PDHonline Course G257 (5 PDH)

Adhesives

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SCOPE:

This course will concentrate primarily on providing information that allows the engineer or manager to better select adhesives relative to a variety of needs. While some theory of adhesion will be given, we wish to spend most of our time discussing adhesive types, application, material specifications, surface preparation, testing and material standards. We will limit the study to adhesives only and omit materials used for gasketing, potting and encapsulation, retaining, thread locking and thread sealing. These adhesives are very specific and demand scrutiny as independent subjects. Since pressure sensitive tapes (PSTs) are such a huge portion of the adhesive industry, we will take a brief look at what is available as far as types, global usage, specifications, vendors, etc.

I would like to direct your attention to the Appendix and the Glossary of Terms for Pressure Sensitive Tapes and the Glossary of Terms for Adhesives. The terminology is somewhat different for both types of adhesives so I have included both glossaries in this course. Looking at the Glossary of Terms will aid your efforts in reading and understanding the text, so please take a brief look before you begin reading the course material.

INTRODUCTION:

The dictionary defines an adhesive as "a substance capable of holding materials together by surface attachment." This is a simple definition for materials that serve as the basis for a multi-billion dollar industry with more than 750 companies. It is estimated that 50 of those companies are responsible for at least 50% of the sales dollars in the adhesive industry.

This course will examine adhesives and give an overview relative to adhesive types, uses, advantages and disadvantages, characteristics and various failure modes that could result due to use or over use. Adhesive technology is a dynamic industry with new compounds being developed frequently to satisfy growing consumer and industrial needs. “The need for speed” and bond strength, with minimal surface preparation, are the driving forces behind development efforts. Oddly enough, retail cost seems to be a lesser concern when searching for a suitable material. Get the job done right is the clarion call.

The history of adhesives is fascinating and goes back to the time of the Pharaohs. We will take a look at that now.

HISTORY:

The first evidence of a substance being used as an adhesive dates back to 4000 B.C. Archaeologists studying burial sites of pre-historic tribes found foodstuffs buried with the deceased in broken pottery vessels that had been repaired with sticky resins from tree sap. Archaeologists have also uncovered statues from Babylonian temples that have ivory eyeballs glued into eye sockets. This tar like glue has held for almost 6000 years.

The first references in literature concerning glue and the art of glue appears about the year 2000 B.C. Simple procedures for making and using animal glue were written. The ancient Egyptians used them in veneering the treasures of Tutankhamen. The ancient Greek word for glue is κολλα, from which we get the word colloid. In all centuries up and including the 19th, glues originated from plants and animals; during the 20th century, however, synthetic chemicals have largely taken over, and the more respectable name of “adhesive” is generally used instead of “glue”.

The period of time between 1500 and 1000 B.C. gave further proof that glue had become a method of assembly. Paintings and murals showed details of wood gluing operations. A casket removed from the tomb of King Tut shows the use of glue in its construction. Our museums today contain many art objects and furnishings from the tombs of Egyptian Pharaohs that are bonded or laminated with some type of animal glue.

The next period of activity is from 1-500 A.D. when the Romans and Greeks developed the art of veneering and parquetry, which is the bonding of thin sections or layers of wood. From this art, the making of animal and fish glues were refined and other types of adhesives were developed, such as an adhesive from egg whites to bond gold leaf. In addition to egg whites, other natural ingredients were used to prepare glue such as blood, bones, hide, milk, cheese, vegetables and grains. The Romans were one of the first to use tar and beeswax to caulk the planking in boats and ships.

A study of history shows the use of glue fell into disuse until about 1500-1700 A.D. when adhesives were used in the building of furniture. Some of the greatest furniture and cabinet makers of all times used adhesives in their products--names you will still recognize today like Chippendale and Duncan Phyfe.

Another name in history who may owe his notoriety, at least in part, to adhesives is Genghis Khan. About 1000 A.D. the Great Khan overcame all attackers because of the exceptional power and range of the weaponry his men carried. Bows were made from laminated lemon wood and bullhorn bonded with an adhesive whose formula has been lost in antiquity.

The secret of violins made by Antonio Stradivarius was the adhesive process used to laminate his specially treated woods. His methods have also been lost in antiquity, and have not been rediscovered even with today´s sophisticated analytical methods.

About the year 1700, the widespread use of glue brought rapid changes in the history of adhesive. The first commercial glue factory was started in Holland to manufacture animal glue from hides.

In 1750, the first glue patent was issued in Britain for fish glue. Patents were then rapidly issued for adhesives using natural rubber, animal bones, fish, starch, milk protein (casein). By 1900, the U.S. had a number of factories producing glue from the previously mentioned bases.

The Industrial Revolution created an explosion in technical breakthroughs which resulted in new materials becoming available for use in formulating adhesives. The first plastic polymer to be synthesized was cellulose nitrate, a thermoplastic material derived from the cellulose of wood. Its first use was in the manufacture of billiard balls, which had been made of ivory. The era of plastics began with the introduction of Bakelite phenolic, a thermoset plastic, in 1910. Within a year, adhesives using phenolic resin were put on the market. The 1920´s, 30´s and 40´s saw many new plastics and rubbers synthetically produced, many- out of an urgent necessity--developed during World War II. Although adhesives have been known for about 6000 years, most of the technology has been developed during the last 100 years.

The formulation of plastics and elastomers has rapidly advanced the development of adhesives. These discoveries have given a wide variety of products that can change and improve various properties of adhesives. Properties such as flexibility, toughness, curing or setting time, temperature and chemical resistance result from constant experimentation.

Adhesives touch our lives every day. They are never more than an arm´s length away, even though we may not be aware of their presence. A description of some of the more common types of adhesives and their uses should make you more aware of how adhesives touch your life. We certainly will consider the adhesive types but first, let us look at the global usage and how prevalent they have become over the years.

GLOBAL USAGE:

Global usage for all types of adhesives was estimated to be 33 billion pounds in 2007. If all countries would optimize their usage, as compared to Western industrialized nations, that number would be approximately 190 billion pounds. The table below will indicate those countries and regions that represent the largest users for that year.

REGION	DEMAND (MM LBS.)	LBS/PERSON
North America	9720	28.60
Latin America	1641	3.00
Western Europe	7613	19.00
Eastern Europe	1747	5.00
China	5227	3.90
Japan	1893	14.70
Other Asia	4518	1.80

Table 1 Global Usage

The market leaders, by country, are: 1.) United States, 2.) China, 3.) Japan, 4.) Germany and 5.) The United Kingdom. Growth of the global adhesive market is approximately two to three percent per year. It is very interesting to note that it has generally taken eighteen (18) years for a new adhesive application to be used by ninety percent (90) of the products adopting that application. One reason for this is the time to prove the quality and reliability of the use in question. This frequently involves extensive reliability testing, especially for "mission critical" parts. Another factor is designing joints so that any adhesive bond failure is a "fail safe" proposition. Case in point being the Boeing "Dreamliner". Substantial testing, over the years, has been conducted on all of the bonded surfaces and every application has been proven by environmental testing and by flight testing.

If we look at the **annual U.S.** adhesive demand for 2007, we find the following usage categories:

Durable goods—6%

Industrial Products—2%

Household adhesives—2%

Construction—40%

Packaging—39%

Nondurable goods—11%

Further examination reveals the 2007 **annual U.S.** usage for adhesive material types:

Phenolics—37%

Vinyls—18%

Acrylics—4%

Urea and melamine—19%

Synthetic elastomers—15%

Polyurethanes—3%

The global market for adhesive emulsions categories is: Packaging (56%), Tapes and Labels (19%), Consumer and Other (15%) and nonwovens (10%).

The primary vendors supplying these markets are 1.) Henkel (Germany), 2.) National Starch and Chemical (UK), 3.) HB Fuller (US), 4.) Bostik Finkley (France), 5.) Rohm and Hass (US), 5.) Konishi (Japan), 6.) ITW (US), 7.) Three Bond (Japan) and 8.) Reichhold (Dainippon Ink and Chemical (Japan). Henkel controls most of the market with a global share of approximately 14%. In looking at the tape suppliers, 3M and Avery Dennison are the top two with 9% and 7% respectively, of the global market.

The trends for usage in the United States and throughout the world are definitely up. More and more applications for adhesives are being used as research continues on how to adequately test for quality and reliability.

ADVANTAGES AND DISADVANTAGES:

ADVANTAGES:

There would be no continued need for adhesives unless there were advantages to their use. The list below will give several verified advantages proven over the years. This list increases in length every year as more and more research is conducted and better adhesives reach the market place. There are so many possible applications involving so many substrates that time is necessary for quality assurance to make sure the correct adhesive is used relative to the substrates in question. Also, testing agencies are developing better methods and better equipment to test the integrity of a bond and assure no voids, cracks, porosity, inclusions, etc. The list is as follows:

1. Allows for fabrication of smoother surfaces: a.) reduction of drag.
2. Reduction in temperature due to reduction in drag.
3. Allows for a closer fit for adjoining parts.
4. Allows for better contour of raidused surfaces.
5. Elimination of holes.
6. Permits the use of lighter weight materials.
7. Can give a reduction in stress concentration factors.
8. Can lessen ultimate vibration of fabricated assemblies.
9. Provides for a better distribution of stresses.
10. Provides for better fatigue resistance.
11. Good shock and impact resistance.
12. Allows for the joining of dissimilar materials.
13. Allows for the joining of materials of differing thicknesses.
14. Lesser issues with the coefficient of thermal expansion.
15. Easier fabrication.
16. Faster fabrication.
17. Can act as a seal.
18. Some adhesives are sound-proofing in nature.
19. Can prevent the advent of encapsulated moisture.
20. Some adhesives are insulators.
21. Generally lower costs when compared with bolts, screws, etc.
22. Easy to automate process.
23. Can be less expensive than mechanical fasteners.

As with any technology, there can be disadvantages. Several are listed below. As you will see, there are certainly some conditions and situations in which adhesives are unsuitable. Environmental conditions such as temperature and humidity can dictate the need for traditional mechanical fasteners. Of course there is a definite need to examine the loads applied to a joint to preclude failure prior to deciding upon the technique in securing the bond.

DISADVANTAGES:

1.) Limited to lesser temperatures; i.e. < 550 degree F.
2.) Proper surface preparation is an absolute must.
3.) Joint design must be adequate and proper. **(NOTE: We never "stick" the materials together. Proper joint design prior to using an adhesive is absolutely necessary. A joint designed for a mechanical fastener may not be adequate when using an adhesive.)**
4.) Service life may be lessened due to wear of adhesive. Long term behavior may not be as good nor as predictable. This is where reliability testing is a must.
5.) Specification of adhesives must be more exact and detailed. It is critical that the engineer work with a potential vendor to achieve the proper specification and adhesive type prior to usage. **THEN; APPLY, TEST and PROVE the application.**
6.) Differing substrates must be factored into the proper specification of the adhesive.
7.) Better training required for application of adhesive. The usage and application of an adhesive requires trained workers.
8.) The bond area is critical to integrity.
9.) Uncertainty of bond is a worry. The reproducibility of the bond can be difficult to control.
10.) Difficult to "pre-test" adhesive relative to substrates.
11.) Coefficient of expansion must be considered relative to the substrates.
12.) Curing time can be high depending upon the adhesive and the process.
13.) Depending upon the adhesive, there can be assembly hazards such as fire or toxicity. It Is always recommended that training precede the use of adhesives, primers, cleaning agents and accelerants.
14.) Usually, no disassembly is possible. This can eliminate the possibility of repair.
15.) Difficult to inspect bonded joints. "X"-ray and ultrasonic non-destructive testing are changing this to some extent.
16.) Can be change in mechanical properties of assemblies.
17.) Lack of nondestructive quality control methods.
18.) Bond quality is very dependent upon many variables in the bonding process.
19.) No single "universal" adhesive for all applications.
20.) Proper storage of the adhesive and any accelerant is necessary prior, during and after usage.

USES:

We have talked about the advantages and the disadvantages of adhesives so now let us address some of the uses for modern day adhesives, both synthetic and natural. Even a partial list is impressive.

Packaging Sealants	Dental Technology
Automotive	Aerospace
Aircraft Assembly	Shoe Fabrication and Assembly
Computer Equipment	Commercial Electrical Equipment

Appliance Manufacturing and Assembly

Assembly of Toys	Thread Locking Adhesives

Potting Compounds for Electrical and Electronic Devices

Assembly of Business Machines	Health Care Products
Pressure Sensitive Tape	RTV Silicones for Moisture Prevention
Manufacture of Boats	Kitchen Utensils
Manufacture of Light Bulbs	Windows and Doors
Furniture and Cabinets	TV Sets
Radios	i-PODS
Belts for Men and Women	Golf Club Heads

Closing Wounds from Surgical Procedures

Car batteries	Picture Frames
Cell Phones	Electrical Assemblies
PC Boards	Medical Equipment
Handbags for Ladies	Picture Frames
Book Binding	DVD Players
Play Station Devices	Power Tools
Hand Tools	Sandpaper
GPS Devices	Computer Equipment
Lighting Fixtures	Carpet Backing
Ceiling Fans	Robotic Equipment
Jewelry	Clocks / Watches
Home Repairs	Industrial Maintenance
Plywood	Paneling
Cigarette Packs	Wallpaper

Band-Aids Baby Diapers

Floor Tiles

THEORIES OF ADHESION:

I mentioned earlier that this course is meant to be a practical guide on how to select an adhesive and the various theories of adhesion would be a minor concern. Since we are buying adhesives and not MAKING adhesives, I felt this would be a viable approach. With that being said, we do need to know something about how the adhesives and substrates interact to form a cohesive bond. First, let us look at the basic chemistry involved.

All adhesives either contain polymers, or polymers are formed within the adhesive bond. This is universal. Polymers give adhesives cohesive strength, and can be thought of as strings of beads (identical chemical units joined by single covalent bonds), which may be either linear, branched or crosslinked. Linear and branched polymers have similar properties and it is not easy to distinguish between them. They will flow at higher temperatures and dissolve in suitable solvents. The latter properties are essential in hot melt and solvent-based adhesives but may be very detrimental in other applications. It is essential that the proper adhesive be specified for the proper usage **KNOWING** all environmental conditions that could possibly exist. Cross linked polymers will not flow when heated, and may swell, but not dissolve in solvents. All structural adhesives are cross linked. This eliminates creep.

Many adhesives contain additives that are not polymers. These include stabilizers that help prevent degradation by oxygen and / or UV, plasticizers which can increase flexibility and lower the glass transition temperature, and powered mineral fillers, which may reduce shrinkage on hardening, lower costs and modify flow properties. Other additives are tackifiers and silane coupling agents. There are six theories of adhesion, as follows:

1.) Physical Adsorption 2.) Chemical Bonding 3.) Diffusion

4.) Electrostatic 5.) Mechanical Interlocking 6.) Weak Boundary Layer

Physical Adsorption Theory:

Attractive forces due to physical adsorption are usually designated as secondary or van der Waals forces across an interface. Van der Waals forces are the result of electrostatic attraction between neighboring molecules having permanent or instant transient dipole groups. These include molecules with permanent dipoles, dipoles induced by permanent dipoles in neighboring molecules, known as Debye forces and finally, London dispersion forces which are present in all molecules. Dispersion forces are dipoles produced by the motion of electrons within the molecule and are independent of the polarity or lack of polarity of the molecule. These forces are more than sufficient to produce bonds stronger than the cohesive strength of most materials used as adhesives. The researcher Eley estimates the theoretical value for shear force necessary to move a molecule across a surface to be as high as 56,000 PSI. Dispersion forces are usually considered to be the major attractive force even in the presence of polar groups and hydrogen-bonding groups.

Chemical Bonding Theory:

The chemical bonding theory of adhesion invokes the formation of covalent, ionic or hydrogen bonds across the interface. There is some evidence that covalent bonds are formed with coupling agents. It is possible that adhesives containing isocynate groups react with active hydrogen atoms, such as hydroxyl groups, when wood or paper are the substrates. One example of this type of bond is the attachment of a postage stamp to a letter. Hydrogen bonds contribute to that attachment where the adhesive (polyvinyl alcohol) and paper (cellulose fibers) both contain- OH groups. This is an intermolecular bond formed when a hydrogen atom chemically bonds with another neighboring atom.

Diffusion:

The diffusion theory takes the view that polymers in contact may interdiffuse, so that the initial boundary is eventually removed. Such interdiffusion will occur only if the polymer chains are mobile. The theory is generally only applicable in bonding like rubbery polymers, as might occur when surfaces are coated with contact adhesives and then pressed together. This theory is gaining less popularity as more is known about adhesive bonding.

Electrostatic:

The electrostatic theory originated by proposing that when two metals are placed in contact, the electrons will be transferred from one to the other to form a double electrical layer. This layer provides the force of attraction. Since polymers are insulators, it seems very difficult to apply this theory to adhesives.

Mechanical Interlocking:

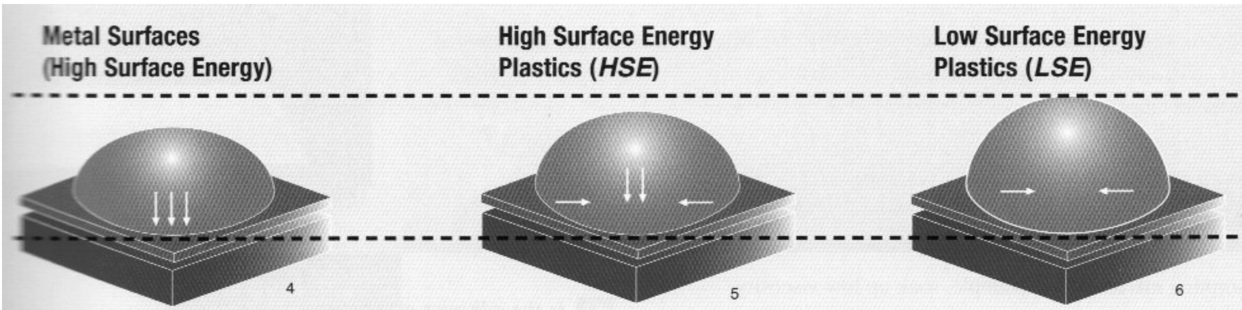
If the substrate has an irregular surface, then the adhesive may enter the irregularies prior to hardening. This simple idea works well for adhesive bonds for porous materials such as wood and textiles. An example is the use of iron-on patches for clothing. The patches contain hot melt adhesive that, when molten, invades the textile material. This theory is the simplest of theories and basically states that the adhesive penetrates these feature irregularities and hardens forming strong bonds. Ideally, the weakest part of the bonded joint is the adhesive strength.

Weak Boundary Layer:

This theory proposes that clean surfaces can give strong bonds to adhesives, but some contaminants such as rust, oils and greases give a layer which is cohesively weak. Not all contaminants will form weak boundary layers. In some cases, they will be dissolved by the adhesives. This is an area where acrylic structural adhesives are superior to epoxies because of their ability to dissolve oils and greases.

WETTING:

This is an appropriate time to discuss the "wetted substrate, or adherent, surface". This wetting process is absolutely necessary for proper adhesion of the substrates. It involves spreading a drop of liquid adhesive over the surface of the substrate and providing for intimate contact of the solid surfaces. **Liquids will wet only solid surfaces with higher surface energy than their own**. Water will wet metals but not polyethylene; naphtha will wet acrylic but not Teflon. The figure below will give you some idea as to the surface tension for various substrates.



mJ/m²	Surfaces	mJ/m²	Surfaces	mJ/m²	Surfaces
1103	Copper	50	Kapton® Industrial Film	37	PVA
840	Aluminum	47	Phenolic	36	Polystyrene
753	Zinc	46	Nylon	36	Acetal
526	Tin	45	Alkyd Enamel	33	EVA
458	Lead	43	Polyester	31	Polyethylene
700-1100	Stainless Steel	43	Epoxy Paint	29	Polypropylene
250-500	Glass	43	Polyurethane Paint	28	Polyvinyl Fluoride Film
		42	ABS		
		42	Polycarbonate	18	PTFE Fluoropolymer
		39	PVC Rigid		
		38	Noryl® Resin		
		38	Acrylic		

Figure 1 Surface Energy

The solution to this problem of "non-wettable" surfaces is to modify the surface, converting it to a surface of higher energy. This can be accomplished by 1.) Flaming, 2.) Acid etching or 3.) Treatment with UV radiation. The result is a reaction between the low-energy polymeric surface and oxygen in the air. Adhesives must be fluid enough to flow outward and conform to the shape of the substrate surface if strong joints are to be formed. Only liquids can penetrate the valleys and crevices of a solid surface. Typically the angle between the apparent surface and the real surface is 15 to 30 degrees. The spreading adhesive must flow over a series of hills and into the bottoms of a series of valleys if good contact is to be made. The spreading adhesive must displace or absorb all weakly held contaminants for maximum adhesion. This can happen only when the adhesive wets the surface well. The actual wetting angle characterizes the ability of the adhesive on the substrate. Good wetting values result when the wetting angle is < 90 °. Poor wetting occurs when the angle is high; i.e., between 90 and 180 °. The figure below will demonstrate what we are talking about.

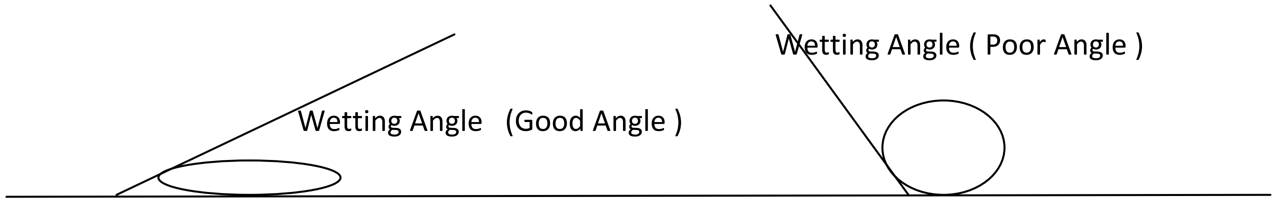


Figure 2 Wetting Angle

Good examples of the wetting ability of epoxies on varied surfaces are copper liners bonded to internal fiberglass missile structure, and fabrication of printed circuit boards, which utilize numerous dissimilar metals. Wetting and penetration are also of critical importance in honeycomb-sandwich bonding, where node wetting and filleting are absolutely essential for success. The ability to wet is also critical in glass laminates, because the adhesive must wet the individual glass strands in order to produce high strengths.

ADHESIVE TYPES:

We now wish to investigate the various types of adhesive by categories and give very brief descriptive information as to how these types are formulated. In general, adhesives can be grouped into the following categories:

A) Water Based - Adhesives that use water as a carrier or diluting medium, and set by allowing the water to evaporate or be absorbed by the substrate. There are several types of water-based adhesives.

1) Vegetable Glues – Adhesives are based on starch. They are usually amber to brown in color, commonly know as dextrine adhesives. These can also be made in a high viscosity, high tack version called jelly gum. Relatively low cost adhesive commonly used in paper bonding, packaging and labeling. Low moisture resistance. Bond lines tend to be brittle.
2) Resin Cements - These adhesives are based on an emulsion of EVA (Ethylene Vinyl Acetate) or PVA (Poly Vinyl Acetate) polymers blended into an emulsion with water as a carrier. These emulsions are capable of bonding to wood, paper and some plastics and foams. White in color. Bonds have higher degree of moisture resistance than dextrine, but cost of resin cement is higher. Certain resins may be blended with dextrines to form a hybrid product. Bond lines have some flexibility, and are relatively clear when dry.
3) Animal/Protein Glues - The two major types of adhesive in this category are hot animal glue (which is made from processed animal parts) and casein glue (derived from milk). Hot animal glue is amber to brown in color, and is applied at approximately 140°F. It can be thinned with water. When first applied it has very high tack, but dries to a non tacky film. Commonly used in situations where the high tack will hold the parts together while setting, but will not be exposed to high temperatures or high humidity. Casein glue is applied at room temperature, but forms a bond with a high degree of moisture resistance. Commonly used for labeling beer, champagne and some types of wine bottles. Casein is light to tan in color.
4) Latex Cements - These adhesives are a blend of latex or other elastomers in a water base

emulsion. In most cases they are applied to parts, allowed to dry, and form a layer, which serves as a contact cement (two way cements). Some types can also be applied to one surface and will form bonds as they dry (one way cements). Can be formulated to remain tacky or become dry to the touch (contact types). Generally white in color. Wide variety of uses such as self-stick envelopes, fabric bonding, and leather goods.

B) Thermal Adhesives - Thermal adhesives are those adhesives that are brought to a liquid state by heating, and are applied to the product hot - either as liquid or as a high viscosity paste. The most common types are hot melt adhesives and waxes.

Hot melt adhesives have seen tremendous development over the past thirty years. These adhesives are blends of various polymers, but most are based on a high percentage of EVA (ethylene vinyl acetate). To obtain the desired characteristics, other polymers may be blended into the mix, as well as waxes, oils, various types of rubber, and tackifying resins.

Hot melt adhesives can be used to bond many types of materials, and are available in three general types categorized by how fast they set up after application. The general categories are fast set, delayed set, and pressure sensitive.

Fast setting hot melts are types that form a bond very quickly as they cool. These are used for situations where fast setting is important such as the sealing of flaps on cartons or certain labeling applications. Delayed set hot melts are also known as adhesives having a "long open time". These adhesives remain tacky for some period of time after application, but eventually set to form a bond line that has very little residual tack. They are useful in applications where the parts must be positioned after application of the adhesive, or in situations where the parts cannot be assembled immediately after the adhesive is applied. Shoe and leather goods assembly is an example of one area where delayed set adhesive is used.

Pressure-sensitive hot melts remain tacky indefinitely after application. This allows the adhesive to be applied to a part that may not be assembled to a substrate for a long period of time. It also allows the bonding of parts that are difficult to bond (example would be polyethylene foam). In some cases pressure-sensitive hot melts are applied to a part and put on silicone-coated release paper. The release paper is peeled off to expose the pressure-sensitive layer, which is then bonded to the substrate.

Pressure-sensitive hot melts are available in many degrees of tackiness, from adhesives that form a temporary bond that can be easily broken (fugitive bond adhesives) to very aggressive pressure sensitives that will tear fiber from the substrates if removal is attempted.

Specialty hot melts are also available which have characteristics tailored to specific types of applications or temperature ranges. A few of these are as follows:

a) Remoistenable hot melts - This is a type of fast-set hot melt that is formulated with a component of the blend being sensitive to moisture. If moistened, it forms a tacky layer that can be used for envelope sealing or labels.
b) Polyamide hot melts - These are high temperature hot melts with high performance

characteristics. Generally the application temperature is around 400° F, and structural strength is higher than the more common types of hot melt.

c) Reactive hot melts - These are hot melts that are formulated with chemistry similar to polyurethane polymers. After application, an isocyanate component of the blend reacts with moisture in the air or substrate to form a polyurethane compound. Once cured, the material is no longer thermo plastic in nature but has excellent flexibility, high bond strength, high moisture and heat resistance, and resistance to most chemicals. The disadvantage of reactive hot melts is that they require specially designed application equipment, since any adhesive that is exposed to atmospheric moisture will react with it and form an inert polymer. Applications for the reactive hot melts are found in bookbinding, footwear construction, and recreational vehicle assembly.

Waxes are the oldest form of thermal adhesive, having been used for sealing documents for centuries. In today's world they see use as laminating adhesives for foils and films. Bonds are formed to the substrates when hot, but the strength is sufficient to keep the materials bonded at lower temperatures. One special form of adhesive wax is paste-up wax. This is a blend of sticky waxes and tackifying agents that is used to form a temporary bond that allows parts to be removed and repositioned after bonding. It is used by newspapers and printers during page layout (paste-up) process since it allows photos and columns of type to be moved around as the page layout is being developed.

C) Two-part Adhesives – These adhesives are made by mixing two or more components that react chemically to form a cross-linked adhesive. In general, they are higher cost than other types of adhesives but also provide very high strength bonds and outstanding performance characteristics. The most common two-part adhesives are epoxies, polyurethanes, acrylics, and silicones. Many adhesives such as these are used in construction and manufacturing.

Two-part adhesives are able to cure in the absence of air or moisture, and are often used to form structural bonds to metal, wood and plastic components.

Epoxies consist of a base resin and a hardener. In most cases the base resin is a high viscosity paste, and the hardener (catalyst) a lower viscosity, but mixes can be formulated to differing viscosities and mix ratios. Most types will set at room temperature, but some require a heat cure to trigger the cross-linking reaction. Heat will accelerate the cure rate of most epoxies, and will often help the epoxy form better bonds and attain higher strength levels. Some types of epoxies are available as single component pastes which are kept cold to inhibit the reaction, but which will form bonds and crosslink when exposed to heat. A cure time of about 24 hours may be accelerated by applying heat to the joint.

Polyurethane adhesives are available as two -part formulas or as one-part components which are pre-mixed but mixed with a carrier material such as solvent. Polyurethanes generally form bonds that are more flexible than epoxies but are quite tough. Urethanes form strong bonds to most materials, and can form strong bonds to rubber, plastics, metal, wood, paper, ceramic, and fabrics. **Most types are limited to service temperatures below 250° F.** Polyurethane adhesive are available in a wide range of viscosities and mix ratios. They must be very well mixed to obtain top quality bonds. Some types contain isocyanates or heavy metal catalysts that can pose health risks to workers, and require extra handling precautions.

Acrylic adhesives are available either as two-part adhesives or as products that are cured by exposure to ultraviolet light. Acrylic adhesives produce bonds with excellent peel strengths as well as high shear and impact strengths. They are generally more tolerant of dirty or poorly prepared surfaces then other adhesives. Acrylics offer excellent adhesion to unprepared metals, ceramic magnets and plastics. Viscosities range from paste to liquid and the set times range from 2 to 35 minutes. Full cure time is about 2 hours at room temperature.

Most types (with the exception of the U.V. cured types) are prepared by mixing the two components, but some types are available that allow the one component to be applied to one substrate, and the second component to the other. When the two substrates are brought together, the reaction occurs to bond the parts. **Acrylics are generally limited to temperatures below 300° F.**

Silicone adhesives are available as both one-part and two-part adhesives. The one-part versions are known as RTV silicones (room temperature vulcanizing) and cure by reacting with moisture in the atmosphere. These are used most often as caulking and gasketing materials. Two part silicones offer higher performance, and can be used for bonding metal, glass and ceramic components. These types of silicone adhesives find use in the electronics industry.

The primary advantage of silicone adhesives and sealants are their temperature resistance. Silicones can be formulated to withstand temperatures as high as 500° F, but provide flexible bond lines or sealing throughout their service range.

D) Moisture-Cure Adhesives – Moisture-cure adhesives are formulated to react with the moisture in the air or in the substrates to form a cured polymer layer with high strength. They are actually two component adhesives with one component being moisture. The two best-known types are silicone and polyurethane. The silicones are known as RTV silicones (room temperature vulcanizing), and are most commonly used as caulking compounds, gasket compounds, and sealants.

Polyurethane moisture cure adhesives are available in liquid form. In most cases the urethane monomer is dissolved in a solvent carrier, and reaction with moisture occurs as the solvent evaporates. Some types of water-borne urethanes are also available, but the newest types of moisture-cure urethanes are made in the form of hot-melt adhesives. These are called reactive hot melts, and exhibit a dual property. They are applied like regular hot melts, but after application begin to crosslink with moisture to form a tough adhesive layer with high resistance to heat, moisture, and impact.

E) Ultraviolet Cure Adhesives - These are adhesives which contain monomers that will cross-link upon exposure to ultraviolet light to form a polymer. The cross linking (or cure) can happen in less than a second at proper energy levels, so these adhesives can be used in high speed situations. Acrylic adhesives lend themselves to U.V. curing quite well, but U.V. cure versions of silicones, urethanes/acrylic blends and cyanoacrylates are also used.

Ultraviolet cure adhesives can form high-strength bond lines on materials which will pass the U.V. light. The primary advantage of U.V. cure adhesives is the fast cure speed.

F) Cyanoacrylate Adhesives - These are fast setting one-component adhesives that are popularly known as "crazy glue". Cyanoacrylates are solvent free and react with the moisture on the surfaces of the substrate materials to form a rigid plastic adhesive layer that has high strength characteristics. The cured adhesive is very high in tensile and shear strength, but low in peel strength.

Cyanoacrylates are expensive compared to other adhesives, but only a very small amount is needed to cover the area to be bonded, since this material works best when spread into a very thin bond line. The material is available in a range of viscosities from water thin to thickened versions that are in the form of thixotropic pastes or gels.

G) Anaerobic Adhesives - These adhesives cure to a solid polymer in the absence of oxygen. They are commonly used as thread - locking compounds and retaining compounds for metal parts such as bearings and shafts. Anaerobic adhesives remain liquid as long as they are exposed to the atmosphere, but cure rapidly once confined. They are packaged in special containers that can "breathe" to prevent the materials from setting up in the containers. They are easy to use and are available in a range of viscosities and bond strengths. Some versions are available for making structural bonds between substrates that need to be laminated.

H) Film Adhesives - These adhesives are made in the form of sheets. In most cases, they are carried on release paper although some types are heat activated and do not require release paper. Film adhesives are made from water base, solvent base, or hot melt adhesives which are cast into a thin film leaving only the adhesive. They find use in situations where the release paper can be left in place and peel off prior to application to the substrate. They are popular for mounting of plastic components such as warning stickers, die cut parts such as letters and numbers, and a multitude of other parts. This form of adhesive also finds use for cold laminating of paper, plastics and films. The heat reactivated versions find use in fabric bonding and industrial applications where heat can be applied to the substrates to melt the adhesive.

Some types of film adhesives are cast onto a supporting material such as a scrim cloth or nonwoven fabric. These prevent stretching of the adhesive in use and simplify handling. Double back carpet tape is made in this manner. Film adhesives tend to be expensive relative to other adhesives because the cost of the release paper carrier must be included in the price of the adhesive. For many applications, the release paper stays with the product until it is applied, so the cost premium is justified. Film adhesives are also useful in cases where liquid adhesives might distort the substrates to be bonded. This is the case with some types of thin papers, films and foils, especially in low volume applications where ease of handling is of primary importance.

MECHANICAL CHARACTERISTICS:

We now wish to consider the mechanical characteristics and selection criteria for the adhesives themselves. We will be discussing a variety of performance capabilities such as 1.) Impact strength, 2.) Peel strength, 3.) Shear strength, 4.) Gap fill, 5.) Temperature rating, 6.) Cure time, 7.) Viscosity, 8.) Tack time, etc. These, and other characteristics, are very important when specifying an adhesive but first we must take a look at 1.) Substrates, 2.) Design of Joints and 3.) Surface preparation. The first two will definitely factor into aiding our efforts in deciding the type of adhesive to use. Surface preparation is the key to successful bonding and that will be discussed also in the course.

SUBSTRATES:

A picture is worth a thousand words so please take a look at the sketch below

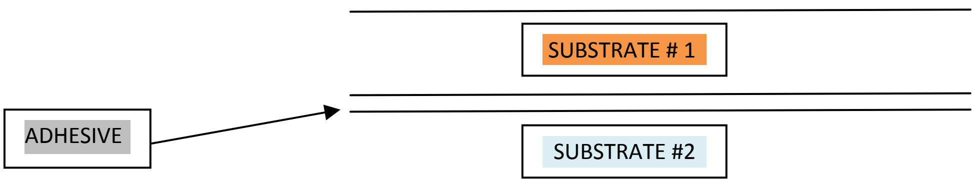


Figure 3 Bonding Substrates

Keep in mind that the substrate can be any variety of materials and the joint design can be of any configuration; i.e. rods, tubes, extrusions, rectangular, corrugated, flanged, angle joints, corner joints, etc. As mentioned earlier, we will discuss joint design later in the course and what configurations are good, better and best as far as configuration.

Let us now look at "cuts "; one from LOCTITE'S **"The Adhesive Source Book", Vol 5, 2008** Table 2,and the second Table 3, from the Master Bond Inc "**Substrate Reference Table.** In looking at Table 3, you will notice the table indicates two substrates, one given at the top of the page and one given at the left side of the page. The guide details those material classifications most commonly bonded together. The only real omission in this listing is composite materials. When considering composites, it is best to consult the adhesive manufacturer for advice and guidance. This table allows for selection when identical substrates or substrates of differing materials are used. The adhesive numbers at the intersection of each row and column is the recommended "starting point" for the initial selection. I say starting point because, as you notice, only material classifications are given and not the material callout itself. The "metals" classification does not specify whether it's steel, aluminum, copper, zinc, lead, etc. The initial determination is a "gross" indicator and may not be the very best for the substrates in question. All of the materials listed in this table are for epoxies and urethanes, but manufacturers have other tables for comparable data for the correct usage of cyanoacrylates, hot melts, light cures, silicones, etc.

Table 3 demonstrates another arrangement of substrates, only in a different fashion. The broad classifications are: 1.) Plastics, 2.) Rubbers, 3.) Metals, 4.) Miscellaneous and 5.) Substrate combinations. As with LOCTITE, the exact materials are not called out. It is left up to the engineer or program manager to contact specific vendors for exacting data and recommendation relative to any application. Please note:

IT IS CRITICAL THAT ADHESIVES BE PROVEN IN APPLICATION AND WITH ADEQUATE TESTING.

There are many variables and many ways a misapplication can occur. For the most part, the tables from LOCTITE and Master Bond will guide you in achieving long-term success. If the bond is "mission critical", sample coupons can be assembled from the substrates being used and tested to demonstrate survivability with the most critical load(s). This is the place to start; then fabricate a sample or model using the same adhesive material but with the joint design contemplated for use. Install that assembly or subassembly in a reliability test lab or environmental test chamber for cycle testing. There are many test labs that can duplicate the most rigorous conditions a product will face in real usage. We wish to test for reliability over the expected life of the product prior to putting the product on the commercial market. I definitely recommend a sample size that will allow for statistical significance. Most reliability tests engineers will require a sample size of at least thirty (30) pieces or subassemblies. **It is important to prepare these samples in a fashion identical to the proposed manufacturing method(s).** Deviation will allow possible misrepresentation of the data and SKU understanding of the results. This is very important!

SUBSTRATE SELECTOR GUIDE

Loctite® brand Hysol® Structural Adhesives Bond to a Variety of Substrates

Simply determine which substrates you're bonding and find the adhesive recommendations in the table below. Refer to the previous charts for typical performance properties of the recommended adhesive. These recommendations should be used as a starting point only. It is recommended to evaluate the selected product in your application to determine suitability.

	Metals	Thermo-Plastics	Thermoset Plastics	Rubber	Glass	Ceramic	Masonry	Wood	Leather	Paper/ Hardboard
Metals	E-20NS™ E-214HP™ U-05FL™	U-05FL™ E-40FL™ E-20HP™ 9430™	E-20NS™ E-20HP™ E-120HP™ 608™	U-05FL™ E-40FL™ U-09LV™ 9460™	E-30CL™ E-20NS™ U-05FL™ 0151™	E-20HP™ E-30CL™ E-20NS™ 9430™	E-20HP™ E-120HP™ E-20NS™ 9432NA™	E-00NS™ E-20HP™ E-40FL™ 608™	U-05FL™ E-40FL™ U-09LV™ 9460™	E-05CL™ E-40FL™ E-00CL™ D609™
Thermo-Plastics	U-05FL™ E-40FL™ E-20HP™ 615™	U-05FL™ U-09LV™ E-40FL™ 615™	U-05FL™ U-09LV™ E-40FL™ 615™	U-05FL™ E-40FL™ U-09LV™ 9460™	U-05FL™ U-09LV™ E-40FL™ 9460™	U-05FL™ U-09LV™ E-40FL™ 9460™	E-40FL™ E-05CL™ E-20HP™ 615™	E-05CL™ E-40FL™ E-20HP™ 11C™	U-05FL™ U-09LV™ E-40FL™ 9460™	E-05CL™ E-40FL™ E-20HP™ 9433™
Thermoset Plastics	E-20HP™ E-20NS™ E-120HP™ 615™	U-05FL™ U-09LV™ E-40FL™ 615™	E-20HP™ E-120HP™ E-214HP™ 615™	U-05FL™ E-20HP™ E-40FL™ 9460™	E-30CL™ U-05FL™ E-00CL™ 0151™	E-30CL™ E-20HP™ E-40FL™ 9433™	E-20HP™ E-120HP™ E-00CL™ 9432NA™	E-20HP™ E-40FL™ E-00NS™ 11C™	E-05CL™ U-09LV™ E-40FL™ 615™	E-40FL™ E-00CL™ U-05FL™ D609™
Rubber	U-05FL™ E-40FL™ U-09LV™ 9460™	U-05FL™ U-09LV™ E-40FL™ 9460™	U-05FL™ E-40FL™ E-20HP™ 9433™	E-40FL™ E-90FL™ U-05FL™ 9460™	U-05FL™ E-40FL™ U-09LV™ 9460™	U-05FL™ E-40FL™ U-09LV™ 9460™	E-40FL™ E-90FL™ E-05CL™ 9460™	E-40FL™ E-05CL™ E-20HP™ 9433™	U-05FL™ U-09LV™ E-40FL™ 9460™	E-40FL™ E-05CL™ U-09LV™ 9460™
Glass	E-20NS™ E-30CL™ U-05FL™ 0151™	U-05FL™ U-09LV™ E-40FL™ 9460™	E-00CL™ E-30CL™ U-05FL™ D609™	E-05CL™ U-05FL™ U-09LV™ 615™	E-30CL™ E-00CL™ U-09LV™ D609™	E-30CL™ E-20NS™ U-05FL™ 0151™	E-30CL™ E-00NS™ E-20HP™ 0151™	E-30CL™ E-40FL™ E-00CL™ D609™	E-40FL™ E-05CL™ U-09LV™ 615™	E-05CL™ E-40FL™ E-30CL™ 9460™
Ceramic	E-20NS™ E-30CL™ E-20HP™ 9430™	U-05FL™ U-09LV™ E-40FL™ 9460™	E-40FL™ E-20HP™ E-30CL™ 9433™	U-05FL™ U-09LV™ E-40FL™ 9460™	E-30CL™ E-00CL™ U-05FL™ D609™	E-20HP™ E-30CL™ E-120HP™ 9433™	E-00NS™ E-20HP™ E-20NS™ 608™	E-20HP™ E-40FL™ E-00NS™ 608™	E-40FL™ E-05CL™ U-09LV™ 9460™	E-40FL™ E-05CL™ E-00CL™ D609™
Masonry	E-20NS™ E-20HP™ E-120HP™ 9433™	E-40FL™ E-20HP™ E-05CL™ 9433™	E-20HP™ E-120HP™ E-00CL™ D609™	E-40FL™ E-90FL™ E-05CL™ 615™	E-30CL™ E-00NS™ E-20HP™ 0151™	E-00NS™ E-20HP™ E-20NS™ 9433™	E-20HP™ E-00NS™ E-120HP™ 608™	E-20HP™ E-00NS™ E-40FL™ 9433™	E-05CL™ E-40FL™ U-05FL™ 9460™	E-05CL™ E-00CL™ E-20HP™ D609™
Wood	E-20HP™ E-40FL™ E-00NS™ 9433™	E-40FL™ E-05CL™ E-20HP™ 11C™	E-20HP™ E-40FL™ E-00NS™ 11C™	E-40FL™ E-05CL™ E-20HP™ 9433™	E-30CL™ E-40FL™ E-00CL™ 0151™	E-20HP™ E-40FL™ E-00NS™ 608™	E-20HP™ E-00NS™ E-40FL™ 608™	E-00CL™ E-20HP™ E-40FL™ 11C™	E-05CL™ E-40FL™ E-90FL™ 615™	E-00CL™ E-20HP™ E-40FL™ D609™
Leather	E-40FL™ U-05FL™ U-09LV™ 9460™	U-05FL™ U-09LV™ E-40FL™ 9460™	E-05CL™ U-09LV™ E-40FL™ 9460™	U-05FL™ U-09LV™ E-40FL™ 9460™	E-40FL™ E-05CL™ U-09LV™ 9460™	E-40FL™ E-05CL™ U-09LV™ 9460™	E-05CL™ E-40FL™ U-05FL™ 615™	E-05CL™ E-40FL™ E-90FL™ 9460™	U-05FL™ U-09LV™ E-40FL™ 9460™	E-05CL™ E-40FL™ U-05FL™ 9460™
Paper/ Hardboard	E-40FL™ E-05CL™ E-00CL™ D609™	E-40FL™ E-05CL™ E-20HP™ 9433™	E-40FL™ E-05CL™ U-05FL™ 9460™	E-40FL™ E-05CL™ U-09LV™ 9460™	E-05CL™ E-40FL™ E-30CL™ 0151™	E-40FL™ E-05CL™ E-00CL™ D609™	E-05CL™ E-00CL™ E-20HP™ D609™	E-00CL™ E-20HP™ E-40FL™ 9460™	E-05CL™ E-40FL™ U-05FL™ 615™	E-05CL™ E-40FL™ E-00CL™ D609™

Thermoplastics: ABS, PC, Acrylic, Nylon, SAN, PVC   Thermoset Plastics: Epoxy, Phenolic, Polyester, DAP   Rubber: Butyl, Neoprene, Nitrile, SBR, Natural, EPDM

Table 2 LOCTITE Selector Guide

MASTER BOND SUBSTRATE REFERENCE TABLE

Selected Adhesives, Sealants, Coatings, Encapsulants & Potting Materials
Partial Listing Only —— Other Grades Available

Master Bond's vast product line offers bonding solutions for virtually any substrate combination and service requirement. This table gives examples of Master Bond systems suitable for specific substrate bonding from actual user field experience. It should by no means be considered all-inclusive and there may be a better Master Bond system for your particular application's environmental exposures and performance requirements. Please consult with Master Bond's technical staff before ordering to ensure you get the best product for your particular application.

SIMILAR SUBSTRATES

Plastics	Adhesives		
ABS / ABS	EP51M	EP21LV	EP21TDC
Acrylic / Acrylic	EP21LV	MasterSil 415	UV15-7SP4
*Delrin / *Delrin (Acetal)	MB297	EP30R	EP31
*EVA / *EVA	X17	MB297FL	EP21ND
Fiberglass / Fiberglass	EP24	EP33	Supreme 10HT
Kevlar / Kevlar	EP30HT	EP42HT	Supreme 45HT
*Krayton / *Krayton	EP30D7	EP21FL	EP21TDC-2
K Resin / K Resin	MB297	EP37-3FLF	EP21LV
Liquid Crystal Polymer / Liquid Crystal Polymer	EP30HT	EP45HT	UV15-7
Noryl / Noryl (PPO)	EP21	EP31	EP21TDCHT
Nylon / Nylon	MB297	EP21TDC	EP3HT
PBT / PBT	EP21LV	MasterSil 711	EP30D7
Pebax / Pebax	MB297 MED	EP21TDC-2	EP30D15
PEEK / PEEK	EP42HT	EP45HT	Supreme 10HT
*PET / *PET	LTX163	MasterSil 705	EP21LV
Phenolic / Phenolic	Supreme 10HT	EP34CA	EP35
Plexiglas / Plexiglas	EP30-1	EP21LSCL	UV10TK
PMMA / PMMA	EP21FL	UV15X5	MasterSil 410
Polycarbonate/Polycarbonate	EP21LV	UV15X2	MasterSil 711
Polyester / Polyester	EP21	EP37-3FLF	EP30
*Polyethylene/ *Polyethylene	EP41S-4	EP21AR	EP42LV
Polyethylene / Polyethylene	X17	MB514	LTX164
*Polypropylene/*Polypropylene	EP41S-1	EP42HT	EP27
Polypropylene/Polypropylene	X17	MB514	LTX164
Polystyrene / Polystyrene	MB297	EP21	EP30R
Polyurethane / Polyurethane	EP30D7	EP30D12	EP21TDC-2
*PPS / *PPS	EP45HT	EP42HT	Supreme 10HT
*PTFE / *PTFE	EP21AR	EP30HT	EP34CA
PVC (rigid) / PVC (rigid)	EP21ND	EP50-1.5	X5
Ultem / Ultem	EP42HT	Supreme 10HT	EP45HT
Valox / Valox	EP21	EP21TDC-2	EP3HT
*Viton / *Viton	EP42LV	EP30HT	EP21AR
Rubbers	**Adhesives**		
Butyl / Butyl	X5	MB297	EP21TDC-4
*EPDM / *EPDM	EP42HT	EP39MHT	EP21TDC-7
Latex / Latex	MB297	LTX117	LTX163
Natural / Natural	MB297	EP21TDC-7	X5
Neoprene / Neoprene	MB297	EP21TDCHT	EP21TDC-7
Nitrile / Nitrile (NBR)	X5	MB297	EP21TDC-4
SBR / SBR	X5	EP37-3FLF	EP21TDC-7
*Santoprene / *Santoprene	EP21FL	EP21TP-2	EP41S-1
Santoprene / Santoprene	X17	MB297FL	EP21TDC-4
Metals	**Adhesives**		
Aluminum / Aluminum	Supreme 11HT	Supreme 10HT	EP31
Brass / Brass	Supreme 11HT	EP21TDCHT	EP3HT

***PRIMED OR ETCHED SURFACE**

All trademarks are the property of their respective owners

Table 3 Master Bond Substrate Reference Guide

Metals (continued)	Adhesives		
Carbon Steel / Carbon Steel	EP31	Supreme 10HT	Supreme 45HT
Copper / Copper	Supreme 10HT	EP35	EP21TDCHT
Kovar / Kovar	EP34CA	Supreme 10HT	EP21HT
Nitenol / Nitenol	EP45HT	Supreme 11HT	Supreme 10HT
*Stainless Steel / *Stainless Steel	EP31	Supreme 10HT	Supreme 11HT
*Titanium / *Titanium	Supreme 10HT	EP30HT	EP45HT
*Tungsten Carbide / *Tungsten Carbide	Supreme 45HT	Supreme 10HT	EP31
Miscellaneous	**Adhesives**		
Ceramic / Ceramic	EP30LTE	EP34CA	EP125
Concrete / Concrete	EP21	EP24	EP27
Glass / Glass	UV15-7	EP30	EP39-2
Silicone / Silicone	MasterSil 718 primer plus MasterSil 410	MasterSil 718 primer plus MasterSil 701	MasterSil 718 primer plus MasterSil 711
Wood / Wood	EP21LV	EP21SL5	EP51

DISSIMILAR SUBSTRATES

Substrate Combination	Adhesives		
Acrylic / Polycarbonate	EP21LV	MasterSil 415	UV15-7
Aluminum / Glass	EP21TDC	MasterSil 711	UV15-7TK1A
Aluminum / Fiberglass	Supreme 11HT	EP21FL	EP31
Aluminum / Phenolic	EP21TDCHT	Supreme 45HT	Supreme 11HT
Aluminum / Polyurethane	EP30D-7	EP30D10	EP30D12
Aluminum / Steel	Supreme 11HT	Supreme 10HT	Supreme 45HT
Aluminum / *Titanium	Supreme 3HT	EP34CA	Supreme 33
*Carbide / *Steel	SteelMaster 43HT	Supreme 10AOHT	Supreme 10HT
Ceramic / Fiberglass	EP21TDCHT	Supreme 30	Supreme 45HT
Ceramic / Steel	Supreme 11AOHT	EP31	Supreme 33
Concrete / Wood	EP21	EP24	EP27
Copper / Fiberglass	EP21TDC	Supreme 11	EP72M3
Copper / Glass	EP21TDC-2	UV15-7SP4	MasterSil 705
Fiberglass / Steel	EP33	EP51HT	EP21TDCHT
Nylon / *Neoprene	MB297FL	EP3HT	EP21TDC-7
*PET / Aluminum	LTX163	Supreme 11HT	Supreme 30
*PET / PBT	LTX163	MasterSil 711	EP21LV
Polycarbonate / Aluminum	EP37-3FLF	UV15X2	MasterSil 415
*Polyethylene / *Polypropylene	EP21TDC	EP21	EP72M3
Polyethylene / Polypropylene	X17	MB514	LTX164
*Polyethylene / Steel	EP21TDCHT	EP51M	EP35
Polyethylene / Steel	X17 as a primer plus Supreme 11HT	X17 as a primer plus EP21TDC	X17 as a primer plus EP21AR
Polystyrene / Steel	EP50-1.5	EP24	EP21
Polystyrene / PVC (rigid)	EP21	EP51	EP30
Polyurethane / Neoprene	EP21TDC-4	EP30D7	MB297
Polyurethane / Steel	EP30D-7	EP30D10	EP30D12
*PPS / Steel	EP42HT	EP21AR	EP45HT
Steel / Glass	EP30	EP21TDC-2	UV15-7SP4
Steel / Nylon	MB297	EP3HT	EP21TDC
Steel / *PET	LTX163	EP21LV	Supreme 30
Steel / Phenolic	Supreme 10HT	Supreme 11HT	EP31
Steel / *PTFE	EP45HT	Supreme 10HT	EP42LV
Steel / PVC (rigid)	EP21ND	Supreme 11HT	EP21TDCHT
Steel / *Titanium	Supreme 10HT	Supreme 33	Supreme 45HT
*Titanium / Aluminum	EP31	Supreme 10HT	Supreme 45HT
*Titanium / Glass	EP30	EP21TDC-2	UV15X5
*Titanium / Ultem	EP21TDCHT	EP42HT	EP45HT

***PRIMED OR ETCHED SURFACE**

Table 3 (Cont.) Master Bond Substrate Reference Guide

JOINT DESIGN:

The design of any adhesive joint, regardless of substrates, involves selecting the proper geometry and dimensions, the correct adhesive, quality control measures and practices and bonding process and bonding techniques. The basic rules most often repeated by adhesive authorities relative to joint design are as follows:

1.) Design to utilize the largest contact area as possible. This will give the greatest "real estate" for adhesion and bonding.
2.) Design to put the maximum proportion of bond area to work. This involves examining, not only the loads, but the direction of the loads.
3.) Design to put the main working stress in shear or tension, minimizing cleavage or peel stresses.

The following questions should be asked **and answered** prior to designing the joints:

1.) What materials are to be joined? What particular alloys? What hardness conditions and surface finishes? (This is a matter of specifying the materials and knowing their mechanical characteristics.)
2.) What are the thicknesses of the substrates? Is a sketch or print available of the part or the subassembly? (Having a drawing of the assembly and /or parts is critical for quality control purposes. I definitely recommend obtaining this documentation prior to continuing.)
3.) What is the end use of the part or subassembly?
4.) What are the conditions of usage for the part or subassembly? We are talking about the maximum and minimum conditions including any momentary "excursions" relative to temperature, pressure, loading, humidity, etc. These limitations are called the "limits of acceptability". All products should have this information as a part of the specifications.
5.) Will these conditions be constant while in use or intermittent? If cycling, discover what the cycle times are and prepare for those cycle times.
6.) What qualification tests will the part or assembly be subjected to?
7.) What specifications; i.e., Mil-Specs, FDA, AHAM, etc must the part meet?
8.) What chemical solvents, oils, and other fluids will the part and the bond be subjected to when in normal use? What are the temperatures the fluids will have when coming in contact with the adhesive and the parts?
9.) Will the part need electrical continuity? If so, what is the voltage and current?
10.) Is the adhesive expected to be an insulator? If so, what are the specifications for the dielectric, resistivity, etc?
11.) What strength is the joint expected to withstand? What tensile, shear, peel, impact, compression, vibration etc will the joint "see"? What are the upper and lower limits expected for bond strength?
12.) Is there any reason to prefer a tape adhesive over a paste adhesive? If so, why? Is this true for all of the assembly or just a portion of the assembly?

13.) What is the bonding sequence? What are the steps; i.e. surface preparation, bonding, curing?
14.) What type of reliability testing will be necessary to "prove" the joint design and the adhesive type?
15.) What quality control will be effective? This is determined by the complexity of the design concept, the size and mobility of the part and the materials to be joined.
16.) What is the expected performance life of the product, subassembly and parts?

We would like now to portray several joint designs that represent good, better and best approaches to configuration when adhesives are in use. These designs exemplify the " three rules" as given above.

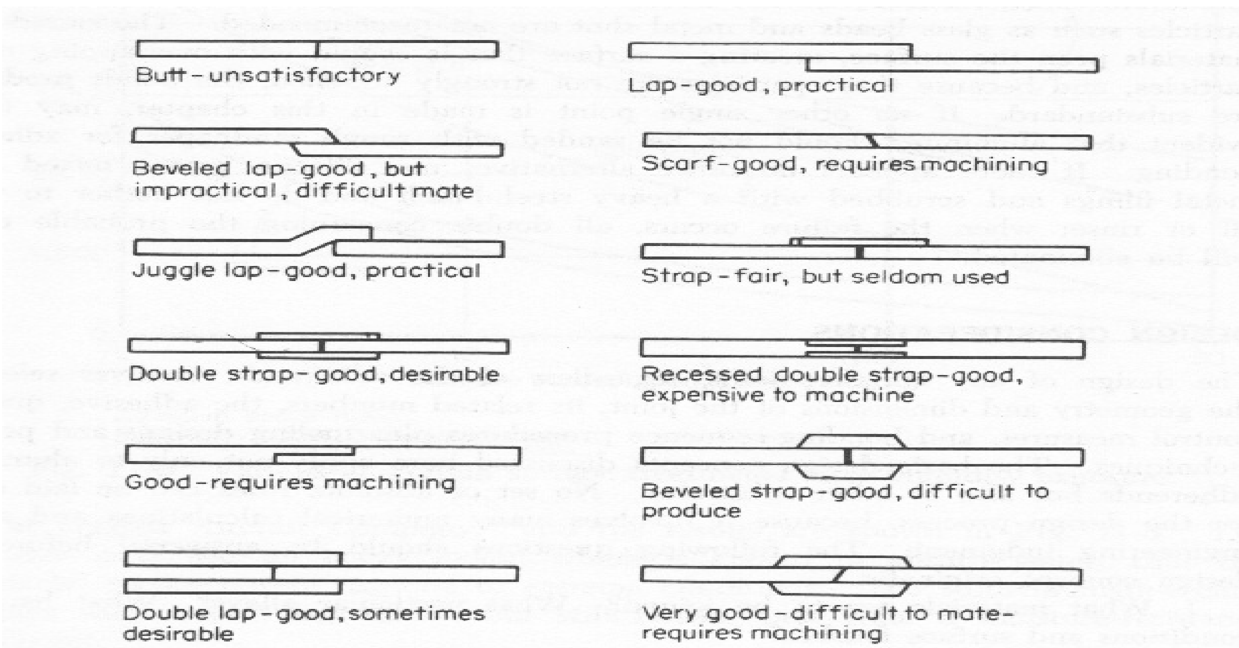


Figure 4 Lap Joints

As you can see, some joint configurations are very questionable and should not be tried unless there are no other options.

The second type of joint we wish to show is an angle joint. As you can see, there are also configurations that are more acceptable than others and should be considered if at all possible. Again, we are designing so as to maximize the surface area of the mating substrates.

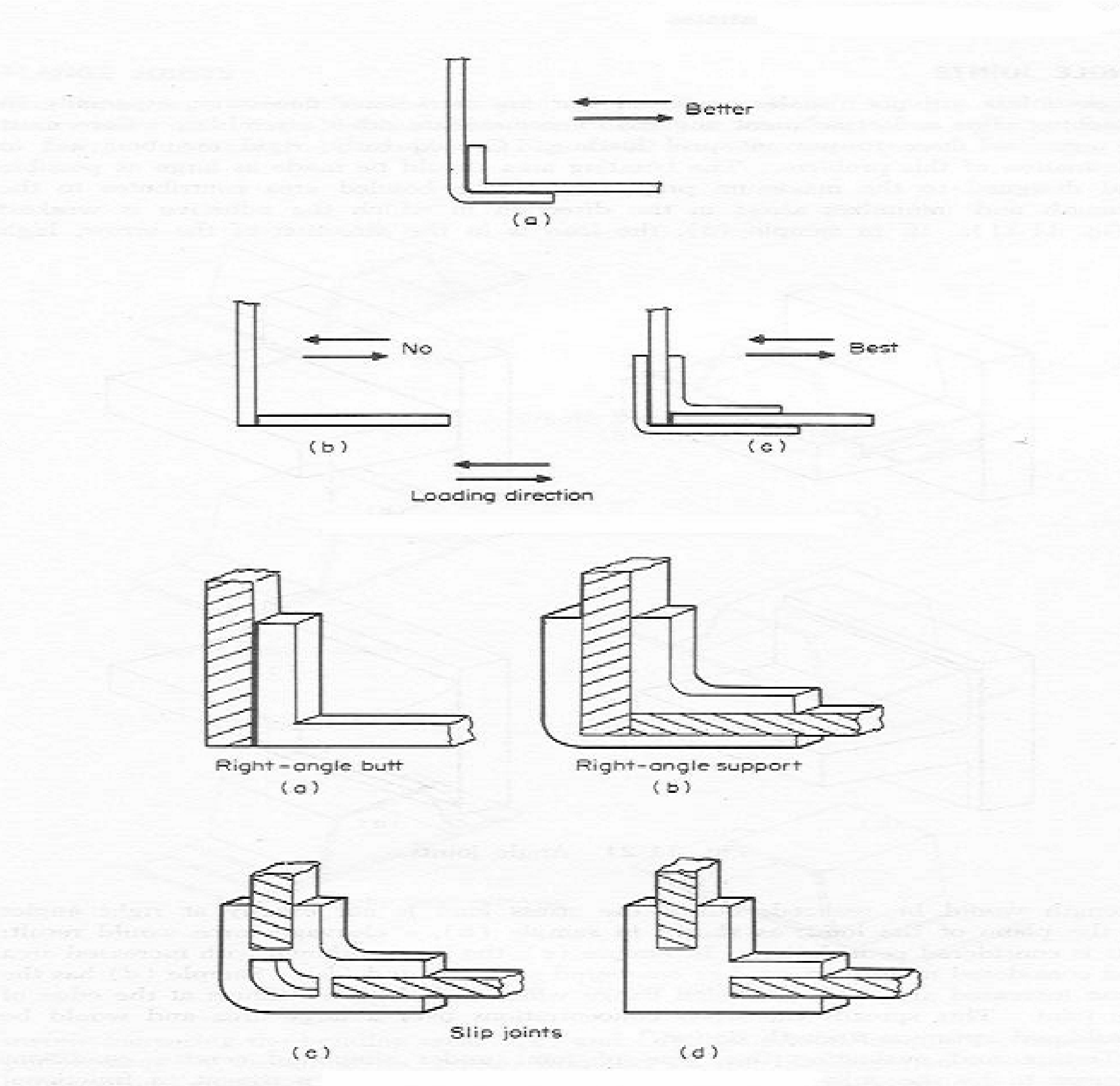


Figure 5 Angle Joints

Flanges and fillets present a problem when the beam is a cantilever beam. The following sketches will give the configurations best for adhesive usage. Designs “c” and “d” are preferable due to increased surface area.

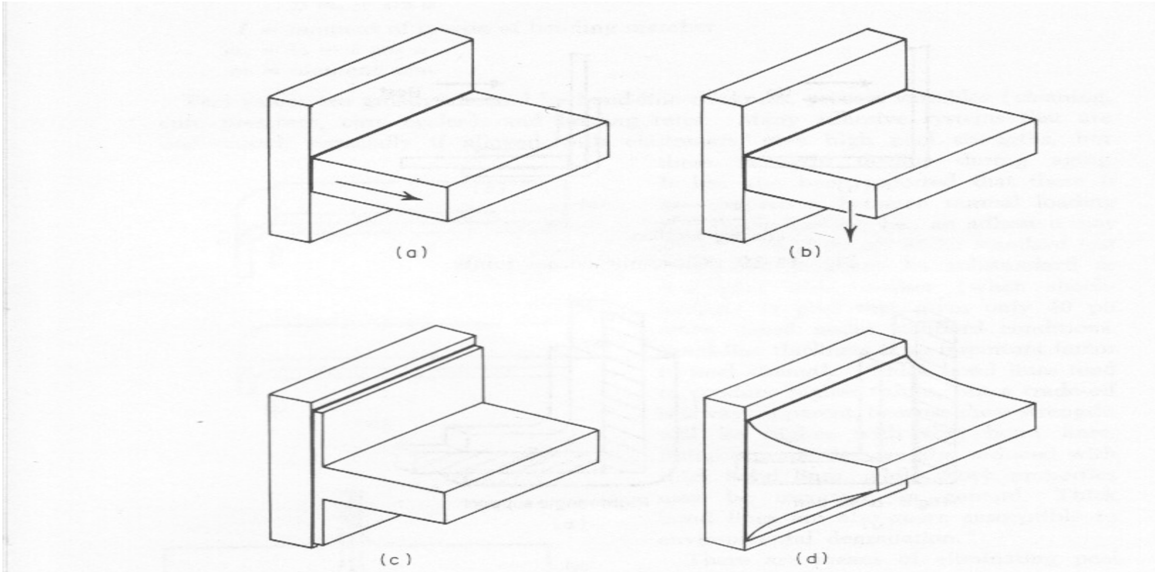


Figure 6 Angle Joints

Flange joints are easier to adhere but there are guidelines that should prevail when using adhesive.

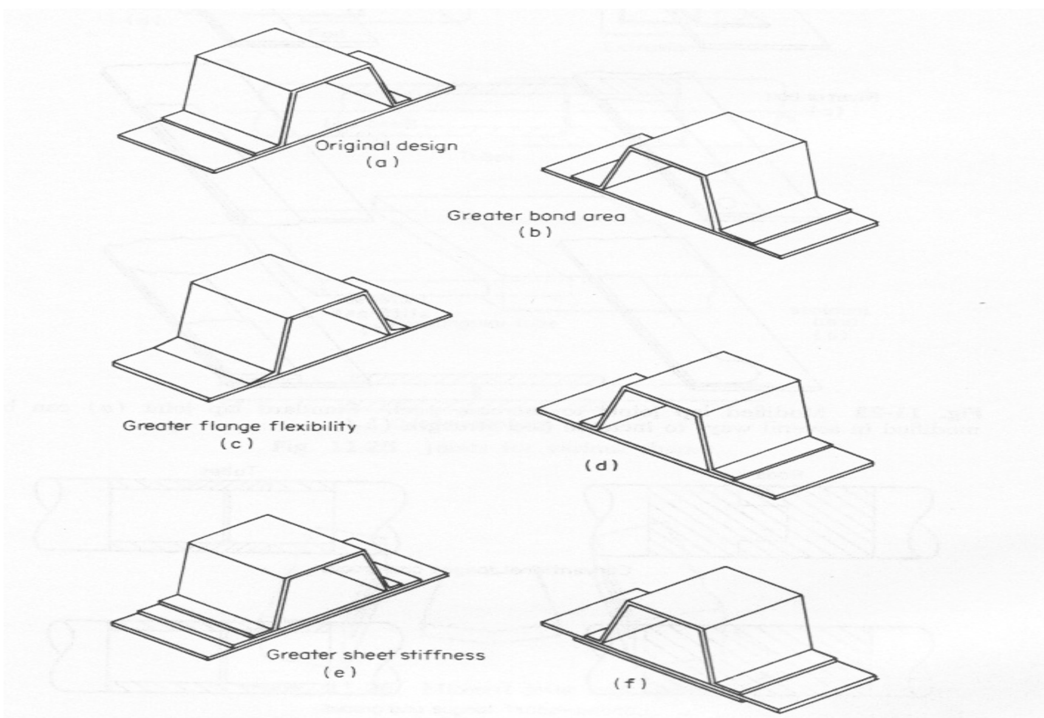


Figure 7 Flange Joints

Overlay joints, rod joints and tube joints are very common and represent challenges of their own. Figures 7, 8 and 9 show acceptable designs.

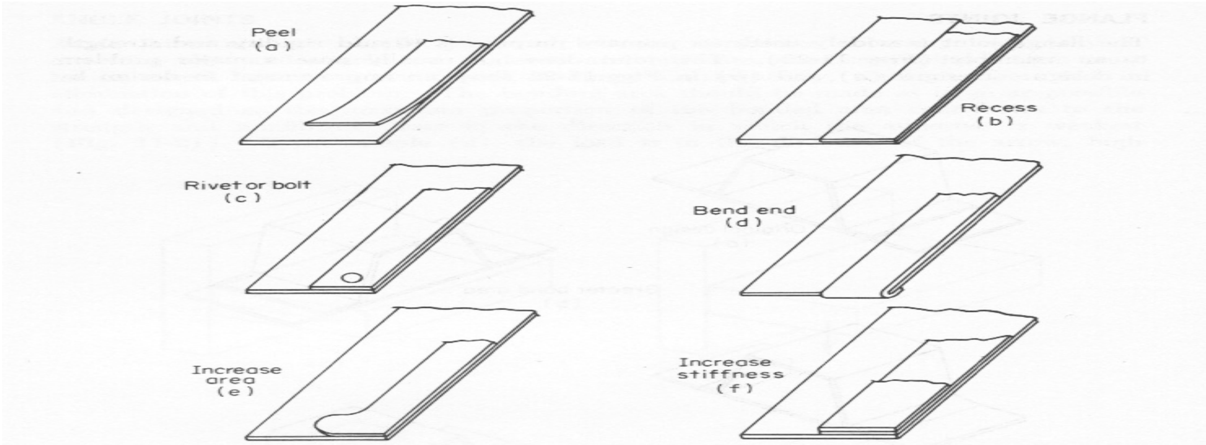


Figure 8 Overlay Joints

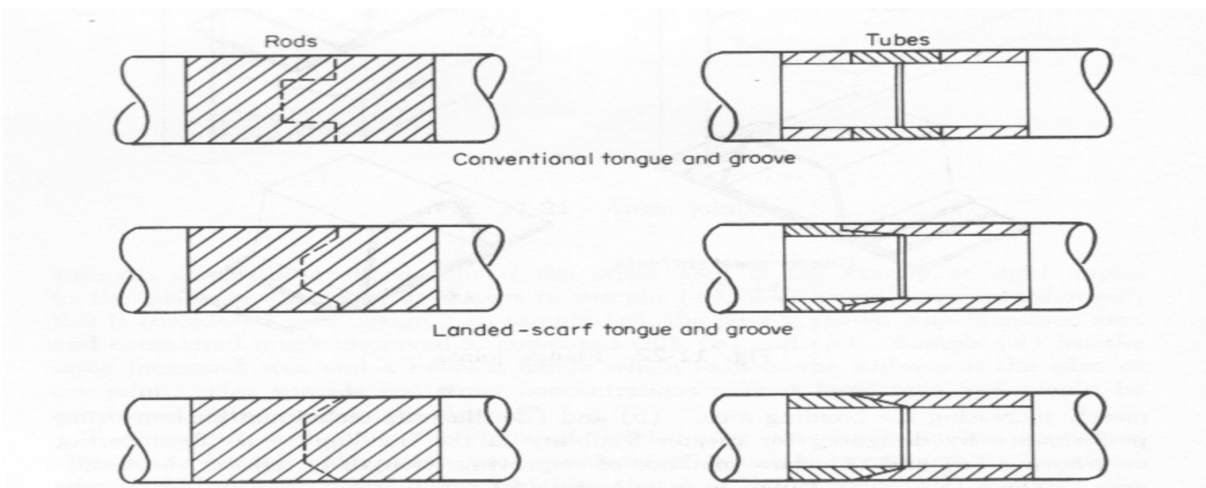


Figure 9 Rod and Tube Joints

The following joints are basically miscellaneous joints commonly seen in construction and assembly. Again, please note that we are striving for a maximum of surface area upon which to deposit the adhesive. This fact applies for the overlay joints, rot and tube joints and all of the miscellaneous joints shown in these line drawings.

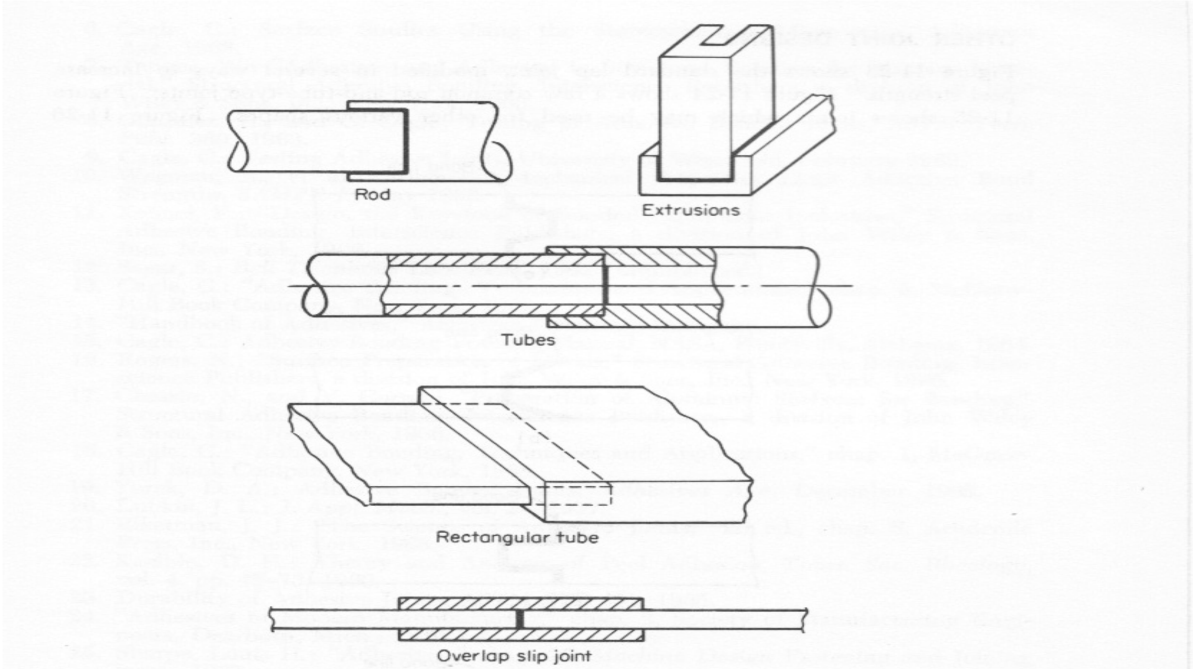


Figure 10 Miscellaneous Joint

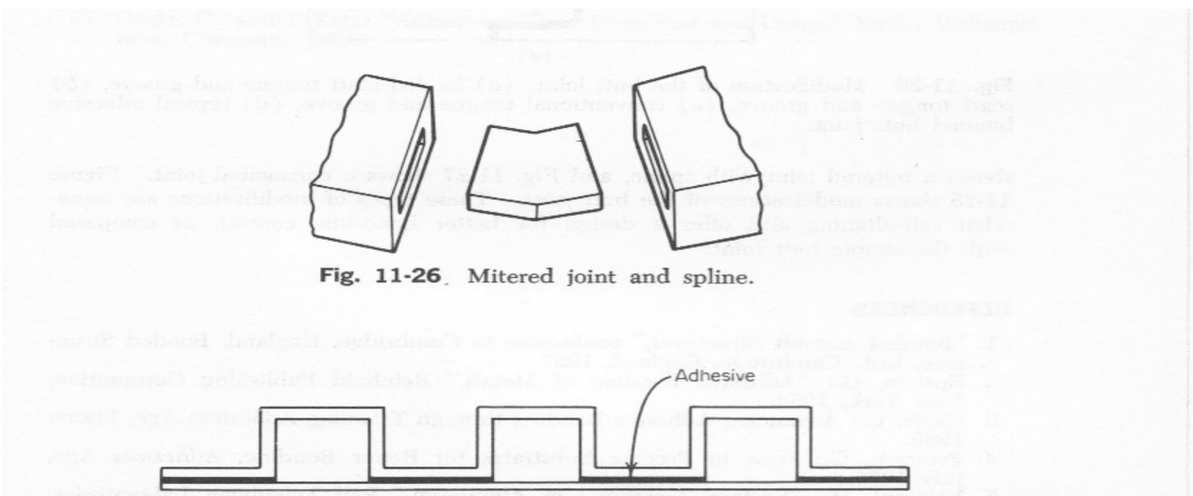


Figure 11 Miscellaneous Joint

SURFACE PREPARATION:

Surface preparation is critical to bonding and will vary depending upon the substrates and adhesives being used. As you recall from earlier discussions, the adhesive must wet the surface and flow into the crevices and valleys for proper bonding. Contaminats such as oil, grease, corrosion, scale, etc greatly impede that process. Substrate surfaces should be as clean as possible to facilitate this wetting process and allow for proper contact between the adhesive and the substrate surface. It may be critical for the assembly personnel to wear gloves when cleaning the substrates and applying the adhesives. This will minimize the transfer of oils from hands to parts. Let us now look at the recommended preparation for various substrates. These treatements represent **minimum acceptable practice**. It is strongly recommended that the adhesive supplier be contacted prior to cleaning in order to get their recommendations.

The evolution of adhesives is ongoing and manufacturers always strive for products that require the least surface preparation.

SUBSTRATE	**PRETREATMENT**
Aluminum	Solvent degreases, abrade or acid etch with concentrated sulfuric acid, sodium dichromate solution at 180° for 10 minutes: alternative treatment is phosphoric acid etch.
Copper and Copper Alloys	Solvent degrease abrade and etch with ferric choride/nitric acid solution at ambient temperatures for 1 to 2 minutes: alternative treatment is ammonium persulphate(25% in water) etch.
Zinc andZinc Alloys	Solvent degrease, abrade and degrease or etch with solution of Bromderite 250 or equivalent.
Solder	Solvent degrease, abrade and degrease
Glass	Solvent degrease followed by rinse with silane coupling agent.
Tungsten carbide	Solvent degrease, abread, degrease, etch with 15% caustic soda at 180° for 10 minutes.
Wood	Abrade and solvent wipe.
Rubber	Abrade or acid etch with concentrated sulfuric acid for several minutes at room temperature.
Thermoplastice	Solvent degrease, abrasion: for polyolefins, acid etch with concentrated sulfuric acid at room temperature or flame treat: special sodium etch for PTFE and other fluoropolymers.
Thermosets	Solvent degrease with aggressive hydrocarbons or equivalent and abrade.

Table 4 Pretreatment

Generally, the following sequence of practices is recommended for cleaning the surfaces of the substrates in question:

1.) Degrease (There are degreasers commercially available for any material uses as a substrate.)
2.) Acid Etch or Alkaline clean
3.) Rinse
4.) Dry
5.) Surface Conditioning (This is not considered a standard procedure but is sometimes used.)
6.) Prime. (The longer the time lapse from cleaning to priming or bonding the more the probability of contamination from handling, air contaminants, etc. Parts should be primed as soon as possible after cleaning, handled in clean white gloves, wrapped in Kraft paper and sealed in polyethylene bags for storage.)

Highest strength structural bonds are obtained when parts are free from oils, greases, paints, oxide films, dust, mold release agents, rust inhibitors and other contaminants. The amount of surface preparation to be carried out depends directly on the required bond strength, the desired durability to environmental service conditions, and the cost of surface preparation.

The three major methods for removing surface contaminants are degreasing, chemical cleaning and abrasion. They may be used alone or in combination for greater effectiveness depending on the degree of surface cleanliness required. A preferred sequence of surface preparation methods to give highest bond strengths comprises 1.) Abrasion, 2.) Degreasing and 3.) Chemical etching. A recently developed promising alternative is 4.) Plasma etching.

Degreasing can be carried out with solvents such as acetone, isopropanol or proprietary cleaners including hot alkali solutions. Degreasing alone is used where maximum bond strength or outdoor durability are not needed. Abrasion methods including sandblasting, use of abrasives and vapor honing may be required to help remove mill scale, oxide films and certain anti-rust treatments. Chemical cleaning such as etching is popular for preparing metals and, where applicable, provides a superior surface for adhesion.

Greases, oils, mold releases etc. can generally be removed with EPA approved environmentally safe organic solvents or proprietary cleaners. Paints and oxide films are advantageously removed by techniques such as sanding followed by solvent cleaning. For maximum possible bond strength follow up with a special surface treatment such as etching for metals. **The supplier of the adhesive should always be consulted for special surface cleaning problems.** A simple yet effective test for surface cleanliness is to place a few drops of water on the areas to be bonded. Parts are sufficiently clean if the water spreads to cover the area with a continuous film. If the water beads, a conventional solvent (degreasing) operation will usually prove sufficient for cleaning. Use acetone, isopropanol or similar solvent.

Adhesive primers can be applied to freshly cleaned metal surfaces to avoid recontamination during storage or production delays. They are not necessary if cleaned parts are bonded immediately after cleaning. For specific details on surface preparation, consult the supplier's technical staff. **When using recommended chemicals follow appropriate federal, state and**

local regulations for safe handling and disposal. Appropriate care is required when carrying out necessary surface preparation procedures.

PERFORMANCE CONSIDERATIONS:

We wish now to consider the performance characteristics for various groups of adhesive materials. The following material is taken from vendor references and is based upon their considerable experience in recommending products to users. We want to consider the benefits and limitations of the adhesives types as well as general characteristics. These tables are meant to be **general guidelines** to help you determine which adhesive category is best suited for the particular application. After "zeroing in" on the category, you then can delve deeper into the characteristics of the specific adhesive products. As always, contacting vendors will be your best option prior to making a decision on which adhesive meets your individual needs.

We will be looking at performance AND process considerations. Process considerations are every bit as important in the decision-making process and factors such as 1.) Cure time, 2.) Gap fill, 3.) Fixture time, 4.) Tack time, etc may be critical when selecting any one adhesive material.

I would like now to present several observations taken from Tables 7 and 8 that will indicate basically what is available from the standpoint information. We will start with viscosity.

An important characteristic of any adhesive is **viscosity**. Viscosity is measured in "centipoises" and is abbreviated cp. The glossary in the appendix indicates that viscosity "measures the ability of the adhesive to flow". The following table will give you a comparison for several substances.

PRODUCT	APPROXIMATE VISCOSITY IN CENTIPOISE (cP)
WATER @ 70	1 TO 5
BLOOD	10
AINTI-FREEZE	15
MOTOR OIL SAE 10	50 TO 100
MAZOLA CORN OIL	50TO 100
MOTOR OIL SAE 30	150 TO 200
MOTOR OIL SAE 40	250 TO 500
MOTOR OIL SAE 60	1,000 TO 2,000
KARO CORN SYRUP	2,000 TO 3,000
HONEY	2,000 TO 3,000
HERSHEY CHOCOLATE SURUP	10,000 TO 25,000
KETCHUP	50,000 TO 70,000
TOMATO PASTE	150,000 TO 250,000
PEANUT BUTTER	150,000 TO 250,000
CRISCO	1,000,000 TO 2,000,000
CAULKING COMPOUND	5,000,000 TO 10,000,000
WINDOW PUTTY	100,000,000

Table 5 Viscosity

Gap Fill—There are times when the mating substrates are less than flat relative to each other. It is important that the adhesive "wets" both substrates for the best possible bond. We want the adhesive to fill the voids between mating surfaces. Gap fill is a measure of how much "space" can be filled by various adhesives. Please notice the various adhesives types generally can fill between 0.0001 inch and 0.0400 inches. If I had a gap of 0.030 inch, I would not specify a cyanocrylate (CA), all things being considered. It simply won't do the job.

Water-Based Adhesive—You definitely wish to use a water-based adhesive when adhering wood, paper or paperboard products. As you can see from the tables, there are some adhesive that are definitely not suited for bonding paper products.

Electrical Insulation Properties—Epoxies have excellent properties when electrical insulation is needed. Hot-melt adhesives and water-based adhesives are not recommended when electrical insulation is required.

Humidity Resistance—Silicones are excellent for high humidity environments. If they are compatible with the substrates in question, they provide qualities that will guarantee long life.

Fixture Time—Fixture time is how long the parts will need to remain stationary before removing from holding fixtures. If you need a very fast fixture time, due to daily production needs, you will have to choose an adhesive providing that characteristic. The very fastest cure times and fixture times are available with light cures. Of course, these can only be used if one or both substrates are transparent. For many substrates light cures are not usable due to joint configuration or non-transparency. Frequently, fixture time may be lessened by applying temperature to the bonded surfaces. You may also find that applying pressure to a bonded surface improves wetting capability and if a material requires an accelerator, fixture time is reduced by virtue of that pressure.

Bonding Strength—Epoxies provide the best bonding strength, generally.

Full Cure Time—Full cure time is generally 12 to 24 hours, except for light cure adhesives. This is the time it takes for the adhesive to be completely hardened. Please note that fixture time and full cure time are not the same. It is entirely possible to remove an assembly from a fixture, package, rack and then allow that assembly to cure prior to shipment to the customer. The important thing to remember is the full cure time should be reached before the product is used.

Flexibility—Silicones are the most flexible due to their formulation but they exhibit the lowest hardness. Generally, the harder the adhesive material, the lower the flexibility.

Impact Strength—Silicones have excellent impact strength. Most adhesives with high hardness exhibit lower impact strength.

Plastic Bonding—Cyanoacrylates and UV light cures are excellent when bonding plastic substrates. In looking at the charts below, you will notice that epoxies and silicones are only fair when bonding plastic. Most suppliers of adhesives will recommend staying away from these two products when bonding plastic.

Rubber Bonding—Epoxies are just about the only adhesive category that can assure successful performance for rubber.

Glass / Ceramic Bonding—Epoxies and epoxy alloys provide excellent strength for glass and ceramic substrates. (I have had a great deal of experience in bonding glass and enameled products. This is a very tricky application of adhesives and extensive trial and error may be expected before finding the right product for the right application. I definitely recommend testing before launching the product on a commercial basis.)

Shear Strength—Hot melts and silicones do not give high shear strengths so if the major criteria for success is shear, they should not be candidates.

Hardness—Adhesives vary in hardness with silicones being the least hard. This is the reason that silicones have greater flexibility and greater vibration resistance relative to other adhesive materials. The table given below will indicate hardness vs several common materials we see and use every day.

DUROMETER HARDNESS

SHORE A	SHORE D	ROCKWELL M	REFERENCE OBJECT
30			Art Gum Eraser
40			Pink Pearl Eraser
50	15		Rubber Stamp
60			Pencil Eraser
70	30		Rubber Heel
80			Rubber Sole
90	45		Typewriter Roller
100	55		Pipe Stem
	74	0	Textbook Cover
	78	32	Douglas Fir Plywood
	82	63	
	86	95	Hardwood Desktop
	90	125	Glass or Formica

Table 6 Hardness

Resistance to Water and Humiditity—CAs are not very resistive to polar solvents such as water. As a matter of fact, CA performance can be very poor when applied in an atmosphere that will exhibit moisture. On the other hand CAs are very good when subjected to non-polar solvents. Adhesive manufacturers are your best bet when selecting adhesives that will be subjected to solvents. Please keep in mind also that the adhesive industry works every day to formulate suitable products for developing markets. New products are introduced routinely that “break the mold” and any “rules of thumb” may be blown away by advances for any one product category.

The following two tables were developed by LOCTITE (Table 7) and Master Bond (Table 8)and are presented as general guidelines for selection.

PERFORMANCE CONSIDERATIONS	ADHESIVE CATEGORY							
	Cyanoacrylates	Epoxies	Hot Melts	Light Cure	Silicones	Urethanes	2-Part Acrylics	2-Step Acrylics
Benefits	Excellent adhesion to most rubber or plastics	Wide range of formulations	Fast, large gap filling	Rapid cure/adhesion to plastics	Excellent temperature resistance	Excellent toughness/ flexibility	Good impact resistance/ flexibility	Good impact resistance, no-mix
Limitations	Low solvent resistance	Mixing required	Low heat resistance	Light Cure System required	Low strength	Sensitive to moisture	Mixing required	Primer required
Temperature Resistance Typical for the category (°F) Highest Rated Product (°F)	 -65 to +180 +250	 -65 to +180 +400	 -65 to +250 +330	 -65 to +300 +350	 -65 to +400 +600	 -65 to +250 +300	 -65 to +250 +250	 -65 to +300 +400
Environmental Resistance Polar Solvents *(ex. H_2O, Ethylene Glycol, IPA, Acetone)* Non-Polar Solvents *(ex. Motor Oil, Toluene, Gasoline, ATF)*	 Poor[1] Good	 Very good Excellent	 Good Good	 Good Very good	 Good Poor-fair	 Good Good	 Good Very good	 Good Very good
Adhesion to Substrates Metals Plastics[2] Glass Rubber Wood	 Very good Excellent Poor Very good Good	 Excellent Fair Excellent Fair Very Good	 Good Very good Good Fair Excellent	 Good Excellent Excellent Fair Poor	 Good Fair Very good Good Fair	 Good Very good Good Good Fair	 Excellent Excellent Good Poor Good	 Excellent Fair Excellent Poor Good
Overlapping Shear Strength	High	High	Low	High	Low	Medium	High	High
Peel Strength	Low	Medium	Medium	Medium	Medium	Medium	High	Medium
Tensile Strength	High	High	Low	High	Low	Medium	High	High
Elongation/Flexibility	Low	Low	High	Medium	Very High	High	High	Medium
Hardness	Rigid	Rigid	Semi-soft	Semi-rigid	Soft	Soft	Semi-rigid	Semi-rigid
PROCESS CONSIDERATIONS								
Number of Components	1	2	1	1	1	2	2	2
Cure Temperature	Room Temp.	Room Temp.	Room Temp.[3]	UV/Visible	Room Temp.	Room Temp.	Room Temp.	Room Temp.
Fixture Time Average Fastest	 60 seconds 10 seconds	 35 minutes 3-5 minutes	 70 seconds 20 seconds	 30 seconds 5 seconds	 25 minutes 10 minutes	 25 minutes 5 minutes	 20 minutes 3-5 minutes	 5 minutes 30 seconds
Full Cure Time	24 hours	12 - 24 hours	1 hour (or when cooled)[4]	30 - 60 seconds	24 hours	24 hours	24 hours	24 hours
Gap Fill Ideal (in inches) Maximum (in inches)	 0.001 - 0.003 0.010	 0.004 - 0.006 0.125	 0.002 - 0.005 0.240	 .002 to .010 0.25	 0.004 - 0.006 0.250	 0.004 - 0.006 0.125	 0.010 - 0.040 0.5	 0.002 - 0.004 0.040
Dispensing/Mixing Equipment Required?	No	Yes	Yes	No	No	Yes	Yes	No
Light Cure Versions Available?	Yes	Yes	No	Yes	Yes	No	No	Yes
For more information on each adhesive category, refer to pages...	12-15, 29, 31, 59, 60	16-19, 21, 59, 61	24-27	28-31, 58-60	29, 31, 59, 61	17, 20, 21, 59, 61	9, 11	8, 10

[1] Cyanoacrylates have very good moisture resistance on plastics.
[2] Uncured liquid adhesives may cause stress cracking of certain thermoplastics, e.g. polycarbonate, acrylic, and polysulfone. Special products and process techniques are available. Consult the Loctite® Design Guide to Bonding Plastics (LT2197) or contact 1-800-LOCTITE for more information.
[3] Elevated temperatures are required to dispense liquid Hot Melt Adhesives.
[4] Urethane Hot Melts require 24 hours for full cure.

Table 7 Mechanical Characteristics

MASTER BOND TECHNICAL PRODUCTS SELECTOR GUIDE

Polymer Type

Product Property	Acrylic	Anaerobic	Cyanoacrylate	Epoxy	Epoxy Alloy	Hot Melt	Polyurethane	Polysulfide	Silicone	Solvent Based	Water Based	UV Cures
Viscosity	L,FL,T	L-FL	L,FL	L,FL,T	L,FL,T	T	L,FL,T	L,FL,T	L,FL,T	L,FL	L,FL	L,FL,T
Gap (Void) Filling	F	P-F	P-F	E	E	G-E	G-E	G-E	E	F	P-F	F,G,E
Bonding Strength (Lap Shear)	F-G	F-G	G-E	E	G-E	F,M	F-G	G-E	F-M	F-G	F	F,G,E
Flexibility	F-G	F-G	P-F	F-G	F-E	F-G	G-E	G-E	E	G-E	F-G	G-E
Heat Resistance	F-G	G	F	G-E	G-E	P-F	F-G	G	E	G	P-F	F-G
Cold Resistance	F	G	F	G-E	G-E	F	F-G	G-E	E	G	P	F-G
Impact Strength	F-G	F-G	P-F	G-E	G-E	F-G	G-E	G-E	E	G-E	P-F	F-G
Thermal Shock Resistance	F-G	G	P-F	G	G-E	F-G	G-E	G-E	E	G	P-F	F-G
Electrical Insulation Properties	F-G	G	G-E	E	G-E	F-G	G-E	G-E	E,SP	G,SP	F-G	G-E
Thermal Insulation Properties	F	G	G	E,SP	E,SP	F	G	G-E	E	G	F-G	G-E
Humidity Resistance	F	G	F	G-E	G-E	G	F	G-E	E	G	P-F	F-G
Chemical Resistance	F	G	G	G-E	G-E	F	F-G	G	F-G	G	P-F	F-G
Working (Pot) Life	FT-M	M	FT	FT-S	FT-S	F-T	FT-S	M	M-S	FT-M	M	S
Cure Time	FT-M	M	FT	FT-S	FT-S	FT	FT-M	FT-M	S-M	FT-M	M	FT
Metal Bonding (Alum., Steel, Copper etc.)	F-G	F	G	G-E	G-E	P-F	F-G	G	F	G	P-F	F-G
Bonding Inorganics (Glass, Ceramics etc.)	F-G	F	G	G-E	G-E	P	F-G	G	G	G	F-G	F-G
Elastomer Bonding	F	P	G	F-G	G-E	F	G	G	G	G	P-F	F-G
Plastic Bonding	F-G	P	G-E	F-G	G	P	G	F-G	F-G	F-G	P-F	G-E
Polyolefin Bonding	PR	NS	PR	PR	PR	F	F-G	PR	F	F-G	P-F	F-G
Fluoropolymer Bonding	PR	NS	PR	PR	PR	NS	NS	NS	NS	PR	P	NS
Wood	F	NS	NS	G	G	G-E	F-G	NS	NS	F-G	E	F-G
Paper/Paperboard	FG	NS	NS	NS	NS	G-E	F-G	NS	NS	F-G	E	F-G

KEY

P=Poor	**FT=Fast**	**PR=Primer**
F=fair	**M=Medium**	**T=Thick**
G=Good	**S=Slow**	**L=Low**
E=Excellent	**NS=Not suggested**	**FL=Flowable**

SP=Special formulations available for electrical conductivity

Master Bond Inc.

Adhesives, Sealants & Coatings • 154 Hobart Street • Hackensack, N.J. 07601 • Tel: 201-343-8983 • Fax: 201-343-2132

Table 8 Mechanical Characteristics

<u>EPOXIES, CAs and PSTs:</u>

I would like now to discuss three categories of adhesives that garner the greatest usage on a global basis, 1.) Epoxies, 2.) Cyanoacrylates (CAs) and 3.) Pressure-sensitive adhesives or PSAs. All three are widely used for a variety of purposes ranging from "sticking" a dinner plate back together to use as a structural adhesive. We will go into some detail relative to pressure sensitive tapes because of the huge usage on a global basis.

EPOXIES:

Epoxies are the workhorse adhesives and the most widely used materials for structural purposes. Due to their high tensile strength, up to 10,000 PSI, they are especially resistant to impact, vibration and shock. The service temperatures range from -70° F to 450° F and a few retain their strength at temperatures exceeding 500° F.

Epoxy adhesives consumption has grown, not only because of performance capabilities but because of their simplicity of use. Advanced epoxy adhesive bonding technologies are replacing traditional mechanical fasteners. Rivets, nuts and bolts, and screws are being replaced with one-part and two-part epoxies. They are even competing with processes such as brazing and, in some applications, welding. Single component systems have heat-activated curing agents and need not be mixed. The resin and curing agents of a two-part epoxy must be mechanically mixed before curing takes place. Cures vary from resin to resin but generally take between one to three hours with applied temperatures of 200° F to 400° F. Postcure heating can further extend the mechanical properties for some system.

Epoxy bonds are usually very rigid but exhibit poor peel strength, although new formulations have greatly improved resistance to peel. Generally, pressure above 50 PSI is required to insure wetting of surfaces and precleaning is definitely recommended.

CYANOACRYLATES (CA):

Another category of adhesives are the "super glues" or CAs. Like the epoxies, they are widely used in the United States and the world today. They are very very fast setting and go by several brand names; i.e. "Gorilla glue", "Krazy glue", etc. Technology has created these adhesives with a wide variety of viscosities, low odor, rapid cure times and high temperature resistance. Their gap fill characteristics range from 0.006 inches to 0.020 inches with temperature limits between -76°F and 500°F. Some CAs have overcome the resistance to many plastics, such as PTFE as well as dissimilar metals.

PRESSURE SENSITIVE-ADHESIVES (PSA):

Pressure sensitive adhesives (PAs) form a bond by the application of light pressure, which marries the adhesive with the substrate. These adhesives are designed with a balance between flow and resistance to flow. The bond forms because the adhesive is soft enough to flow or wet the substrate. The bond has strength because the adhesive is hard enough to resist flow when stress is applied. Once the adhesive and the substrate are in close proximity, molecular interactions, such as van der Waals forces, become involved, contributing significantly to its ultimate strength. Pressure sensitive adhesives are designed for either permanent or removable applications. Examples of permanent applications include safety labels for power equipment, foil tape for HVAC duct work, automotive interior trim assembly, assembly of appliance doors, assembly of refrigerator structures and sound / vibration damping films. Some high performance permanent PSAs exhibit high-adhesion values and can support pounds of weight per square inch of contact area, even at elevated temperatures. Permanent PSAs may be initially removable and build adhesion to a permanent bond after several hours or even days.

Removable adhesives are designed to form a temporary bond, and ideally can be removed after months or even years without leaving a residue on the substrate. Removable adhesives are used in applications such as surface protection films, masking tapes, bookmarks, price marking labels, promotional graphic materials and for skin contact (wound care dressings, EKG electrodes, athletic tape, analgesic and transdermal drug patches, etc.) Some removable adhesives are designed to repeatedly stick and then be removed. They have low adhesion and generally cannot support much weight.

Pressure-sensitive adhesives are manufactured with either a liquid carrier or in 100 percent solid form. Articles are made from liquid PSAs by coating the adhesive and drying off the solvent or water carrier. They may be heated to initiate a crosslinking reaction and increase molecular weight. One hundred percent PSAs may be low-viscosity polymers that are coated and then reacted with radiation to increase molecular weight and form the adhesive; or they may be high-viscosity materials that are heated to reduce viscosity enough to allow coating, and then cooled to their final form.

PRESSURE-SENSITIVE TAPES (PSTs):

The sale of pressure sensitive tapes, world wide, will expand by 2010 to an annual usage of approximately 30 billion square meters. The value in dollars will exceed $25 billion and projected growth, in terms of tape sales, will increase throughout the remainder of this decade. At the present time, the United States is the largest user of PSTs with $4.7 billion annually but it is projected that China will surpass the USA in usage by the end of 2010. This is a global growth of 10 %. To give you an example of how much tape is used and where, annually, more than 1.65 billion square feet of wiring harness tape is used by the automotive industry around the world. The average vehicle's wire harness system consists of approximately 3,500 linear feet, most of which is held together by PSTs.

PSTs consist of two distinct types: adhesive-coated PCV and non-adhesive coated or dry vinyl material. The products are 1.) Single-sided tape such as carton tape, masking tape, medical tape, duct tape, electrical tape and 2.) Double-sided tape such as those used in manufacturing firms. The grades are typically segmented into four temperature ranges: 1.) T1 not to exceed 85°C, 2.) T2 86° C to 105° C, 3.) T3 106°C to 125°C and 4.) T4 125°C to 150°C. By far, the most predominant usage is for corrugated box sealing.

The industry leaders are: 1.) 3M, 2.) Intertape Polymer Group, 3.) Tyco International, 4.) Shurtape, 5.) Avery, 6.) Beiersdorf and 7.) Nitto Denko. There are over 300 tape manufacturers listed in the Thomas Register, which underscores the fact that companies feel that continued usage will improve over the remainder of this decade.

A very popular form of tape for structural purposes is acrylic foam tape. Acrylic foam tapes have been demonstrated to be very capable bonding products over the past 25 years, providing an often ideal combination of performance, durability, and ease of use. They have been successfully used in a wide variety of demanding industrial applications in areas such as appliance assembly, aircraft subassembly, automotive usage, and commercial building construction. Although these tapes have proven themselves in actual use, the viscoelastic nature of pressure-sensitive adhesives has provided a challenge for the design engineer because suitable performance values for evaluating adhesively-bonded joints have not been widely available. This has remained a consistent problem over the years. Underwriters Laboratories (UL) has published a test standard, UL 746C, that strives to take the guess work out of evaluating performance. Portions of that standard are given in the appendix to this paper and address cycle testing in high humidity conditions and with elevated temperatures.

A series of other tests have been recently performed demonstrating that acrylic foam tapes are capable of providing performance on par with other bonding materials used in the construction industry. The results from these tests have also been used to generate simple, useful, and conservative values for tape performance that can be used in design calculations. These design criteria provide sufficient performance for many construction applications, while incorporating safety factors typical of the industry. The leading global manufacturers of pressure-sensitive tapes is the 3M Company. Their product line includes the following:

- 3M VHB Tapes
- 3M Double-coated Foam Tapes
- 3M Double-coated Tapes
- 3M Removable / Repositionable Tapes
- 3M Adhesive Transfer Tapes
- 3M Extended Linear Tapes
- 3M Membrane Switch Adhesives

- Scotch ATG Adhesive Systems

VHB tapes are used basically for structural purposes and have been on the commercial market for twenty-five years. Characteristics of 1.) High holding power, 2.) Good shock absorbtion properties and 3.) Resistance to common solvents make VHB tape very popular for many commercial applications. The following tables will demonstrate several tape categories, possible uses and temperature ranges for those uses. Similar tables exist for other 3M tape categories.

3M™ Bonding Tapes

3M™ VHB™ Tapes

	Product Number	Tape Thickness w/o liner Mils (mm)	Liner Type	Description	Adhesive Type	Temperature Resistance: Minutes Hours	Temperature Resistance: Days Weeks	Solvent Resistance	Relative Adhesion: HSE	Relative Adhesion: LSE	Application Ideas
Conformable Foam Tapes	4926	15 (0.4)	A	• Gray, closed-cell acrylic foam carrier • Conformable • Good adhesion to many painted metals • Plasticizer resistant • UL 746C	Multi-purpose acrylic	300°F (149°C)	200°F (93°C)	High	High	Med.	Bond and seal polycarbonate lens over LCD. Bond and seal plastic windows to pre-painted control panels/switch gear. Mount vinyl wiring ducts and conduit channels. Seam vinyl banners.
	4936	25 (0.64)	A								
	4936F	25 (0.64)	F								
	4941	45 (1.1)	A								
	4941F	45 (1.1)	D								
	4956	62 (1.6)	A								
	4956F	62 (1.6)	F								
	4991	90 (2.3)	F			250°F (121°C)	200°F (93°C)				
	4919F	25 (0.64)	F	• Black version of 4936F tape		300°F (149°C)	200°F (93°C)				
	4947F	45 (1.1)	F	• Black version of 4941F tape							
	4979F	62 (1.6)	F	• Black version of 4956F tape							
	5915	16 (0.4)	D	• Black, closed-cell acrylic foam carrier • Very conformable • Good adhesion to many painted surfaces, including powder coated paint • UL 746C	Modified acrylic	300°F (149°C)	250°F (121°C)	High	High	Med.	Bonds to a variety of plastics and paint systems. Various bonding applications for back-lit signs. Bond architectural signs to frames. Bond powder painted metal stiffeners to office desks and file cabinets.
	5925	25 (0.64)	D								
	5930	32 (0.8)	D								
	5952	45 (1.1)	D								
	5958FR*	40 (1.0)	D								
	5962	62 (1.6)	D								
	4943F	45 (1.1)	C	• Gray conformable foam • Apply as low as 32°F (0°C)	Low-temp acrylic	300°F (149°C)	200°F (93°C)	High	High	Low	Bond antennas. Bond automatic toll tags to vehicle.
	4957F	62 (1.6)	C								
Firm Foam Tapes	4611	45 (1.1)	D	• Dark gray, closed-cell acrylic foam carrier • High temperature resistance • UL 746C	General purpose acrylic	450°F (232°C)	300°F (149°C)	High	High	Low	Pre-powder coat paint applications: hat channels and stiffeners.
	4646	25 (0.64)	D								
	4655	62 (1.6)	D								
	4914	10 (0.25)	A	• White, closed-cell acrylic foam carrier • All-purpose adhesive • UL 746C	General purpose acrylic	300°F (149°C)	200°F (93°C)	High	High	Low	Attach stiffeners in air conditioners, office furniture and telecommunications equipment.
	4920	15 (0.4)	A								
	4930	25 (0.64)	A								
	4950	45 (1.1)	A								
	4929	25 (0.64)	C	• Black version of 4930							
	4949	45 (1.1)	C	• Black version of 4950							
	4955	80 (2.0)	C	• White, closed-cell acrylic foam carrier • All-purpose adhesive • UL 746C		400°F (204°C)	300°F (149°C)				
	4959	120 (3.0)	C								
	4945	45 (1.1)	A	• White, closed-cell acrylic foam carrier • Plasticizer resistant	Multi-purpose acrylic	300°F (149°C)	200°F (93°C)	High	High	Low	Attach vinyl trim. Bond vinyl extrusions.
	4946	45 (1.1)	B	• Film liner version of 4945 • UL 746C							
	4951	45 (1.1)	C	• White, closed-cell acrylic foam carrier • Apply as low as 32°F (0°C)	Low-temp acrylic	300°F (149°C)	200°F (93°C)	High	High	Low	Low temperature installed products.
	4932	25 (0.64)	A	• White, closed-cell acrylic foam carrier • Good adhesion to polypropylene and many powder paints	LSE	200°F (93°C)	160°F (71°C)	High	High	High	Bond powder painted metal stiffeners to office desks and file cabinets. Bond polypropylene and polystyrene.
	4952	45 (1.1)	A								
Clear	4905	20 (0.5)	D	• Clear, acrylic construction for joining transparent material	General purpose acrylic	300°F (149°C)	200°F (93°C)	High	High	Low	Mount backlit translucent signs. Edge-bond resin filled glass.
	4910	40 (1.0)	D								
Transfer	F9460 PC	2 (0.05)	E	• Clear adhesive transfer tape • High shear strength adhesive • UL 746C	100MP	500°F (260°C)	300°F (149°C)	High	High	Low	Bond decorative metal trim. Bond flexible circuits to aluminum rigidizers or heat sinks.
	F9469 PC	5 (0.13)	E								
	F9473 PC	10 (0.25)	E								

Liner Types:
A – 3 mil 54# Densified Kraft Paper
B – 5 mil Clear Polyethylene Film
C – 2 mil Polyester Film
D – 5 mil Red Polyethylene Film
E – 4 mil 58# Polycoated Kraft Paper
F – 5 mil Red Printed Polyethylene Film

Relative Adhesion:
HSE – High Surface Energy
LSE – Low Surface Energy

Multi Purpose Acrylic: Bonds to a wide range of materials including metals, glass, and high and medium surface energy plastics and paints. Resists migration of plasticizers in vinyl substrates.

Modified Acrylic: Bonds to medium low surface energy paints and plastics, including many powder coated paints in addition to the substrates listed with the multi-purpose acrylic adhesive (except plasticized vinyl).

General Purpose Acrylic: Bonds to most higher surface energy substrates including metal, glass, and high surface energy plastics.

Low Temperature Acrylic: Bonds down to 32° F (0°C) compared to 50°F (10°C) for most acrylic adhesives. Bonds most high surface energy substrates including metal, glass, and high surface energy plastics.

Low Surface Energy: High performance synthetic adhesive bonds to many lower surface energy substrates, including many plastics and powder coated paints, plus smooth general purpose substrates.

100MP: Bonds with higher peel strength than most other acrylic formulations. Up to 500°F (260°C) short term heat resistance.

Table 9 3M VHB Bonding Tapes

Tape Selection Guide

This matrix gives you a few of our most commonly used tapes for various surface combinations. Products shown represent only a small part of the total line.

Surface B		Surface A: Steel, Aluminum, Glass, Ceramics – Thin	Thick	ABS, Acrylic, Enamel & Epoxy Paints, Kapton® Industrial Film, Noryl Resin, Nylon, Lexan® Polycarbonate, Polyester, Rigid Vinyl – Thin	Thick	Polystyrene, Polypropylene, Polyethylene, Powder Paints – Thin	Thick	Plasticized Vinyl – Thin	Thick	Paper – Thin	Thick	Cloth – Thin	Thick	Rubber – Thin	Thick
Rubber	Transfer	950/969* 9472LE		950/969* 9472LE		950/969* 9472LE		950/969*		950/969*		950/969*		950/969* 9472LE	
	Double coated	444 9495LE		444 9495LE		444 9495LE				444		444		444	
Cloth	Transfer	950/969 9485/926		950/969 9485/926		950/969 9485/926		950/969		465/924 950/969 9485/926		465/924 950/969 9485/926			
	Double coated	444 9690		444 9690		444 9690		9443NP		444 9690		444 9690			
Paper	Transfer	465/924 950/969		465/924 950/969		950/969		950/969 9465PC		465/924 950/969					
	Double coated	410M 415		410M 415		444				410M 415					
Plasticized Vinyl	Transfer	950/969 9465PC		950/969 9465PC		950/969		950/969 9465PC							
	Double coated		4941		4941				4941						
Polystyrene, Polypropylene, Polyethylene, Powder Paints	Transfer	950/969 9485PC/ 926 9472LE	4462	950/969 9485PC/ 926 9472LE	4462	950/969 9472LE	4462								
	Double coated	444 9589 9495LE	4952 5952 (powder paint)	444 9589 9495LE	4952 5952 (powder paint)	444 9443NP 9495LE	4952 5952 (powder paint)								
ABS, Acrylic, Enamel & Epoxy Paints, Kapton® Industrial Film, Noryl® Resin, Nylon, Lexan® Polycarbonate, Polyester, Rigid Vinyl	Transfer	950/969 F9469PC 9485PC/926 468MP	4046/4016 4462 4492	950/969 F9469PC 9485PC/926 468MP	4046/4016 4462 4492										
	Double coated	444 9500PC 9495MP	4941 5952	444 9500PC 9495MP	4941 5952										
Steel, Aluminum, Glass, Ceramics	Transfer	468MP 9085 9469 9485PC/ 926	4046/4016 4462 4492												
	Double coated	9495MP 9500PC	4941 4950												

Easy access to the knowledge

For direct access to product data, downloadable product data pages, or to request sample product for evaluation:

www.3M.com/industrial

*For temporary holding only.

NOTE: The technical information and data provided here should be considered representative or typical only and should not be used for specification purposes. User should evaluate the 3M product to determine whether it is fit for a particular purpose and suitable for user's method of application.

Table 10 3M Tape Selection Guide

TYPES OF ADHESIVE FAILURES:

We wish to discuss now the types of failures that can occur when substrates are bonded together using an adhesive. Practice says that all parts eventually fail. It's good to know the failure modes so that careful examination, through periodic preventative maintenance, can be predictive and repairs can be made before failure does occur. We always hope our adhesive bond is perfect but we suspect that there are times when porosity, voids, inclusions and cracks do occur due to improper cleaning, contamination, worker's errors, etc. We also know that overloading is suspect when catastrophic failure occurs.

There are three failure modes or fracture types as follows:

1.) Structural Failures
2.) Adhesive or Interfacial Failures
3.) Cohesive Failures

Structural Failures: Structural failures occur in the substrate material usually close to the adhesive bond joint. In this case the adhesive remains intact and is still bonded to one substrate and the remnants of the other. For example, when one removes a price label, adhesive usually remains on the label and the surface. This is cohesive failure. If, however, a layer of paper remains stuck to the surface, the adhesive has not failed.

Adhesive Failures: The fracture is adhesive or interfacial when debonding occurs between the adhesive and the substrate. In most cases, the occurrence of adhesive failure for a given adhesive is due to smaller fracture toughness relative to the substrate. The interfacial character of a fracture surface usually follows the precise location of the crack path in the interphase.

Cohesive Failures: Cohesive fracture occurs if a crack propagates in the bulk polymer which constitutes the adhesive. In this case the surface of both substrates, after debonding, will be covered by the adhesive. The crack may propagate in the center of the layer or near an interface. For this last case, the cohesive fracture can be said to be cohesive near the interface. Most quality control standards consider a good adhesive bonding must be cohesive.

Mixed Failure Modes:

There is also a mixed fracture type which occurs if the crack propagates at some spots in a cohesive and interfacial manner. Mixed fractures can be characterized by a certain percentage of adhesive and cohesive fractures.

The alternating crack path fracture jumps from one adhesive interface to another. This type of fracture appears in the presence of tensile prestresses in the adhesive layer.

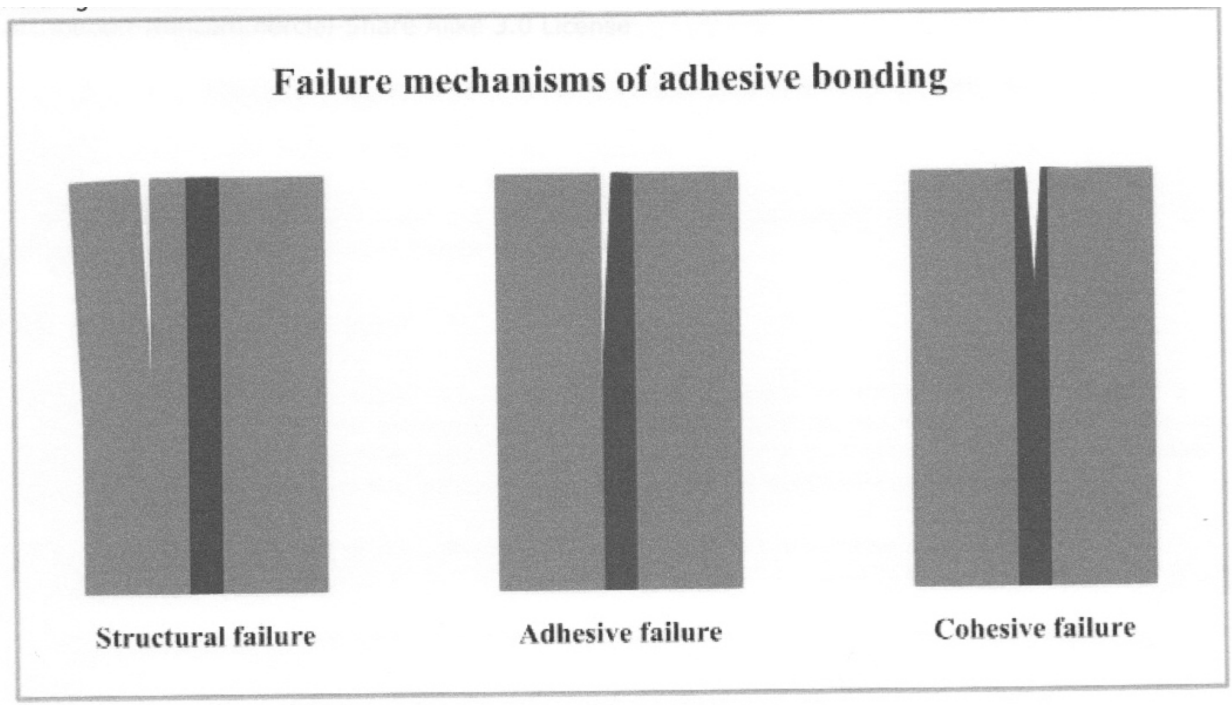


Figure 12 Failure Modes

The following graphic will show the four basic failure modes for adhesive / substrate loading. Please note that the failure mechanism, as given by Figure 12, can occur in each of the four modes.

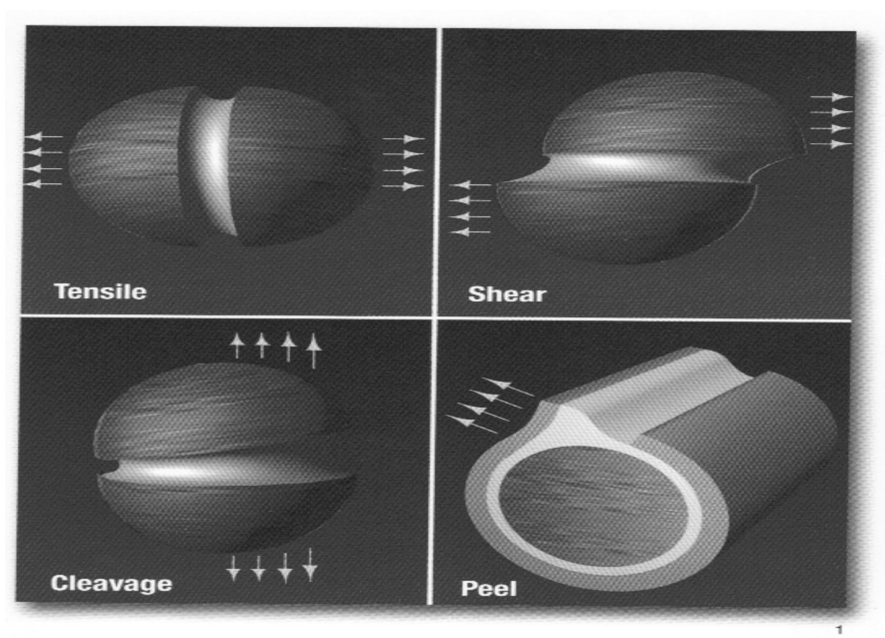


Figure 13 Loading Failure Modes

ADHESIVE TESTING:

All manufacturers test their products to see what mechanical characteristics they have. Adhesives are absolutely no different than any other material with one big exception; any one given adhesive applied to differing substrates will exhibit different mechanical characteristics. Manufacturers spend a great deal of time in determining the characteristics of products. Some of the tests that are routinely performed are:

1.) Tensile 2.) Creep 3.) Shear 4.) Fatigue 5.) Impact 6.) Cleavage
7.) Fire Resistance 8.) Bearing Strength 9.) Compressive Strength 10.) Modulus

There are prescribed standards for all of these tests, such as ASTM Method D 897 (Tensile Strength), ASTM Method D 1002 (Shear Strength) and ASTM D 14 (Peel Strength). These are quasi-governmental standards but, as mentioned earlier, there are standards from the industry groups that serve the very same purpose. We wish to now look at several test methods. Figure 12 will aid our discussion in describing how the tests are conducted.

Peel Tests: When a bonded adhesive joint is gradually forced apart from the edges inward, the tearing of the adhesive which occurs is called peeling. Field and laboratory experience has shown that an unbounded area in a bonded panel can become a localized source of failure which will progressively become enlarged when the panel is subjected to sufficiently high static or alternating loads. There are several methods used to test for peel; i.e. 1.) "T" Peel testing, 2.) "Climbing Drum" Peel Testing and 3.) " Four Foot Diameter" Peel Tester.

Wedge Tests: This mode measures the fracture resistance of an adhesive used to bond thin plates. These tests consist of inserting a wedge between two bonded plates until adhesive failure occurs. This is also called a cleavage test. The adhesives are actually loaded in the peel mode, but the substrates are rigid.

Delaminating Beam Tests: This is not that different from the wedge tests except the substrates are forcefully separated by wedges inserted at the adhesive / substrate interface.

End Notch Flexure Tests: This test involves two bonded beams built in on one side and loaded by a force on the other. Force is applied as strategic points along the lower beam to the point where separation of the adhesive / substrate boundary layer occurs.

Crack Lap Shear: Two plates are bonded on a limited length and loaded in tension on both ends. The tests can be either symmetrical or non-symmetrical.

Fire Resistance: Fire resistance ratings are very important and must be known if there is a chance the adhesive and substrate will be subjected to elevated temperatures.

Creep: The elongation, or shear strain, which occurs in an adhesive bonded specimen under a constant tensile stress over a long period of time, is referred to as creep.

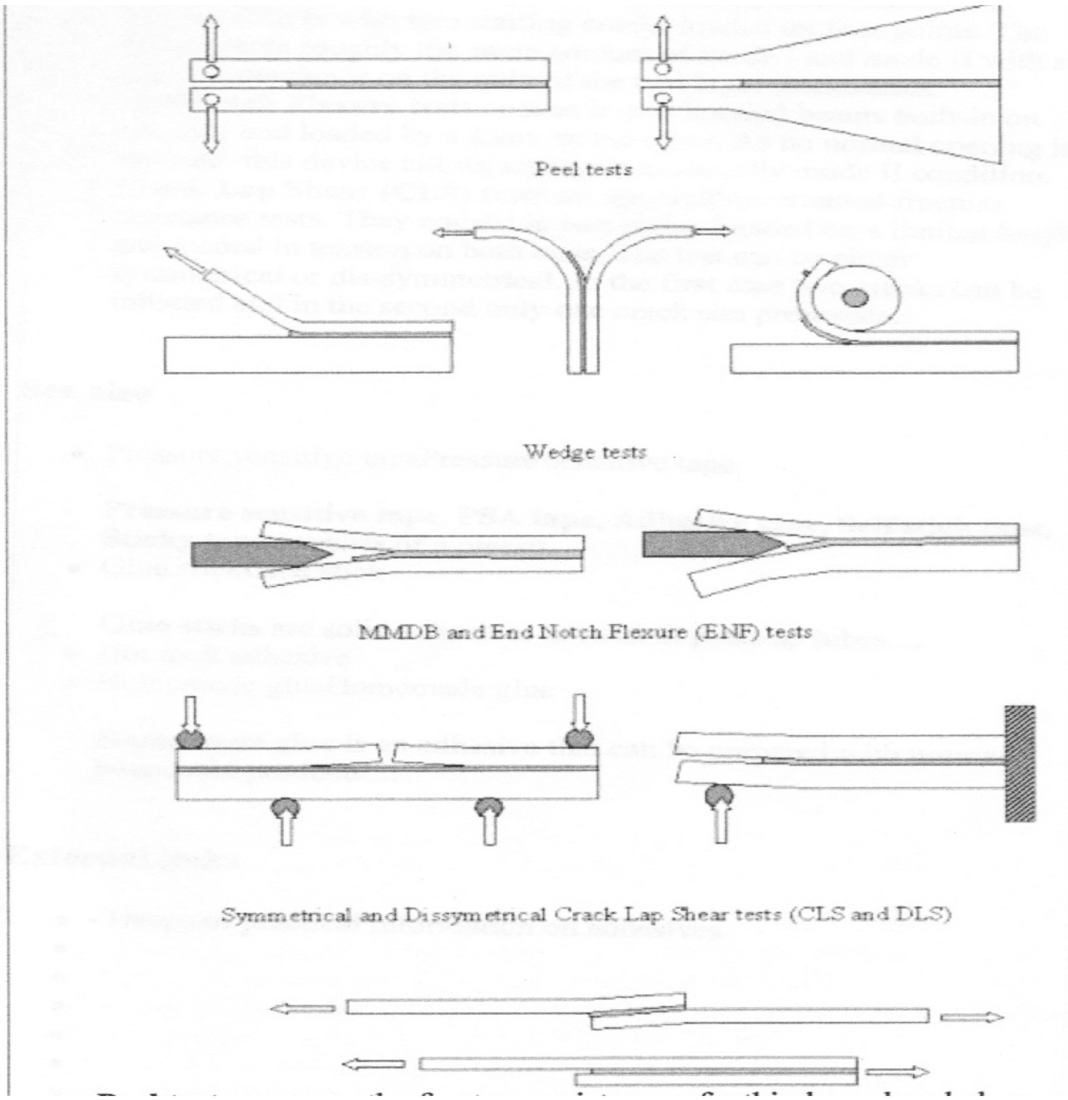


Figure 14 Test Methods

Shear Tests: By far the most common and useful type of adhesive tests is the shear test. Not only is it quite simple and economical to run, but it also duplicates and evaluates the type of loading to which structural adhesives are most often subjected to in service.

Tensile Tests: An adhesive is in tensile loading when the acting forces are applied perpendicularly to the plane of the adhesive. The test may be affected by several factors, namely 1.) Temperature during the test, 2.) Alignment of the test device, 3.) Alignment of the joined area, 4.) Rate of loading.

Immersion Tests: This test is to determine the resistance of the bonded joints to various fluids. Specific immersion times, temperatures and fluid concentrations are prescribed for each material.

<u>STANDARDS:</u>

As mentioned earlier, there are numerous standards relevant to adhesives. These standards provide a wide range of guidelines for 1.) Safety, 2.) Performance, 3.)Adhesive formulation, 4.) Cleanliness, 5.) Bonding involving adhesive type relative to substrate type, 6.) Mechanical classification, etc. Several sponsors delivering adhesive standards are:

a.) The Department of Defense; i.e. MIL standards
b.) The American Society of Testing Materials (ASTM)
c.) The American Society of Mechanical Engineers (ASME)
d.) Federal Specifications
e.) Underwriters' Laboratory (UL)
f.) National Sanitation Foundation (NSF)
g.) American Bureau of Shipping (ABS)
h.) Canadian Food Inspection Agency (CFIA)
i.) Food and Drug (FDA)
j.) ISO 10993 Compliance

There is a significant number of industry standards that govern packaging, tape, fire hazards, environmental hazards, safety in usage, etc. The very best suggestion is to allow the vendor you are dealing with to aid your efforts in determining which standards are most applicable to the individual application. If you are working as a supplier and providing a bonded assembly, you will want to ask your client if there are any outstanding specifications and / or standards they need adherence to. If the answer is yes, make sure you have the most up-to-date version WITH any addenda. Agree upon this with them and "nail them down" as to applicability.

EQUIPMENT:

The type of equipment for dispensing adhesives will depend upon 1.) Adhesive type, 2.) Daily production needs, 3.) Calibration requirements and 4.) The "trainability of production workers". The equipment required for light-cure adhesives, RTVs, one-part adhesive, two-part adhesive and epoxies is all different. **In most cases, the equipment for one adhesive category type is NOT interchangeable for another category type.** Low production requirements may necessitate a hand-held piece of equipment instead of a robotic dispensing system, whereas daily requirements involving thousands of bonded parts may demand a much more sophisticated work cell. It is also very important to consider receiving methodology for incoming adhesive products, storage area and procedures for any adhesive that must be disposed of. Do you need a storage area that must be "sprinkled"? Is there a need to call OSHA prior to manufacturing? What PPE (personal protection equipment) will be needed to insure the safety of employees? How much training must employees have prior to working with adhesives and accelerants? Is it necessary to remove any odors created by the adhesive and / or accelerant during the production process? These are all good questions to ask and must be answered prior to dispensing the materials.

The following figures will show the large variety of equipment used on a daily basis today.

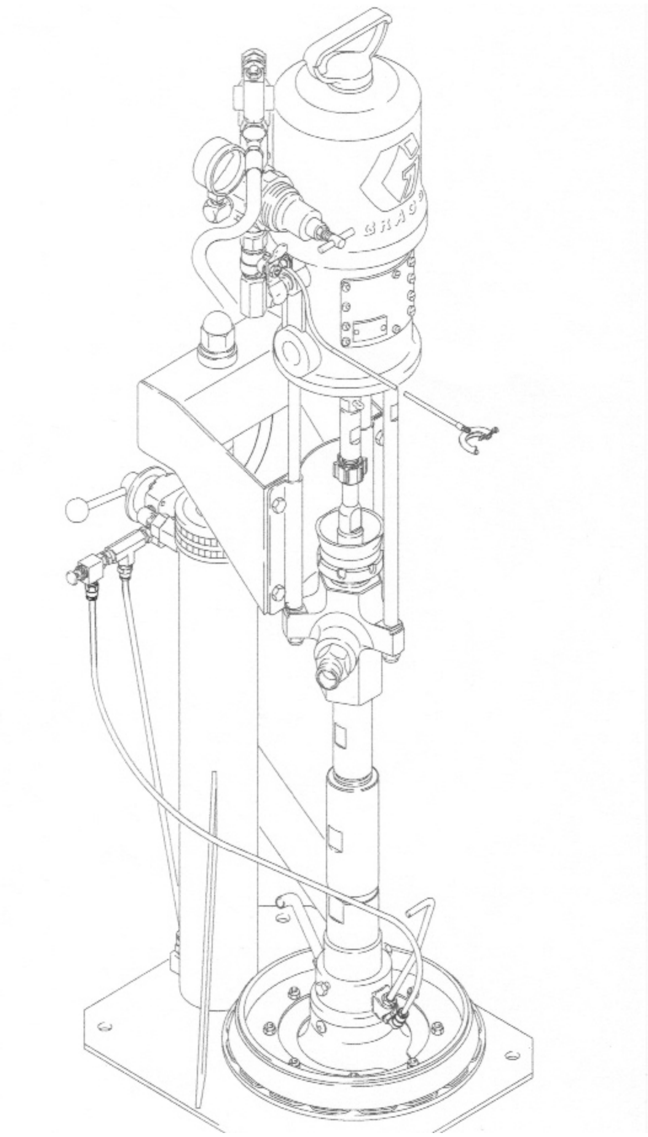


Figure 15 Pump / Pail Assembly

The line drawing above shows a pump / pail system marketed by the LOCTITE Corporation using a GRACO pump. It is a system used extensively in manufacturing organizations to dispense a variety of adhesives including very viscous RTVs. The pail is placed below the plunger plate on the bottom of a ram. As material is used, the plate advances downward moving the adhesive through a distribution hose. The hose is not shown in the drawing.

The distribution hose may be connected to a hand-held “wand” or a robotic work cell dispensing adhesives on a programmed basis.

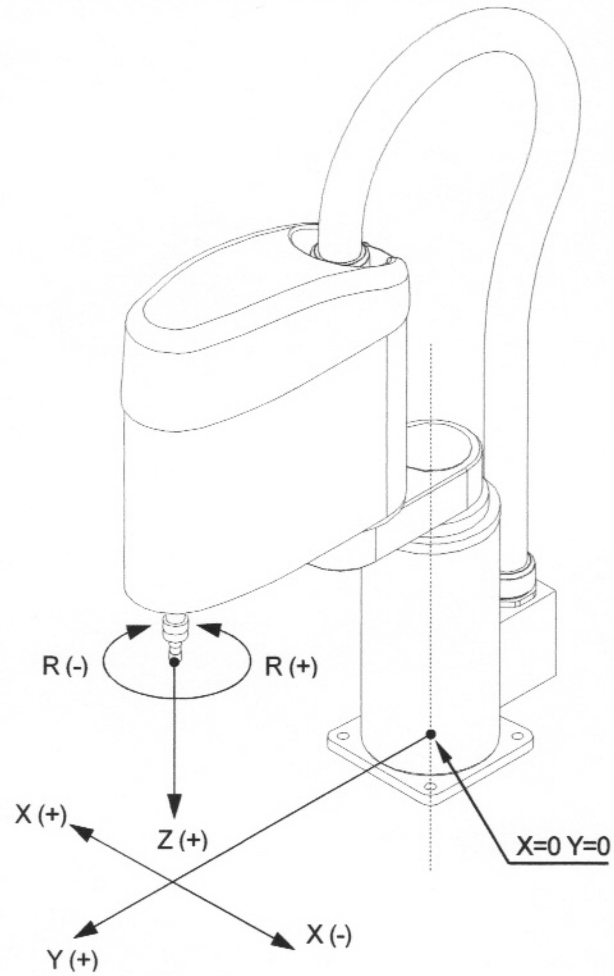
COORDINATE SYSTEM

Two coordinate systems, (X,Y) and (J1,J2) are used for the JS series SCARA robots.

X-Y Cartesian Coordinate System

These are Cartesian coordinates whose origin (0 point) is the rotation center of the J1 Arm.

There are therefore two possible J1-J2 conditions at the same X-Y coordinates. (See illustration below.)



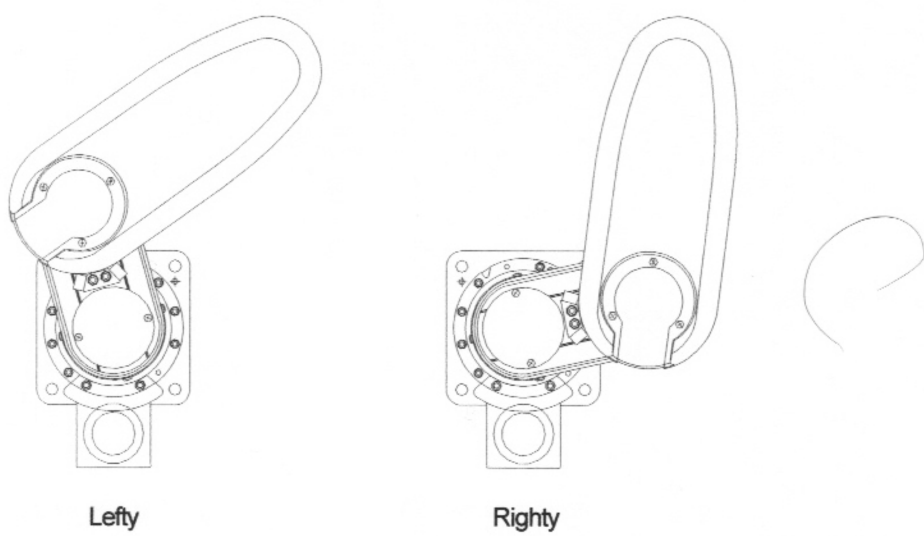


Figure 16 SCARA Robot

The line drawing above gives the basic details of a SCARA robot. This robot can deliver adhesive at the rate of six (6) inches per second over a flat or "angled " surface. It is a remarkably capable device and one that can save hours of setup time and production time, but it is not cheap. Another type of robot is shown below.

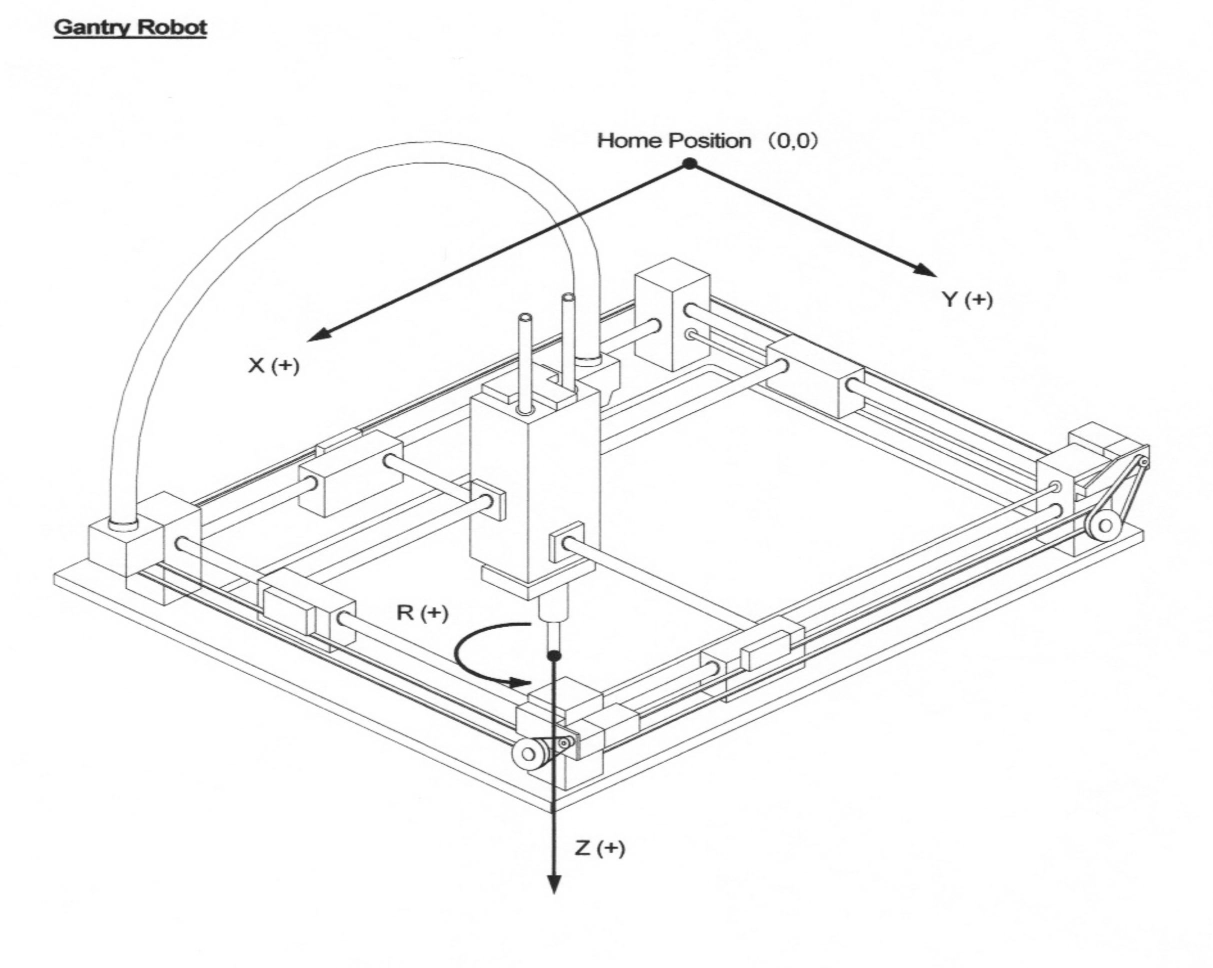


Figure 17 Cartesian Robot

This is a gantry or Cartesian robot. It has the same basic four axis capabilities but cannot articulate to provide adhesive for parts with compound angles. It is basically designed for flat parts. In both cases; i.e. SCARA and Cartesian, a dispensing head is installed to the movable post. This head is supplied with adhesive from storage such as a pump / pail assembly. The system is driven by "dry", compressed air, usually at around 80 to 100 psi. Most systems operate with 230 VAC, single phase voltage and require a 30 amp breaker. Depending upon adhesives, a ventilation hood may be required.

Now let us look at several "bench top" hand-held systems. The one given directly below is a reservoir used for dispensing a variety of adhesive types. As you can see, it is a "pressure pot".

Figure 18 Adhesive Storage

The photograph below shows a hand-held device loaded with a cartridge of 332 acrylic adhesive. The device operates in a fashion very similar to a caulking gun.

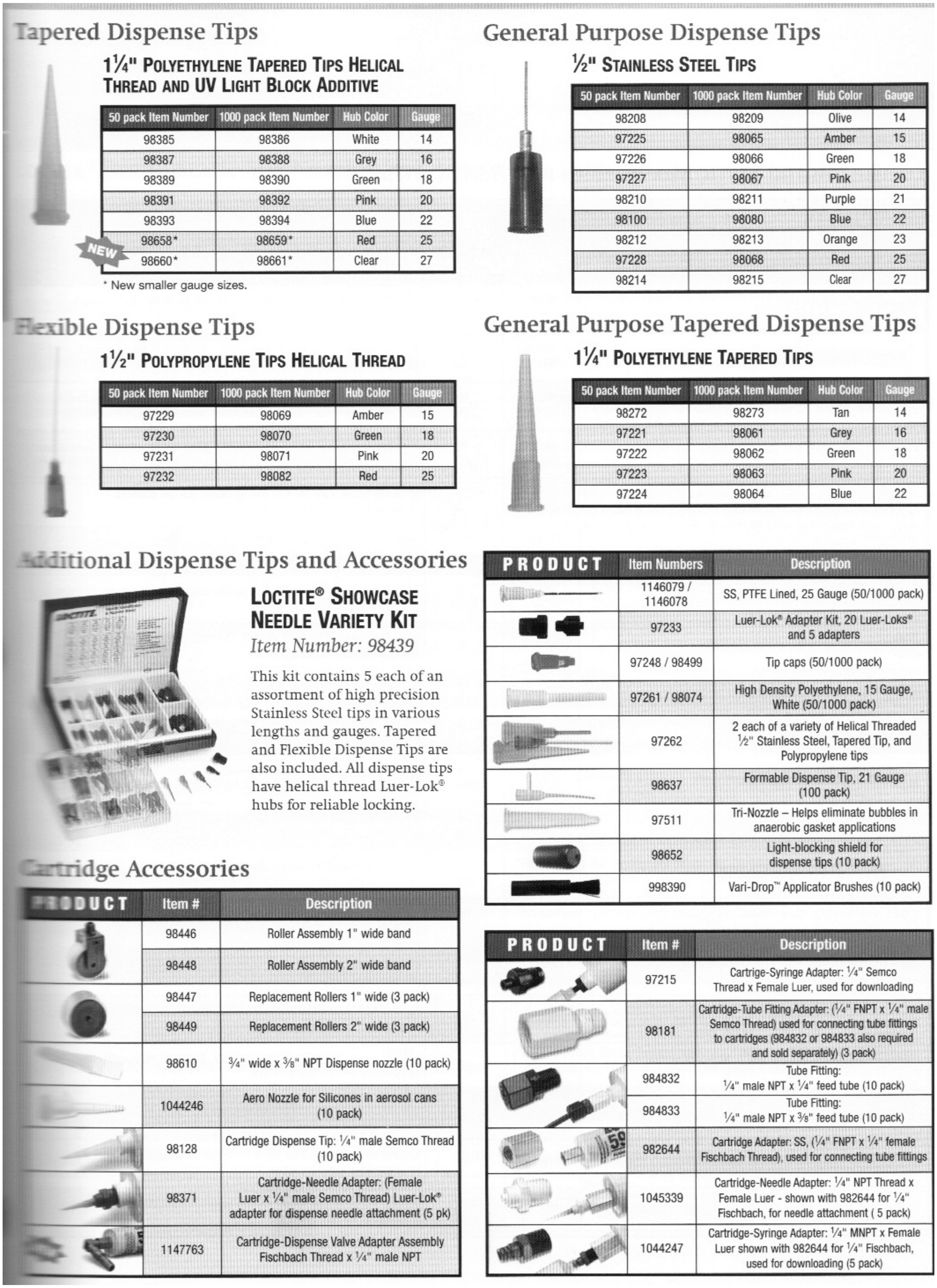
TECHNICAL SPECIFICATIONS	
Used to Dispense	Any fluid in a 30 ml syringe including 25 ml net fill syringes
Package Types & Sizes	30 ml syringes
Viscosity Range	Low to High
Parts Included	(1) 30 ml manual syringe applicator (1) Manual (1) Plunger
Additional Information	For Dispense Tips, see pages 82-83.

Figure 19 Cartridge Dispenser

The devices below show a hand-held hot melt "glue gun". These are primarily for low production applications. Please note the "glue sticks" protruding from the guns. As mentioned earlier, there are three types of hot melt adhesives: 1.) Remoistenable, 2.) Polyamide and 3.) Reactive. Hot melts are rapid cure and are used greatly in carton sealing application, generally dispensed from bulk storage.

Figure 20 Hot Melt "Glue Guns"

Regardless of the method used for dispensing adhesive, there are great varieties of dispensing "tips" or nozzles available to calibrate the proper amount of material provided on the substrate. This is demonstrated with the figure below. The varieties include dispensing tips, one-part and two-part static mix nozzles and syringe barrel components. These devices are made in various lengths from materials such as stainless steel and polyethylene.



Tapered Dispense Tips

1¼" Polyethylene Tapered Tips Helical Thread and UV Light Block Additive

50 pack Item Number	1000 pack Item Number	Hub Color	Gauge
98385	98386	White	14
98387	98388	Grey	16
98389	98390	Green	18
98391	98392	Pink	20
98393	98394	Blue	22
98658*	98659*	Red	25
98660*	98661*	Clear	27

NEW

* New smaller gauge sizes.

General Purpose Dispense Tips

½" Stainless Steel Tips

50 pack Item Number	1000 pack Item Number	Hub Color	Gauge
98208	98209	Olive	14
97225	98065	Amber	15
97226	98066	Green	18
97227	98067	Pink	20
98210	98211	Purple	21
98100	98080	Blue	22
98212	98213	Orange	23
97228	98068	Red	25
98214	98215	Clear	27

Flexible Dispense Tips

1½" Polypropylene Tips Helical Thread

50 pack Item Number	1000 pack Item Number	Hub Color	Gauge
97229	98069	Amber	15
97230	98070	Green	18
97231	98071	Pink	20
97232	98082	Red	25

General Purpose Tapered Dispense Tips

1¼" Polyethylene Tapered Tips

50 pack Item Number	1000 pack Item Number	Hub Color	Gauge
98272	98273	Tan	14
97221	98061	Grey	16
97222	98062	Green	18
97223	98063	Pink	20
97224	98064	Blue	22

Additional Dispense Tips and Accessories

Loctite® Showcase Needle Variety Kit

Item Number: 98439

This kit contains 5 each of an assortment of high precision Stainless Steel tips in various lengths and gauges. Tapered and Flexible Dispense Tips are also included. All dispense tips have helical thread Luer-Lok® hubs for reliable locking.

PRODUCT	Item Numbers	Description
	1146079 / 1146078	SS, PTFE Lined, 25 Gauge (50/1000 pack)
	97233	Luer-Lok® Adapter Kit, 20 Luer-Loks® and 5 adapters
	97248 / 98499	Tip caps (50/1000 pack)
	97261 / 98074	High Density Polyethylene, 15 Gauge, White (50/1000 pack)
	97262	2 each of a variety of Helical Threaded ½" Stainless Steel, Tapered Tip, and Polypropylene tips
	98637	Formable Dispense Tip, 21 Gauge (100 pack)
	97511	Tri-Nozzle – Helps eliminate bubbles in anaerobic gasket applications
	98652	Light-blocking shield for dispense tips (10 pack)
	998390	Vari-Drop™ Applicator Brushes (10 pack)

Cartridge Accessories

PRODUCT	Item #	Description
	98446	Roller Assembly 1" wide band
	98448	Roller Assembly 2" wide band
	98447	Replacement Rollers 1" wide (3 pack)
	98449	Replacement Rollers 2" wide (3 pack)
	98610	¾" wide x ⅜" NPT Dispense nozzle (10 pack)
	1044246	Aero Nozzle for Silicones in aerosol cans (10 pack)
	98128	Cartridge Dispense Tip: ¼" male Semco Thread (10 pack)
	98371	Cartridge-Needle Adapter: (Female Luer x ¼" male Semco Thread) Luer-Lok® adapter for dispense needle attachment (5 pk)
	1147763	Cartridge-Dispense Valve Adapter Assembly Fischbach Thread x ¼" male NPT

PRODUCT	Item #	Description
	97215	Cartrige-Syringe Adapter: ¼" Semco Thread x Female Luer, used for downloading
	98181	Cartridge-Tube Fitting Adapter: (¼" FNPT x ¼" male Semco Thread) used for connecting tube fittings to cartridges (984832 or 984833 also required and sold separately) (3 pack)
	984832	Tube Fitting: ¼" male NPT x ¼" feed tube (10 pack)
	984833	Tube Fitting: ¼" male NPT x ⅜" feed tube (10 pack)
	982644	Cartridge Adapter: SS, (¼" FNPT x ¼" female Fischbach Thread), used for connecting tube fittings
	1045339	Cartridge-Needle Adapter: ¼" NPT Thread x Female Luer - shown with 982644 for ¼" Fischbach, for needle attachment (5 pack)
	1044247	Cartridge-Syringe Adapter: ¼" MNPT x Female Luer shown with 982644 for ¼" Fischbach, used for downloading (5 pack)

Figure 21 Dispensing Nozzles

APPENDIX

- Glossary of Terms for Adhesives
- Glossary of Terms for Pressure-Sensitive Adhesives
- Excerpts from UL 746C
- Example of HAZMAT Sheet for PSTs
- Typical Specification Sheet

GLOSSARY OF TERMS FOR ADHESIVES

Definitions of widely used terms in the technology of adhesives, sealants, potting compounds, encapsulants and impregnants.

A-stage- The early stage in the reactions of certain thermosetting polymers wherein the material is still quite soluble in various liquids and flowable at elevated temperatures; readily formable into specific configurations.

ABS - Acrylonitrile - Butadiene Styrene Resins - versatile widely employed thermoplastic polymer compositions with moderate resistance to heat, low temperatures and chemicals; bonds readily to many different adhesive materials.

Acetal - Acetal resins based on formaldehyde are high performance engineering plastics with superior abrasion resistance and toughness; may require pretreatments to enhance adhesion properties.

Accelerators - Substances employed to speed up the cure of adhesives, sealants, potting/encapsulation compounds and impregnants; See also 'catalyst'.

Acrylics - A family of thermoplastic synthetic resins based largely on acrylic esters with a wide range of performance properties; acrylic resins are often recognized for their superior optical clarity, strength and high durability; acrylic adhesives are available which feature remarkable adhesion to many different substrates and quick cure times; limited resistance to elevated temperatures and/or chemical exposure are factors to be considered when selecting such adhesives, sealants, etc. for specific applications.

Adhesion - The state in which two surfaces are held together by interfacial forces which may be chemical or mechanical in nature or both; frequently called bonding.

Adhesive - A substance with the capability of holding two surfaces together by either chemical or mechanical interfacial forces or combinations thereof; bonding agent.

Adhesive assembly - An adhesive which can be employed to bond parts together such as in the manufacture of aircraft and automotive components, electronic circuitry, medical devices, furniture and many other structures or goods.

Adhesive strength - The strength with which two surfaces are held together with an adhesive, also known as the bond strength; quantitative tests are available for measuring the adhesive strength under various environmental conditions; measured in units such as psi or N/mm^2

Aqueous - Related to or based on water containing compositions.

Bonding - The assembly of materials by means of adhesives; may be carried out at ambient or at elevated temperatures for specified time periods.

Bond strength - See "adhesive strength". Specific measurements include the load applied in tension, compression, flexure, peel, impact or shear needed to break an adhesive assembly with failure noted in or near the plane of the bond.

B-Stage - The intermediate stage in the reaction of certain thermosetting polymers wherein the material can still be softened when heated or swelled in contact with certain liquids but cannot be completely fused or dissolved; B-staged resins generally permit some degree of formability or shaping into certain specific configurations.

Break- Failure of an adhesively bonded assembly when subjected to excessive loads and/or hostile environmental conditions such as exposure to excessively high or low temperatures, aggressive solvents etc; failures can also occur as the results of inadequate joint design or contamination of the surfaces to be bonded by oils, grease, particulates and so on. It can also result from insufficient adhesive application to a joint.

Cartridge - A rigid container employed to store unmixed adhesive compositions in pre-measured amounts; cartridges may feature a side-by-side or coaxial configuration.

Catalyst - A chemical substance employed to speed up the cure of adhesives, sealants, potting/encapsulation compounds and impregnants; see also "accelerator"; frequently used as the "B" component of a two-part thermosetting adhesive, sealant or potting compound.

C-stage - The final stage in the reaction of certain thermosetting polymers wherein the material becomes largely insoluble and infusible; the attainment of the C-stage signals achievement of completeness of the cure of these products and realization of their optimum strength and other pertinent performances characteristics.

Composite - A material made up of two or more different substances, each having its own properties, combined to form a third substance with its own specific performance properties; thus epoxy or polymer type resins can be combined with glass or graphite fibers to create higher strength glass or graphite fiber reinforced laminates with enhanced toughness, dimensional stability etc.

Crazing - Fine cracks that may extend in a polymer network on or under the surface of or through a layer of an adhesive or substrate.

Creep - Dimensional change that can occur with time with a material under load, following instantaneous or rapid deformations especially after repeated cycling; creep at ambient temperatures is often called cold flow.

Cryogenic - Applicable to very low temperature conditions such as liquid nitrogen and below; usually referred to temperatures below 100°K.

Curing - The process which changes the properties of a material by chemical reactions; it frequently involves a physical change from the liquid to the solid state; often called hardening or setting; fully cured materials exhibit maximum physical, thermal and chemical properties in use.

Curing Agent - See accelerator, catalyst, and hardener.

Cyanoacrylates - A family of exceptionally fast curing so called "instant glue" adhesives with the capability of quick bonding to a wide range of metallic and nonmetallic substrates; special primers are also available for certain difficult-to-bond to substrates.

Dilutents - Ingredients usually added to an adhesive composition to decrease the concentration of the active bonding materials so as to achieve enhanced flow properties or reduce cost.

Drying - To change the physical state of an adhesive on an adherend surface by evaporation of the solvent components of the adhesive composition; drying can also be accomplished by absorption of the solvent components on the adherend surface.

Elastomer - A polymeric material which at ambient temperatures can be stretched to at least twice its original length by a deforming force and then returns to its original length upon removal of that force; elastomers can be synthetic or natural materials (rubbers).

Epoxy - A most versatile group of thermosetting polymers for adhesive, sealant, coating, potting/encapsulation, impregnation and coating uses; can be two component room temperature curing or one part heat curing compositions; feature high physical strengths, superior resistance to chemical and/or environmental damage and excellent dimensional stability; widely employed for structural adhesive applications and as electrical insulation materials; special formulations are available which feature high electrical and/or thermal conductivity; remarkably wide service temperature range.

Exothermic - Chemical reactions which release heat; the opposite of endothermic reactions which require heat to proceed.

Extenders - Ingredients frequently having some adhesive property, added to an adhesive composition in order to reduce the cost of the amount of the primary adhesive component required per unit of bond area.

Extinguishing - See also self-extinguishing. Compounds having resistance to burning.

Failure, adhesive - Breakage of an adhesive bond such that the separation takes place at the adhesive/adherend interface.

Failure, cohesive - Breakage of an adhesive bond such that the separation takes place within the adhesive bond layer.

Fillers - Relatively non-adhesive substances added to an adhesive composition to improve ease of application and/or some specific performance property such as strength, durability, hardness, dimensional stability or other characteristics.

Fillet - That portion of an adhesive which fills the corner or angle formed where two adherends are joined.

Flow - Movement of an adhesive compound during application and the bonding process, prior to the onset of cure.

FRP - Fiber reinforced plastics.

Gelation - Description of the process wherein an initially liquid composition thickens and changes from liquid to solid state; formation of a solid polymer network from a liquid.

Hardener - A substance or mixture of substances added to an adhesive composition to promote the curing reaction; hardeners become part of the cured adhesive compound (see also catalyst)

Inhibitor - A substance which is added to slow down the rate of a chemical reaction; they are at times useful to prolong the storage or working life of certain types of adhesives.

Impregnation - The process of imbedding a reactive liquid into a porous substrate in order to change its properties.

Joint - The location at which two or more adherends are held together with a layer of adhesive (see also bond).

Joint, lap - A joint made by placing one adherend partly over another and then bonding together the overlapped portions.

Joint, starved - A joint that has an insufficient amount of adhesive to produce a satisfactory bond.

Laminate - A product made by bonding together two or more layers of material with adhesive.

Load - The amount of force that a body, joint or board can sustain; the force applied to a body, joint or bond;

Luer Lock - A device used as a connector between a static mixer and a hose or application tool such as a disposable needle.

Methacrylates - A family of high performance thermoplastics featuring superior optical clarity, abrasion resistance and good physical strength properties; the term is also used to describe certain modified acrylic adhesives.

Modifier - Any inert chemical ingredient added to an adhesive compound that changes its properties (see also extenders, fillers etc).

Monomer - A simple chemical building block with reactivity to make possible the formation of a polymer.

Motionless mixers - Devices which employ passive (unmoving) means to combine and mix two or more substances; commonly found attached to cartridge systems or meter-mix equipment; frequently called static mixers.

Neoprene elastomers - Synthetic rubbers with superior resistance to heat and many aggressive chemicals based on chloroprene.

Nitrile elastomers - Synthetic rubbers featuring excellent resistance to oils, fuels etc. over a wide range of temperatures based on butadiene acrylonitrile.

Nylon plastics - Tough thermoplastics polyamide based resins with superior physical strength properties, toughness and environmental resistance, usually employed as molding compounds.

O-ring - A circular disc of rubber which fits snugly around the piston to help maintain a seal between piston and cartridge wall.

Paste - An adhesive composition having the characteristic plastic-like consistency of a paste; i.e. a high order of yield value compared to a liquid.

Peel strength - An adhesive's resistance to be stripped from a bonded joint, usually with the stripping force applied at a predetermined angle and rate.

Penetration - The entering of an adhesive into an adherent, measured by the depth of the penetration achieved in a given time.

Piston - A disc which fits tightly into the back of a cartridge against its content.

Plastic - 1.)A synthetic polymeric material made from organic compounds. 2) A malleable material capable of being formed into different shapes.

Plasticizer - An ingredient incorporated into an adhesive composition that enhances flow, deformation and flexibility; the addition of plasticizers also tends to reduce melt viscosity, tensile strength properties and elastic moduli while increasing toughness and impact strength.

Plunger - A rod or stick which forces the piston and thus the contents of the cartridge to the front and through the opening.

Polymer - A complex compound made by the reaction of simple molecules having functional groups which permit their combination to proceed to a high molecular weight given appropriate reaction conditions; polymers may be formed by addition or condensation reactions; additional polymers include acrylics, ABS, nylons and styrene's; condensation polymers are epoxies, phenolics and silicones.

Polymerization - The process involving chemical reactions leading to the formation of the large molecules known as the high molecular weight materials also called polymers.

Post cure - A treatment usually involving the application of heat which is applied to an adhesive assembly following initial cure; its purpose is to modify certain specific joint properties such as heat resistance, chemical inertness etc.

Polyethylene - A family of thermoplastics based mainly on the ethylene monomer widely used in injection molding; extrusion and calendaring processes to produce various plastic products including films, sheets and fibers.

Polypropylene - A family of thermoplastic products mainly based on propylene monomers; they generally feature a higher degree of heat resistance and enhanced stiffness compared to polyethylene plastics.

Polystyrene - A group of commodity plastics produced chiefly of styrene monomers; easily processed; especially popular for manufacturing injection molded parts at moderate cost.

Polyurethane - A family of rigid and flexible plastics characterized by the utilization of the urethane group in their manufacture; many polyurethane products exhibit high flexibility and abrasion resistance after cure; special polyurethane based adhesive formulations are available.

Pot life - The period of time an adhesive or potting compound remains useful after adding an accelerator, catalyst or exposure to curing conditions.

Potting - The process of filling a cavity or space. Usually, electronic or electrical components are contained in this space. The purpose being to protect them from vibration, shock and/or environmental hazards such as moisture, aggressive chemicals such as fuels and lubricants, heat etc.

Primer - A formulated coating applied to a surface prior to the application of an adhesive in order to enhance the strength of the bond.

PVC - Polyvinylchloride; polymer family based on vinyl chloride monomer used in diverse applications such as flexible films for packaging or rigid pipe.

Resin - 1) a solid, semi-solid or pseudo solid organic material with no definite melting point usually comprised of high molecular weight material; when subjected to stress a resin typically tends to flow; 2) in adhesives, sealants, etc., resins are the basic raw materials from which these compositions are made.

Rheology - The study of the flow properties of different materials especially of non-Newtonian liquids and plastics; non-Newtonian materials are substances where the flow is not proportional to the stress applied.

Rosins - Resins obtained as a residue from the distillation of turpentine derived from the sap of pine trees (gum resin) or from an extract of the stumps and other parts of the tress (wood resins).

Sag - A decrease in the thickness of a polymer section.

Self-extinguishing - See also extinguishing. Compounds having resistance to burning.

Setting - The hardening or solidification of an initially liquid plastic material by chemical and/or physical action.

Shear strength - The ability of a plastic material to withstand shear stresses.

Shortness - A qualitative term describing the characteristic of a polymeric material that does not string or otherwise form filaments or threads during application.

Silicones - A family of polymeric materials containing the Si-O chemical group in their structure; the most widely used silicones are elastomeric adhesives and sealants capable of service over the exceptionally wide temperature range of –100°F to over 500°F. Both one and two component silicone compounds are available.

Solids content - The percentage by weight of nonvolatile material in an adhesive or sealant.

Spread - The quantity of adhesive per unit joint area applied to an adherend, generally expressed in pounds of adhesive per thousand square feet of joint area.

Squeeze out - The amount of adhesive pressed or squeezed out at the bond line of a joint due to pressure applied to the adherends.

Substrate - The basic surface upon which the adhesive is applied and to which it is expected to adhere.

Surface preparation - Physical and/or chemical pretreatments to enhance the adhesive strength of an adhesive to be applied to a specific surface.

Tack - Adhesive "stickiness" on a coated surface that is not yet completely dry; the property of an adhesive that permits it to form a bond of measurable strength immediately after the adhesive and the adherends have been brought into direct contact by application of low pressure.

Tensile strength - The maximum stress a material can be subjected to without tearing when stretched under tensile load.

Thermoplastic - Polymeric materials which will repeatedly soften and flow as the temperature is increased and harden as the temperature falls.

Thermosetting - Polymeric materials which harden when exposed to high temperatures and pressures but cannot be softened or re-melted upon further heating; the hardening of polymeric materials upon heating is due to a largely irreversible chemical reaction.

Thinners - Volatile liquids added to adhesives to modify their consistency and enhance flow.

Thixotrophy - The property of certain adhesive compositions to thin upon isothermal agitation and to thicken upon subsequent resting i.e. cessation of the agitation.

Viscosity - The resistance of a fluid to flow; the ratio of shear stress between laminae of moving fluid and the rate of shear between these laminae.

Wetting - The coating of a substrate surface with an adhesive.

Wicking - The flow of an adhesive into a tightly restricted opening.

Glossary of Terms Used in the Pressure-Sensitive Adhesive Industry

90 OR 180 – DEGREE PEEL – Peel testing measures the amount of force needed to remove an adhesive from a specified substrate. The adhesive can be peeled from the substrate at either a 90 or a 180-degree angle. Adhesive with higher peel values are more difficult to remove than adhesive with lower peel values. Peel is measured in pounds of force per lineal inch on a 1.0 mil coated samples unless otherwise noted.

ABRASION RESISTANCE — The ability of a tape to withstand rubbing and still function satisfactorily.

ACCELERATED AGING — A means whereby the deterioration of a tape encountered in natural aging may be accelerated and reproduced in the laboratory.

ACCELERATED WEATHERING (weathering) — A means whereby the deterioration caused by outdoor exposure may be accelerated and reproduced in the laboratory.

ACETATE (cellulose acetate) — A transparent film which is used for various reasons in tape backings; the primary characteristic is that of being more moisture resistant than cellophane.

ACRYLIC — a synthetic polymer with excellent aging characteristics that can be used as either a single component adhesive or a coating or saturant, depending upon composition.

ADHESION — (pressure sensitive) A bond produced between a pressure-sensitive adhesive and a surface.

ADHESION BUILD-UP — An increase in the peel adhesion value of a pressure-sensitive tape after it has been allowed to swell to the applied surface.

ADHESION TO BACKING — The bond produced by contact between a pressure-sensitive adhesive and the tape backing when one piece is applied to the back of another piece of the same tape.

ADHESIVE — Any material which will usefully hold two or more objects together solely by intimate surface contact.

ADHESIVE DEPOSIT — Adhesive which is pulled away from the tape and remains on the surface to which the tape was applied.

ADHESIVE FAILURE – When the adhesive is left entirely on the substrate to which it is coated. For example, when performing a loop tack test, after the initial touch of the coated stock to the stainless steel plate, all of the adhesive remains on the coated stock.

ADHESIVE MASS — Sometimes used as another name for the adhesive.

ADHESIVE RESIDUE — See adhesive deposit.

ADHESIVE TRANSFER — The transfer of adhesive from its normal position on the tape to the surface to which the tape was attached, either during unwind or removal.

BACKING — A relatively thin flexible material to which the adhesive is applied. Theoretically, any material which is reasonably flat, relatively thin, and flexible could be used as a tape backing.

BI-DIRECTIONAL — Related to strapping tapes, in which the reinforcing material consists of filaments in both strength and cross directions, usually a woven cloth.

BLEACHING — An erroneous term used to denote a corrosion of the surface under a tape which has remained the original surface color while the surrounding surface area has discolored.

BLEEDING — Penetration through the tape of a coloring liquid (paint, etc.) onto the surface to which the tape is applied.

BURSTING STRENGTH — The ability of a tape to resist damage when force is evenly applied perpendicularly to the surface of the tape.

CARRIER — Sometimes used to refer to the backing material, particularly in double-faced tapes.

CELLOPHANE (regenerated cellulose) — a thin transparent film manufactured from wood pulp.

COATED CLOTH — Fabric with a rubber or plastic back coating to give increased moisture resistance and longer wear.

COHESION (cohesive strength, internal bond) — The ability of the adhesive to resist splitting. Good cohesion is necessary for clean removal.

COHESIVE FAILURE – When the adhesive is left on both the substrate that it was coated to and the substrate that it comes into contact with, after it is removed from that substrate. For example, when performing a loop tack, after the initial touch of the coated stock to the stainless steel plate, the adhesive is left on both the coated stock and the stainless steel plate.

COLD-FLOW — The tendencies of a pressure-sensitive adhesive to act like a heavy viscous liquid over long periods of time. Such phenomena as oozing and increases in adhesion are the result of this characteristic.

COLOR — The particular color of a tape, when looking at the backing, regardless of the color of the adhesive.

COLOR STABILITY — The ability of a tape to retain its original color, particularly when exposed to light.

CONFORMABILITY — The ability of tape to fit snugly or make essentially complete contact with the surface of an irregular object without creasing or folding.

CREEP — A slow movement of the adhesive or backing under stress.

CREPED — Paper which has small "folds" in it, giving it high stretch.

CROSS-LINKED — The development of a three-dimensional structure in an adhesive, which is activated normally by heat. An improvement in shear resistance, high temperature resistance, and oil or solvent resistance will normally result.

CUPPING — A slightly U-shaped deformation of the tape (at right angles to the length) which usually appears after unwind tension is relaxed.

CURED — (See Cross-Linked)

CURLING — The tendency of a tape to curl back on itself when unwound from the rod and allowed to hang from the roll.

DEAD STRETCH — The net increase in length after tape has been elongated without breaking and allowed to recover.

DELAMINATION — A separation or splitting of the tape such as separation of the backing into two distinct layers, separation between laminations of a tape consisting of more than one backing, or the separation between filaments and backing of a filament reinforced tape.

DELAYED STRAIN — See Latent Stain.

DIELECTRIC STRENGTH — The voltage, which a tape will withstand without allowing passage of the current through it.

DISCOLORATION — See Stain.

DISHING — See Telescoping.

DOUBLE-COATED — The adhesive is applied on both sides of the backing, which serves principally as a carrier for the adhesive.

EDGE CURL — The peeling back or lifting of the outer edge of a tape after application (see Cupping).

ELASTIC MEMORY — A tendency of some tape backings to attempt to return to their original length after being elongated.

ELECTROLYTIC CORROSION FACTOR — A measure of the tape's corrosive effect on a copper conductor. This is particularly important in selection of tapes for use as electrical insulation.

ELONGATION (stretch, ultimate elongation) — The distance a tape will stretch lengthwise before breaking, expressed as a percentage of original length. Elongation is not necessarily an indication of conformance.

FALL-OFF — Tape pulls completely away from the surface to which applied and drops off.

FEATHERING — A jagged, irregular paint line frequently characterized by small "feathers" of the top-coat projecting into the masked area.

FILAMENTS — Thin longitudinal "threads" of glass, polyester, nylon, or other high strength materials.

FILM — Uniform, homogenous, non-fibrous synthetic webs.

FISHEYES — Relatively small deformations (pock-marks) in the adhesive caused by the entrapment of air between layers in the roll are not an indication of a quality defect.

FLAGGING — A peeling away from the surface of the end of a length of tape, particularly in a spiral-wrap application.

FLAKING— A condition sometimes occurring during the removal of masking tape, in which flakes or particles of paint break off of the tape backing.

FLAME RESISTANCE— The ability of a tape to withstand exposure to flame. Fireproof materials will not burn even when exposed to flame. Flame Resistant (fire retardant, self-extinguishing) materials will bum when exposed to flame, but will not continue to burn after the flame is removed.

FLATBACK— Smooth paper backing.

FLEXIBILITY — The ability of a tape to be freely bent or flexed.

FLUOROCARBON FILMS — A film with very high and low temperature limits, excellent electrical characteristics. Such as a very slippery, non-sticking surface. One example is DuPont's Teflon.

FOAM — A soft, cushiony material formed by creating bubbles in base materials, such as natural or synthetic rubbers, or other elastomeric materials.

FREEZING — A hardening or resinifying of the adhesive after application, so that tape cannot be easily or cleanly removed.

GAPPING — Openings between layers of tape within a roll.

GHOSTING — See Off-setting.

GLOSS — An appearance characteristic of tape backings. Usually expressed by such terms as glossy, low gloss, matte, etc.

HEAT RESISTANCE — The ability of a tape to withstand exposure to specified temperatures after application to a surface. Clean removal after exposure may or may not be important depending on the intended function of the tape and the type of adhesive.

HIGH-SPEED UNWIND — Unwinding or dispensing of tapes at a relatively high rate of speed, usually over 50 feet per minute.

HOLDING TOWER (shear adhesion) — The ability of a tape to resist the static forces applied in the same plane as the backing. Usually expressed in time required for a given weight to cause a given amount of tape to come loose from a vertical panel.

HOLIDAY — A small defect, particularly in an electrical or pipe wrapping tape, which lowers the dielectric strength at the point of the defect below a certain desired minimum.

HOT MELT — (Pressure-Sensitive Adhesive)—A pressure-sensitive adhesive applied to the backing in a hot molten form which cools to form a conventional pressure-sensitive adhesive.

IMPACT RESISTANCE (shock resistance) — The ability of a tape to resist sudden pulls or shocks as may sometimes be encountered by packages in transit.

INSULATION RESISTANCE — The ability of a tape to prevent the flow of current across its surface, usually measured on the backing.

INSULATING TAPE — Normally refers to tape used for electrical insulation.

KRAFT — A sulphate wood pulp paper. (See Saturation)

LABEL STOCK — Pressure-sensitive materials, which are usually printed, frequently die-cut, furnished in roll or sheet form with a liner, and intended for use as labels.

LAMINATION — A combination of two or more similar or dissimilar materials, which function as one backing, i.e, acetate and tissue in acetate fiber tapes.

LATENT STAIN — A stain in a surface to which tape has been applied, which does not become noticeable until some time after removal, usually after the surface has been exposed to sunlight or heat.

LIFTING — A situation where a section of tape has pulled away from the surface to which it has been applied.

LOOP TACK (pli) – The initial attraction or grab of an adhesive to a substrate without any external pressure. Measured in pounds per lineal inch.

MASS — Sometimes used as another name for the adhesive.

METAL FOIL — Thin, flexible sheets of metal such as aluminum and lead used as tape backings properties such as weather-resistance, reflectivity, etc.

MIGRATION — The movement, over a long period of time, of an ingredient from one component to another when the two are in surface contact. May occur between tape components or between a tape and the surface to which it is applied. Some plastic films and foams contain plasticizers, which are apt to migrate into the tape adhesive, causing the adhesive to soften.

MULTIPLE COMPONENT ADHESIVE — A pressure-sensitive adhesive containing one or more elastomers combined with resins and other components, which impart tack, adhesion, and other necessary properties.

NON-WOVEN MATERIALS — Paper "tissues" or synthetic (e.g. rayon) non-woven fabrics.

OFF-CORE — Layers of tape are in correct alignment, but tape is displaced sideways on core.

OFFSETTING — Occurs when a printed tape is unwound and some of the printing ink is picked off by the adhesive or migrates into the adhesive. It is in effect a delamination of the ink.

OOZING — A "squeezing out" of the adhesive from under the backing. When occurring when the tape is in roll form, the edges of the roll become tacky.

OPAQUENESS — The ability of a tape to prevent the transmission of light.

PAINT LINE — The line between a tape masked surface and a painted or otherwise treated surface.

PEAKING — Large singular upheavals in the outer layers of a roll of tape.

PEEL ADHESION — The force per unit width, expressed in oz/in. width, required to break the bond between a tape and a surface when peeled back usually at 180 degrees at a standard rate and condition.

PENETRATION RESISTANCE — The ability of a tape to resist slow puncture under pressure.

PIN HOLE — A very small hole, which may permit the passage of light, moisture or electrical current.

PLAIN CLOTH — Fabric woven from cotton, glass or other fibers, without further treatment.

POLYETHYLENE — A tough, stretchy film having very good low temperature characteristics.

POLYESTER — A strong film having good resistance to moisture, solvents, oils, caustics, and many other chemicals. It is usually transparent.

POLYPROPYLENE — A new cousin of polyethylene, with generally similar properties, but stronger and having a higher temperature resistance.

POLYVINYLIDENE CHLORIDE — A usually very thin transparent film with excellent resistance to acids, water and organic solvents.

PRESSURE-SENSITIVE — A term commonly used to designate a distinct category of adhesive tapes and adhesives which in dry (solvent free) form are aggressively and permanently tacky at room temperature and firmly adhere to a variety of dissimilar surfaces upon mere contact without the need of more than finger or hand pressure. They require no activation by water, solvent or heat in order to exert a strong adhesive holding force toward such materials as paper, plastic, glass, wood, cement and metals. They have a sufficiently cohesive holding and elastic nature so that, despite their aggressive tackiness, they can be handled with the fingers and removed from smooth surfaces without leaving a residue. General trade usage by leading tape manufacturers does not sanction extension of the term "pressure-sensitive" to embrace tapes and adhesives merely because they are sticky (i.e. flypapers), or merely because they adhere or cohere to a particular type of surface (e.g. self-sealing envelopes); and terms other than"pressure-sensitive" should be used in such cases to avoid confusion.

PRIMING — Coating the backing on the adhesive side with a thin layer of adhesive-like material, which serves as a bonding agent between the adhesive and the backing.

PRINTABILITY — The ability of a tape to accept and hold a printed legend, and especially to resist offset of the printing when rewound into a roll after printing.

PRINTING — The pattern of a tape left on a surface after tape has been removed. Most apt to occur when tape is applied to a freshly painted surface which has not fully hardened.

PUCKERING — The uneven, non-flat condition of masking paper to which tape has been applied.

QUICK STICK — {Tack. Finger Tack. Initial Adhesion. Wet Grab) — The property of a pressure-sensitive adhesive which allows it to adhere to a surface under very light pressure. Quick stick is determined by the ability of the adhesive to quickly wet the surface contacted.

RECOVERY — The difference between ultimate elongation and dead stretch.

REINFORCEMENTS — A material added to a tape to provide additional strength.

RELEASE COATING (easy unwind treatment) — A coating applied to the backing on the side opposite the adhesive, which provides ease of unwind, and prevents delamination or tearing.

RELEASE COAT TRANSFER — Particles of the release coat sticking to the adhesive on unwind and the resulting tape will have little or no ability to stick.

RELEASE LINER — A web or sheet of material covering the adhesive side of a tape. It is removed prior to application. Most frequently found on double-coated tapes and label stocks.

REMOVAL — The act of pulling tape away from the surface to which it has been applied.

RESIDUE — See Adhesive Residue.

RESISTANCE TO WEATHER, SOLVENTS, ACIDS, ALKALIES, OILS, GREASES, ETC. — The ability of a tape to resist exposure to varying conditions after application and to perform satisfactorily.

REVERSE STAIN — See Bleaching.

RIDGING — A mound-like swelling on the outer layers of a roll, lengthwise to the tape. Usually found on the more moisture-sensitive materials, such as cellophane.

ROPE STOCK — A smooth paper made of hemp fiber for high tensile strength.

SAFT – Shear Adhesion Failure Temperature. The SAFT refers to the upper temperature limit at which an adhesive is able to support a certain amount of weight. Polymer degradation, incorrect raw material ratios and incorrect blending can affect the SAFT results. This is not a measure of the bond between the adhesive and a substrate, but a measure of the internal strength of the adhesive itself. Generally, as the shear strength of an adhesive system is increased, tack and adhesive performance will decrease. This is generally measured in Fahrenheit.

SATURATION (impregnation) — Adding materials (saturant) to the backing for improvement of physical properties, and resistance to various deleterious environments. The backing of paper tapes, for instance, may actually contain as much as 50% by weight of a rubber-based impregnant.

SEPARATING — See Gapping.

SHEAR ADHESION — See Holding Power

SHRINKAGE — Reduction in any dimension of a tape.

SILICONE — A unique polymer system, which can be a very effective release coating, or pressure-sensitive adhesive capable of functioning effectively at extreme temperatures.

SINGLE-FACED — The adhesive is applied to one side of the backing only. Most pressure-sensitive tapes are of this type.

SIZED — Fabric, usually cotton, treated to give added stiffness and easier handling.

SLIP SHEET OR INTERLINER — A treated sheet used to cover the adhesive to facilitate handling.

SLIVERING — Tape tears or breaks into small pieces, either on unwind or removal from a surface.

SMOOTHNESS - The relative flatness of the tape backing.

SOFTENING POINT – The temperature at which an adhesive goes from a solid to a molten form. This is measured in Fahrenheit or Celsius.

SPLITTING — See Determination.

STAIN — A discoloration of a surface to which tape has been applied.

STAIN RESISTANCE — The ability of a tape to be applied to a surface without discoloring the surface.

STIFFNESS — The measure of a tape's flexibility and ability to conform.

STORAGE STABILITY (roll-aging resistance) — The ability of a tape to retain its original properties after storage.

STRINGINESS — A condition of the adhesive in which it feels very soft and mushy, and on close examination relatively long "legs" or "strings" of adhesive can be pulled out of the adhesive.

TACKY — The condition of the adhesive when it feels sticky or highly adhesive. Sometimes used to express the idea of pressure-sensitivity.

TEARING — Breaking or slivering of a tape during unwind.

TEAR RESISTANCE — The ability of a tape to resist tearing, after a tear has been started by cutting or nicking the edge.

TELESCOPING — A sideways sliding of the tape layers, one over the other, such that the roll looks like a funnel or a telescope.

TENSILE STRENGTH (breaking strength) — The force required to break a piece of tape by pulling on opposite ends of the piece. **Machine Direction Tensile** is the tensile strength measured parallel to the length of the tape. Unless otherwise specified, tensile strengths are measured in the machine direction.
Cross direction tensile is the tensile strength measured at right angles to the length.
Wet tensile is the tensile strength of tape, which has been kept wet for a specified period of time. Measures ability of tape to function satisfactorily when exposed to moisture.

Tg – Glass Transition Temperature. The temperature at which an adhesive will become markedly less elastic and flexible. At temperatures below 0°C the adhesive will have more room temperature properties.

THERMOPLASTIC ADHESIVES — Adhesives which become softer as temperature increases, regardless of the number of heating cycles to which they are exposed.

THERMOSETTING ADHESIVES — Adhesives, which set up or harden on first exposure to heat, and remain set regardless of subsequent temperature cycles.

THICKNESS — (Caliper, Gauge) Distance from one surface of either a tape, backing or adhesive to the other, usually expressed in mils or thousandths of an inch. This is usually measured under slight pressure with a special gauge.

TRANSFER — Normally refers to "adhesive transfer," but sometimes said of any tape component which moves from its proper place to some other position during either unwind or removal.

TRANSPARENCY — The ability of a tape to allow transmission of light. A tape is rated as transparent if 10-point type can be easily read when the tape is applied directly over it.

TREATMENTS — (See Priming, Release Coating, Coloring, Saturation, Sizing)

TWISTING — The curling around the lengthwise axis of a length of tape which has been unwound from the roll and allowed to hang freely.

TxOVER – High Temperature Crossover. This is the temperature at which the adhesive loses its elastomeric properties and melts to a flowable liquid. This value is a stability indicator for high temperature applications. For example, the higher the tx over number, generally, the more heat stable the product is.

ULTIMATE ADHESION — The maximum adhesion available from a pressure-sensitive adhesive, determined by the force necessary to remove a strip of tape from a surface after an extended period of time.

UNIFORMITY — The consistency of a single type of tape, either within a roll, or from roll to roll, or from lot to lot.

UNPLASTICIZED VINYL OR UPVC — A tough durable plastic film, differing from PVC principally in that UPVC is not very stretchy.

UNROLLING — See Unwind.

UNWIND (Unrolling) — The force required to remove tape from the roll.

UNWIND ADHESION — See Unwind (Unrolling).

VINYL or PLASTICIZED POLYVINYL CHLORIDE (PVC) — A tough durable plastic film having excellent resistance to oils, chemicals and many solvents. It has excellent abrasion-resistance. It can also be colored. Its high stretch is due to the addition of a plasticizer.

VISCOSITY (cps) – A measurement of the resistance to flow of a material. The higher the viscosity reading at a certain temperature, the more the resistance to flow a product exhibits.

VOID — A bare uncoated area on either the adhesive or release- coated side of the tape.

WATER ABSORPTION — The measure of the amount of water which will be soaked up by a tape and held.

WATER PENETRATION RATE (WPR) — The measure of a tape's ability to resist the passage of water through the tape itself expressed as g/100sq/in./24h.

WATER VAPOR TRANSMISSION (WVT) — The weight of water vapor transmission through a tape measured in gram/hundred square inches/24 hours.

WEAVING — A poorly wound roll of tape in which the individual layers of tape are not in alignment with the other layers.

The following is portion of Underwriter's Laboratory UL 746 C specification for testing pressure sensitive tapes. The purpose of this copy is to simply give an example of a performance specification. Please keep in mind this is merely a portion of the specification.

71 Adhesives – Specialized Applications

71.1 General

71.1.1 Unless otherwise specified, all testing shall be conducted in a standard laboratory atmosphere at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity.

71.1.2 Specimens shall be of the type described in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. Specimen preparations shall be in accordance with the manufacturer's specification for fabrication. Surface preparation shall remove all contaminating substances (mold releases on polymeric surfaces; paint, rust, oxide films, oil, and dust from metal surfaces). Freshly cleaned surfaces shall be protected by a primer if the adhesive cannot be applied immediately. The adhesive can be applied by spray, brush, knife, or film. The temperature and pressure application during bonding shall be in accordance with the adhesive manufacturer's specifications.

71.2 As-received test

71.2.1 For each primary property to be evaluated, 20 specimens shall be conditioned for 40 hours at 23.0 ±2.0°C (73.0±3.6°F) and a relative humidity of 50 ±5 percent prior to testing.

71.2.2 The specimens are to be subjected to applicable tests to determine the value of the critical properties in the as-received condition. In the case of bond-strength evaluation, specimens that break at an obvious flaw remote from the adhesive line shall be discarded and a retest made. The average value of the property is to be computed. This value is to be used for comparison with values of the same property after the environmental conditioning described in 71.1.1 – 71.5.1.

71.3 Effect of temperature

71.3.1 For each primary property to be evaluated, ten specimens shall be conditioned for 1000 hours at the oven temperature taken from the respective thermal-endurance-profile line in Figure 71.1, where the temperature index T is the measured normal operating temperature of the adhesive, but not less than 60°C (140°F).

Exception No. 1: The effect-of-temperature test need not be conducted on joints bonded by fusion techniques, such as solvent or ultrasonic welding, and the like.

Exception No. 2: On the same thermal-endurance-profile line in Figure 71.1, a shorter or longer time at a higher or lower temperature respectively may be employed if agreeable to all concerned, but a period no less than 300 hours is to be used.

71.3.2 After the conditioning, the specimens shall be brought to and tested at room temperature to determine the critical property values. The average conditioned value for each property is to be at least 50 percent of the unconditioned value.

The following page represents an adhesive specification. It is given for observation only and to familiarize the reader with the type of content, the overall layout and the format used for material specifications.

FASTEN. BOND. SEAL.

Avery Dennison™ UHA

Transfer Tape

AVERY DENNISON

Specialty Tape Division

250 Chester Street
Painesville, Ohio 44077
Phone: 866-GO-AVERY (866-462-8379)
Fax: 440-398-3298
email: psa.tape@averydennison.com
URL: stus.averydennison.com

Surface Preparation

It is essential, as with all pressure-sensitive tapes, that the surface to which the tape is applied be clean, dry, and free of grease or oil.

US Patent No. 4820746 5166226

Temperatures

Min Application Temp	50° F	10° C
Max Continuous Operating Temp	225° F	107° C
Max Intermittent Operating Temp	275° F	135° C

Storage and Shelf Life

One year when stored at 70°F (21°C) 50% RH out of direct sunlight.

Limited Warranty

All statements, technical information and recommendations concerning products sold or samples provided by AVERY DENNISON are based upon tests believed to be reliable but do not constitute a guarantee or warranty. All products are sold and samples of products provided with the understanding that PURCHASER has independently determined the suitability of such products for its purposes. AVERY DENNISON warrants the products to be free from defects in material and workmanship. Should any failure to conform to this warranty appear within one year* after the initial date of shipment, AVERY DENNISON shall, upon notification thereof and substantiation that the products have been stored and applied in accordance with AVERY DENNISON's standards, correct such defects by suitable repair or replacement without charge at AVERY DENNISON's plant or at the location of the products (at AVERY DENNISON's election) provided, however, if AVERY DENNISON determines that the repair or replacement is not commercially practical, AVERY DENNISON shall issue credit in favor of PURCHASER in an amount not to exceed the purchase price of the products.

This warranty is exclusive and is in lieu of any implied warranty of merchantability, fitness for a particular purpose or other warranty of quality, whether express or implied, except the warranty of title and against patent infringement. No waiver, alteration, additions or modifications of the foregoing conditions shall be valid unless made in writing and manually signed by an officer of Avery Dennison. *Or in the time period stated on the specific product specification sheet, if any, and if not then on the specific product information literature in effect at time of shipment.

Limitation of Liability

In no event shall AVERY DENNISON be liable for any incidental or consequential damages, including but not limited to, loss of profit, loss of use of production or loss of capital. The remedies of PURCHASER set forth herein are exclusive and the total liability of AVERY DENNISON with respect to any contract, or anything done in connection therewith such as the performance or breach hereof, or from the manufacture, sale, delivery, resale, installation or use of products whether arising out of contract, negligence, strict tort, or under any warranty, or otherwise, shall not exceed the purchase price of the products upon which the liability is based.

PRODUCT DESCRIPTION

Applications

Designed for applications requiring high adhesion, tack and shear tc low surface energy substrates such as polypropylene and polyethylene This product also produces excellent adhesion to textured materials

Features

Patented adhesive technology
Firm, high tack adhesive
Heavy adhesive mass

Benefits

Excellent high temperature resistance
Excellent quick stick and adhesion to low surface energy substrates

PRODUCT DATA (Not for Specification Use)

Product Construction Test Methods: PSTC-33, ASTM D-1000, TAPPI T-411-M-44

		US Mils	MM's
Adhesive	Crosslinked Elastomer	11.0	0.28
Liner	76 # Densified Kraft	4.6	0.12
	Total Construction	15.6	0.40

Adhesive Properties

Peel Adhesion — Test Method(s): PSTC-3, ASTM D-3330, STD-10
2 mil PET 180° 12" min Initial

Substrate	Test Side	Lbf / in	US Oz / in	N / Meter
SS	Liner	13.5	216	2359

Peel Adhesion — Test Method(s): PSTC-3, ASTM D-3330, STD-10
2 mil PET 180° 12" min Initial

Substrate	Test Side	Lbf / in	US Oz / in	N / Meter
ABS	Liner	9.4	150	1641

Peel Adhesion — Test Method(s): PSTC-3, ASTM D-3330, STD-10
2 mil PET 180° 12" min Initial

Substrate	Test Side	Lbf / in	US Oz / in	N / Meter
PP	Liner	9.2	147	1606

Peel Adhesion — Test Method(s): PSTC-3, ASTM D-3330, STD-10
2 mil PET 180° 12" min Initial

Substrate	Test Side	Lbf / in	US Oz / in	N / Meter
Talc PP	Liner	9.1	146	1595

Peel Adhesion — Test Method(s): PSTC-3, ASTM D-3330, STD-10
2 mil PET 180° 12" min Initial

Substrate	Test Side	Lbf / in	US Oz / in	N / Meter
LDPE	Liner	6.3	100	1100

Peel Adhesion — Test Method(s): PSTC-3, ASTM D-3330, STD-10
2 mil PET 180° 12" min Initial

Substrate	Test Side	Lbf / in	US Oz / in	N / Meter
HDPE	Liner	6.5	104	1133

Peel Adhesion — Test Method(s): PSTC-3, ASTM D-3330, STD-10
2 mil PET 180° 12" min Initial

Substrate	Test Side	Lbf / in	US Oz / in	N / Meter
TPO	Liner	10.4	167	1825

Peel Adhesion — Test Method(s): PSTC-3, ASTM D-3330, STD-10
2 mil PET 180° 12" min Initial

Substrate	Test Side	Lbf / in	US Oz / in	N / Meter
Painted Metal	Liner	10.8	172	1888

Loop Tack — Test Method(s): PSTC-5, STD-7
2 mil PET 20" min Initial

Substrate	Test Side	Lbf / in	US Oz / in	N / Meter
SS	Liner	27.4	438	4794

Static Shear — Test Method(s): PSTC-7, ASTM D 3654, STD-9
2 mil PET @ 72°F / 22°C 1" sq (6.5 cm2) 10 lbs (4.5 kg)

Substrate	Test Side	Min to Fail
SS	Liner	>10,000

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ADHESIVES

14 November 2008

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