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## Bonding, Joining & Sealing

### Harsh Environments

#### New Adhesive Systems Provide Excellent Performance And Durability in Severe Operating Environments

Many of today's products must be designed to deliver long service lives while operating in harsh environments. The most striking example is NASA's space shuttle, which is subjected to extreme dynamic and static stresses, temperatures, and radiation during launch and re-entry. To keep the shuttle's aluminum structure below 350°F during re-entry when temperatures reach 2,300°F, much of the vehicle's underside, which takes the brunt of frictional heat, is covered with silica insulation tiles. The 24,300 tiles are not mechanically fastened to the vehicle but rather are glued to Nomex felt strain isolation pads with silicone adhesive. The pads, which in turn are bonded to the underlying aluminum vehicle skin, isolate the brittle tiles from the orbiter's structural deflections and expansions.

But you don't need to go into outer space to find difficult environments that test the ability of adhesives to perform under extreme conditions. Military and commercial aircraft, reliant on an increasing number of adhesive bonds, undergo similar dynamic and static stresses, operate at temperature extremes from tropical ground level to sub-zero cruising altitudes and are subjected to humidity, rain, corrosive salt spray, solvents, and jet fuel.

For everyday ground transportation vehicles – cars, trucks, buses, trains, subways, light rail – designers have increasingly replaced traditional fasteners with adhesives. Despite this, they operate year after year in difficult, gritty environments that often add road salt and summer and winter temperature extremes to the mix.

Even seemingly more benign applications such as industrial machinery, household appliances, personal electronics devices, and medical equipment must deal with environmental conditions that are far more challenging than might be expected. And, once again, adhesives often are preferred to conventional fastening methods.



Pressure-sensitive foam tapes and adhesive transfer tapes accommodate expansion/contraction cycles.

Whether in aerospace or ground-based applications, innovative, engineered liquid adhesives and thin bonding products (pressure-sensitive foam tapes and adhesive transfer tapes) that maintain properties in harsh environments have significant advantages for joining many substrates, including metals, plastics, rubbers, and glass. Compared to mechanical fastening and thermal joining, adhesives distribute rather than concentrate stress loads, accommodate flex and vibration, separate potentially reactive metals, and form seals that conform to joints and protect them from corrosion.

### **What Makes a Good Adhesive?**

The single most important variable when considering an environmentally resistant adhesive is operating temperature. Other important factors are humidity and exposure to solvents and ultraviolet (UV) light. For outdoor, non-aerospace applications, the maximum temperature – even inside a closed automobile or truck cab on a hot, sunny day – is not likely to exceed 140°F and winter minimums will range from freezing to -25°F. Outdoor applications also will be exposed to water, UV, and perhaps salt spray, corrosive chemicals, solvents, and/or fuels. Most common adhesive products are well within

their performance ranges in outdoor environments.

Applications involving water require adhesives with special resistance to wet and humid environments. Boats and other maritime equipment, pools, spas, and water/wastewater treatment, handling, and testing systems may need further resistance to the effects of solvents, fuels, and other corrosive liquids that are part of the environment in which they operate.

Other applications may encounter higher temperatures or stronger solvents or chemicals. For example, certain medical devices must be designed to withstand repeated sterilization processes that use autoclaving and cleaning solutions. Electric motors, generators, electricity transmission components, and under-hood automotive components may operate at temperatures exceeding the boiling point of water and be exposed to highly corrosive chemicals. Acrylic, urethane, epoxy, and silicone adhesives maintain good properties at temperatures of 300°F and above.

Products that undergo thermal cycling expand when heated and contract when cooled. Because dissimilar materials, such as metals and plastics, usually have very

different coefficients of expansion, a rigidly fastened joint can experience stresses that cause buckling, cracking, and failure. More flexible, softer adhesives, such as urethanes and silicones, have an advantage in these applications. But the real standouts are flexible thin bonding products – pressure-sensitive foam tapes and adhesive transfer tapes – that accommodate substrate expansion/contraction while maintaining outstanding durability and performance, cycle after cycle. In many situations, thin bonding products are superior to rivets, spot welds, thermal joining, rigid liquid adhesives, and other permanent fasteners.

### **Adhesive Choices**

Several families of liquid adhesives and flexible thin bonding systems offer designers products that resist environmental stress and degradation. Selection of the best adhesive alternative depends on the specific application being considered, including substrates to be bonded, maximum/minimum temperature requirements, extent of thermal cycling, vibration and other physical stresses, exposure to UV, moisture, humidity, salt spray, chemicals, solvents, and production and processing requirements.

## Liquid Adhesives

**Anaerobics** are one-part adhesives that cure in the absence of air into temperature-resistant, thermoset plastics. Used primarily to bond metal substrates, they function at temperatures of up to 160°F and are resistant to water, mild solvents, and hydrocarbons.

**Hot Melts** are thermoplastic compounds applied as flowing liquids. A bond is formed

when they cool between substrates. Because they soften as temperatures rise, hot melts are generally limited to maximum temperatures of about 160°F. However, Polyamides are used for potting applications where higher-temperature resistance is needed. Polyolefins provide good moisture resistance, adhesion to low-surface-energy plastics (polyethylene, for example), and resistance to polar solvents, acids, bases, and alcohols. Other hot melts include

reactive urethane and ethyl vinyl chloride. A chief advantage of hot melts is short setup time that eliminates the need for fixtures to hold parts in place.

**Polyurethanes** are one- and two-part adhesives that are tougher than epoxies because of their combination of flexibility and cohesive strength. Compared to epoxies, they have greater flexibility, better peel strength, and lower modulus.

Performance Considerations	Adhesive Category										
	Cyanoacrylates	Epoxies	Hot Melts	Light Cure	Silicones	Elastomers	Urethanes	2-Part Acrylics	2-Step Acrylics	VHB Foam Tapes	Adhesive
<b>Benefits</b>	Wide range of bonding applications	Wide range of formulations	Versatile, fast, large gap filling	Rapid cure/adhesion to plastics	Excellent temperature resistance	Flexible, paintable, bonder/sealant	Excellent toughness/flexibility	Good impact resistance/flexibility	Good impact resistance/no-mix	High holding strength	Excellent environmental resistance
<b>Limitations</b>	Low solvent resistance	Mixing required	Limited heat resistance	Light cure resistance	Low adhesion resistance	High temperature resistance	Sensitive to moisture	Mixing required	Primer required	Does not provide structural bond, limited gap filling	Does not provide structural bond, limited gap filling
<b>Temperature Resistance</b>											
Typical for the category	-65°F to +180°F	-65°F to +180°F	-65°F to +250°F	-65°F to +300°F	-65°F to +400°F	-65°F to +200°F	-65°F to +250°F	-65°F to +250°F	-65°F to +300°F	-122°F to +230°F	-122°F to +230°F
Highest rated product	+250°F	+400°F	+330°F	+350°F	+725°F	+200°F	+300°F	+250°F	+400°F	+400°F	+500°F
<b>Environmental Resistance</b>											
Polar Solvents (EX. H <sub>2</sub> O, ETHYLENE GLYCOL IPA, ACETONE)	Poor <sup>1</sup>	Very Good	Good	Good	Good	Good	Good	Good	Good	Fair	Fair
Non-Polar Solvents (EX. MOTOR OIL, TOLUENE, GASOLINE, ATF)	Good	Excellent	Good	Very Good	Poor to Fair	Poor	Good	Very Good	Very Good	Fair	Fair
<b>Adhesion to Substrates</b>											
Metals	Very Good	Excellent	Good	Good	Good	Very Good	Good	Excellent	Excellent	Excellent	Excellent
Plastics <sup>2</sup>	Excellent	Fair	Very Good	Excellent	Fair	Good	Very Good	Excellent	Fair	Good	Excellent
Glass	Poor	Excellent	Good	Excellent	Very Good	Good	Good	Good	Excellent	Good	Good
Rubber	Very Good	Fair	Fair	Fair	Good	Poor	Good	Poor	Poor	Fair	Fair
Wood	Good	Very Good	Excellent	Poor	Fair	Very Good	Fair	Good	Good	Good	Good
Overlapping Shear Strength	High	High	Low	High	Low	Medium	Medium	High	High	High	High
Peel Strength	Low <sup>3</sup>	Medium	Medium	Medium	Medium	Medium	Medium	High	Medium	High	High
Tensile Strength	High	High	Low	High	Medium	Medium	Medium	High	High	High	High
Elongation/Flexibility	Low	Low	High	Medium	High	High	High	Medium	Medium	Medium	Medium
Hardness	Rigid	Rigid	Semi-Soft	Semi-Rigid	Soft	Soft	Soft	Semi-Rigid	Semi-Rigid	Semi-Rigid	Semi-Rigid
<b>Gap Fill</b>											
Ideal (in inches)	0.001 to 0.006	0.004 to 0.006	0.002 to 0.005	0.002 to 0.010	0.001 to 0.006	0.001 to 0.006	0.004 to 0.006	0.010 to 0.040	0.002 to 0.004		
Maximum (in inches)	0.010	0.125	0.240	0.25	0.25	0.24	0.125	0.5	0.040		

<sup>1</sup> Cyanoacrylates have very good moisture resistance on plastics.

<sup>2</sup> Uncured liquid adhesives may cause stress cracking of certain thermoplastics, e.g., polycarbonate, acrylic, and polysulfone. Special products and process techniques are available.

<sup>3</sup> Exception: Toughened cyanoacrylates have HIGH peel strength.

**PLEASE NOTE:** This chart should not be used to specify products without specific testing. It is recommended that you conduct one-part testing to ensure product performance before specifying any adhesives.



Thin bonding systems attach and seal components against moisture, heat, and corrosive solutions.

Polyurethane formulations have good chemical resistance and maximum temperature capabilities from 160°F to 300°F. Moisture can impair bonding performance and appearance, and long-term exposure to high temperatures will degrade polyurethanes more rapidly than epoxies.

Acrylics are available in two forms:

1) One-part, solvent-free, light-cure acrylics that set up in seconds and create high bond strengths with a wide variety of substrates. Formulated for flexibilities ranging from soft to brittle, they have very good thermal, chemical, and environmental resistance. And, 2) Two-part acrylics that have equally good environmental properties and form strong, flexible bonds with many metals and plastics, giving them long-term fatigue resistance and durability. Acrylic formulations are available with maximum temperature capabilities of 160°F to greater than 400°F, rivaling the performance of some epoxies. Acrylics also have the ability to form strong bonds on oily metal surfaces, such as cold-rolled steel.

Epoxies are one- and two-part structural adhesives that, when cured, have very good chemical resistance, exceptional fluid resistance, and the ability in certain formulations to operate at greater than

400°F. They are very rigid and inflexible. One drawback to epoxies is their relatively long cure times of up to two hours.

Silicones are the high-temperature champs that retain properties in the 450°F to 700°F range. They are softer and more flexible than rigid, highly cross-linked acrylic and epoxy formulations. However, silicone doesn't provide the bond strengths of acrylics, epoxies, or polyurethanes. Silicones are useful as sealants and gaskets because of their resistance to non-polar solvents like gasoline and oil, their ability to form a protective surface seal at the bond line to prevent the corrosive effects of water and salt water, and their resistance to temperature extremes.

#### **Flexible, Thin Bonding Systems**

Although available for about 25 years, recent advances in flexible, thin bonding systems are attracting a new generation of designers and manufacturers because of their significant advantages in performance, versatility, and overall production savings compared to conventional fasteners and adhesives.

Conformable foam tapes and adhesive transfer tapes provide toughness and durability for applications that demand

strength, flexibility, and resistance to harsh environments. These pressure-sensitive bonding systems are based on acrylic formulations that assure instant adhesion to specific or a broad range of materials – from high-surface-energy substrates (aluminum, steel, etc.) to difficult-to-bond, low-surface-energy plastics (polypropylene, powder coatings, etc.).

With foam tapes, ranging in thickness from 0.015-0.120 inches, the thin foam layer absorbs and dissipates energy to increase the effective strength of the surface bond, giving tapes the ability to replace rivets, spot welds, some liquid adhesives, and other permanent fasteners in many applications. These all-acrylic systems are highly resistant to heat, ultraviolet light (UV), water, salt water, and chemical attack, and are able to strongly bond oily surfaces, such as steel, and vinyl in the presence of plasticizers.

Rigorous environmental testing and years of use in critical applications has shown that flexible, thin bonding systems can tolerate periodic, short-term temperature extremes up to 300°F for foam tapes and 500°F for adhesive transfer tapes. In accelerated weathering, which subjects stainless steel overlap foam tape bonds to heat, humidity

and UV exposure, bond strength does not deteriorate below its original level after 7,000 hours. Outdoor weathering for 2 to 5 years shows 100% foam tape bond strength retention with aluminum, glass, PVC and painted metal in climates ranging from hot and humid, hot and dry, to cyclical cold/hot extremes. Aluminum-to-aluminum foam tape bonds submerged in 5% salt water and tap water show continued high-performance levels after 10 years. When the adhesive is removed, bright aluminum surfaces are exposed.

## **Adhesive Solutions for Harsh Environments**

### **Liquid Adhesive Applications**

New formulations of liquid adhesives deliver stronger, tougher, and more reliable bonds on metals, plastics, composites, polyolefins, and other substrates than traditional fasteners or welding while offering excellent resistance in severe operating environments. They are available in fast-cure, easily dispensed formulations with superior moisture resistance, excellent hot strength, and chemical resistance.

Application and curing can be automated to speed production and reduce labor costs. With their combination of strength and ability to operate in harsh environments, these general-purpose structural adhesives are widely used in agricultural and construction equipment, specialty vehicles, furniture, appliances, signage, tubs and spas, and architectural/building components where metal-to-metal, rubber-to-metal, plastic-to-metal,

and glass-to-metal bonding can be a challenge.

Similarly, adhesive formulations for low-surface-energy materials are capable of bonding fiberglass, gel coat, thermoplastics, polycarbonate, ABS, PVC, polyethylene, and polypropylene. Flexible adhesives have fast fixture times, good bond clarity, and UV resistance so important in outdoor applications.

### **Thin Bonding Systems Applications**

Flexible, pressure-sensitive acrylic foam tapes and adhesive transfer tapes offer unique application opportunities because of their high holding strength, excellent resistance to harsh environments, and prevention of bi-metallic corrosion. These systems save time and money with fast and easy assembly that eliminates drilling, grinding, refinishing, screwing, welding, and cleanup. In addition to tapes, adhesive peel-and-stick masks can be die cut to precisely fit any shape, size, or profile. Pressure-sensitive adhesives bond parts instantly, eliminating the need for fixtures and long cure times. Because of their viscoelasticity, tape adhesives absorb shock and flexing and improve fatigue resistance caused by environmental factors such as wind, vibration, and substrate expansion and contraction caused by temperature cycling.

One of the most demanding applications of a thin bonding system is aircraft exteriors. Several commercial aircraft models bond stainless steel anti-chafing strips to

aluminum wing flaps with adhesive transfer tape. These strips help prevent abrasion and chafing between the flap and the underside of the wing during deployment of the flaps for takeoffs and landings. Bond durability and resistance to environmental extremes is a key requirement for this application because the bond often is subjected to high skin temperatures in direct sunlight on the ground and -64°F at high altitude, a cycle that may be repeated several times a day. This application has been in use since 1984.

Another demanding and visible application of thin bonding foam tapes is on ambulance bodies where aluminum body panels are bonded to the vehicle frame. This application requires durability under harsh conditions and performance over an extended period of time.

There are many architectural applications for thin bonding systems, but perhaps the best example is in curtain wall construction. Exterior building skin panels are stiffened against wind loads by attaching unseen stiffeners to the inner surface with thin bonding tape. These bonds must sustain wind loads, daily thermal expansion and contraction cycles, and elevated temperatures. Architectural signage and traffic signs using thin foam tapes must also endure constant weathering, buffeting winds, and occasional storms. These have been in use since the early 1980s.

In transportation vehicles, there are many applications for thin bonding systems. They

are now successfully used inside automobiles to invisibly adhere window switch plates and other plastic trim pieces to vinyl substrates, eliminating unsightly fasteners. Plasticizers compounded in soft vinyl can migrate into adhesives and significantly degrade their performance. The tapes used are specially formulated to bond strongly to vinyl and resist the effect of plasticizers.

Water resistant thin bonding systems are used to adhere salt water keel protectors to boats. UV resistant thin bonding systems are used on solar electric power collectors to bond panels to support frames and affix electric power collection buses to the

assemblies. And a range of personal electronic and medical devices use thin bonding systems to attach and seal components against moisture, heat, cleaning solutions, and corrosive fluids.

### **About Fabrico**

Fabrico is a recognized leader in cost-effective product design and engineering, as well as converting and custom fabrication services for flexible materials. The company designs and manufactures components and sub-assemblies using flexible materials for industries as diverse as transportation, medical device, general industrial, solar, and military.

