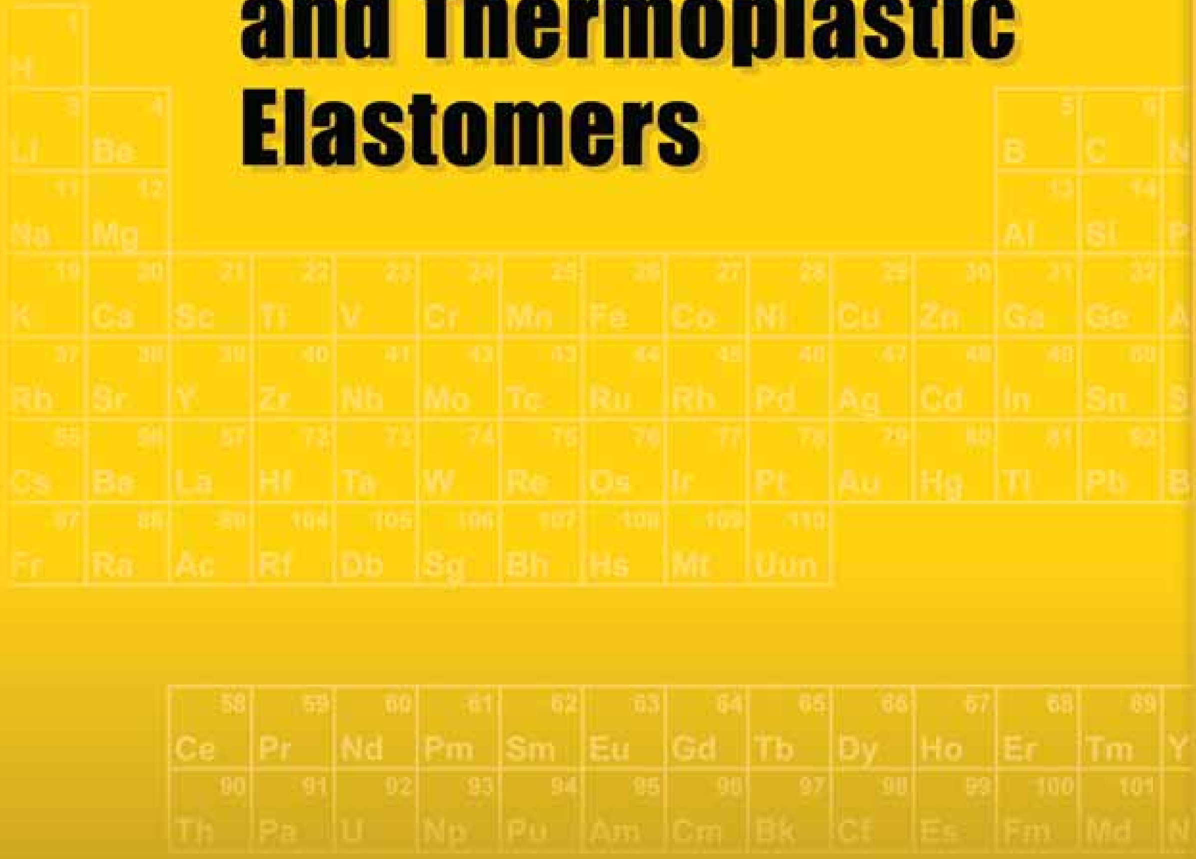
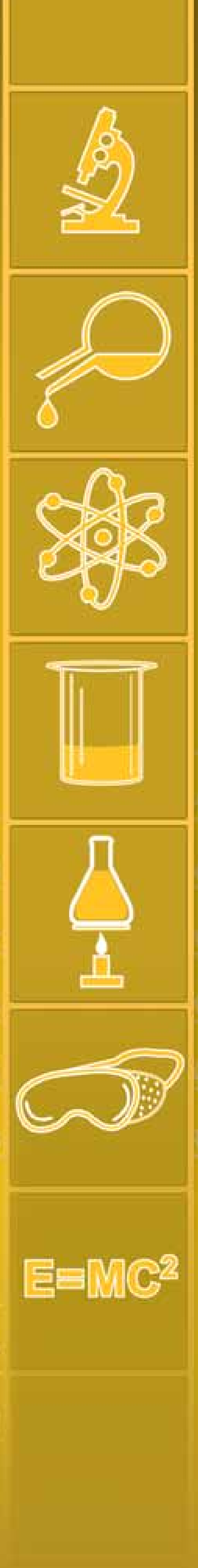
LOCTITE®

The Design Guide for

Bonding Rubber and Thermoplastic Elastomers





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Henkel

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The Problem

From the discovery of natural rubber to the development of modern day thermoplastic elastomers (TPEs), elastomeric materials have found a wide variety of uses that make them an integral part of an industrial society. In a diverse variety of products ranging from automobile tires to lifesaving implantable medical devices, their unique ability to be greatly deformed and return to their original shape fills an important niche in the world of engineering materials. It would be difficult to identify a manufacturing process which does not use elastomers in one form or another.

Elastomeric materials have achieved widespread acceptance due to the virtually limitless combinations of elastomer types, fillers and additives which can be compounded at relatively low costs and processed by a wide variety of methods. This gives end-users the ability to develop specific formulations with properties tailored to their needs. By properly selecting the base elastomer, additives and fillers, as well as the appropriate cure method, the physical, chemical and thermal properties of an elastomer can be made to meet or exceed the performance requirements of almost any application requiring elastomeric properties.

However, while the limitless variety of elastomers is an invaluable asset to a designer selecting an elastomer, it is the designer’s biggest limitation when selecting an adhesive. The countless adhesives available, coupled with the virtually limitless elastomer formulations possible, make it highly unlikely that there will be bond strength data for the specific adhesive/elastomer combination in the designer's application.

The Solution

Bond Strength Information

This guide is designed to indicate the bondability of the 26 most commonly used families of elastomers. This was accomplished using two approaches. The majority of elastomers which were evaluated were compounded specifically to determine the effect different additives and fillers had on the bondability of these materials. Once the designer identifies the elastomer formulations containing the same fillers and additives that are desired to be bonded, the adhesives can then be pinpointed which performed best on those materials. Although this will probably not tell the designer the exact bond strength that will be achieved by that specific adhesive on that specific material, it will give the designer a general idea of what bond strengths can be achieved. For the other elastomers, bond strength testing was performed on commercially available grades which were selected to represent each major category of the elastomer based on the major end-use applications, and/or the chemical structure of that elastomer.

Adhesive Information

An adhesive cannot be selected for an application solely on the basis of bond strength information. Other factors such as the cure speed, environmental resistance, thermal resistance, and suitability for automation of an adhesive will play a critical role in determining the best adhesive for a specific application. To give a designer insight into these design parameters, an in-depth description of the seven adhesive types, namely cyanoacrylates, no-mix/static mix acrylics, hot melts, epoxies, polyurethanes, silicones and light curing acrylics, has been included in this guide. These adhesive sections contain a general description of each adhesive, a detailed discussion of the chemical structure and cure mechanism of each adhesive, and the benefits and limitations of using each adhesive.

Elastomer Information

Manufacturers may have the flexibility to select the elastomers which are best suited for their applications in terms of performance and bondability. To aid the designer, an in-depth discussion of each of the elastomer types is included. Information covered includes a general description of the elastomer and its properties, as well as a list of trade names, suppliers and typical applications.

Cure Process Effects

For thermoset rubbers, the ultimate bond strength might be improved by stopping the vulcanization process before all cross-linking sites available have been consumed. Stopping the vulcanization process before the rubber has achieved its ultimate modulus will leave unreacted cross-linking sites on the rubber backbone and form a polymer with a lower cross-link density. As a result, the unreacted cross-linking sites may improve bond strength by reacting with the adhesive. In addition, the lower cross-link density of the rubber may facilitate adhesive penetration of the rubber polymer network. To investigate this phenomenon, each of the thermoset rubbers, except the PEBA, was cured to 80% of their ultimate modulus (noted as T80 cure in the adhesive shear strength tables), and tested for bond strength. These results were then compared with those of the control for statistically significant differences.

Bond Design Information

Finally, a manufacturer may have a design in which he desires to incorporate an adhesively bonded joint. To effectively design that joint, the designer must know which parameters are critical to the bond strengths achieved by a bonded joint and the effect that changing these parameters will have. A bond design section which reviews the basics of designing an adhesively bonded single lap joint is included in an attempt to give the designer insight into this area. Although most “real world” bond geometries are more complex than single lap joints, this information can be extrapolated as a general indicator of the effects caused by changing bond geometries.

Cyanoacrylate Adhesives

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, cyanoacrylates cure rapidly to form rigid thermoplastics with excellent adhesion to most substrates.

One of the benefits cyanoacrylates offer is the availability of a wide variety of specialty formulations with properties tailored to meet particularly challenging applications. For example, rubber-toughened cyanoacrylates offer high peel strength and impact resistance to complement the high shear and tensile strengths characteristic of cyanoacrylates. Thermally resistant cyanoacrylates are available which offer excellent bond strength retention after exposure to temperatures as high as 250°F for thousands of hours. Moreover, "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 cyanoacrylate. In some cases, the use of a general-purpose cyanoacrylate adhesive was hampered by the appearance of a white haze around the bond line. This phenomenon is known as "blooming" or "frosting" and occurs when cyanoacrylate monomer volatizes, reacts with moisture in the air, and settles on the part. To eliminate this problem, "Low Odor/Low Bloom" cyanoacrylates were developed. They have a lower vapor pressure than standard cyanoacrylates and therefore are less likely to volatize. Ultraviolet curing (UV) cyanoacrylates are the latest advancement in cyanoacrylate technology. UV cyanoacrylates utilize proprietary photoinitiators to allow cyanoacrylates to surface cure in seconds when exposed to ultraviolet or visible light of the appropriate wavelength. Light Cure Technology makes cyanoacrylates cure even faster, overcome blooming, and limiting or eliminating stress cracking. While advances in cyanoacrylate formulating technology have played a key role in offering additional benefits to the end user, there have also been important developments in cyanoacrylate primer and accelerator technology.

Accelerators speed the cure of cyanoacrylate adhesives and are primarily used to reduce cure/fixture times, to cure fillets on bond lines and/or excess adhesive. Accelerators consist of an active ingredient dispersed in a solvent. The accelerator is typically applied to a substrate surface prior to the application of the adhesive. Once the carrier solvent has evaporated, the cyanoacrylate can immediately be applied and its cure initiated by the active species that the accelerator has left behind. Depending on the particular solvent and active species present in the accelerator, the solvent can require 10 to 60 seconds to evaporate, and the active species can have an on-part life ranging from 1 minute to 72 hours. Accelerator can also be sprayed over a drop of free cyanoacrylate to rapidly cure it. This technique has been widely used for wire tacking in the electronics industry.

Another benefit offered by cyanoacrylates is the availability of primers which enable them to form strong bonds with polyolefins and other difficult-to-bond plastics such as fluoropolymers and acetal resins. Like the accelerators, polyolefin primers consist of an active ingredient dispersed in a solvent. Once the carrier solvent has evaporated, the surface is immediately ready for bonding, and the primer will have an on-part life ranging from minutes to hours. Depending on the plastic, bond strengths up to 20 times the unprimed bond strength can be achieved.

Chemistry

Cyanoacrylate adhesives are cyanoacrylate esters, of which methyl and ethyl cyanoacrylates are the most common. Cyanoacrylates undergo anionic polymerization in the presence of a weak base, such as water, and are stabilized through the addition of a weak acid. When the adhesive contacts a surface, the water present on the surface neutralizes the acidic stabilizer in the adhesive, resulting in the rapid polymerization of the cyanoacrylate.

Advantages

- One-part system
- Solvent-free
- Rapid room temperature cure
- Excellent adhesion to many substrates
- Easy to dispense in automated systems
- Wide range of viscosities available
- Excellent bond strength in shear and tensile mode
- Primers available for polyolefins and difficult to bond plastics
- UV/Visible cure formulas available

Disadvantages

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

Epoxy Adhesives

General Description

Epoxy adhesives are typically two-part systems (resin and hardener) which cure at room temperature, although one-part pre-mixes which utilize a heat cure are also available, as are UV curable one and two component epoxies. The two components react stoichiometrically, so maintaining proper mix ratio is important to ensure consistent performance. Upon mixing, the curing reaction of the epoxy can release a great deal of heat and result in a significant temperature rise in the adhesive. In some applications, such as deep section potting, this heat rise can be sufficient to char the adhesive. Upon cure, epoxies form tough, rigid thermoset polymers with high adhesion to a wide variety of substrates and good environmental resistance. The viscosities of epoxy adhesives can range from a few thousand centipoise to thixotropic pastes.

The wide variety of chemical species that can react with the epoxide end group and the inherent stability of two-part adhesive systems lead to a wide variety of epoxy formulations available to the end-user. The performance properties of epoxies can be tailored to specific needs through a wide variety of techniques. Epoxy adhesives are typically rigid and formulating techniques must be employed to produce flexible epoxies. These techniques include the use of non-reactive plasticizers, the incorporation of rubber into the epoxy and the use of epoxy resins with flexible backbones. The properties of epoxy adhesives are also varied through the use of fillers. For example, quartz fillers can impart improved impact resistance, ceramic fillers can offer improved abrasion resistance, and silver can be used to produce epoxies which are electrically conductive.

Chemistry

Epoxy adhesives polymerize to form thermoset polymers when covalent bonds between the epoxy resin and the hardener are formed through the reaction of the epoxide ring with the ring-opening species on the hardener. Amines, amides, mercaptans, and anhydrides are some of the types of hardener that are commonly used. Catalysts can be employed to accelerate the reaction rate between the epoxy resin and hardener. In addition, heat will also accelerate the reaction. If heat is used to accelerate the cure of the epoxy, the increase in temperature can result in a drop of viscosity and an increased flow of the adhesive. In addition, curing the epoxy at a higher temperature will usually result in a stiffer material with a higher cross-link density and glass transition temperature.

Advantages

- High cohesive strength
- High adhesion to a wide variety of substrates
- Good toughness
- Cure can be accelerated with heat
- Excellent depth of cure
- Good environmental resistance

Disadvantages

- Two-part systems require mixing
- One-part systems require heat cure
- Long cure and fixture times
- Limited pot life and work time
- Exotherm may be problematic

Hot Melt Adhesives

General Description

Hot melt adhesives are one-part solvent-free thermoplastic adhesives that are solid at room temperature and a low to medium viscosity (750-10,000 cP) adhesive at dispense temperatures (typically greater than 195°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 latest advancement in hot melt technology is the reactive polyurethane adhesive (PUR). PURs initially behave like standard hot melts. That is, heat is added to the soften the urethane prepolymer and it is dispensed hot. Once the PUR cools, it reacts with moisture to cross-link into a tough thermoset polyurethane adhesive that cannot be remelted by adding heat.

Chemistry

Chemistries include ethylene vinyl acetate (EVA), polyolefin and polyamide based hot melts. EVA hot melts are the "original" hot melt and are thought of as the low cost, low performance hot melt. EVAs provide good adhesion to steel aluminum, rubber, and many plastics. Typical EVA hot melt applications include box and carton sealing. EVA hot melts can be formulated to carry a FDA approval for use in food packaging. Out of all available hot melts, EVAs typically have the poorest high 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-94V-0 rating (flame resistance). Polyamide hot melts have a tendency to absorb moisture from the air and require special packaging and storage considerations.

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

Reactive polyurethanes are supplied as an urethane prepolymer, behaving much like a standard hot melt until it cools. Once the PUR cools, it reacts with moisture over time (a few days) to cross-link into a tough thermoset polyurethane.

Advantages

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

Disadvantages

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

Light Curing Acrylic Adhesives

General Description

Light curing acrylic adhesives are supplied as one-part, solvent-free liquids with viscosities ranging from 50 cP to thixotropic gels. Upon exposure to ultraviolet or visible light of the proper intensity and spectral output, these adhesives cure rapidly to form thermoset polymers with excellent adhesion to a wide variety of substrates. The cure times of light curing acrylic adhesives are dependent on many parameters, however, cure times of 2 to 60 seconds are typical and cure depths in excess of 0.5" (13 mm) are possible. Formulations of light curing acrylic adhesives are available which vary in cured properties from very rigid, glassy materials to soft, flexible elastomers.

Light curing acrylic adhesives cure rapidly on demand, which minimizes work in progress and offers virtually unlimited repositioning time. In addition, the wide range of viscosities available facilitates the selection of a product for automated dispensing. These qualities make light curing acrylics ideally suited for automated bonding processes.

Chemistry

Light curing acrylic adhesives are composed of a blend of monomers, oligomers, and polymers containing the acrylate functionality to which a photoinitiator is added. Upon exposure to light of the proper intensity and spectral output, the photoinitiator decomposes to yield free radicals. The free radicals then initiate polymerization of the adhesive through the acrylate groups to yield a thermoset polymer.

When the adhesive is cured in contact with air, the free radicals created by the decomposition of the photoinitiator can be scavenged by oxygen prior to initiating polymerization. This can lead to incomplete cure of the adhesive at the adhesive/oxygen interface, yielding a tacky surface. To minimize the possibility of forming a tacky surface, the irradiance of light reaching the adhesive can be increased, the spectral output of the light source can be matched to the absorbance spectrum of the photoinitiator, and/or the adhesive can be covered with an inert gas blanket during cure.

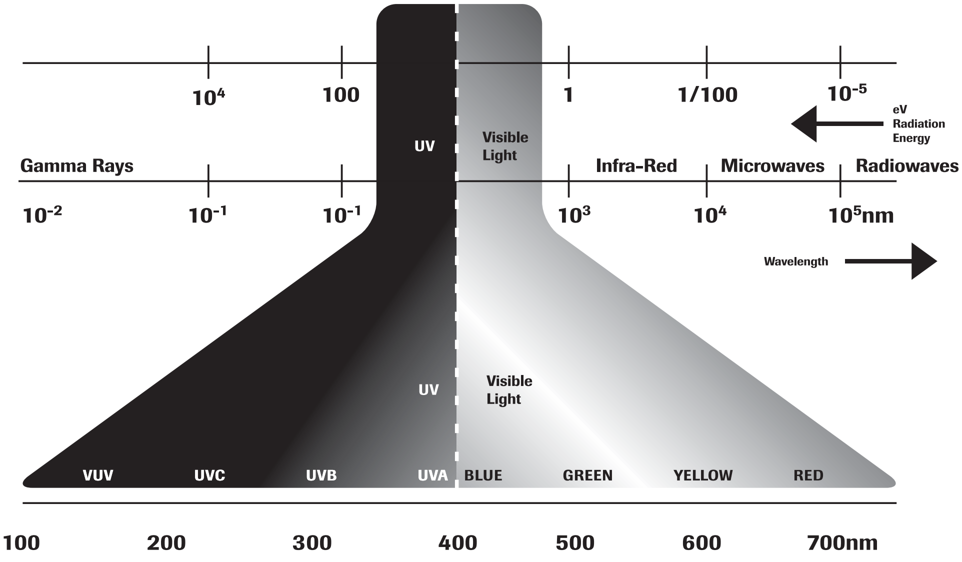
Advantages

- Cure on demand
- Good environmental resistance
- Wide range of viscosities available
- Solvent-free
- Good gap filling
- One part
- Dispensing is easily automated
- Clear bond lines
- Rapid fixture and complete cure
- Wide range of physical properties
- UV/Visible cure systems available
- Fluorescent dyes can be added to ease inspection/detection

Disadvantages

- Light must be able to reach bond line
- Oxygen can inhibit cure
- Equipment expense for light source
- Ozone created by high intensity light source must be vented

The Electromagnetic Spectrum



Polyurethane Adhesives

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 which makes them very tough, durable adhesives.

Polyurethanes 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"(9.5 mm). Two-part systems, on the other hand, offer unlimited depth of cure.

Chemistry

One-part polyurethane adhesives can react with moisture to polymerize. Another cure mechanism involves the evolution of species that inhibit the cure of the polyurethane. In either case, cure is dependent on a chemical species diffusing through the polyurethane matrix, so the depth of cure is limited. Two-part polyurethanes, which generally cure through the reaction of an isocyanate and a polyol, avoid this limitation and offer superior depth of cure. In either case, the polyurethane polymer forms rigid and soft domains that give the polymer its balance of flexibility and high strength.

Advantages

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

Disadvantages

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

Silicone Adhesives

General Description

Silicone adhesives are typically supplied as one-part systems which 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. Silicones have good adhesion to many substrates, but are limited in their utility as structural adhesives by their low cohesive strength.

Silicone adhesives are typically cured via reaction with ambient humidity, although formulations are also available which can be cured by exposure to ultraviolet light of the proper irradiance and spectral output. Since the cure of moisture curing silicones is dependent on moisture diffusing through the silicone matrix, the cure rate is strongly affected by the ambient relative humidity. Moisture curing silicones have a maximum depth of cure which is limited to 0.375 - 0.500". At 50% RH, moisture cure silicones will cure to a tack free surface in 5-60 minutes depending on the type used. Complete cure through thick sections of silicone can take up to 72 hours. It should be noted that adhesive strength may continue to develop for 1-2 weeks after the silicone has been applied. This occurs because the reaction between the reactive groups on the silicone polymer and the reactive groups on the substrate surface is slower than the cross-linking reaction of the silicone groups with themselves.

Moisture curing silicones are categorized by the by-product given off as they cure with moisture. For example, acetoxy cure silicones give off acetic acid. Alkoxy cure silicones give off alcohols, typically methanol or ethanol, and oxime curing silicones evolve oxime. Acetoxy cure silicones are known for their ability to cure rapidly and develop good adhesion to many substrates. Their largest limitation is the potential for the by-product acetic acid to promote corrosion. Alkoxy cure silicones, on the other hand, do not have this limitation because the alcohol by-products are non-corrosive. This makes them well suited for electronic and medical applications where the acetic acid could be a problem. Unfortunately, alkoxy silicones typically have lower adhesion and take longer to cure than acetoxy silicones. Oxime evolving silicones offer cure speeds and adhesion which rivals, and in some cases surpasses, that of acetoxy cure silicones. However, the oxime they evolve will not corrode ferric substrates, although it can stain copper or brass. Consequently, oxime silicones have found widespread use in automotive gasketing applications. The chief limitation of all moisture curing silicones is the difficulty associated with accelerating the cure rate. This concern was addressed through the development of UV cure silicones.

Ultraviolet light curing silicones generally also have a secondary moisture cure mechanism to insure that any silicone which is not irradiated with ultraviolet light will still cure. Upon exposure to ultraviolet light of the proper irradiance 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 portion of the silicone, full bond strength can take 1-2 weeks to develop. The adhesive strength achieved by a UV/moisture cure silicone is typically a function of the type of moisture cure used. Silicones with a secondary acetoxy cure show good bond strength while those with a secondary alkoxy cure are lower.

Chemistry

Silicone formulations are available which can be cured through moisture, heat, mixing two components and exposure to ultraviolet light. The silicones used for adhesives are typically the one-part moisture curing and UV curing silicones. All silicones have a chemical backbone made up of silicone to oxygen bonds, known as siloxane bonds. It is the high energy of this bond that gives silicones their unique high temperature performance properties.

Advantages

- One-part systems available
- Solvent free
- Room temperature cure
- Excellent adhesion to many substrates
- Extremely flexible
- UV Curing formulations available

Disadvantages

- Poor cohesive strength
- Moisture cure systems have limited depth of cure
- Swelled by non-polar solvents

No-Mix and Static Mix Acrylic Adhesives

General Description

Acrylic adhesives consist of a resin and an activator/hardener. The resin component is a solvent-free, high-viscosity liquid, typically in the range of 10,000 to 100,000 cP, while the activator component can be a solvent dispersion of the cure catalyst (no-mix) or a high viscosity mix of the cure catalyst and performance additives.

If the carrier solvent present in the activator solvent dispersion is undesirable, the pure catalyst is also available as a solvent-free activator. However, when using a solvent-free activator, the amount of activator applied must be tightly controlled, as excessive activator will detrimentally affect the performance of the adhesive. With static-mix acrylics, the viscosity of the resin and hardener are formulated to be very similar in order to ensure good mixing through the static mix tip. A primer may also be incorporated into the resin or hardener in order to enhance the bond strength on some substrates.

The resin base of no-mix acrylic adhesives can also be heat cured. A typical heat cure cycle is ten minutes at 300°F (149°C). Heat curing normally offers higher bond strengths and shorter cure times. However, heating the adhesive lowers the resin's viscosity and may result in some adhesive flow out of large gaps. In some instances, it is desired to use a combination of these two cure methods, fixturing the assembly with activator prior to heat cure.

Application Method

When an activator is used, the adhesive is cured in the following manner:

- ✓ The resin is applied to one of the substrate surfaces.
- ✓ The activator is typically applied to the other surface.
- ✓ The activator's carrier solvent is allowed to flash off.
- ✓ The two surfaces are mated together.
- ✓ The catalyst from the activator then initiates the polymerization of the resin.

Typically, these systems develop fixture strength in two minutes and full strength in 4-24 hours. The activator serves only as a catalyst for the polymerization of the resin, so when using an activator, the ratio of activator to resin is not critical. However, this is not the case for solventless activators, because the activator is so concentrated that excess activator can prevent the adhesive from forming an intimate bond with the substrate. Since polymerization is initiated at the interface between the activator and resin, the cure depth is limited. Typically, the maximum cure-through-depth is 0.30" (0.76 mm) from this interface.

Static-mix acrylic adhesives are dispersed using hand held applicators and the appropriate static-mix tip (typically 24 elements). Static-mix acrylics offer unlimited depth of cure but due to the exothermic nature of the reaction, caution must be exercised. The exotherm may deform temperature sensitive substrates or cause "read-through" on the opposite surface.

Chemistry

The resin base consists of an elastomer dissolved in acrylic monomers. Peroxides are then blended in to provide the resin with a source of free radicals. The elastomers form a rubbery phase which gives the adhesive its toughness, and the acrylic monomers form the thermoset polymer matrix which gives the adhesive its environmental resistance and strength.

The type of cure catalyst used in the activator will vary depending on the cure chemistry of the adhesive. In no-mix acrylics, the catalyst(s) are often diluted in a solvent, although in some cases, they are supplied in solventless formulations. In static-mix acrylics the catalyst is blended in with a portion of the elastomer in order to match the viscosity of the resin. Upon contact of the cure catalyst(s) with the resin base, the peroxide in the resin base decomposes to yield free radicals. These radicals then initiate polymerization through the acrylate groups on the monomer in the resin base.

Advantages

- No mixing required (no-mix acrylics only)
- Good environmental resistance
- High peel and impact strength
- Bonds to lightly contaminated surfaces
- Fast fixture and cure
- Room temperature cure
- Good adhesion to many substrates
- Cure can be accelerated with heat

Disadvantages

- Higher viscosity systems can make automated dispensing difficult
- Activator may contain solvents (no-mix acrylics only)
- Unpleasant odor
- Limited cure-through depth (no-mix acrylics only)
- High exotherm (static-mix acrylics)
- Short worklife of some formulations (static-mix acrylics)

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 their 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.

How To Use The Bonding Chapters

Ⓐ Trade Names

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

Ⓑ Typical Applications

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

Ⓒ General Description

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

Ⓓ Relative Adhesive Performance

Provides relative ranking of bond strengths achieved with adhesives tested.

Ⓔ General Properties

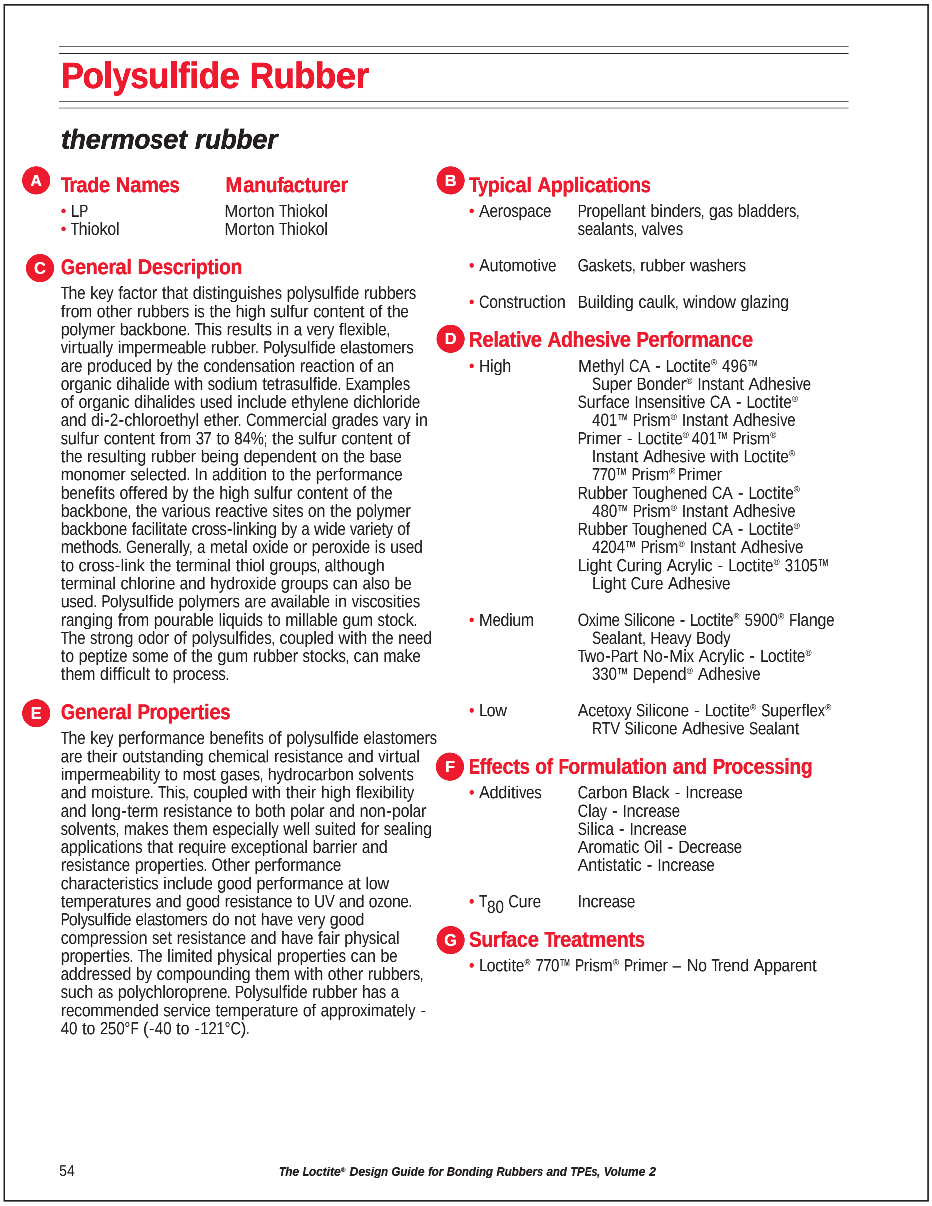
Describes the key characteristics of each elastomer.

Ⓕ Effects of Formulation and Processing

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

Ⓖ Surface Treatments

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



Polysulfide Rubber

thermoset rubber

Ⓐ Trade Names

Trade Names	Manufacturer
• LP	Morton Thiokol
• 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
• T_{80} Cure	Increase

Ⓖ Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

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How To Use The Adhesive Shear Strength Table

Ⓐ 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.

Ⓑ Elastomer Description

The elastomer formulations were selected in two ways. For five of the twenty-five elastomers evaluated, commercially available grades were evaluated which were selected to represent each of the major categories of that elastomer. The twenty 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.

Ⓒ Notes

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

Ⓓ Shading

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

Ⓔ 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".

Ⓕ 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.

T80 Cure (not shown)

Stopping the polymerization process before completion could theoretically increase its bondability for two reasons. The first reason being that the lower cross-link density of the polymer allows for increased diffusion of the adhesive into the rubber. The second reason being 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.

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Styrene Butadiene TPE

Kraton by Shell Chemical and C-Flex by Concept Polymer Technology

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
A Control: Kraton G 1650 S-EB-S		100 phr	290 2.00	>510∆ >3.52∆	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 N-550	100 phr 100 phr	530 3.65	>810∆ >5.59∆	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 Dixie Clay	100 phr 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	>1090∆ >7.52∆
Silica	Kraton G 1650 Hi Sil 233	100 phr 50 phr	440 3.03	>550∆ >3.52∆	>550∆ >3.79∆	390 2.69	510 3.52	30 0.21	60 0.41	390 2.69	>660∆ >4.55∆
Whiting	Kraton G 1650 Precipitated Whiting	100 phr 100 phr	50 0.34	180 1.24	>200∆ >1.35∆	40 0.28	40 0.28	30 0.21	30 0.21	30 0.21	180 1.24
Aromatic Oil	Kraton G 1650 Aromatic Oil	100 phr 100 phr	140 0.97	>300∆ >2.07∆	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 Naphthenic Oil	100 phr 100 phr	80 0.55	300 2.07	>370∆ >2.55∆	90 0.62	80 0.55	<10 <0.07	50 0.34	40 0.28	170 1.17
Plasticizer	Kraton G 1650 Dioctyl Phthalate	100 phr 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 Carnauba Wax	100 phr 10 phr	290 2.00	510 3.52	370 2.55	390 2.69	230 1.59	90 0.622	110 0.76	210 1.45	410 2.83
EVA Blend	Kraton G 1650 EVA	100 phr 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 Polyethylene	100 phr 100 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 Armostat 550	100 phr 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	>240∆ >1.65∆	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		100 phr	160 1.10	280 1.93	370 2.55	230 1.59	230 1.59	50 0.34	170 1.17	130 0.90	>430∆ >2.96∆
PS Blend	Kraton D 1101 Polystyrene	100 phr 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

B

D

E

F

C **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.

∆ = 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

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*This format is applicable to all substrates excluding PEBA (pg. 44-45).

Butyl Rubber (IIR)

thermoset rubber

Trade Names	Manufacturer
• Exxon Butyl	Exxon Chemical
• Polysar Butyl	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
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – Increase

ADHESIVE SHEAR STRENGTH

(psi)
(MPa)

Butyl Rubber

Butyl Rubber by Exxon Chemical

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 165 100 phr 1.2% Unsaturation	>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
T_{80} 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 Butyl 065 100 phr 0.8% Unsaturation	▒ >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 Butyl 268 100 phr 1.6% Unsaturation	>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	Manufacturer
• Hypalon	DuPont Dow 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
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – Increase

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Chlorosulfonated Polyethylene

Hypalon by DuPont Dow Elastomers

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	190 1.31	270 1.86	▧ 50 0.34	120 0.83	▧ 110 0.76	▧ 180 1.24
Low Chlorine	Hypalon 45 24% Chlorine	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	Hypalon 48 43% Chlorine	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 N-990	100 phr 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 Calcium Carbonate	100 phr 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 Dixie Clay	100 phr 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 Hi Sil 233	100 phr 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 Titanium Dioxide	100 phr 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 Sundex 790	100 phr 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 Calsol 8240	100 phr 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 AC617A	100 phr 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 Armostat 550	100 phr 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

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

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

Copolyester TPE

thermoplastic elastomer

Trade Names	Manufacturer
• Ecdel	Eastman
• Hytrel	DuPont
• Lomod	GE
• Riteflex	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 2 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 3000 to 8000 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

(psi)

(MPa)

Copolyester TPE

Hytrel by DuPont

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
Hytrel G5544	100 phr	**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**
Hytrel 7246	100 phr	**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**

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 Required

Epichlorohydrin Rubber (CO, ECO, GCO, GECO)

thermoset rubber

Trade Names	Manufacturer
• Hydrin	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
• T_{80} Cure	Increase CA

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH

(psi)
(MPa)

Epichlorohydrin Rubber

Hydrin by Zeon Chemical Corporation

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 Homopolymer		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
T_{80} Cure Cured to 80% of Modulus at Full Cure	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 ECO copolymer	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 GECO Terpolymer	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 N-550	100 phr 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 Calcium Carbonate	Hydrin H 50 phr	100 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 Dioctyl Phthalate	100 phr 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

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

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

Ethylene Acrylic Rubber (EEA)

thermoset rubber

Trade Names	Manufacturer
• Vamac	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
• T_{80} Cure	Increase

Surface Treatments

- Loctite® 770™ Prism® Primer – Increase

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Ethylene Acrylic Rubber

Vamac by DuPont

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		100 phr	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
T_{80} Cure Cured to 80% of Modulus at Full Cure	Vamac B-124	100 phr	>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	Vamac B-124 N-550	100 phr 25 phr	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	Vamac B-124 Dixie Clay	100 phr 50 phr	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	Vamac B-124 Hi Sil 233	100 phr 15 phr	>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
Antistatic	Vamac B-124 Armostat 550	100 phr 5 phr	>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

NOTES:

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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	Manufacturer
• Nordel	DuPont
• Polysar EPDM	Bayer
• Royalene	Uniroyal
• Vistalon	Exxon Chemical

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 whitings. EPDM has favorable thermal properties. Heat resistance of 300°F (150°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.

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

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
• T_{80} Cure	Increase

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Ethylene Propylene Rubber

Vistalon 2504 by Exxon Chemical, Nordel by DuPont, Royalene by Uniroyal

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
T_{80} 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 N-550	100 phr 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 Dixie Clay	100 phr 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 Hi Sil 233	100 phr 20 phr	270 1.86	🟥 >530Δ >3.66Δ	>580Δ >366Δ	230 1.59	240 1.66	🟥 <10 <0.07	▨ 190 1.31	130 0.90	110 0.76
Naphthenic Oil	Vistalon 2504 Naphthanic Oil	100 phr 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 Paraffinic Oil	100 phr 25 phr	🟥 100 0.69	🟥 >500Δ >3.45Δ	>580Δ >4.00Δ	🟥 150 1.03	🟥 200 1.38	🟥 40 0.28	🟥 70 0.48	🟥 90 0.62	🟥 70 0.48
Antistatic	Vistalon 2504 Armostat 550	100 phr 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

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 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 TUADS0	.80 phr
Stearic Acid	1.00 phr

Ethylene-Vinyl Acetate Copolymer (EVA)

thermoset rubber or thermoplastic elastomer

Trade Names	Manufacturer
• Elvax	DuPont
• Escorene	Exxon Chemical
• Evazote	B.P. Chemicals
• Ultrathene	Quantum Chemicals

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, calendering, 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.

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, anaesthesia face masks and hoses
• Miscellaneous	Adhesives, coatings, sealants, solar cell encapsulants, baby bottle nipples

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

Surface Treatments

- Loctite® 770™ Prism® Primer – Increase

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Ethylene-Vinyl Acetate Copolymer

Elvax by DuPont

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 Armostat 550	 100 phr 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:

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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 Used

Fluorocarbon Rubber (FKM)

thermoset rubber

Trade Names	Manufacturer
• Dai-el	Daikin
• Fluorel	3M
• Kalrez	DuPont
• Tecnoflon	Ausimont
• Viton	DuPont Dow 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
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Fluorocarbon Rubber Viton by DuPont Dow Elastomers and Fluorel by 3M

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
T_{80} 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 MT N990	100 phr 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 Barium Sulfate	100 phr 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 Hi Sil 233	100 phr 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 Carnauba Wax	100 phr 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 Dynamar PPA-790	100 phr 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 Armostat 550	100 phr 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:

▨ = 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

Maglite D	3.00 phr
Calcium Hydroxide	6.00 phr

Fluorosilicone Rubber (FVMQ)

thermoset rubber

Trade Names	Manufacturer
• FE	Shinetsu Chemical Company
• FSE	General Electric
• LS	Dow Corning

General Description

Fluorosilicone rubber 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
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – Increase

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Fluorosilicone Rubber

FSE 2620U by General Electric

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		100 phr	60 0.41	>190$^{\Delta}$ >1.31$^{\Delta}$	>240$^{\Delta}$ >1.66$^{\Delta}$	70 0.48	110 0.76	110 0.76	160 1.10	90 0.62	120 0.83
T_{80} Cure Cured to 80% of Modulus at Full Cure	FSE 2620U	100 phr	60 0.41	▨ 230 1.59	>240$^{\Delta}$ >1.66$^{\Delta}$	70 0.48	110 0.76	🟥 80 0.55	160 1.10	🟥 60 0.41	120 0.83
Carbon Black	FSE 2620U N-550	100 phr 25 phr	▨ 80 0.55	▨ 210 1.45	>240$^{\Delta}$ >1.66$^{\Delta}$	▨ 120 0.83	▨ 120 0.83	110 0.76	▨ 240 1.66	90 0.62	120 0.83
Calcium Carbonate	FSE 2620U Calcium Carbonate	100 phr 40 phr	▨ 100 0.69	>190$^{\Delta}$ >1.31$^{\Delta}$	>240$^{\Delta}$ >1.66$^{\Delta}$	▨ 90 0.62	110 0.76	▨ 170 1.17	160 1.10	90 0.62	▨ 190 1.31
Silica	FSE 2620U Aerosil 200	100 phr 10 phr	60 0.41	>190$^{\Delta}$ >1.31$^{\Delta}$	>240$^{\Delta}$ >1.66$^{\Delta}$	70 0.48	110 0.76	110 0.76	160 1.10	90 0.62	120 0.83
Fluorosilicone Oil	FSE 2620U Fluorosilicone Oil	100 phr 10 phr	▨ 260 1.79	🟥 >130$^{\Delta}$ >0.90$^{\Delta}$	🟥 >150$^{\Delta}$ >1.03$^{\Delta}$	🟥 50 0.34	🟥 80 0.55	110 0.76	160 1.10	🟥 <10 <0.07	🟥 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 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	Manufacturer
• Exxon Bromobutyl	Exxon Chemical
• Exxon Chlorobutyl	Exxon Chemical
• Polysar Bromobutyl	Bayer
• Polysar Chlorobutyl	Bayer

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
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Halogenated Butyl Rubber
Bromobutyl and Chlorobutyl by Exxon Chemical

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
T_{80} 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 N-550	100 phr 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 Calcium Carbonate	100 phr 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 Dixie Clay	100 phr 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 Hi Sil 233	100 phr 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 Aliphatic Oil	100 phr 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 Naphthenic Oil	100 phr 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 Struktol 40 MS	100 phr 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 Armostat 550	100 phr 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	Manufacturer
• Therban	Bayer
• Zetpol	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
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – Decrease

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Hydrogenated Nitrile Rubber

Zetpol by Zeon Chemical

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 100 phr 50% Acrylonitrile, 10% unsaturation	>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
T-80 Cure Zetpol 0020 100 phr Cured to 80% of Modulus at Full Cure	>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 Zetpol 2000L 100 phr 37% Acrylonitrile, 5% unsaturation	>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 Zetpol 0020 100 phr N-339 50 phr	>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 Zetpol 0020 100 phr Hi Sil 255 50 phr	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 Zetpol 0020 100 phr Dibutyl Phthalate 25 phr	>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 Zetpol 0020 100 phr Armostat 550 5 phr	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	Manufacturer
• Alcryn	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, calendering, 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

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Melt Processible Rubber

Alcryn by DuPont

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 TiO_2	100 phr 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 PVC-based yellow dye	100 phr 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 Armostat 550	100 phr 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:

▨ = 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 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® 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 Antistatic - Increase CA
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Natural Rubber **Standard Malaysian Rubber (SMR)**

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	SMR-5 100 phr	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
T_{80} Cure Cured to 80% of Modulus at Full Cure	SMR-5 100 phr	160 1.10	>300Δ >2.07Δ	>270Δ130 >1.86Δ	140 0.90	40 0.97	▨ 50 0.28	40 0.34	230 0.28	1.59
SMR-10	SMR-10 100 phr	▨ >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	SMR-5 100 phr N-550 25 phr	▨ 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	SMR-5 100 phr Calcium Carbonate 100 phr	▨ 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	SMR-5 100 phr McNamee Clay 100 phr	▨ 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	SMR-5 100 phr Hi Sil 233 15 phr	▨ 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	SMR-5 100 phr Naphthenic Oil 10 phr	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	SMR-5 100 phr Polyethylene 1702 4 phr	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	SMR-5 100 phr Santoflex 13 3 phr	▨ >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	SMR-5 100 phr Armostat 550 5 phr	▨ >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:

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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

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	Manufacturer
• Baypren	Bayer
• Butaclor	Enichem Elastomers
• Neoprene	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 calendering 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
• T_{80} Cure	Increase

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polychloroprene Rubber

Neoprene by DuPont

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		100 phr	>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
T_{80} Cure Cured to 80% of Modulus at Full Cure	Neoprene W	100 phr	>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	Neoprene GN	100 phr	>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	Neoprene TW	100 phr	>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	Neoprene W N-550	100 phr 25 phr	>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	Neoprene W Calcium Carbonate	100 phr 50 phr	>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	Neoprene W Dixie Clay	100 phr 100 phr	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	Neoprene W Hi Sil 233	100 phr 15 phr	>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	Neoprene W Aromatic Oil	100 phr 20 phr	>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	Neoprene W Naphthenic Oil	100 phr 20 phr	>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	Neoprene W Armostat 550	100 phr 5 phr	>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

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 Neoprene W 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	Manufacturer
• Breon	B.P. Chemicals
• Chemigum	Goodyear
• Humex	Huels Mexicanos
• Krynac	Polysar International
• Nipol	Nippon Zeon
• Nysen	Copolymer Rubber
• Perbunan	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
• T_{80} Cure	Decrease

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Nitrile Rubber **Chemigum by Goodyear**

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
T_{80} 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	Chemigum N984B 20% Acrylonitrile	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	Chemigum 386B 40% Acrylonitrile	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 FEF N-550	100 phr 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 Dixie Clay	100 phr 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 Hi Sil 233	100 phr 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 Dibutyl Phthalate	100 phr 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 Struktol WB-16	100 phr 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 Armostat 550	100 phr 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:

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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

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	Manufacturer
• Pebax	Arkema Inc.

General Description

Polyether block amide (PEBA) is a thermoplastic elastomer formed via the copolymerzation 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 processable 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

ADHESIVE CHEMISTRY CATEGORY	LIGHT CURE ACRYLIC	EPOXIES						FLEXIBLE CYANOACRYLATES	
Loctite® Brand Industrial Adhesive	Loctite® 3105™ Light Cure Adhesive	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® E-214HP™ Hysol® Epoxy Adhesive	Loctite® 4851™ Prism® Instant Adhesive	Loctite® 4861™ Prism® Instant Adhesive
Loctite® Brand Medical Adhesive	Loctite® 3311™ Light Cure Adhesive			Loctite® M-31CL™ Hysol® Medical Device Epoxy Adhesive	Loctite® E-21HP™ Hysol® Medical Device Epoxy Adhesive			Loctite® 4851™ Prism® Instant Adhesive	Loctite® 4861™ Prism® Instant Adhesive
Pebax 6333	240	535	695	365	635	295	200	915	680
Pebax 7233	180	495	445	430	380	385	285	815	625$^{\Delta}$
Pebax 4033	225	210	165	140	115	60	60	135	260
Pebax 5533	615	225	670	520	395	415	355	445	595
Pebax 2533	100	170	100	120	40	40	60	395$^{\Delta}$	490$^{\Delta}$

ADHESIVE CHEMISTRY CATEGORY	CYANOACRYLATES						FLASHCURE® CYANOACRYLATE	SILICONES	
Loctite® Brand Industrial Adhesive	Loctite® 401™ Prism® Instant Adhesive	Loctite® 401™ Prism® Instant Adhesive with Loctite® 770™ Prism® Primer	Loctite® 401™ Prism® Instant Adhesive with Loctite® 793™ Prism® Primer	Loctite® 414™ Super Bonder® Instant Adhesive	Loctite® 480™ Prism® Instant Adhesive	Loctite® 496™ Super Bonder® Instant Adhesive	Loctite® 4305™ Flashcure® Light Cure Adhesive	Loctite® 5900® Flange Sealant	Loctite® Superflex® RTV
Loctite® Brand Medical Adhesive	Loctite® 4011™ Prism® Medical Device Instant Adhesive	Loctite® 4011™ Prism® Medical Device Adhesive with Loctite® 7701™ Prism® Primer					Loctite® 4305™ Flashcure® Light Cure Adhesive		
Pebax 6333	840$^{\Delta}$	630	985$^{\Delta}$	590$^{\Delta}$	480$^{\Delta}$	670	680	199	122
Pebax 7233	1030$^{\Delta}$	750	1275$^{\Delta}$	690$^{\Delta}$	520	680	845	116	107
Pebax 4033	395	485	690$^{\Delta}$	645$^{\Delta}$	90	95	625	107	61
Pebax 5533	580$^{\Delta}$	910$^{\Delta}$	830$^{\Delta}$	285$^{\Delta}$	440	455	560	113	55
Pebax 2533	455$^{\Delta}$	305$^{\Delta}$	505$^{\Delta}$	460$^{\Delta}$	310	275$^{\Delta}$	405	49	37

ADHESIVE CHEMISTRY CATEGORY	ACRYLICS				HOT MELTS			MRO	
Loctite® Brand Industrial Adhesive	Loctite® H3000™ Speedbonder™ Structural Adhesive	Loctite® H4500™ Speedbonder™ Structural Adhesive	Loctite® 3030™ Adhesive	Loctite® 330™ Depend® Adhesive	Loctite® 3631™ Hysol® Reactive Urethane Hot Melt Adhesive	Loctite® 7804™ Hysol® Hot Melt Adhesive	Loctite® 1942™ Hysol® Hot Melt Adhesive	Loctite® Fixmaster® Epoxy Adhesive	Loctite® Fixmaster® Rapid Rubber Repair Urethane Adhesive
Loctite® Brand Medical Adhesive									
Pebax 6333	280	594	436	201	902	158	164	335	493
Pebax 7233	185	326	193	228	947	174	159	198	550
Pebax 4033	116	349	162	207	375	46	51	331	483
Pebax 5533	124	864	592	377	870	175	14	754	511
Pebax 2533	69	133	128	97	192	128	95	100	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	Manufacturer
• Europrene	Enichem Elastomers America
• Hycar	B.F. Goodrich
• HyTemp	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
• T_{80} Cure	Increase

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polyacrylate Rubber HyTemp by Zeon Chemical

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
T_{80} 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 4054	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 N-550	100 phr 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 A99 Graphite	100 phr 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 Carbowax 3350 3 phr, Dixie Clay	100 phr 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 Carbowax 3350 3 phr, Diethylene Glycol 2 phr, Hi Sil 233	HyTemp 4051	100 phr 15 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 Paraplex G-25	100 phr 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 Vanfre A1-2	100 phr 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 Armostat 550	100 phr 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:

▨ = 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

NPC-50	1.50 phr
Sodium Stearate	1.00 phr

Polyisoprene (IR)

thermoset rubber

Trade Names	Manufacturer
• Isolene	Hardman
• Natsyn	Goodyear
• Nipol	Goldsmith and Eggleton
• SKI-3	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 (RSSSRRS). Consequently, in order to create a stereoregular polymer matrix which 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 processability. 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
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polyisoprene Natsyn by Goodyear

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			>240$^{\Delta}$ >1.66$^{\Delta}$	>240$^{\Delta}$ >1.66$^{\Delta}$	>290$^{\Delta}$ >2.00$^{\Delta}$	>250$^{\Delta}$ >1.72$^{\Delta}$	>200$^{\Delta}$ >1.38$^{\Delta}$	50 0.34	60 0.41	50 0.34	100 0.69
T$_{80}$ Cure Cured to 80% of Modulus at Full Cure	Natsyn 2200	100 phr	▨ >270$^{\Delta}$ >1.86$^{\Delta}$	▨ >300$^{\Delta}$ >2.07$^{\Delta}$	>290$^{\Delta}$ >2.00$^{\Delta}$	>250$^{\Delta}$ >1.72$^{\Delta}$	▨ >290$^{\Delta}$ >2.00$^{\Delta}$	50 0.34	60 0.41	▧ 40 0.28	100 0.69
Carbon Black	Natsyn 2200 N-550	100 phr 25 phr	▨ >450$^{\Delta}$ >3.10$^{\Delta}$	▨ >480$^{\Delta}$ >3.31$^{\Delta}$	▨ >480$^{\Delta}$ >3.31$^{\Delta}$	▨ >370$^{\Delta}$ >2.55$^{\Delta}$	▨ 360 2.48	▨ 60 0.41	▨ 90 0.62	▨ 70 0.48	100 0.69
Calcium Carbonate	Natsyn 2200 Calcium Carbonate	100 phr 100 phr	▧ >190$^{\Delta}$ >1.31$^{\Delta}$	>240$^{\Delta}$ >1.66$^{\Delta}$	>290$^{\Delta}$ >2.00$^{\Delta}$	>250$^{\Delta}$ >1.72$^{\Delta}$	>200$^{\Delta}$ >1.38$^{\Delta}$	▨ 70 0.48	▨ 110 0.76	▨ 70 0.48	▨ >280$^{\Delta}$ >1.93$^{\Delta}$
Clay	Natsyn 2200 Dixie Clay	100 phr 100 phr	▧ 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	Natsyn 2200 Hi Sil 233	100 phr 15 phr	>240$^{\Delta}$ >1.66$^{\Delta}$	>240$^{\Delta}$ >1.66$^{\Delta}$	>290$^{\Delta}$ >2.00$^{\Delta}$	▧ 170 1.17	▧ >150$^{\Delta}$ >1.03$^{\Delta}$	50 0.34	▨ 70 0.48	▨ 60 0.41	100 0.69
Naphthenic Oil	Natsyn 2200 Naphthenic Oil	100 phr 25 phr	>240$^{\Delta}$ >1.66$^{\Delta}$	>240$^{\Delta}$ >1.66$^{\Delta}$	>290$^{\Delta}$ >2.00$^{\Delta}$	▧ 130 0.90	>200$^{\Delta}$ >1.38$^{\Delta}$	▧ 40 0.28	▧ 40 0.28	▧ 40 0.28	▧ 40 0.28
Antioxidant	Natsyn 2200 Venox 2-AZ	100 phr 2 phr	>240$^{\Delta}$ >1.66$^{\Delta}$	>240$^{\Delta}$ >1.66$^{\Delta}$	>290$^{\Delta}$ >2.00$^{\Delta}$	>250$^{\Delta}$ >1.72$^{\Delta}$	>200$^{\Delta}$ >1.38$^{\Delta}$	▧ 40 0.28	▧ 40 0.28	▧ 40 0.28	100 0.69
Antistatic	Natsyn 2200 Armostat 550	100 phr 5 phr	>240$^{\Delta}$ >1.66$^{\Delta}$	>240$^{\Delta}$ >1.66$^{\Delta}$	▧ >210$^{\Delta}$ >1.45$^{\Delta}$	▧ >220$^{\Delta}$ >1.52$^{\Delta}$	▨ >280$^{\Delta}$ >1.93$^{\Delta}$	▧ 30 0.21	▧ 30 0.21	▧ 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.

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 Superlite	1.50 phr
Sulfur	2.00 phr
Durax	1.00 phr
TMTM	0.20 phr

Polyolefin Elastomers (POE)

thermoplastic elastomer

Trade Names	Manufacturer
• Engage	DuPont Dow Elastomers
• Hercuprene	J-Von
• Sarlink	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 Dow 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 (-76°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

(psi)

(MPa)

Polyolefin Elastomer **Engage by DuPont Dow Elastomers**

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	EP 8500 Armostat 550	100 phr 5 phr	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

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

Poly(propylene oxide) Rubber (GPO)

thermoset rubber

Trade Names	Manufacturer
• Parel	Zeon Chemical

General Description

Poly(propylene oxide) rubber 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 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
• T_{80} Cure	Decrease

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Poly(propylene oxide) Rubber

Parel 58 by Zeon Chemical

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	Parel 58	100 phr	>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
T_{80} Cure Cured to 80% of Modulus at Full Cure	Parel 58	100 phr	▧ >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	Parel 58 N550	100 phr 25 phr	▨ >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	Parel 58 Aromatic Oil	100 phr 20 phr	▧ >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	Parel 58 Dioctyl Phthalate	100 phr 15 phr	▧ >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	Parel 58 Armostat 550	100 phr 5 phr	▧ >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:

▨ = 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	5.00 phr
Sulfur	1.25 phr
TMTM	1.50 phr
MBT	1.50 phr

Polysulfide Rubber

thermoset rubber

Trade Names	Manufacturer
• LP	Morton Thiokol
• 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
• T_{80} Cure	Increase

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Polysulfide Rubber

Thiokol by Morton Thiokol

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 Linear structure	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
T$_{80}$ Cure Cured to 80% of Modulus at Full Cure	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 Branched structure	Thiokol ST 100 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

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.

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	Manufacturer
• Royaltherm	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
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Silicone Modified EPDM

Royaltherm by Uniroyal Chemical Company

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
T_{80} Cure Cured to 80% of Modulus at Full Cure	Royaltherm 1411	100 phr	>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	Royaltherm 1721 Improved heat resistance	100 phr	▧ >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	Royaltherm 1411 N-330	100 phr 30 phr	>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	Royaltherm 1411 VN-3 silica	100 phr 45 phr	▨ 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	Royaltherm 1411 Dioctyl Phthalate	100 phr 12 phr	▧ >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	Royaltherm 1411 Armostat 550	100 phr 5 phr	▧ >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

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

Silicone Rubber (MQ, VMQ, PMQ, PVMQ)

thermoset rubber

Trade Names	Manufacturer
• Blensil	G.E. Silicones
• Elastosil	Wacker Chemical Corp.
• Silastic	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 forms 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 5-10% 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
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – Increase

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Silicone Rubber **SE 456U by General Electric**

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		100 phr	<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
T_{80} Cure Cured to 80% of Modulus at Full Cure	SE 456U	100 phr	▨ 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	SE 456U N-550	100 phr 30 phr	<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	SE 456U Calcium Carbonate	100 phr 30 phr	<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 Polyethylene Glycol 3 phr,	SE 456U Whitex Clay	100 phr 30 phr	▨ 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	SE 456U Aerosil 200	100 phr 11.5 phr	<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	SE 456U Min-U-Sil 10	100 phr 30 phr	<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	SE 456U Red Iron Oxide E-4182	100 phr 30 phr	<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	SE 456U 1000 cP fluid	100 phr 15 phr	<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	SE 456U Armostat 550	100 phr 4 phr	▨ 170 1.17	▨ 210 1.45	🟥 190 1.31	▨ 170 1.17	▨ 170 1.17	210 1.45	200 1.38	<10 <0.07	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 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	Manufacturer
Afpol	Cal Polymers
Buna	Bayer
Copeflex	Coperbo
Duradene	Firestone
Europrene	Enichem
Kraton	Shell Chemical
Plioflex	Goodyear
Pliolite	Goodyear
Solprene	Housmex
Stereon	Firestone

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 41-50°F (5-10°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 4-7% 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.

Typical Applications

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

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
T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH

(psi)

(MPa)

Styrene Butadiene Rubber **Plioflex by Goodyear**

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 100 phr Cold Emulsion Polymer, 23.5% Styrene	>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
T_{80} Cure Plioflex 1502 100 phr Cured to 80% of Modulus at Full Cure	>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 Plioflex 1513 100 phr Cold Emulsion Polymer, 40% Styrene	>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 1502 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	120 083	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
TMTD	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	Manufacturer
• C-Flex	Concept
• Coperflex	Coperbo
• Dynaflex	GLS Corp.
• Europrene SOL	EniChem
• K-Resin	Phillips
• Kraton	Shell Chemical Co.
• Rimflex	Synthetic Rubber Tech.
• Solprene	Housmex

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 processability. 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 processability. Useful service temperatures are low for styrenic TPEs ranging from -70 to 200°F (-57 to 93°C).

Typical Applications

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

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
• T_{80} Cure	No Trend Apparent

Surface Treatments

- Loctite® 770™ Prism® Primer – No Trend Apparent

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Styrene Butadiene TPE

Kraton by Shell Chemical and C-Flex by Concept Polymer Technology

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 N-550	100 phr 100 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 Dixie Clay	100 phr 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 Hi Sil 233	100 phr 50 phr	440 3.03	>550Δ >3.52Δ	>550Δ >3.79Δ	390 2.69	510 3.52	30 0.21	60 0.41	390 2.69	>660Δ >4.55Δ
Whiting	Kraton G 1650 Precipitated Whiting	100 phr 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 Aromatic Oil	100 phr 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 Naphthenic Oil	100 phr 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 Dioctyl Phthalate	100 phr 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 Carnauba Wax	100 phr 10 phr	290 2.00	510 3.52	370 2.55	390 2.69	230 1.59	90 0.622	110 0.76	210 1.45	410 2.83
EVA Blend	Kraton G 1650 EVA	100 phr 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 Polyethylene	100 phr 100 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 Armostat 550	100 phr 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		100 phr	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 Polystyrene	100 phr 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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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	Manufacturer
• Geolast	Advanced Elastomer Systems
• Santoprene	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 calendering.

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

Surface Treatments

- Loctite® 770™ Prism® Primer – Increase

ADHESIVE SHEAR STRENGTH
(psi)
(MPa)

Thermoplastic Vulcanizates

Santoprene and Geolast by Advanced Elastomer Systems

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	Santoprene 101-55	100 phr	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	Santoprene 101-73	100 phr	<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	Santoprene 103-50	100 phr	<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	Santoprene 201-55	100 phr 100 phr	30 0.21	70 0.48	210 1.45	<10 <0.07	30 0.21	<10 <0.07	<10 <0.07	50 0.34	180 1.24
Santoprene 201-55 w/Grey Concentrate	Santoprene 201-55 Grey Concentrate	100 phr 4 phr	🟥 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	Santoprene 201-73	100 phr	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	Santoprene 201-73 Grey Concentrate	100 phr 4 phr	🟥 <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	Santoprene 203-50	100 phr	<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	Santoprene 203-50 Grey Concentrate	100 phr 4 phr	<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	Geolast 701-70W183	100 phr	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	Geolast 701-80W183	100 phr	320 2.21	360 2.48	>350Δ >2.41Δ	320 2.21	400 2.76	30 0.21	70 0.48	180 01.24	320 2.21
Geolast 701-87W183	Geolast 701-87W183	100 phr	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	Geolast 703-45	100 phr	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

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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 System Used in All Information

None Required

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.

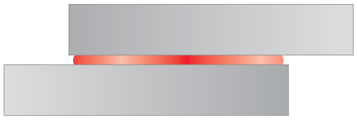
Joint Geometry: Joint geometry refers to the general shape of an adhesive bond. Is the shape of the bond long and narrow, short and wide, thick or thin?

Types of Joints

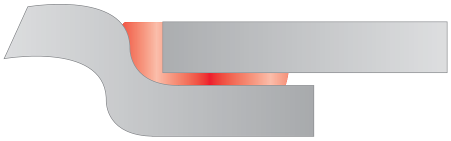
The specific types of joints which will be examined in this section include:

• Lap/Overlap • Joggle Lap • Butt Joint • Scarf Joint
• Strap/Double Strap • Cylindrical

Lap/Overlap Joint: A lap joint, also called an overlap joint, is formed by placing one substrate partially over another substrate.



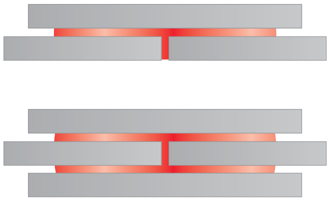
Joggle Lap Joint: The joggle lap joint is an offset joint and is very similar to the lap joint.



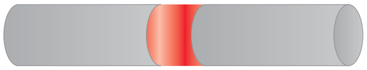
Butt Joint: A butt joint is formed by bonding two objects end to end.

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

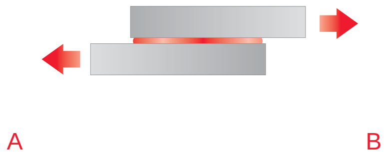
Joint stress distribution is the location of stresses within a bond.

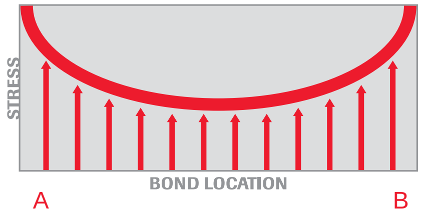
Stress: Usually expressed as Newtons per square meter (N/m^2), which is equivalent to a Pascal (Pa.) In the English system, stress is normally expressed in pounds per square inch (psi).

Types of Stresses

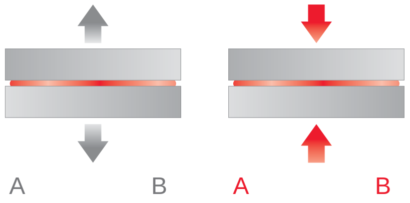
There are several types of stresses commonly found in adhesive bonds which include:

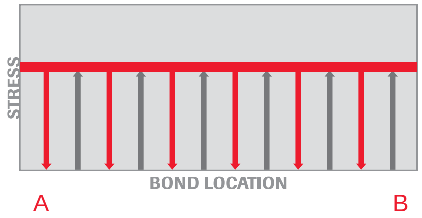
- Shear
- Tensile
- Compressive
- Peel
- Cleavage



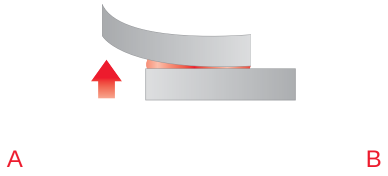


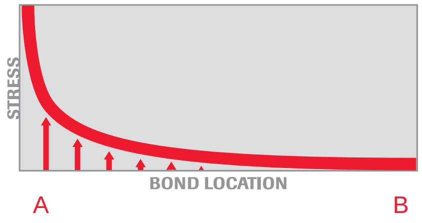
Shear Stress: A shear stress results in two surfaces sliding over one another.





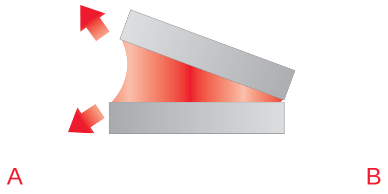
Tensile and Compressive Stress Distribution: When a bond experiences either a tensile or a compressive stress, the joint stress distribution is illustrated as a straight line. The stress is evenly distributed across the entire bond. Tensile stress also tends to elongate an object.

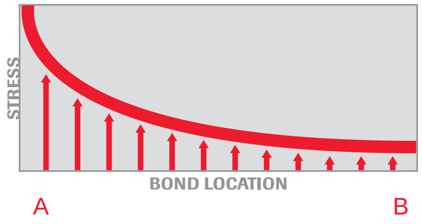




Peel Stress: A peel stress occurs when a flexible substrate is being lifted or peeled from the other substrate.

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.

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.

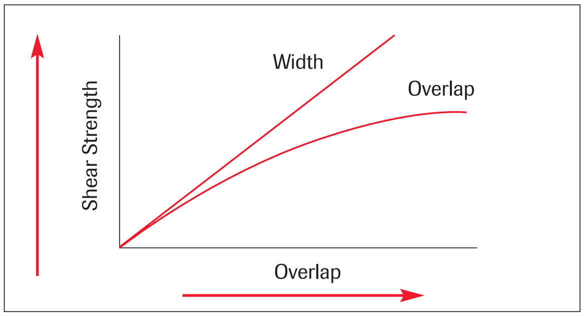
- **Maximize Shear/ Minimize Peel and Cleavage**
  Note from the stress distribution curve for cleavage and peel, that these bonds do not resist stress very well. The stress is located at one end of the bond line. Whereas, in the case of shear, both ends of the bond resist the stress.

- **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 resist a greater amount of stress than does the middle of the bond. If the width of the bond is increased, the bond area at each end also increases; 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").



Mathematical Conversions

The following are some common conversions that might be helpful when utilizing Loctite® brand products:

- 1 milliliter (ml) = 1 cubic centimeter (cc)
- 1,000 ml = 1 liter
- 29.5 ml = 1 fl. oz.
- 3.78 liters = 1 gallon
- 473 ml = 1 pint
- 454 grams = 1 lb.
- 947 ml = 1 quart
- 1 kilogram = 2.2 lbs.
- Weight to Volume: grams ÷ specific gravity = cc (ml)
- Volume to Weight: cc (ml) x specific gravity = grams
- Density = specific gravity x 0.99823
- Centipoises = centistokes x density (at a given temp.)
- Temperature: degrees F - 32 x 0.556 = degrees C
  degrees C x 2 - 10% + 32 = degrees F
- Square Inches to Square Feet: ÷ by 144
- Square Feet to Square Inches: x by 144
- In./lbs. ÷ 12 = ft./lbs.
- Ft./lbs. x 12 = in./lbs.
- 16 in. oz. = 1 in. lb.
- 192 in. oz. = 1 ft. lb.

Area Coverage

Flat Parts:
Length(in.) x Width(in.) x bond line Thickness(in.) x 16.4 = cc/ml requirement per part

Non-threaded Cylindrical Parts:
Diameter x Engagement Length x bond line Thickness (on radius/per side) x 3.14 x 16.4 = cc/ml requirement per part

Potting/ Encapsulating Applications:
Area (3.14 x R2) x Potting Depth x 16.4 = cc/ml requirement per part

For no induced gap, make the bond line thickness figure 0.001".
16.4 is a constant for converting cubic inches to cubic centimeters.

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:

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® 3030™ 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® 4305™ Flashcure® Light Cure Adhesive *FLUORESCENT: 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® E-31CL™ Hysol®***	**Clear, glass bonding epoxy**
Loctite® E-20HP™ Hysol® Epoxy Adh. ***MEDICAL: Loctite® E-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**

The Selection of Elastomers

The various types of elastomers which are currently available were surveyed, and twenty-six 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:

<u>Specialty Formulations</u>

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.

<u>Commercially Available Grades</u>

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.

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 moduli. 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" 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.

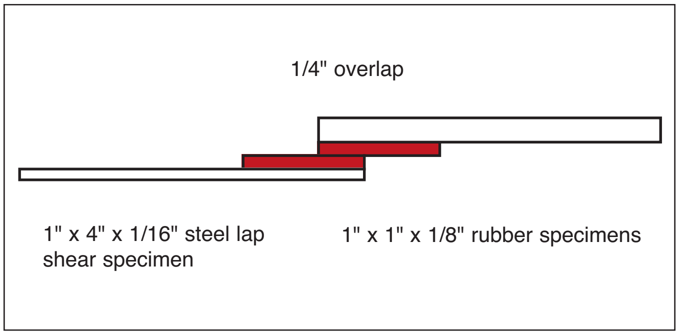


Figure 1 Rubber Bonding Test Specimen

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" by 1" by 0.125" 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" 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 1 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" 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 1 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" 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® 4305™ Flashcure® Light Cure Adhesive)

1. Adhesive was applied in an even film to one test specimen.
2. A UV transparent, polycarbonate 1" by 1" by 0.125" test specimen was cleaned with isopropyl alcohol.
3. The second test specimen was mated to the first with a 0.5" 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/cm^2 @ 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"/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® 3030™ 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 1 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
FSE	Fluorosilicone Rubber	General Electric	30
FVMQ	Fluorosilicone Rubber	Acronym for Elastomer	30
GCO	Epichlorohydrin Rubber	Acronym for Elastomer	20
GECO	Epichlorohydrin Rubber	Acronym for Elastomer	20
Geolast	Thermoplastic Vulcanizate	Advanced Elastomer Systems	64
GPO	Poly(propylene oxide) Rubber	Acronym for Elastomer	52
Hercuprene	Polyolefin	J-Von	50
H-NBR	Hydrogenated Nitrile Rubber	Acronym for Elastomer	34
HSN	Hydrogenated Nitrile Rubber	Acronym for Elastomer	34
Humex	Nitrile Rubber	Huels Mexicanos	42
Hycar	Polyacrylate Rubber	B.F. Goodrich	46
Hydrin	Epichlorohydrin Rubber	Zeon	20
Hypalon	Chlorosulfonated Polyethylene	DuPont	16
HyTemp	Polyacrylate Rubber	Zeon Chemical	46
Hytrel	Copolyester TPE	DuPont	18
IIR	Butyl Rubber	Acronym for Elastomer	14
IR	Polyisoprene	Acronym for Elastomer	48
Isolene	Polyisoprene	Hardman	48
Kalrez	Fluorocarbon Rubber	DuPont	28
Kraton	Styrene-Butadiene Rubber	Shell Chemical	60
Kraton	Styrenic TPE	Shell Chemical	62
K-Resin	Styrenic TPE	Phillips	62
Krynac	Nitrile Rubber	Polysar International	42
Lomod	Copolyester TPE	General Electric	18
LP	Polysulfide Rubber	Morton Thiokol	54
LS	Fluorosilicone Rubbers	Dow Corning	30
MPR	Melt Processible Rubber	Acronym for Elastomer	36
MQ	Silicone Rubber	Acronym for Elastomer	58
Natsyn	Polyisoprene	Goodyear	48
NBR	Nitrile Rubber	Acronym for Elastomer	42
Neoprene	Polychloroprene	DuPont	40
Nipol	Polyisoprene	Goldsmith & Eggleton	48
Nipol	Nitrile Rubber	Nippon Zeon	42
Nordel	Ethylene Propylene Rubber	DuPont	24
NR	Natural Rubber	Acronym for Elastomer	38
Nysen	Nitrile Rubber	Copolymer Rubber	42
Pale Crepe	Natural Rubber	International Type of NR	38
Parel	Poly(propylene oxide) Rubber	Zeon Chemical	52
Pebax	Polyether Block Amide	Arkema Inc.	44
Perbunan	Nitrile Rubber	Mobay	42
Plioflex	Styrene-Butadiene Rubber	Goodyear	60
Pliolite	Styrene-Butadiene Rubber	Goodyear	60
PMQ	Silicone Rubber	Acronym for Elastomer	58
POE	Polyolefin	Acronym for Elastomer	50
Polysar EPDM	Ethylene Propylene Rubber	Bayer	24
Polysar Bromobutyl	Halogenated Butyl Rubber	Bayer	32
Polysar Butyl	Butyl Rubber	Bayer	14

Trade Name/Acronym	Elastomer Type	Manufacturer/Comment	Page
Polysar Chlorobutyl	Halogenated Butyl Rubber	Bayer	32
Pure Smoked Blanket Crepe	Natural Rubber	International Type of NR	38
PVMQ	Silicone Rubber	Acronym for Elastomer	58
Ribbed Smoked Sheet	Natural Rubber	International Type of NR	38
Rimflex	Styrenic TPE	Synthetic Rubber Technologies	62
Riteflex	Copolyester TPE	Hoescht Celanese	18
Royalene	Ethylene Propylene Rubber	Uniroyal Chemical	24
Royaltherm	Silicone-Modified EPDM	Uniroyal Chemical	56
Santoprene	Thermoplastic Vulcanizate	Advanced Elastomer Systems	64
Sarlink	Polyolefin	DSM Thermoplastic	50
SBR	Styrene-Butadiene Rubber	Acronym for Elastomer	60
S-B-S	Styrenic TPE	Acronym for Elastomer	62
S-EB-S	Styrenic TPE	Acronym for Elastomer	62
Silastic	Silicone	Dow Corning STI	58
S-I-S	Styrenic TPE	Acronym for Elastomer	62
Ski-3	Polyisoprene	Alcan	48
Solprene	Styrene-Butadiene Rubber	Housmex	60
Solprene	Styrenic TPE	Housmex	62
Stereon	Styrene-Butadiene Rubber	Firestone	60
Synthetic Natural Rubber	Polyisoprene	Common Name for IR	48
Tecnoflon	Fluorocarbon Rubber	Ausimont	28
Therban	Hydrogenated Nitrile Rubber	Bayer	34
Thick Blanket Crepe	Natural Rubber	International Type of NR	38
Thin Brown Crepe	Natural Rubber	International Type of NR	38
Thiokol	Polysulfide Rubber	Morton Thiokol	54
TPV	Thermoplastic Vulcanizate	Acronym for Elastomer	64
Ultrathene	Ethylene-Vinyl Acetate	Quantum Chemicals	26
Vamac	Ethylene Acrylic Rubber	DuPont	22
Vistalon	Ethylene Propylene Rubber	Exxon Chemical	24
Viton	Fluorocarbon Rubbers	DuPont	28
VMQ	Silicone Rubber	Acronym for Elastomer	58
XNBR	Nitrile Rubber	Acronym for Elastomer	42
Zetpol	Hydrogenated Nitrile Rubber	Zeon Chemical	34

The trade names mentioned above are the property of the manufacturing companies 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 their process to insure that the adhesive does not detrimentally affect the performance of the plastic or elastomer.

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