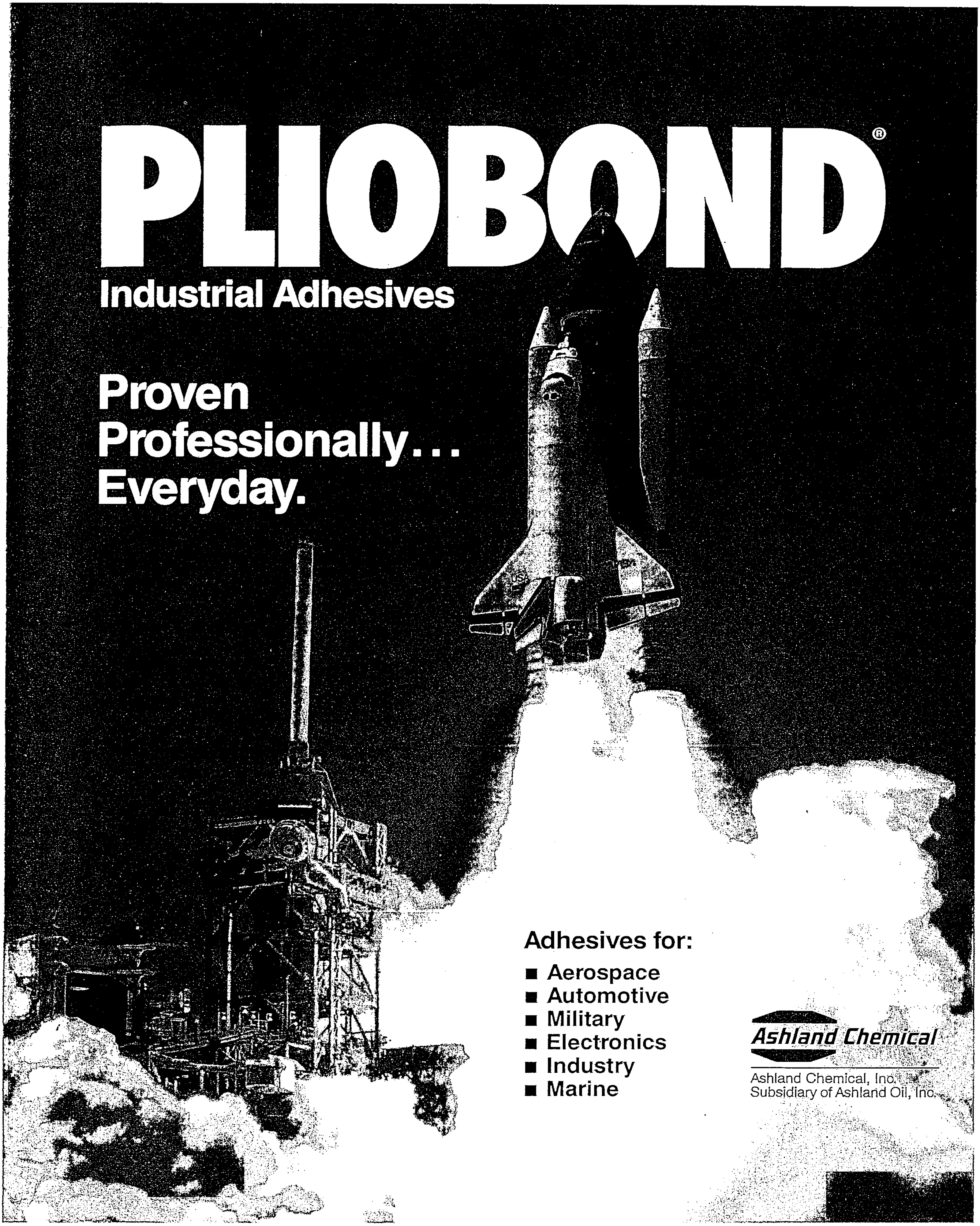

PLIOBOND®
Industrial Adhesives
Proven Professionally… Everyday.
Adhesives for:
■ Aerospace
■ Automotive
■ Military
■ Electronics
■ Industry
■ Marine
Ashland Chemical
Ashland Chemical, Inc.
Subsidiary of Ashland Oil, Inc.

TABLE OF CONTENTS

PLIOBOND Adhesives 3

Physical Properties 4

Theory Adhesion 5

Preparation of Surfaces for Bonding 8

Methods of Application 9

Physical and Adhesion Properties 16

Chemical and Environmental Resistance 22

Uses 24

Summary and History 26

Cover photo

PLIOBOND Adhesive has been used by NASA on the space shuttle program in a variety of ways for years. While the basic adhesive formulation has been available to industry for over 40 years, it's constantly being updated, and now qualifies as space-aged.

Internal photos

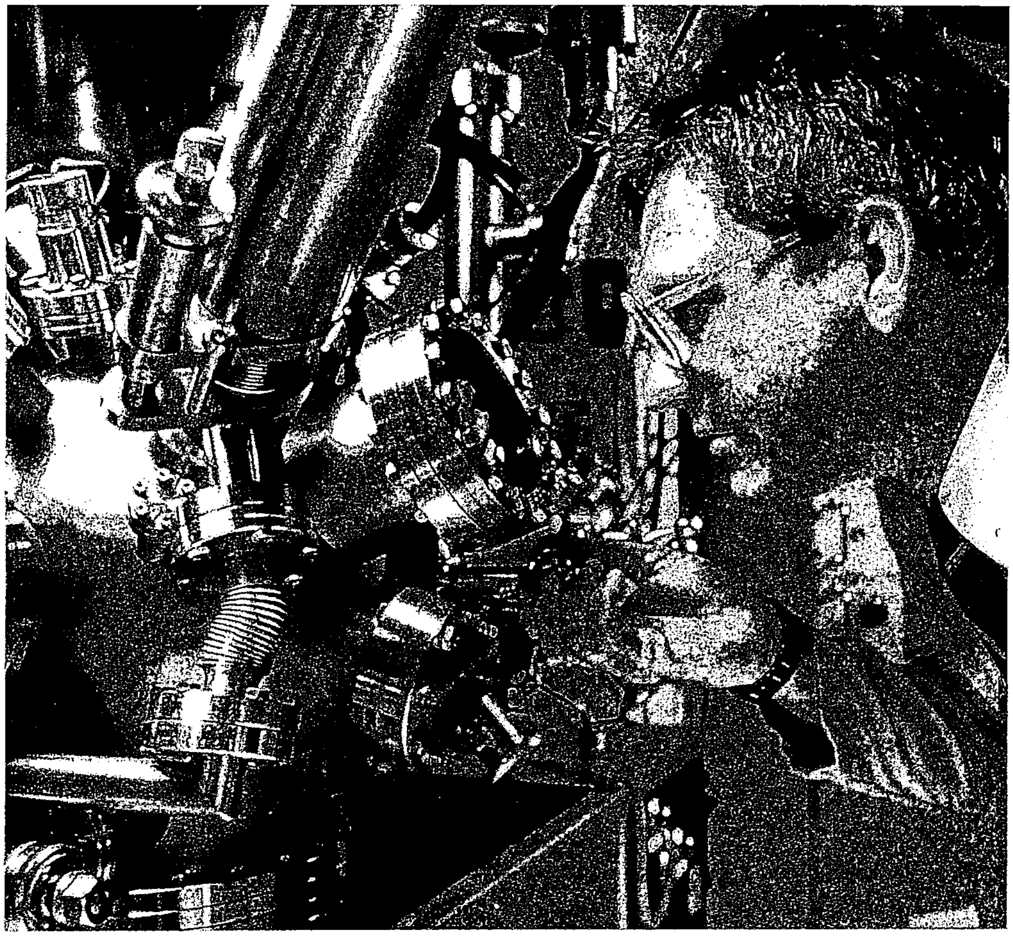
The photographs appearing throughout the brochure represent Ashland Chemical personnel constantly striving to improve PLIOBOND adhesive and expand its multiple uses. Specialized testing for unique applications, to fit specific client requirements, are virtually always underway, and new challenges are enthusiastically invited.

Ashland Chemical

Ashland Chemical, Inc.
Subsidiary of Ashland Oil, Inc.

PLIOBOND INDUSTRIAL ADHESIVES PROVEN PROFESSIONALLY. . . . . EVERYDAY.

For seaming, splicing and bonding of gaskets, rubber matting, belts and hose to rubber, wood, metal, plastic, glass and fabrics.



PLIOBOND 20, 30 and 40 are all-purpose, thermosetting adhesives which can be used to bond virtually all porous substrates. When cured, PLIOBOND 20, 30 and 40 adhesives provide bonds that toughen with age. Constant flexing, pulsing or vibration over wide temperature extremes will not affect these cured bonds. Cured bonds offer excellent chemical and environmental resistance. Dielectric qualities of PLIOBOND 20, 30 and 40 adhesives make them ideal for a wide variety of electrical applications.

Since 1945, PLIOBOND 20, 30 and 40 have found uses as sealers, primers and water repellents, as well as for the seaming or bonding of gaskets, rubber matting, belts and hoses, to wood, metal, plastic, glass and fabric.

Two variations to the unique chemistry used in PLIOBOND 20, 30 and 40 adhesive are offered for specific applications.

- PLIOBOND 1000 adhesive is formulated for printed circuit boards. Elimination of sulfur from the formula makes corrosion of copper components non-existent.
- PLIOBOND HT-30 adhesive is thermocuring. Curing chemistry used in PLIOBOND HT-30 adhesive will not cure below a temperature of 300°F. It offers good shelf life at normal temperatures. Above 300°F, however, fast cures result which exhibit all the properties of PLIOBOND 20, 30 and 40 adhesives with the additional ability to resist elevated temperatures.

PLIOBOND adhesives are produced by Ashland Chemical and are packaged and marketed by the W.J. Ruscoe Company, Akron, Ohio.

Other special formulations available from W.J. Ruscoe Company on special order include:

- Sprayable PLIOBOND adhesive
- Colored versions which include green, red, blue or black.

The registered trademark of PLIOBOND adhesive, which appears on all containers, packages and labels, is your assurance that you are using the all-purpose adhesive which meets all of the performance criteria of our manufacturing specifications and the data outlined in this technical bulletin.

PLIOBOND adhesives are manufactured under the most rigid statistical quality control procedures, which assure regular delivery of products meeting performance requirements of various military, government and other manufacturers' specifications.

Typical physical properties of PLIOBOND adhesives

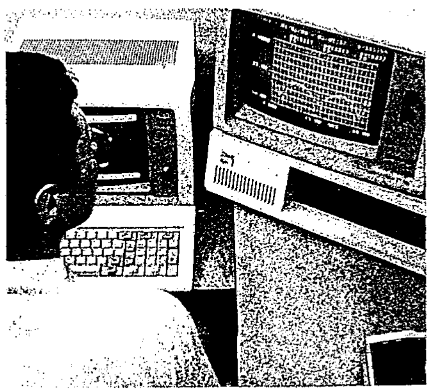
Table 1	PLIOBOND 20	PLIOBOND 30	PLIOBOND 40	PLIOBOND 1000	PLIOBOND HT-30
BASE POLYMER	NITRILE RUBBER				
BASE RESIN	THERMOSETTING PHENOLIC				
TOTAL SOLIDS, %	20	30	40	20	30
VISCOSITY, CPS	600	4,000	30,000	600	4,000
SPECIFIC GRAVITY	0.87	0.89	0.93	0.87	0.89
POUNDS/GALLON	7.2	7.4	7.7	7.2	7.4
COLOR	TAN	TAN	TAN	TAN	TAN
SOLVENT (S)	MEK	MEK	MEK	MEK	MEK/ ALCOHOL
FLASH POINT, °F SETA	20	20	20	20	21

Shelf Life: Six months in closed containers under ambient conditions (rotate stock). D.O.T. label required: flammable liquid.

Handling

PLIOBOND adhesives contain ingredients which could be harmful if mishandled. Contact with skin and eyes should be avoided and necessary protective equipment and clothing should be worn.

For important health, safety and handling information, consult Ashland's Material Safety Data Sheet for each individual adhesive before use.



Theory of adhesion using PLIOBOND adhesives.

How do PLIOBOND adhesives work?

The phenomenon of adhesion and the selection of bonding methods involves the following physical factors:

1. Strength and flow characteristics of the adhesive film.
   a) Tensile, shear and compressive strength
   b) Viscosity
   c) Elastic properties
   d) Resistance to creep
2. Wetting action and interfacial attraction of the adhesive and substrate.
3. The porosity and configuration of the adhering surface.
4. Thickness of the adhesive film.

For strong bonds, adhesives should form a thin continuous film. As a general rule, with non-porous substrates, the thinner the bondline the stronger the bond. With porous surfaces, thin films are not as easy to achieve nor are they as critical. For these surfaces, continuity should be stressed and the film should form an unbroken layer over the projections of the surface. Film should maintain its continuity during application, assembling, and through the final hardening or curing.

Coating thickness depends on the viscosity of the adhesive and on the method of application. On non-porous surfaces requiring very thin films, a low viscosity/low solids adhesive is easiest to use. For porous surfaces, a more viscous adhesive with higher solids content gives thicker films with better penetration control.

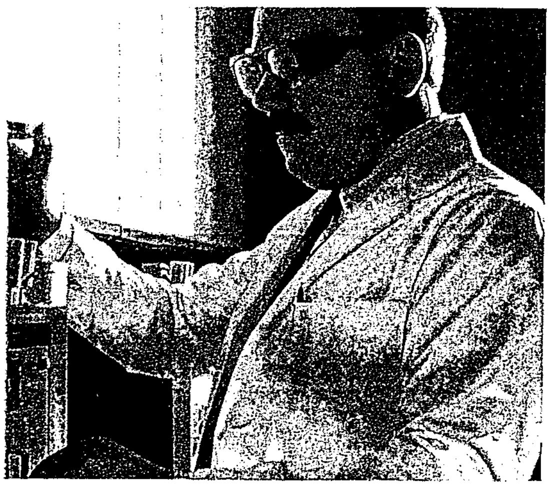
Occasionally, with adhesives containing high solids, a film of uniform thickness is difficult to apply because early evaporation of the solvent may cause stringing. This condition can be corrected by adjusting the evaporation rate. Thick films are sometimes discontinuous because of voids left by evaporating solvent. Heat and pressure during assembly will improve film continuity. The condition of the substrate surfaces (smoothness, cleanliness, and temperature) affects the physical properties of the film.

An adhesive must wet the surfaces to be bonded, or strong bonds cannot be formed. Both the viscosity and the interfacial tension of the adhesive directly influence spreading and coverage. Good wetting on relatively smooth surfaces is characterized by a low contact angle between the liquid and solid. If the cohesion and surface tension forces of the adhesive solution are greater than the attraction of the surface for the liquid, little wetting occurs, and the contact angle is large. Droplets of adhesive form on the solid surface and result in poor coverage.

True bonding is largely a phenomenon of molecular attraction, i.e., specific adhesion. The film solids must possess chemical affinity for the surface. The concept of bonding commonly called mechanical adhesion, receives little recognition in modern practice. Mechanical adhesion pictures the adhesive as a solution or melt which flows into the pores and cavities and subsequently hardens to form interlocked solid phases.

If this were the principal mechanism of bonding, the rougher surfaces should form stronger bonds—actually, the opposite is true. We can sometimes observe that the adhesive enters surface openings and wets the walls of the pores and cavities. To the degree that interfacial area is increased, the joint strength may be improved, but excessive roughness usually results in gaps and starved areas in the coating, producing weaker bonds.

The hardening or setting-up of an adhesive may be either a chemical or a



physical process or a combination. Solvent-based adhesives generally harden by a more or less complete evaporation of a volatile liquid carrier. Or, an adhesive may be melted or fused between joining surfaces and then allowed to solidify by cooling. These are purely physical processes.

Chemical hardening processes are those in which the adhesive cross links or cures under the influence of heat or a catalyst. The polymerizing adhesives are generally more complicated to use, requiring mixing of ingredients, or precisely controlled heat treatment. For these adhesives to be effective, the surface attraction forces should preferably be of a strong polar nature and relatively unaffected by the polymerization. The polymerization will then increase the internal cohesive strength and result in a strong bond.

Depending on the use, bond failure may be caused by a number of mechanical or environmental factors. A non-elastic adhesive, having a coefficient of expansion differing from that of the substrates, will undergo high stress with temperature change. Thermoplastic bonds may creep or deform under stress. Bonds that are subjected to shock or vibration require adhesives with good elastic properties for maximum impact resistance.

Effects of compounding

PLIOBOND adhesives are solvent-based thermoplastics, although, as we explain later, a prolonged heat history appears to cause some cure, with greater toughness and improved resistance to heat and chemicals.

PLIOBOND 20, 30 and 40 are identical except for the ratio of solvent to solids content.

Special complex resin and rubber polymers are used in PLIOBOND adhesives. Significantly, the rubber contains nitrile groups which have good bonding action on metals, textiles, and polar surfaces. The resin gives the bonds high strength and hardness, while the rubber offers elasticity and good impact resistance.

For most bonding applications, a liquid adhesive which can be applied at room temperature is the only practical form.

The methyl ethyl ketone (MEK) in PLIOBOND adhesives contributes little or nothing to the final adhesive properties. The solvent only provides the means of applying the solids in a thin, uniform film. Ultimate bond strengths are obtained after the solvent evaporates. Depending on the method of bonding, solvent removal is accomplished by one or more of the following mechanisms:

1. Evaporation during pre-bond drying.
2. Slow diffusion to the edges of non-porous bonds.
3. Diffusion through the capillaries and interstices of porous materials.

While a coating of PLIOBOND adhesive is drying, the viscosity progressively increases and the film acquires the property of tack (a state of adhesion and plastic deformability). Ideally, in wet bonding, the substrates should be joined when the tack is almost gone. PLIOBOND adhesives can be dried to a hard tack-free state, and a light application of MEK or other solvent (reactivation bonding) will restore tack for easy assembly. In these methods, a slight amount of solvent remains after the surfaces are joined, and the joints take longer to reach top strength. Evaporation of the solvent can be completed at 150°F in an oven or by other heating methods without thermal softening of the adhesive.

Effects of heat

Because of their thermoplastic properties, PLIOBOND adhesives can be used in hot bonding applications. After pre-drying, which removes all solvent from the adhesive coating, the substrates are joined or clamped together and heated to 300° – 350°F. The films fuse together and solidify when cooled. In effect, the tack is produced by heating.

Ultimate strength is appreciably greater in hot-bonded assembly. The film solids possess a measure of residual reactivity which is accelerated by high bonding temperatures. Considerable cross-linking is evident from gains in solvent and chemical resistance. The degree of cure depends on the time-temperature history of the PLIOBOND adhesives bond, but in

general, aging properties are not perceptibly different for cold or hot bonding.

With hot bonding, the maximum observed values of tensile and shear strength of assemblies bonded with PLIOBOND adhesives range from 1500–1850 psi. While such values are obtained under nearly ideal bonding conditions, nevertheless, many PLIOBOND adhesives applications under less ideal conditions produce bonds which are stronger than the substrate.

Effects of pressure

With very few exceptions, all bonding methods and all types of substrates require some degree of compression on the bondline while the PLIOBOND adhesive is drying.
Pressure helps:

- Achieve a thin bondline.
- Maintain uniform contact while air and solvent vapor are displaced.
- Prevent slipping and misalignment of the substrates before the bond cures.

Ideally, no pressure would be needed if the surfaces made uniform contact and held position during the bonding. In practice, the nearest approach to such conditions is by perfect matching of surfaces, application of adhesive in thin films, and assembly after complete evaporation of solvent, i.e., hot bonding. However, the care and precision required to circumvent the use of pressure is usually not justified.

In bonding films, textiles, papers and foils with a sealing iron, pressure is applied for only a few seconds. Horizontal bonds with many substrates will develop good bond strength if they are simply rolled or weighted.

The strength and compressibility of the substrates place limitations on the allowable pressures. For example, rubber components may be bonded with about 25 psi, while metal to plywood bonds may take 300 psi. For all materials, the useful pressure range for PLIOBOND adhesives is from 5 to 500 psi.

Since easily compressed substances tolerate only minimum pressures, the surfaces should be bonded with sufficient force to squeeze the bondline but should be short of deforming the substrates, even though the materials are capable of assuming their normal dimensions when the compressing force is released. If pressure disturbs dimensional stability, stresses set up in the bondline upon release of the pressure may cause a weakened assembly. In bonding rigid materials, the chief controlling factor is the plasticity of the adhesive layer. Assemblies made by the wet bonding method require less pressure than with dry bonding since PLIOBOND adhesive has better flow properties than the thermally softened film.

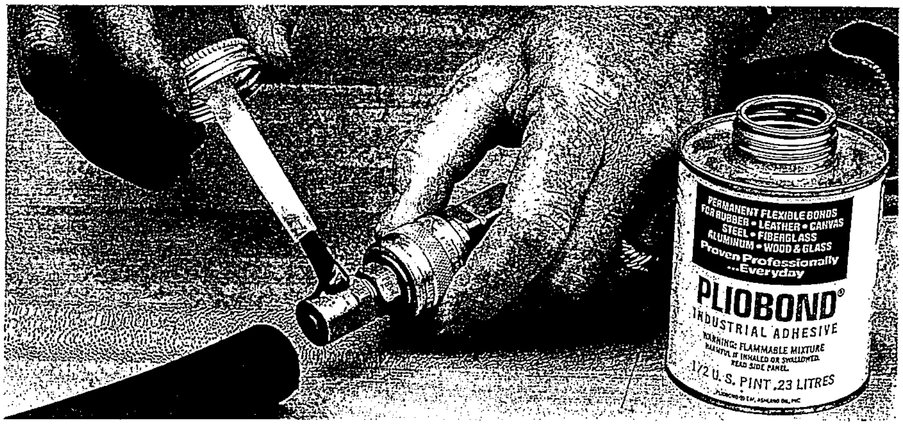
Although bondlines are desirable for impervious surfaces, bonding pressure should not displace excessive amounts of adhesive from the bond. Porous materials and substrates with irregular surfaces may develop thin spots or gaps in the coating if pressure is too high. A few trials at different pressures will quickly establish the optimum pressure for such surfaces. For weak or deformable materials, tests will determine the correct balance of bond strength and material strength.

Effect of PLIOBOND 9000 Activator

PLIOBOND 9000 activator is a chemical additive which may be used to accelerate the cure rate of PLIOBOND 20, 30 and 40 adhesive. At a level of 32–50 grams per gallon of adhesive, the pot life of the system is approximately 6–8 hours. PLIOBOND 9000 activator is useful when effecting a chemical cure of PLIOBOND 20, 30 or 40 adhesive versus a heat-type cure. This accelerated adhesive system can be used to pre-cure the adhesive before heat curing a bond. Parts may be bonded at room temperature and then heat cured after 24 hours with little to no pressure. PLIOBOND 9000 activator may also be used to achieve accelerated heat cures at lower temperatures for shorter cure times (exact reduced time and temperature depend upon part configuration).

Surface preparation

Surface preparation for bonding with PLIOBOND adhesives.



For best results, PLIOBOND adhesives should be applied to clean, dry surfaces. Satisfactory wetting and spreading of the adhesive is possible only on surfaces free of foreign matter. Dirty areas prevent the application of a uniform coating, and cause uneven displacement of the film when pressure is applied. Methods of producing thoroughly clean surfaces for bonding include:

1. Sanding
2. Sandblasting
3. Buffing
4. Alkali degreasing
5. Vapor degreasing
6. Solvent degreasing
7. Solvent wiping

Rinsing with water and drying in an airblast or oven should supplement any cleaning technique which leaves residue or loose particles.

Sanding, sandblasting and buffing remove oxide, scale and rust from metallic surfaces. These mechanical cleaning methods on metals should be followed by chemical or solvent treatment. Alkali degreasing, hot water rinsing and airblast or oven drying may be used to complete the cleaning operation.

Sanding is widely used to clean and prepare wood, plastic, leather, plaster, cement, stone, rubber, wallboard and insulation products for bonding. Sanding cleans some substrates by removing surface dirt. Sanding smooths harder surfaces and cleans softer surfaces. Since the MEK in PLIOBOND adhesives may soften or lift paints and enamels, these coatings should be removed before bonding. Baked enamel finishes generally have good solvent resistance and make good surfaces for joining with PLIOBOND adhesives.

Alkali degreasing (solution at 140° – 150°F) is recommended for removing dirt, oil and grease. Stainless, cold and hot rolled steels, copper, lead, most aluminum and magnesium alloys, ceramics, glass and a number of plastics can be cleaned by alkali degreasing. A wetting agent in the alkali solution improves the cleaning action. The degreasing should always be followed by a hot water (150° – 212°F) rinse. Before applying PLIOBOND adhesive, surfaces should be dried by a hot airblast or in an oven.

Pure aluminum or magnesium should not be degreased with an unbuffered alkali because these surfaces will become etched. Solvents and detergents effectively clean most surfaces of oil and grease. Vapor degreasing or solvent washing and wiping methods can be used satisfactorily on the light metals.

A convenient means of determining when thorough cleansing has been accomplished is to flow water over the vertically held surface. If the water runs off in a continuous film, cleaning is complete.

Fabrics and paper usually require no preparation before applying PLIOBOND adhesive. Rubber is generally cleaned by buffing lightly. Then if cleanliness is still questionable, solvent wiping can be used. For some applications, mild chlorination of the rubber may prove advantageous. Dip the surface in a liquid chlorine bleach and water solution for approximately 10 minutes, rinse with clear water and dry. Adhesive should be applied to ceramic, glass and similar materials when the parts have been oven dried and are still warm. This eliminates surface moisture weakening the bond.

Methods of application

PLIOBOND adhesives may be applied by brushing, spraying, roller coating, knife coating or by dipping.

Brushing

A uniform application of PLIOBOND 20 or 30 adhesive can be made with a stiff bristle brush.

Spraying

A sprayable PLIOBOND adhesive formulation is available from W.J. Ruscoe Company on special order–this is not a standard product.

Roller coating

PLIOBOND 20 adhesive can be applied with roller coating equipment, as long as the rollers are not affected by MEK. Ceramic rollers are recommended. Roller coating applications are more economical than spraying because there is no overspraying. Where production rates are reasonably high and cycles are short, PLIOBOND 20 adhesive can be used straight from the container. With low production rates and longer cycles, or where PLIOBOND 20 adhesive thickens on the rollers because of evaporation of solvent, a small amount of MEK brings the adhesive back to the correct viscosity.

Knife coating

Knife coating applications of PLIOBOND adhesives are fast and are commonly used for high-speed flat surface production applications.

Dipping

For dip coating, PLIOBOND 20 adhesive may be modified with MIBK in the amount needed to control coating thickness and drying properties.

Special techniques

PLIOBOND adhesives can also be applied by metering a controlled bead of adhesive from a small orifice to the part or by using an adhesive saturated pad in a "kiss" transfer technique.

Notes on application and assembly

The generally recommended method of application is to apply coatings of equal thickness on each surface, but satisfactory bonds may be made by coating only one surface. Some substrates, including some plastics, may be softened or dissolved by MEK. For joining these materials to non-soluble surfaces, a heavy coating of PLIOBOND on the non-plastic surface, and a light coating (or no coating) on the soluble plastic is recommended. Total weight of PLIOBOND adhesive should be about the same, regardless of how it is distributed between surfaces. Most plastic films are more convenient to join and make good bonds with a coating.

Level surfaces on solids or closely matched non-porous substrates make strong bonds with bondlines as thin as .001″ to .002″.

When assembling in areas of high humidity, and particularly fluctuating temperatures, dense materials such as metals, ceramics and glass may have an invisible film of moisture on their surfaces. If PLIOBOND adhesive is applied over a surface in this condition, unsatisfactory bonding will result. Under humid conditions, dense surfaces should be pre-heated to eliminate the moisture film just before applying the adhesive.

"Blushing" may occur during high humidity levels because of the cooling effect of solvent evaporation and the condensation of moisture on the coating. Pre-heating for a short time before assembling the bond will evaporate the moisture from the bonding surface.

For elevated temperature service, improved heat resistance is gained from prolonged heating after curing.

Adhesive coverage rates

The area that a unit volume of PLIOBOND adhesive will cover depends on:

a. Type of substrate
b. Porosity of the substrate
c. Condition of the substrate surface
d. Surface tension of the adhesive
e. Viscosity
f. Wettability of the substrate surface
g. Flow properties of the adhesive
h. Thickness of the bondline

If the substrates are metals, or other non-porous surfaces, only a thin bondline is needed and coverage can range from 130 to 330 square feet per gallon. If the bond involves fabrics or other porous surfaces, coverage is lower–nominally 100 to 130 square feet per gallon–because a thicker bondline is required. Data on coverage and adhesive recommendations can be obtained from your PLIOBOND adhesives sales representative.

Pre-bond drying of PLIOBOND adhesive films

The drying of films for wet bonding consists of evaporating solvent to create good tack. Three to five minutes at room temperature (77°F) is usually adequate.

Pre-bond drying for dry bonding

In order to obtain maximum bond strength, solvent must be removed from non-porous substrates which have been coated with PLIOBOND adhesives.

Dry bonding is superior to other methods for impervious surfaces. Before making the bond, the films should be dried on a time-temperature schedule (Figure 1). This procedure should be followed for all of the dry bonding methods and, to a limited extent, for reactivation bonding.

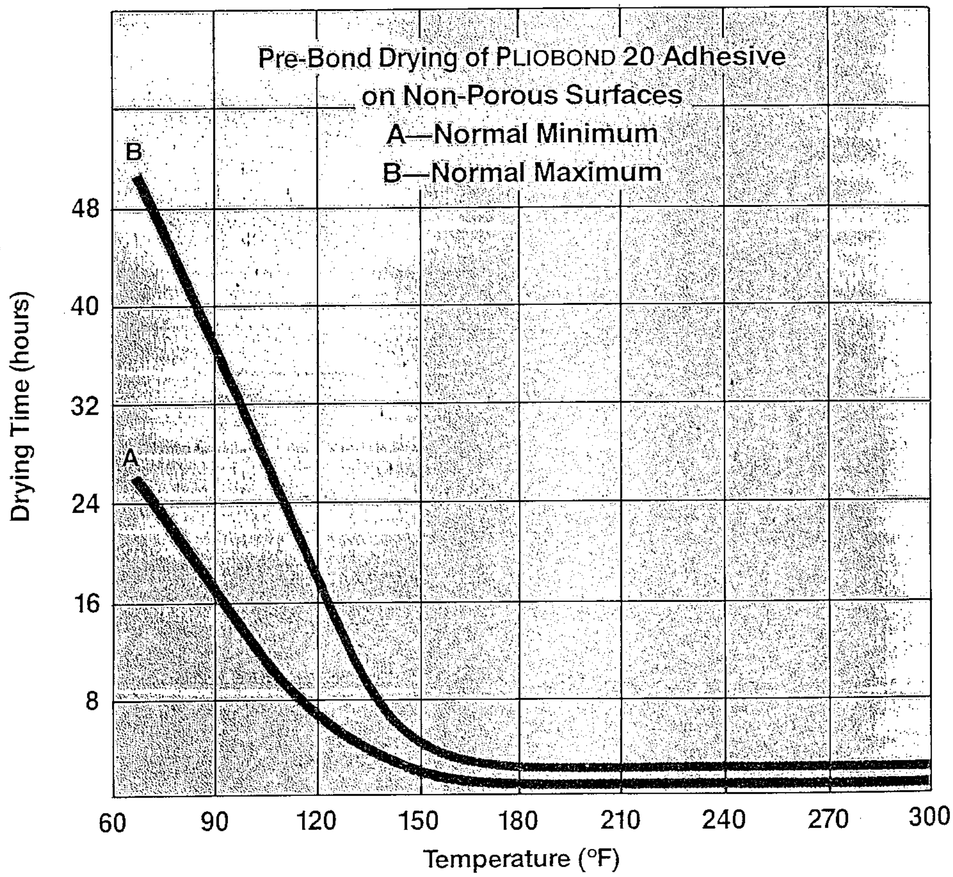


Figure 1

Table 2 Coverage of PLIOBOND 20 Adhesive 1/16″ Laminated High Pressure Plastic Bonded to Various Materials

	PLIOBOND 20, wet spread per 1000 sq. ft. bondline*	PSI	Dry Shear % Wood Failure
Tempered Masonite	6.2 gals.	646	100
Birch Plywood	7.5 gals	853	10
Fir Plywood	5.4 gals	425	100

*Based on dividing the coating weight equally between two contact surfaces.

Methods of Bonding

The bonding of substrates coated with PLIOBOND adhesives can be accomplished by:

Wet bonding techniques

- Wet bonding
- Reactivation bonding

Dry bonding techniques

- Hot press bonding
- *Oven bonding*
- Strip heater bonding
- Sealing iron bonding
- Pre-heat and cold press bonding

Wet bonding techniques

Wet bonding is the easiest method. It can be used for most surfaces. The technique includes these simple steps:

1. Apply an even coat of PLIOBOND adhesive to both substrates.
2. Allow the adhesive to dry (usually 3 to 5 minutes) until maximum tack has developed.
3. Apply pressure by clamping, rolling, weighting, binding or pressing.

Pressure should be adjusted to suit the particular substrates and maintained for 15 minutes to overnight. With weak materials, pressure should be maintained long enough for the adhesive to cohere and hold the assembly, or to reach a point where the bond is stronger than the substrate. With dense substrates, the longer the pressure phase, the stronger the bond.

Development of bond strength parallels the rate of evaporation of the solvent. Maximum strength is achieved when all the solvent is eliminated. With porous materials, bonds as strong as the components are achieved at room temperature in one to 48 hours. Substrates of limited porosity may require seven to 10 days at room temperature for complete solvent removal. Early maximum strength can be obtained by heating the assembly overnight at 110° – 150°F.

Although wet bonding is the easiest and quickest assembly method, other techniques have specific advantages.

Reactivation bonding

Reactivation bonding is recommended where:

- Bonding porous to non-porous substrates.
- A cold bond is *desirable with* a minimum of solvent.
- A short assembly cycle is necessary with a cold bond.

Reactivation bonding procedure includes four steps:

1. Apply PLIOBOND adhesive to one or both surfaces.
2. Allow the adhesive to dry thoroughly. (Figure 1).
3. Wipe the surface of the denser component lightly with MEK. Apply just enough solvent to produce the tack needed for assembling.
4. Join the parts immediately and apply pressure.

Where a longer assembly time is required, use a solvent with a higher boiling point to wipe the bond area. With reactivation bonding, bond strength develops more rapidly than with wet bonding.

Dry bonding techniques

Hot press bonding

Hot press bonding is a typical assembly-line technique. Steps are as follows:

1. Assemble the pre-dried parts.
2. Place the adhesive coating part in a hot press for a time and temperature following a schedule from Figure 2.
3. Cool the press.
4. Discharge the assembly.

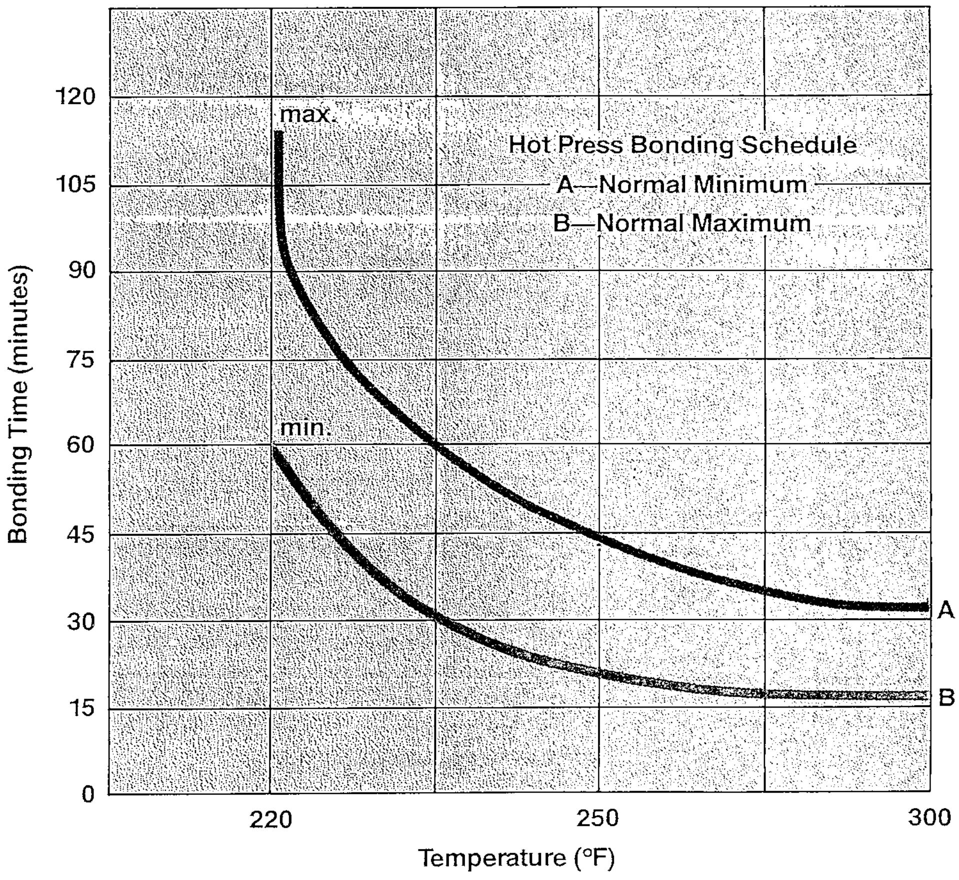


Figure 2

Adjust the pressure to fit the type of substrate and maintain for 15 minutes to overnight (shorter times for weaker materials). Bond strength develops quickly with one porous substance in the assembly, and top strength is usually reached in less than 48 hours. With non-porous materials, seven days may be needed to attain maximum strength. Pressure can be released and the assembly heated overnight at 100° – 150°F to develop full bond strength in a shorter time.

A hot press schedule depends on the physical properties of the substrates, the thickness of the assembly and the heat capacity of the substrates. The strongest bonds will be obtained with longer press times, higher temperatures and greater pressures. High strength metal-to-metal adhesions ordinarily require five minutes at 300°F and 200 psi.

Oven bonding

Oven bonding is an alternate technique for mass production items. The procedure includes four steps:

1. Assemble the adhesive coated and dried parts.
2. Put the assembly under pressure suitable for the materials being bonded.
3. Place in an oven and heat until the bondline reaches oven temperature.
4. Cool and release pressure.

Choose a time and temperature schedule from Figure 2, based on the heat capacity of the materials and the size of the assembly.

Strip heater bonding

Strip heater bonding is used for specialized applications and is generally employed where hot press and oven bonding are impractical. The technique includes five steps:

1. Assemble the pre-dried and adhesive coated parts.
2. Install electric strip heaters to cover the bonded area.
3. Apply pressure.
4. Heat the assembly (usually 1½ to 2 minutes) until the bondline reaches 300° – 350°F.
5. Discontinue heaters and cool the assembly under pressure for about 15 minutes. Pressure may be released while the bond is still hot, but the strongest bond is obtained by cooling before relieving the pressure.

Sealing iron bonding

Sealing iron bonding is used where one or both of the substrates permits quick penetration of heat, such as plastic films, papers or textiles.

1. Assemble the parts, one or both of which has been coated with adhesive and dried.
2. Apply the sealing iron to the bond. Heat should be applied only long enough to fuse the PLIOBOND adhesive. Times will vary with the physical characteristics of the materials in the bond.

Pre-heat and cold press bonding

These techniques are practical where at least one of the components will retain heat during the time required to assemble the parts. The procedure includes these steps:

1. Coat parts with adhesive.
2. Heat one or both parts.
3. Assemble and apply pressure in a cold press.
4. Maintain pressure until the bond is cool.
5. Remove assembly from press.

Bonding specialty materials with PLIOBOND adhesives.

Ceramics

1. Degrease surface, if necessary, with alkali, solvent wash, and wiping or vapor degreasing.
2. Rinse with 150° – 212°F water.
3. Test with water film for clean condition.
4. Dry in oven or hot air stream.
5. Apply PLIOBOND 20* adhesive while surfaces are warm by brushing, spraying, dipping or roll coating.
6. Dry per Figure 1.
7. Join coated surfaces by hot bonding, reactivation bonding or wet bonding.
8. Cool assembly before releasing pressure.

*PLIOBOND 30 adhesive may be used on porous ceramics.

Concrete

1. Clean surface, as required, with alkali, solvent wash, wiping or vapor degreasing.
2. Rinse with 150° – 212°F water.
3. Test with water film for clean condition.
4. Dry in an oven or hot air stream.
5. Apply PLIOBOND 20* adhesive while surfaces are warm by brushing, spraying or roll coating.
6. Dry per Figure 1.
7. Join coated surfaces by wet bonding or reactivation bonding.

*PLIOBOND 30 adhesive may be used on porous concrete.

Fabrics

1. Apply PLIOBOND 30 adhesive by brushing, roll coating or knife coating.
2. Dry per Figure 1.
3. Join coated surfaces by wet bonding, reactivation bonding or sealing iron bonding.

Note: The wide range of synthetic fiber and fiber combinations used in textiles, plus the special coatings on these goods make it difficult to bond many fabrics uniformly. **Test Before Use!**

Leather [1], [2]

1. Roughen the surface with abrasive. [3]
2. Apply PLIOBOND 30 adhesive by brushing, roll coating or knife coating.
3. Dry per Figure 1.
4. Join coated surfaces by wet bonding, reactivation bonding or sealing iron.

[1] Peel tests for #1 prime sole leather bonding to itself gave values of 30-35 lbs./in.
[2] Highly oiled leathers are not suitable for adhesive bonding.
[3] Not required with suedes or naturally rough leathers.

Metal [1]

1. Oxide, scale or rust must be removed by sanding, sandblasting, wire brushing or buffing.
2. Degrease surface if necessary, with alkali or solvent washing, wiping, or vapor degreasing.**
3. Rinse with 150° – 212°F water.
4. Test with water film for clean condition.
5. Dry in an oven or hot air stream.
6. Apply PLIOBOND 20 adhesive while surfaces are warm by brushing, spraying or roll coating.
7. Dry per Figure 1.
8. Join coated surfaces by hot bonding, reactivation bonding or wet bonding. (Small assemblies, like name plates.)
9. Cool assembly before releasing pressure.

[1] Test data is given in Figures 8, 9, 10.
** Unalloyed aluminum and magnesium, should be cleaned with buffered alkali degreasers to protect the surfaces from etching.

SHEAR AND PEEL TESTS ON MATERIALS BONDED WITH PLIOBOND ADHESIVES

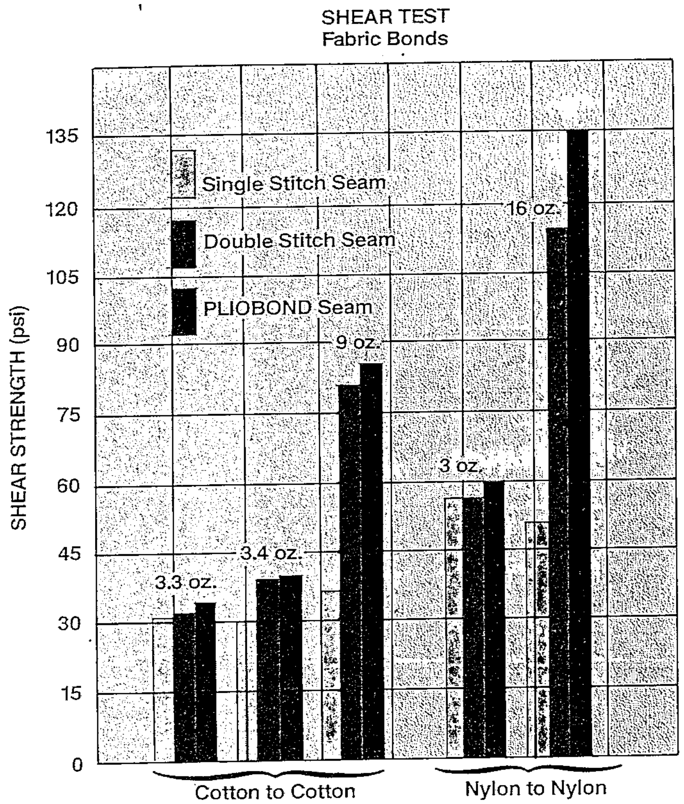


Figure 3

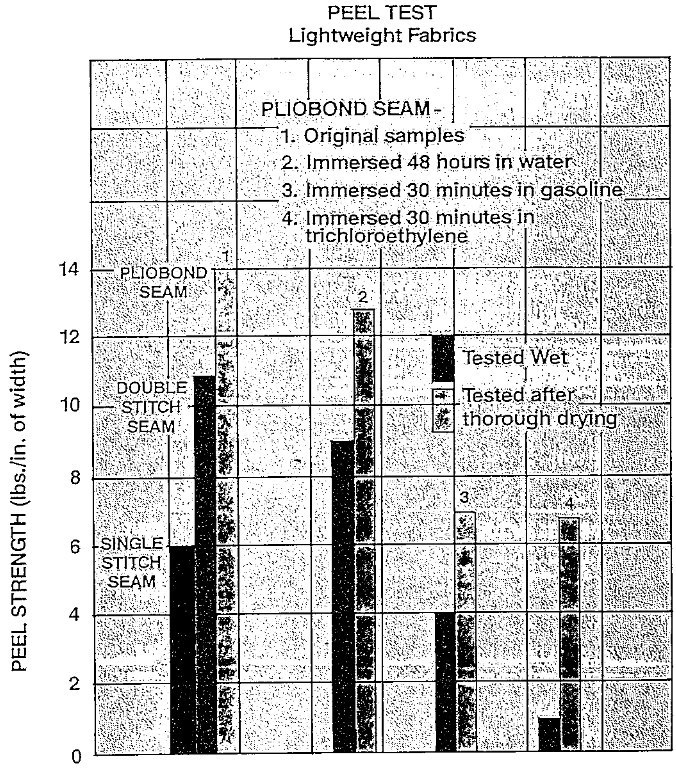


Figure 4

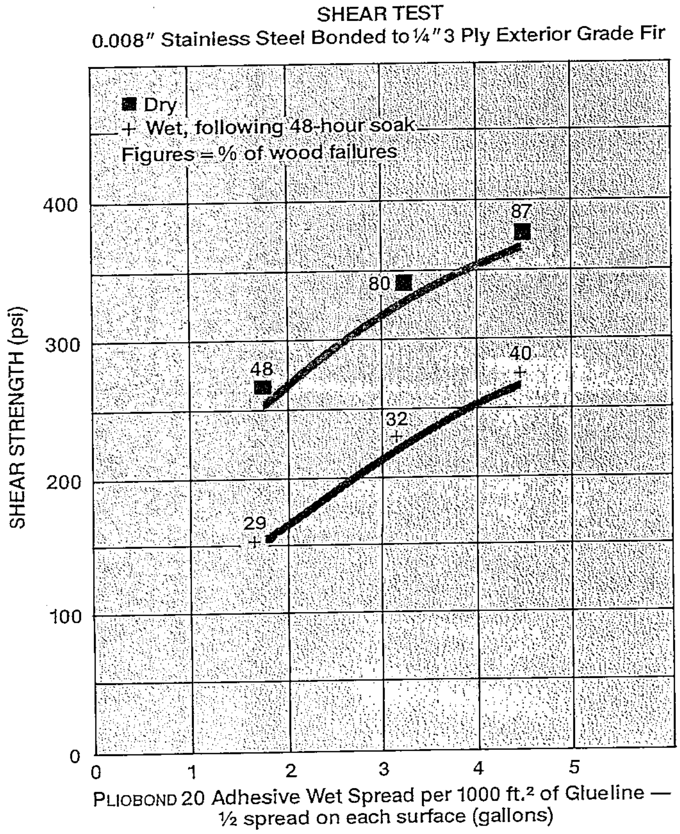


Figure 5

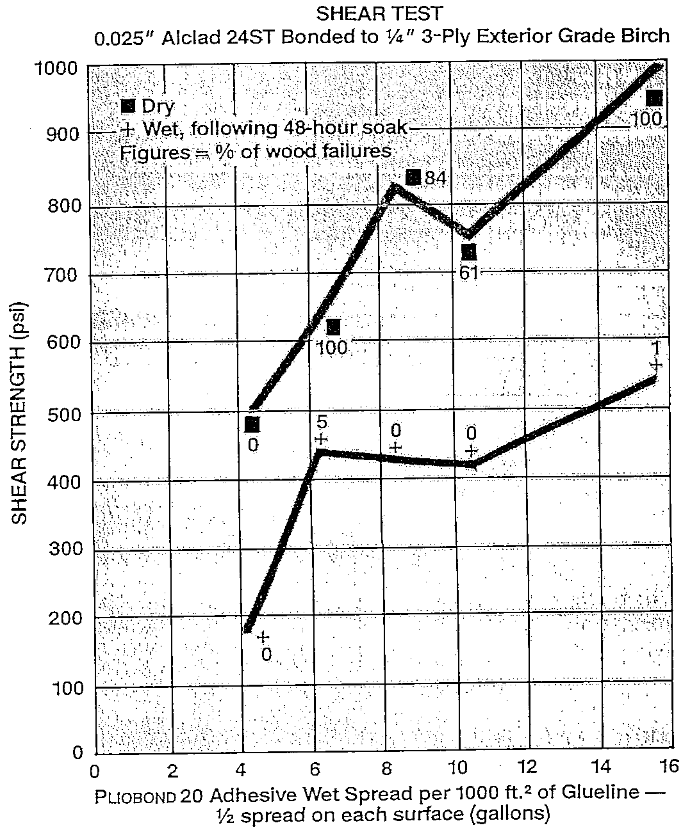


Figure 6

Paper [1]

1. Apply PLIOBOND 30 adhesive [2] by brushing, spraying, roll coating or knife coating.
2. Dry per Figure 1.
3. Join coated surfaces by wet bonding, reactivation bonding or sealing iron bonding.

[1] Oiled papers cannot be adhesive-bonded.
[2] Use PLIOBOND 20 adhesive on dense, hard-surfaced papers.

Non-porous natural or synthetic materials, flexible

1. Apply PLIOBOND 20 adhesive by spraying*, brushing or roll coating.
2. Dry per Figure 1.
3. Join coated surfaces by wet bonding, reactivation bonding or hot press bonding.**
4. Cool assembly before releasing pressure.

*Light spray application preferred.
**Use is limited by the physical properties of the flexible material.

Porous natural or synthetic materials, flexible

1. Apply PLIOBOND 30* adhesive by brushing, roll coating or knife coating.
2. Dry per Figure 1.
3. Join coated surfaces by wet bonding or reactivation bonding.

*For joining to other materials, apply PLIOBOND 30 adhesive to the denser surface only.

Glass

Follow instructions given for bonding ceramics.

Non-porous insulation products, rigid

1. Apply PLIOBOND 20 adhesive by brushing, spraying or roll coating.
2. Dry per Figure 1.
3. Join coated surfaces by wet bonding, reactivation bonding or hot bonding.
4. Cool assembly before releasing pressure.

Porous Insulation Products, non-rigid

1. Apply PLIOBOND 30* adhesive by brushing, roll coating or knife coating.
2. Dry per Figure 1.
3. Join PLIOBOND coated surfaces by wet bonding or reactivation bonding.

*For joining to other materials, apply PLIOBOND 30 adhesive to the denser surface only.
Note: The wide range of new types of insulation make uniform bonding difficult. **Test Before Use!**

Plaster

For bonding to plaster, follow directions under concrete.

Plastic

1. Most plastics require no treatment prior to coating with PLIOBOND adhesive. If the substrate surfaces are well matched, plastic adhesions develop high strength.
2. Apply PLIOBOND 20 or 30 adhesive by spraying, brushing, roll coating, knife coating or by dipping.
3. Dry per Figure 1.
4. Join coated surfaces by wet bonding, hot bonding, reactivation bonding or sealing iron bonding (film or thin gauge sheet).

Rubber [1]

1. Roughen the rubber surface. When necessary, clean surface with solvent. [2]
2. Apply PLIOBOND 20 or 30 adhesive by spraying, brushing or roll coating.

[1] Test data is given in Figures 8, 9.
[2] For surface treatment by mild chlorination, clean surface with solvent, immerse 10 minutes in liquid chlorine bleach and water solution, rinse and dry. This process improves adhesion of rubber surfaces.

SHEAR TESTS
Cold Rolled Steel

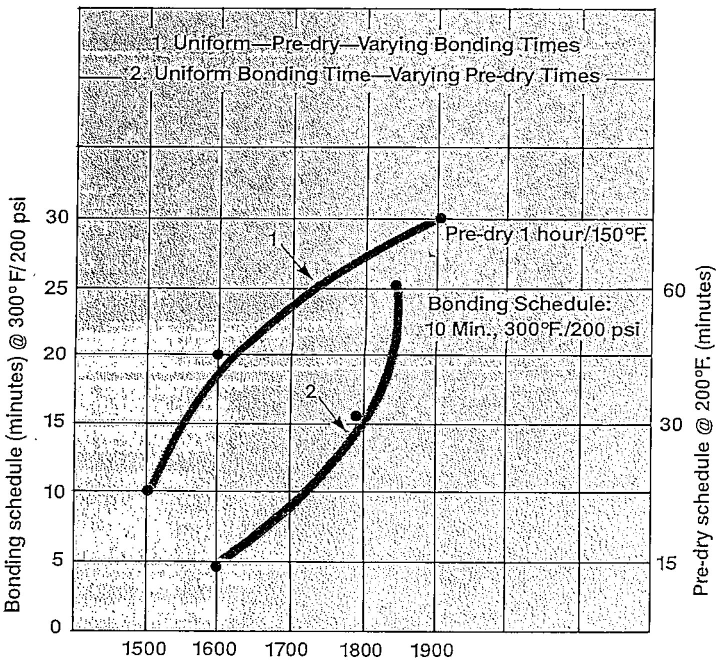


Figure 7 SHEAR STRENGTH (psi)

PEEL TEST

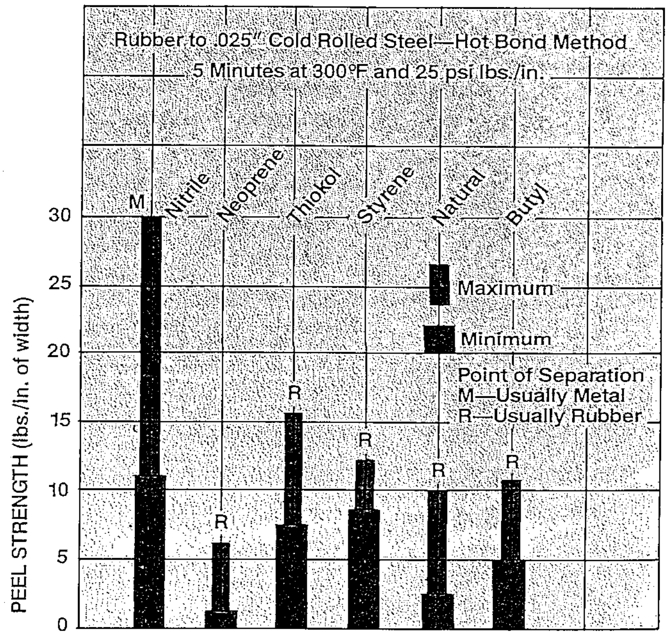


Figure 8

3. Dry per Figure 1.
4. Join coated surfaces by wet bonding, hot bonding, reactivation bonding or sealing iron bonding (film or thin gauge sheet).

Stone

For bonding to stone, follow directions under concrete.

Wallboard

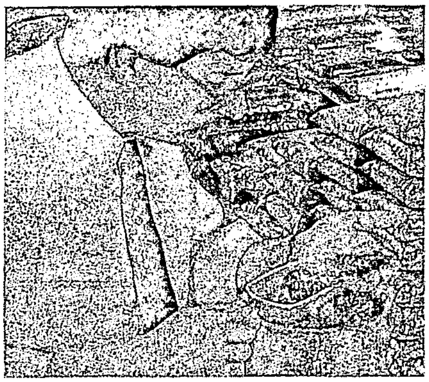
For bonding to wallboard, follow directions under insulation products.

Wood

1. Sand smooth. Remove wax, oil or grease with solvent.
2. Apply PLIOBOND 20 [1] adhesive by brushing, spraying, roll coating, knife coating or dipping.
3. Dry per Figure 1.
4. Join PLIOBOND coated surfaces by wet bonding, reactivation bonding or hot bonding (not normally used for wood-to-wood bonding).

[1] For end grain and porous woods, use PLIOBOND 30 adhesive.

A wholly satisfactory test has not yet been devised for determining the effectiveness of bonds of thin wood veneers to sheet metal. However, when thin veneer (walnut, mahogany, birch, avodire, etc.) is bonded to sheet aluminum, using a hot press time of five minutes at 300°F and 200 psi, the assembly will withstand a 48-hour cold soak test and will not delaminate or blister in hot water at 150°F for immersions of up to one hour.



PEEL TEST

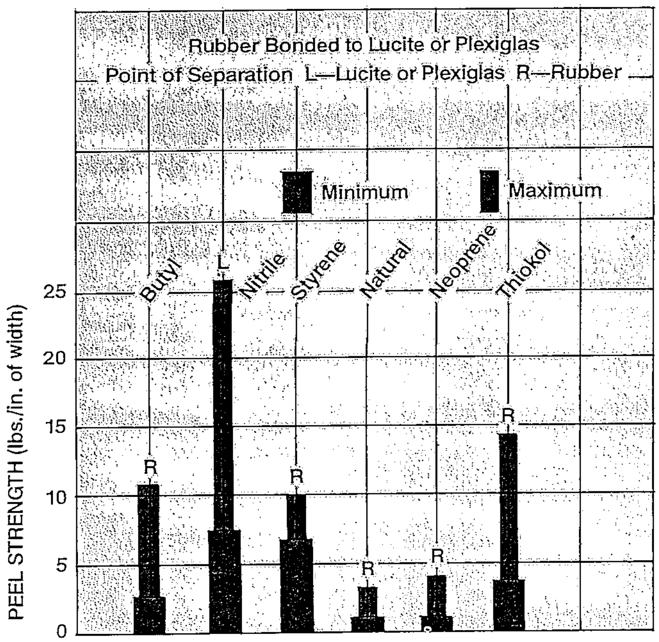


Figure 9

PEEL TEST
Fir Plywood

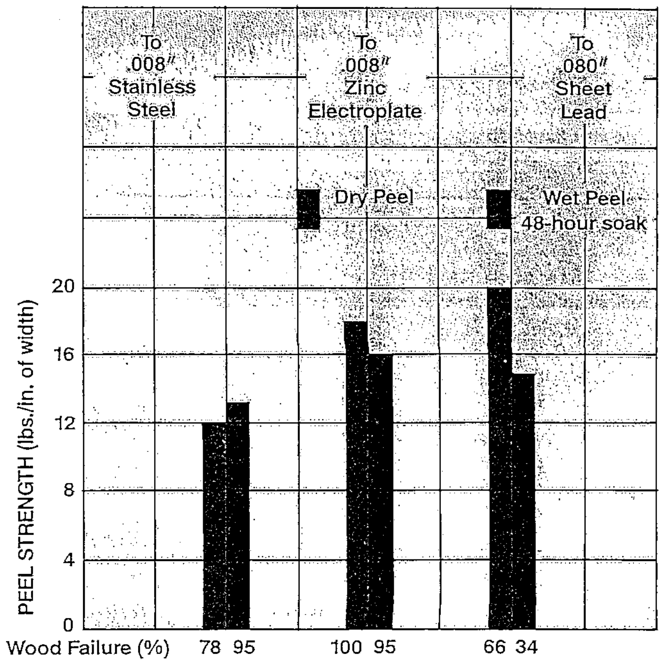


Figure 10

Typical physical and adhesion properties of PLIOBOND

Flexibility

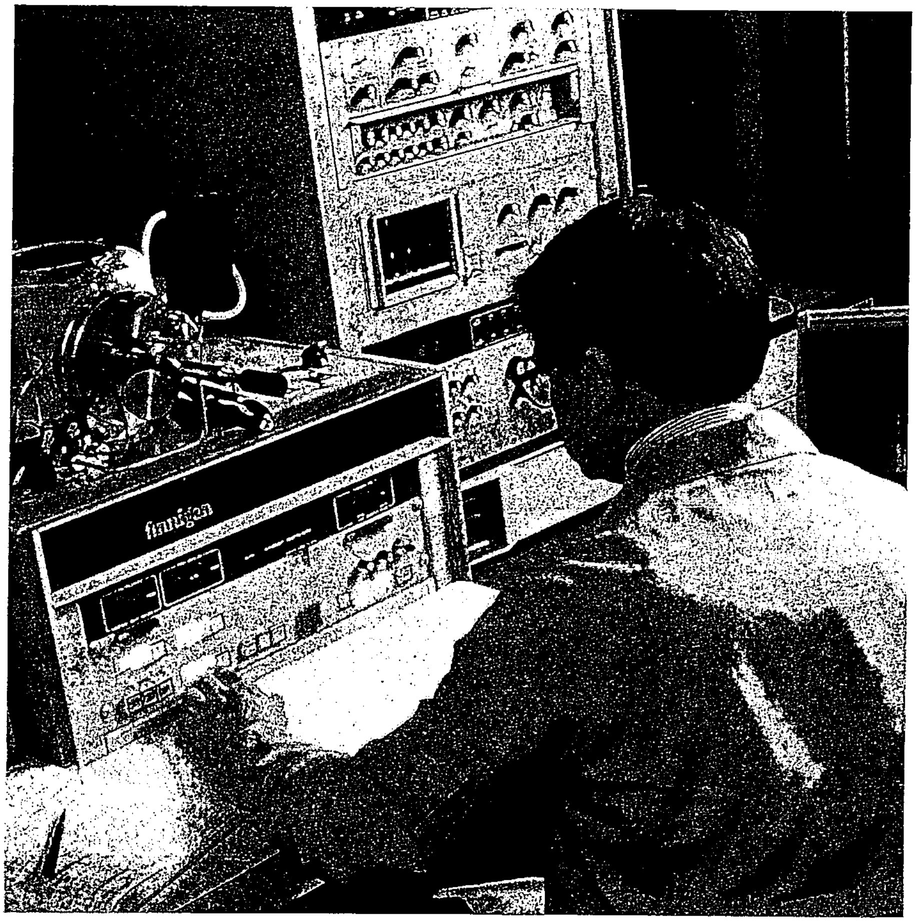
The thermosetting nitrile rubber phenolic resin blend used in PLIOBOND adhesives are offered at a variety of solid/solvent ratios and viscosity ranges. This blend of rubber/resin creates bonds exhibiting good resistance to mechanical shock because of their blend of strength and flexibility. These properties can be maintained over long periods. Bonds actually become stronger with aging. These properties are maintained over a wide service temperature range with -0°F temperatures causing no measurable embrittlement. Bonding of non-rigid substrates that undergo dimensional changes in use is excellent.

Color

The initial light tan color of PLIOBOND adhesives darkens to a medium tan with age. Extreme heat during curing will create a brown bond.

Tack

The development of tack in a PLIOBOND adhesive application is a controllable property. Tack is produced by partial evaporation of solvent from the film. In wet bonding, surfaces are usually joined when the maximum tack level is reached. Tack is usually an aid in assembly, but is not a requisite. In dry bonding, the bond is assembled with solvent-free films *which possess no* tack until heated.



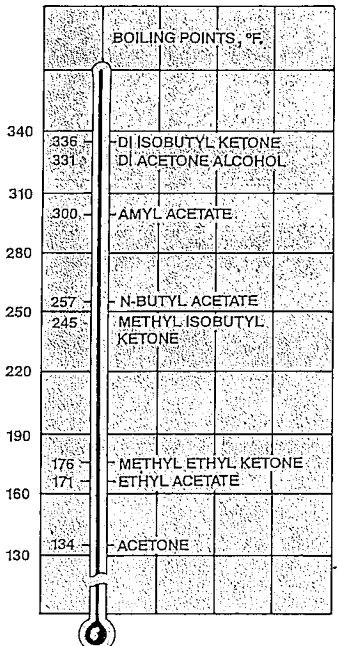


Figure 11

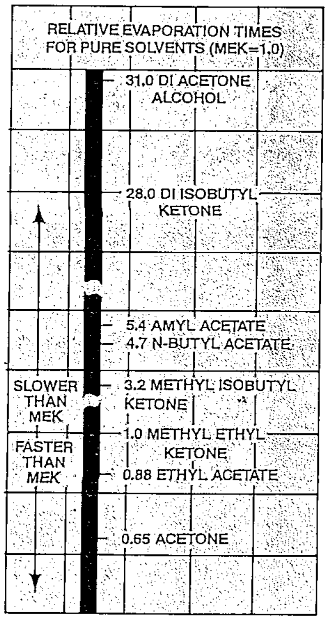


Figure 12

Solvent

Solvent offers an intermediate application range. The drying times of PLIOBOND adhesive on specific substrates do not differ greatly under a given set of conditions. (Film thickness will usually be in inverse ratio to solvent content.) Drying time can be adjusted by using solvents of different evaporation rates. In addition to the solvents described in Figures 11 and 12, others may be used.

Some users prefer to buy only one concentration of PLIOBOND adhesive and reduce the concentration to fit their needs. Effects of diluting PLIOBOND adhesives with solvents other than methyl ethyl ketone are as follows:

Acetone lowers the viscosity slightly, and the adhesive dries faster to the tack stage.

Methyl isobutyl ketone produces an adhesive with higher viscosity and longer drying time.

Ethyl acetate lowers the viscosity slightly without materially affecting other properties.

Odor

In the container and during the early drying states of the film PLIOBOND adhesive has a characteristic pungent odor of methyl ethyl ketone. It contains a small amount of deodorant, and in the latter stages of drying, has a mild, pleasant odor.

Toxicity

PLIOBOND adhesive contains ingredients which could be harmful if mishandled. Contact with skin and eyes should be avoided and necessary protective equipment and clothing should be worn. **For important health, safety and handling information, consult Ashland's Material Safety Data Sheet before using this product.**

Shelf Life

PLIOBOND adhesive has excellent shelf life. Full bonding properties are retained over long periods. On extended storage, slight settling may occur. However, mild agitation returns the adhesive to its original appearance and viscosity. The agitated material exhibits all normal adhesive qualities and develops representative bond strengths. It is suggested that all stored PLIOBOND adhesives be agitated before use to maximize uniform results in production.

PLIOBOND adhesive as a sealer, primer and water repellent

PLIOBOND adhesives are an effective water repellent on wood, masonry, metal and fabrics. The following applications make use of the flexibility and durability of the adhesive.

A spray coating of PLIOBOND adhesive seals porous surfaces and makes them air-and gastight. PLIOBOND adhesives are an excellent primer for vinyl coatings. Without it the vinyl coating would peel.

PLIOBOND adhesive can seal plaster surfaces, prevent passage of air through walls and minimize dirt streaking and marking. The adhesive adds mechanical strength and prevents growth of cracks and deterioration caused by excessive moisture.

PLIOBOND adhesives anchor nonslip materials to floors, stair treads, fire escapes, ramps, ladders and catwalks. Nonslip surfaces are made by sprinkling granular materials on wet PLIOBOND adhesives. A variety of substances are used, ranging from carborundum to rubber and cork. A nonslip deck can be achieved by cementing canvas to wood or metal. The life of the nonskid is increased by a top coat of PLIOBOND.

PLIOBOND adhesive weatherproofs and seals awnings, tarpaulins, tents, convertible tops, pack sacks and porch and deck furniture.

A finish coating of PLIOBOND adhesive protects the above-water surfaces of work boats, such as fishing vessels, tugs, barges, fire boats, dredges and cargo carriers.

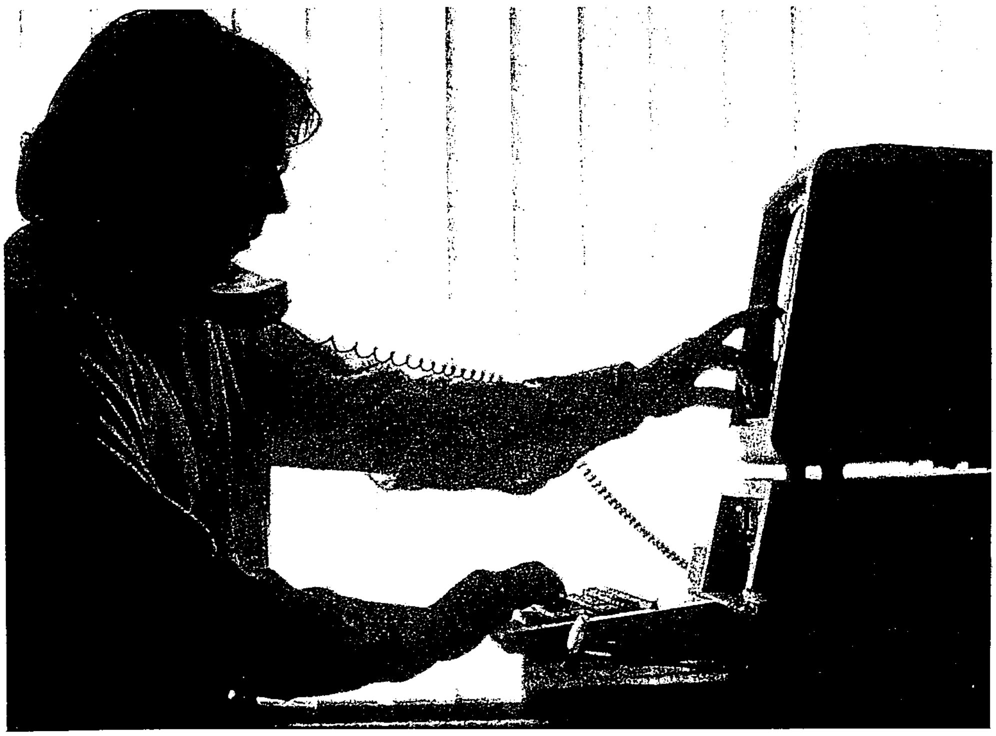
Table 3 Typical Adhesion Properties of Pliobond HT-30 Adhesive

A. Lap Shear Adhesion (ASTM D-1002)—Cured at 300°F, 500 psi for 30 min.

Substrate	Lap Shear, psi
Cold Rolled Steel	1,450
Galvanized Iron	1,300
Copper	750
Aluminum	1,300
Magnesium	600
Black Iron	1,000
Fiberglass-Polyester Laminate	1,300

B. 180° Peel At Room Temperature—Material Bonded To Cold Rolled Steel

Material, lb.	Test Result
SBR/Reclaim Compound 17.5	Rubber tore.
SBR/Natural Rubber 17.0	Rubber tore.
SBR 14.5	Adhesive pulled away from rubber.
Vinyl-Nitrile Rubber 7.5	Adhesive pulled free from metal.
Nitrile Rubber 28.0	Rubber tore.
Neoprene WHV 23.5	Rubber tore.
Hypalon 14.0	Small segments of elastomer tore.
Butyl Rubber 9.0	Adhesive pulled free from both metal and rubber.
Vinyl Sheet 8.5	In general, the adhesive pulled free from the metal, but small segments of adhesive and plastic remained in the metal.
Nylon Fabric 5.5	The adhesive film pulled away from the metal.
Cotton Duck 25.0	The adhesive film pulled away from the metal.



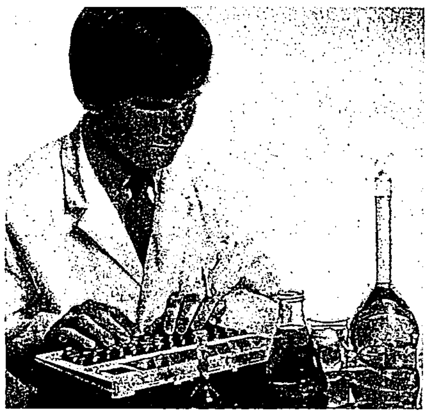


Table 4 Shear Resistance of PLIOBOND HT-30 Adhesive

Temperature, °F	No. of Pieces	Shear Resistance, psi
Room Temperature	6	1,450
112	6	1,007
122	5	708
195	4	288
254	5	228
300	3	101
400	3	67
500*	3	64

*Material chars somewhat at a point below 500°F.

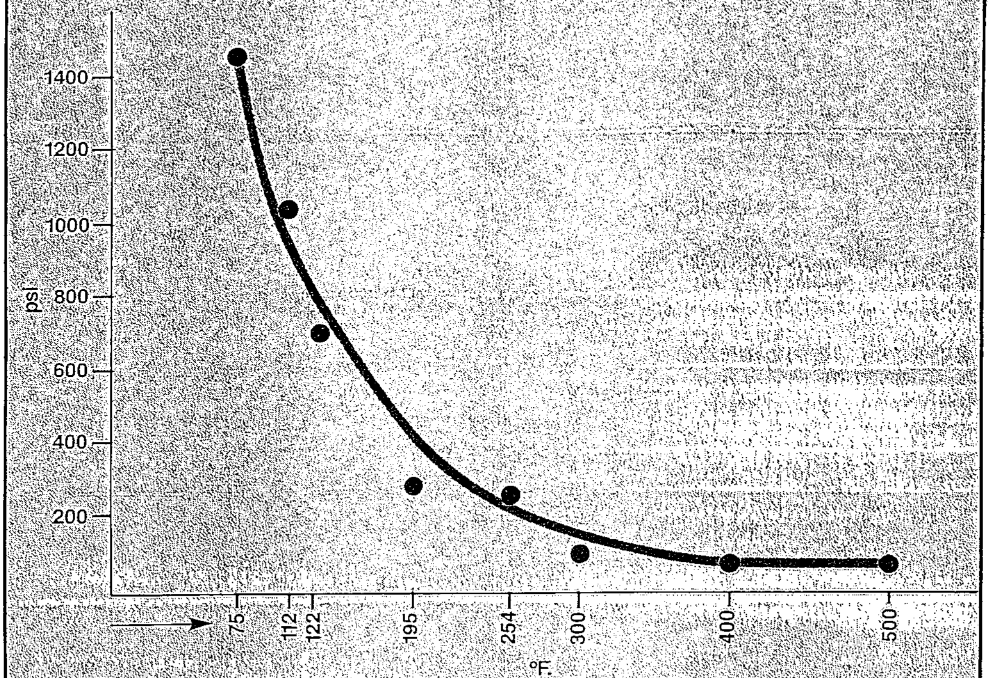
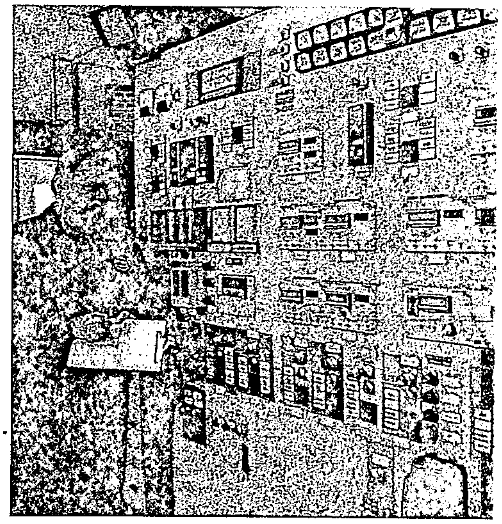


Figure 13



Electrical insulating properties of PLIOBOND

Since PLIOBOND adhesives are composed primarily of non-conducting polymers, the dry films possess good insulating properties. In addition to the non-conducting characteristics, the other properties of strength, easy application, toughness and chip resistance are useful for assembling electrical appliances and equipment.

Dielectric properties

PLIOBOND adhesives can be used to insulate coils and transformer windings, particularly at radio frequencies.

Figures 14 and 15 give data on adhesive performance, tested in alternating current fields at different frequencies.

PLIOBOND adhesives are particularly good as a coil dope when used in thin layers. Thin films are not only practical because of the high tenacity and outstanding durability of adhesive, but they also improve the power factor. Most coil dopes have either high internal heating or low adhesive and cohesive strengths. The latter fault creates inadequate mechanical safeguards against shock, displacement of the windings or protection against aging. The high film strength of PLIOBOND adhesive gives excellent protection to the coil in comparison with the shortcomings of many other dopes.

The dielectric constant of PLIOBOND adhesive is nominal at low frequencies and excellent at the higher radio frequencies.

Coils doped with PLIOBOND adhesive can be overcoated with microcrystalline or ceresin waxes without crazing or softening. Inasmuch as the adhesive is softened by polar solvents, the films should be thoroughly dried to attain best results. PLIOBOND adhesive films withstand heating at 300°F for considerable periods of time. During the first 30 minutes of heating, a progressive improvement in dielectric characteristics occurs. Because heating causes the adhesive to become tacky,

Table 5 Resistivity of PLIOBOND Adhesives

(Direct Current Measurements) ASTM D-257

Conditioning of Films	Surface Resistivity	Volume Resistivity
Oven dried 96 hours at 35°C and 0% relative humidity.	468×10^{10} ohms-cm	553×10^{10} ohms-cm
Immersed 96 hours in tap water, dried, and tested at 35°C.	47.6×10^{10} ohms-cm	15.8×10^{10} ohms-cm

Table 6 Dielectric Strength of PLIOBOND Adhesives

(Alternating Current Measurements) ASTM D-149

Method	No. of Tests	Average Dielectric Strength
Short time	20	503 volts per mil
Step by step	3	515 volts per mil

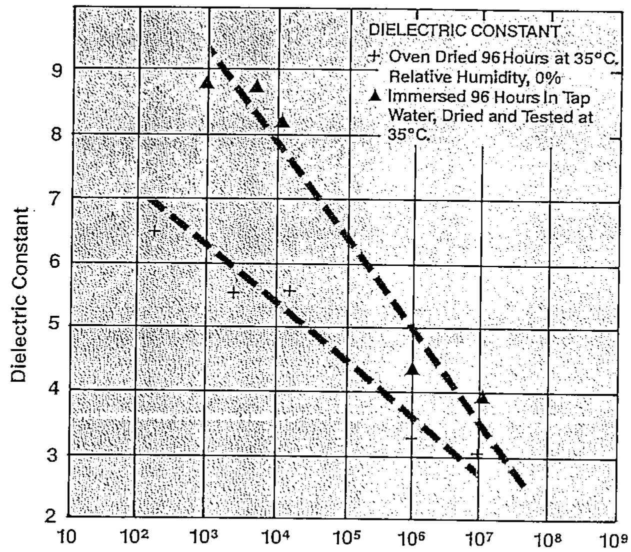


Figure 14

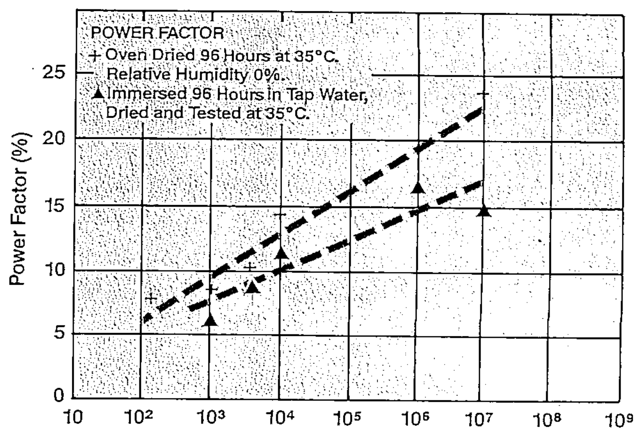


Figure 15

the hot coatings should not contact foreign surfaces. Normal hardness and toughness return to the cooled films.

The dielectric characteristics of PLIOBOND adhesives in a high frequency range are shown in Figure 16. Electrical properties vary with the preparation, the conditioning, and in some cases, the temperature of the adhesive film. In general, the dielectric attributes of a PLIOBOND adhesive film are considerably better in the higher frequency range.

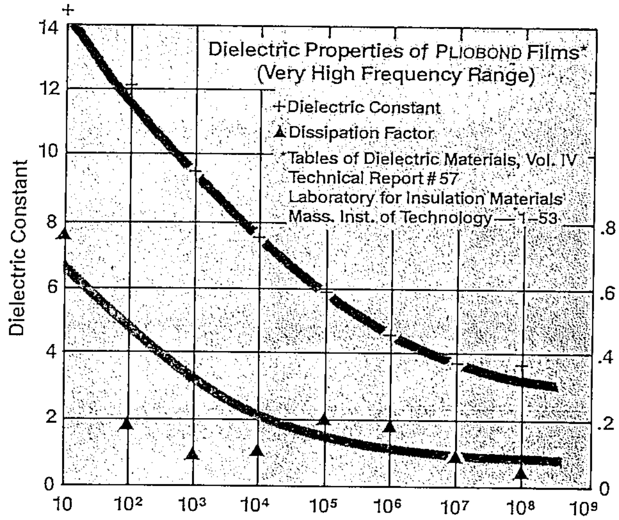


Figure 16

Resistivity

Leakage characteristics have been determined for PLIOBOND adhesives applied as an electrical insulating varnish. Table 5 shows the effect of water immersion on the resistivity. Wet resistivity compares favorably with most insulating varnishes. Leakage is not a problem for PLIOBOND adhesive insulating coatings in average service.

Dielectric strength

PLIOBOND adhesive films or impregnated tapes have good resistance to electrical puncture. Dielectric strength data, given in Table 6, shows the breakdown potential in agreement by two methods. A PLIOBOND adhesive coating is not a cure for a poor dielectric base material where the adhesive is coated on other insulation.

Resistance to insects, fungi, molds and bacteria

PLIOBOND adhesives are not attacked by insects. Cured adhesive films will not support the growth of fungi, molds or bacteria. These growths cause mechanical breakdown in many other adhesives.

Chemical resistance of PLIOBOND adhesives

Water resistance/water absorption

PLIOBOND adhesives have low water absorption, which is particularly useful in electrical insulation applications. Resistance to water absorption can be further augmented by longer drying or press time or by higher pre-drying and assembling temperatures. Hot water or detergent solutions may weaken PLIOBOND adhesive bonded assemblies. In cold water alone, bond strength levels off on long exposure at about 50 percent of initial strength. Re-dried bonds regain initial strength.

Immersion tests–28 days

PLIOBOND adhesive films, applied to the ends of rounded metal rods, were immersed in various chemicals for 28 days at room temperature. Following examination, the films were air-dried for seven days at room temperature and examined again. Results are shown in Tables 7 and 8. PLIOBOND has increased resistance to solvents and reagents after long aging or after baking at 300°F.

Environmental Resistance

Cured PLIOBOND adhesives offer excellent environmental resistance. See Table 9.

Note: All data shown here is on totally exposed, thin films. Bonded substrates would have minimal exposure of the PLIOBOND adhesive, thus considerably lessening the chemical effects shown here.

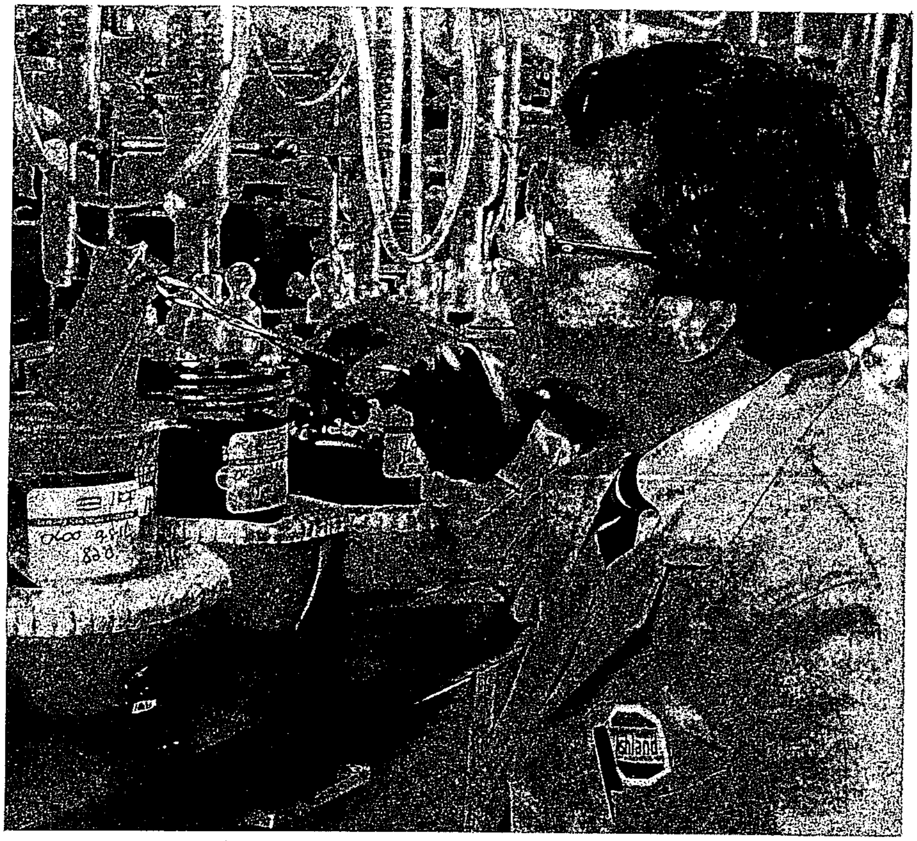


Table 7 Chemical Resistance of PLIOBOND Adhesives

Chemical	Adhesive after 28 days	Adhesive dried 7 days following the immersion test
Distilled water	Film whitened	Normal appearance and physical properties
Tap water	Film whitened	Normal appearance and physical properties
10% hydrochloric acid	Film slightly whitened	Normal appearance and physical properties
10% sulfuric acid	No visible change	Normal appearance and physical properties
35% sulfuric acid	No visible change	Normal appearance and physical properties
10% nitric acid	Strongly attacked	———
Acetic acid (all concentrations)	Film darkened, softened	Normal appearance and physical properties
5% trisodium phosphate	Film slightly softened and darkened	Normal appearance and physical properties
Saturated trisodium phosphate solution	Strongly attacked	———
10% salt solution (table)	No visible change	Normal appearance and physical properties
Saturated salt solution (rock)	No visible change	Normal appearance and physical properties
10% sodium hydroxide	Strongly attacked	———
16% sodium hypochlorite	No visible change	Normal appearance and physical properties

RESISTANCE OF PLIOBOND ADHESIVES TO VARIOUS SOLVENTS, CHEMICALS AND OILS

Table 8 Percent Volume Swell—24 Hours at Room Temperature

	Percent Swell
Aromatics	
Benzene	123
Toluene	102
Xylene	70.5
Aliphatics	
Regular Gasoline	0.0
Kerosene	0.0
Aromatic-Aliphatic Hydrocarbon Blends	
Aviation Gasoline—40% Aromatic	18.2
Aromatic Hydrocarbon[1]—13.9% Aromatic	3.12
Mineral Spirits—12.6% Aromatic	1.56
Aliphatic Hydrocarbon[2]	0.0
Aromatic Hydrocarbon[3]—64% Aromatic	18.5

[1]Ashland HI-SOL 70
[2]Ashland 140 Solvent
[3]Ashland VM&P Naptha

	Percent Swell
Chlorinated Solvents	
Carbon Tetrachloride	36.5
Ethylene Dichloride	High—unable to measure
Ortho Dichlorbenzene	507
Perchlorethylene	203
Alcohols	
Methyl Alcohol	46.6
Butyl Alcohol	18.6
Isopropyl Alcohol	21.8
Ethylene Glycol	0.0

	Percent Swell
Terpenes	
Dipentene	5.0
Turpentine	0.0
Acids	
Hydrochloric—Concentrated	16.3
Sulphuric—50%	0.0
Acetic—50%	176
Nitric—50%	Physical Breakdown
Oleic—Concentrated	0.0
Lactic—Concentrated	4.62
Alkalies	
Sodium Hydroxide—10%	62.4
Potassium Hydroxide—10%	84.8
Ammonia—28%	11.9
Oils	
Detergent Motor Oil	0.0
Non-Detergent Motor Oil	0.0
Mineral Oil	0.0
Hydraulic Oil	0.0
Vegetable Oil	0.0

Note: Volume swell tests in oils were repeated at 158°F, with the same results as at room temperature.

ENVIRONMENTAL RESISTANCE OF PLIOBOND ADHESIVES

Table 9 Oxidation Resistance

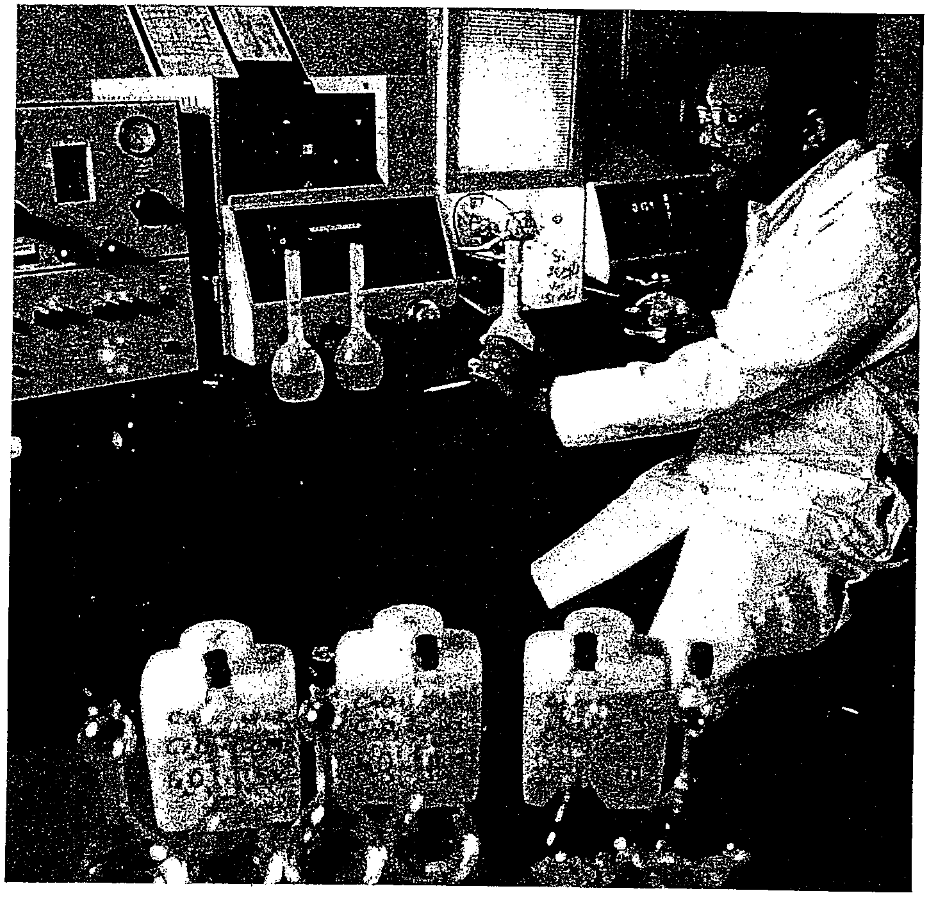
Oxygen Bomb, 250 Hours ASTM D 572-73

	Control	Oxygen Exposed
Cotton/Aluminum Peels	33–38 pli	40–44 pli
Cotton/Neoprene Peels	5–6 pli	4.5–5.5 pli
Hardness, Shore A (R.T. Cure)	82	79
Hardness, Shore A (Heat Cured)	89	88
Tensile Strength	1553 psi	1536 psi
300% Modulus	1270 psi	1225 psi
400% Modulus	1553 psi	1492 psi
Elongation, %	400	410

USES OF PLIOBOND ADHESIVES

PLIOBOND adhesive applications

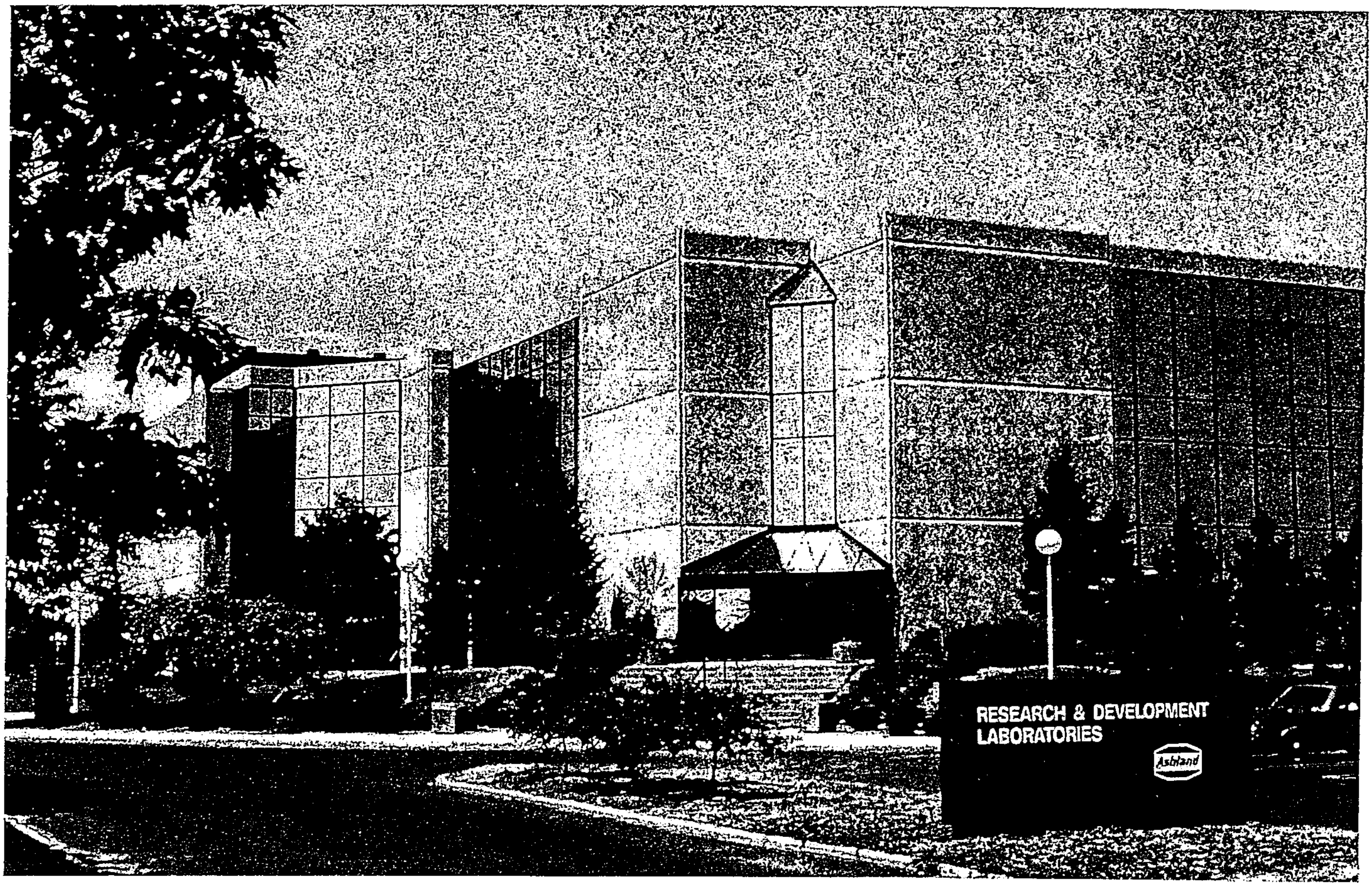
- Aviation and aerospace
- Commercial aeronautical service
- Appliance aftermarkets–hoses, fluid lines, gaskets, central vacuum systems
- Commercial marine maintenance–Coast Guard, et al.
- Electrical motors–manufacture and service
- Heat exchanger gaskets–new and replacement
- Filters–automotive, chemical, water
- Textile and paper mills
- Hose/belting–commercial
- Sheet rubber goods–industrial
- Electronic equipment–manufacturing, maintenance, repair
- Oil field service and maintenance
- Various U.S. Navy, Air Force and Army Ordnance



PLIOBOND Adhesive products meet the performance requirements of many military specifications including:

Specification:	
MIL - A - 81270	Adhesive, Synthetic Rubber
MIL - C - 2399	Cement, Liquid, Tent Patch

Federal stock numbers are available upon request. PLIOBOND Adhesive is also called out in various OEM specifications.



QUALITY PLUS

Ashland Chemical has adopted a unique business philosophy called QUALITY PLUS℠ to make certain that every product we sell is of the highest quality possible.

This companywide philosophy evaluates and controls product development, product specifications, incoming raw materials, manufacturing, internal accounting and control systems, and customer contacts through a system of measurement, statistical analysis, quality control and employee training.

Ashland Chemical

Ashland Chemical, Inc.
Subsidiary of Ashland Oil, Inc.

Summary and History of PLIOBOND Adhesives

One-Component, All-Purpose Adhesives

PLIOBOND adhesives have been performing for thirty plus years. These unique, one component, all-purpose adhesives are based on a blend of nitrile rubber phenolic resin that exhibits a wide range of bonding techniques. These techniques can be used to bond a variety of dissimilar materials with ease. The resulting bonds have excellent adhesion and maintain these high adhesion levels for years of service

over wide temperature extremes and severe environmental and chemical conditions. The electrical properties of PLIOBOND adhesives open many doors, from fixing an electrical cord to voyages into space.

The registered trademark PLIOBOND on all containers, packages, and labels is your assurance that you are using the all-purpose adhesive which is manufactured under the most rigid statistical quality control procedures. PLIOBOND will always be a uniform, high quality, high performance adhesive for this generation and many more.

Ashland Chemical

Ashland Chemical, Inc.
Subsidiary of Ashland Oil, Inc.