

Adhesive Shear Strength

Fluorosilicone Rubber

FSE 2620U by General Electric

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: FSE 2620U <i>100 phr</i>	60 0.41	>190Δ >1.31Δ	>240Δ >1.66Δ	70 0.48	110 0.76	110 0.76	160 1.10	90 0.62	120 0.83
T₈₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> FSE 2620U 100 phr	60 0.41	230 1.59	>240Δ >1.66Δ	70 0.48	110 0.76	80 0.55	160 1.10	60 0.41	120 0.83
Carbon Black FSE 2620U 100 phr N-550 25 phr	80 0.55	210 1.45	>240Δ >1.66Δ	120 0.83	120 0.83	110 0.76	240 1.66	90 0.62	120 0.83
Calcium Carbonate FSE 2620U 100 phr Calcium Carbonate 40 phr	100 0.69	>190Δ >1.31Δ	>240Δ >1.66Δ	90 0.62	110 0.76	170 1.17	160 1.10	90 0.62	190 1.31
Silica FSE 2620U 100 phr Aerosil 200 10 phr	>440Δ >3.03Δ	>530Δ >3.66Δ	>520Δ >3.59Δ	>520Δ >3.59Δ	>560Δ >3.86Δ	70 0.48	190 1.31	240 1.66	>830Δ >5.72Δ
Fluorosilicone Oil FSE 2620U 100 phr Fluorosilicone Oil 50 phr	260 1.79	>130Δ >0.90Δ	>150Δ >1.03Δ	50 0.34	80 0.55	110 0.76	160 1.10	<10 <0.07	70 0.48

- NOTES:**
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 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System and Reinforcement Used in All Formulations

DiCup R 2.00 phr
Aerosil 200 5.00 phr

Halogenated Butyl Rubber (BIIR, CIIR)

thermoset rubber

Trade Names

- EXXON BROMOBUTYL ExxonMobil Chemical
- EXXON CHLOROBUTYL ExxonMobil Chemical
- POLYSAR BROMOBUTYL Bayer
- POLYSAR CHLOROBUTYL Bayer

Manufacturer

General Description

Halogenated butyl rubber is created by the halogenation of butyl rubber with either bromine or chlorine. Bromine or chlorine is added to the butyl polymer at a 1:1 molar ratio of halogen to isoprene. The addition of the halogen atoms to the butyl backbone increases the polarity of the non-polar butyl rubber. The increase in polarity yields rubber with better resistance to non-polar hydrocarbons and allows it to be blended with more polar rubbers which contain unsaturation. As a result, halobutyl rubbers can be covulcanized with natural rubber, neoprene, styrene butadiene, nitrile, chlorosulfonated polyethylene, butyl, EPDM and epichlorohydrin elastomers. Another benefit of halogenation is that the allylic halogen structures formed facilitate cross-linking by cure systems other than sulfur. This avoids the thermal limitations of sulfur-cured butyl rubber while retaining the low gas permeability and good environmental resistance inherent in butyl rubbers.

General Properties

The key performance feature of butyl rubber is its extremely low permeability to gas and moisture. This is attributed to the long aliphatic polymer backbone and absence of bulky pendant groups which allow the polymer chains to pack together very well. The primary difference between halogenated butyl and butyl rubbers is that the former can be cross-linked by a variety of different cure systems, while the latter cannot. This results in halogenated butyl rubbers having improved thermal resistance over butyl rubbers because they can be cross-linked with non-sulfur cross-link systems. Furthermore, the use of non-sulfur based cure systems also results in a purer rubber with less extractables. This makes halobutyl rubber compounds well suited for pharmaceutical closures. When formulated to offer good flex resistance, chlorobutyl covulcanizates with natural rubber are widely used as inner liners for tubeless tires, especially in steel-belted radial tires.

Typical Applications

- Automotive** Tire inner liners, tire sidewalls, tire tread components, hoses, engine mounts
- Electronics** Electrical insulation
- Industrial** Conveyor belts, curing bladders, membranes, tank linings, steam hose, diaphragms, gas bladders
- Medical** Pharmaceutical closures
- Miscellaneous** Bridge bearing pads, ball bladders, pond-liner membranes, roofing

Relative Adhesive Performance

- High** Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
- Medium** Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Low** Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Effects of Formulation and Processing

- Additives** Carbon Black - Increase
Calcium Carbonate - Increase
Clay - Increase
Silica - Increase
Aliphatic Oil - Increase
Naphthenic Oil - Decrease
Antistatic - Increase for CAs
- T₈₀ Cure** No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Halogenated Butyl Rubber

BROMOBUTYL and CHLOROBUTYL by ExxonMobil Chemical

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Bromobutyl 2244 100 phr	>170Δ >1.17Δ	>190Δ >1.31Δ	>180Δ >1.24Δ	80 0.55	110 0.76	40 0.28	80 0.55	60 0.41	130 0.90
T₈₀ Cure Cured to 80% of Modulus at Full Cure Bromobutyl 2244 100 phr	>170Δ >1.17Δ	>190Δ >1.31Δ	>180Δ >1.24Δ	80 0.55	>130Δ >0.90Δ	20 0.14	60 0.41	60 0.41	130 0.90
Chlorobutyl Chlorobutyl 1066 100 phr	>130Δ >0.90Δ	>130Δ >0.90Δ	>130Δ >0.90Δ	80 0.55	110 0.76	40 0.28	80 0.55	80 0.55	130 0.90
Carbon Black Bromobutyl 2244 100 phr N-550 40 phr	500 3.45	>560Δ >3.86Δ	>540Δ >3.72Δ	140 0.97	230 1.59	50 0.34	130 0.90	140 0.97	130 0.90
Calcium Carbonate Bromobutyl 2244 100 phr Calcium Carbonate 100 phr	>140Δ >0.97Δ	>140Δ >0.97Δ	>140Δ >0.97Δ	120 0.83	>110Δ >0.76Δ	60 0.41	80 0.55	100 0.69	190 1.31
Clay Bromobutyl 2244 100 phr Dixie Clay 100 phr	190 1.31	240 1.66	180 1.24	160 1.10	150 1.03	80 0.55	140 0.97	140 0.97	320 2.21
Silica Bromobutyl 2244 100 phr Hi Sil 233 15 phr	>260Δ >1.79Δ	>280Δ >1.93Δ	>320Δ >2.21Δ	150 1.03	180 1.24	50 0.34	100 0.69	100 0.69	210 1.45
Aliphatic Oil Bromobutyl 2244 100 phr Aliphatic Oil 20 phr	>300Δ >2.07Δ	>300Δ >2.07Δ	>260Δ >1.79Δ	130 0.90	150 1.03	60 0.41	80 0.55	80 0.55	130 0.90
Naphthenic Oil Bromobutyl 2244 100 phr Naphthenic Oil 15 phr	>130Δ >0.90Δ	>140Δ >0.97Δ	>140Δ >0.97Δ	80 0.55	>110Δ >0.76Δ	40 0.28	60 0.41	60 0.41	130 0.90
Processing Aid Bromobutyl 2244 100 phr Struktol 40 MS 10 phr	140 0.97	>180Δ >1.24Δ	>180Δ >1.24Δ	100 0.69	130 0.90	30 0.21	80 0.55	60 0.41	130 0.90
Antistatic Bromobutyl 2244 100 phr Armostat 550 5 phr	>170Δ >1.17Δ	>190Δ >1.31Δ	>180Δ >1.24Δ	>130Δ >0.90Δ	>140Δ >0.97Δ	40 0.28	80 0.55	60 0.41	130 0.90

- NOTES:**
- = The addition of the indicated additive (or processing change) caused a statistically significant increase in the bond strength within 95% confidence limits.
 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System Used in All Formulations

Stearic Acid	1.00 phr
Zinc Oxide	5.00 phr
Maglite D	0.50 phr
Sulfur	2.00 phr
TMTD	1.00 phr

Hydrogenated Nitrile Rubber (H-NBR, HSN)

thermoset rubber

Trade Names

- THERBAN
- ZETPOL

Manufacturer

Bayer
Zeon Chemical

General Description

Nitrile elastomer is produced through the emulsion copolymerization of butadiene and acrylonitrile monomer. Selective hydrogenation is then performed in a solvent with a noble metal catalyst to yield highly saturated hydrogenated nitrile polymer.

General Properties

Due to the aliphatic nature of the backbone, the thermal and chemical resistance are much improved over that of nitrile rubber. Hydrogenated nitriles are known for their exceptional oil, gasoline and solvent resistance, tensile properties and extreme temperature performance. These properties, coupled with their good abrasion and water resistance, make them suitable for a wide variety of applications. Hydrogenated nitriles react to filler loading, plasticizer loading and acrylonitrile content in much the same manner as unsaturated nitriles, except that the physical properties of hydrogenated nitriles are higher. The acrylonitrile content determines the performance characteristics of the rubber. For superior tensile properties and oil resistance, a high level of acrylonitrile should be used. If low temperature performance is more important, a low acrylonitrile level is more appropriate. Fillers can also be used to increase the performance of hydrogenated nitriles. The addition of carbon black and/or mineral fillers will increase the hardness at the cost of decreased elongation. These relationships occur in an almost linear fashion. Fillers can also be used to increase the tensile strength of halogenated nitriles; however, the effect is not as clear. Normally, the tensile strength will increase to a maximum and begin decreasing. Another way to increase the strength, particularly the abrasion resistance, is to carboxylate the polymer. This produces carboxylic acid groups on the backbone, which form additional cross-link sites during vulcanization. These additional cross-link sites increase the cross-link density of the resulting nitrile elastomer which, consequently, increases the strength as well. To increase the heat resistance of nitrile elastomers, antioxidants may be permanently bound into the polymer molecule. Since the antioxidants cannot evaporate or be extracted by solvents, this dramatically prolongs the useful life of the material.

Typical Applications

- Automotive** Lip seals, valve-stem seals, o-rings, gaskets
- Industrial** Oil field valve seals, o-rings, piston cups, annular blowout preventers

Relative Adhesive Performance

- High** Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
- Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
- Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
- Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
- Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
- Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Medium** Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
- Low** Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
- Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body

Effects of Formulation and Processing

- Additives** Low Acrylonitrile - Decrease
Carbon Black - Decrease
Silica - Increase
Antistat - Decrease
- T₈₀ Cure** No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer - Decrease

Adhesive Shear Strength

Hydrogenated Nitrile Rubber

ZETPOL by Zeon Chemical

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Zetpol 0020 50% Acrylonitrile, 10% Unsaturation <i>100 phr</i>	>930Δ >6.41Δ	>1060Δ >7.31Δ	280 1.93	>500Δ >3.45Δ	770 5.31	50 0.34	150 1.03	220 1.52	1050 7.24
T₈₀ Cure Cured to 80% of Modulus at Full Cure <i>Zetpol 0020 100 phr</i>	>930Δ >6.41Δ	>1060Δ >7.31Δ	280 1.93	>830Δ >5.72Δ	>990Δ >6.83Δ	60 0.41	150 1.03	170 1.17	660 4.55
Low Acrylonitrile 37% Acrylonitrile, 5% Unsaturation <i>Zetpol 2000L 100 phr</i>	>760Δ >5.24Δ	>700Δ >4.83Δ	>960Δ >6.62Δ	>500Δ >3.45Δ	>770Δ >5.31Δ	50 0.34	120 0.83	180 1.24	350 2.41
Carbon Black <i>Zetpol 0020 100 phr</i> <i>N-339 50 phr</i>	>530Δ >3.66Δ	>500Δ >3.45Δ	>430Δ >2.97Δ	>500Δ >3.45Δ	>490Δ >3.38Δ	40 0.28	100 0.69	110 0.76	480 3.31
Silica <i>Zetpol 0020 100 phr</i> <i>Hi Sil 255 50 phr</i>	710 4.90	>1240Δ >8.55Δ	420 2.90	500 3.45	>770Δ >5.31Δ	50 0.34	210 1.45	340 2.34	1050 7.24
Plasticizer <i>Zetpol 0020 100 phr</i> <i>Dibutyl Phthalate 25 phr</i>	>660Δ >4.55Δ	>1060Δ >7.31Δ	>750Δ >5.17Δ	>880Δ >6.07Δ	>770Δ >5.31Δ	100 0.69	200 1.38	220 1.52	770 5.31
Antistatic <i>Zetpol 0020 100 phr</i> <i>Armostat 550 5 phr</i>	400 2.76	410 2.83	400 2.76	500 3.45	>400Δ >2.76Δ	50 0.34	130 0.90	160 1.10	1050 7.24

- NOTES:**
- = The addition of the indicated additive (or processing change) caused a statistically significant increase in the bond strength within 95% confidence limits.
 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System Used in All Formulations

Zinc Oxide	6.00 phr
Naupard 445	1.50 phr
Vanox ZMTI	1.50 phr
Struktol WB212	2.00 phr
Vul Cup 40KE	8.25 phr

Melt Processible Rubber (MPR)

thermoplastic elastomer

Trade Names

- ALCRYN

Manufacturer

DuPont

General Description

Melt processible rubber is a single phase polymer alloy. The first and only commercially available single phase MPR was developed by DuPont and is known exclusively by the trade name Alcryn. It is a blend of ethylene interpolymers, chlorinated polyolefins with partial cross-linking of the ethylene components, plasticizers and fillers. Hydrogen bonding between the ethylene interpolymers and the chlorinated polyolefins is achieved by incorporating the proper functional groups on the ethylene interpolymer. The strong resulting attraction between the two polymer species enables Alcryn to function as a single phase system. Alcryn can be processed by typical methods used for thermoplastics such as extrusion, injection molding, calendaring, vacuum forming and blow molding. Alcryn does not melt, but softens above 300°F (149°C) enough to be molded with sufficient shear and pressure.

General Properties

Alcryn is a very soft rubber with a suppleness and feel similar to vulcanized rubber. The key benefits offered by Alcryn are oil resistance, good heat aging resistance and weatherability. Alcryn shows good resistance to hydrocarbon-based oils, as well as lithium- and silicone-based greases. In solvents and fuels, Alcryn has poor resistance to aromatic and chlorinated structures. Alcryn offers excellent property retention when exposed to water and aqueous solutions of inorganic acids up to 212°F (100°C). However, mineral acids degrade Alcryn, especially at elevated temperatures. It has a (continuous recommended) service temperature ranging from -40° to 225°F (-40° to 107°C). This is typical of many of the non-vulcanized elastomers. While Alcryn exhibits good property retention in this range, its low crystallinity and lack of a vulcanizate phase make it prone to unacceptable compression set at elevated temperatures. Alcryn is thermally stable below 360°F (182°C) but degrades above 400°F (204°C) to evolve hydrochloric acid. Alcryn has shown good property retention in both long-term exposure to outdoor weathering and simulated aging environments.

Typical Applications

Construction	Weatherstripping
Electrical	Wire and cable jackets, electrical boots
Industrial	Seals, gaskets, tubing, hoses, conveyor belts, coated fabrics
Miscellaneous	Suction cups, athletic field markers

Relative Adhesive Performance

High	Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
Medium	Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
Low	Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant

Effects of Formulation and Processing

Additives	Titanium Dioxide - Increase Colorant - Decrease
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Surface Treatments

Loctite® 770™ Prism® Primer - No Trend Apparent

Adhesive Shear Strength

Melt Processible Rubber

ALCRYN by DuPont

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Alcryn 2070 NC 100 phr	250 1.72	>470Δ >3.24Δ	>590Δ >4.07Δ	190 1.31	370 2.55	60 0.41	170 1.17	230 1.59	540 3.72
Titanium Dioxide Alcryn 2070 NC 100 phr TiO ₂ 30 phr	400 2.76	>640Δ >4.41Δ	>590Δ >4.07Δ	360 2.48	370 2.55	10 0.07	170 1.17	230 1.59	540 3.72
Colorant Alcryn 2070 NC 100 phr PVC-based yellow dye 6 phr	210 1.45	>320Δ >2.21Δ	>390Δ >2.69Δ	190 1.31	370 2.55	20 0.14	170 1.17	150 1.03	540 3.72
Antistatic Alcryn 2070 NC 100 phr Armostat 550 5 phr	280 1.93	>360Δ >2.48Δ	>400Δ >2.76Δ	370 2.55	>450Δ >3.10Δ	<10 <0.07	170 1.17	230 1.59	360 2.48
Alcryn 1070 BK 100 phr	80 0.55	>680Δ >4.69Δ	>700Δ >4.83Δ	180 1.24	250 1.72	40 0.28	140 0.97	150 1.03	130 0.90
Alcryn 2070 BK 100 phr	60 0.41	>400Δ >2.76Δ	320 2.21	240 1.65	180 1.24	<10 <0.07	150 1.03	120 0.83	350 2.41
Alcryn 2265 UT 100 phr	200 1.38	>550Δ >3.79Δ	>540Δ >3.72Δ	240 1.65	300 2.07	30 0.21	170 1.17	120 0.83	200 1.38
Alcryn 3055 NC 100 phr	60 0.41	250 1.72	>250Δ >1.72Δ	80 0.55	110 0.76	10 0.07	110 0.76	170 1.17	>270Δ >1.86Δ

- NOTES:**
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 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System Used in All Formulations
None Required

Natural Rubber (NR)

thermoset rubber

International Types of Natural Rubber

- Compo Crepe
- Estate Brown Crepe
- Flat Bark Crepe
- Pale Crepe
- Pure Smoked Blanket Crepe
- Ribbed Smoked Sheet
- Thick Blanket Crepe
- Thin Brown Crepe

General Description

Natural rubber is created by processing the latex of *Hevea brasiliensis*. *Hevea brasiliensis* is a plant indigenous to the Amazon valley and is the only known plant to produce high molecular weight linear polymer with 100% cis 1,4 polyisoprene. The average dry weight of latex is normally between 30 and 35%, typically ranging from 25 to 45%. To obtain the latex, the tree is “tapped.” This is the process of cutting the bark back in thin sections so that the latex flows. The latex is then collected, treated with a stabilizer to prevent premature coagulation and brought to a processing center. The collection and processing technique determines the grade of natural rubber. There are eight different types of natural rubber which are then classified into 35 technically specified international grades. The grade indicates the color, cleanliness, presence of bubbles and uniformity of appearance.

General Properties

Rapid crystallization on stretching gives natural rubber its exceptional tensile strength, tear strength and abrasion resistance properties. The tensile strength of unfilled vulcanates ranges from 2,500 to 3,500 psi (17 to 24 MPa), while fillers can increase that in excess of 4,500 psi (31 MPa). The resilience of natural rubber is excellent. At large strains, the fatigue life of natural rubber is better than SBR. At low strains, the opposite is true. The strength characteristics of natural rubber decrease with increasing temperature. However, the strength at temperature of natural rubber is normally superior to that of other elastomers. Natural rubber has very good processing properties and can be processed by a variety of different techniques. Conventional processing yields natural rubber with excellent initial properties such as strength, abrasion resistance and fatigue resistance. The thermal resistance, creep and stress-relaxation properties of conventionally processed natural rubber are not as desirable. To increase the thermal stability and improve the low compression set, an efficient (EV) accelerated sulfur vulcanization system can be used. A semi-EV system can be used to help trade off the increase in cost with the increase in performance.

Typical Applications

- Industrial** Hoses, conveyor belts, gaskets, seals
- Engineering** Springs, mountings, bushings
- Latex** Gloves, condoms, carpet backing, threads

Relative Adhesive Performance

- High** Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Medium** Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
- Low** Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
Oxime Silicone - Loctite® 5900® FlangeSealant, Heavy Body
Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Effects of Formulation and Processing

- Additives** Carbon Black - Increase
Calcium Carbonate - Increase
Clay - Increase
Antistatic - Increase CA
- T₈₀ Cure** No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Natural Rubber

Standard Malaysian Rubber (SMR)

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: SMR-5 <i>SMR-5 100 phr</i>	160 1.10	>300Δ >2.07Δ	>270Δ >1.86Δ	130 0.90	140 0.97	30 0.21	50 0.34	40 0.28	230 1.59
T₈₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> <i>SMR-5 100 phr</i>	160 1.10	>300Δ >2.07Δ	>270Δ >1.86Δ	130 0.90	140 0.97	40 0.28	50 0.34	40 0.28	230 1.59
SMR-10 <i>SMR-10 100 phr</i>	>200Δ >1.38Δ	>300Δ >2.07Δ	>200Δ >1.38Δ	130 0.90	140 0.97	30 0.21	50 0.34	40 0.28	70 0.48
Carbon Black <i>SMR-5 100 phr</i> <i>N-550 25 phr</i>	470 3.24	490 3.38	>470Δ >3.24Δ	200 1.38	270 1.86	40 0.28	110 0.76	80 0.55	240 1.66
Calcium Carbonate <i>SMR-5 100 phr</i> <i>Calcium Carbonate 100 phr</i>	300 2.07	300 2.07	>390Δ >2.69Δ	190 1.31	230 1.59	60 0.41	120 0.83	80 0.55	110 0.76
Clay <i>SMR-5 100 phr</i> <i>Dixie Clay 100 phr</i>	290 2.00	300 2.07	270 1.86	170 1.17	140 0.97	40 0.28	130 0.90	100 0.69	240 1.66
Silica <i>SMR-5 100 phr</i> <i>Hi Sil 233 15 phr</i>	250 1.72	>300Δ >2.07Δ	270 1.86	130 0.90	140 0.97	30 0.21	80 0.55	40 0.28	60 0.41
Naphthenic Oil <i>SMR-5 100 phr</i> <i>Naphthenic Oil 10 phr</i>	160 1.10	300 2.07	>270Δ >1.86Δ	190 1.31	140 0.97	40 0.28	50 0.34	40 0.28	230 1.59
Processing Aid <i>SMR-5 100 phr</i> <i>Polyethylene 1702 4 phr</i>	160 1.10	>300Δ >2.07Δ	>270Δ >1.86Δ	130 0.90	140 0.97	30 0.21	40 0.28	40 0.28	50 0.34
Antiozonant <i>SMR-5 100 phr</i> <i>Santoflex 13 3 phr</i>	>280Δ >1.93Δ	>660Δ >4.55Δ	>270Δ >1.86Δ	130 0.90	140 0.97	40 0.28	50 0.34	40 0.28	80 0.55
Antistatic <i>SMR-5 100 phr</i> <i>Armostat 550 5 phr</i>	>240Δ >1.66Δ	300 2.07	>270Δ >1.86Δ	>360Δ >2.48Δ	>280Δ >1.93Δ	30 0.21	50 0.34	40 0.28	230 1.59

NOTES:

- = The addition of the indicated additive (or processing change) caused a statistically significant increase in the bond strength within 95% confidence limits.
- = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
- Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System Used in All Formulations

Stearic Acid	1.00 phr
Zinc Oxide	3.00 phr
Agerite Stalite S	1.50 phr
Sulfur	2.00 phr
Accelerator MBTS	1.00 phr
TMTD	0.10 phr

Neoprene Rubber (Polychloroprene, CR)

thermoset rubber

Trade Names

- BAYPREN
- BUTACLOR
- NEOPRENE

Manufacturer

Bayer
Enichem Elastomers
DuPont

General Description

Polychloroprene is manufactured by the emulsion polymerization of 2-chloro-1,3 butadiene monomer and can be modified with sulfur and/or 2,3 dichloro-1,3-butadiene (ACR). The final structure and performance properties of the rubber are determined by three variables: the addition of chain transfer agents during the polymerization process; quenching the reaction through the addition of stabilizers; and breaking down the gel formed during the polymerization process through peptization. Consequently, the manufacturing technique used will strongly influence the performance properties of the resulting rubber.

General Properties

Neoprene offers better resistance to oxidation, ozone, weathering, water, oil and fuel than natural rubber. Although neoprene does not have any performance properties that are particularly outstanding, it does offer a good balance of various properties. The selection of the gum stock will determine the range of properties which can be attained in the final rubber. The cure method and selection of type and level of fillers, plasticizers, processing aids and antioxidants will determine where the properties will fall in that range. The differences between the most common grades used for molded assemblies can be explained in terms of their processing differences. Neoprene GN, for example, is produced by polymerizing chloroprene monomer in the presence of elemental sulfur. The resulting polymer is then broken down through peptization. This yields a rubber with the best tear strength, flex and resiliency. On the other hand, the T and W types of neoprene cannot be peptized, but offer superior stability in the uncured form as well as better heat aging and compression set resistance when cured. The T and W types of neoprene are similar but principally differ in terms of nerve, with the T type having much less than the W. This makes it much more suitable for extrusion and calendaring processes. In general, neoprenes also offer high tensile strength, good abrasion resistance and less compression set. Neoprenes show good performance at low temperatures, although some types are more prone to crystallization than others. In recent years, the use of neoprene in automotive applications has decreased due to the demand for performance at higher temperatures.

Typical Applications

- Aerospace** Gaskets, seals, deicers
- Automotive** Timing belts, window gaskets, fuel hose covers, cable jacketing, spark plug boots, hoses, joint seals
- Industrial** Pipeline pigs, gaskets, hoses, power transmission belts, conveyor belts, escalator handrails
- Electronics** Wire and cable jacketing
- Miscellaneous** Sponge shoe soles, foam cushions

Relative Adhesive Performance

- High**
 - Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
 - Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
 - Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
 - Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
 - Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
 - Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Medium**
 - Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
 - Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
- Low**
 - Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant

Effects of Formulation and Processing

- Additives**
 - Neoprene GN - Increase
 - Neoprene TW - Increase
 - Carbon Black - Increase
 - Calcium Carbonate - Increase
 - Clay - Increase
 - Silica - Increase
 - Aromatic Oil - Decrease
 - Antistat - Increase
- T₈₀ Cure** Increase

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Polychloroprene Rubber

NEOPRENE by DuPont

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Neoprene W <i>100 phr</i>	>270Δ >1.86Δ	>310Δ >2.14Δ	>270Δ >1.86Δ	>260Δ >1.79Δ	>280Δ >1.93Δ	60 0.41	50 0.34	60 0.41	200 1.38
T₈₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> <i>Neoprene W 100 phr</i>	>270Δ >1.86Δ	>310Δ >2.14Δ	>340Δ >2.34Δ	>260Δ >1.79Δ	>280Δ >1.93Δ	60 0.41	80 0.55	60 0.41	>430Δ >2.97Δ
Neoprene GN <i>Neoprene GN 100 phr</i>	>750Δ >5.17Δ	>580Δ >4.00Δ	>570Δ >3.93Δ	>350Δ >2.41Δ	>450Δ >3.10Δ	60 0.41	110 0.76	90 0.62	630 4.34
Neoprene TW <i>Neoprene TW 100 phr</i>	>790Δ >5.45Δ	>580Δ >4.00Δ	>510Δ >3.52Δ	>260Δ >1.79Δ	>280Δ >1.93Δ	60 0.41	110 0.76	60 0.41	>440Δ >3.03Δ
Carbon Black <i>Neoprene W 100 phr</i> <i>N-550 25 phr</i>	>800Δ >5.52Δ	>930Δ >6.41Δ	>600Δ >4.14Δ	>640Δ >4.41Δ	>630Δ >4.34Δ	60 0.41	150 1.03	100 0.69	>980Δ >6.76Δ
Calcium Carbonate <i>Neoprene W 100 phr</i> <i>Calcium Carbonate 50 phr</i>	>330Δ >2.28Δ	>380Δ >2.62Δ	>360Δ >2.48Δ	>350Δ >2.41Δ	>350Δ >2.41Δ	60 0.41	130 0.90	110 0.76	>540Δ >3.72Δ
Clay <i>Neoprene W 100 phr</i> <i>Dixie Clay 100 phr</i>	340 2.34	420 2.90	350 2.41	380 2.62	380 2.62	80 0.55	180 1.24	310 2.14	>870Δ >6.00Δ
Silica <i>Neoprene W 100 phr</i> <i>Hi Sil 233 15 phr</i>	>700Δ >4.83Δ	>990Δ >6.83Δ	>510Δ >3.52Δ	>580Δ >4.00Δ	>570Δ >3.93Δ	60 0.41	130 0.90	110 0.76	>1190Δ >8.21Δ
Aromatic Oil <i>Neoprene W 100 phr</i> <i>Aromatic Oil 20 phr</i>	>200Δ >1.38Δ	>250Δ >1.72Δ	>210Δ >1.45Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	40 0.28	50 0.34	60 0.41	>390Δ >2.69Δ
Naphthenic Oil <i>SMR-5 100 phr</i> <i>Naphthenic Oil 20 phr</i>	>270Δ >1.86Δ	>310Δ >2.14Δ	>270Δ >1.86Δ	>260Δ >1.79Δ	>280Δ >1.93Δ	40 0.28	50 0.34	60 0.41	>940Δ >6.48Δ
Antistatic <i>Neoprene W 100 phr</i> <i>Armostat 550 5 phr</i>	>270Δ >1.86Δ	>310Δ >2.14Δ	>360Δ >2.48Δ	>260Δ >1.79Δ	>280Δ >1.93Δ	60 0.41	50 0.34	90 0.62	>460Δ >3.17Δ

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 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure Systems Used in All Neoprene with Formulations

Stearic Acid	0.50 phr
Zinc Oxide	5.00 phr
Agerite Stalite S	2.00 phr
Magnesium Oxide	4.00 phr
Ethylene Thiourea	0.60 phr
Vanax NP	1.00 phr

Nitrile Rubber (NBR, XNBR)

thermoset rubber

Trade Names

- BREON
- CHEMIGUM
- HUMEX
- KRYNAC
- NIPOL
- NYSEN
- PERBUNAN

Manufacturer

B.P. Chemicals
Goodyear
Huels Mexicanos
Polysar International
Nippon Zeon
Copolymer Rubber
Mobay

General Description

Nitrile elastomers are produced via the copolymerization of butadiene and acrylonitrile monomers. The properties of the resulting elastomer are dependent on the acrylonitrile/butadiene ratio of the elastomer. The acrylonitrile content typically ranges from 15 to 50%. Although thiazole and sulfenamide cure systems (the cure systems typically used to process SBR and natural rubber) can be used to vulcanize nitrile rubber, thiurams and peroxides are normally the preferred cure systems due to the increased thermal resistance.

General Properties

Nitriles are known for their superior high and low temperature performance and their exceptional oil, gasoline and solvent resistance. These properties, coupled with their good abrasion resistance, water resistance and compression set, make them suitable for a wide variety of applications. Their thermal resistance allows them to be used at service temperatures ranging from -49° to 300°F (-45° to 149°C). Since the monomer ratio has a large effect on the properties of the elastomer, the ratio is dictated by its end use. For superior tensile properties or oil resistance, a high level of acrylonitrile should be used. If low temperature performance is paramount, a low acrylonitrile level is more appropriate. Fillers can also be used to increase the performance of nitrile elastomers. The addition of carbon black and/or mineral fillers will increase the hardness at the cost of decreased elongation. These relationships occur in an almost linear fashion. Fillers can also be used to increase the tensile strength of nitrile elastomers; however, the effect is not as clear. Normally, the tensile strength will increase to a maximum at approximately 50 phr of reinforcing filler and begin decreasing. Another way to increase the strength, particularly the abrasion resistance, is to carboxylate the polymer to form carboxylated nitrile rubber (XNBR). This produces carboxylic acid groups on the backbone which form additional cross-link sites during vulcanization. These additional cross-link sites increase the cross-link density of the resulting elastomer thereby increasing its strength. To increase the heat resistance of nitrile elastomers, antioxidants may be

permanently bound into the polymer molecule. Since the antioxidants cannot evaporate or be extracted by solvents, this dramatically prolongs the useful life of the material. Hydrogenated nitrile rubbers are also available which contain little or no unsaturated groups in the polymer backbone. These elastomers show improved resistance to severe environments and are covered in more detail in a separate chapter.

Typical Applications

- Automotive** Seals, hoses, tubing, belts, electrical jacketing, gaskets
- Consumer** Shoe products, coated fabrics, flooring
- Miscellaneous** Adhesives, cements, PVC and ABS additive

Relative Adhesive Performance

- High** Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
- Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
- Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
- Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
- Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
- Medium** Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
- Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
- Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Low** Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant

Effects of Formulation and Processing

- Additives** Low Acrylonitrile - Decrease
Carboxylated - Increase
Carbon Black - Increase
Clay - Increase
Silica - Increase
Plasticizer - Decrease
- T₈₀ Cure** Decrease

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Nitrile Rubber

CHEMIGUM by Goodyear

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Chemigum N687B 33% Acrylonitrile 100 phr	>260Δ >1.79Δ	>290Δ >2.00Δ	>290Δ >2.00Δ	220 1.52	>240Δ >1.66Δ	60 0.41	130 0.90	240 1.66	>240Δ >1.66Δ
T80 Cure Cured to 80% of Modulus at Full Cure Chemigum N687B 100 phr	>260Δ >1.79Δ	>290Δ >2.00Δ	>240Δ >1.66Δ	220 1.52	>240Δ >1.66Δ	60 0.41	130 0.90	150 1.03	240 1.66
Low Acrylonitrile 20% Acrylonitrile Chemigum N984B 100 phr	>260Δ >1.79Δ	>290Δ >2.00Δ	>260Δ >1.79Δ	>170Δ >1.17Δ	>200Δ >1.38Δ	50 0.34	130 0.90	130 0.90	240 1.66
High Acrylonitrile 40% Acrylonitrile Chemigum 386B 100 phr	>260Δ >1.79Δ	>290Δ >2.00Δ	>290Δ >2.00Δ	270 1.86	>300Δ >2.07Δ	60 0.41	130 0.90	170 1.17	240 1.66
Carboxylated Chemigum NX775 100 phr	>280Δ >1.93Δ	>290Δ >2.00Δ	>290Δ >2.00Δ	280 1.93	>270Δ >1.86Δ	90 0.62	130 0.90	250 1.72	430 2.97
Carbon Black Chemigum N687B 100 phr FEF N-550 60 phr	>360Δ >2.48Δ	>450Δ >3.10Δ	>370Δ >2.55Δ	>340Δ >2.34Δ	>370Δ >2.55Δ	100 0.69	200 1.38	280 1.93	240 1.66
Clay Chemigum N687B 100 phr Dixie Clay 120 phr	300 2.07	>290Δ >2.00Δ	>330Δ >2.28Δ	>310Δ >2.14Δ	>300Δ >2.07Δ	80 0.55	190 1.31	>330Δ >2.28Δ	530 3.66
Silica Chemigum N687B 100 phr Hi Sil 233 30 phr	>970Δ >6.69Δ	>950Δ >6.55Δ	>710Δ >4.90Δ	670 4.62	>680Δ >4.69Δ	60 0.41	190 1.31	240 1.66	240 1.66
Plasticizer Chemigum N687B 100 phr Dibutyl Phthalate 15 phr	>210Δ >1.45Δ	>290Δ >2.00Δ	>250Δ >1.72Δ	>240Δ >1.66Δ	>200Δ >1.38Δ	40 0.28	130 0.90	110 0.76	>240Δ >1.66Δ
Processing Aid Chemigum N687B 100 phr Struktol WB-16 2.5 phr	>260Δ >1.79Δ	>290Δ >2.00Δ	>240Δ >1.66Δ	>220Δ >1.52Δ	>240Δ >1.66Δ	70 0.48	130 0.90	180 1.24	>240Δ >1.66Δ
Antistatic Chemigum N687B 100 phr Armostat 550 5 phr	>210Δ >1.45Δ	>290Δ >2.00Δ	>220Δ >1.52Δ	>220Δ >1.52Δ	>230Δ >1.59Δ	70 0.48	100 0.69	150 1.03	240 1.66

- NOTES:**
- = The addition of the indicated additive (or processing change) caused a statistically significant increase in the bond strength within 95% confidence limits.
 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure Systems Used in All Formulations

Stearic Acid	1.50 phr
Zinc Oxide	5.00 phr
Agerite Stalite S	1.50 phr
Rubber Maker's Sulfur	1.75 phr
Accelerator MBTS	1.50 phr

Polyether Block Amide (PEBA)

thermoplastic elastomer

Trade Names

- PEBAX

Manufacturer

Arkema Inc.

General Description

Polyether block amide (PEBA) is a thermoplastic elastomer formed via the copolymerization of polyether and polyamide. The PEBA resin family is commonly referred to by the trade name Pebax. PEBA is a two-phase linear chain of polyamide segments interconnected with flexible polyether segments. Hence, PEBA is a flexible polyamide without plasticizers.

General Properties

The core characteristics of PEBA include outstanding flexibility and impact resistance at wide range of temperatures, its low density, high elastic memory, and superior chemical resistance. It is melt processible, and accepts various colors, filler, and reinforcement systems.

PEBA is available in a variation of durometers from 70 Shore A to 72 Shore D. This thermoplastic elastomer has high load bearing capabilities, high tensile strength, good hydrolytic stability, and is biocompatible and chemically resistant, with high mechanical properties. PEBA has low water absorption, although it can be formulated for high absorption, and can be welded and sterilized.

Typical Applications

Industrial	Conveyor belts, gears, packaging
Medical	Catheters, surgical gowns, bags
Consumer	Sportswear, clothing

Relative Adhesive Performance

High	Cyanoacrylates, Epoxies, Urethanes
Medium	Acrylics, Reactive Urethane Hot Melt
Low	Silicones, Hot Melts

Relative Resin Performance

High	7233, 6333
Medium	5533
Low	4033, 2533

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent
Loctite® 793™ Prism® Primer – Increase

Adhesive Shear Strength

		Loctite® Brand Industrial Adhesive	Loctite® Brand Medical Adhesive	PEBAX 6333	PEBAX 7233	PEBAX 4033	PEBAX 5533	PEBAX 2533
Adhesive Chemistry Category	Light Cure Acrylic	Loctite® 3105™ Light Cure Adhesive	Loctite® 3311™ Light Cure Adhesive	240	180	225	615	100
	Epoxy	Loctite® E-00CL™ Hysol® Epoxy Adhesive		535	495	210	225	170
		Loctite® E-90FL™ Hysol® Epoxy Adhesive		695	445	165	670	100
		Loctite® E-30CL™ Hysol® Epoxy Adhesive	Loctite® M-31CL™ Hysol® Medical Device Epoxy Adhesive	365	430	140	520	120
		Loctite® E-20HP™ Hysol® Epoxy Adhesive	Loctite® M-21HP™ Hysol® Medical Device Epoxy Adhesive	635	380	115	395	40
		Loctite® E-40FL™ Hysol® Epoxy Adhesive		295	385	60	415	40
		Loctite® E-214HP™ Hysol® Epoxy Adhesive		200	285	60	355	60
	Flexible Cyanoacrylates	Loctite® 4851™ Prism® Instant Adhesive	Loctite® 4851™ Prism® Instant Adhesive	915	815	135	445	395Δ
		Loctite® 4861™ Prism® Instant Adhesive	Loctite® 4861™ Prism® Instant Adhesive	680	625Δ	260	595	490Δ
	Cyanoacrylates	Loctite® 401™ Prism® Instant Adhesive	Loctite® 4011™ Prism® Medical Device Instant Adhesive	840Δ	1030Δ	395	580Δ	455Δ
		Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 4011™ Prism® Medical Device Adhesive with Loctite® 7701™ Prism® Primer	630	750	485	910Δ	305Δ
		Loctite® 401™ Prism® Instant Adhesive with Loctite® 793™ Prism® Primer		985Δ	1275Δ	690Δ	830Δ	505Δ
		Loctite® 414™ Super Bonder® Instant Adhesive		590Δ	690Δ	645Δ	285Δ	460Δ
		Loctite® 480™ Prism® Instant Adhesive		480Δ	520	90	440	310
		Loctite® 496™ Super Bonder® Instant Adhesive		670	680	95	455	275Δ
	Flashcure®	Loctite® 4307™ Flashcure® Light Cure Adhesive	Loctite® 4307™ Flashcure® Light Cure Adhesive	680	845	625	560	405
	Silicones	Loctite® 5900® Flange Sealant		199	116	107	113	49
		Loctite® Superflex® RTV		122	107	61	55	37
	Acrylics	Loctite® H3000™ Speedbonder™ Structural Adhesive		280	185	116	124	69
		Loctite® H4500™ Speedbonder™ Structural Adhesive		594	326	349	864	133
		Loctite® 3032™ Adhesive		436	193	162	592	128
Loctite® 330™ Depend® Adhesive			201	228	207	377	97	
Hot Melts	Loctite® 3631™ Hysol® Reactive Urethane Hot Melt Adhesive		902	947	375	870	192	
	Loctite® 7804™ Hysol® Hot Melt Adhesive		158	174	46	175	128	
	Loctite® 1942™ Hysol® Hot Melt Adhesive		164	159	51	14	95	
MRO	Loctite® Fixmaster® Epoxy Adhesive		355	198	331	754	100	
	Loctite® Fixmaster® Rapid Rubber Repair Urethane Adhesive		493	550	483	511	309	

NOTES: Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Polyacrylate Rubber (ACM)

thermoset rubber

Trade Names

- EUROPRENE
- HYCAR
- HYTEMP

Manufacturer

Enichem Elastomers America
B.F. Goodrich
Zeon Chemical

General Description

Polyacrylate rubber is produced by polymerizing acrylic monomers. Since acrylic monomer only contains a single double bond, polyacrylate rubber has a saturated or aliphatic backbone. A comonomer is required if vulcanization is desired because, otherwise, the polymer would lack the reactive species necessary for cross-linking. Typically, an active halogen or epoxide cure system is used to vulcanize polyacrylate rubber. Varying the size of the pendant carboxylate group on the polymer backbone has a dramatic effect on the properties of the elastomer. Acrylate rubbers are commonly reinforced with carbon black and/or silica to achieve acceptable physical properties.

General Properties

Polyacrylate rubbers belong to the family of special purpose, oil-resistant rubbers which have service temperatures in excess of 300°F (149°C). The aliphatic nature of the polymer backbone results in superior performance properties highlighted by resistance to UV, thermal degradation, ozone and oxidation. The size of the pendant carboxylate group has a significant effect on the properties of the resulting polymer. Increasing the length of the alkane chain on the carboxylate group improves the low temperature properties of the polyacrylate. However, this decreases the overall polarity of the polymer which, consequently, reduces its resistance to non-polar solvents. An important characteristic of polyacrylate rubbers is compatibility with sulfur-bearing, extreme-pressure gear lubricants. The tear strength and abrasion resistance of polyacrylate rubbers are not exemplary, while the flame resistance and resistance to acids and bases are poor.

Typical Applications

- Aerospace** Rocket propellant binders
- Automotive** Automotive fluid seals, high pressure hoses, seals, gaskets, boots
- Miscellaneous** Adhesives, caulks, hot melts

Relative Adhesive Performance

- High** Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
- Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
- Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
- Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
- Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
- Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
- Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Low** Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
- Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body

Effects of Formulation and Processing

- Additives** Medium Alkane Chain - Decrease
Long Alkane Chain - Decrease
Carbon Black - Increase
Synthetic Graphite - Increase
Clay - Increase
Silica - Increase
Plasticizer - Decrease
- T₈₀ Cure** Increase

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Polyacrylate Rubber

HYTEMP by Zeon Chemical

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: HyTemp 4051 Short Alkane Chain 100 phr	>80Δ >0.55Δ	>80Δ >0.55Δ	>70Δ >0.48Δ	>70Δ >0.48Δ	>90Δ >0.62Δ	<10 <0.07	60 0.41	>70Δ >0.48Δ	>110Δ >0.76Δ
T80 Cure Cured to 80% of Modulus at Full Cure HyTemp 4051 100 phr	>80Δ >0.55Δ	>80Δ >0.55Δ	>90Δ >0.62Δ	>90Δ >0.62Δ	>110Δ >0.76Δ	10 0.07	70 0.48	>70Δ >0.48Δ	>110Δ >0.76Δ
Medium Alkane Chain HyTemp 4052 100 phr	>50Δ >0.34Δ	>50Δ >0.34Δ	>50Δ >0.34Δ	>50Δ >0.34Δ	>50Δ >0.34Δ	<10 <0.07	50 0.34	>40Δ >0.28Δ	>80Δ >0.55Δ
Long Alkane Chain HyTemp 4052 100 phr	>40Δ >0.28Δ	>50Δ >0.34Δ	>60Δ >0.41Δ	>30Δ >0.21Δ	>50Δ >0.34Δ	<10 <0.07	40 0.28	>40Δ >0.28Δ	>80Δ >0.55Δ
Carbon Black HyTemp 4051 100 phr N-550 25 phr	>440Δ >3.03Δ	>370Δ >2.55Δ	>490Δ >3.38Δ	>380Δ >2.62Δ	>450Δ >3.10Δ	<10 <0.07	110 0.76	110 0.76	350 2.41
Synthetic Graphite HyTemp 4051 100 phr A99 Graphite 20 phr	>120Δ >0.83Δ	>140Δ >0.97Δ	>140Δ >0.97Δ	>130Δ >0.90Δ	>140Δ >0.97Δ	<10 <0.07	80 0.55	>110Δ >0.76Δ	>200Δ >1.38Δ
Clay HyTemp 4051 100 phr Carbowax 3350 3 phr Dixie Clay 50 phr	>210Δ >1.45Δ	>200Δ >1.38Δ	>210Δ >1.45Δ	>200Δ >1.38Δ	>220Δ >1.52Δ	20 0.14	90 0.62	110 0.76	>280Δ >1.93Δ
Silica HyTemp 4051 100 phr Carbowax 3350 3 phr Diethylene Glycol 2 phr Hi Sil 233 30 phr	>140Δ >0.97Δ	>130Δ >0.90Δ	>120Δ >0.83Δ	>140Δ >0.97Δ	>160Δ >1.10Δ	<10 <0.07	60 0.41	>120Δ >0.83Δ	>210Δ >1.45Δ
Plasticizer HyTemp 4051 100 phr Paraplex G-25 15 phr	>60Δ >0.41Δ	>70Δ >0.48Δ	>70Δ >0.48Δ	>70Δ >0.48Δ	>70Δ >0.48Δ	<10 <0.07	40 0.28	30 0.21	>100Δ >0.68Δ
Processing Aid HyTemp 4051 100 phr Vanfre A1-2 5 phr	>80Δ >0.55Δ	>80Δ >0.55Δ	>80Δ >0.55Δ	>70Δ >0.48Δ	>90Δ >0.62Δ	10 0.07	60 0.41	>70Δ >0.48Δ	>110Δ >0.76Δ
Antistatic HyTemp 4051 100 phr Armostat 550 5 phr	>60Δ >0.41Δ	>80Δ >0.55Δ	>90Δ >0.62Δ	>70Δ >0.48Δ	>90Δ >0.62Δ	20 0.14	60 0.41	>70Δ >0.48Δ	>130Δ >0.90Δ

- NOTES:**
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 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
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Cure Systems Used in All Formulations

NPC-50 1.50 phr
Sodium Stearate 1.00 phr

Polyisoprene (IR)

thermoset rubber

Trade Names

- ISOLENE
- NATSYN
- NIPOL
- SKI-3

Manufacturer

Hardman
Goodyear
Goldsmith and Eggleton
Alcan

General Description

Polyisoprene is formed via the polymerization of isoprene in a hydrocarbon solution. When the isoprene monomer is added to the backbone, it can be added in either an R or S configuration. As a result, the polymerization addition can proceed in several different ways. In isotactic addition, the monomer groups are exclusively added in the same configuration (RRRRRR). In syndiotactic addition, the monomer groups are added to the backbone in alternating configurations (RSRSRS). Finally, in atactic addition, the addition is random (RSSRRS). Consequently, in order to create a stereoregular polymer matrix that would have physical properties similar to NR, a stereospecific catalyst is required. This stereospecific catalyst, Al-Ti, was developed in 1960, which resulted in the first commercially viable synthetic polyisoprene.

General Properties

Natural rubber and synthetic isoprene both have high tensile properties, good hysteresis and good hot tear properties. The main advantages that synthetic polyisoprenes have over natural rubbers are their increased process control and processibility. These process characteristics arise from the fact that natural rubber is harvested from a natural source, while synthetic polyisoprene is produced using a highly controlled manufacturing process. The primary processing benefits offered by synthetic isoprene are its increased processing speeds and extrusion values. Other advantages of synthetic polyisoprene are that it does not contain water-sensitive residues or contaminants, and it cures more consistently. In addition, synthetic polyisoprene can be used at a higher loading than natural rubber in SBR and EPDM blends. The disadvantages of synthetic polyisoprene are its decreased green strength, cure speed and aging properties when compared to NR.

Typical Applications

- Automotive** Tires, motor mounts, gaskets, bushings, hoses, coatings, tubes, belts
- Consumer** Rubber bands, baby bottle nipples, footwear, sporting goods, fabric threads
- Miscellaneous** Adhesives, conveyors

Relative Adhesive Performance

- High** Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
- Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
- Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
- Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
- Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
- Medium** Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Low** Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
- Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
- Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Effects of Formulation and Processing

- Additives** Carbon Black - Increase
Calcium Carbonate - Increase
Clay - Decrease CA
Clay - Increase Silicones and Acrylics
Naphthenic Oil - Decrease
Antioxidant - Decrease
Antistatic - Decrease

T₈₀ Cure No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Polyisoprene

NATSYN by Goodyear

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Natsyn 2200	>240Δ >1.66Δ	>240Δ >1.66Δ	>290Δ >2.00Δ	>250Δ >1.72Δ	>200Δ >1.38Δ	50 0.34	60 0.41	50 0.34	100 0.69
T₈₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> <i>Natsyn 2200 100 phr</i>	>270Δ >1.86Δ	>300Δ >2.07Δ	>290Δ >2.00Δ	>250Δ >1.72Δ	>290Δ >2.00Δ	50 0.34	60 0.41	40 0.28	100 0.69
Carbon Black <i>Natsyn 2200 100 phr</i> <i>N-550 25 phr</i>	>450Δ >3.10Δ	>480Δ >3.31Δ	>480Δ >3.31Δ	>370Δ >2.55Δ	360 2.48	60 0.41	90 0.62	70 0.48	100 0.69
Calcium Carbonate <i>Natsyn 2200 100 phr</i> <i>Calcium Carbonate 100 phr</i>	>190Δ >1.31Δ	>240Δ >1.66Δ	>290Δ >2.00Δ	>250Δ >1.72Δ	>200Δ >1.38Δ	70 0.48	110 0.76	70 0.48	>280Δ >1.93Δ
Clay <i>Natsyn 2200 100 phr</i> <i>Dixie Clay 25 phr</i>	140 0.97	240 1.66	180 1.24	100 0.69	120 0.83	60 0.41	120 0.83	100 0.69	220 1.52
Silica <i>Natsyn 2200 100 phr</i> <i>Hi Sil 233 15 phr</i>	>240Δ >1.66Δ	>240Δ >1.66Δ	>290Δ >2.00Δ	170 1.17	>150Δ >1.03Δ	50 0.34	70 0.48	60 0.41	100 0.69
Naphthenic Oil <i>Natsyn 2200 100 phr</i> <i>Naphthenic Oil 25 phr</i>	>240Δ >1.66Δ	>240Δ >1.66Δ	>290Δ >2.00Δ	130 0.90	>200Δ >1.38Δ	40 0.28	40 0.28	40 0.28	40 0.28
Antioxidant <i>Natsyn 2200 100 phr</i> <i>Venox 2-AZ 2 phr</i>	>240Δ >1.66Δ	>240Δ >1.66Δ	>290Δ >2.00Δ	>250Δ >1.72Δ	>200Δ >1.38Δ	40 0.28	40 0.28	40 0.28	100 0.69
Antistatic <i>Natsyn 2200 100 phr</i> <i>Armostat 550 5 phr</i>	>240Δ >1.66Δ	>240Δ >1.66Δ	>210Δ >1.45Δ	>220Δ >1.52Δ	>280Δ >1.93Δ	30 0.21	30 0.21	10 0.07	70 0.48

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 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure Systems Used in All Formulations

Stearic Acid	1.00 phr
Zinc Oxide	3.00 phr
Agerite Superlite	1.50 phr
Sulfur	2.00 phr
Durax	1.00 phr
TMTM	0.20 phr

Polyolefin Elastomers (POE)

thermoplastic

Trade Names

- ENGAGE
- HERCUPRENE
- SARLINK

Manufacturer

DuPont Performance Elastomers
J-Von
DSM

General Description

Polyolefin elastomers can be divided into two major categories. The first type is a two-phase polymer system consisting of a thermoplastic matrix, such as polypropylene or polyethylene, with a dispersed second phase of an unvulcanized rubber, such as EPDM, natural rubber and SBR. Hercuprene is an example of this type of polyolefin elastomer. The second category is a family of ethylene-octene copolymers. They are produced by DuPont Performance Elastomers via a proprietary polymerization technique and marketed under the trade name Engage. These systems can be vulcanized using peroxides, silanes or irradiation to yield improved high temperature properties.

General Properties

Polyolefin elastomers are characterized by excellent low temperature properties, clarity and crack resistance. Engage has a brittle point below -60°F (-51°C) for formulations with hardnesses ranging from 60 to 90 Shore A. In addition, they offer excellent UV, ozone and weatherability resistance. They also offer good resistance to polar fluids. Resistance to non-polar fluids is poor due to the aliphatic nature of the polymer backbone. Room temperature physical properties are good. Like most thermoplastic systems, the physical properties at temperature decrease with increasing temperature. This limitation can be addressed by vulcanizing the polymer. However, this extra processing step mitigates the economic benefits of the polyolefin elastomers over conventional vulcanized rubber. Polyolefin elastomers typically have very low specific gravities and can be utilized in applications where reducing weight is critical.

Typical Applications

- Automotive** Rub strips, fascias, bumper covers, molding, trim
- Electrical** Wire and cable insulation and jacketing

Relative Adhesive Performance

- High** Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
- Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
- Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Medium** Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
- Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
- Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
- Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
- Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
- Low** Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant

Effects of Formulation and Processing

- Additives** Antistatic - Decrease

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Polyolefin Elastomer

ENGAGE by DuPont Performance Elastomers

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Engage EP 8100	270 1.86	>540Δ >3.72Δ	>440Δ >3.03Δ	210 1.45	280 1.93	70 0.48	200 1.38	210 1.45	>540Δ >3.72Δ
Engage EP 8150	270 1.86	>550Δ >3.79Δ	>500Δ >3.45Δ	200 1.38	230 1.59	70 0.48	150 1.03	210 1.45	400 2.76
Engage EP 8200	310 2.14	>460Δ >3.17Δ	>460Δ >3.17Δ	180 1.24	>270Δ >1.86Δ	60 0.41	190 1.31	170 1.17	>560Δ >3.86Δ
Engage EP 8500	230 1.59	>380Δ >2.62Δ	>470Δ >3.24Δ	190 1.31	200 1.38	60 0.41	130 0.90	180 1.24	330 2.28
Antistatic <i>EP 8500 100 phr Armostat 550 5 phr</i>	230 1.59	>380Δ >2.62Δ	>470Δ >3.24Δ	70 0.48	200 1.38	<10 <0.07	70 0.48	180 1.24	330 2.28

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- = The addition of the indicated additive (or processing change) caused a statistically significant increase in the bond strength within 95% confidence limits.
 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure Systems Used in All Formulations
None Required

Poly(propylene oxide) Rubber (GPO)

thermoset rubber

Trade Names

- PAREL

Manufacturer

Zeon Chemical

General Description

Poly(propylene oxide) rubber (GPO) is formed by the copolymerization of propylene oxide and allyl glycidyl ether. The allyl glycidyl ether monomer is present at lower quantities (approximately 6% by weight) and provides cross-link sites for the polymer via the unsaturated group. The propylene oxide provides flexibility in the backbone in several ways. First, the presence of the oxygen atom in the backbone aids polymer chain flexibility. Secondly, the propylene oxide monomer can polymerize with itself to form atactic as well as isotactic regions. The combination of these two regions results in irregular packing of the polymer chains, which reduces crystallinity. Another factor contributing to the flexibility of PPO is the bulky allyl glycidyl ether pendant group, which further reduces crystallinity by disrupting ordered packing of the polymer. Sulfur-based curative systems are generally used with these polymers, even though peroxides are capable of taking advantage of the unsaturation. Peroxide cure systems tend to cause chain scission, resulting in unacceptable properties.

General Properties

The most notable characteristic of poly(propylene oxide) rubber (GPO) is its ability to offer excellent hysteresis properties and dynamic properties over a wide temperature range. Even after exposure to elevated temperatures as high as 302°F (150°C) for a week, the dynamic properties of GPO rubber remain excellent. Typically, they offer good low temperature flexibility, good ozone resistance, fair fuel and oil resistance and good properties retention at high temperatures. GPO rubber has fair resistance to hydrocarbon fuels and oils and good hydrolysis and swelling resistance in polar solvents such as water and alcohol. GPO rubber does not have outstanding physical properties, and tends to have poor compression set and flame resistance. The limited physical properties of GPO rubber can be improved using reinforcing fillers, such as carbon black or silica. However, the poor compression set of GPO rubber is a function of the sulfur cross-links and cannot be easily remedied.

Typical Applications

Automotive Motor mounts, body mounts, suspension bushings, dust seals, boots

Relative Adhesive Performance

High	Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
Medium	Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
Low	Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Effects of Formulation and Processing

Additives	Carbon Black - Increase Aromatic Oil - Decrease Plasticizer - Decrease
T₈₀ Cure	Decrease

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Poly (propylene oxide) Rubber

PAREL 58 by Zeon Chemical

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Parel 58 <i>Parel 58 100 phr</i>	>120Δ >0.83Δ	>120Δ >0.83Δ	>110Δ >0.76Δ	>120Δ >0.83Δ	>110Δ >0.76Δ	40 0.28	50 0.34	50 0.34	>170Δ >1.17Δ
T₈₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> <i>Parel 58 100 phr</i>	>80Δ >0.55Δ	>90Δ >0.62Δ	>90Δ >0.62Δ	>80Δ >0.55Δ	>90Δ >0.62Δ	40 0.28	50 0.34	50 0.34	>150Δ >1.03Δ
Carbon Black <i>Parel 58 100 phr</i> <i>N-550 25 phr</i>	>330Δ >2.28Δ	>350Δ >2.41Δ	>360Δ >2.48Δ	>410Δ >2.83Δ	>350Δ >2.41Δ	50 0.34	100 0.69	70 0.48	170 1.17
Aromatic Oil <i>Parel 58 100 phr</i> <i>Aromatic Oil 20 phr</i>	>90Δ >0.62Δ	>90Δ >0.62Δ	>90Δ >0.62Δ	>90Δ >0.62Δ	>80Δ >0.55Δ	40 0.28	50 0.34	50 0.34	>140Δ >0.97Δ
Plasticizer <i>Parel 58 100 phr</i> <i>Diocetyl Phthalate 15 phr</i>	>80Δ >0.55Δ	>80Δ >0.55Δ	>90Δ >0.62Δ	>90Δ >0.62Δ	>80Δ >0.55Δ	40 0.28	50 0.34	50 0.34	>120Δ >0.83Δ
Antistatic <i>Parel 58 100 phr</i> <i>Armostat 550 5 phr</i>	>110Δ >0.76Δ	>100Δ >0.69Δ	>110Δ >0.76Δ	>100Δ >0.69Δ	>100Δ >0.69Δ	50 0.34	70 0.48	50 0.34	>170Δ >1.17Δ

- NOTES:**
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 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure Systems Used in All Formulations

Zinc Oxide	5.00 phr
Sulfur	1.25 phr
TMTM	1.50 phr
MBT	1.50 phr

Polysulfide Rubber

thermoset rubber

Trade Names

- LP
- THIOKOL

Manufacturer

Morton Thiokol
Morton Thiokol

General Description

The key factor that distinguishes polysulfide rubbers from other rubbers is the high sulfur content of the polymer backbone. This results in a very flexible, virtually impermeable rubber. Polysulfide elastomers are produced by the condensation reaction of an organic dihalide with sodium tetrasulfide. Examples of organic dihalides used include ethylene dichloride and di-2-chloroethyl ether. Commercial grades vary in sulfur content from 37 to 84%; the sulfur content of the resulting rubber being dependent on the base monomer selected. In addition to the performance benefits offered by the high sulfur content of the backbone, the various reactive sites on the polymer backbone facilitate cross-linking by a wide variety of methods. Generally, a metal oxide or peroxide is used to cross-link the terminal thiol groups, although terminal chlorine and hydroxide groups can also be used. Polysulfide polymers are available in viscosities ranging from pourable liquids to millable gum stock. The strong odor of polysulfides, coupled with the need to peptize some of the gum rubber stocks, can make them difficult to process.

General Properties

The key performance benefits of polysulfide elastomers are their outstanding chemical resistance and virtual impermeability to most gases, hydrocarbon solvents and moisture. This, coupled with their high flexibility and long-term resistance to both polar and non-polar solvents, makes them especially well suited for sealing applications that require exceptional barrier and resistance properties. Other performance characteristics include good performance at low temperatures and good resistance to UV and ozone. Polysulfide elastomers do not have very good compression set resistance and have fair physical properties. The limited physical properties can be addressed by compounding them with other rubbers, such as polychloroprene. Polysulfide rubber has a recommended service temperature of approximately -40° to 250°F (-40° to -121°C).

Typical Applications

- Aerospace** Propellant binders, gas bladders, sealants, valves
- Automotive** Gaskets, rubber washers
- Construction** Building caulk, window glazing

Relative Adhesive Performance

- High** Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
- Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
- Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
- Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
- Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
- Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Medium** Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
- Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
- Low** Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant

Effects of Formulation and Processing

- Additives** Carbon Black - Increase
Clay - Increase
Silica - Increase
Aromatic Oil - Decrease
Antistatic - Increase
- T₈₀ Cure** Increase

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend

Adhesive Shear Strength

Polysulfide Rubber

THIOKOL by Morton Thiokol

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Thiokol FA <i>Linear structure</i> 100 phr	150 1.03	>180Δ >1.24Δ	>170Δ >1.17Δ	>190Δ >1.31Δ	>140Δ >0.97Δ	80 0.55	150 1.03	110 0.76	>240Δ >1.66Δ
T₈₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> Thiokol FA 100 phr	>270Δ >1.86Δ	>270Δ >1.86Δ	>230Δ >1.59Δ	>280Δ >1.93Δ	>290Δ >2.00Δ	80 0.55	150 1.03	140 0.97	>370Δ >2.55Δ
Thiokol ST <i>Branched structure</i> Thiokol ST 25 phr	>180Δ >1.24Δ	>180Δ >1.24Δ	>170Δ >1.17Δ	>190Δ >1.31Δ	>180Δ >1.24Δ	70 0.48	150 1.03	150 1.03	>300Δ >2.07Δ
Carbon Black Thiokol FA 100 phr N-550 100 phr	>390Δ >2.69Δ	>380Δ >2.62Δ	>470Δ >3.24Δ	>470Δ >3.24Δ	>500Δ >3.45Δ	110 0.76	250 1.72	290 2.00	240 1.66
Clay Thiokol FA 100 phr Dixie Clay 100 phr	250 1.72	>290Δ >2.00Δ	310 2.14	280 1.93	310 2.14	130 0.90	230 1.59	260 1.79	>460Δ >3.17Δ
Silica Thiokol FA 100 phr Hi Sil 233 100 phr	330 2.28	340 2.34	290 2.00	350 2.41	330 2.28	110 0.76	240 1.66	310 2.14	420 2.90
Aromatic Oil Thiokol FA 100 phr Aromatic Oil 15 phr	>90Δ >0.62Δ	100 0.69	80 0.55	110 0.76	90 0.62	60 0.41	110 0.76	60 0.41	>140Δ >0.97Δ
Antistatic Thiokol FA 100 phr Armostat 550 5 phr	>190Δ >1.31Δ	180 1.24	>220Δ >1.52Δ	>190Δ >1.31Δ	>220Δ >1.52Δ	80 0.55	150 1.03	180 1.24	>340Δ >2.34

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Polysulfide Cure Systems

Thiokol FA formulations

Stearic Acid	0.5 phr
MTBS	0.3 phr
DPG	0.1 phr
Zinc Oxide	10.0 phr
Maglite D	4.0 phr

Thiokol ST formulations

Stearic Acid	1.0 phr
Calcium Hydroxide	1.0 phr
Zinc Peroxide	5.0 phr
Maglite D	4.0 phr

Silicone-Modified EPDM

thermoset rubber

Trade Names

- ROYALTHERM

Manufacturer

Uniroyal Chemical

General Description

Silicone-modified EPDM represents a unique combination of the benefits offered by silicone and EPDM rubbers. The inorganic polysiloxane backbone of the silicone contributes low temperature flexibility and high temperature resistance, while the EPDM contributes good mechanical properties. The resulting polymer has better physical properties than a silicone, and better thermal resistance and strength at temperature than EPDM. Silicone-modified EPDM can be vulcanized by sulfur-based curatives or peroxide cure systems. Peroxide cure systems are generally utilized to maximize heat resistance and compression set resistance. Specialty purpose base compounds offering non-halogen flame retardancy, translucency, FDA approval or utility in sponge applications are also available.

General Properties

The performance properties of silicone-modified EPDM are best understood in terms of the properties of each of the pure components. In general, it has the good mechanical properties of EPDM rubber with the improved thermal resistance of silicone elastomers. However, there are some trade-offs. For example, the service life at temperatures ranging from 300° to 400°F (149° to 204°C) is an order of magnitude longer than that achieved by EPDM and at least an order of magnitude less than that achieved by silicone. Silicone-modified EPDM offers much better strength retention than silicone when exposed to steam at 327°F (164°C), but only slightly less than EPDM. Tensile strength and abrasion resistance follow the same trend. Silicone-modified EPDM also offers the excellent chemical resistance and wet electrical properties of EPDM. The hot tear strength of silicone-modified EPDM exhibits a synergistic effect between the two phases since it has hot tear strengths superior to that of either of its pure components.

Typical Applications

- Automotive** Ignition cables, seals, gaskets, weatherstripping
- Industrial** Steam hoses, gaskets, seals

Relative Adhesive Performance

- High**
 - Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
 - Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
 - Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
 - Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
 - Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
 - Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
- Medium**
 - Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
 - Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
- Low**
 - Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant

Effects of Formulation and Processing

- Additives**
 - Carbon Black - Increase
 - Silica - Increase
 - Plasticizer - Decrease
 - Antistatic - Decrease
- T₈₀ Cure** No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Silicone Modified EPDM

ROYALTHERM by Uniroyal Chemical Company

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Royaltherm 1411	>380Δ >2.62Δ	>350Δ >2.41Δ	>310Δ >2.14Δ	>270Δ >1.86Δ	>250Δ >1.72Δ	40 0.28	110 0.76	110 0.76	>350Δ >2.41Δ
T₈₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> <i>Royaltherm 1411 100 phr</i>	>380Δ >2.62Δ	>420Δ >2.90Δ	>420Δ >2.90Δ	>270Δ >1.86Δ	>250Δ >1.72Δ	40 0.28	110 0.76	110 0.76	>350Δ >2.41Δ
Royaltherm 1721 <i>Improved heat resistance</i> <i>Royaltherm 1721 25 phr</i>	>260Δ >1.79Δ	>350Δ >2.41Δ	>310Δ >2.14Δ	>270Δ >1.86Δ	>250Δ >1.72Δ	60 0.41	160 1.10	140 0.97	350 2.41
Carbon Black <i>Royaltherm 1411 100 phr</i> <i>N-330 30 phr</i>	>380Δ >2.62Δ	>640Δ >4.41Δ	>620Δ >4.27Δ	>480Δ >3.31Δ	>610Δ >4.21Δ	110 0.76	210 1.45	210 1.45	350 2.41
Silica <i>Royaltherm 1411 100 phr</i> <i>VN-3 silica 45 phr</i>	580 4.00	>720Δ >4.97Δ	>720Δ >4.97Δ	>470Δ >3.24Δ	>540Δ >3.72Δ	90 0.62	210 1.45	240 1.66	860 5.93
Plasticizer <i>Royaltherm 1411 100 phr</i> <i>Diocetyl Phthalate 12 phr</i>	>260Δ >1.79Δ	>280Δ >1.93Δ	>260Δ >1.79Δ	>270Δ >1.86Δ	>250Δ >1.72Δ	30 0.21	70 0.48	70 0.48	>350Δ >2.41Δ
Antistatic <i>Royaltherm 1411 100 phr</i> <i>Armostat 550 5 phr</i>	>230Δ >1.59Δ	>290Δ >2.00Δ	>160Δ >1.10Δ	200 1.38	>250Δ >1.72Δ	40 0.28	90 0.62	90 0.62	350 2.41

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Cure System Used in All Formulations

Stearic Acid	1.50 phr
Zinc Oxide	4.00 phr
Di Cup 40C	7.00 phr

Silicone Rubber (MQ, VMQ, PMQ, PVMQ)

thermoset rubber

Trade Names

- BLENsil
- ELASTOSIL
- SILASTIC

Manufacturer

G.E. Silicones
Wacker Chemical Corp.
Dow Corning STI

General Description

Silicone rubber is characterized by an inorganic polymeric backbone made up of silicon to oxygen bonds which are known as siloxane linkages. The majority of silicon atoms in the silicone polymer backbone have two pendant methyl groups, which form the most common silicone polymer used in silicone rubbers, polydimethyl siloxane (MQ). By replacing a portion of the methyl groups with other species, the silicone rubber can be given cross-link sites or properties tailored for specific needs. For example, in peroxide-cured silicone rubber systems, a small percentage of the methyl groups are replaced with vinyl groups (VMQ). The vinyl group containing polymers is also used in conjunction with a platinum catalyst and suitable hydride cross-linkers to produce addition cure silicone formulations. In RTV silicone adhesives and condensation cure compounds, hydrolyzable groups are capped onto the terminal ends of the silicone polymer to provide sites for cross-linking to occur when moisture reacts with these sites to leave reactive silanol sites. As was mentioned, replacing a portion of the methyl groups with other species can also provide properties for specific needs. For example, replacing 5 to 10% of the methyl groups with bulkier phenyl groups will dramatically drop the brittle point of the silicone (PMQ). Replacing a portion of the methyl groups with trifluoropropyl groups will increase the polarity of the silicone rubber, thus improving its resistance to non-polar solvents. These types of silicones are known as fluorosilicone elastomers and are discussed in a separate chapter.

General Properties

The unique properties of polydimethyl siloxane elastomers arise primarily from the high bond energy of the silicon oxygen bonds along the backbone, and from the non-polar nature of the two methyl groups which are pendant from each of the silicon atoms. The result is an elastomer with good flexibility and compression set resistance over a wide temperature range. The silicone oxygen bond results in a polymer with excellent resistance to UV and ozone, as well as long-term exposure to temperatures of 400°F (204°C) and intermittent exposure to temperatures as high as 600°F (316°C). More importantly, silicone elastomers retain much of their tensile strength and compression set resistance at these high temperatures. The large volume of the silicon atom also results in a polymer with a

large amount of free space and flexibility. Consequently, silicone polymers have high gas permeation rates and remain flexible to temperatures as low as -60°F (-51°C). With the addition of phenyl groups on the backbone, the brittle point can be lowered to -120°F (-84°C). The lack of polarity in the silicone elastomer results in very good resistance to polar solvents such as water and alcohols. Non-polar solvents such as aliphatic and aromatic hydrocarbons tend to swell silicones 200-300% and often require the use of the more polar fluorosilicone elastomers. Resistance to many acids and salts is good, though strong bases will degrade the polymer.

Typical Applications

Automotive	Hoses, gaskets, seals, ignition cable insulation
Industrial	Adhesives, oven door gaskets, seals, sponges
Medical	Implantable devices, tubing

Relative Adhesive Performance

High	Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
Medium	Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
Low	Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Effects of Formulation and Processing

Additives	All Except Plasticizer - Increase CA
T₈₀ Cure	No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer – Increase

Adhesive Shear Strength

Silicone Rubber

SE 456U by General Electric

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: SE 456U <i>100 phr</i>	<10 <0.07	70 0.48	220 1.52	<10 <0.07	10 0.07	290 2.00	200 1.38	<10 <0.07	230 1.59
T₈₀ Cure <i>Cured to 80% of Modulus at Full Cure</i> <i>SE 456U 100 phr</i>	20 0.14	190 1.31	290 2.00	<10 <0.07	30 0.21	180 1.24	280 1.93	20 0.14	230 1.59
Carbon Black <i>SE 456U 100 phr</i> <i>N-550 100 phr</i>	<10 <0.07	>250Δ >1.72Δ	>320Δ >2.21Δ	10 0.07	80 0.55	190 1.31	200 1.38	<10 <0.07	140 0.97
Calcium Carbonate <i>SE 456U 100 phr</i> <i>Calcium Carbonate 30 phr</i>	<10 <0.07	190 1.31	>310 >2.14Δ	40 0.28	60 0.41	200 1.38	200 1.38	40 0.28	>290Δ >2.00Δ
Clay <i>SE 456U 100 phr</i> <i>Polyethylene Glycol 3 phr</i> <i>Whitex Clay 30 phr</i>	80 0.55	>300Δ >2.07Δ	>320Δ >2.21Δ	70 0.48	90 0.62	290 2.00	170 1.17	<10 <0.07	140 0.97
Fumed Silica <i>SE 456U 100 phr</i> <i>Aerosil 200 11.5 phr</i>	<10 <0.07	110 0.76	350 2.41	<10 <0.07	190 1.31	190 1.31	200 1.38	<10 <0.07	250 1.72
Ground Silica <i>SE 456U 100 phr</i> <i>Min-U-Sil 10 30 phr</i>	<10 <0.07	130 0.90	290 2.00	<10 <0.07	30 0.21	200 1.38	200 1.38	<10 <0.07	230 1.59
Iron Oxide <i>SE 456U 100 phr</i> <i>Red Iron Oxide E-4182 30 phr</i>	<10 <0.07	110 0.76	>390Δ >2.69Δ	<10 <0.07	80 0.55	180 1.24	200 1.38	<10 <0.07	230 1.59
Silicone Plasticizer <i>SE 456U 100 phr</i> <i>1000 cP fluid 15 phr</i>	<10 <0.07	70 0.48	220 1.52	<10 <0.07	10 0.07	290 2.00	170 1.17	<10 <0.07	60 0.41
Antistatic <i>SE 456U 100 phr</i> <i>Armostat 550 4 phr</i>	170 1.17	210 1.45	190 1.31	170 1.17	170 1.17	210 1.45	200 1.38	<10 1.38	230 1.59

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Cure and Reinforcement System Used in All Formulations

DiCumyl Peroxide 1.50 phr
Aerosil 200 5.00 phr

Styrene-Butadiene Rubber (SBR)

thermoset rubber

Trade Names

- AFPOL
- BUNA
- COPEFLEX
- DURADENE
- EUROPRENE
- KRATON
- PLIOFLEX
- PLIOLITE
- SOLPRENE
- STEREON

Manufacturer

CAL Polymers
Bayer
Coperbo
Firestone
Enichem
Shell Chemical
Goodyear
Goodyear
Housmex
Firestone

Typical Applications

Automotive Tires, hoses, belts
Industrial Foamed products, extruded goods
Consumer Shoe soles, waterproof materials
Miscellaneous Adhesives, asphalt

General Description

SBR is formed via the copolymerization of styrene and butadiene. This can be performed as an emulsion or solution polymerization. In emulsion polymerizations, the monomer is emulsified in a medium, such as water, using an emulsifying agent, such as soap. This can be performed as a hot process at 122°F (50°C) or a cold process at 41° to 50°F (5° to 10°C). Solution polymerizations typically occur in a hydrocarbon solution with an alkyl lithium catalyst. Solution polymerizations offer improved properties due to the increased control of molecular weight and stereospecificity. In addition, emulsion SBR typically contains 4 to 7% of non-rubber emulsifier residues which solution SBR does not.

General Properties

Approximately 75% of the SBR produced in the US is used in tires. This is due to the superior abrasion resistance and traction of SBR. For tire applications, the glass transition temperature (T_g) is critical. If the T_g is too high, the tires will become brittle in cold conditions. If the T_g is too low, the tire traction is compromised. Consequently, any rubber with a T_g which is not between -58° and -94°F (-50° and -70°C) must be mixed with at least one other rubber for tire applications. NR and SBR have T_gs which allow them to be used as the sole elastomer in a tire compound. The processing temperature of SBR has a large effect on the resulting properties of the material. Cold SBR has better abrasion resistance and dynamic properties, as well as a higher capacity to be extended, than hot SBR. Therefore, hot SBR is no longer used for tire applications. Due to the increased control of solution SBR, improved abrasion resistance, traction and hysteretic properties have been realized. Consequently, solution SBR is rapidly replacing emulsion SBR for tire production. The addition of carbon black has many advantageous effects on the properties of SBR. In particular, it increases the strength properties, hardness and dimensional stability of SBR. In addition, it can provide electrical and thermal conductivity, all while lowering cost.

Relative Adhesive Performance

High Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive
Medium Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive
Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
Low Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant

Effects of Formulation and Processing

Additives High Styrene - Increase
Carbon Black - Increase
Clay - Increase
Silica - Increase
Styrene Resin - Increase
Aromatic Oil - Decrease
Processing Aid - Increase
Antioxidant - Increase
T₈₀ Cure No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer - No Trend Apparent

Adhesive Shear Strength

Styrene Butadiene Rubber

PLIOFLEX by Goodyear

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Plioflex 1502 Cold Emulsion Polymer, 23.5% Styrene 100 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>190Δ >1.31Δ	60 0.41	60 0.41	60 0.41	110 0.76
T₈₀ Cure Cured to 80% of Modulus at Full Cure Plioflex 1502 100 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>110Δ >0.76Δ	60 0.41	100 0.69	40 0.28	110 0.76
Cold Solution Polymer Firestone SBR 710 100 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>110Δ >0.76Δ	50 0.34	100 0.69	60 0.41	70 0.48
High Styrene Content Cold Emulsion Polymer, 40% Styrene Plioflex 1513 100 phr	>310Δ >2.14Δ	>340Δ >2.34Δ	>260Δ >1.79Δ	>270Δ >1.86Δ	>290Δ >2.00Δ	60 0.41	90 0.62	130 0.90	110 0.76
Carbon Black Plioflex 1513 100 phr FEF N-550 15 phr	>550Δ >3.79Δ	>560Δ >3.86Δ	>530Δ >3.65Δ	>360Δ >2.48Δ	>350Δ >2.41Δ	60 0.41	140 0.97	110 0.76	110 0.76
Calcium Carbonate Plioflex 1502 100 phr Calcium Carbonate 60 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>190Δ >1.31Δ	80 0.55	140 0.97	140 0.97	110 0.76
Clay Plioflex 1502 100 phr Dixie Clay 60 phr	>410Δ >2.83Δ	>460Δ >3.17Δ	>390Δ >2.69Δ	270 1.86	270 1.86	60 0.41	150 1.03	170 1.17	210 1.45
Silica Plioflex 1502 100 phr Hi Sil 233 15 phr	460 3.17	>510Δ >3.52Δ	>570Δ >3.93Δ	300 2.07	>330Δ >2.28Δ	80 0.55	130 0.90	60 0.41	110 0.76
Styrene Resin Plioflex 1502 100 phr Resin S6B 25 phr	>460Δ >3.17Δ	>510Δ >3.52Δ	>490Δ >3.38Δ	370 2.55	450 3.10	90 0.62	170 1.17	130 0.90	180 1.24
Aromatic Oil Plioflex 1502 100 phr Aromatic Oil 37.5 phr	>160Δ >1.10Δ	>170Δ >1.17Δ	>180Δ >1.24Δ	>180Δ >1.24Δ	>190Δ >1.31Δ	40 0.28	60 0.41	60 0.41	110 0.76
Processing Aid Plioflex 1502 100 phr Struktol WB212 4 phr	>220Δ >1.52Δ	>310Δ >2.14Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>240Δ >1.65Δ	60 0.41	90 0.62	80 0.55	110 0.76
Antioxidant Plioflex 1502 100 phr DMQ 3 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>250Δ >1.72Δ	>250Δ >1.72Δ	60 0.41	90 0.62	80 0.55	110 0.76
Antistatic Plioflex 1502 100 phr Armostat 550 5 phr	>220Δ >1.52Δ	>260Δ >1.79Δ	>260Δ >1.79Δ	>180Δ >1.24Δ	>270Δ >1.86Δ	60 0.41	120 0.83	60 0.41	110 0.76

- NOTES:**
- = The addition of the indicated additive (or processing change) caused a statistically significant increase in the bond strength within 95% confidence limits.
 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System and Reinforcement Used in All Formulations

Stearic Acid	1.00 phr
Zinc Oxide	5.00 phr
Sulfur	2.50 phr
MBTS	1.50 phr
TMD	0.10 phr
Carbon Black FEF N-550	10.00 phr

Styrenic TPEs (S-B-S, S-I-S, S-EB-S)

thermoplastic elastomer

Trade Names

- C-FLEX
- COPERFLEX
- DYNAFLEX
- EUROPRENE SOL
- K-RESIN
- KRATON
- RIMFLEX
- SOLPRENE

Manufacturer

Concept
Coperbo
GLS Corp.
EniChem
Chevron Phillips
Shell Chemical Co.
Synthetic Rubber Tech.
Housmex

Typical Applications

Automotive Hoses, tubing
Consumer Footwear soles
Electrical Insulation and jackets for wire and cable
Miscellaneous Sealants, coatings, caulking adhesives, modified thermoplastics

General Description

Styrenic TPEs are block copolymers of styrene and a diene. In block copolymers, there are two distinct phases present. Each phase is composed of repeating segments of the same molecule. The simplest arrangement being A-B-A or a three-block structure. The dienes most commonly used are butadiene (S-B-S), isoprene (S-I-S) and ethylene-cobutylene (S-EB-S), an olefinic pair. The A indicates the hard copolymer blocks, and the B indicates the soft blocks. A block copolymer with an A-B or B-A-B backbone would not have the desired properties of a TPE because the ends of the elastomeric regions would not be anchored in crystalline regions of the TPE.

General Properties

Styrenic TPEs are typically the lowest cost TPEs but also have the lowest performance. Specific gravities range from 0.9 to 1.1, hardnesses range from 33 Shore A to 55 Shore D, and ultimate tensile strengths range from 500 to 4000 psi (3.5 to 27.6 MPa). Due to the non-polar nature of the backbone, styrenic TPEs can be extended with hydrocarbon-based oils and have excellent chemical resistance to polar solvents such as aqueous solutions, acetones and alcohols. However, this results in poor resistance to such non-polar solvents as oils, fuel and hydrocarbon solvents. As the styrene content is increased, the TPE changes from a weak, soft material to a strong elastomer and then will eventually become leathery. At styrene contents above 75%, they are hard, clear, glass-like products which are used as impact resistant polystyrene. Increasing the styrene content hardens the polymer, while the addition of extending oil softens the polymer. Both increase its processibility. The weathering resistance of styrenic rubbers is dictated by the soft elastomer segment. S-B-S and S-I-S structures have a double bond per original monomer unit in the backbone. This unsaturation limits their thermal, chemical and weathering resistance. Alternatively, S-EB-S has a completely aliphatic backbone, resulting in its superior weatherability. Compounds based on S-EB-S normally contain polypropylene, which increases the solvent resistance, service temperature and processibility. Useful service temperatures are low for styrenic TPEs ranging from -70° to 200°F (-57° to 93°C).

Relative Adhesive Performance

High Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive
Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive

Medium Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive
Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive
Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive

Low Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant
Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body
Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive

Effects of Formulation and Processing

Additives Carbon Black - Increase
Silica - Increase
Whiting - Decrease
Aromatic Oil - Decrease
Naphthenic Oil - Decrease
Plasticizer - Decrease
EVA Blend - Decrease
PE Blend - Increase
Antistat - Decrease
C-Flex - Decrease

T₈₀ Cure No Trend Apparent

Surface Treatments

Loctite® 770™ Prism® Primer – No Trend Apparent

Adhesive Shear Strength

Styrene Butadiene TPE

KRATON by Shell Chemical and C-FLEX
by Concept Polymer Technology

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Control: Kraton G 1650 S-EB-S 100 phr	290 2.00	>510Δ >3.52Δ	370 2.55	230 1.59	230 1.59	90 0.62	170 1.17	170 1.17	660 4.55
Carbon Black Kraton G 1650 100 phr N-550 15 phr	530 3.65	>810Δ >5.59Δ	570 3.93	360 2.48	620 4.27	50 0.34	170 1.17	280 1.93	660 4.55
Clay Kraton G 1650 100 phr Dixie Clay 100 phr	220 1.52	510 3.52	580 4.00	320 2.21	340 2.34	50 0.34	170 1.17	230 1.59	>1090Δ >7.52Δ
Silica Kraton G 1650 100 phr Hi Sil 233 50 phr	440 3.03	>550Δ >3.52Δ	>550Δ >3.52Δ	390 2.69	510 3.52	30 0.21	60 0.41	390 2.69	>660Δ >4.55Δ
Whiting Kraton G 1650 100 phr Precipitated Whiting 100 phr	50 0.34	180 1.24	>200Δ >1.35Δ	40 0.28	40 0.28	30 0.21	30 0.21	30 0.21	180 1.24
Aromatic Oil Kraton G 1650 100 phr Aromatic Oil 100 phr	140 0.97	>300Δ >2.07Δ	150 1.03	150 1.03	140 0.97	20 0.14	50 0.34	40 0.28	160 1.10
Naphthenic Oil Kraton G 1650 100 phr Naphthenic Oil 100 phr	80 0.55	300 2.07	>370Δ >2.55Δ	90 0.62	80 0.55	<10 <0.07	50 0.34	40 0.28	170 1.17
Plasticizer Kraton G 1650 100 phr Diocetyl Phthalate 50 phr	10 0.07	<10 <0.07	20 0.14	10 0.07	20 0.14	<10 <0.07	<10 <0.07	<10 <0.07	20 0.14
Processing Aid Kraton G 1650 100 phr Carnauba Wax 10 phr	290 2.00	510 3.52	370 2.55	390 2.69	230 1.59	90 0.62	110 0.76	210 1.45	410 2.83
EVA Blend Kraton G 1650 100 phr EVA 20 phr	130 0.90	240 1.65	370 2.55	180 1.24	140 0.97	20 0.14	40 0.28	170 1.17	410 2.83
PE Blend Kraton G 1650 100 phr Struktol WB212 4 phr	520 3.59	510 3.52	550 3.79	370 2.55	550 3.79	60 0.41	80 0.55	350 2.41	660 4.55
Antistatic Kraton G 1650 100 phr Armostat 550 5 phr	220 1.52	190 1.31	160 1.10	230 1.59	230 1.59	<10 <0.07	100 0.69	120 0.83	260 1.79
C-Flex Silicone Oil 100 phr	140 0.97	>240Δ >1.65Δ	220 1.52	80 0.55	100 0.69	10 0.07	20 0.14	30 0.21	170 1.17
Kraton D 1101 S-B-S Linear	160 1.10	280 1.93	370 2.55	230 1.59	230 1.59	50 0.34	170 1.17	130 0.90	>430Δ >2.96Δ
PS Blend Kraton D 1101 100 phr Polystyrene 100 phr	530 3.65	510 3.52	630 4.34	450 3.10	520 3.59	90 0.62	250 1.72	290 2.00	1020 7.03
Kraton D 1118X SB Type Branched 100 phr	120 0.83	130 0.90	150 1.03	120 0.83	140 0.97	70 0.48	170 1.17	90 0.62	320 2.21

- NOTES:**
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 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System Used in All Formulations
None Required

Thermoplastic Vulcanizates (TPV)

thermoplastic elastomer

Trade Names

- GEOLAST
- SANTOPRENE

Manufacturer

Advanced Elastomer Systems
Advanced Elastomer Systems

General Description

Thermoplastic vulcanizates are elastomeric alloys of a continuous plastic phase and a fine dispersion of dynamically vulcanized rubber. Santoprene, for example, uses polypropylene as the plastic phase with EPDM as the rubber phase. Geolast also uses polypropylene for the plastic phase; however, nitrile rubber is used for the thermoset rubber phase. Generally, these compounds derive their physical properties from the interaction of the two phases, and do not use the fillers and extenders commonly used with most thermoset rubber systems. Consequently, material properties are primarily a function of the type and level of vulcanizate and its degree of cross-linking. Even though TPVs contain a vulcanizate phase, these materials can still be processed by common thermoplastic processing equipment such as extrusion, injection molding, blow molding, thermoforming and calendaring.

General Properties

In general, TPVs offer the performance properties of a thermoset rubber with the processing ease of a thermoplastic. These properties include good tensile strength, good abrasion resistance and outstanding fatigue flex resistance. The saturated nature of the olefinic backbone in the Santoprene and Geolast plastic phases, coupled with the highly cross-linked nature of their vulcanizate phases, gives them excellent chemical resistance, as well as good thermal and weathering resistance. Santoprene has shown good property retention after long-term exposure to acids, bases and aqueous solutions. Resistance to oils and other hydrocarbons varies with grade and fluid type. However, the higher the polarity of the fluid, the more likely it is to attack Santoprene. For increased oil resistance, Geolast offers superior performance because it utilizes nitrile as the vulcanizate phase rather than EPDM. Unlike most TPEs, which soften at high temperatures, TPVs have shown good property retention at temperatures as high as 275°F (135°C) and good compression set resistance at temperatures as high as 212°F (100°C). Their low temperature performance is also good with brittle points below -67°F (-55°C).

Typical Applications

Automotive	Air ducts, rack and pinion steering boots, motor drive belts
Construction	Glazing seals, expansion joints
Electrical	Specialty wire and cable insulation
Medical	Drug vial stoppers, grommets, syringe plunger tips, volumetric infusion pump tips
Miscellaneous	Sander grips, squeegees, dust seals, clothes washer filter seals

Relative Adhesive Performance

High	Primer - Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer
Medium	Surface Insensitive CA - Loctite® 401™ Prism® Instant Adhesive Rubber Toughened CA - Loctite® 4204™ Prism® Instant Adhesive Two-Part No-Mix Acrylic - Loctite® 330™ Depend® Adhesive Light Curing Acrylic - Loctite® 3105™ Light Cure Adhesive
Low	Methyl CA - Loctite® 496™ Super Bonder® Instant Adhesive Rubber Toughened CA - Loctite® 480™ Prism® Instant Adhesive Acetoxy Silicone - Loctite® Superflex® RTV Silicone Adhesive Sealant Oxime Silicone - Loctite® 5900® Flange Sealant, Heavy Body

Effects of Formulation and Processing

Additives	Grey Concentrate - Increase
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Surface Treatments

Loctite® 770™ Prism® Primer - Increase

Adhesive Shear Strength

Thermoplastic Vulcanizates

SANTOPRENE and GEOLAST
by Advanced Elastomer Systems

(psi)
(MPa)

Loctite® Brand Adhesives	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 480™ Prism® Instant Adhesive	Loctite® 4204™ Prism® Instant Adhesive	Loctite® Superflex® RTV Silicone Adhesive Sealant	Loctite® 5900® Flange Sealant, Heavy Body	Loctite® 330™ Depend® Adhesive	Loctite® 3105™ Light Cure Adhesive
Santoprene 101-55 <i>Santoprene 101-55 100 phr</i>	30 0.21	80 0.55	220 1.52	20 0.14	20 0.14	20 0.14	60 0.41	50 0.34	120 0.83
Santoprene 101-73 <i>Santoprene 101-73 100 phr</i>	<10 <0.07	170 1.17	>390Δ >2.69Δ	90 0.62	140 0.97	20 0.14	60 0.41	110 0.76	210 1.45
Santoprene 103-50 <i>Santoprene 103-50 100 phr</i>	<10 <0.07	180 1.24	1220 8.41	<10 <0.07	<10 <0.07	10 0.07	30 0.21	230 1.59	610 4.21
Santoprene 201-55 <i>Santoprene 201-55 100 phr 100 phr</i>	30 0.21	70 0.48	210 1.45	<10 <0.07	30 0.21	<10 <0.07	<10 <0.07	50 <0.07	180 1.24
Santoprene 201-55 w/Grey Concentrate <i>Santoprene 201-55 100 phr Grey Concentrate 4 phr</i>	30 0.21	140 0.97	>200Δ >1.38Δ	<10 <0.07	30 0.21	20 0.14	60 0.41	70 0.48	180 1.24
Santoprene 201-73 <i>Santoprene 201-73 100 phr</i>	90 0.62	230 1.59	>390Δ >2.69Δ	230 1.59	240 1.66	10 0.07	10 0.07	10 0.07	280 1.93
Santoprene 201-73 w/Grey Concentrate <i>Santoprene 201-73 100 phr Grey Concentrate 4 phr</i>	<10 <0.07	320 2.21	330 2.28	230 1.59	50 0.34	10 0.07	10 0.07	100 0.69	280 1.93
Santoprene 203-50 <i>Santoprene 203-50 100 phr</i>	<10 <0.07	320 2.21	1020 7.03	<10 <0.07	<10 <0.07	<10 <0.07	40 0.28	<10 <0.07	310 2.14
Santoprene 203-50 w/Grey Concentrate <i>Santoprene 203-50 100 phr Grey Concentrate 25 phr</i>	<10 <0.07	430 2.97	1070 7.38	<10 <0.07	130 0.90	<10 <0.07	50 0.34	170 1.17	800 5.52
Geolast 701-70W183 <i>Geolast 701-70W183 100 phr</i>	230 1.59	250 1.72	>250Δ >1.72Δ	150 1.03	>270Δ >1.86Δ	60 0.41	70 0.48	120 0.83	280 1.93
Geolast 701-80W183 <i>Geolast 701-80W183 100 phr</i>	320 2.21	360 2.48	>350Δ >2.41Δ	320 2.21	400 2.76	30 0.21	70 0.48	180 1.24	320 2.21
Geolast 701-87W183 <i>Geolast 701-87W183 100 phr</i>	430 2.97	380 2.62	360 2.48	>240Δ >1.66Δ	270 1.86	<10 <0.07	<10 <0.07	40 0.28	750 5.17
Geolast 703-4045 <i>Geolast 703-4045 100 phr</i>	420 2.90	390 2.69	470 3.24	430 2.97	550 3.79	<10 <0.07	<10 <0.07	230 1.59	250 1.72

- NOTES:**
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 - = The addition of the indicated additive (or processing change) caused a statistically significant decrease in the bond strength within 95% confidence limits.
 - Δ = The force applied to the test specimens exceeded the strength of the material, resulting in substrate failure before the actual bond strength achieved by the adhesive could be determined.

Cure System and Reinforcement Used in All Formulations

None Required

Section 6

Test Methodology

Determining the Experimental Matrix

The Selection of Adhesives

It was desired to evaluate adhesives from all families that are best suited for bonding elastomers. The families were identified as cyanoacrylates; no-mix and static mix acrylics; hot melts; epoxies; polyurethanes; silicones; and light curing acrylics. From each of these categories, an adhesive was then selected which was believed to be representative of the performance of that family of adhesives when bonding elastomers. The adhesives which were selected are tabulated in the table on the right.

The Selection of Elastomers

The various types of elastomers which are currently available were surveyed, and 26 of the most commonly used elastomers were selected for testing. The specific formulations of these elastomers which were evaluated were chosen in one of the two following ways:

Specialty Formulations

1. A grade of the elastomer which had no fillers or additives was selected and tested for bond strength performance with the aforementioned adhesives. This was the control which was used to determine the effect of additives, fillers and processing changes on the bondability of an elastomer.
2. The most common additives and fillers used with each elastomer were identified. Variations in polymer structure which differentiate different grades of the elastomer were also identified. For example, acrylonitrile level in nitrile rubber or vinyl acetate level in ethylene-vinyl acetate copolymer.
3. A separate formulation of the elastomer was compounded which represented a high level of additive or filler, a processing change or a variation in the polymer structure.
4. Adhesive bond strength evaluations were performed.
5. The results were analyzed to determine if the filler, additive or change in polymer structure resulted in a statistically significant change in the bondability of the elastomer in comparison with the unfilled control within 95% confidence limits.

Commercially Available Grades

For five elastomers, commercially available grades were selected to represent a cross-section of the various grades which were available and tested for bond strength.

Adhesive	Adhesive Description
Loctite® 496™ Super Bonder® Instant Adhesive	Methyl cyanoacrylate
Loctite® 401™ Prism® Instant Adhesive MEDICAL: Loctite® 4011™ Prism®	Surface-sensitive ethyl cyanoacrylate
Loctite® 414™ Super Bonder® Instant Adhesive	General-purpose ethyl instant adhesive
Loctite® 480™ Prism® Instant Adhesive	Rubber toughened ethyl cyanoacrylate
Loctite® 4204™ Prism® Instant Adhesive	Clear, rubber toughened, surface-insensitive, thermally resistant cyanoacrylate
Loctite® 4851™ Prism® Instant Adhesive MEDICAL: Loctite® 4851™ Prism®	Flexible instant adhesive
Loctite® 4861™ Prism® Instant Adhesive MEDICAL: Loctite® 4861™ Prism®	Flexible instant adhesive
Loctite® 401™ Prism® Instant Adhesive Loctite® 770™ Prism® Primer MEDICAL: Loctite® 4011™ Prism® Loctite® 7701™ Prism® Primer	Surface-insensitive ethyl instant adhesives used in conjunction with polyolefin primer
Loctite® 401™ Prism® Instant Adhesive Loctite® 793™ Prism® Primer	Surface-insensitive ethyl instant adhesives used in conjunction with polyolefin primer
Loctite® 330™ Depend® Adhesive	Two-part no-mix acrylic adhesive
Loctite® 3032™ Adhesive	Polyolefin Bonder
Loctite® H3000™ Speedbonder™	Two-part acrylic
Loctite® H4500™ Speedbonder™	Two-part acrylic
Loctite® 3105™ Light Cure Adhesive MEDICAL: Loctite® 3105™	Light cure acrylic adhesive
Loctite® 4307™ Flashcure® Light Cure Adhesive	Light cure adhesive
Loctite® E-00CL™ Hysol® Epoxy Adh.	Fast setting epoxy
Loctite® E-90FL™ Hysol® Epoxy Adh.	Tough, flexible epoxy
Loctite® E-30CL™ Hysol® Epoxy Adh. MEDICAL: Loctite® M-31CL™ Hysol®	Clear, glass bonding epoxy
Loctite® E-20HP™ Hysol® Epoxy Adh. MEDICAL: Loctite® M-21HP™ Hysol®	High strength epoxy
Loctite® E-40FL™ Hysol® Epoxy Adh.	High strength epoxy
Loctite® E-214HP™ Hysol® Epoxy Adh.	One component heat cure epoxy
Loctite® 3631™ Hysol® Hot Melt Adh.	Reactive urethane hot melt
Loctite® 7804™ Hysol® Hot Melt Adh.	Polyamide hot melt
Loctite® 1942™ Hysol® Hot Melt Adh.	EVA hot melt
Loctite® Fixmaster® Rapid Rubber Repair OEM: Loctite® U-04FL™ Hysol®	Rapid rubber repair urethane; two-part, fast-setting urethane
Loctite® Fixmaster® Epoxy	High performance epoxy
Loctite® Superflex® RTV	RTV silicone adhesive sealant
Loctite® 5900® Flange Sealant	Heavy body RTV flange sealant

Determining The Test Method

The lap shear test method (ASTM D1002) is typically used to determine adhesive shear strengths. However, because it was designed for use with metals, it has several serious limitations when evaluating elastomers. For example, because elastomers have much lower tensile strength than metals, the lap shear specimens are much more likely to experience substrate failure than the metal lap shear specimens. This makes the comparative analysis of different adhesives on an elastomer very difficult, since many of the adhesives will achieve substrate failure, rendering it impossible to make performance comparisons. Another major disadvantage to using the lap shear test method is that elastomers will deform more readily than metal as a result of their lower modulus. This results in severe part deformation which introduces peel and cleavage forces on the joint. While this cannot be avoided while testing elastomers, especially under high loads, providing a rigid support for the rubber can minimize this effect. For this testing, the rubber samples were bonded to steel lap shears to provide this rigid support.

Proper selection of the joint overlap can also give bond strength results which more accurately reflect the adhesive bond strength. When testing flexible materials in a lap joint, it is desirable to minimize the overlap to produce as uniform a stress distribution as possible over the bond area. Due to the flexibility of elastomeric materials, stresses on a lap joint are concentrated on the leading edge of the bonded assembly. As a result, when the overlap length is increased, the measured bond strength appears to drop. This occurs because the area of the joint increases, but the force that the joint can withstand does not increase proportionately, since it is still concentrated on the leading edges of the joint. Through experimentation, it was found that decreasing the overlap below 0.25 in. did not significantly increase the measured bond strength. As a result, it was concluded that the stress distribution over this bond area was sufficiently uniform to use for comparative testing.

The flexibility and low tensile strength inherent in elastomeric materials make it difficult to design a test specimen which will omit peel forces and not experience substrate failure at low loadings. This is particularly difficult when the test specimen must be compatible with a large-scale test program; that is, it must be amenable to consistent assembly in large numbers. The test assembly which was selected to address these concerns in this test program is shown in Figure 1.

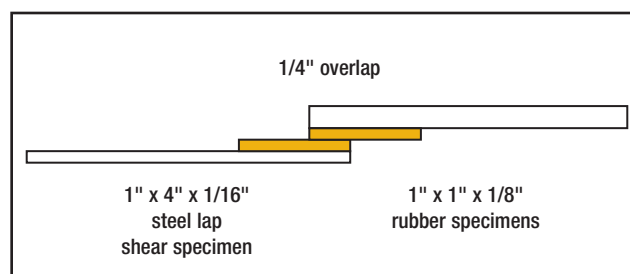


FIGURE 1 Rubber Bonding Test Specimen

Limitations

While the bond strengths in this guide give a good indication of the typical strengths that can be achieved with many elastomers, as well as the effect of many fillers and additives, they also face several limitations. For example, the additives and fillers were selected because they were believed to be representative of the most commonly used additives and fillers. There are, however, many types of each additive and filler produced by many different companies, as well as different types of the same additives and/or fillers. These additives and fillers may not influence the bondability of an elastomer consistently. In addition, the additives and fillers were tested individually in this guide. Consequently, the effect of interactions between these different fillers and additives on the bondability of materials could not be determined.

Another consideration that must be kept in mind when using this data to select an adhesive/elastomer combination is how well the test method will reflect the stresses that an adhesively bonded joint will see in "real world" applications. Adhesively bonded joints are designed to maximize tensile and compressive stresses, and to minimize peel and cleavage stresses. The optimum adhesive joint will have a much larger magnitude of the former two stresses than of the latter two. Thus, the shear strength of an adhesive is generally most critical to adhesive joint performance. However, since all adhesive joints will experience peel and cleavage stresses to some degree, their effects should not be disregarded.

Finally, selecting the best adhesive for a given application involves more than selecting the adhesive which provides the highest bond strength. Other factors such as speed of cure, environmental resistance, thermal resistance, suitability for automation and price will play a large role in determining the optimum adhesive system for a given application. It is suggested that the reader refer to the chapters which explain the properties of the various adhesives in greater detail before choosing the best adhesive for an application.

Test Methods

Substrate Preparation

1. Substrates were cut into 1 in. by 1 in. by 0.125 in. block shear test specimens.
2. All bonding surfaces were cleaned with isopropyl alcohol.

Adhesive Application and Cure Method

Cyanoacrylates

(Loctite® 496™ Super Bonder®, 401™ Prism®, 414™ Super Bonder®, 480™ Prism®, 4204™ Prism®, 4851™ Prism® and 4861™ Prism® Instant Adhesives)

1. Adhesive was applied in an even film to one test specimen.
2. A second test specimen was mated to the first with a 0.5 in. overlap (bond area = 0.5 in.²).
3. The block shear assembly was clamped with two Brink and Cotton No. 1 clamps.
4. The bonded assembly was allowed to cure at ambient conditions for one week before testing.

Cyanoacrylates with Polyolefin Primers

(Loctite® 401™ Prism® Instant Adhesive and Loctite® 770™ Prism® Primer, Loctite® 401™ Prism® Instant Adhesive and Loctite® 793™ Prism® Primer)

1. Polyolefin primer was brushed onto each bonding surface.
2. The polyolefin primer's carrier solvent was allowed to flash off.
3. Adhesive was applied in an even film to one substrate.
4. The second test specimen was mated to the first with a 0.5 in. overlap (bond area = 0.5 in.²).
5. The block shear assembly was clamped with two Brink and Cotton No. 1 clamps.
6. The bonded assembly was allowed to cure at ambient conditions for one week before testing.

Two-Part No-Mix Acrylic

(Loctite® 330™ Depend® Adhesive)

1. Loctite® 7387™ Depend® Activator was sprayed on one test specimen.
2. The activator's carrier solvent was allowed to flash off for more than two minutes.
3. Loctite® 330™ Depend® Adhesive was applied in an even film to a second test specimen.
4. Within 30 minutes, the second test specimen was mated to the first with a 0.5 in. overlap (bond area = 0.5 in.²).
5. The block shear assembly was clamped with two Brink and Cotton No. 1 clamps.
6. The bonded assembly was allowed to cure at ambient conditions for one week before testing.

Light Cure Adhesives

(Loctite® 3105™ Light Cure Adhesive, Loctite® 4307™ Flashcure® Light Cure Adhesive)

1. Adhesive was applied in an even film to one test specimen.
2. A UV transparent, polycarbonate 1 in. by 1 in. by 0.125 in. test specimen was cleaned with isopropyl alcohol.
3. The second test specimen was mated to the first with a 0.5 in. overlap (bond area = 0.5 in.²).
4. The block shear assembly was irradiated (through the polycarbonate) by an ultraviolet light source for 30 seconds to cure the adhesive. The ultraviolet light source used was a Fusion UV Curing System, equipped with an H-bulb having an irradiance of approximately 100 mW/cm² @ 365 nm.
5. The assembly was left at ambient conditions for one week prior to testing.

Block Shear Test Method

1. Assemblies were tested on an INSTRON 4204 mechanical properties tester, equipped with a 50 kN load cell, and a pull speed of 0.05 in./minute.
2. Five replicates of each assembly were tested.

Two-Part Static Mix Adhesives

(Loctite® E-00CL™ Hysol® Epoxy Adhesive, Loctite® E-90FL™ Hysol® Epoxy Adhesive, Loctite® E-30CL Hysol® Epoxy Adhesive, Loctite® E-20HP™ Hysol® Epoxy Adhesive, Loctite® E-40FL™ Hysol® Epoxy Adhesive, Loctite® 3032™ Adhesive, Polyolefin Bonder, Loctite® H3000™ Speedbonder™ Structural Adhesive, Loctite® H4500™ Speedbonder™ Structural Adhesive, Loctite® Fixmaster® Rapid Rubber Repair, Loctite® Fixmaster® Epoxy)

1. The adhesive was dispensed onto the end of one lapshear through an appropriate static mixing nozzle to achieve thorough mixing of the two adhesive components.
2. A second lapshear was mated to the first with an overlap area of 0.5 in.².
3. The mated assembly was clamped with two clamps that exerted a clamping force of approximately 20 lb.
4. The bonded assembly was allowed to cure for one week at ambient conditions before conditioning and testing.

One-Part Heat Cure Epoxy Adhesive

(Loctite® E-214HP™ Hysol® Epoxy Adhesive)

1. Adhesive was applied in an even film to the end of one lapshear.
2. A second lapshear was mated to the first with an overlap area of 0.5 in.².
3. The mated assembly was clamped with two clamps that exerted a clamping force of approximately 20 lb.
4. The clamped assembly was heated at 350°F (177°C) for one hour.
5. The assembly was left at ambient conditions for one week prior to conditioning and testing.

Moisture Cure Products

(Loctite® Superflex™ 595™ RTV, Loctite® 5900® Flange Sealant, Loctite® 3631™ Hysol® Hot Melt Adhesive)

1. Adhesive was applied in an even film to the end of one lap shear.
2. A short length of 10 mil thick wire was embedded in the sealant to induce a 10 mil gap between the bonded lap shears (except for Loctite® 3631™ Hysol® Hot Melt Adhesive).
3. A second lapshear was mated to the first with an overlap area of 0.5 in.².
4. The mated assembly was clamped with two clamps that exerted a clamping force of approximately 20 lb.
5. The mated assembly was allowed to moisture cure for one week prior to conditioning and testing.

Hot Melt Products

(Loctite® 7804™ and 1942™ Hysol® Hot Melt Adhesives)

1. The adhesive was heated to its dispense temperature in the appropriate hot melt dispenser.
2. Adhesive was applied in an even film to the end of one lapshear.
3. A second lapshear was mated to the first with an overlap area of 0.5 in.².
4. The mated assembly was clamped with two clamps that exerted a clamping force of approximately 20 lb.
5. The assemblies were left at ambient conditions for one week prior to conditioning and testing.

Index of Trade Names and Acronyms

Trade Name/Acronym	Elastomer Type	Manufacturer/Comment	Page
ACM	Polyacrylate Rubber	Acronym for Elastomer	50
Afpol	Styrene-Butadiene Rubber	CAL Polymers	64
Alcryn	Melt Processible Rubber	DuPont	40
Baypren	Polychloroprene	Bayer	44
BIIR	Halogenated Butyl Rubber	Acronym for Elastomer	36
Blensil	Silicone	General Electric Silicones	62
Breon	Nitrile Rubber	B.P. Chemicals	46
Buna	Styrene-Butadiene Rubber	Bayer	64
Butaclor	Polychloroprene	Enichem Elastomers	44
C-Flex	Styrenic TPE	Concept	66
Chemigum	Nitrile Rubber	Goodyear	46
CIIR	Halogenated Butyl Rubber	Acronym for Elastomer	36
CO	Epichlorohydrin Rubber	Acronym for Elastomer	24
Compo Crepe	Natural Rubber	International Type of NR	42
Copeflex	Styrene-Butadiene Rubber	Coperbo	64
Coperflex	Styrenic TPE	Coperbo	66
CR	Polychloroprene	Acronym for Elastomer	44
CSM	Chlorosulfonated Polyethylene	Acronym for Elastomer	20
Dai-el	Fluorocarbon Rubbers	Daikin	32
Duradene	Styrene-Butadiene Rubber	Firestone	64
Dynaflex	Styrenic TPE	GLS Corporation	66
Ecdel	Copolyester TPE	Eastman	22
ECO	Epichlorohydrin Rubber	Acronym for Elastomer	24
EEA	Ethylene Acrylic Rubber	Acronym for Elastomer	26
Elastosil	Silicone	Wacker Chemical Corporation	62
Elvax	Ethylene-Vinyl Acetate	DuPont	30
Engage	Polyolefin	DuPont Performance Elastomers	54
EPDM	Ethylene Propylene Rubber	Acronym for Elastomer	28
EPM	Ethylene Propylene Rubber	Acronym for Elastomer	28
Epsyn	Ethylene Propylene Rubber	Copolymer Rubber Co.	26
Escorene	Ethylene-Vinyl Acetate	ExxonMobil Chemical	30
Estate Brown Crepe	Natural Rubber	International Type of NR	42
Europrene SOL	Styrenic TPE	Enichem	66
Europrene	Styrene-Butadiene Rubber	Enichem	64
Europrene	Polyacrylate Rubber	Enichem Elastomers America	50
EVA	Ethylene-Vinyl Acetate	Acronym for Elastomer	30
Evazote	Ethylene-Vinyl Acetate	B.P. Chemicals	30
Exxon Bromobutyl	Halogenated Butyl Rubber	ExxonMobil Chemical	36
Exxon Butyl	Butyl Rubber	ExxonMobil Chemical	18
Exxon Chlorobutyl	Halogenated Butyl Rubber	ExxonMobil Chemical	36
FE	Fluorosilicone Rubber	Shinetsu Chemical	34
FKM	Fluorocarbon Rubber	Acronym for Elastomer	32

The trade names mentioned above are the property of the manufacturers listed.

Trade Name/Acronym	Elastomer Type	Manufacturer/Comment	Page
Flat Bark Crepe	Natural Rubber	International Type of NR	42
Fluorel	Fluorocarbon Rubber	3M	32
FSE	Fluorosilicone Rubber	General Electric	34
FVMQ	Fluorosilicone Rubber	Acronym for Elastomer	34
GCO	Epichlorohydrin Rubber	Acronym for Elastomer	24
GECO	Epichlorohydrin Rubber	Acronym for Elastomer	24
Geolast	Thermoplastic Vulcanizate	Advanced Elastomer Systems	68
GPO	Poly(propylene oxide) Rubber	Acronym for Elastomer	56
Hercuprene	Polyolefin	J-Von	54
H-NBR	Hydrogenated Nitrile Rubber	Acronym for Elastomer	38
HSN	Hydrogenated Nitrile Rubber	Acronym for Elastomer	38
Humex	Nitrile Rubber	Huels Mexicanos	46
Hycar	Polyacrylate Rubber	B.F. Goodrich	50
Hydrin	Epichlorohydrin Rubber	Zeon Chemicals	24
Hypalon	Chlorosulfonated Polyethylene	DuPont	20
HyTemp	Polyacrylate Rubber	Zeon Chemicals	50
Hytrel	Copolyester TPE	DuPont	22
IIR	Butyl Rubber	Acronym for Elastomer	18
IR	Polyisoprene	Acronym for Elastomer	52
Isolene	Polyisoprene	Hardman	52
Kalrez	Fluorocarbon Rubber	DuPont	32
Kraton	Styrene-Butadiene Rubber	Shell Chemical	64
Kraton	Styrenic TPE	Shell Chemical	66
K-Resin	Styrenic TPE	Chevron Phillips	66
Krynac	Nitrile Rubber	Polysar International	46
Lomod	Copolyester TPE	General Electric	22
LP	Polysulfide Rubber	Morton Thiokol	58
LS	Fluorosilicone Rubbers	Dow Corning	34
MPR	Melt Processible Rubber	Acronym for Elastomer	40
MQ	Silicone Rubber	Acronym for Elastomer	62
Natsyn	Polyisoprene	Goodyear	52
NBR	Nitrile Rubber	Acronym for Elastomer	46
Neoprene	Polychloroprene	DuPont	44
Nipol	Polyisoprene	Goldsmith & Eggleton	52
Nipol	Nitrile Rubber	Nippon Zeon	46
Nordel	Ethylene Propylene Rubber	DuPont	28
NR	Natural Rubber	Acronym for Elastomer	42
Nysen	Nitrile Rubber	Copolymer Rubber	46
Pale Crepe	Natural Rubber	International Type of NR	42
Parel	Poly(propylene oxide) Rubber	Zeon Chemicals	56
Pebax	Polyether Block Amide	Arkema Inc.	48
Perbunan	Nitrile Rubber	Mobay	46
Plioflex	Styrene-Butadiene Rubber	Goodyear	64
Pliolite	Styrene-Butadiene Rubber	Goodyear	64

The trade names mentioned above are the property of the manufacturers listed.

Trade Name/Acronym	Elastomer Type	Manufacturer/Comment	Page
PMQ	Silicone Rubber	Acronym for Elastomer	62
POE	Polyolefin	Acronym for Elastomer	54
Polysar EPDM	Ethylene Propylene Rubber	Bayer	28
Polysar Bromobutyl	Halogenated Butyl Rubber	Bayer	36
Polysar Butyl	Butyl Rubber	Bayer	18
Polysar Chlorobutyl	Halogenated Butyl Rubber	Bayer	36
Pure Smoked Blanket Crepe	Natural Rubber	International Type of NR	42
PVMQ	Silicone Rubber	Acronym for Elastomer	62
Ribbed Smoked Sheet	Natural Rubber	International Type of NR	42
Rimflex	Styrenic TPE	Synthetic Rubber Technologies	66
Riteflex	Copolyester TPE	Hoescht Celanese	22
Royalene	Ethylene Propylene Rubber	Uniroyal Chemical	28
Royaltherm	Silicone-Modified EPDM	Uniroyal Chemical	60
Santoprene	Thermoplastic Vulcanizate	Advanced Elastomer Systems	68
Sarlink	Polyolefin	DSM Thermoplastic	54
SBR	Styrene-Butadiene Rubber	Acronym for Elastomer	64
S-B-S	Styrenic TPE	Acronym for Elastomer	66
S-EB-S	Styrenic TPE	Acronym for Elastomer	66
Silastic	Silicone	Dow Corning STI	62
S-I-S	Styrenic TPE	Acronym for Elastomer	66
SKI-3	Polyisoprene	Alcan	52
Solprene	Styrene-Butadiene Rubber	Housmex	64
Solprene	Styrenic TPE	Housmex	66
Stereon	Styrene-Butadiene Rubber	Firestone	64
Synthetic Natural Rubber	Polyisoprene	Common Name for IR	52
Tecnoflon	Fluorocarbon Rubber	Ausimont	32
Therban	Hydrogenated Nitrile Rubber	Bayer	38
Thick Blanket Crepe	Natural Rubber	International Type of NR	42
Thin Brown Crepe	Natural Rubber	International Type of NR	42
Thiokol	Polysulfide Rubber	Morton Thiokol	58
TPV	Thermoplastic Vulcanizate	Acronym for Elastomer	68
Ultrathene	Ethylene-Vinyl Acetate	Quantum Chemicals	30
Vamac	Ethylene Acrylic Rubber	DuPont	26
Vistalon	Ethylene Propylene Rubber	ExxonMobil Chemical	28
Viton	Fluorocarbon Rubbers	DuPont	32
VMQ	Silicone Rubber	Acronym for Elastomer	62
XNBR	Nitrile Rubber	Acronym for Elastomer	46
Zetpol	Hydrogenated Nitrile Rubber	Zeon Chemicals	38

The trade names mentioned above are the property of the manufacturers listed.

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Disclaimer

The information contained herein is intended to be used solely as an indicator of the bondability of the evaluated elastomers. The information is believed to be accurate, and is well suited for comparative analysis; however, the testing was performed using a limited number of adhesive lots, elastomer lots, and replicates. Consequently, this makes the information contained herein inappropriate for specification purposes.

All polymeric materials have the potential for swelling or stress cracking when exposed to uncured adhesive, depending on the exposure time, part geometry, stresses and composition variables. Consequently, it is important that the end user evaluate the suitability of the adhesive in his or her process to insure that the adhesive does not detrimentally affect the performance of the plastic or elastomer.

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