Elastomeric Adhesives Deliver Flexibility for Appliance Designs

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Appliances survive a great deal of stress over their lives. During shipping and in use, large appliances are exposed to varying degrees of thermal stress and environmental cycling. Thousands of parts make up an appliance, all made of different materials from glass to plastics to metals. These substrates are attached to one another to form one unit. When all these substrates expand and contract at different rates, the appliance is exposed to irregular forces that can cause structural damage.

Some appliances such as stoves, cooktops and microwaves must withstand extreme temperature variations. The strength of the assembly is tested when the appliance operates at temperatures greater than 400F. Washing machines and dishwashers withstand intense vibration, along with regular, long-term heat and moisture exposure that can compromise the structural integrity of the design.

Many assembly methods are used for attaching appliance components, from mechanical fastening to double-sided tapes to adhesive bonding. Adhesives offer the most benefits for design and manufacturing as they can very effectively bond dissimilar substrates, distribute stress loads, withstand vibrational forces, and enhance the aesthetics of appliance assemblies [1]. In particular, elastomeric adhesives are formulated for flexibility and stress management. Easy to automate and formulated for innovation, these adhesives reduce the cost, time, and waste associated with traditional assembly methods and allow for sleek and inventive designs. Their excellent impact/shock resistance, peel strength, and UV/thermal resistance provide structural integrity and strength.

Design Considerations

Appliance manufacturers have many reasons for choosing elastomeric adhesives for structural bonding.

Elastomeric adhesives are made up of both natural and synthetic polymers that exhibit superior elongation and toughness [2], so they are capable of:

- dampening noise and vibration – critical for laundry and dish appliances;
- absorbing impact and shock – needed for glass cooktops, glass

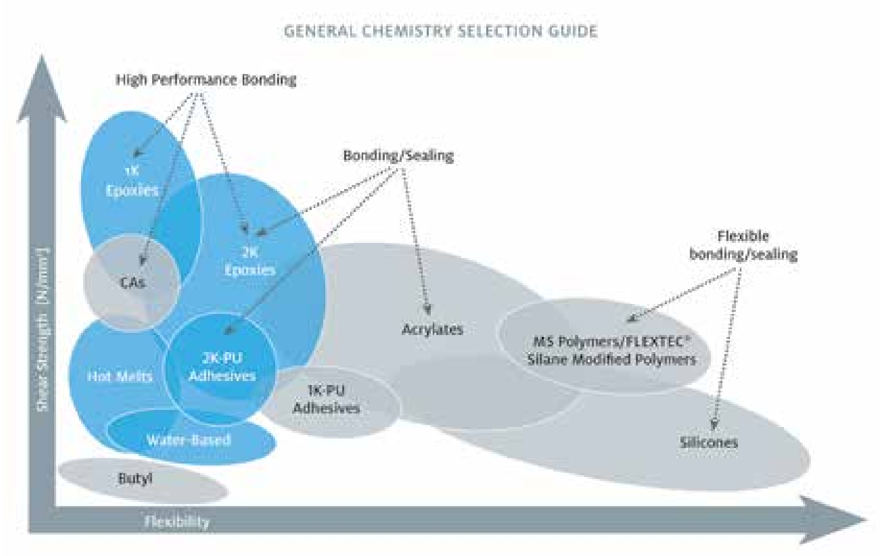


Figure 1: Generalization of percent elongation expected from various adhesive product chemistries.

- washer lids and oven doors;
- sealing joints – eliminates leaks on cooktops and replaces cut gaskets; and
- bonding dissimilar materials – allows for variations in the coefficients thermal expansion between differing materials that make up all appliances. [2]

The high elongation properties of elastomeric adhesives may result in bond joints that perform robustly on exposure to peel or cleavage stresses. Similar in nature, peel and cleavage are the least desirable forces to apply to a bonded joint. These forces affect the leading edge of the joint, applying an uneven distribution of stress that pulls apart the joint along the leading edge, propagating fractures in the adhesive throughout the bond line. [3]

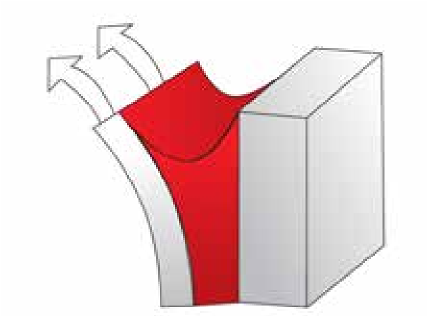


Figure 2: Example of Peel Force

Understanding the forces that may affect the bonded joint is critical to the adhesive selection process. Some adhesives perform better under certain conditions, or have been designed to withstand specific forces better than other adhesives.

During the adhesive selection process, manufacturers should consider the environmental conditions the appliance will encounter throughout its intended life, including:
- elevated operating temperatures,
- UV and weather exposure when appliances are installed outdoors or near salt water,
- surface contamination and surface treatment encountered during the manufacturing process, and
- solvent and chemical exposure that occurs during post-manufacturing cleaning or in-use when owners use detergents, fabric softeners and sanitizing agents. Different adhesive chemistries are formulated to meet specific manufacturing and end use conditions. [4]

Available Structural Elastomeric Technologies

A wide variety of elastomeric adhesive technologies are available to meet the bonding needs of manufacturers. The top performing elastomeric adhesives used to structurally bond appliances fall into three main categories: Silane Modified Polymers (SMP), Silicones, and Polyurethanes.

Elastomeric adhesives are available as one-part moisture curing systems and as two-competent static mix systems that range in viscosity from self-leveling liquids to non-slumping pastes. Typically, these materials cure to soft thermoset elastomers with excellent property retention over a wide temperature range. Many elastomeric adhesives offer good primerless adhesion to a wide variety of substrates, but have relatively low cohesive strength when compared to other adhesive joining methods. [5]

Choosing the type of adhesive that is most appropriate for a manufacturing system depends on the materials being bonded, joint design, and the projected end use conditions of the appliance. Silicones and SMPs are typically considered the most flexible adhesives technologies, with silicones offering excellent high temperature resistance and SMPs responding better to lower temperature applications. Reactive urethanes offer excellent moisture resistance and can best withstand vibration, making them an appropriate technology for laundry systems.

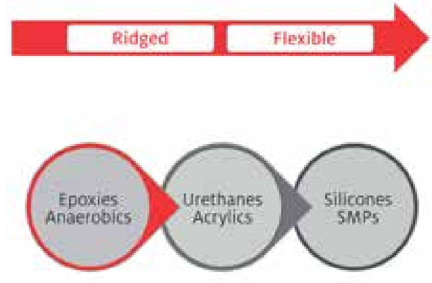


Figure 3: Generalization of flexibility expected from various adhesive product chemistries.

Polyurethanes

Polyurethanes are polymers made up of organic units joined by carbamate (urethane) links. The polymers are formed by combining isocyanate(NCO) containing compounds with hydroxyl(OH) containing compounds. The specific starting components used in the reaction affect the final characteristics of the urethane. The final polymer can range from hard to very soft and flexible.

Polyurethane foam has been available for close to 70 years. Foam and other urethane products including adhesives continue to be developed and improved. Polyurethane adhesives cure to form thermoset polymers with good solvent and chemical resistance. Cohesive strength and flexibility make polyurethane adhesives attractive for a wide variety of applications.

Manufacturers seeking an economical bonding solution that offers toughness at low temperatures should consider using polyurethane technology. Because of the relative low cost of most raw materials used to make polyurethanes the final price remains low.

One-Component Polyurethane Adhesives

Like many other single component reactive adhesives, one-component polyurethanes react with moisture in the atmosphere and on the surface of the substrates. 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-inch. [7]

The cure mechanism for one part moisture cure polyurethanes off-gasses carbon dioxide. The polymer chains formed consist of soft and hard components contributing to both toughness and flexibility.

Two Component Polyurethane Adhesives

Two component polyurethane adhesives are made up of an isocyanate containing component and a polyol containing component. When combined the result is an adhesive that cures quickly to provide a tough, durable bond.

Overall bond performance is good but in certain instances a primer may be required to achieve the best possible bond. Polyurethanes can be formulated to weather well in outdoor environments where UV exposure is an issue.

Silane Modified Polymer Adhesives

Silane modified polymer (SMP) adhesives have an organic backbone terminated with reactive silyl groups. The silyl groups are highly attracted to inorganic surfaces such as metals and glass. These adhesives cure in the presence of moisture through a condensation reaction.

SMPs originated in Japan in the 1980s and have become increasingly popular due to their performance advantages over polyurethane adhesives. One component moisture cure products are the norm but two component systems are available. The fact that SMPs are isocyanate and silicone free opens a variety of application possibilities.

Broad primerless adhesion, paintability, and excellent UV stability make SMPs great choices for appliances exposed to exterior environments. When painting components bonded with SMPs, is important to paint as soon as possible after the adhesive forms a skin since paint will have a harder time bonding once the SMP cures completely.

In appliance manufacturing, SMP adhesives are currently used for bonding glass into beverage refrigerator doors, seam sealing, sealing dishwasher cabinets, bonding heat exchanger air bypasses, and bonding various components of range hoods.

Silicones

Silicones are inorganic materials comprised of a backbone of repeating siloxane groups. Normally, the two pendant groups on the silicone are methyl groups. The polymer is called poly dimethyl siloxane.

Silicone rubber was initially used commercially as electrical insulation for applications enduring high temperatures, and silicones were too expensive for widespread commercial use. Technical breakthroughs have led to improved methods for producing silicone raw materials, bringing the price of silicone products into a range where they are economically competitive for many applications.

A primary consideration for using a silicone adhesive in a bonding application will likely be temperature extremes. Silicone adhesives maintain superior flexibility from -85°F to 400°F. These materials offer excellent thermal resistance, and can handle temperature of up to 400°F continuously, and 600° intermittently. These adhesives are an excellent choice for bonding almost any cooking appliance including ovens, cooktops, microwaves, and convection/toaster ovens.

One-Component Silicone Adhesives

One-component silicone adhesives are typically cured though a chemical reaction with ambient humidity. The cure rate of single component moisture cure silicone is strongly affected by relative humidity, and the ability of the moisture to diffuse through the applied adhesive. The maximum cure-through depth of most single component moisture cure silicones is limited to the range of 0.375 inches to 0.5 inches. [5]

After application, when exposed to 50% relative humidity, most moisture cure silicones will typically cure to a “tack-free” surface within 5 and 60 minutes. Complete cure-through of thick sections of product can take up to 72 hours. Since the reaction between the reactive groups on the polymer and the reactive groups on the substrate surface is slow, strength build of the product may continue to develop for one to two weeks after product application. [5]

As one-component moisture cure silicones react with ambient humidity, they give off a gas byproduct. These silicone adhesives are categorized by the byproduct they off-gas during cure. There are four main categories of single component silicone adhesives: acetoxy, oxime, methoxy, and alkoxy.

Acetoxy cure silicones outgas acetic acid, which can promote corrosion on some metal assemblies. Generally, these materials have good adhesion, relatively fast cure speeds and are the lowest cost materials of the single component silicones. [5]

Both alkoxy and methoxy based silicones are non-corrosive, and outgas alcohol during cure. In general, these materials offer lower adhesion than acetoxy cure silicones, but due to their non-corrosive nature, these products may be appropriate for bonding sensitive electronics where parts cannot be exposed to the acetic acid, for example control and display panels.

Oxime based silicones outgas methyl

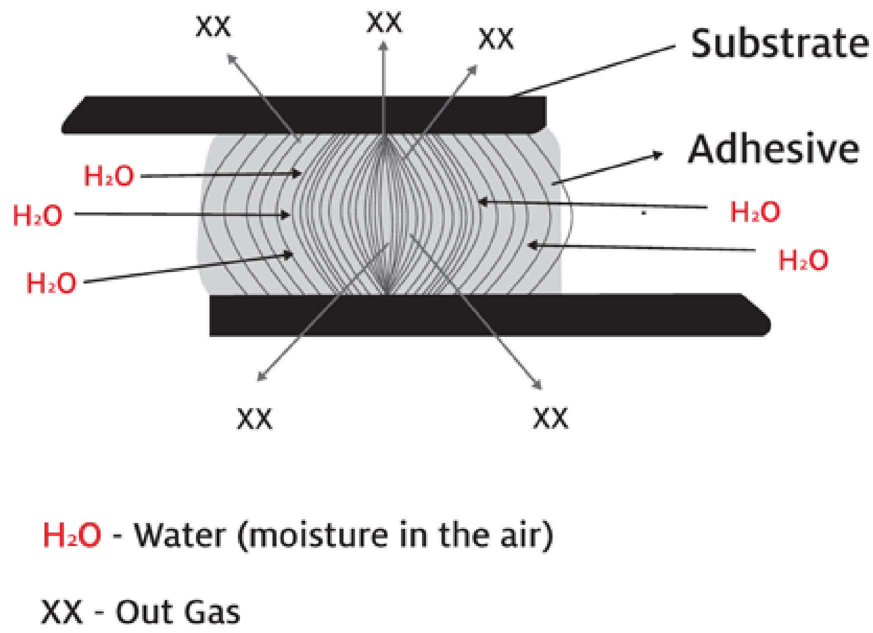


Figure 4: Depicts the reaction of a single component moisture cure silicone between 2 substrates.

ethyl ketoxime, and are generally non-corrosive, although this chemistry will tarnish brass and copper. Oxime-based silicones generally have the best adhesion and are the most chemically-resistant of single-component silicone materials.

Single-component silicones are frequently used in bonding applications with high temperature demands and intense thermal cycling requirements like appliance cooktops, brackets and other heat cycled components. In addition to thermal cycling, many of these adhesives can resist extreme UV cycling without hardening, shrinking, or cracking.

Single-component adhesives are relatively simple to dispense through both manual operation and automated systems. However, when using an automated dispense system with a valve, the system must be designed to prevent moisture from entering the wetted components. To that end, moisture-lock hoses and dryers should be used to remove moisture from the air that could cause the product to cure in the system. [5]

Two-Component Silicone Adhesives

Two-component silicone adhesives used in structural bonding applications cure through a condensation reaction. When mixed in proper ratio, a chemical reaction occurs initiated by the catalyst reacting with water (in formulation). These materials are alkoxy cure, and the by-product of this reaction is alcohol.

Two-component, condensation-cure silicones offer good adhesion to metals, plastics, and glass components. These products also have a rapid fixture time — some formulas fixture in less than 5 minutes. This rapid fixture can help eliminate work in process (WIP) associated with typical 24-hour cure one-component silicone materials. The two-component chemistry provides the additional benefit of unlimited cure-through depth, which is not present in one-component moisture cure elastomers.

Many of these condensation cure products were developed for high speed production, and structural bonding of glass to metals and plastics in the appliance manufacturing industry.

These high performance, two-component silicone materials are often used for bonding applications in the appliance industry. Examples include bonding and sealing glass cooktops to painted and stainless steel frames, bonding and sealing decorated glass control panels to painted and stainless steel consoles, metal bracket bonding, and bonding and sealing various plastics to glass in laundry lid applications. If enhanced bond strengths or fixture times are required, the end user can treat their parts with a primer.

Two-component condensation cure silicones have several limitations. These products are not currently available in clear formulations, and dispensing these materials is more challenging than dispensing one-component silicones.

Two component silicones can be dispensed manually onto an assembly using a pneumatic cartridge gun, or from bulk packaging through custom meter-mix dispense equipment. The end user must consider mix nozzle work life and set up automated equipment work cells to auto-purge product frequently, ensuring that material does not cure in the mix nozzle between applications.

Primers

There are various surface treatment techniques that can be used to improve the bond strength of an elastomeric adhesive or sealant. Applying a chemical primer to the surface of a substrate has the potential to significantly increase the bond strength of an elastomeric

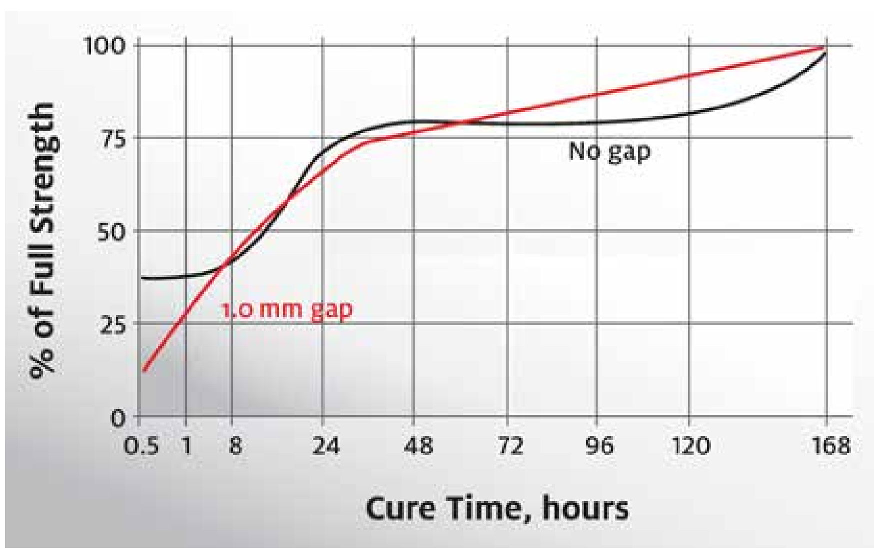
SILICONES	TYPE	*MIX RATIO [VOLUME]*	*MIX RATIO [WEIGHT]*	WORK LIFE [MINUTES]	*SKIN OVER TIME [MINUTES]*	*FIXTURE TIME [MINUTES]*	COLOR	NOTES	NA	LAN	LAS	IMEA	WE/EE	APAC
LOCTITE® SI 5600™	2-part	2:1	100:66	1	2	5	Black, grey, almond	UL 746C at 180 C	x	x	x			x
LOCTITE® SI 5604™	2-part	4:1	100:33	2	4	10	Black, grey, almond	UL 746C at 180 °C	x	x				
LOCTITE® SI 5605™	2-part	4:1	100:66	1	3	5	Grey	Fast work life	x					
LOCTITE® SI 5606™	2-part	4:1	100:33	5	10	20	Grey	UL 94 HB, RTI 105	x				x	
LOCTITE® SI 5607™	2-part	2:1	100:67	6	25	50	Grey	Extended work life	x	x	x		x	x
LOCTITE® SI 5610™	2-part	2:1	100:67	2	3	5	Black	UL 94 HB, RTI 105, service temperature up to 180 °C			x	x	x	x
LOCTITE® SI 5612™	2-part	4:1	100:34	6	22	30	Red	Service temperature up to 220 °C.					x	x
LOCTITE® SI 5613™	2-part	2:1	100:65	3	10	15	Black	Oil resistant	x					x
LOCTITE® SI 5615™	2-part	2:1	100:66	5	12	12	Black	UL 94 HB, RTI 105, service temperature up to 180 C			x	x	x	x
LOCTITE® SI 5616™	2-part	2:1	100:66	5	21	13	White	UL 746C at 105 °C, service temperature up to 180 °C				x	x	
LOCTITE® SI 5618™	2-part	10:1	100:7	4	10	14	Black	Fast work life					x	
LOCTITE® SI 5640™	2-part	10:1	100:9	2	4	10	Grey	UL 94 V0, RTI 105, low viscosity for potting applications	x					

These non-corrosive products exhibit tensile/cohesive strengths of approximately 250 psi, and an elongation of >150%. Several of Henkel's two-component silicone offerings are 180°C, UL 746C listed and are available in black, grey, and almond colors.

adhesive.

A primer is a chemical species which is applied to the surface of a substrate through a solvent carrier. Once applied, the user should allow a certain amount of time for the solvent in the primer to flash off. After the solvent evaporates, the active species of the primer is left behind on the surface. This active species is a multifunctional reactive group; one reactive site reacts with the surface and the second site reacts with the adhesive. The overall effect of the primer is to increase the strength of the bonded assemblies [6].

Before priming, a thorough cleaning of the substrates is essential to achieve a serviceable adhesion on metals, plastics and coated surfaces. To prevent contamination of the contents in the original primer packaging, the cleaner/primer should either be poured onto the tissue or transferred into another clean container. The end user should take care to only dispense the optimum amount of material required, and then close the original container immediately. Once the cleaner is applied to the part, the operator should allow time for



Graph 1: Bond Strength Development vs. Cure Time (Loctite® 5607)

solvent to flash-off of the part prior to adhesive application.

The following section highlights some of the primers which are regularly used in elastomeric bonding applications.

Teroson FL is a clear/transparent cleaner that cleans all surfaces before application of a silane modified polymer. The carrier solvent of Teroson FL is a petroleum spirit. approximately 2 minutes.

Depending on the degree of contamination, size and shape of the parts to be treated, Teroson FL is applied and wiped off with a non-woven tissue. To prevent contamination of the contents in the original packaging, the cleaner should either be poured onto the tissue or transferred into another clean container. The end user should take care to only dispense the required amount of material required, and then close the original container immediately.

Teroson FL is strictly a cleaner, therefore product does not have a limited on-part life. However, if the parts are racked and become soiled prior to bonding, the end user should prepare parts with the cleaner again prior to bonding.

Teroson SB 450 is a transparent, active cleaner which assists in increasing adhesion of SMPs, polyurethane and silicone on plastics, metals, and painted surfaces. The carrier solvent of Teroson SB 450 is isopropyl alcohol (IPA). Once applied to the part, the operator should allow for a solvent flash-off and then wait 10 to 60 minutes prior to adhesive application to maximize adhesion.

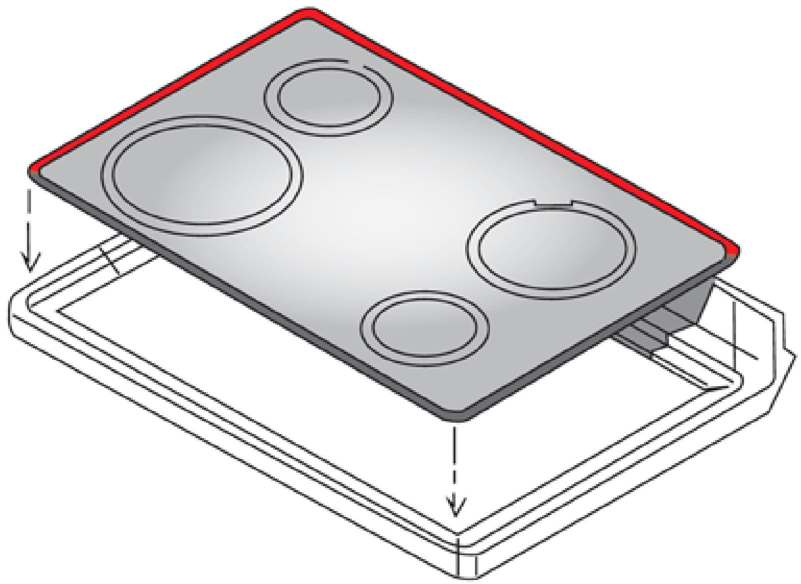


Figure 5: Depicts boding glass cooktop to steel frame.

This product cleans the surface and leaves behind active sites where silane-based chemistries attach for better adhesion. Teroson SB 450 should be applied to the part finely and evenly using a suitable clean cloth or paper. The cloth or paper should be changed once contamination becomes apparent. The on-part life of Teroson SB 450 is up to 24 hours

To verify that Teroson SB 450 covers the entire substrate, manufacturers can place the part under a UV lamp with a wave length of approximately 380nm. The primer contains a UV indicator that makes areas coated with the primer visible when exposed to UV light.

Loctite® 7555CL is a clear transparent primer that assists in increasing adhesion of silanes on plastics, metals, and painted surfaces. The carrier solvent of Loctite® 7555CL is heptane. Loctite® 7555CL is packaged in 1.75oz glass bottles and was originally developed for use with Loctite® 5655 two-part silicone, which has limited adhesion to any surface without a primer.

Loctite® 7555CL is a true primer that leaves behind a closed barrier between the substrates being bonded. Polyurethane and silicone-based chemistries grab onto the coating created by the primer to increase adhesion on difficult to bond surfaces.

Once applied to the part, the operator should allow for a flash-off time of 5 minutes on metals, and between 15 and 120 minutes on plastics to maximize bond strength. The on-part

PRIMERS & CLEANERS					
	TEROSON® FL	TEROSON® SB 450™	LOCTITE® 7555CL™	TEROSON® 8519 P™	TEROSON® 8517 H™
Solvent Carrier	Petroleum Spirit	Isopropyl Alcohol (IPA)	Heptane	Methyl Ethyl Ketone (MEK)	Methyl Ethyl Ketone (MEK)
Flash Time	2 min	10 to 60 min	• 5 min on metal • 15 min to 2 hours on plastic	2 to 15 minutes	2 to 15 minutes
On Part Life	Up to 24 Hours	Up to 24 hours	Up to 72 hours	Up to 12 hours	Up to 24 hours

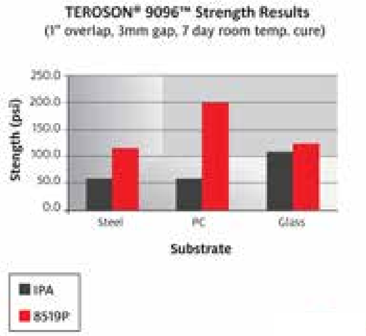
This table highlights some of the primers which are regularly used in elastomeric bonding applications.

life of 7555CL is up to 72 hours.

Teroson 8519 P is a black primer designed to increasing the adhesion of silanes on glass, plastics, metals and painted surfaces. The carrier solvent of Teroson 8519 P is methyl ethyl ketone (MEK).

This product is a true primer that leaves behind a closed barrier between the substrates being bonded. Polyurethane and silicone-based chemistries grab onto the coating created by the primer to increased adhesion on difficult to bond surfaces. Bar Graph 1 depicts the increase of bond strength that can be attributed to Teroson 8519 P on steel, polycarbonate, and glass substrates

Once applied to the part, the operator should allow for a flash-off time of 2 to 15 minutes. The on-part life of Teroson 8519P is up to 12 hours.



This chart shows the improvement of bond strength associated with primer use.

Teroson 8517 H is a black primer designed to increase the adhesion of polyurethanes and silicones on glass and ceramics. The carrier solvent of Teroson 8517 H is MEK.

If the surface was first cleaned with Teroson FL, the operator should allow the surface to dry for at least 30 minutes prior to application of the Teroson 8517 H. Once Teroson 8517 H has been applied to the part, the operator should allow for a flash-off time of 2 to 15 minutes. The on-part life of 8517H is up to 24 hours.

Adhesive, primer and cleaner compatibility should never be generalized because of the variations and exceptions within chemistries and substrates. Therefore, it is critical that manufacturers work closely with their adhesive supplier during the design phase of the appliance. Together, the manufacturer and adhesive supplier can verify actual end use performance on the final device before going into large scale production.

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