Concise Guide To

STRUCTURAL ADHESIVES

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New York

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To my wife, Mara,
without whose patient help
this work would not have been possible.

PREFACE

With the tremendous increase in the manufacture and uses of structural adhesives, there has developed a definite need for a reference work surveying this field. The fact that only a few years ago such a publication could not have listed a sufficient number of adhesives and manufacturers to justify its appearance, testifies to the rapidity with which the structural adhesives industry has expanded and diversified its products.

From the modest start in the 1940's when epoxy-based cements first began to show promise as structural or load-bearing adhesives until today when these cements successfully bond the integral parts of strategic bombers, missiles, automobiles and skyscrapers, adhesive research had to keep pace with the constantly increasing demands for cements which could meet the varied requirements of a host of new applications.

Bonding agents which could withstand the temperature extremes of arctic regions or frictional heat at supersonic speeds, as well as resist attack by specific chemicals, oils, solvents, fungi, etc., had to be developed for military and civilian uses. In addition to satisfying the demands made by environmental and service conditions, formulations of adhesives had to be adjusted to meet other specifications such as color, viscosity, curing time, and temperature, methods of hand, or machine applications and other factors affecting assembly and appearance of bonded parts.

The adhesives industry responded to the challenge and produced hundreds of excellent structural cements with specific recommendations for their uses and methods of application.

The rapid expansion and development of new adhesives continues at such an astonishing rate and with such a tremendous variety of formulations and applications that no book can possibly represent an exhaustive study of the subject.

If properly used, this reference book can save the user a great deal of time in experimentation and in locating manufacturers of structural adhesives. It will also acquaint the reader with the versatility of structural adhesives and the problems relating to this field.

It is not meant, of course, to be used as a kind of "cook book" containing definite recipes for the solution of structural adhesive problems. The requirements are usually far too specific and the range of adhesives and their modifications far too wide to make the writing of such a book even remotely feasible.

Although it is impossible to cross-index all structural adhesives according to every service condition, the "Concise Guide to Structural Adhesives" has attempted to compile and cross-index as complete as possible a list of structural adhesives, correlating them to the most important types of bonds between specified materials.

By presenting a general picture of the problems involved in the selection and application of adhesives, potential users may gain additional insight into some of the production problems and economics involved in a particular operation.

The official specifications and tests should prove particularly helpful to those who intend to make bids on government or defense work where adhesives must meet specific requirements. In this connection, thanks are expressed to The Office of the Assistant Secretary of Defense (Supply and Logistics) for permission to reproduce Military Specifications pertaining to test procedures for structural adhesives, and to the Specifications and Standard Branch, Standardization Division, Federal Supply Service, of the General Services Administration for permission to reproduce "Adhesives: Methods of Testing" of the Federal Test Method Standard No. 175.

An attempt has been made to keep the technological content in such a manner that adhesive users on various levels of experience may benefit from the information contained therein. Some sections will therefore be found more technically advanced than others.

The "Concise Guide to Structural Adhesives" can:

1. Assist in selecting groups of adhesives which because of their listed properties should be considered for testing or experimentation.

2. Assure optimum results in performance by using proper surface preparation and application techniques.

3. Help to prevent costly accidents in production by following the recommended precautions.

4. Save valuable time in locating responsible manufacturers.

5. Extend the use of structural adhesives by indicating their potential in production and performance.

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New York, N. Y.
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1. ADHESION AND STRUCTURAL ADHESIVES

The phenomenon of adhesion must have been known to man for thousands of years. Although many theories have been advanced to analyze it, no complete explanation has as yet been found.

Structural adhesives can be defined as bonding agents capable of joining structural materials and maintaining at least the same resistance to specific stresses as the material itself. The joint thus becomes an integral part of the total structure.

The two theories which have been generally accepted divide adhesion into *mechanical* adhesion and *chemical* adhesion.

Mechanical Adhesion

In this instance, the adhesive while in a fluid state, penetrates the voids or pores of fibrous materials to produce a kind of anchor upon hardening. The glue line bonds the two surfaces in a mechanical interlocking action.

Chemical Adhesion

Here, adhesion is caused by attraction of molecular forces between the adhesive and the adherend. These forces can be produced by primary and secondary valences, or electrical forces (van der Waals') or dipoles. They may act singly or in unison to form a bond.

The specific electrostatic conditions produced by these forces are essential to the formation of the bond between adhesive and adherend. However, besides being able to adhere to the surface of the adherend, the molecules of the adhesive must also possess sufficient attraction to each other to form a structurally stable interface between the surfaces. This property is known as cohesion.

When adhesive mixtures are properly applied and cured, adhesion to the bonding surface and cohesion within the adhesive layer can become so strong that stress failure may occur in the material being bonded rather than in the adhesive layer.

Structural bonds are mainly based on chemical adhesion although in some instances, such as in the case of porous materials, a certain amount of mechanical adhesion is also involved in their formation.

BASIC MATERIALS IN STRUCTURAL ADHESIVES

The following types of material may be present in the formulation of structural adhesives as bases or as modifiers.

Synthetic Resins

Thermosetting. Resins of this type are among the most important materials on which structural adhesive formulations are based. Their basic property is to change under heat by polymerization to form infusible cross-linked compounds.

Since this process is irreversible, reapplication of heat will not restore their flowability. Although the bond is no longer fusible, degradation by temperature extremes, specific chemicals, etc., is possible. The properties of thermosetting resin formulations can be enhanced for specific applications by addition of modifying agents and fillers.

Thermoplastic. Thermoplastic resins are long-chain compounds which soften under heat and harden upon cooling. As they undergo no chemical change under the influence of heat, they can be softened again on reapplication of heat.

Although their limited resistance to heat, solvents, and load-induced stresses makes them undesirable as sole bases for structural adhesives, thermoplastic resins, like vinyls and polyamides are used successfully in combination with such thermosetting resins, as epoxies and phenolics, to which they impart greater flexibility, peel strength, and impact resistance.

Elastomeric Materials

These include natural and synthetic rubbers. Use of elastomers in structural formulations is limited to synthetic types, such as neoprene, nitrile, and polysulfide which are mainly used as modifying agents to add resiliency, greater peel strength, and resistance to shock and vibration to rigid bonds of thermosetting adhesives.

Inorganic Materials

These include ceramic compositions based on various silicates and metallic oxides which are capable of fusing to the bonding surface under high temperatures. Besides being used directly as adhesives, these materials can also be incorporated as fillers to retard oxidation-degradation of organic adhesives like epoxies and phenolics at high temperatures.

Fillers. The properties of adhesive formulations can be changed significantly by incorporation of materials like silica, powdered asbestos, carbon, mica, and a number of metal powders and oxides. When added in proper proportions (which differ with formulations), fillers may increase bond strength by as much as 30 to 40 per cent.

By reducing shrinkage and coefficient of thermal expansion and increasing modulus of elasticity and impact absorption capacity, fillers can add greatly to the stability of structural bonds. Fillers can also be used to change other properties of the bond, such as electrical conduction, radiation shielding capacity, etc. Adhesives employed for gap-filling applications contain a high percentage of filling materials.

A different variety of filler is that employed for adhesives in tape form. Here, fabrics of asbestos, glass fiber, nylon, or cotton are used to reinforce the bond line and to act as spacers between bond surfaces.

Fabric-supported tapes are used primarily in metal honeycomb sandwich construction where the thin edges of the core have a tendency to cut through the film resulting in direct contact between the adherent surfaces.

Forms of Adhesives

Structural adhesives are available in the form of liquids, pastes, powders, rods (solder), and supported or unsupported tapes.

Liquids and pastes can be obtained either as pre-mixed compositions ready for immediate use or as packaged units containing separate base resin and curing agent, which require mixing before application.

Powders, rods, and tapes are generally precatalyzed by the manufacturer and can be used without addition of other curing agents.

Precatalyzed adhesives may require shipping and storage at low and sometimes refrigeration temperatures in order to prevent premature polymerization.

In a recent development by the National Cash Register Research Laboratories microencapsulation has been used successfully to pre-mix resins and catalysts without initiating a chemical reaction until the capsules are broken under heat or pressure.

STRUCTURAL ADHESIVE COMPOSITIONS

The following types of adhesive compositions are used for structural bonding applications. They are listed alphabetically and not necessarily in the order of their importance.

Ceramics

Being among the latest developments in the field of structural adhesives, relatively few ceramic compositions are commercially available. Such metals as tungsten, molybdenum, platinum, vanadium, beryllium, as well as various types of glass and ceramics can be bonded for service at extremely low and extremely high temperatures.

Different types of ceramic formulations are required for bonding materials with different coefficients of thermal expansion.

The cement usually comes packaged as a powder and a liquid suspension medium which is mixed to paste consistency. Application can be made by brush, flow-on, dip, or pressure equipment.

Most of these adhesives are capable of producing vacuum-tight seals after firing at temperatures ranging from approximately 425° to 750°C. The average service temperatures of commercially available material go up to 700°C. No definite lower service temperature has been established up to this time but bonds are known to remain stable at nitrogen-liquefying temperatures.

The modulus of rupture at 25°C can be as high as 10,000 psi.

Cyanoacrylate

A clear, colorless, low-viscosity liquid which can be applied with dropper, flow-on or spatula. It differs from all other types in that it polymerizes immediately on application of manual or mechanical pressure on adherent surfaces and at room temperature. It is versatile in bonding to various types of surfaces.

Time for setting ranges from 30 seconds for rubber-to-rubber, and glass-to-glass, to 5 minutes for metal-to-metal, and wood-to-wood, and 1-10 minutes for plastic-to-plastic bonds. Bond strength increases with aging. Lap shear strength of 3,500 psi have been realized on steel-to-steel bonds after 48 hours aging.

It produces thin, rigid bonds which have generally good resistance to solvents but are weakened in varying degree by high humidity, prolonged immersion in water, dilute acids, and alkaline solutions. Service temperatures range from approximately −65° to 176°F for prolonged exposures and to 212°F for intermittent use.

Epoxies

Epoxy resins are the condensation products of epichlorohydrin with diphenols, and are produced mainly by reaction with bisphenol A.

When reacted further by addition of specific catalysts or accelerators they are capable of curing at room or elevated temperatures to form adhesives with outstanding structural qualities. Because of the practically unlimited scope of modification and application possibilities which these resins offer, epoxy-based compositions probably form the largest and most versatile group among structural adhesives.

Epoxies are thermosetting resins which can be polymerized by addition of various amines, acids, or other resins (copolymers). In the most frequently employed polymerization reactions, all of which are exothermic in character, either anhydrides or primary or secondary amines act as accelerators in cross-linking with the epoxies, or tertiary amines can merely catalyze the reaction without entering it. The choice of curing agent has a decisive influence on the viscosity and work life of the uncured adhesive as well as on certain properties of the cured bond.

Epoxy adhesives are available as pre-mixed single-component formulations in liquids, pastes, powders, rods, and tapes or as two-component pastes or liquids made up of separate base resin and curing agent, packaged for future mixing.

These adhesives are capable of cementing a wide variety of surfaces including metals, plastics, rubbers, glass, ceramics, wood, and others, and without evolution of volatiles during cure.

Most bonding operations with epoxy adhesives require no more than contact pressure. General glue-line thickness ranges from 0.001-0.01 inch. Bonds are resistant to water, most solvents, oil, and fungus.

Unmodified epoxies exhibit minimal shrinkage, high tensile but low peel strength. The bond is rigid and creep resistant but tends to develop brittleness, particularly at low temperatures. Tensile strengths of 8,000-10,000 psi have been realized with no significant change up to about 180°F.

Besides modification with flexibilizing agents, elastomers, and other resins, the properties of epoxy formulations can be changed by addition of various fillers (*q.v.*).

Epoxy-Phenolics

Formulations based on these two thermosetting resins are particularly suitable for bonding materials exposed to high service temperatures for extended periods. Widely used in the form of fibrous glass cloth supported tapes, this type of adhesive is employed for both metal-to-metal and honeycomb sandwich skin-to-core applications. It can be used with or without previous application of primer depending on type of bonding surface.

Epoxy-phenolic compositions are widely used to bond stainless steel, titanium, beryllium, and other high-temperature alloys.

Typical cures require about forty minutes to one hour at 325°-350°F under pressures which may range from a few pounds per square inch to 100 psi. Cured bonds are resistant to aircraft fuels, salt spray, commercial solvents, and other corrosive materials.

At room temperature, lap shear strength on aluminum-to-aluminum bonds range from 2,500-3,000 psi, and for stainless to stainless from about 3,100-3,800 psi.

Service temperatures for these materials range from approximately −67° to 500°F plus. At the latter temperature, aluminum bonds retain a shear strength of approximately 1,500-1,800 psi, with stainless steel somewhat higher in strength. At −67°F strength values are practically fully retained for both materials.

Modification of epoxy-phenolic tapes with nitrile elastomer greatly improves their peel strength. Typical climbing drum-peel values run about 60 lb/3 in. width on .02-inch aluminum skins bonded to aluminum honeycomb cores. Characteristic service temperatures range from −65° to 180°F.

A modification of epoxy-phenolic adhesives are epoxy-novolak types, recently developed to provide improved heat resistance. These combinations of epoxy and phenol-formaldehyde can be cross-linked by curing agents, such as melamine and arsenic pentoxide.

Epoxy-Polyamides

Polyamide-modified formulations of epoxy resins have gained wide popularity because of their versatility, low toxicity and the ease with which they can be applied. They are suitable for bonding a wide variety of rigid and flexible materials, including metals, rubbers, glass, ceramics and most plastics, particularly nylon.

Bonds exhibit good shear, peel, and impact strength, but are more subject to deformation or "creep" at elevated temperatures than unmodified epoxies. Degree of resistance to heat, chemicals, oils, and solvents decreases with increase of polyamide content.

Flexible polyamide resins containing polar amine, carboxyl and amide groups react with epoxies acting simultaneously as modifiers and curing agents. By varying epoxy to polyamide mixing ratios, the bond can be rendered more or less flexible.

Contrary to most other curing agents, the percentage at which polyamides can be added to the epoxy resin is not critical and can be accomplished in most cases by eye assessment of composition volumes.

Exothermic reaction develops more slowly than with amine curing agents, resulting in longer pot life of mixture. Cures range from approximately 3-5 days at room temperatures to 3-5 minutes at 400°F.

Typical lap shear values for aluminum-to-aluminum bonds run between 3,000 and 4,000 psi at room temperature with good strength retention down to −70°F and approximate reduction of shear values by 33-50 per cent at temperatures between 200° and 250°F. Higher percentage of polyamide resin in mixture will increase peel but lower shear strength.

Epoxy-Polysulfides

Combinations of epoxy and "Thiokol"-polysulfide resins have gained wide popularity as highway construction and architectural materials.

They are used primarily for bonding new concrete to old, as well as metal and ceramic tiles, steel plates, beams and dowels, etc., to concrete structures. Materials are usually applied by trowel or pressure gun.

Compositions for interior use cure at temperatures between 70° and 90°F within 8-24 hours while those for exterior use are capable of curing at about 40°F in 20 hours or longer at lower temperatures.

Epoxy-polysulfide adhesives can also be heat cured; 20 minute cures at 150°F are possible. While the usual lower service temperature limit for these materials is about −30° to −40°F, ranges down to −70°F are obtainable with some compositions.

Shear strength for steel-to-concrete averages 1,000 psi at room temperature. Tensile-strength tests on concrete-to-concrete indicate that epoxy-polysulfide bonds are stronger than the concrete itself since failure occurs in the adherend and not at the glue line. Shear strength may drop rapidly from 3,000-4,000 psi at room temperatures to about 100 psi at 350°F. Bonds are resistant to water, oil, gasoline, weathering, and freeze-thaw cycling.

Epoxy-Silicones

This organic polymer system offers high-temperature resistance and has proved especially useful in the bonding of stainless steel and titanium. It is used for applications involving extended service at temperatures of 500°-600°F and intermittent exposures up to 900°F.

In the form of asbestos fabric-supported tape, it has been used in airframe bonding and other applications where resistance to heat and oxidation at elevated temperatures is mandatory.

Lap-shear-strength values on stainless-to-stainless bonds run between 1,500-2,000 psi at room temperature, gradually tapering off to approximately 1,000 psi at 900°F. Curing cycles run about three to four hours at about 600°F with pressures between 50 and 100 psi. Post-curing for 16-24 hours at temperatures between 450° and 550°F may be required.

Phenolic-Neoprenes

Primarily used in metal-to-metal applications where resistance to vibratory fatigue and low temperatures are especially important.

It is particularly effective when used in form of supported tapes for bonding metals, rubbers, thermosetting plastics, ceramics, and glass, to themselves or to each other.

Priming of surfaces prior to application may be required. Curing cycles run from 40-60 minutes at temperatures from 300°-450°F and pressures from twenty-five to several hundred pounds psi.

Shear strength of aluminum lap joints may be between 2,500 and 3,500 psi at room temperature with possible increases in strength at −70°F to

5,000-6,000 psi. Bonds are heat-resistant to 180°-200°F toward which latter temperature shear strength may taper off to about 1,500-2,000 psi. Compositions of this type have good resistance to salt spray, hydraulic oils, anti-icing fluids, water, and some solvents.

Phenolic-Nitriles

Adhesives of this group are predominantly used in the form of supported or unsupported tapes but can also be applied in liquid form. Widely used for applications requiring structural stability, resistance to a relatively wide range of temperatures, chemicals, oils, fuels and solvents; it will bond a large variety of metals, plastics, rubbers and other materials employed in aircraft manufacture, as well as friction materials (brake linings). It has been employed in the structural sealing of fuel tanks, bonding of air frames and metal helicopter-rotor-blades, and similar applications where reliability factors are important. Its general ability to maintain high-tensile shear and peel strength through low and intermediate service temperatures is an additional advantage.

Phenolic-nitrile adhesives can be used with or without primer, depending upon the specific formulation employed and the use for which it is intended.

Cures from two hours at 300°F down to eight minutes at 425°F with pressures from 10-200 psi are possible.

Aluminum-to-aluminum lap joints exhibit shear strengths from about 3,200-4,600 psi at room temperature tapering off to 1,500-2,500 psi at about 300°F. Shear strength values are not only generally well-maintained down to −67°F but show significant increases in certain instances.

Good bond strength values are maintained through 500°F for intermittent service.

Phenolic-Vinyls

Formulations containing phenolic resin combined with polyvinyl formal or polyvinyl butyral are generally available in the form of emulsions, tapes, or as separate components (liquid phenolic resin and polyvinyl formal powder). This type of adhesive is suitable for honeycomb sandwich construction with paper, metal, or fibrous glass cores, bonding polystyrene foam or other porous materials to metal and various nonporous surfaces.

Phenolic-vinyls offer versatility in application methods. Single-component emulsions can be diluted with water, dried after application to surface within 2-6 minutes at 140°-180°F and bonded in tacky state under pressure of about 100 lb/linear in. Coats can also be dried and reactivated by heat.

The two-component form can be applied by coating parts with liquid phenolic resin and dusting the coat with polyvinyl powder. Tapes are especially useful for honeycomb applications.

Cures range from 15-30 minutes at 300°F under pressures from contact to 100 psi.

Service temperatures for aluminum-to-aluminum bonds approximate between 2,000-3,000 psi at room temperature with little change in bond strength down to −67°F. Bond strength may taper off to about 50 per cent of its room temperature value by the time it reaches 180°F.

Phenolic-vinyls have good resistance to water, certain solvents and oils.

Polyurethanes

A large variety of these compositions which can be formed by cross-linking highly reactive isocyanates with different polyols are available. They can be used for metal-to-metal bonding, including steel, aluminum, magnesium, stainless steel, beryllium, uranium, etc. They can also be used for bonding elastomers, foams, and plastics, including rigid vinyl chloride, nylon, glass, ceramics, etc., to themselves, to each other, and to metal. Special formulations of this adhesive are used in critical aircraft and space applications. Typical cures may range from several weeks at room temperature or below to 45 minutes to an hour at 300°-350°F, at pressures between 5-500 psi. Shear strengths in excess of 6,000 psi at room temperature have been reported on various metal-to-metal bonds.

Glue-line thickness is generally between .005 and .01 inch. Bonds are flexible with good peel-strength and resistance to shock and vibration, acids, alkalis, most solvents, oils, and aliphatic compounds, but more or less sensitive to high-humidity conditions.

Prolonged exposure at temperatures extending from below −100° to approximately 200°F is possible without decrease in bond-strength values.

2. SELECTING ADHESIVES FOR SPECIFIC APPLICATIONS

Selection of adhesives for specific structural applications is generally determined by two main steps: problem analysis and testing of bond.

PROBLEM ANALYSIS

Before requesting advice from a manufacturer's technical representative or a consultant, much time and energy can be saved by careful and specific answers to the questions which appear on the problem analysis forms available from most responsible adhesive manufacturers. No useful recommendations can be made without first studying the answers. Unfortunately, many forms are incomplete in the information requested and leave too many loopholes for errors in analyzing the problem.

The main factors in the selection of a structural adhesive and questions pertaining to them should be answered in as much detail as possible. Materials to be bonded should be listed as specifically as feasible. Example: 2024-T3 clad aluminum to Type 301, ½ hard, 2B finish stainless steel. A sample of the material should be submitted with this information.

Indicate whether special surface preparation, such as chemical etching, will be used on materials. Describe process or type of etching solution used. Most manufacturers supply instruction sheets on methods of preparing various types of surfaces.

A blueprint, photograph or simple pencil sketch of the joint must be included, indicating thickness or gauge of each adherend and measurements of the bonding area.

While structural adhesives are outstanding in shear and tensile strength, their resistance to peel and cleavage stresses is relatively poor. Even though modification with elastomers and plasticizers can help overcome this weakness to a certain degree, shear and tensile strengths still remain far above attainable peel-strength values. It is, therefore, important that load-bearing joints be designed with a view to eliminate peel and cleavage stresses as much as possible.

Give a short description of the end use of the product and state whether or not it is a sub-assembly.

Service requirements are important. Upper and lower temperature limits which the joint or assembled product must be able to withstand continuously or intermittently, and time periods involved in exposures must be stated.

Chemical solvents, oils, water, etc., to which assembly must have resistance should be given. It is necessary to furnish exact names of substances, their concentrations, and temperature to which the bond will be exposed, i.e., 50 per cent sulfuric acid at 70°-80°F.

Type and period of exposure should be stated, i.e., immersion, vapor, etc., continuously for 500 hours, etc.

Exposure to weather, sunlight, snow, etc., should be indicated by periods and approximate geographical location (arctic, sub-tropical, etc.).

Special physical properties, like volume resistivity, dielectric strength, etc., should be given for adhesives used in bonding electrical and electronic appliances.

The bond strength required should be defined in amount of tensile, shear, peel, compression, impact, vibration, or other stresses which the joint must withstand. State type of tests by which these values are to be determined. Indicate minimum bond-strength-values permissible for the upper and lower temperature limits.

Although definite requirements on bond-line thickness and degree of flexibility should be shown, manufacturers will have their own recommendations after analyzing the problem.

Color is rarely an important factor in structural bonding but where special requirements exist, a sample of the desired color should be submitted.

Unless there are special reasons for preference, the form of adhesive to be used (liquid, paste, etc.) should be decided after extensive tests with recommended adhesives of various types have been completed.

Indicate the type of manual application tools or automatic equipment currently used and whether a change in method is desired. What kind of mixing equipment is available and whether multi-component adhesives are acceptable should also be stated.

Accurate description of existing curing equipment should be given, outlining types and sizes of ovens, hot presses, etc. Information is also necessary on type of ventilation system in use, since vapors of certain mixtures given off during cure require more thorough ventilation than others.

Capabilities of autoclaves, vacuum bags, and other available equipment should be stated together with their size or volume capacity.

Calculations must be made regarding time allowable for curing under existing production schedule, as well as the space available for air-drying of primed surfaces, or for room temperature curing of bonded assemblies.

Indicate approximate storage facilities available, prevailing temperatures and whether refrigeration is possible.

Complete code and specification numbers should be given if the adhesive is to be used on assemblies which must conform to military or other official specifications.

Give conservative estimated monthly volume and price compatible with the service expected. Small quantities of adhesives are necessarily higher priced per unit than larger ones. Although a small-quantity consumer cannot expect a manufacturer to spend a lot of time on his problems, exaggeration of quantities to be used, or putting too low a limit on the unit price of the adhesive will make it impossible for the manufacturer to work satisfactorily with the user. If the consumer has neither facilities for extensive tests nor technical personnel to modify commercially available adhesives, he may then have to use the services of a consultant.

Name and/or sample of material should be submitted; whether material has been satisfactory in any respect; why, and in which way a change is desired. Submit samples showing type of bond failure or other unsatisfactory performance which is typical of the adhesive in its present use. State under what conditions failure, etc., occurred.

TESTING OF BOND

All adhesives intended for structural applications require a great deal of testing prior to use in production. Valid data which are indicative of the adhesive's suitability for intended application can be gained only by testing the bond under the specific stresses and conditions encountered in actual service.

Destructive Tests

In order to determine the maximum bond performance, these stresses are increased to the point of bond failure. Destructive tests are in order for all specimen performance investigations and for spot-checking a certain percentage of production assemblies. Specimens should be constructed of the same material and with the same type of joint structure as the assembled product for which the adhesive is intended.

In the preparation and testing of specimens, the procedures listed in the Federal Test Method Standard No. 175 or in the specifications of the American Society for Testing Materials should be followed. As the testing methods in these two are in most cases identical, Federal Test Method Standard No. 175 has been included in this book since it offers the additional advantage of informing adhesive users of government requirements. Similar methods are to be found in certain of the Military Specifications.

Nondestructive Tests

Testing bonds by nondestructive methods is particularly suited for quality control and inspection of assemblies coming off the production line. While these tests are able to detect flaws in the bond line, they cannot determine bond strength.

Tapping is probably the oldest and most frequently used method to detect defective bonds. By tapping the bonding area with a small hammer or mallet, voids in the glue line can sometimes be recognized by a hollow sound. This technique has been refined somewhat by the introduction of mechanically operated tapping devices and microphones which pick up the sound and transmit it to the head phones of the operator.

The tapping technique is generally regarded as a rough checking method which must base its reliance on the sensitivity of the operator's ear and cannot possibly detect voids which are very small and covered by the thickness of the adherend.

Electronic and Ultrasonic Inspection. Existing equipment and techniques for electronic and ultrasonic inspection of bonded assemblies are being improved continually. The chief goal is in the direction of discovering more accurate methods through reflected ultrasonic signals and reliable interpretation by which the quality of the bond can be determined.

The evaluation of bonds by ultrasonic devices is based on the theory that transmission of ultrasonic signals will be better through good bonds than through weak or porous bonds or voids. By comparing recorded signals of good or defective bonds with those being tested, conclusions can be drawn as to their quality. The interpretation of these signals requires the services of highly trained operators.

Patterns of honeycomb constructions can be recorded electronically on special paper by a pen which traces the good areas and skips the voids. The resulting chart shows the good bond areas as well as the location of voids and excess adhesive build-up.

Other nondestructive tests include x-ray, infrared, and other photographic scanning methods to detect defective bonds. None of these, however, give a conclusive indication in regard to the strength of the joint. Until a nondestructive method is found by which the performance of the bond under specific stresses can be predicted, destructive tests will have to continue to be employed for assembly spot-checking and specimen testing.

3. PRECAUTIONS IN HANDLING RESINS AND CURING AGENTS

The importance of taking specific hygienic measures in working with resins and curing agents cannot be stressed too strongly.

Phenolics, epoxies and most catalysts and accelerators employed in curing thermosetting resins can cause severe allergic reactions following direct contact, inhalation or ingestion. Although chances of ingesting these materials are relatively few, except by touching food or cigarettes with contaminated hands, they can be a danger to the skin, eyes, and respiratory tract.

Sensitization of eyes and/or skin can develop over a long period during which no signs of irritation may be visible. Once the body is sensitized, it may be impossible for the operator to continue working with adhesives since mere proximity to these materials can bring out skin rashes, eye inflammation, etc.

While to chemists and laboratory personnel, vigilance in handling toxic materials is second nature, workers who have to meet production schedules may become careless in observing rules necessary for their own protection.

Those who despite ignoring safety rules have experienced no irritating effects while dealing with resins and curing agents are a danger not only to themselves, but to others who may touch tools, door knobs, switches, work benches, etc., contaminated by such persons.

Safety Rules

Areas in which adhesives are handled should be separate from other work premises and should not be entered by personnel other than those engaged in work with them. The immediate work area should contain the following minimum safety facilities aside from the usual fire-fighting equipment, etc.: Running hot and cold water, eye shower or rinsing fountain, first-aid kit, particularly castor oil eye-drops and ointment for skin burns.

Ventilation must be adequate throughout work area to allow vapors and fumes from uncured mixtures and curing assemblies to be drawn to the outside of the building. Ventilating hoods must be placed *over* ovens, presses and other curing equipment and *in front of* persons mixing or applying adhesives. Large assemblies should be cured in vented ovens.

Eyes should be protected by wearing safety goggles or plastic eye-shields. Corrosive fumes and splashing of amine type and anhydride curing agents can cause severe damage to eye tissue. Splashing by solvents and low-viscosity mixtures is equally to be guarded against, particularly during stirring or clean-up operations. In case of irritation by fumes or splashing, eyes should be irrigated at once and thoroughly with water. Castor oil should then be applied repeatedly with an eye dropper until medical aid is available.

Skin which is the most frequent area of contamination must be protected against direct contact with resins and curing agents at all times. Hands, arms, face, and neck should be shielded by application of barrier ointments, such as "Kerodex," "Ply," or "Silicare." Hands must also be covered by rubber, vinyl, or polyethylene gloves.

Gloves should be cleaned immediately after use and not placed on tables while in contaminated condition. A fairly versatile clean-up mixture to remove resins from gloves, tables, floors, etc., can be prepared from isopropyl alcohol, acetone, and toluene (or xylene) in approximately 1:1:2 ratio (in the aforementioned order of solvents). This should be followed by washing with soap and water. Amine and the anhydride type of curing agents do not require washing by solvents but should be removed by soap and water only. Gloves should be dried thoroughly to avoid contaminating adhesives or surfaces with water.

By making mandatory that once gloves are worn, no equipment or objects other than the ones involved in the bonding operation may be touched, contamination of door knobs, switches, etc., can be avoided. Unless gloves have been cleaned while on the hands, they should be removed by handling them with a paper towel.

In case of contamination, curing agents should be removed from hands, first by rinsing under running cold water, followed by soap washing in lukewarm water. Resins should be removed with soap and water, or isopropyl, or denatured ethyl alcohol. Only where this has proved insufficient for removing the resin should solvents, such as acetone be used sparingly for cleaning the skin.

Since solvents dissolve the resin but take away the natural oils from the skin at the same time, the dissolved resin is free to penetrate through the skin pores. The action of the acetone should therefore be buffered by addition of alcohol or water. The cleaning mixture must not be poured over the hands but should be applied sparingly to a cotton rag or piece of absorbent cotton with which the contaminated area is gently wiped without pressure.

Burns and rashes require medical attention and should not be treated in the manner of the occasional cut or bruise. While administration of a slightly water-diluted mixture of aluminum acetate solution, N.F. VI (Burrow's Solution) or calamine lotion may relieve the itching temporarily, it may also hide the onset of an allergic condition.

Since many skin conditions are difficult to diagnose and may require time-consuming tests, the doctor should be told by technically informed personnel at the beginning of the treatment which type of curing agent or resin caused the irritation. After relief of the acute condition, a person may or may not be able to continue working with adhesives or curing agents of the type which brought about the skin reaction.

This is particularly true of individuals who have a low resistance to the sensitizing action of these materials or of persons whose initial resistance has been broken down gradually by repeated contact with these materials.

Dermatitis, conjunctivitis, and even asthmatic symptoms can develop either on immediate contact or after a year or more of prolonged contact.

Clothing can be protected against contamination by wearing laboratory or shop coats, plastic aprons, or coveralls.

After cutting openings for head and sleeves, polyethylene clothes bags can be worn for short periods during particularly messy operations. Slip-over sleeves reaching from shoulder to glove can be made from smaller polyethylene bags and fastened to the arm with rubber bands. Nondisposable work clothes should be laundered every two or three days. At least two sets of spare work clothes should be kept for each operator, so that contaminated clothing can be changed immediately.

The strict enforcement of these rules is the best guarantee for maintaining high health and work standards with a minimum of accidents and loss of time.

4. PREPARATION OF ADHERENT SURFACES

Where maximum bonding properties are desired, careful preparation of the adherent surface is essential. Bonding areas must be free from oil, grease, rust, moisture, or fingerprints. Skin grease or perspiration deposited on the bonding surface by ordinary handling can cause sufficient contamination to reduce bond strength by as much as 75 per cent.

Depending upon the type of contaminant and the material from which it is to be removed, surfaces can be cleaned by mechanical and/or chemical methods. Wire brushing, sandpapering, sandblasting and other types of abrasion can be used to eliminate dirt, scale, rust, etc. Oils, greases and most other contaminants must be removed by chemical cleaning agents such as solvents and detergents. The safest way to prepare adherent surfaces is to follow any abrading procedures by solvent cleaning.

SOLVENT CLEANING OF METALS

Metals can be cleaned by solvent wiping or vapor bath immersion. Chemicals commonly employed for solvent wiping bonding areas include acetone, MEK, isopropyl alcohol, xylene, and toluene. Clean white cotton rags or absorbent cotton should not remain so wet that application to the surface will merely dissolve the grease but not absorb it into the fabric. The same surface should be wiped repeatedly with fresh pieces of cotton or rag to make certain that contaminants have been completely removed.

Since the above solvents are flammable, wiped parts should not be placed in the oven for drying as ignition of solvent vapors may cause fire or explosion. Combustible solvents should be allowed to air-dry at room temperature or by application of air blower.

Trichloroethylene is an excellent nonflammable degreasing agent which can be used either in liquid form for wiping the bonding area, or as a vapor bath in which parts can be immersed for degreasing. A thirty-second immersion period in a trichloroethylene vapor bath is usually sufficient for complete degreasing.

This method is especially economical for either cleaning large surfaces or large quantities of small parts which can be lowered into the bath in a wire basket. In using trichloroethylene as a cleaning agent, it must be kept in mind that it is slow-drying and like any chlorinated solvent will inhibit the cure of most structural adhesives if present on the bonding surface in even extremely small quantities.

At least 2 hours at room temperature or 15 minutes at 200°F should be allowed for complete evaporation of entrapped traces of trichloroethylene after cleaning honeycomb structures.

Following the trichloroethylene wash or vapor bath, parts should be wiped with isopropyl alcohol or MEK, or immersed in an alkaline detergent or appropriate etching solution.

CHEMICAL ETCHING OF METAL SURFACES

Special surface preparation of bonding areas *after solvent wiping or vapor-bath treatment* can increase bond strength by as much as 300 per cent. It should be mentioned at this point, however, that this is an additional expense in production which should be entered into only after extensive tests with a number of adhesives have shown that sufficient bond strength cannot be attained without it. Although for light metals, such as aluminum and magnesium alloys, chemical etching or anodizing (an electrolytic process) is indispensable where optimum bond strength is required, other surfaces, such as ferrous metals and certain types of stainless steel may give excellent adhesion without etching.

Successful etching depends not only on the amount of care exercised in the preparation of solutions but on the proper handling of the materials to be bonded during and after the etching procedure. Observation of the following rules will result in safe and successful etching operations.

All etching solutions should be prepared in glass, porcelain, polyethylene, or "Teflon" laboratory ware and stirred with rods of the same materials. Metals other than those to be etched must not be allowed to touch the solutions. Etching solutions containing hydrofluoric acid or fluorides should be kept in "Teflon" or polyethylene trays and stirred with "Teflon" or polyethylene rods. Solutions in plastic trays can be heated by immersion in hot water baths at appropriate temperatures.

Safety Precautions

Safety precautions in preparing and working with chemical etching solutions should be adhered to rigidly. Skin and eye burns can be prevented easily by wearing slip-proof neoprene gloves and safety goggles. Neoprene gloves should not be removed from hands until operator has washed them thoroughly under running tap water. Gloves must be dry when opening sulfuric acid bottles since a drop of water falling into acid can cause explosion. *Never* add water to acid but add acid slowly to water without splashing. Inhalation of acid fumes should be avoided.

Operators should be cautioned that "the more the better" does not apply to etching of metal surfaces in preparation for structural bonding. Overetching can reduce adhesion to a point below the bonding fitness of the unetched metal. Unless indicated otherwise by the adhesive manufacturer, the concentrations, exposure periods and temperatures of recommended solutions should be adhered to for best results.

In locations where tap water is rusty or has a high mineral content, etched parts should be rinsed in distilled water or at least receive a distilled water spray following the tap-water rinse.

Forced draft ovens are excellent for drying water-rinsed parts speedily. This is of importance since fast drying at safe temperatures will prevent water from oxidizing etched surfaces.

Where ovens for drying purposes are not available, pieces can be air-dried in a dust-free atmosphere, blown dry with hot air or tapped gently against clean dry filter paper. Open air-drying can be speeded up by spraying water-rinsed parts with acetone (N.F. grade or better). Do not place acetone-sprayed parts in the oven, since fire or explosion may result from ignition of vapors.

Iron and ordinary steel require special drying methods to prevent oxidation of etched surface (see Ferrous Metals other than Stainless under Metal Etching and Cleaning Solutions).

Etched metal surfaces should be cemented as soon as possible after drying. Storing etched parts should be avoided because of the likelihood of contamination or oxidation of surfaces. In cases where storage is necessary, the etched surface should be covered with lint-free tissue paper and the entire part tightly wrapped or placed in an air-tight container.

METAL ETCHING AND CLEANING SOLUTIONS

For best results etching solutions should be freshly prepared. Etched surfaces should be free from striations and hold a break-free water film. This proves that surfaces are clean and etched uniformly. If the result is unsatisfactory, wipe with acetone and repeat etching procedure.

Aluminum and Aluminum Alloys

1. Solvent-clean metal (see p. 17).
2. Prepare solution *in exact order* as follows:

Dissolve	Sodium dichromate	30 parts/wt
	Distilled or clean tap water	170 parts/wt
Add slowly	Conc. sulfuric acid	50 parts/wt

While adding sulfuric acid stir gently with glass rod.

CAUTION: OBSERVE SAFE MIXING PROCEDURES (SEE SAFETY PRECAUTIONS, p. 18).

3. Immerse metal in solution for 5-10 min at 150°-160°F. Do not exceed 160°F since crystallization may develop on the surface of metal interfering with the bond. Agitate bath slightly during treatment.

4. Rinse metal thoroughly under clean cold tap water, followed by a short rinse under hot tap water.

5. Dry in oven at 140°-150°F. Do not exceed this temperature.

There are many variations possible in the proportions of the above formulation. Examples of commonly used ones are:

Alternate proportions per part of

Sodium dichromate: Water: Sulfuric acid,

in the aforegoing order:

7/17/2, 2/15/5, 4/12/4, 2/14/4

Beryllium

1. Solvent-clean metal (see p. 17).
2. Prepare solution of the following:

Sodium hydroxide	20-30 parts/wt
Water (preferably distilled)	170-180 parts/wt

3. Immerse metal for 5-10 min.
4. Rinse under tap water and finish with distilled water spray.
5. Oven dry at 250°-350°F for 10-15 min.

Brass
Bronze } See Copper and Copper Alloys

Copper and Copper Alloys

1. Solvent-clean metal (see p. 17).
2. Prepare solution of the following:

Ferric chloride (42% solution)	18 parts/volume
Conc. nitric acid	32 parts/volume
Water	200 parts/volume

3. Immerse metal for 1-2 min at room temperature.
4. Rinse metal thoroughly under clean cold tap or distilled water and dry.

Alternate proportions per part of

Ferric chloride: Nitric acid: Water,

in the aforegoing order:

1/2/7, 1/2/20, 6/12.4/81.6, 15/30/197

Ferrous Metals Other Than Stainless

Because of the tendency of the metal to rust, pretreatment of this type of surface should not be started until ready to follow through with the entire procedure from cleaning and etching to cementing without interruption. Where this is not possible, it may be better not to employ chemical etching at all but to cement the parts immediately after sandblasting and solvent-cleaning them. Otherwise, either of two etching methods may be employed.

Method I

1. Prepare a solution consisting of equal parts by weight of concentrated hydrochloric acid and distilled water.

2. Before immersing part in above solution make sure that sandblasting and solvent-cleaning (as described above) successfully removed all rust, scale, oils, etc.

3. Immerse in solution for 5-10 min at room temperature.

4. Rinse thoroughly under tap followed by spray of distilled water. It is essential that the metal be dried as rapidly as possible to avoid formation of rust. Since oven

drying of iron or steel, even under forced draft, may cause freshly etched surfaces to rust, parts should be dried immediately after final water rinse.

This can best be done by tapping part gently against dry clean filter paper, followed by blowing warm air over surface or placing part in forced draft oven for 5-10 min at 200°F. Where oven is not available, follow filter paper drying by wiping surface gently with xylene or toluene moistened absorbent cotton. Do not use acetone or other ketones since even slight water content in these solvents may cause formation of rust on this type of surface.

5. When dry, cement parts immediately.

Method II (Recommended by U.S. Government, Forest Products Laboratory)

1. Prepare the following solution in *exact order* as follows:

Dissolve	Sodium dichromate	20 parts/wt
	Distilled or clean tap water	150 parts/wt
Add slowly	Conc. sulfuric acid	50 parts/wt

While adding sulfuric acid stir gently with glass rod.

CAUTION: OBSERVE SAFE MIXING PROCEDURES (SEE SAFETY PRECAUTIONS, p. 18).

2. Examine part as outlined under same point in Method I.
3. Immerse in solution for 10 min at 160°-170°F.
4. Rinse and dry as outlined under same point in Method I.
5. Cement as outlined under same point in Method I.

Magnesium and Magnesium Alloys

1. Solvent-clean metal (see p. 17).
2. Prepare the following two solutions:

Solution A:

Sodium metasilicate	55 parts/wt
Tetrasodium pyrophosphate	35 parts/wt
"Nacconol NR" (National Aniline Co.)	5 parts/wt
Sodium hydroxide	15 parts/wt
Water	2400 parts/wt

Solution B:

Chromium trioxide	1 part/wt
Water (clean tap or distilled)	4 parts/wt

3. Immerse for 5-10 min in Solution A at 165°-185°F.
4. Rinse thoroughly under tap water.
5. Immerse for 5-10 min in Solution B at 150°-160°F.
6. Rinse thoroughly under clean tap or distilled water and dry in oven for 15-20 min at 175°-200°F.

Stainless Steel

Any one of the following methods can be used. Since there are various types of stainless steel, it is recommended that several methods be tested individually to determine maximum efficiency.

Method I

1. Solvent-clean metal (see p. 17).
2. Prepare solution in *exact order* as follows:

Dissolve	Sodium dichromate	3.5 parts/wt
	Distilled clean tap water	3.5 parts/wt

Add slowly	Conc. sulfuric acid	200 parts/wt
	While adding sulfuric acid stir gently with glass rod.	

CAUTION: OBSERVE SAFE MIXING PROCEDURES (SEE SAFETY PRECAUTIONS, p. 18).

3. Immerse metal for 15-20 min at 160°-170°F.
4. Rinse thoroughly under tap water; finish with distilled water spray and dry in oven for 10-15 min at 200°F.

Method II

1. Solvent-clean metal (see p. 17).
2. Prepare the following solutions:

Solution A:

(Same as Solution A under Magnesium and Magnesium Alloys)

Solution B:

Conc. hydrochloric acid	20 parts/volume
Distilled clean tap water	180 parts/volume

Solution C:

	(See CAUTION above)	
	Water	100 parts/wt
Add slowly	Conc. sulfuric acid	40 parts/wt
	"Nacconal NR" (National Aniline Co.)	0.5 parts/wt

Solution D:

Water	100 parts/wt
Conc. nitric acid	20 parts/wt
Hydrofluoric acid	2.5 parts/wt

3. Immerse metal in Solution A for 5-10 min at 165°-185°F.
4. Rinse thoroughly under tap water.
5. Dip metal in Solution B for 15-30 sec.
6. Immerse metal in Solution C for 5-10 min at 150°-160°F.
7. Rinse under distilled or clean tap water.
8. Immerse metal in Solution D for 5-10 min at room temperature.
9. Rinse under tap water; finish with distilled water spray and dry in oven for 10-15 min at 200°F.

Method III

1. Solvent-clean metal (see p. 17).
2. Prepare solution as follows:

Dissolve	Hexamethylenetetramine	25 parts/wt
	Water	100 parts/wt
	Conc. hydrochloric acid	10 parts/wt
Mix and add		
	30% Hydrogen peroxide	5 parts/wt

3. Immerse for 5-10 min at 150°-160°F.
4. Rinse under tap water; finish with distilled water spray and dry in oven for 10-15 min at 200°F.

Method IV

1. Solvent-clean metal (see p. 17).
2. Prepare the following solution:

Conc. hydrochloric acid	80 parts/wt
Conc. phosphoric acid	8 parts/wt
Conc. hydrofluoric acid	4 parts/wt

3. Immerse metal for 1-2 min at 180°-190°F.
4. Rinse under tap water; finish with distilled water spray and dry in oven for 10-15 min at 200°F.

Steel (see Ferrous Metals Other Than Stainless)

Titanium and Titanium Alloys

Method I

1. Solvent-clean metal (see p. 17).
2. Prepare solution in *exact order* as follows:

Dissolve	Sodium fluoride	10 parts/wt
	Chromium trioxide	5 parts/wt
	Water	250 parts/wt
Add slowly	Sulphuric acid	50 parts/wt

While adding sulfuric acid stir gently with "Teflon" or polyethylene rod.

CAUTION: OBSERVE SAFE MIXING PROCEDURES (SEE SAFETY PRECAUTIONS, p. 18).

3. Immerse metal for 5-10 min at room temperature.
4. Rinse under tap water; finish with distilled water spray and dry in oven for 10-15 min at 160°-180°F.

Method II

1. Solvent-clean metal (see p. 17).
2. Prepare the following solution:

Conc. nitric acid	30 parts/volume
Hydrofluoric acid	5 parts/volume
Water	100 parts/volume

3. Immerse metal for 10-15 min at 100°-125°F.
4. As under Method I.

Tungsten and Tungsten Alloys

1. Solvent-clean metal (see p. 17).
2. Prepare solution as follows:

	Conc. nitric acid	30 parts/wt
	Water	15 parts/wt
	Hydrofluoric acid	5 parts/wt
Add slowly	Conc. sulfuric acid	50 parts/wt

While adding sulfuric acid stir gently with "Teflon" or polyethylene rod. Add a few drops of 20% hydrogen peroxide.

3. Immerse metal from 1-5 min at room temperature.
4. Rinse under tap water; finish with distilled water and dry in oven for 10-15 min at 160°-180°F.

Zinc and Galvanized Metals

1. Solvent-clean metal (see p. 17).
2. Prepare solution as follows:

Conc. hydrochloric acid	10-20 parts/volume
or	
Glacial acetic acid	10-20 parts/volume
Water	80-90 parts/volume

3. Immerse metal for 2-4 min at room temperature.
4. Rinse under warm tap water; finish with distilled water spray and dry in oven for 20-30 min at 150°-160°F.

PREPARATION OF NONMETAL SURFACES

Ceramics

1. Solvent-clean (see p. 17) or wash in warm solution of commercial detergents, such as Oakite, Vel, etc.
2. Immerse for 10-15 min in either the chromium trioxide solution, listed under Magnesium and Magnesium Alloys (Solution B), or in the acid-dichromate solution employed for Stainless Steel (Method I). Use solutions at room temperature.
3. Rinse under tap water; finish with distilled water spray and dry in oven at 150°F.

Concrete

1. Clean by sandblasting, chipping or wire brushing. Then sweep, air-blow or vacuum surface.
2. Remove oils or grease with solution of commercial detergents such as "Oakite" 26 Cleaner. Flush thoroughly with water and allow to dry completely.
3. Prepare the following solutions:

Solution A:

Conc. Hydrochloric acid	10 parts/wt
Water	190 parts/wt

Solution B:

Sodium bicarbonate	20 parts/wt
Water	180 parts/wt

4. Apply Solution A to surface.
5. After this solution has spent itself, neutralize residual acid by applying Solution B; then flush with clear water and allow to dry completely.

Glass

Follow general procedure as outlined under Ceramics. Glass used for optical purposes must not be exposed to etching solutions of any kind but should be cleaned preferably in an ultrasonically agitated detergent bath. Drying temperatures should be kept at 100°-125°F.

Plastics (types used in structural applications)

All molded and most laminated plastics require removal of release agents. Complete removal by solvents or detergents may be extremely difficult in certain cases, and sanding may be necessary.

Where "slip agents," such as stearates, etc., or large amounts of plasticizer have been incorporated in the molding powder, bonding may be impossible unless the incorporated agent can be brought to the surface by migration under heat, and removed completely. Bonding such type of material is inadvisable since migration of release agents and plasticizers may continue after parts have been assembled.

Abrading by sandpaper, emery cloth or steel wool followed by solvent wiping is usually the best method to prepare most plastic surfaces for bonding. It is recommended that the entire part be washed in a warm solution of a commercial detergent such as "Vel," "Oakite," etc., before sanding, so as to reduce the possibility of recontaminating prepared bonding area by handling.

Following the abrading operation, surfaces should be dusted by blower or vacuum. If steel wool has been used, steel particles can be removed by going over surfaces with a magnet wrapped in clean white cotton cloth.

Diallylphthalate, Epoxy, Melamine, Nylon, Phenolic, Polyester, and Polyurethane

These can be prepared for bonding by sanding or steel wooling, followed by wiping with ketones, such as acetone or MEK.

Polystyrene, Polyvinyl Chloride

Only the rigid, not the highly plasticized flexible type, can be prepared by sanding or steel wooling followed by solvent wiping with isopropyl or methyl alcohol.

Fluorinated Polymers

Fluorinated polymers, such as "Teflon," "Kel-F," etc., are bondable after etching surfaces with sodium. Since preparation of sodium etching bath can be quite awkward and hazardous unless handled with professional skill, etching solutions are usually obtained as ready-to-apply dispersions, such as "Bondaid" (W. W. Shamban & Co., Culver City, Calif.), "Tetra-Etch" (W. L. Gore & Associates, Newark, Del.), and others.

Specific application methods are recommended by manufacturer. Some etching solutions can be applied by dipping, brushing or spraying. Areas for treatment are isolated by masking tape. Treatment generally takes no more than 5-15 sec, after which the dispersion is flushed away with water. Sodium-treated surfaces may be washed with detergent or solvent wiped, but not abraded before use.

Treated fluorinated polymer materials ready for bonding can be obtained from suppliers of plastic materials by specifying "Bondable Teflon," etc., when ordering.

Acetal ("Delrin"), Chlorinated Polyether, Polyethylene, and Polypropylene

These can be prepared in the following exact order:

1. Wipe with acetone.
2. Dissolve

Dissolve	Sodium dichromate	15 parts/wt
	Distilled or clean tap water	24 parts/wt
Add slowly	Conc. sulfuric acid	300 parts/wt

While adding sulfuric acid stir gently with glass rod.

CAUTION: OBSERVE SAFE MIXING PROCEDURES (SEE SAFETY PRECAUTIONS, p. 18).

3. Immerse materials as follows:

Acetal ("Delrin")	10-20 sec at room temperature
Chlorinated polyether	5-10 min at 150°-160°F
Polyethylene	60-90 min at room temperature
Polypropylene	1-2 min at 150°-160°F

4. Rinse with tap water; finish with distilled water spray and allow to air-dry.

Rubbers (natural and synthetic)

By etching with concentrated sulfuric acid, surfaces of natural and synthetic rubbers can by cyclized, i.e., rendered brittle. This can be done either by immersing the surface of the rubber in sulfuric acid or by applying a baryte paste, which can be prepared by mixing barium sulfate with sulfuric acid. Rubber and tool used for handling part must be absolutely dry before contact with acid.

Method I

1. Wipe with isopropyl or methyl alcohol. Allow to dry.
2. Immerse surface in concentrated sulfuric acid:

Natural rubber	5-10 min at room temperature
Synthetic rubber	10-15 min at room temperature

3. Rinse thoroughly under tap water.

4. Neutralize residual acid by 5-min immersion in a 10-20 per cent solution of ammonium hydroxide at room temperature.
5. Rinse under clean tap or distilled water, dry, and break small fissures in the surface by flexing. (This should be done while wearing clean rubber or plastic gloves. Fibres of cotton gloves may catch in the fissures.)

Method II

1. See Method I.
2. Mix concentrated sulfuric acid with barium sulfate until a heavy paste is obtained.
3. Apply paste with stainless steel or glass spatula to rubber surface and allow to remain for periods as stated in Method I, No. 2.
4. Rinse thoroughly under tap water.
5. As in Method I, No. 4.
6. Same as in Method I, No. 5.

Once surface preparation has been completed, parts must not be handled except with clean white cotton gloves to avoid marring or contamination of surfaces.

5. THE BONDING OPERATION *

Following the preparation of adherent surfaces, the bonding operation can be divided into three stages: (1) mixing or preparation of the adhesive; (2) application of the adhesive to the bonding surface; and (3) curing of the assembly.

MIXING OR PREPARATION OF THE ADHESIVE

Contamination

While the above steps differ in handling details and equipment employed, they must all be executed with the same care and protection against contamination. This caution is essential to the success of the bonding operation.

Since the effectiveness of most structural bonds depends mainly on chemical rather than mechanical adhesion even slight contamination of the adhesive or the adherent surface can partly or completely destroy the bonding power of the adhesive.

Instructing workers who handle adhesives in some of the fundamentals of adhesion will help them to avoid committing costly errors, which are bound to occur when they just "follow instructions."

Personal Cleanliness

Certain basic rules should be observed in working with adhesives. Whether they appear to be dirty or not, hands should be washed with soap and water before and after handling adhesives. Reasons for this are mentioned in detail in the chapters entitled "Preparation of Adherent Surfaces" and "Precautions in Handling Resins and Curing Agents."

Operators using hand creams should wear vinyl, rubber, or polyethylene gloves. If spilling occurs, hands and/or gloves should be cleaned at once in the manner recommended under "Precautions in Handling Resins and Curing Agents."

* Because of their outstanding importance as a group among structural adhesives and the skill which they demand in their use, epoxy-based adhesives were selected to demonstrate the bonding operation.

Premises

Premises on which adhesives are mixed and applied should be

(1) in conformity with the general safety regulations as listed under "Precautions in Handling Resins and Curing Agents"

(2) as dust-free as possible to avoid contamination of adhesives and bonding surfaces

(3) low in humidity to prevent moisture condensation on adhesives, bonding surfaces, mixing and application equipment

(4) kept at approximately 70°F room temperature. Maintenance of about one pound positive pressure in room will help to keep out dust coming through open doors and cracks.

Shelves, tables and overhead pipes and fixtures should be cleaned frequently. However, sweeping and dusting should take place only when there is no bonding operation in process. While adhesives are being mixed or applied, there must be no planing or sandpapering in the same or adjoining area.

Storage

Whenever possible, base resins and curing agents should be stored on different shelves or away from each other, so that accidental breakage of containers will not cause contamination.

For optimum shelf life, precatalyzed single-component adhesives should be kept below room temperature or under refrigeration (as specified by manufacturer). Containers must be closed immediately after use in order to avoid mix-ups in replacing covers and escape of vapors from amine-type catalysts, solvents, etc..

Manual Mixing of Two-Component Adhesives

Mixing of small batches can best be accomplished in beakers or straight-sided containers, preferably made of corrosion-resistant materials like glass, porcelain, "Teflon," or stainless steel. The spatula or stirring paddle should be constructed of light material and not of wood, which may absorb part of the catalyst before it can be dispersed in the mixture.

The mixture should not occupy more than about two-third capacity of the beaker. For the sake of accuracy, it is preferable to weigh the correct amount of base resin in the mixing beaker rather than transfer it to another container after weighing, since some of the resin may remain on the walls of the first container even after scraping.

In catalyzation with amine-type curing agents, accurate weighing is an absolute necessity if optimum properties are desired. While an insufficient amount of catalyst will fail to help polymerize the mixture completely, too much catalyst will ruin adhesion by rendering the mixture too cohesive and producing a brittle bond. Unreacted excess of amine- or anhydride-type catalysts may also cause corrosion of the bonding surface.

The margin of error can be extremely small and a few drops can make the difference between optimum properties and bond failure. Most curing agents are corrosive and should be weighed in glass beakers before being added to the resin base.

Not all two-component adhesives have critical mixing ratios. Epoxy-polyamide mixtures require far less care in that respect. Many can actually be mixed by eye assessment of volumetric quantities, such as one-half epoxy to one-half polyamide resins.

The mixture must be stirred from the moment the curing agent is added until it is completely and uniformly dispersed throughout the resin. In order to avoid spilling over of the curing agent, stirring should at first proceed slowly until the curing agent is no longer on the surface of the mixture.

Thereafter, the stirring motion should be speeded up. Vigorous and thorough mixing should not be interrupted except for repeated scraping of resin from upper parts of the beaker wall and the spatula for reincorporation into the mixture.

Mechanical Mixing of Two-Component Adhesives

Where large production quantities necessitate mechanical mixing, the equipment should be kept as simple and easy to clean as possible. A mixing paddle clamped into the chuck of a drill press running at speeds up to 100 rpm can be employed for mixing one-gallon batches.

Other equipment for mixing large production batches is commercially available from manufacturers of automatic jacketed mechanical mixers. This type of equipment has water-cooling and is suitable for automatic volume loading and preparing mixtures for transfer to automatic metering equipment.

Large mixed batches can be stored for stated periods under refrigeration or frozen in dry ice until ready for use.

Under no circumstances should second batches, even if immediately following the first one, be catalyzed in the same equipment without prior cleaning.

Mixing equipment should be cleaned or soaked immediately after use in solvents like acetone, toluene or other cleaning agents recommended by the manufacturer.

Extending Pot Life

The pot life of catalyzed thermosetting mixtures is limited by the speed at which polymerization progresses after the curing agent has been added to the base resin. Depending upon the total mass, the type and amount of curing agent used as well as the ambient temperature and the method of mixing, the exothermic reaction will progress with more or less intensity. The greater accumulation of heat within large mixing batches renders their work life shorter than that of smaller masses.

During application, the pot life of the mixture can be extended by dissipating the heat within the mass or through the outside of the container. This can be accomplished by any of the following methods:

Spread out mixture over a wider surface on a pan or plate.

Immerse beaker partly in dry ice or allow cold water to circulate around it.

Use a beaker with a large bottom area and place it on a cool, heavy aluminum or copper plate or any other good heat conductor.

Immerse a thin stainless steel cylinder filled with chipped ice in the center of the mass.

APPLICATION OF THE ADHESIVE TO THE BONDING SURFACE

Manual Application

The tools conventionally used for the manual application of adhesives in paste or liquid form are: trowel (notched), spatula, knife (putty, coating, sheathing, radius or hook), roller (hand), and brush. The choice of tool is primarily indicated by the viscosity of the adhesive as well as by the type and size of the bonding area to which it is to be applied.

Whether it be pin or trowel, the tool to use is the one which will do the best job in applying the adhesive. With an imaginative approach, manual tools for unconventional applications or unusual surfaces can be constructed easily from stock forms of polyethylene, "Teflon" or thermosetting plastics, if stainless steel is too costly.

In order to be certain that tools are absolutely clean and free from grease or fingerprints, they should be solvent-wiped and allowed to dry completely just before use.

Solvents like toluene or xylene are preferable for this purpose since acetone or other ketones, unless they have been redistilled, contain a certain percentage of water which may remain undetected on the surface after evaporation of the solvent.

Where frequent cleaning of tools interferes with production or is difficult, a disposable piece of polyethylene film can be stretched tightly over the application tool and fastened to the handle with rubber bands. Sharp corners on tools should be smoothed and slightly rounded to prevent puncturing the wrapper.

Operators should handle freshly cleaned surfaces (see "Preparation of Adherent Surfaces") with clean, soft cotton gloves. Persons who have excessively oily or sweaty skin or who use hand lotions or barrier cream should wear clean vinyl, rubber or polyethylene gloves instead.

Sneezing, coughing, and breathing close to the bonding surface will deposit moisture on it and reduce the strength of the bond. Operators should, therefore, be careful not to talk directly against the bonding surface while applying the adhesive.

Before application, joints and mating surfaces should be checked for proper clearance and complete and uniform contact by holding them together with little or no pressure. Where close tolerances cannot be kept, tighter fits are preferable since the chances of obtaining a satisfactory bond are better in the case of a uniformly thin glue line than in one which is too thick.

Manufacturers' recommendations in regard to clearances between bonding surfaces should be followed carefully as the thickness at which the glue line is most effective can differ with adhesives and materials.

Although glue line thicknesses can range from .0005-.015 inch, the most effective are generally considered to be between .001-.005 inch. Bond lines in excess of .01-inch thickness are not recommended.

Where the thickness of the glue line is of critical importance and tolerances are close, spacers may be inserted between the adherent surfaces in the form of fibrous glass threads. Depending upon the size and contours of the bonding area, spacers can be inserted at distances of 2 to 3 inches from each other or on two opposite ends.

Adhesives should be applied in such a way as to assure complete wetting of the bonding surfaces. Precatalyzed single-component pastes or liquids may require slight warming up before application if the viscosity appears too high for adequate wetting of the part. Since this procedure shortens the work life of the adhesive, no more than the amount needed for the particular job should be warmed up at a time. As an alternative, the adhesive can be spread on a warm bonding surface. Two-part adhesives should be applied to the bonding area when the exotherm is at its peak and the mixture possesses high wetting power.

Exceptions are sloping and vertical surfaces in which case the mixture should be allowed to gel a little before application in order to avoid sagging or running.

In the case of horizontal surfaces, the adhesive should be applied first and then allowed to gel slightly before mating both surfaces. This procedure is advisable where exotherm has lowered the viscosity of the adhesive to a point where the additional heat and pressure of the cure would cause excessive flow or squeeze out.

While in certain instances, low-viscosity mixtures may permit application to one of the surfaces only, pastes and other high-viscosity cements should be applied to both. Parts which require complete coverage by the adhesive can be dipped in mixtures of suitable viscosity.

The coating should be applied evenly with an approximate thickness of between .004-.015 inch to each surface. The adhesive film should be thin, yet thick enough to allow for squeeze-out when the surfaces are mated. Voids must be filled in completely and special allowance should be made in the coating thickness for partial absorption by porous surfaces.

Besides direct application from tool to bonding area, cheesecloth or other suitable fabrics can be freshly impregnated with low-viscosity mixtures and placed between the bonding surfaces.

Parts should be mated carefully and without catching air between the bonding area. Moving them gently against each other will help to remove any entrapped air and ensure even distribution of the adhesive. Once the parts are properly positioned, adhesive squeeze-out should be removed with clean white cotton rags or in smaller assemblies, with absorbent cotton swabs.

Semi-automatic Application

Devices which will automatically pressure-feed the adhesive from a supply chamber to a manually operated tool, such as spray gun, caulking gun, flow roller, hand extruder or other pressure-operated device of this type, fall under this category.

Suitable for medium to large production operations, semi-automatic equipment has to be selected on the basis of the adhesive type and viscosity used as well as the size and contours of the bonding surface.

Employment of this type of equipment offers certain advantages as well as disadvantages. Some advantages are:

Faster application to large areas.

Better control of amount of adhesive dispensed.

Possibility of using disposable adhesive cartridges in guns.

Cleaner operation and, in some cases, simpler clean-up of equipment.

Some disadvantages are:

Necessity of different equipment for various viscosities and surfaces.

Not suitable for short pot-life mixtures.

Possibility of mechanical trouble due to improper care (as allowing adhesive to cure in vital parts of equipment).

Before installing automatic pressure equipment, the practicability of the operation should be tested by using hand-pressure operated equipment, such as ratched type hand-caulking gun, insecticide sprayer or polyethylene squeeze bottle. Any one of these may be suitable for specific applications on smaller production lots.

Automatic Application

Coating equipment capable of applying a metered amount of adhesive while conveying the coating surface past the point of application is particularly suited for continuous application of adhesives to materials in sheet or strip form.

The amount of adhesive can be controlled or adjusted either before (premetering) or after (postmetering) it is deposited on the material.

The premetered type of application includes such operations as: kiss-roll coating, reverse-roll coating, brush-coating, spray-coating, and engraved-roll or gravure coating.

Except for spray-coating in which the material moves past one or more spray nozzles, the adhesive is usually fed from the pan to the applicator by the action of pick-up rolls, pressure or gravity feed. The amount of adhesive which is deposited on the material is generally controlled by the pressure or gap between pick-up and transfer roll or by the action of a brush or a doctor blade or roll, which removes excess adhesive from the roll before it is applied to the material.

The postmetered type coatings are applied in knife-over-roll coating, knife-on-blanket coating and pressure-roll coating. In this operation the thickness of the coat is adjusted after the adhesive has been deposited on the material by scraping or squeezing off the excess.

Film thickness in general is controlled by the tension of the knife against the material as it moves under it or by the pressure and gap between two rolls through which the material must pass.

In air-blade metering the excess coating can be blown off by a jet of air operating at predetermined pressure, angle of impingement and distance of the nozzle from the coating surface.

The operation and maintenance of automatic coating machinery requires skilled operators and attendance by experienced technical personnel. A variety of difficulties which may develop during production runs must be eliminated immediately to avoid tie-up of machinery and waste of materials.

Excessive foaming, stringing, spattering, or spotty application are some of the problems which may call for change of viscosity, modification of formulation, or machine adjustment.

Development of new electronic process controls, utilization of emanations from radioactive materials for automatic gauging and adjustment of coating thickness and other innovations continue to improve the efficiency of coating equipment.

APPLICATION OF ADHESIVES IN DRY FORM

Powders

Adhesives in powder form can be applied to bonding areas in several ways. An even layer of powder can be dusted on the bonding surfaces and sintered by mild heating to hold the adhesive in place. The part can also be dipped into a melt of the powder. A third method is to dip or dust the heated metal surface. Some powder formulations are suitable for application by spraying from a flame gun.

Once the adhesive is fused to the bonding surfaces, the parts can be stored until they are assembled and cured. Powders can also be applied to surfaces coated with either a tackifying agent which holds the powder in place or with another resin which copolymerizes with the powder. Bondline clearance is generally kept to 4-6 mils. Some advantages are:

- Ease and speed of application.
- Can be applied over large bonding areas where special conditions make use of adhesives in liquid, paste or tape form inadvisable.
- Properties of powders can be modified by dry blending with fillers, such as mica or silica to increase heat resistance, reduce thermal expansion, etc.
- Powders can be pelleted or preformed for special applications.

Some disadvantages are:

- Possibility of depositing powder accidently on wrong surfaces adjoining bonding area. Adjoining areas may require masking.
- Difficulty in applying an even layer of adhesive.
- Special care necessary to avoid overheating in fusing powder to parts prior to assembly.

Rods

Adhesives in rod form are used in the manner of solder. The parts to be bonded are heated to a specific temperature and the necessary amount of adhesive is melted from the tip of the rod onto the bonding surfaces.

The bonding surfaces are kept in intimate contact while the parts are allowed to cool and the joint hardens. The assembly is then subjected to heat curing. Usual clearance is 6-8 mils.

Some advantages are:

- Exact positioning of intricate parts.

Speed of operation.

Coated parts can be stored for future assembly [similar to powders, (*q.v.*)].

Little or no equipment clean-up.

Some disadvantages are:

Application limited to specific contours and bonding surfaces.

Difficulty in manipulating heated parts.

Difficulty in applying an even or uniform coating.

Special care necessary to avoid overheating solder while positioning parts.

Tapes

Adhesives in tape form can be cut by knife or scissors to the exact shape required to cover the bonding area. When cutting large sections, the material can be laid out on a clean and smooth table with the protective polyethylene liner between tape and table.

Tapes should be handled with clean cotton gloves. Since most tapes require more closely controlled storage conditions than other single-component adhesives, they should be returned to low temperature or refrigerated vaults as soon as cutting of the required material has been completed.

Tapes can simply be placed on one of the adherent surfaces or in the case of vertical areas, held temporarily in position by tacking paste.

In handling asymmetric tape systems for honeycomb sandwich constructions, care should be exercised in putting proper sides on cores and skins respectively.

The thickness of the cured glue line is a function of the curing pressure, the bond area, and the weight of the tape. Materials weighing 0.05 lb/sq ft will under proper pressure develop a glue line approximately .005 inch in thickness.

Metal honeycomb sandwich constructions usually require use of a fabric-supported or heavier tape than straight metal to metal bonding. Where heavier type material is not immediately available for applications requiring it, multiple layers of the lighter material can be used.

Some advantages are:

Ease and speed of preparing and applying adhesive to bonding area.

Application to one surface only.

Greater accuracy in predetermination of glue-line thickness allows work with close tolerances over large bonding areas.

Some disadvantages are:

Requires cures under higher and controlled pressure to ensure complete wetting of bonding surfaces and proper thickness of glue line.

Some tapes necessitate priming of bonding surface before they can be applied.

Limited shelf-life requires storage, and sometimes application under controlled low temperatures.

CURING OF THE ASSEMBLY

Pre-Cure and Drying

In the case of solvent type adhesives or primed surfaces, air- and/or force-drying may be necessary to remove volatiles from the coating before the parts can be assembled and cured.

Solvents entrapped in adhesive layers between nonporous surfaces will cause bubbling and prevent the formation of satisfactory bonds between the adherent surfaces. Most solvents used in solvent-type adhesives and primers are flammable and therefore require drying for at least thirty minutes at room temperature before force-drying in ovens at elevated temperatures.

Air-circulating ovens which distribute heat evenly across surfaces are safest and should be used whenever possible. Thermostatic control is necessary in all cases in order to avoid temperatures from passing permissible limits. In force-drying thermosetting adhesive coats, prescribed temperatures must be rigidly adhered to, so as to prevent resin from setting prematurely.

Unless parts are especially pre-cured for storage and future assembly, surfaces should be mated as soon as possible after drying to prevent contamination by dust, dirt or handling.

Curing Cycle

The curing cycle is based on a time-temperature-pressure relationship during which thermosetting adhesives undergo three distinct changes:

A-Stage. This phase is characterized by an initial lowering or viscosity during which the resin is subject to flow. The amount and type of pressure applied during this stage exerts a definite influence upon the formation and thickness of the glue line.

Depending upon the kind of materials and surfaces to be bonded and the type and viscosity of adhesive, pressures vary from those provided by mere contact to several hundred pounds per square inch.

Whereas adhesives which are suitable for bonding with light contact pressure may be squeezed out under heavier loads, others may form weak or spongy bonds due to either shrinkage or bubbling, unless they are cured under considerable pressure.

Pressures on dry-form adhesive layers (tapes, etc.) are particularly critical since complete wetting of the bonding surfaces depends on a sufficient amount of pressure at recommended temperatures.

Besides the curing properties of the adhesive itself, other factors such as the possibility of partial absorption of the adhesive by porous surfaces can make higher pressures mandatory.

B-Stage. This transitional phase is characterized by a marked increase of viscosity. Polymerization progresses with increasing speed and the resin is in a state of gelation. Pressure must be maintained.

C-Stage. In this final phase, polymerization is complete and the adhesive has become relatively infusible and cured to what may be a rigid, semirigid, flexible or rubbery type bond. Pressure can be released.

Devices for maintaining uniform pressure include: autoclaves, vacuum bags, laminating presses, spring-loaded belts, clamps, cushioned pads, plates, or simple weights. In structural bonding, stacking is not recommended since pressure on items at the top is less than on those at the bottom.

Curing temperatures for thermosetting adhesives are possible from below room temperature to approximately 600°F.

The temperatures necessary to polymerize the adhesive depend upon its composition particularly the type and percentage of curing agent used.

Room temperature curing adhesives may set within an hour at which time bonded parts can be safely handled. But full bond strength is not usually developed until five to seven days. Most of the room temperature curing compositions attain 60-85 per cent of their ultimate strength within the first 24 hours, after which the curing rate is considerably slower, requiring several days to completion of the cycle.

Heat cures require close control of temperatures and frequently also of the rate at which they must be increased until proper curing temperature has been reached. Special cooling rates may also be recommended by manufacturers.

The purpose of these controls is to prevent development of stresses within the adhesive layer by rapid curing or cooling. These are particularly apt to appear in rigid-type bonds. Controls will also deter possible weakening of bonds between materials with different coefficients of expansion.

Where equipment is not adapted for the control of gradual increases in temperature, the bond should at first be allowed to cure partly at room or slightly elevated temperatures and post-cured afterwards at high temperatures. Flexibilized or elastomeric adhesive compositions do not usually require precautions of this type.

Heat curing operations can be performed under infrared lamps, between hot platens of laminating presses, in laboratory-type or conveyortype ovens. Whichever method is used, temperatures at the glue line must be uniform. For this reason, air-circulating ovens are preferable to ordinary types where parts placed at various distances from heating elements will develop different glue-line temperatures. The curing temperatures recommended by manufacturers are glue-line temperatures, therefore, in curing larger pieces, additional time should be allowed for the bonding area to reach the necessary temperature.

Some adhesives are compounded with temperature indicators which change color when the proper curing temperature has been reached. If necessary, temperatures can be checked easily by application of indicator crayons, such as "Tempilstiks," to the glue line area.

Curing by dielectric heating is sometimes used on assemblies which can absorb energy from a rapidly alternating electromagnetic field. Energy is developed within the dielectric materials by molecular action.

Where this method can be used it offers the advantage of fast and uniform heating since heat transfer does not depend on conduction.

Whatever heat curing methods are used, parts should be allowed to cool gradually upon completion of cure to avoid thermal shock to the bond.

6. ADHESIVES IDENTIFICATION AND PROPERTIES CHART

The number of adhesives in this chart is but a small percentage of the products available in this field. Because of space limitations, it was impossible to list the complete line of each manufacturer.

The data contained in the various columns are based on information disseminated by the individual manufacturer and believed to be accurate. It should be pointed out, however, that all manufacturers of adhesives disclaim responsibility for the results obtained by the user, who should conduct his own tests to determine the suitability of these materials for his particular purpose. Since the performance of adhesives depends upon the conditions of use, such as humidity, skill of application, etc., diffierences in results from those given here are possible.

EXPLANATION OF INFORMATION LISTED

Column 1: KEY: The purpose of the key number is:

(a) to identify the adhesives for applications listed in the ALPHABETICAL CROSS-REFERENCE INDEX OF SPECIFIED STRUCTURAL BONDS AND LISTED ADHESIVES and

(b) to identify manufacturers of those adhesives in numerical sequence in Part B of the DIRECTORY OF ADHESIVE AND EQUIPMENT MANUFACTURERS.

Column 2: DESIGNATION of ADHESIVE: Lists manufacturers' trade designation of adhesive in alphabetical and numerical sequence.

Column 3: TYPE or BASE: The information given here is not necessarily complete. Many manufacturers do not wish to reveal the exact composition of their product. The listing "epoxy" may mean epoxy-phenolic, epoxy-polyamide, etc. A few give only the type in general terms, such as "resin-elastomer," etc.

Column 4: NUMBER of COMPONENTS: Besides resins and curing agents, primers are counted as additional components.

Column 5: FORM, VISCOSITY or CONSISTENCY: This is given at room temperature (68°-86°F) and stated in terms of approximate cps where information was available. Unless otherwise indicated, viscosities given for two-component materials refer to the unmixed resin only.

Column 6: COLOR: Information given where available.

Column 7: APPLICATION METHOD: Methods listed are not necessarily the only ones that can be used. Many of the adhesives for which manufacturers have suggested manual application methods can also be applied by mechanical equipment. Nevertheless, manufacturers should be consulted before using methods other than those listed.

Column 8: WORK LIFE of ADHESIVES: "Work Life" is to be read as "Pot Life" for two-component materials and "Shelf Life" in the case of pre-mixed one-component adhesives. Unless stated otherwise "Pot Life" is given for mixtures ranging approximately between 50-150 grams at room temperature (68°-86°F). "Shelf Life" is given in terms of specific periods, and temperatures in most cases. Where not stated, it is at room temperature.

Column 9: TYPICAL CURING CYCLE or RANGE: Temperatures indicated are glue line temperatures. Additional time may be necessary for glue line in large assemblies to arrive at them. Range (from-to) indicates that adhesive may be cured anywhere between the longest and the shortest cycle given. Schedules of in-between curing cycles can be obtained from manufacturers. It should also be noted that:

or—indicates alternate cure for same mixture.

OR—indicates alternate cure for same base resin with different curing agent.

Column 10: PRESSURE REQUIRED: Types and amount of pressure indicated except in a few cases where information was not specifically stated.

Column 11: TYPICAL SHEAR STRENGTH (LB/PSI) of CURED BOND and TEMPERATURE AT TIME OF TEST: Data pertaining to shear strength are based on test results obtained by individual manufacturers. Although the results of shear strength tests are of major importance in assessing the bond strength of structural adhesives, it must be realized that the data given here were not obtained under uniform conditions. Since there are differences in preparation of bonding surfaces, application techniques and test methods employed, these data should not be used for purposes of making qualitative comparisons between the adhesives but should serve rather as an indication of the general strength category within which they fall. Information regarding the type of specimen, material, and cure has been stated wherever available.

Column 12: MAIN USES, SPECIAL PROPERTIES, GENERAL INFORMATION: Because it is in condensed form, the range of possibilities is limited to the most important points. It remains for the potential user to get additional information from the manufacturer and to determine the suitability of the material for his own uses by individual tests.

ABBREVIATIONS USED IN ADHESIVES IDENTIFICATION AND PROPERTIES CHART

Al	aluminum
aver	average
applic	application(s)
approx	approximate (or approximately)
betw	between
chem	chemical
conc	concentrated
const	construction
Cop	copper
cur agt	curing agent
dep	depending
dil	diluted
elec	electrical
fr	from
hr	hour(s)
incl	including (or inclusive)
Magnes	magnesium
manuf	manufacture (ed, er)
mat	material
max	maximum
med	medium
min	minute(s)
mo or mos	month(s)
N.S.	not stated
recom	recommended
refrig	refrigerated (or refrigeration)
req	requirements
resist	resistance
r.t.	room temperature
sec	second(s)
serv	service
spec	specification(s)
Stain	stainless steel
St	steel
surf	surface
temp	temperature
ult	ultimate
visc	viscosity
with.	within

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
1	A-1	Epoxy	2	Paste	Reddish brown	Spatula Trowel Knife	30 min to 3 hrs depending on choice of curing agent (see under Main Uses)
2	A-2	Epoxy	2	Paste	Light gray	Spatula Trowel Knife	30 min to 3 hrs depending on choice of curing agent (see under Main Uses)
3	A-3	Epoxy	2	Paste	Black	Spatula Trowel Knife	30 min to 3 hrs depending on choice of curing agent (see under Main Uses)
4	A-4	Epoxy	2	Paste	Aluminum gray	Spatula Trowel Knife	30 min to 3 hrs depending on choice of curing agent (see under Main Uses)
5	A-5	Epoxy	2	Paste	Aluminum	Spatula Trowel Knife	30 min to 3 hrs depending on choice of curing agent (see under Main Uses)
6	A-6	Epoxy	2	Paste	Dark gray	Spatula Trowel Knife	30 min to 3 hrs depending on choice of curing agent (see under Main Uses)
7	A-12	Epoxy	2	Paste	*Resin:* Reddish brown *Cur Agt:* Gray	Spatula Trowel Knife	90 min

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 6 days @ r.t. To: 20 min @ 250°F dep on choice of curing agent (see under Main Uses)	Contact Clamping	Al/Al 2350 @ temp N.S. St/St 3350 @ temp N.S. (1″ wide specimens—½″ overlap)	Metals, wood, glass, hard rubber, ceramics & thermosetting plastics. Applic like st/tungsten carbide, polyester/wood, phenolic laminated wear plates/cast iron. Bond rigid. Flexibilizer available. Choice of 3 cur agts to meet specific pot life & cur temp requirements.
FROM: 6 days @ r.t. To: 20 min @ 250°F dep on choice of curing agent (see under Main Uses)	Contact Clamping	Al/Al 2400 @ temp N.S. St/St 3600 @ temp N.S. (1″ wide specimens—½″ overlap)	As A-1, with electrical resistance properties. Good resistance to weather, most chemicals, acids & alkalis. Specially recommended for ceramics, porcelain, glass.
FROM: 6 days @ r.t. To: 20 min @ 250°F dep on choice of curing agent (see under Main Uses)	Contact Clamping	As A-1	As A-1.
FROM: 6 days @ r.t. To: 20 min @ 250°F dep on choice of curing agent (see under Main Uses)	Contact Clamping	Al/Al 2550 @ temp N.S. St/St 2300 @ temp N.S. (1″ wide specimens—½″ overlap)	Aluminum alloys or other rigid materials as listed under A-1. High viscosity makes it useful for bonding vertical surfaces. Choice of curing agt as under A-1.
FROM: 6 days @ r.t. To: 20 min @ 250°F dep on choice of curing agent (see under Main Uses)	Contact Clamping	Al/Al 2000 @ temp N.S.	Aluminum/aluminum or other materials when bond having soldered appearance is required. Choice of two cur agts to meet specific pot life and cur temp requirements.
FROM: 6 days @ r.t. To: 20 min @ 250°F dep on choice of curing agent (see under Main Uses)	Contact Clamping	Al/Al 3070 @ 77°F Al/Al 2460 @ 180°F Al/Al 2940 @ −70°F (1″ wide specimens—½″ overlap)	Designed primarily for bonding aluminum to itself or to most other rigid materials; also for copper & copper alloys and materials listed under A-1. Resistant to impact, moisture, most solvents, petroleum products & fungus. Choice of two curing agts to meet specific pot life and curing temp requirements.
FROM: 48 hrs @ r.t. To: 10 min @ 300°F	Contact Clamping	Al/Al 3300 @ r.t. Al/Al 875 @ 250°F St/St 3600 @ r.t. (1″ wide specimens—½″ overlap)	Versatile adhesive for bonding most rigid materials as listed under A-1. Flexibility of bond can be adjusted by changing ratio of components in mixture. Curing agt serves as modifier. Different colors of components simplify proper mixing. Minimum toxicity in handling.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
8	A-12 T	Epoxy	2	Paste, thixotropic	*Resin:* Reddish brown *Cur Agt:* Gray	Spatula Trowel Knife	90 min
9	APCO #1252	Polyurethane	2	Liquid	Amber, pale	Roller Brush Spray	6 hrs
10	BOND-MASTER M 611	Modified Epoxy	2	Heavy paste	Gray, opaque	Spatula Trowel Knife	3 hrs
11	BOND-MASTER M 620	Modified Epoxy	1	Thixotropic paste, buttery	Light tan, opaque	Spatula Trowel Knife Roller	At least one year
12	BOND-MASTER M 648	Modified Epoxy	2	Medium visc 25,000-35,000 cps	Pale amber, clear	Spatula Trowel Knife Brush	20 to 45 min
13	BOND-MASTER M 648 T	Modified Epoxy	2	Free-flowing. About 10,000 cps, mixed	Pale amber, clear	Spatula Trowel Knife Roller Brush	20 to 45 min
14	BOND-MASTER M 654	Modified Epoxy	2	Heavy paste, approx 150,000 cps	Gray	Spatula Trowel Knife	20 to 45 min

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 48hrs @ r.t. To: 10 min @ 300°F	Contact Clamping	Similar to A-12	As A-12. Consistency tends to eliminate running of adhesive when applied to sloping surfaces.
Air dry 20-30 min @ r.t. Assembly: 6 hrs @ 150-180°F or 45 min @ 300°F (r.t. cure possible in 3 days–3 weeks)	5-500 psi	St/St 3100 @ r.t. Al/Al 3500 @ r.t. Copper/Copper 2300 @ r.t. Beryllium/Stain 2500 @ r.t. 45 min cure @ 300°F (1″ wide specimens—½″ overlap)	Metal/metal including steel, aluminum, magnesium, stainless, beryllium, copper, uranium, etc. Also elastomers and plastics, including rigid vinyl chloride, nylon, etc. Also ceramics, wood and foams. Resistant to acid, alkalis, most solvents including gasoline, oil and aliphatic compounds. Shock resistant bond. Serv temp from −200°F to 200°F.
2½ hrs @ 330° to 340°F	Contact Clamping	Al/Al 3800 @ r.t. (1″ wide specimens—½″ overlap)	Metals & other rigid materials to themselves & to each other. Qualified under MIL-A-5090 B spec if used with primer M 602 for added peel strength. Aircraft applic & sandwich construction.
FROM: 5 hrs @ 300°F To: 7 min @ 535°F	Contact Clamping	Al/Al 2200 @ r.t. (1″ wide specimens—½″ overlap)	Metals & rigid materials, such as glass, ceramics, plastics, plastic foams & structural laminates to themselves & to each other. Does not flow during cure cycle. For poor fit & void filling applic. Resistant to weather, galvanic action—most chemicals, acids & alkalis.
FROM: 7 days @ r.t. (85% of ult strength in 24 hrs) To: 10 min @ 250°F	Contact Clamping	Al/Al 5000 @ r.t. (1″ wide specimens—½″ overlap)	Materials as listed under BONDMASTER M 620. Available with two curing agts for either general purpose properties or added impact & peel strength. Chem resist as BONDMASTER M 620.
FROM: 7 days @ r.t. (85% of ult strength in 24 hrs) To: 10 min @ 250°F	Contact Clamping	Al/Al 5000 @ r.t. (1″ wide specimens—½″ overlap)	Lower viscosity version of BONDMASTER M 648.
FROM: 7 days @ r.t. (85% of ult strength in 24 hrs) To: 10 min @ 250°F	Contact Clamping	Al/Al 3200 @ r.t. (1″ wide specimens—½″ overlap)	For bonding materials as listed under BONDMASTER M 620 as well as treated Kel-F plastic. Recommended for poor fit & void filling applic. Available with two curing agts for either general purpose properties or added peel strength. Chem resist as BONDMASTER M 620.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
15	BOND-MASTER M 685	Modified Epoxy	2	Free-flowing 2000 to 6000 cps	Pale, amber, clear	Spatula Trowel Knife Roller Brush	45 to 90 min
16	BOND-MASTER M 686	Modified Epoxy	2	Buttery, Thixotropic	Light tan, opaque	Spatula Trowel Knife	30 to 45 min
17	BOND-MASTER M 688	Epoxy	2	Buttery, Thixotropic	Light tan, opaque	Spatula Trowel Knife	45 min to 6 hrs
18	BOSTIK #7026	Synthetic resin (solvent type)	1	Liquid, 2000-3500 cps	Amber	Brush Knife Spatula Pressure gun	12 mos below r.t.
19	BR-92	Epoxy	2	75,000-120,000 cps	Green, light	Spatula Trowel	3 hrs
20	BR-95	Epoxy	2	Paste, thixotropic	Green, light	Spatula Trowel	30 min
21	CARBO-LINE 4-EP	Epoxy	2	Liquid, low to med visc	Tan, opaque	Brush Spray Dip Glue spreader	2 hrs

Typical Curing Cycle or Range	Pressure Required	Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test	Main Uses Special Properties General Information
FROM: 7 days @ r.t. (85% of ult strength in 24 hrs) To: 10 min @ 250°F	Contact Clamping	Al/Al 2000 @ r.t. (1″ wide specimens—½″ overlap)	Designed for bonding rigid plastic foams to themselves or to metal & other rigid skins. Available with two curing agts for modification of pot life.
FROM: 7 days @ r.t. (85% of ult strength in 24 hrs) To: 10 min @ 250°F	Contact Clamping	Al/Al 2000 @ r.t. (1″ wide specimens—½″ overlap)	Designed for materials listed under BONDMASTER M 685. Does not flow during curing cycle. For poor fit & void filling applic. Can be used with either of three curing agents depending on pot life, curing cycle or type of bond strength desired.
FROM: 7 days @ r.t. (85% of ult strength in 24 hrs) To: 10 min @ 250°F	Contact Clamping	Al/Al 2800 @ r.t. (1″ wide specimens—½″ overlap)	For bonding materials listed under BONDMASTER M 620. Does not flow during curing cycle. For poor fit & void filling applic. Can be used with any of five curing agts depending on pot life, curing cycle & type of bond strength desired. Chem resist as BONDMASTER M 620.
Air dry 1 hr @ r.t. plus 7-18 min @ 300-400°F Assembly: 11-18 min @ 300-400°F	Up to 250 psi	Al/Al 4950 @ 75°F, Al/Al 2730 @ 160°F, Al/Al 2820 @ −70°F (cured at 400°F) (1″ wide specimens—½″ overlap)	Metals, glass, ceramics, phenolics, urea, melamine plastics. Used in: manuf. of switch and contact assemblies, speaker coils, and general purpose applic in electrical assemblies. Can be reactivated before cure by heat, alcohol or MEK. Resistant to vibration, water and gasoline. Serv temp up to 250°F.
2 hrs @ 165°F or 90 min @ 200°F	Contact	Al/Al 4300 (aver) @ betw 70-80°F Al/Al 3200 (aver) @ betw 178-182°F Al/Al 750 (aver) @ betw 298-302°F Al/Al 2600 (aver) @ betw −98°F to −102°F (½″ overlap)	Aluminum alloys, steels, fibreglass laminates, rubbers & other materials. Resistant to salt spray and high humidity conditions.
1-2 hrs @ 150°F	Contact	Mat. N.S. 3950 @ r.t. 4700 @ 165°F	Thixotropic modification of BR-92. Compounded especially to prevent sagging or running of relatively thick layers of adhesive during curing cycle. Same resistance properties as BR-92. Bonds same materials as BR-92.
FROM: 24-49 hrs @ r.t. To: 1 hr @ 225°F	N.S.	Mat. N.S. 2200 @ r.t.	Steel, aluminum, ceramics, cork, wood and concrete. Resistant to water, acids, alkalis, salts and solvents. Serv temp up to 250°F.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
22	CARBO-LINE 192	Modified Epoxy	2	Liquid	Brick red	Brush Spray Roller	2 hrs
23	CHEMO-TEC 702	Epoxy	1	Paste	Silver	Spatula	6 mos @ 70-75°F
24	CHEMO-TEC 703	Epoxy	1	Liquid, low visc	Silver	Brush Spray Roller Dip	6 mos @ 70-75°F
25	CHEMO-TEC 722	Epoxy	1	Paste	Neutral, opaque	Spatula	6 mos @ 70-75°F
26	CHEMO-TEC 723	Epoxy	1	Liquid, low visc	Neutral, opaque	Brush Spray Roller Dip	6 mos @ 70-75°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
15-45 min @ 70-90°F or 30-60 min @ 50-70°F	Contact	Stronger than concrete	Bonding new concrete to old. Not recommended for old concrete soaked with oil and grease that cannot be cleaned properly. Serv temp up to 200°F (continuous) and 280°F (intermittent).
FROM: 24 hrs @ 250°F To: 15 min @ 450°F	Contact Jigs	Al/Al 8100 @ r.t. St/St 6950 @ r.t. Stain/Stain 7600 @ r.t. Copper/Copper 7000 @ r.t. Bronze/Bronze 7500 @ r.t. Brass/Brass 6500 @ r.t. (overlap to thickness ratio 5:1)	Ferrous & nonferrous metals, such as steel, stainless, aluminum, copper alloys, titanium, magnesium, tungsten carbide & zinc. Also glass, graphite, asbestos & ceramics. Serv temp from –20°F to 250°F. Applic as bonding tungsten carbide, sintered tubes/alloy carbon shanks, Alnico/copper or steel in magnetic chucks, etc. Resist to weather, galvanic action & most solvents, conc alkalis & dil acids.
FROM: 24 hrs @ 250°F To: 15 min @ 450°F	Contact Jigs	Similar to CHEMOTEC 702 (overlap to thickness ratio 5:1)	Ferrous & nonferrous metals, such as steel, stainless, aluminum, copper alloys, titanium, magnesium, tungsten carbide & zinc. Also glass, graphite, asbestos & ceramics. Serv temp from –20°F to 250°F. Applic as bonding tungsten carbide, sintered tubes/alloy carbon shanks, Alnico/copper or steel in magnetic chucks, etc. Resist to weather, galvanic action & most solvents, conc alkalis & dil acids.
FROM: 24 hrs @ 250°F To: 15 min @ 450°F	Contact Jigs	Similar to CHEMOTEC 702 (overlap to thickness ratio 5:1)	Ferrous & nonferrous metals, such as steel, stainless, aluminum, copper alloys, titanium, magnesium, tungsten carbide & zinc. Also glass, graphite, asbestos & ceramics. Serv temp from –20°F to 250°F. Applic as bonding tungsten carbide, sintered tubes/alloy carbon shanks, Alnico/copper or steel in magnetic chucks, etc. Resist to weather, galvanic action & most solvents, conc alkalis & dil acids.
FROM: 24 hrs @ 250°F To: 15 min @ 450°F	Contact Jigs	Similar to CHEMOTEC 702 (overlap to thickness ratio 5:1)	Ferrous & nonferrous metals, such as steel, stainless, aluminum, copper alloys, titanium, magnesium, tungsten carbide & zinc. Also glass, graphite, asbestos & ceramics. Serv temp from –20°F to 250°F. Applic as bonding tungsten carbide, sintered tubes/alloy carbon shanks, Alnico/copper or steel in magnetic chucks, etc. Resist to weather, galvanic action & most solvents, conc alkalis & dil acids.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
27	CHEMO-TEC 802	Epoxy	2	Paste, 615,000 cps (mixed)	Silver	Spatula	1-2 hrs
28	CHEMO-TEC 803	Epoxy, (solvent containing)	2	Liquid, 500 cps (mixed)	Silver	Brush Roller Dip	2-4 hrs
29	CHEMO-TEC 804	Epoxy, (solvent containing)	2	Liquid, 120 cps (mixed)	Silver	Spray	4-8 hrs
30	CHEMO-TEC 805	Epoxy	2	Liquid, 10,000 cps (mixed)	Silver	Brush Roller	2-4 hrs
31	CHEMO-TEC 822	Epoxy	2	Paste, 615,000 cps (mixed)	Neutral opaque	Spatula	1-2 hrs
32	CHEMO-TEC 823	Epoxy, (solvent containing)	2	Liquid, 500 cps (mixed)	Neutral opaque	Brush Roller Dip	2-4 hrs
33	CHEMO-TEC 824	Epoxy, (solvent containing)	2	Liquid, 120 cps (mixed)	Neutral opaque	Spray	4-8 hrs
34	CHEMO-TEC 825	Epoxy	2	Liquid, 10,000 cps (mixed)	Neutral opaque	Brush Roller	2-4 hrs

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
24 hrs @ r.t.	Contact Jigs	Al/Al 2000-2500 @ r.t. (1″ wide specimens—½″ overlap)	Particularly suitable for small porous or nonporous surfaces. Neoprene & natural rubber to copper, aluminum & steel, aluminum to itself, etc. Resistant to weather, galvanic action, most chemicals, acids & alkalis. Electrical insulating properties. Serv temp from −20°F to 250°F.
72 hrs @ r.t.	Contact Jigs	Al/Al 1700-2000 @ r.t. (1″ wide specimens—½″ overlap)	Applicable to small & large surfaces. Recommended for applic in which at least one of the parts is porous to permit escape of solvent. Metal to wood, metal to brick, metal to tile lining, etc. Physical & chemical properties as in CHEMOTEC 802. Serv temp from −20°F to 250°F. Used for attaching transite table tops to tables, etc.
72 hrs @ r.t.	Contact Jigs	Al/Al 1500-1800 @ r.t. (1″ wide specimens—½″ overlap)	As CHEMOTEC 803 in applic where spraying is preferred. Chem resist as CHEMOTEC 802.
24-72 hrs @ r.t.	Contact Jigs	Al/Al 2000-2500 @ r.t. (1″ wide specimens—½″ overlap)	Applicable to small & large porous & nonporous surfaces. Metal to glass & tile, stainless steel sheets to carbon steel, steel to brass, etc. Physical & chemical properties as in CHEMOTEC 802. Serv temp from −20°F to 250°F. Used in "cladding" stainless steel sheets to carbon steel in elevator doors, attaching steel inserts to brass door knobs, etc.
24 hrs @ r.t.	Contact Jigs	Al/Al 2000-2500 @ r.t. (1″ wide specimens—½″ overlap)	As CHEMOTEC 802.
72 hrs @ r.t.	Contact Jigs	Al/Al 1700-2000 @ r.t. (1″ wide specimens—½″ overlap)	As CHEMOTEC 803.
72 hrs @ r.t.	Contact Jigs	Al/Al 1500-1800 @ r.t. (1″ wide specimens—½″ overlap)	As CHEMOTEC 804.
24-72 hrs @ r.t.	Contact Jigs	Al/Al 2000-2500 @ r.t. (1″ wide specimens—½″ overlap)	As CHEMOTEC 805.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
35	CONCRESIVE #1	Epoxy polysulfide	2	Liquid	Sand	Brush Trowel Knife Pressure gun	20-30 min
36	CYCLE-WELD C-3-S-25 and CYCLE-WELD C-3-S-50	Solvent type, base N.S.	1	Liquid Low viscosity (C-3-S-50)	Black	Brush Spreader Spray (C-3-S-50)	8-10 mos @ 55-60°F
37	CYCLE-WELD C-6	Solvent type, base N.S.	1	Gel	Amber	Brush Roller	8-10 mos @ 55-60°F
38	CYCLE-WELD C-14	Epoxy	2	Liquid	Amber	Spatula Brush	30-45 min
39	CYCLE-WELD H-2-P and CYCLE-WELD H-2-S	Solvent type, base N.S.	1	Paste Liquid, low visc (H-2-S)	Black	Spatula Extruder Roll coater Spray (H-2-S)	60 days @ r.t.
40	CYCLE-WELD 55-9 CYCLE-WELD 55-9-100 and CYCLE-WELD 55-10-S	Thermosetting N.S.	1	Liquid	Amber	Brush Roller (55-9-100) Spray (55-10-S)	8-10 mos @ 55-60°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 3 days @ r.t. To: 20 min @ 150°F	Contact	Concrete/Concrete 3650 @ 80°F (3 day cure) Concrete/Concrete 4250 @ 80°F (28 day cure)	Concrete to metal, glass, wood, ceramics and to itself (including old to new). Serv temp from −70°F to 350°F. Resistant to water, gasoline, fuel, lubricating oils, and hydrocarbon fluids.
Air dry 15 hrs @ r.t. or 30 min @ r.t. plus 20 min @ 180°F Assembly: 20 min @ 325°F or 15 min @ 350°F	200-300 psi	Mat. N.S. 2800-3000 @ r.t. (75% strength increase @ −70°F)	Metals, wood, thermosetting plastics, ceramics and fibrous materials to themselves and to each other. Good resistance to vibration fatigue, weathering, fungus and mite corrosion. Not recommended for continuous use over 300°F.
Air dry 15-20 min @ r.t. plus 30-45 min @ 170-180°F Assembly: 15 min @ 325°F or 30 sec @ 400°F	25-400 psi	Mat. N.S. 2400-3200 @ r.t.	Metals, wood, thermosetting plastics, ceramics and fibrous materials to themselves and to each other. Resistant to nuclear radiation. Recommended for bonding type metal to aluminum or magnesium. Serv temp from −70°F to 200°F. Must be liquefied in double boiler @ 180°F before applic.
6 days @ r.t. (60% of ult strength in 18 hrs) or 20-30 min @ 170-180°F	Contact	Al/Al 3000 @ r.t.	Metals, wood, phenolic laminates, glass and rubber to themselves and to each other. Specially useful for end grain Formica in machine ways. High capillary attraction, no shrinkage, good sealing properties. Serv temp from −70°F to 160°F.
Air dry 15 min @ r.t. plus 30 min @ 170-180°F or Heat gradually from 100-180°F in 20 min Assembly: 15-20 min @ 325-350°F	100-200 psi	Mat. N.S. 1800-2000 @ r.t.	Metals to friction materials (brake linings, clutch facings, transmission bands). Recommended for metal to metal bonding for high temp resistance. Linings can be pre-coated and stored for 1 year at temp of 100°F or below. Serv temp up to 500°F.
Air dry 1 hr @ r.t. plus 20 min @ 200-220°F Assembly: From 20 min @ 310°F To 10 min @ 325°F	50-200 psi	Mat. N.S. 3200-3500 @ r.t. (75% strength increase @ −70°F)	Metals, rubbers and synthetics except Thiokol; wood, ceramics, thermosetting plastics and fibrous materials to themselves and to each other. Recommended for veneer and heat resistant core materials to metals. Not recommended for continuous use over 250-270°F.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
41	DURO-LOK 2001	Vinyl-phenolic (emulsion type)	1	Fluid, approx 700 Stormer grams LP-100 rpm	Blue-gray	Roller Trowel Brush (Spray, if thinned)	3 mos @ 50-75°F
42	DURO-LOK 41-1001	Epoxy	2	Paste, thixotropic	Gray-white	Spatula Trowel Knife	1 hr
43	DURO-LOK 41-2003	Vinyl-phenolic (emulsion type)	1	Fluid, 5000-8000 cps (approx)	Blue-gray	Brush Roller Spray	3 mos @ 50-70°F
44	DURO-LOK 76-4601	Vinyl-phenolic (emulsion type)	1	Fluid, 3000 cps (approx)	N.S.	Roller Spray Roll coater	3 mos @ 72°F (approx)
45	EASTMAN 910	Cyano-acrylate	1	Liquid, low visc, approx 100 cps	Clear, colorless	Dropper Flow-on Spatula	6 mos to a year. Storage @ 40-45°F recommended.

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
Wet bonding: 4-6 days @ 90-120°F Hot (dry) bonding: Oven dry 2-6 min @ 140-180°F and bond while hot and tacky under 100 lbs/ linear inch pressure.* Heat reactivation: Air or oven dry (approx 4 min @ 150°F); reactivate @ 150-180°F and bond while hot and tacky under pressure.*	Wet bond: 30-60 psi Hot (dry): 100 lbs/ linear inch Heat react: max within limits of materials	Al/Al 2500 (aver) @ r.t. (10 min cure @ 200°F)	Particularly suited for bonding nonporous surfaces, such as metals, to porous types, such as wood, insulating board, etc. Sandwich type constructions, such as, polystyrene foam to metal and other nonporous materials. Offers versatility in applic methods. Can be diluted with water.
7 days @ 75°F or 1 hr @ 200°F	Contact	Al/Al 3070 @ 75°F Al/Al 2440 @ 180°F	For general purpose applic. Aluminum, steel, rubber, concrete, foam and fibreglass, polystyrene foam, asbestos board, wood and honeycomb applic. Passes Mil Specs 5090-B, A-8331, A-8623. Serv temp up to 180°F approx.
8-24 hrs @ r.t. plus 15 min @ 300°F	Non-porous material: Contact Porous material: 30-100 psi	Al/Al 2000 (approx) @ r.t.	Specially suited for bonding steel-honeycomb partitions for interior use and a variety of surfaces. Metal skins to paper honeycombs. Serv temp up to 180°F approx.
8-24 hrs @ r.t. plus 15 min @ 300°F	Non-porous material: Contact Porous material: 30-100 psi	Al/Al 2000 (approx) @ r.t.	Steel-honeycomb-steel const, steel partitioning, assemblies. Aluminum or steel skins to foam or paperbacked honeycomb. Serv temp up to 150°F approx.
Sets at r.t. within 30 sec to 8 min. Metals: Ult strength after 2-3 days @ r.t. Rubber: Ult strength with. 30 sec to 5 min @ r.t.	Approx 10 psi (Manual or mechanical pressure)	St/St 3500 @ r.t. (after 48 hrs @ r.t.) Al/Al 2500 @ r.t. (after 48 hrs @ r.t.) Copper/Copper 3000 @ r.t. (after 6 days @ r.t.)	Metals, rubbers, wood, glass and plastic. Adhesive sets on applic of manual or mechanical pressure within seconds or minutes depending on materials with increase in bond strength on aging, except in atmospheres of high humidity. Serv temp from −65°F to 176°F. Rigid bond. Resist to solvents.

* Can be further cured by aging 4-6 days @ 90-120°F.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
46	EC-1386	Epoxy	1	Paste, flowable	Light cream	Spatula Trowel Knife Flowing into place	1 yr, approx
47	EC-1469	Epoxy	1 or 2	Paste, flowable	White (Catalyst, if used, is Yellow)	Spatula Trowel Knife Flowing into place	*Without catalyst:* requires storage @ 45°F or below. Shelf life N.S. *Mixed with catalyst:* 4 hrs
48	EC-1471	Modified phenolic	1	Thin syrup	Pale amber	Brush	1 yr
49	EC-1472/ EC-1473	Epoxy	2	Syrup, medium visc	*Resin:* Yellow *Cur agt:* Pink	Spatula Trowel Knife Flowing into place	1 hr @ 80°F in water bath
50	EC-1751/ EC-1752	Epoxy	2	Paste	*Resin:* Aluminum *Cur agt:* Amber	Spatula Trowel Knife Extruder Caulking gun Pressure gun	45 min, 1 lb mass

Typical Curing Cycle or Range	Pressure Required	Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test	Main Uses Special Properties General Information
1 hr @ 350°F	25-50 psi	Al/Al 4670 @ r.t. Al/Al 4630 @ 180°F Al/Al 2620 @ 250°F Al/Al 2910 @ −65°F (1″ wide specimens—½″ overlap)	Bonding metal to metal, such as brass, steel, aluminum & for other impervious surfaces. Flexible bond with good bend strength. For industrial & aircraft applic.
Without catalyst: 1 hr @ 350°F *With catalyst:* 90 min @ 200°F	25-50 psi	without catalyst: Al/Al 2950 @ r.t. Al/Al 3800 @ 180°F Al/Al 3660 @ 250°F Al/Al 2760 @ 300°F Al/Al 2620 @ −65°F with catalyst: Al/Al 2365 @ r.t. Al/Al 2650 @ 180°F Al/Al 2880 @ 250°F Al/Al 1480 @ 300°F Al/Al 1840 @ −65°F (1″ wide specimens—½″ overlap)	Metal to metal bonding, brass, steel, aluminum. For use in metal-to-metal honeycomb sandwich structures. Has self-filleting properties. Can be used with or without catalyst. Serv temp from −65°F to 300°F. Resist to salt spray, water, JP-4, anti-icing, hydraulic & hydrocarbon fluid.
Air dry 30 min @ r.t. plus 20 min @ 250°F Assembly: 1 hr @ 350°F	150 psi	Al/Al 4978 @ r.t. Al/Al 3923 @ 180°F Al/Al 2710 @ −67°F (1″ wide specimens—½″ overlap)	Honeycombs and metal to metal panels. Good filleting properties and peel strength. Serv temp from −65°F to 180°F.
7 days @ room temp OR 30 min @ 200°F	Contact Clamping	7 day cure @ room temp: Al/Al 3430 @ r.t. Al/Al 2030 @ −65°F 30 min @ 200°F cure: Al/Al 1770 @ r.t. Al/Al 3745 @ −65°F (1″ wide specimens—½″ overlap)	Flexible bond. Good peel strength at low and room temp. Not to be used in applic where temp above 120°F are encountered.
FROM: 2 to 3 days @ 75°F To: 1½ min @ 400°F	10 psi	48 hr cure @ 75°F: Al/Al 2300 @ 75°F Al/Al 800 @ 180°F Al/Al 1400 @ −67°F 72 hr cure @ 75°F: Al/St 2160 @ 75°F Al/Cop 2570 @ 75°F Cop/St 2245 @ 75°F St/St 2440 @ 75°F 2 hr cure @ 150°F: Al/Al 2400 @ 75°F Al/Al 800 @ 180°F Al/Al 1400 @ −67°F (1″ wide specimens—½″ overlap)	Bonds to metals including aluminum and steel, also to plastics, such as nylon, glass reinforced laminates of epoxy or polyester resins, and to porous surfaces, such as wood and concrete. This product has nonsag properties. For use as adhesive and/or void filler.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
51	EC-1838 B/A	Epoxy	2	Paste	*Resin:* White *Cur agt:* Green	Spatula Trowel Knife Extruder Caulking gun Pressure gun	45 min, 1 lb mass
52	EC-2054 B/A	Epoxy	2	Paste	*Resin:* Aluminum *Cur agt:* Amber	Spatula Trowel Knife Extruder Caulking gun Pressure gun	1 hr, 1 lb mass
53	ECCO-BOND 45	Epoxide	2	Medium visc, 40,000 cps (mixed)	Black	Brush Knife Roller	3 hrs
54	ECCO-BOND 51	Epoxy	2	Low visc, 4500 cps (mixed)	Black	N.S.	30 min or 12 hrs depending on curing agent
55	ECCO-BOND 55	Epoxide	2	Low visc, 8000 cps (mixed)	White, milky	Brush Roller Knife	30 min or 4 hrs depending on curing agent

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 1 to 2 days @ 75°F To: 45 min @ 250°F	Contact	Al/Al 3000 @ 75°F, Al/Al 1000 @ 140°F, Al/Al 1400 @ −67°F (24 hr cure @ 75°F); Al/Al 3600 @ 75°F, Al/Al 2000 @ 140°F, Al/Al 2000 @ −67°F (2 hr cure @ 150°F); (1″ wide specimens—½″ overlap)	Metals, wood, and glass reinforced polyester. Contrasting component colors facilitate mixing operation. Paste viscosity allows applic on vertical and overhead surfaces with little or no tendency to flow or sag during cure. Resist to high humidity, salt spray & JP-4 fuel.
FROM: 24 hrs @ 75°F To: 2 min @ 300°F	Contact	Al/Al 2800 @ 75°F (24 hr cure @ 75°F) Al/Al 3900 @ 75°F (1 hr cure @ 200°F) (1″ wide specimens—½″ overlap)	As EC-1751/EC-1752.
FROM: 8 to 24 hrs @ r.t. To: 15 min @ 220°F	Contact	Mat. N.S. 3200 @ r.t.	Metals, glass, ceramics, and plastics. Designed for use where shock and peel resistance are required. Flexibility of bond adjustable by varying resin-curing agent ratio. Serv temp from −70°F to 300°F. Used for TV tube bases (nylon/glass seal).
24 hrs @ r.t. or 1 hr @ 150°F *OR* 2 hrs @ 250°F or 12 hrs @ 150°F plus 1 hr @ 250°F (Dep on curing agt selected)	Contact	Al/Al 6000 @ r.t. Al/Al 2000 @ 200°F (1″ overlap)	Metals, plastics and ceramics. Low thermal coefficient of expansion. Available with two catalysts giving different pot life and cure cycle. Serv temp from −100°F to 350°F.
FROM: 12 hrs @ 170°F To: 30 min @ 300°F *OR* 6-24 hrs @ r.t. (Dep on curing agt selected)	Contact	Al/Al 4700 @ r.t. Al/Al 1900 @ 200°F Al/Al 3100 @ −70°F (1″ overlap)	Metal, glass, ceramics and plastics. Rigid bond. Serv temp from −70°F to 300°F. Available with two catalysts giving different pot life and cure cycle. Has gap-filling properties.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
56	ECCO-BOND SOLDER 56C	N.S.	2	Paste, nonflow	Silver	Spatula	30 min or 3 hrs depending on curing agt
57	ECCO-BOND SOLDER 57C	Epoxide	2	Paste	Silver	Spatula (spray or brush if thinned)	1 hr
58	ECCO-BOND SOLDER 58C	Epoxide	1	Paste	Silver	Spatula Knife (roller brush or spray if thinned)	1 yr @ r.t.
59	ECCO-BOND CONDUCTIVE ADHESIVE 60C	N.S.	1	Paste	Black	Spatula Brush or spray if thinned	3 mos @ r.t. 6 mos under refrig
60	ECCO-BOND CONDUCTIVE ADHESIVE 60L	N.S.	2	Paste	Black	Spatula Brush or spray if thinned	½ hr
61	ECCO-BOND SOLDER 70C	Epoxide	2	Paste, coarse texture	Silver	Spatula	1 hr
62	ECCO-BOND 76	Epoxide	2	Liquid, high visc, mixed with powder catalyst makes nonflowing paste	Black	Spatula	1 week

Typical Curing Cycle or Range	Pressure Required	Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test	Main Uses Special Properties General Information
2 hrs @ 120°F or few min @ 150-200°F *OR* 4 hrs @ 150°F or 1 hr @ 250°F } Dep on curing agt selected	Contact	Mat. N.S. 2900 @ r.t.	Low resistance conductive cement for electrical applic where hot soldering is impractical. Nichrome, conductive plastics, etc. Will not flow when applied. Serv temp from −70°F to 350°F. Can be thinned with toluene. Available with two catalysts giving different pot life and curing cycle. Used in printed circuits.
FROM: 8 hrs @ 75°F To: 30 min @ 225°F	Contact	Mat. N.S. 3000 @ r.t.	R.T. curing version of ECCOBOND SOLDER 56 C.
FROM: 2 hrs @ 300°F To: 15 min @ 500°F	Contact	Mat. N.S. 3200 @ r.t.	Low resistance conductive material with high thermal conduction for use in electrical and heat dissipation applic. Metals, glass, plastics and ceramics. Can be thinned with toluene or methyl ethyl ketone. Serv temp between −65°F and 500°F. Used in high temp de-icers.
FROM: 90 min @ 300°F To: 15 min @ 500°F	Contact	Al/Al 3400 @ r.t. Al/Al 1700 @ 200°F Al/Al 2700 @ −70°F (1″ overlap)	Conductive adhesive. Applications include electrical connections, prevention of r.f. leakage at joints, thermal conductivity, etc. Cement adheres to itself & to a variety of other materials. Can be thinned with toluene. Serv temp from −65°F to 500°F.
FROM: 4 hrs @ r.t. To: 15 min @ 300°F	Contact	Al/Al 3000 @ r.t. Al/Al 1100 @ 200°F Al/Al 2300 @ −70°F (1″ overlap)	General purpose bonding where electrical conductivity must be maintained. In metal to metal joints where r.f. leakage must be eliminated, adhesive provides mechanical bond and electrical seal. High thermal conductivity for heat dissipation applic. Can be thinned with toluene. Serv temp between −70°F and 350°F. Adheres to most materials.
FROM: 6 hrs @ 70°F (approx) To: 3 min @ 300°F	Contact	Mat. N.S. 4100 @ r.t.	Conductive cement. For gross metal to metal joints, heat conduction and r.f. shielding. Not for delicate applic. Serv temp between −75°F and 300°F.
3 hr @ 220°F plus 3 hr @ 300°F For Stain St post cure of 5 hrs @ 500°F recommended	N.S.	Al/Al 4300 @ r.t. Al/Al 1520 @ 500°F	Metal, glass, ceramics and high temp plastic compositions. Aircraft applic. Serv temp from −70°F to 500°F and to 600°F for short periods. Resistant to chlorinated hydraulic fluids, e.g. SKYDROL 500.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
63	ECCO-BOND 88	Epoxide	1	Paste, nonflowing	Black	Spatula Knife	6 mos @ r.t. Indefinite under refrigeration
64	ECCO-BOND POWDER 98	Epoxide	1	Powder, spreadable on surfaces heated to about 250°F	Tan	Dust-on Melt-on	1 yr @ r.t.
65	ECCO-BOND 104	Epoxide	2	Part A: Liquid Part B: Fine powder (makes paste)	Tan	Spatula	24 hrs
66	ECCO-BOND PASTE E	Epoxide	2	Paste, nonflowing	Black	Spatula Trowel Knife	4 hrs
67	EPIBOND 100A	Epoxy	1	Powder, 100 mesh, spreadable @ 220°F	Amber	Dust-on Melt-on	6 mos @ 75°F
68	EPIBOND 101	Epoxy	2	Liquid, high visc	Yellow	Spatula	45 min
69	EPIBOND 104	Epoxy	2	Paste, nonflowing	Cream, natural	Spatula	15-25 min
70	EPIBOND 115	Epoxy	1	Liquid, med to thin visc. May be diluted to any desired visc. (see Main Uses)	Yellow, light	Brush Roller Dip Spray	3 mos @ temp below 70°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bonds and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 2 hrs @ 300°F To: 15 min @ 500°F	Contact	Al/Al 4800 @ r.t. Al/Al 2200 @ 200°F Al/Al 2800 @ −70°F (1″ overlap)	Metal, glass, ceramics and plastics. Serv temp from −70°F to 400°F. Used in electrical generators, etc.
FROM: 3 hrs @ 250°F To: 45 min @ 350°F	Contact	Al/Al 4500 @ r.t. Al/Al 2100 @ 200°F Al/Al 2800 @ −70°F (1″ overlap)	Metal, glass, ceramic and plastic. Serv temp from −70°F to 400°F. Used in stator laminations.
FROM: 6 hrs @ 250°F To: 1 hr @ 400°F Post Cure of at least 12 hrs @ 500°F recommended for assemblies exposed to above 500°F	Contact	Mat. N.S. 3000 @ 70°F 2000 @ 300°F 950 @ 500°F	Metal, ceramics and plastics. High temp elec applic. Material retains good volume resistivity at elevated temp.
FROM: 48 hrs @ r.t. To: 30 min @ 200°F	N.S.	Al/Al 4600 @ r.t. Al/Al 1950 @ 200°F Al/Al 2900 @ −70°F (1″ overlap)	Particularly useful for bonding ill-fitting joints. Metals, glass, ceramics and plastics. Flow-resistant, cures to a hard, rigid bond. Serv temp from −70°F to 350°F.
FROM: 24 hrs @ 250°F To: 30 min @ 400°F	N.S.	Al/Al 4000-5000 @ r.t.	Metal to metal. Electronic devices, fin tubes, insulator bases, aircraft components. Adaptable to "fluidized bed" methods of applic. Serv temp up to 200°F.
4 days @ r.t. *OR* 1-2 hrs @ 140-212°F	Contact	Al/Al 2000 @ r.t.	Metals, ceramics, plastics, nonporous materials to themselves and to each other. Developed primarily for high peel strength and resistance to shock and vibration. Serv temp up to 200°F.
FROM: 3 days @ 77°F To: 30 min @ 150°F	N.S.	Al/Al 2000 @ r.t.	Metals, plastics, concrete, ceramics and rubber. Uncured paste will adhere to vertical surfaces. Can be used as honecomb edge sealer. Vibration dampers, press pads, sealant bond for foam insulation, etc. Serv temp up to 200°F.
FROM: 14 hrs @ 255°F To: 10 min @ 428°F Nonporous materials: Air or oven dry until tack free before mating surfaces.	Clamping	Mat. N.S. 4450-4900 @ 60°F 4420-4760 @ 68°F 2880-3580 @ 212°F 1100-1365 @ 249°F	Motor laminations, stator coils, heat exchanger tubes, etc. Capillary cementing. Close fit required. Can be "B" staged for later assembly. May be used as supplied or thinned with toluol, MEK, acetone. Serv temp up to 250°F.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
71	EPIBOND 121	Epoxy	2	Liquid, med visc	Amber, clear	Spatula Brush	25 min
72	EPIBOND 122	Epoxy	2	Paste, heavy	Gray	Spatula	3 hrs or 70 min (dep on curing agt selected)
73	EPIBOND 123	Epoxy	2	Paste	Gray, dark	Spatula	25 min or 3 hrs (dep on curing agt selected)
74	EPIBOND 129	Epoxy	2	Liquid	Clear	Brush Roller	50-60 min
75	EPIBOND 1210	Epoxy	2	Paste	N.S.	Spatula	1½-2 hrs
76	EPON VI	Epoxy	2	Thixotropic paste, 600,000 cps	*Resin:* Reddish tan *Cur agt:* Red	Spatula Trowel	1 to 2 hrs @ 70°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bonds and Temperature at Time of Test*	*Main Uses Special Properties General Information*
Overnight @ 70-80°F or 1-2 hrs @ 150-200°F	N.S.	Al/Al 2300 @ r.t.	General purpose applic. Metals, glass, glass cloth, unglazed ceramics, dissimilar rigid materials, plastic. Close fit with minimum gap porosity at glue line for most effective results. Serv temp up to 180°F.
24 hrs @ r.t. OR 24 hrs @ r.t. plus 1 hr @ 200°F (dep on cur agt selected)	N.S.	Al/Al 3000 @ r.t.	Qualified under spec MIL-A-8623. Metals, plastics, wood and related materials. Space and gap-filling properties. Available with two curing agents for modification of pot life, curing cycle and heat resistance. Serv temp up to 250°F.
24 hrs @ r.t. OR 24 hrs @ r.t. plus 1 hr @ 200°F (dep on cur agt selected)	N.S.	Al/Al 3100-3400 @ r.t.	Metals, plastics, thermal applic, hot air ducts, thermocouple installations. Good heat resistance with gap-filling properties. Available with two curing agents for modification of pot life, curing cycle and heat resistance. Serv temp up to 250°F.
24 hrs @ r.t. or 2 hrs @ 150°F	N.S.	Al/Al 2500-2800 @ r.t.	Flat sheet bonding to dissimilar surfaces, such as Formica to aluminum backing sheets. Resiliency of bond can be controlled by altering resin/hardener ratio. Serv temp up to 200°F.
48 hrs @ 80°F or 2 hrs @ 150°F	N.S.	Al/Al 3500 @ r.t. St/St 3600 @ r.t. Polyester/Polyester 1800 @ r.t. (laminate) (failure in laminate)	General purpose adhesive which may be combined with various hardeners to bond metals, plastics, wood and related materials. Serv temp up to 250°F.
FROM: 6 to 7 days @ 70°F To: 45 min @ 240°F Recom cure: 45 min @ 240°F	Contact Clamping	Al/Al 3800 @ 77°F Al/Al 1250 @ 180°F Al/Al 2700 @ −70°F (heat cured) Al/Al 1800 @ 75°F (7 days—room temp cured) (1″ wide specimens—½″ overlap)	Meets req Spec MIL-A-8623A, II. EPON adhesives bond to the following materials: *Metals:* Aluminum, beryllium, brass, copper, gold, iron, silver, steel, stainless steel, titanium, nickel. *Inorganic nonmetals:* Brick, concrete, china, glass, pottery, stone, stucco, plaster. *Organics:* Styrene plastics, acrylic plastics, rubber, phenolic plastics, polyesters, paper and fabric laminates, wood, paper. The following can be bonded if the surfaces are first specially treated: nylon, polyethylene, Kel-F, Teflon. Serv temp up to 190°F. Resist to salt spray, water, ethyl glycol, anti-icing, hydraulic & hydrocarbon fluid.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
77	EPON VIII	Epoxy	2	Thixotropic paste, 1,000,000 cps	*Resin:* Light gray *Cur agt:* Red	Spatula Trowel	2½ hrs @ 75°F
78	EPON IX	Epoxy	1	Thixotropic paste, 1,200,000 cps	Gray	Spatula Trowel	1 yr @ 75°F
79	EPON 422	Epoxy-phenolic	1	Tape, glass-fabric supported, 10, 12, 15 or 20 mils	Gray	Cut to size and place	6 to 9 mos @ 0°F 2 to 4 wks @ 40°F
80	EPON 901/A	Epoxy	2	Thixotropic paste, 1,200,000 cps	*Resin:* Gray *Cur agt:* Red	Spatula Trowel	2 hrs @ 75°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bonds and Temperature at Time of Test*	*Main Uses Special Properties General Information*
1½ hrs @ 200°F	Contact Clamping	Al/Al 3550 @ 77°F Al/Al 3325 @ 180°F Al/Al 1200 @ 250°F Al/Al 2650 @ −70°F (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Meets requirements of spec MIL-A-8623A, Type II. Primarily for metal bonding but can be used for other materials, such as wood, plastics, glass and rubber. Serv temp up to 260°F. Resist to JP-4 fuel & chems as listed under EPON VI.
1½ hrs @ 345°F	Contact Clamping	Al/Al 2810-3320 @ 77°F Al/Al 3200-4170 @ 180°F Al/Al 2200 @ 250°F Al/Al 1000-1300 @ 300°F Al/Al 2900-3200 @ −70°F (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Meets requirements of spec MIL-A-8623A, Type III. Particularly used for metal/metal bonding and aluminum/aluminum bonding in aircraft manuf. Service temp up to 300°F. Chemical resistance as EPON VI.
30 min or longer @ 330°F	25 psi	Al/Al 2500 @ 77°F Al/Al 2300 @ 250°F Al/Al 1100 @ 600°F Al/Al 3000 @ −100°F Stain/Stain 3100 @ 77°F Stain/Stain 2600 @ 250°F Stain/Stain 1000 @ 800°F Stain/Stain 3300 @ −67°F Magnes/Magnes 1800-2100 @ 77°F Magnes/Magnes 1100-1300 @ 400°F Titan/Titan 2300-2700 @ 77°F Titan/Titan 1600-1700 @ 500°F (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Meets requirements of spec MIL-A-8431 (USAF), Types I and II, Class F. Designed for metal/metal and honeycomb sandwich bonding of aluminum, stainless steel, or other metals in high temp serv. Serv temp from −425°F to 700°F.
2 hrs @ 200°F	Contact Clamping	Al/Al 2900 @ 75°F Al/Al 2200 @ 220°F Al/Al 2500 @ −67°F (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Flow-resistant. Combines long pot life with moderate curing temp. Serv temp up to 225°F.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
81	EPON 901/B-1	Epoxy	2	Thixotropic paste, 1,200,000 cps	*Resin:* Gray *Cur agt:* Amber Mix: red	Spatula Trowel	50 min @ 75°F
82	EPON 901/B-2	Epoxy	2	Thixotropic paste, 1,200,000 cps	*Resin:* Gray *Cur agt:* Clear Mix: deep red	Spatula Trowel	30 min @ 75°F
83	EPON 901/B-3	Epoxy	2	Thixotropic paste, 1,200,000 cps	Gray	Spatula Trowel	6 hrs @ 75°F
84	EPON 903	Epoxy	1	Paste, 1,400,000 cps	Gray	Spatula Trowel	More than 1 yr @ 75°F
85	EPON 907	Epoxy	2	Paste, buttery, 75,000-79,000 cps	*Resin:* White *Cur agt:* Creamy yellow	Spatula Trowel	1 hr @ 75°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
Overnight @ 75°F or 1 hr @ 200°F	Contact Clamping	24 hr cure @ 75°F: Al/Al 2800 @ 75°F; Al/Al 1100 @ 150°F; Al/Al 1800 @ −67°F heat cured: Al/Al 3500 @ 75°F; Al/Al 2500 @ 200°F; Al/Al 3400 @ −67°F (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Flow-resistant. Color change reveals extent of mixing. Serv temp up to 225°F. Resist to salt spray, water, JP-4, Skydrol 500, anti-ice, hydrocarbon & hydraulic fluid.
2 hrs @ 200°F	Contact Clamping	Al/Al 3000 @ 75°F Al/Al 2650 @ 220°F Al/Al 3000 @ −67°F (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Color change reveals extent of mixing. Serv temp up to 225°F. Resist to water, JP-4 fuel, de-icing, hydraulic & hydrocarbon fluid.
30 min @ 240°F plus 90 min @ 350°F	Contact Clamping	Al/Al 3100 @ 75°F Al/Al 3800 @ 250°F Al/Al 1200 @ 350°F Al/Al 3100 @ −67°F (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Meets requirements of spec MIL-A-8431 (USAF), Type I, Class B heat resistant structural adhesive for aluminum. Flow-resistant at high temps on vertical surfaces while in uncured state. Serv temp up to 350°F. Resist to salt spray and materials as listed under EPON 901/B-2.
2 hrs @ 350°F	Contact Clamping	Al/Al 3200 @ 75°F Al/Al 3500 @ 250°F Al/Al 900 @ 350°F Al/Al 3400 @ −67°F (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Serv temp up to 325°F.
Overnight @ 75°F or 2 hrs @ 180°F	Contact Clamping	24 hr room temp cure (sand-blasted surf): Al/Al 2800 @ 75°F; Brass/Brass 1800 @ 75°; Copper/Copper 1850 @ 75°F; St/St 2400 @ 75°F Al/Al 4000 @ 75°F (24 hrs room temp cure, etched surf) heat cured: Al/Al 6000 @ 75°F; Al/Al 1300 @ 150°F; Al/Al 3100 @ −67°F (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Best for the greatest number of various substrates. Flow-resistant. Develops high bond strength at room temp cure. Easy to use. Will bond to various sand-blasted metals making chemical etching unnecessary. Serv temp up to 150°F. Good resistance to water and salt spray.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
86	EPON 911 F, 911 M, 911 S	Epoxy	2	Heavy paste	*Resin:* Yellow *Cur agt:* Dark gray	Spatula Trowel	911 F—5 to 10 min 911 M—30 to 40 min 911 S—2 to 4 hrs
87	EPON 913	Epoxy	2	Paste, 300,000 cps	Gray	Spatula Trowel Knife Brush	Over 8 hrs
88	EPON 914	Epoxy	1	Thixotropic paste, 1,200,000 cps	Dark gray	Spatula Trowel	Over 1 yr
89	EPON 915	Epoxy	1	Thixotropic paste, 700,000 cps	Dark gray	Spatula Trowel	Over 1 yr

Typical Curing Cycle or Range	Pressure Required	Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test	Main Uses Special Properties General Information
911 F: FROM: 30 min to 7 days @ 75°F (90% of ult strength obtained in 2 hrs) *911 M:* *911 S:* N.S. (See under Main Uses)	Contact Clamping	Al/Al 4200 @ 75°F; Al/Al 2200 @ 120°F; Al/Al 1500 @ 140°F; Al/Al 2000 @ −67°F (cured 3 days @ 75°F) (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. *911 F:* For fast assembly work. Attains shear strength of 1900 psi in 30 min, progressing rapidly to 3900 psi within an additional 30 min. *911 M:* *911 S:* Have slower curing rates, however, all three members of this series develop equally high strengths after 24 hrs @ 75°F. All three possess good peel strength. Good performance on metals but require well-prepared surfaces. Less effective on glass and wood. Serv temp up to 150°F. Resist to water, salt spray, Skydrol 500, JP-4, hydraulic oil & gasoline.
FROM: 3 to 7 days @ 75°F To: 20 min @ 400°F (About 75% of ult strength obtained in 4 days @ room temp)	Contact Clamping	Al/Al 4000 @ 75°F; Al/Al 1900 @ 150°F; Al/Al 3200 @ −67°F (heat cured); Al/Al 3000 @ 75°F; Al/Al 400 @ 200°F; Al/Al 1700 @ −67°F (7 days cure @ room temp) (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Long pot life with ability to cure at room and intermediate temps. Better-than-average peel strength. Bonds to oily surfaces. Good bend strength on oily steel. Bond strengths of 2900 psi @ 75°F have been obtained on oily steel panels (heat-cured). Superior adhesion to Buna-N rubber and acrylics. Serv temp up to 180°F. Resist to water, salt spray, Skydrol 500, JP-4, hydraulic oil.
30 min or longer @ 400°F	Contact Clamping	Al/Al 2900 @ 75°F; Al/Al 3900 @ 250°F; Al/Al 2300 @ 350°F; Al/Al 2600 @ −67°F (1″ wide specimens—½″ overlap)	Bonds to materials listed under EPON VI. Applic requiring high temp and fluid resistance, such as automotive engines, etc. Serv temp up to 375°F. Resist to salt spray, water, most organic liquids, incl boil ethyl glycol.
40 min or longer @ 400°F	Contact Clamping	Al/Al 3000 @ 75°F; Al/Al 4300 @ 250°F; Al/Al 1300 @ 350°F; Al/Al 2500 @ −67°F (1 hr cure @ 400°F) (1″ wide specimens—½″ overlap)	As EPON 914. Resist to salt spray, water, and various radiator coolant fluids.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
90	EPON 916	Epoxy-phenolic	1	Tape, glass-fabric supported Mils N.S.	Gray	Cut to size and place	Over 1 yr
91	EPON 917	Epoxy	1	Powder melts @ about 120°F	Gray	Sinter to hold in place or melt in container and apply to warm surfaces	At least 6 months @ 35°F. Gradual increase of melt visc when stored @ 75°F. Usable for about 1 month @ that temp.
92	EPO-WELD 406	Epoxy	2	Paste, thixotropic	N.S.	Spatula Trowel	1 hr
93	EPOXY-LITE #1331	Epoxy	2	Paste, light	Blue	Spatula	4 to 5 hrs, 1 lb mass
94	EPOXY-LITE #3101	Epoxy	2	Syrup, light	Amber, light	Spatula Brush	20 to 30 min, ½ lb mass
95	EPOXY-LITE #3151	Epoxy	2	Liquid	Amber, light	Brush Roller	45 to 60 min, ½ lb mass

Typical Curing Cycle or Range	Pressure Required	Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test	Main Uses Special Properties General Information
40 min or longer @ 350°F (lower temp can be used)	Clamping	Al/Al 2600 @ 75°F Al/Al 2900 @ 200°F Al/Al 2200 @ −67°F cured 1 hr @ 350°F (1″ wide specimens—½″ overlap)	As EPON 914.
1 hr or longer @ 300°F	Clamping	Al/Al 2400 @ 75°F Al/Al 3500 @ 300°F Al/Al 2100 @ 350°F Al/Al 2100 @ −67°F cured 1 hr @ 300°F (1″ wide specimens—½″ overlap)	Bonds to materials as listed under EPON VI. Can be handled with powder feeders. The melt (See FORM) does not re-solidify when cooled to room temp. Serv temp up to 375°F.
3 days @ r.t. or 1 hr @ 250°F	Contact	N.S.	For bonding irregular surfaces where voids must be filled. Bonds metals, plastics, ceramics, glass, etc. Flexibility can be adjusted by varying resin-to-curing agent ratio. Resistant to water, weather, most chemicals, acids & alkalis. Serv temp range from −55°F to 250°F.
Overnight @ room temp, then post cure for 2 hrs @ 180°F	Contact	Al/Al 3000 @ room temp	Metals, ceramics, rubber, glass & most plastics. Resistant to moisture, acids, alkalis, corrosive salts, petroleum solvents, lubrication oils, alcohols, acetone & jet fuels. For applic where filleting, filling & sealing properties are required. Rigid bonds. Good impact resistance & low temp performance. Continuous serv @ 250°F & higher temp for short duration.
FROM: Overnight @ room temp To: 1 hr @ 200°F	Contact	Al/Al 2300 @ room temp	For application where glue lines cannot be held in close tolerance yet gap-filling properties are not required. Rigid bonds resistant to plastic creep, good resistance to impact, vibration and thermal shock. Continuous serv @ 200°F and higher temps for short durations. Chemical resistance as EPOXYLITE #1331.
FROM: Overnight @ room temp To: 1 hr @ 200°F	Contact	Al/Al 2400 @ room temp	Dissimilar surfaces, metals, rubbers, most hard-to-bond plastics. For applic requiring a shock-resistant, semi-rigid, moisture-proof, gas-tight seal between plastics and metallic or other surfaces. For use @ room or slightly elevated temps. Chemical resistance as EPOXYLITE #1331.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
96	EPOXY-LITE #3351	Epoxy	2	Paste, light, tacky	Creamy-amber	Spatula	45 to 60 min, ½ lb mass
97	EPOXY-LITE #3402	Epoxy	2	Paste, heavy	Black	Spatula	30 to 45 min, ½ lb mass
98	EPOXY-LITE #5302	Epoxy	2	Part A: Fluid liquid Part B: Powder	Brown, light	Spatula	16 hrs, 1 lb mass
99	EPOXY-LITE #5403	Epoxy	2	Part A: Paste, heavy Part B: Powder	Brown, light	Spatula	16 hrs, 1 lb mass
100	EPOXY-LITE #7138	Epoxy	2	Liquid	Amber	Spatula Brush	60 sec @ 65°F, 30 sec @ 90°F, 1 oz mass
101	EPOXYN EA-201	Epoxy	2	685,000 to 715,000 cps	Buff	Spatula Spreader	2 hrs
102	EPOXYN EA-224	Epoxy	2	14,500 to 16,000 cps	Amber, clear	Roller Brush	90 min
103	EPOXYN EA-371	Epoxy	2	106,000 to 125,000 cps	Gray	Spatula Spreader	4 hrs

Typical Curing Cycle or Range	Pressure Required	Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test	Main Uses Special Properties General Information
FROM: Overnight @ room temp To: 1 hr @ 200°F	Contact	Al/Al 2800 @ room temp	A high-initial-tack paste version of EPOXYLITE #3151. Tack aids in positioning parts & inserts. Gap filling & filleting properties. Metals to most hard-to-bond plastics, including rigid vinyl, linear polyethylene, etched Teflon, etc.
FROM: Overnight @ room temp To: 1 hr @ 200°F	Contact	Al/Al 2800 @ room temp	A thixotropic paste version of EPOXYLITE #3101. Gap-filling properties. Won't run during cure.
FROM: 8 hrs @ 250°F To: 1 hr @ 400°F (Best temp properties obtained @ cures between 350° and 400°F)	Contact	Al/Al 2000 @ room temp	Metal to metal high temp applic. Rigid bond. For continuous serv @ 500°F & higher for intermittent serv. Chem resistance as EPOXYLITE #1331.
FROM: 8 hrs @ 250°F To: 1 hr @ 400°F (Best temp properties obtained @ cures between 350° and 400°F)	Contact	Al/Al 1800 @ room temp and at temps up to 350°-400°F	High-temp resistant plastics, such as sodium etched Teflon to themselves and to metals. Rigid bond. For continuous service @ 500°F; for intermittent serv to at least 800°F. Chemical resistance as EPOXYLITE #1331.
30 min to 1 hr @ room temp	Contact	Al/Al 2500 @ room temp	For applic requiring fast-setting bond and no more than small batches at one time. Rigid bond. For continuous serv at temp up to 250°F and higher for short durations. Chemical resistance as EPOXYLITE #1331.
7 days @ r.t. or 30 min @ 250°F	Contact	Mat. N.S. 2800 @ r.t. (r.t. cure) 2900 @ r.t. (heat cure)	Ferrous metals (iron and steel) nonferrous metals (alum, copper, etc.), phenolics, wood, concrete, hard rubber, ceramics, polyesters, polystyrene, epoxies, molded nylon. Serv temp from −20°F to 149°F. Preparation by chemical etching recommended for nonferrous surfaces.
7 days @ r.t. or 30 min @ 250°F	Contact	Mat. N.S. 2500 @ r.t. (r.t. cure) 2750 @ r.t. (heat cure)	As EPOXYN EA-201.
2 hrs @ 180°F or 20 min @ 300°F	Contact	Mat. N.S. 2150 @ r.t.	As EPOXYN EA 201. Recommended when temps of 300°F are encountered.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
104	EPOXYN EA-822	Epoxy	2	24,500 to 27,500 cps	Amber, light, clear	Roller Brush	15 min
105	EPOXYN EA-836	Epoxy	2	14,000 to 16,000 cps	Gray	Roller Brush	75 min
106	EPOXYN EA-838	Epoxy	2	46,000 to 48,000 cps	Buff	Roller Brush	20 min
107	EPOXYN EA-20-43	Epoxy	2	Thixotropic	Cream	Spatula	1 hr
108	FM-61	Modified Epoxy-Elastomer	2	.015″ Film, nylon fabric supported and liquid primer	Core Side: Brown Skin Side: Tan Primer: Green	Primer: Spray Film: Cut to size and place	N.S., store @ 30°F or below
109	FM-97	Epoxy	1	Film, glass fabric supported	White	Cut to size and place	N.S., store @ 40°F or below
110	HELIX R-313	Epoxy	2	Liquid, 3600 cps	Clear	Spatula Knife Brush	1 hr
111	HELIX R-318	Epoxy	2	Liquid, 40,000 cps	Gray, light, opaque	Spatula	1 hr

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
5 days @ r.t. or 10 min @ 200°F	Contact	Mat. N.S. 1500 @ r.t. (r.t. cure)	As EPOXYN EA-201.
3 days at r.t. or 10 min @ 300°F	Contact	Mat. N.S. 2250 @ r.t. (r.t. cure) 3875 @ r.t. (heat cure)	As EPOXYN EA-201.
5 days @ r.t. or 10 min @ 200°F	Contact	Mat. N.S. 2300 @ r.t. (r.t. cure) 3500 @ r.t. (heat cure)	As EPOXYN EA-201.
7 days @ r.t. or 30 min @ 250°F	Contact	Mat. N.S. 2100 @ r.t. (r.t. cure) 2950 @ r.t. (heat cure)	As EPOXYN EA-201.
Primer: Air dry 30 min @ r.t. plus 1 hr @ 250°F Assembly: 1 hr @ 350°F	10-50 psi	Al/Al 2900 @ r.t. Al/Al 2200 @ 180°F Al/Al 1000 @ 350°F Al/Al 3500 @ −67°F (Tested to spec MIL-A-5090B)	Designed for bonding both sandwich and all metal construction. For perforated and nonperforated honeycomb sandwich construction and for large area metal-to-metal bonds. Core need not be primed. Retains good peel strength at low temp. Meets requirements of spec MIL-A-5090B, MIL-A-5090C, and MIL-A-25463. Serv temp from −70°F to 300°F. Resist to salt spray, hydraul oil, JP-4 fuel, Skydrol 500, anti-ice & hydrocarbon fluid, boiling water.
From: 5 hrs @ 200°F To: 30 min @ 350°F	Contact or Moderate	Mat. N.S. 3200 @ r.t.	Specially developed for bonding structural plastics, such as phenolics, polyesters and epoxies, and various composite structural sandwiches. Serv temp from −100°F to 300°F.
From: 3 days @ r.t. (72°F) To: 6 min @ 300°F (Bond develops about ⅓ of ult strength in 4 hrs)	Contact	Mat. N.S. 3000 @ r.t.	Metal to metal, glass to metal, most plastics to metal. For attaching small metal parts to metal and other materials, such as glass, plastics, neoprene, mica, quartz, Teflon, rubber, wood, etc. For moisture and fungus-proof sealing of instruments. Good electrical properties. Resistance to conc acids and alkalis @ r.t. Serv temp from −100°F to 350°F.
2-16 hrs @ r.t. (72°F) (Bond develops about ½ of ult strength in 4 hrs)	Contact	Mat. N.S. 2000 @ r.t.	Metal to rubber, neoprene; metal to metal; flexible bond. Good resistance to impact and vibration. Good peel strength. Serv temp from −100°F to 350°F. Resist to acids & alkalis.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
112	HELIX R-324	Epoxy	2	Liquid, heavy	Clear	Spatula	1 hr
113	HELIX R-363	Epoxy	2	Liquid, 10,000 cps	N.S.	Spatula	2 hrs
114	HELIX R-385	Epoxy	1	Paste, thixotropic	Olive (dark brown when cured)	Spatula Trowel Knife Brush	1 yr @ mod temp
115	HELIX R-390	Epoxy	2	Paste, heavy, tacky	Black	Spatula	1 hr
116	HT-424	Epoxy-phenolic	1 or 2	.01-approx .03″ Film, supported With or without primer	Greenish-gray	Primer: (if used) Brush Spray Roller Film: Cut to size and place	12 days @ 75°F 180 days @ −10°F
117	HYSOL 2038	Epoxy	2	Resin: 700 cps Mixed: 400-8000 cps depending on cur agt selected	Amber, light	Brush Roller	30 min-4 hrs depending on cur agt selected

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
16 hrs @ r.t. (72°F)	Contact	Mat. N.S.	Nylon to metals and to itself. Warming compound to 100°F recommended for ease of applic. Serv temp from −65°F to 300°F.
FROM: 24 hrs @ r.t. (72°F) To: 20 min @ 300°F	Contact	Mat. N.S. 2000 @ r.t.	Metals to each other and to most other materials. Cures to tough, rubberlike bond. Easy to apply. Good peel strength. Good electrical properties. Resists conc acids and alkalis @ r.t. Serv temp from −60°F to 250°F.
1 hr @ 325°F Post cure (optional) 1 hr @ 400°F	Contact Clamping	Mat. N.S. 3500 @ r.t. 2000 @ 180°F 1800 @ 250°F 1200 @ 400°F	Intended for use in supersonic aircraft and missile const. Metal to metal and metal honeycomb const; also ceramics, glass and thermosetting plastics. No run-off or drip in applic. Serv temp from −60°F to 500°F without post-curing, to 600°F with post-curing. Resist to acids & alkalis.
16 hrs @ r.t. (72°F)	Contact	Mat. N.S. 2800 @ r.t. 1800 @ 180°F 1250 @ 250°F	Metal to metal and other materials; tacky consistency allows small objects to stay attached to vertical surfaces during cure without holding fixtures. Resistant to oil, greases, cleaning solvents and conc acids and alkalis at r.t. Serv temp from −60°F to 400°F.
Primer: (if used) Air dry 30 min @ r.t. plus 1 hr @ 150°F Assembly: Raise temp gradually to 320°F-340°F in 30 to 120 min and cure for 30 min @ 325°F-350°F	Contact to 100 psi	Al/Al 2800 @ r.t. Al/Al 2100 @ 300°F Stain/Stain 3775 @ r.t. Stain/Stain 2600 @ 300°F Stain/Stain 2380 @ 500°F Stain/Stain 2000 @ 600°F Stain/Stain 3550 @ −67°F (Tested to spec MIL-A-8431)	Large area metal-to-metal bonds, sandwich constructions. Can be used with or without any of three primers. Available for modification of bond strength, peel strength and temp resistance. Requires careful preparation of surfaces. Resistant to salt spray, water, JP-4 fuel, hydraulic oil, anti-icing & hydro-carbon fluid.
24 hrs @ 68°F OR 1-3 hrs @ 140°F (above cycles dep on cur agt selected)	Contact	Al/Al 2268 (aver) @ r.t. (1″ wide specimens—½″ overlap)	Metals including copper plated steel, silver plated brass; quartz, synthetic sapphire, wood subjected to trichloroethylene vapors, polystyrene foam and fibreglass. Choice of several cur agts offers modification of pot life, curing cycle, viscosity and bond properties. Serv temp from −60°F to 250°F.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
118	HYSOL 2039	Epoxy	2	Resin: 10,000 cps Mixed: 60-30,000 cps depending on cur agt selected	Amber, light	Spatula	30 min-4 hrs depending on cur agt selected
119	HYSOL 4143	Epoxy	2	Resin: Med visc Mixed: 3500-7000 cps depending on cur agt selected	Tan, light	Spatula Brush	30 min-3 hrs depending on cur agt selected
120	HYSOL 4219	Epoxy	2	Mixed: 1700 cps	Amber, light	Spatula Brush	30 min
121	HYSOL 4307	Epoxy	2	80,000 cps	Amber, light	Spatula	1-2½ hrs depending on cur agt selected
122	HYSOL 4309	Epoxy	2	Paste, non-flowing	Tan	Spatula	60 min
123	HYSOL 4314	Epoxy	1	Powder, spreadable @ 200°F	Amber, light	Dust-on cold or heated surface	8-12 mos @ r.t. To be kept from direct sunlight or heat
124	HYSOL 4315	Epoxy, solvent type	1	Liquid, 52% solvent, 8-10 cps	Amber, light	Brush Roller Spray Dip	Approx 5 mos @ r.t.

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
24 hrs @ 68°F OR 1-2 hrs @ 140°F (above cycles dep on cur agt selected)	Contact	Al/Al 2524 (aver) @ r.t. (1″ wide specimens—½″ overlap)	Metal, hard rubber, wood, phenolic, polystyrene foam, etched Teflon, fibreglass. Choice of several curing agents offers modification of pot life, curing cycle, viscosity and bond properties. Serv temp from −60°F to 300°F.
24 hrs @ 68°F OR 1-3 hrs @ 140°F (above cycles dep on cur agt selected)	Contact	Al/Al 2000 (aver) @ r.t. (1″ wide specimens—½″ overlap)	Glass, metal, wood, plastic. For same uses as HYSOL 2038. Reduced thermal expansion, less contraction, better heat conductivity, less shrinkage. Choice of different curing agent offers modifications as under HYSOL 2038. Serv temp range from −50°F to 250°F.
FROM: 24 hrs @ 77°F To: 10-30 min @ 212°F	Contact	Al/Al 1700 @ r.t. Al/Nylon 455 @ r.t. (1″ wide specimens—½″ overlap)	Metal to metal, nylon, ceramics, glass, electrical applic. Resilient bond. Serv temp from −50°F to 200°F.
24 hrs @ r.t. OR 2-3 hrs @ 140°F (above cycles dep on cur agt selected)	Contact	Al/Al 1662 (aver) @ r.t. OR Al/Al 3500 (plus) @ r.t. (depending on curing agt selected) (1″ wide specimens—½″ overlap)	Metal, plastic, glass, ceramics. Not for use in extreme humidity. Bonds slightly resilient. Serv temp range from −60°F to 200°F. Choice of different curing agt offers modifications as under HYSOL 2038.
24-30 hrs @ r.t. or 90 min @ 140°F	Contact	Al/Al 1920 (aver) @ r.t. (1″ wide specimens—½″ overlap)	Rubber to metal and to itself. Metal to glass & to itself; glass to wood. Serv temp from −50°F to 200°F.
FROM: 7 hrs @ 284°F To: 10 min @ 428°F	Jigs	Al/Al 4000-5700 @ r.t. (1″ wide specimens—½″ overlap)	Metal, glass, ceramics. Fillers such as silica and mica can be mixed with adhesive to increase heat resistance and reduce thermal expansion. Can be dusted over areas where use of liquid adhesives not advisable or for preforming into pellets for special applic. Serv temp from −70°F to 300°F.
. Air Dry @ r.t. or up to 122°F until tack free Assembly: FROM: 24 hrs @ 212°F To: 40 min @ 392°F	Clamping	Al/Al 1700 @ r.t. (24 hr cure @ 212°F) Al/Al 3200 @ r.t. (40 min cure @ 392°F) (1″ wide specimens—½″ overlap)	For bonding heat resistant materials. Adaptable to mass production techniques. Coated surfaces can be stored 2-3 mos @ r.t. prior to assembly. Bond resistant to water, chemical attack; good mechanical & electrical properties. Serv temp from −50°F to 300°F.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
125	HYSOL 4321	Epoxy	1	Paste, heavy	Tan, opaque	Spatula Pressure gun Stiff brush	6 mos @ r.t.
126	HYSOL 4322	Epoxy	1	Paste, thixotropic	Gray, dark	Spatula Stiff brush	14 mos @ 77°F
127	HYSOL 4323	Modified epoxy, solvent type	1	14,000-16,000 cps	Amber, light	Spatula Knife Roller (Brush or spray, if thinned)	6 mos @ 75°F
128	HYSOL 4326	Epoxy	2	90,000 cps	Gray, dark	Spatula	4 hrs
129	HYSOL SYSTEM 10-001	Epoxy	2	Paste, thixotropic, light paste @ 140°F (See Main Uses)	Orange	Doctor blade Caulking gun Brush	3-4 days
130	J-1151	Epoxy	2	Paste, heavy	Green-gray	Spatula Knife	1-6 hrs, dep on cur agt selected
131	J-1156	Epoxy	2	Liquid, syrupy	Resin: White Cur agt: Black Cured: Blue-gray	Trowel Brush Caulking gun	4 hrs

Typical Curing Cycle or Range	Pressure Required	Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test	Main Uses Special Properties General Information
FROM: 20 hrs @ 260°F To: 40 min @ 400°F	N.S.	Al/Al 3000-3200 @ r.t. (1″ wide specimens— ½″ overlap)	Metal to metal, for joints not fitting to close tolerance. Serv temp from −20°F to 200°F.
FROM: 4 hrs @ 302°F plus 16 hrs @ 320°F To: 1½ hrs @ 392°F	Contact	Al/Al 3164 @ r.t. (77°F) Stain/Stain 3500 @ r.t. (77°F) (1″ wide specimens— ½″ overlap)	Particularly suited for nonporous surfaces. Flow resistant during cure. Bond slightly resilient, resistant to thermal shock. For bonding metal, plastics, ceramics and glass. Careful surface preparation recommended, i.e. etching or abrading. Serv temp from −60°F to 400°F. Chem resist as HYSOL SYSTEM 10-001.
Air dry 1-2 hrs @ r.t. OR 5-30 min @ 140-250°F Assembly: 15 min @ 300-325°F	150-300 psi	Al/Al 2660 @ r.t. (1″ wide specimens— 1″ overlap)	Bonding rubber, cork, wood, glass, ceramics or metals to plastics (thermosetting). Recommended for bonding phenolics. Serv temp from −35°F to 185°F.
FROM: 2 hrs @ 165°F To: 30 min @ 240°F (65-70% of full strength obtained by above cures after 7 days @ 77°F)	Contact	Al/Al 2580 @ 77°F Al/Al 2730 @ 180°F } 7 day cure @ 77°F Al/Al 3618 @ 77°F Al/Al 2830 @ 180°F } 45 min cure @ 200°F (1″ wide specimens— ½″ overlap)	Designed primarily for metal to metal applic; also used for wood, glass, rubber and some plastics. Good impact strength. Serv temp from −55°F to 250°F.
FROM: 16 hrs @ 215°F To: 1 hr @ 320°F	Pressure uniform, psi N.S.	Al/Al 3300 @ r.t. (4 hr cure @ 275°F) Al/Al 2200 @ r.t. (1 hr cure @ 320°F) (1″ wide specimens— ½″ overlap)	For bonding aluminum honeycomb panels; also for ferrous metals, ceramics & glass. Good peel strength. Components require heating to 140°F before mixing. Serv temp from −55°F to 200°F. Resist to humidity, hydraulic coolants, JP-4, alcohol & naphtha.
24 hrs @ r.t. (70°F or above) OR 2 hrs @ 212°F (dep on cur agt selected)	Contact to 100 psi	Al/Al 3200 @ 70°F Al/Al 2000 @ 180°F } heat cured Al/Al 2400 @ 70°F (r.t. cured) (Tested to Spec MIL-A-8623)	Metal to metal including aluminum, steel, copper. Available with three curing agents for modification of pot life, curing cycle and bond properties. Serv temp range from −40°F to 200°F (approx).
FROM: 3-4 days @ r.t. To: 30 min @ 300°F	Contact to 100 psi	Al/Al 3200 @ r.t. Carbide/St 3500 @ r.t. (1″ overlap)	Metal to metal, hardboards, phenolics, polyester and epoxy laminates, glass and most metal surfaces. Resistant to alkali, solvents, salt water and oil. Serv temp range from −40°F to 150°F (approx). Resist to alkali, solvents, salt water & oil.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
132	J-1158	Epoxy	2	Liquid, med visc	Amber, clear	Spatula Knife Brush	30 min, one pint mass
133	LEFKO-WELD TYPE 35	Epoxy	2	Paste, heavy	Brown	Spatula Trowel Blade	45-60 min
134	LEFKO-WELD TYPE 46	Epoxy	2	Paste, med	Yellow	Spatula Trowel	30 min or 4 hrs (dep on cur agt selected)
135	LEFKO-WELD TYPE 108	Epoxy	2	Paste, med-heavy	Gray	Spatula Trowel Blade Roller	4 or 8 hrs (dep on cur agt selected)
136	LEFKO-WELD TYPE 109	Epoxy	2	Paste, med-low visc	Gray	Spatula Trowel Blade Roller	30 min or 1 hr or 4 hrs or 8 hrs (dep on cur agt selected)
137	LEFKO-WELD TYPE 201	Epoxy	2	Paste, low visc	Charcoal gray	Spatula Trowel Blade Roller	30 min or 4 hrs (dep on cur agt selected)

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 48 hrs @ r.t. To: 1½ hrs @ 200°F	Contact Clamping	Al/Al 1800 @ 70°F Al/Al 2800 @ −65°F 2 hr cure @ 180°F, 10 psi (Tested to Spec MIL-A-8623)	General purpose applic. Glass to glass, metal to metal, plastic to metal, glass and to itself. Recommended for bonding materials with different coefficients of expansion, flexible bond. Can be preset by heat to give pressure sensitive properties for holding parts together for r.t. cure. Good strength at low and r.t., limited strength at high temp.
24-36 hrs @ 80°F	Contact Clamping	N.S.	Honeycomb sandwich panels, aluminum spandrels, prefabricated wood. Rigid plastics and metal components, ceramics. Bulky, lightweight material. Serv temp up to 200°F.
24 hrs @ 80°F OR 2 hrs @ 165°F OR 15 min @ 200°F dep on cur agt selected	Contact Clamping	Al/Al 3760 @ 77°F Al/Al 4160 @ 180°F Al/Al 3462 @ −70°F 15 min cure @ 200°F	General purpose applic. Metals, rubber, wood, glass, rigid plastics. Available with three different curing agents for modification of pot life, curing cycle and other properties. Serv temp up to 250°F.
45 min @ 250°F OR 2 hrs @ 330°F OR 2 hrs @ 350°F dep on cur agt selected	Contact Clamping	Al/Al 3906 @ 80°F Al/Al 4048 @ 180°F Al/Al 3110 @ 300°F Al/Al 2952 @ −70°F dep on cur agt & cycle selected	Metal to metal including aluminum, brass, copper, magnesium, nickel, steel and titanium. Also plastics, rubber, ceramics, wood and honeycomb sandwich const., airframe and ordnance components. Serv temp up to 300°F for continuous service, and 500°F for intermittent serv.
24 hrs @ 80°F OR 1 hr @ 150°F OR 90 min @ 200°F OR 2 hrs @ 330° to 350°F	Contact Clamping	Al/Al 4866 @ 77°F Al/Al 4740 @ 0°F Al/Al 3972 @ −65°F dep on cur agt & cycle selected	Recommended for rigid or semi-rigid materials in airframe bonding, electronics, ordnance and industrial applic. Metals, plastics, ceramics, glass and wood. Good peel strength, especially at low temp. Serv temp up to 300°F.
24 hrs @ 80°F OR 1 hr @ 200°F	Contact Clamping	Al/Al 3625 @ 77°F Al/Al 4325 @ 180°F Al/Al 2725 @ −70°F	Rigid or semi-rigid materials. Architectural, airframe, electronics, industrial applic. Metals, plastics, ceramics, glass, wood, and hard rubber. Honeycomb sandwich panels, aluminum spandrels, prefabricated wood. Serv temp up to 250°F.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
138	M/M (MULTRON R-12/ MONDUR CB-75)	Polyurethane	2	Liquid, 200-500 cps	Yellow, pale	Brush Spray	24 hrs
139	MARASET 532 C and MARASET 532 F	Epoxy	2	Med visc	532 C: Amber 532 F: Ivory white	Spatula	1 hr
140	MARASET 533 A	Epoxy	2	Paste, med heavy	Gray	Spatula	2 hrs
141	METABOND 301	Epoxy	2	Thixotropic	Resin: White Cur agt: Black	Spatula Knife	1 hr
142	METABOND 303	Epoxy	2	Liquid, med visc	Resin: Amber Cur agt: Tan	Brush	1 hr
143	METABOND 315	Epoxy (solvent type)	2	Liquid, low visc	Resin: Clear Cur agt: Tan	Brush Roller Knife Dip (Spray if thinned)	2-3 days

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
Air dry 30 min to 1 hr @ r.t. Assembly: FROM: 8 days @ r.t. (30-35% of ult strength obtained after 15-20 hrs) To: 1 hr @ 355°F (or longer when high shear strength at elevated temp is required)	Sufficient to insure intimate contact	St/St 3300 @ r.t. (r.t. cure) St/St 5200 @ r.t. (2 hr cure @ 265°F) St/St 1000 @ 300°F (8 hr cure @ 355°F) (0.8″ wide specimens—0.2″ overlap)	Steel, soft iron, aluminum and magnesium to themselves and to each other. Bond resist to ethyl alcohol, gasoline, other solvents, oils.
16 hrs @ r.t. or 1 hr @ 200°F OR 3 hrs @ 180°F plus 3 hrs @ 250°F dep on cur agt selected	Contact	Al/Al 2000 @ 77°F (r.t. cure) Al/Al 3800 @ 77°F (heat cure)	General purpose applic. Originally developed for metal bonding. Also for fibreglass, plastic, glass, wood, masonry, etc. Available with two curing agents for modification of cure cycle and heat resisting properties. Serv temp from −60°F to 190°F (approx).
FROM: 2 days @ r.t. To: 10 min @ 250°F	Contact	Al/Al 2650 @ r.t. (r.t. cure) Al/Al 3100 @ r.t. (80 min cure @ 150°F) Al/Al 3900 @ r.t. (10 min cure @ 180°F)	Primarily developed for bonding aluminum, steel, brass, copper and magnesium. Meets spec MIL-A-8623 A, Type II (aircraft industry). Also for wood, plastics (except polyethylene, vinyl, Teflon), glass, rubber. Serv temp from −60°F to 250°F.
4-5 hrs @ r.t. or 10-15 min under heat lamp	Contact	Al/Al 3000 @ 77°F Brass/Brass 2000 @ 77°F St/St 2500 @ 77°F	Glass, ceramics, metals, wood, most plastics and certain types of rubber, flexible bond. Easy to use. May be used to fillet or fill in wide gaps. Serv temp from −90° to 300°F. Bond resistant to thermal shock.
4-5 hrs @ r.t. or 15 min under heat lamp	Contact	Al/Al 3200 @ 77°F Al/Al 1500 @ 180°F Brass/Brass 2100 @ 77°F Brass/Brass 1150 @ 180°F St/St 2800 @ 77°F St/St 1500 @ 180°F	Aluminum, iron, steel, copper, lead, zinc, glass, ceramics and other materials. Will bond slightly moist parts. Glue line not critical. Serv temp from −76°F to 284°F.
Air dry @ r.t. until tack free or Force dry 30 min @ 140°F Assembly: FROM: 3 hrs @ 140°F To: 30 min @ 250°F	Clamping	Mat. N.S. 2000 @ r.t.	Metals, glass, ceramics, phenolics. Resilient bond. Good peel strength. Serv temp from −67°F to 257°F. Can be thinned to desired consistency with xylol.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
144	META-BOND 321	Epoxy	1	Paste, thixotropic	Brown	Spatula	1 yr below r.t.
145	META-BOND 331	Epoxy	1	Paste, thixotropic	Red, dark	Spatula Knife	6 mos @ 72°F 1 yr @ 60°F
146	METL-BOND 302	Epoxide-Phenolic	1	Tape, fibrous glass cloth supported .010″-.015″ or approx .020″	N.S.	Cut to size and place	30 days @ 40°F or below—from shipping date
147	METL-BOND 303	Neoprene-modified phenolic	2	Tape, nylon fabric supported and liquid metal primer .011″-.013″	N.S.	Primer: Brush Spray Tape: Cut to size and place	6 mos @ 72°F
148	METL-BOND 304	Modified phenolic	1	Tape, fibrous glass fabric supported .010″-.014″	N.S.	Cut to size and place	3 mos @ 40°F
149	METL-BOND 305	Modified phenolic	1	Tape, fibrous glass fabric supported .013″-.015″	N.S.	Cut to size and place	90 days @ 40°F or below—from shipping date

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 45 min @ 329°F To: 30 min @ 374°F	Contact	Al/Al 3200 @ 77°F Al/Al 3500 @ 185°F Al/Al 2000 @ 248°F Al/Al 1300 @ 302°F Al/Al 3000 @ −67°F	Metals, ceramics, glass, cement and other temperature-stable materials. Can be applied to vertical surfaces without sagging. Bond resistant to most fluids. Electrical insulating properties. Serv temp from −67°F to 392°F.
FROM: 2½ hrs @ 250°F To: 15 min @ 335°F	Contact Clamping	Al/Al 3200 @ 77°F Al/Al 1800 @ 248°F Al/Al 2100 @ −94°F Brass/Brass 1850 @ 77°F	Aluminum, brass, copper, ferrous metals, ceramics, phenolics, polyesters, and other plastics, glass, wood. Moderately resilient bond permits bonding of materials with different expansion coefficients. Resistant to most acids, alkalis and solvents. Good electrical properties. Serv temp from −94°F to 257°F.
1 hr @ 350°F	25 psi	Al/Al 2600 @ r.t. Al/Al 2200 @ 220°F Al/Al 1700 @ 500°F Al/Al 2600 @ −67°F Stain/Stain 3100 @ r.t. Stain/Stain 2200 @ 300°F Stain/Stain 1700 @ 500°F (1″ wide specimens—½″ overlap)	Metal to metal and sandwich core-to-skin applic. High temp resistant. Skin or core prime not necessary. Performs well under short exposures to 1000°F. Particularly suited to bonded assemblies of glass canopy attachments. Also for high-temp alloys such as titanium and beryllium. Serv temp from −67°F to 500°F plus. Resist to aircraft fuels, salt spray, most solvents, & other corrosive materials.
Primer: Air dry 30 min @ r.t. plus 45 min @ 180°F Assembly: 45 min @ 330°F	40 psi	Al/Al 2930 @ r.t. Al/Al 1620 @ 180°F Al/Al 5430 @ −67°F (1″ wide specimens—½″ overlap)	Primarily intended for metal to metal bonding of aluminum and magnesium to themselves and to each other. High bond strength at low temp and high resistance to vibratory fatigue. Serv temp up through 180°F. Resist to salt spray, anti-icing fluid, hydraulic oil, ethylene glycol, hydrocarb fluid.
1 hr @ 350°F	25 psi	Al/Al 2200 @ 75°F Al/Al 2000 @ 500°F Stain/Stain 2400 @ 75°F Stain/Stain 2200 @ 500°F Titan/Titan 2170 @ 500°F	Intended for bonding aluminum, titanium and stainless steel in metal to metal and sandwich applic. Good retention of shear properties between r.t. and 500°F over extended periods and 800°F for short periods.
•45 min @ 275°F	25 psi	Al/Al 2350 @ r.t. Al/Al 2000 @ 500°F Al/Al 3250 @ −67°F Stain/Stain 2000 @ r.t. Stain/Stain 1800 @ 500°F Stain/Stain 800 @ 900°F (1″ wide specimens—½″ overlap)	Large-area bonding of aluminum and stainless steels. High-temp resistant. No surface priming required. Serv temp up through 700°F. Resist to anti-icing fluid, hydraulic oil, JP-4 fuel, hydrocarbon fluid.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
150	METL-BOND 306	Modified phenolic	1	Tape, glass fabric supported	N.S.	Cut to size and place	45 days @ 40°F or below—from shipping date
151	METL-BOND 311	Epoxy-silicone	1	Tape, asbestos fabric supported	N.S.	Cut to size and place	30 days @ 40°F or below
152	METL-BOND 406	Modified epoxy	1, 2 or 3	Tape, unsupported; liquid primer and tacking paste	N.S.	Prime surface (optional), tack tape in place	3 mos (approx) @ temp not exceeding 40°F
153	METL-BOND X 800	Inorganic ceramic	1	Powder, to be mixed with deionized water to spray-gun consistency	N.S.	Spray	Indefinite
154	METL-BOND 4021	Nitrile-modified phenolic	2	Tape, unsupported .009″-.012″	N.S.	Prime surface and place tape	6 mos (approx) @ 50°-75°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
1 hr @ 350°F	25 psi	Al/Al 2100 @ r.t. Al/Al 2000 @ 260°F Al/Al 1680 @ 500°F Al/Al 850 @ 600°F Al/Al 2400 @ −67°F (1″ wide specimens—½″ overlap)	Metal to metal or sandwich core bonding with metal or reinforced plastic facings. Absence of metallic fillers permits use in microwave applic. Serv temp from −65°F to 550°F.
Increase from r.t. to 300-350°F under 50 psi pressure, then increase to 75 psi and raise temp to 600°F. Cure at 600°F for 3 hrs (75 psi). Post-cure 24 hrs @ 500°F.	75 psi	Stain/Stain 1700 @ r.t. Stain/Stain 1430 @ 300°F Stain/Stain 1240 @ 600°F Stain/Stain 1050 @ 925°F (1″ wide specimens—½″ overlap)	Thermal- and oxidative-resistant properties at elevated temp. Particularly useful for bonding stainless steel in applic involving temp up to 900°F. Resist to salt spray, tap water, JP-4 fuel, hydraulic oil, anti-icing and hydrocarbon fluid.
Primer (if used): Air dry 15 min @ r.t. plus 15 min @ 180°F. Assembly: Increase from r.t. to 350°F (plus or minus 20°F) raising temp at rate of 3.5°F to 10°F per min. Hold at 350°F for one hr.	25 psi	Al/Al 5000 @ r.t. Al/Al 3200 @ 180°F Al/Al 5000 @ −67°F Al/Al 4000 @ −325°F (1″ wide specimens—½″ overlap)	Large-area, low-pressure adhesive system. Sandwich construction and metal to metal bonding. Applic of primer neither enhances nor detracts from the mechanical properties of the adhesive. Prime not needed on core or skins. Paste used for tacking tape to adherends combines and cures with tape, eliminating tacking irons or heated lay-up tables. High peel strength. Serv temp from −350°F to 200°F.
1 hr @ 1150°F	25 psi (10 psi for sandwich bonding)	Stain/Stain 2650 @ r.t. (75°F) Stain/Stain 2127 @ 750°F	Designed for applic involving temp up to 800°F and high stresses.
Primer: 1 hr @ r.t. plus 15 min @ 250°F Assembly: 1 hr @ 350°F	100 psi	Al/Al 4500 @ r.t. Al/Al 2900 @ 180°F Al/Al 1450 @ 350°F Al/Al 3300 @ −67°F (1″ wide specimens—½″ overlap)	Qualified under spec MIL-A-5090 B, Type E: liquid and film. Primarily intended as metal to metal bonding agent. High tensile shear and peel strength, throughout low to intermediate applic temp. Resist to salt spray, tap water, hydraulic oil, JP-4 fuel, anti-icing & hydrocarbon fluid.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
155	METL-BOND 4041	Nitrile-modified phenolic	2	Tape, unsupported and liquid primer	N.S.	Prime surface and place tape	6 mos @ 72°F
156	NARMCO 3120	Epoxy	2	Liquid, 2250 cps	N.S.	Brush Dip Spray	45 min
157	NARMCO 3133	Modified Epoxy	2	N.S.	N.S.	N.S.	1 hr
158	NARMCO 3135	Modified Epoxy	2	Liquid, thick, 20,000-50,000 cps	Straw yellow	Brush Spatula Knife	1½-3 hrs
159	NARMCO 3144	Modified Epoxy	2	Liquid, thin, 1000-2500 cps	Yellow, light	Brush Roller Spray	1½-2½ hrs
160	NARM-TAPE 102	Elastomer-modified phenolic	2	Tape, glass fabric supported and liquid primer	N.S.	Primer: Roller Tape: Cut to size and place	6 mos (approx) @ 72°F or below
161	NARM-TAPE 103	Nitrile-modified phenolic	3	.009″-.011″ Tape, glass fabric supported, Liquid skin primer, Liquid core primer	N.S.	Primer: Roller Tape: Cut to size and place	6 mos (approx) @ 72°F or below

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
Primer: Air dry 1 hr @ r.t. plus 15 min @ 250°F. Assembly: 1 hr @ 350°F (100 psi) or increase gradually from 100°F to 325°F and hold for 30 min then lower to 180°F (40 psi).	40 or 100 psi	Al/Al 4000 @ r.t. Al/Al 2100 @ 180°F Al/Al 5500 @ −67°F (1″ wide specimens—½″ overlap)	Metal to metal. Response to wide range of cure pressures and temp. Good strength at negative temp. High resistance to corrosive fluids and fuels. Serv temp up to 220°F particularly in large area bonds. Resist to salt spray, humidity, JP-4 fuel, hydrocarbon fluid and Skydrol 500.
24 hrs @ r.t.	Contact	Al/Al 2000 @ r.t. Copper/Copper 3000 @ r.t. (Alloys) (½″ overlap)	Metals, glass, wood and most plastics. Will set within 4-6 hrs after catalyst has been added. For serv at r.t. Good chemical & solvent resistance.
24 hrs @ r.t. or 1 hr @ 200°F	Contact	Al/Al 1429 @ r.t. Al/Al 1641 @ −67°F (1″ wide specimens—½″ overlap)	Metal, glass, wood and various synthetic materials. For low and r.t. applic. Good chemical & solvent resistance.
24 hrs @ r.t. or 1 hr @ 200°F	Contact	Al/Al 4500 @ r.t. Al/Al 3000 @ 200°F (½″ overlap)	Metal, glass, wood and various synthetic materials. Cures at r.t. in large volume with low exotherm. Easy to apply. Serv temp up to 200°F. Chemical and solvent resistance good to excellent dep on solvent.
24 hrs @ r.t. or 1 hr @ 200°F	Contact	N.S.	Aluminum, galvanized sheet metal, steels, glass, wood and various synthetic materials, such as polystyrene foam. Easy to apply. Good chemical & solvent resistance.
Primer: Air dry 8 hrs @ r.t. or 30-45 min @ 160°F to 180°F Assembly: 1 hr @ 320°-350°F	30 psi	Al/Al 1920 @ r.t. Al/Al 1130 @ 180°F Al/Al 3590 @ −67°F (1″ wide specimens—½″ overlap)	Metal to metal and sandwich applic. No prime coat on metal skin surfaces is necessary. Serv temp from −80°F through 180°F. Resist to salt spray, tap water, hydraulic oil, fuel, anti-icing & hydrocarbon fluid.
Primer: (Skin) Air dry 1 hr @ r.t. plus 15 min @ 250°F Primer: (Core) Air dry 2 hrs @ r.t. plus 1 hr @ 180°F or 30 min @ 250°F Assembly: 1 hr @ 350°F	25 to 40 psi	Al/Al 2850 @ r.t. Al/Al 1300 @ 180°F Al/Al 2350 @ −67°F (1″ wide specimens—½″ overlap)	Metal or fibreglass sandwich core materials to metal or fibreglass skins. Separate primers for cores and skins. Core primers available with 15%, 25% and 35% solid content. Good peel strength. Serv temp from −65°F through 260°F.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
162	NARM-TAPE 105	Vinyl-modified phenolic	1	.007″ Tape, cotton fabric supported (flame-proof)	N.S.	Cut to size and place	90 days @ 77°F (from shipping date)
163	NARM-TAPE 107	Nitrile-modified phenolic	2	Tape, glass fabric supported and liquid primer	Tan	Primer (Core only): Roller Tape: Cut to size and place	6 mos @ 80°F or below
164	NARM-TAPE 108	Nitrile-modified phenolic & epoxy	2	.017″ Tape, nylon fabric supported and liquid primer	Black (core side of tape)	Primer: Brush Spray Dip Tape: Cut to size and place	90 days @ 40°F or below
165	NARM-TAPE X 111	Epoxy system	2	Tape, supported and liquid primer	Core side: Gray Skin side: Tan	Primer: Brush Spray Flow coat Tape: Cut to size and place	Approx 90 days @ r.t.
166	NP-428	Epoxy	2	Thixo-tropic	Amber, clear	Brush Spray Roller	90 min
167	PHENO-WELD 7	Modified Phenolic	1	Liquid	Reddish brown	Spatula Brush Spreader Rolls	6 mos @ 70°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
30 min @ 300°F	10-20 psi	Al/Al 2830 @ 75°F Al/Al 1100 @ 180°F Al/Al 2050 @ −67°F (1″ wide specimens—½″ overlap)	Sandwich construction. Resilient bond. Particularly adaptable for honeycomb sandwiches using paper, metal or fibreglass core material. Easy to apply. Serv temp up to 180°F.
Air dry 8 hrs @ r.t. or 30-45 min @ 160°-180°F Assembly: 1 hr @ 320°-350°F	30 psi	Al/Al 2888 @ r.t. Al/Al 862 @ 180°F Al/Al 2758 @ −67°F (1″ wide specimens—½″ overlap)	Qualified under spec MIL-A-14443, Type II, Class I. Sandwich construction. Resist to salt spray, tap water, hydraulic oil, JP-4 fuel, anti-icing & hydrocarbon fluid.
Primer (skins only): Air dry for 1 hr @ r.t. plus 30 min @ 250°F. Assembly: 1 hr @ 350°F	50 psi	Al/Al 2700 @ r.t. Al/Al 1800 @ 130°F Al/Al 1100 @ 220°F Al/Al 3950 @ −67°F (1″ wide specimens—½″ overlap)	Sandwich applic. Phenolic adhesive overcoated on one surface with epoxy filleting resin. Eliminates need for core primer. Primer for metal skins only. Good peel strength. Serv temp from −65°F through 180°F. Resist to JP-4 fuel, hydrocarbon fluid, hydraulic & other oils.
Primer (skins only): Air dry for 1 hr @ r.t. plus 1 hr @ 160°F. Assembly: Increase from r.t. to 350°F at rate of 12°F per min and maintain for 1 hr.	Sandwich: 25 psi Metal/Metal: 50 psi	Al/Al 4000 @ r.t. Al/Al 2000 @ 180°F Al/Al 695 @ 250°F Al/Al 4500 @ −67°F	Designed for bonding sandwich panels utilizing perforated or nonperforated honeycomb core; also for metal/metal applic. Eliminates need for core priming in sandwich assemblies. Good peel strength at low temp. Resist to salt spray, humidity, Skydrol 500, tap water, anti-icing, hydraulic, and hydrocarbon fluid.
FROM: 4-6 hrs @ 150°F To: 20 min @ 300°F (72 hr r.t. cure where optimum properties are not required)	Contact	Metal/Metal 5000 plus @ r.t.	Metals, glass, etc. Flow resistant during cure. Aluminum honeycomb to glass, metal, asbestos board, etc. Flexibility of bond can be adjusted by modification of resin to hardener ratio. Easy to use. Serv temp from −40°F to 325°F. Higher temp for intermittent serv. Resistant to water, weathering, galvanic action and most chemicals and solvents.
Air dry 1 hr @ r.t. plus 15 min @ 175°F Assembly: 15-30 min @ 300°F	50-300 psi	Al/Al 2620 @ r.t. St/St 2823 @ r.t. Nylon/Stain.St 1770 @ r.t.	Metals, thermosetting plastics, wood, glass. Resistant to water, gasoline, kerosene, pyranol, mineral oils and mixtures of polar and nonpolar solvents. Resistant to gasoline, acetone, water, 5% salt water, toluene, alcohol, kerosene.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
168	PHENO-WELD 8	Modified Phenolic	1	Liquid	Reddish brown	Spatula Brush Spreader Rolls (Spray, if thinned)	6 mos @ 70°F
169	PLACCO C-560	Epoxy-Poly-sulfide	2	Paste, heavy visc	Resin: Brown-gray Cur agt: Brown-purple	Trowel	1 hr
170	PLASTI-LOCK 601	Nitrile rubber-phenolic	1	Film .012″ Unsupported	Tan	Cut to size and place	4 to 6 mos @ 80°F 1 yr @ 40°F
171	PLASTI-LOCK 604	Synthetic resin, solvent type	1	Slightly more than water	Tan	Brush	6 mos @ 80°F 1 yr @ 40°F

Typical Curing Cycle or Range	Pressure Required	Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test	Main Uses Special Properties General Information
Air dry 1 hr @ r.t. plus 15 min @ 150°F Assembly: 4 hrs @ 185°F or 15-30 min @ 300°F	50-300 psi	Al/Al 2761 @ r.t. St/St 2834 @ r.t. Nylon/Stain.St 1542 @ r.t.	As PHENOWELD 7. Recommended where high cleavage strength is required. Resistant to salt spray, gasoline, toluene, water, ethylene, kerosene.
24 hrs @ r.t. (70°F)	Contact	St/Concrete (aver) 1000 @ r.t.	Flooring material for bonding steel plate or tile to concrete, wood, terrazzo, unglazed ceramic tiles and latex terrazzo. Serv temp from 0°F to 200°F.
Oven: 40-50 min @ 400°F Press: From 25-30 min @ 350°F to 6 min @ 425°F	100-200 psi	Al/Al 3378 @ 72-76°F Al/Al 2322 @ 178-182°F Al/Al 2890 @ −65 to −70°F St/St 4000 @ r.t. (1″ wide specimens—½″ overlap)	Most ferrous and nonferrous metals to themselves, plastics to glass, steel to wood, cloth to steel or itself, brake linings to steel and assembly application in aircraft manufacture. Other applic where structural stability is required. Approved to USAF spec 14164. Serv temp in brake bonding applic from −40 to 500°F; in aircraft applic from −67 to 200°F. Chem resist to salt spray, water, ethyl glycol, anti-icing, hydraulic & hydrocarbon fluids.
Room temp cure: Air dry 10 min @ room temp, assemble and allow to cure for 96 hrs @ room temp. Heat cure: Air dry for 12 hrs @ room temp or 30 min @ room temp plus, prebake @ 180-190°F for 30 min. Cure assembly for 8 min @ 400°F.	10-200 psi	St/St 4000 @ r.t.	Friction materials, such as phenolic laminates or nitrile rubber to metal surfaces. Also most metals to themselves. Adheres to extremely smooth surfaces; heat resistant and structurally stable. Semi-rigid bond. Used for aircraft applic operating at −67 to 200°F.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
172	PLASTI-LOCK 605-4 -15 -20 -25 -30 -35	Synthetic rubber-phenolic resins, solvent type	1	4-35,000 cps	Black	#605-4: Spray #605-15: Brush Roller #605-20: Brush Roller #605-25: Brush Roller #605-30: Extrusion #605-35: Extrusion	6 mos @ 80°F 1 yr @ 40°F
173	PLASTI-LOCK 608	Nitrile rubber-phenolic	1	Film, unsupported .010-.013″	Black	Cut to size and place	4-6 mos @ 80°F 12 mos @ 40°F
174	PLASTI-LOCK 635-636	Nitrile rubber-phenolic	2	.008-.012″ Film, unsupported and liquid primer	Tan	Primer: Brush Film: Cut to size and place	3 mos @ 71-75°F 6 mos @ 41-50°F
175	PLASTI-LOCK 637-636 CV	Nitrile rubber-phenolic	2	.008-.012″ Film and liquid primer	N.S.	Primer: Brush Spray Film: Cut to size and place	3 mos @ 70-85°F 6 mos @ 40°F
176	PLASTI-LOCK 638-636 LA	Nitrile rubber-phenolic	2	.008-.012″ Film and liquid primer	N.S.	Primer: Brush Spray Film: Cut to size and place	3 mos @ 70-85°F 6 mos @ 40°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
Air dry 12 hrs @ room temp or 10 min @ room temp plus, pre-bake @ 180-190°F for 30 min. Assemble and cure raising temp gradually to 400°F and lower gradually to 260°F, using manufacturer's cure chart for individual timing. In general, cycle timed to reach 400°F in 12 min.	100-200 psi	St/St 4000 (aver) @ r.t.	Friction materials to metals. Applic requiring heat resistant and structural stability. Shock resistant bond. Metal to metal; brake bonding. Serv temp ranging from −40 to 500°F.
45 min @ 350°F	100 psi	Al/Al 3272 @ 72-76°F Al/Al 2795 @ 178-182°F Al/Al 3047 @ −65 to −70°F (1″ wide specimens—½″ overlap)	Metal to metal. Aircraft and high temp applic. Serv temp to 425°F plus. Chem resist as PLASTILOCK 601.
Primer: Air dry 3 hrs @ room temp or 20 min @ 170-180°F. Assembly: 30 min–2 hrs @ 335-400°F.	50-200 psi	Al/Al 4628 @ room temp Al/Al 2310 @ 180°F Al/Al 2838 @ −67°F 1 hr cure @ 350°F, 100 psi. (1″ wide specimens—½″ overlap)	Approved to spec MIL-A-5090 B, Type E. Primarily for airframe bonding of metal to metal. Serv temp from −67°F to 260°F plus. Aluminum, stainless steel, steel, magnesium, copper zinc plate. Chem resist as PLASTILOCK 601.
Primer: Air dry 1 hr @ temp above 60°F or 30 min @ 150-160°F. Assembly: From 2 hrs @ 300°F to 30 min @ 350°F.	50-200 psi	Al/Al 4597 @ room temp Al/Al 2680 @ 180°F Al/Al 3917 @ −67°F 1 hr cure @ 350°F, 100 psi. (1″ wide specimens—½″ overlap)	Approved to spec MIL-A-5090 B, Type E. Metal to metal. Airframe bonding. Chem resist as PLASTILOCK 601.
Primer: Air dry 1 hr @ room temp plus 30 min @ 150-160°F. Assembly: From 2 hrs @ 300°F to 30 min @ 350°F.	50-200 psi	Al/Al 4638 @ room temp Al/Al 2422 @ 180°F Al/Al 3351 @ −67°F 1 hr cure @ 350°F, 100 psi. (1″ wide specimens—½″ overlap)	Metal to metal. Airframe bonding. Approved to spec MIL-A-5090 B, Type E. Aluminum, stainless steel, steel, magnesium, copper zinc plate. Serv temp from −67°F to 260°F. Chem resist as PLASTILOCK 601.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
177	PLASTI-LOCK 650	Nitrile rubber-phenolic	1	Film, unsupported .008-.012″	Tan, light	Cut to size and place	Store @ 40°F
178	PLASTI-LOCK 31-10-054	Phenolic-synthetic rubber	1 or 2	Film, with or without liquid primer	Tan	Primer: (if used) Brush Dip Spray Film: Cut to size and place	6 mos @ 40°F
179	PRO-SEAL EP 502	Epoxy	2	Liquid, 1500 cps mixed	Translucent	Brush Spatula Pressure gun	15 to 30 min
180	PYRO-CERAM #45	Ceramic	2	Powder & liquid suspension medium (low visc)	White	Brush Flow-on Dip Pressure equip.	4-6 hrs

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
From 2 hrs @ 300°F to 30 min @ 350°F	45-150 psi	Al/Al 3800 plus @ room temp Al/Al 2500 @ 300°F Al/Al 2500 @ −67°F 1 hr cure @ 350°F, 100 psi. (1″ wide specimens—½″ overlap)	Metal to metal where serv at high temp is required. Airframe bonding for serv temp above 300°F. Approved to spec MIL-A-8431, Type I, Class F.
Primer: Air dry 5 min @ room temp plus 15-30 min @ 167°F. Assembly: 1 hr @ 350°F Post-cure (optional): 30 min–2 hrs @ 400-500°F	100 psi	Al/Al 3910 @ 77°F Al/Al 560 @ 500°F Al/Al 4313 @ −67°F With primer No post-cure Al/Al 3057 @ 77°F Al/Al 1210 @ 500°F Al/Al 3637 @ −67°F with primer 1 hr post-cure @ 500°F Stain/Stain 4000 @ 77°F Stain/Stain 2040 @ 300°F Stain/Stain 1210 @ 500°F Stain/Stain 7465 @ −67°F with primer and post-cured 1 hr @ 450°F plus 1 hr @ 500°F Magnes/Magnes Alloy 2790-3380 @ 77°F Magnes/Magnes Alloy 1700-1965 @ 300°F Magnes/Magnes Alloy 1095 @ 500°F Magnes/Magnes Alloy 2875-3220 @ −67°F with primer & post-cured 1 hr @ 450°F plus 1 hr @ 500°F	Metal to metal. Chemical etching of surfaces recommended prior to bonding. Use of primer and post-cure optional but recommended for high temp applic.
5 days @ r.t. (75°F) or 1 hr @ 200°F	Contact	Mat. N.S. 2500 @ r.t.	Glass, metal, wood, concrete and most plastics, including polyester laminates. Easy to use. Shock resistant bond. Serv temp from −60°F to 150°F.
Air dry several hrs @ r.t. or 15-30 min @ 115°C Preglaze (if necessary): 10 min @ 660°C Assembly: Increase temp grad to 750°C at rate of 3-5°C/min. Hold @ 750°C for 1 hr and cool gradually at same rate/min.	Contact Jigs	10,000 @ 25°C (Modulus of Rupture)	Metals: Tungsten, molybdenum. Glasses: Corning Codes 1710; 1720; 1723. Ceramics: Standard Electrical. Vacuum-tight seals, high temp resistant. Expansion range: 40 to 50 × 10 −7/°C. Serv temp up to 700°C.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
181	PYRO-CERAM #89	Ceramic	2	Powder & liquid suspension medium (low visc)	White	Brush Flow-on Dip Pressure equip.	4-6 hrs
182	PYRO-CERAM #95	Ceramic	2	Powder & liquid suspension medium (low visc)	White	Brush Flow-on Dip Pressure equip.	4-6 hrs
183	Ray-BOND R-81001	Synthetic rubber-phenolic	1	Liquid, 3000-3500 cps	Black	Brush Roller Spray	3 mos @ 80°F 6 mos @ 45-60°F
184	Ray-BOND R-81002	Synthetic rubber-phenolic	1	Liquid, heavy, 33,000-45,000 cps	Black	Spatula Extruder	45 days @ 80°F 6 mos @ 45-60°F
185	Ray-BOND R-84015	Phenolic	1	Liquid, 740-770 cps	Brown	Brush Roller Spray	90 days @ 80°F 6 mos @ 45-60°F

Typical Curing Cycle or Range	Pressure Required	Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test	Main Uses Special Properties General Information
Air dry several hrs @ r.t. or 15-30 min @ 115°C Preglaze (if necessary): 10 min @ 390°C Assembly: 1 hr @ 440°C Gradual heating & cooling rates: approx 3-15°C/min.	Contact Jigs	6,000 @ 25°C (Modulus of Rupture)	Metals: Platinum, vanadium, dumet, 50% nickel, D-H #152. Glasses: Corning Code 0120, 0281, 8870, 0010, 9101, 0122. Ceramics: Fosterite, alumina cermets, steatite. Vacuum-tight seals, high temp resistant. Expansion range: 80 to 92 × 10 −7/°C. Serv temp up to 425°C.
Air dry several hrs @ r.t. or 15-30 min @ 115°C Preglaze (if necessary): 10 min @ 390°C Assembly: 1 hr @ 440°C Gradual heating & cooling rates: approx 3-15°C/min.	Contact Jigs	6,000 @ 25°C (Modulus of Rupture)	Metals: Chrome-iron stainless, sylvania #4, 50% nickel alloys, durnet, thorium, beryllium. Glasses: Most lime and electronic glasses Corning Codes 0080, 1927, 8871, 0088. Ceramics: Steatite, fosterite. Vacuum-tight seals, high temp resistant. Expansion range: 90 to 110 × 10 −7/°C. Serv temp up to 425°C.
FROM: 15 min @ 350°F To: 5 min @ 400°F (Allow to dry @ r.t. until free of solvent before cure)	250-1000 psi	St/St 2200 @ r.t. St/St 1500 @ 250°F St/St 1008 @ 400°F (disc shear)	Rubber to metal, plastics to metal, metal to metal, friction material to metal, friction material to itself, friction material to insulating materials. Suitable for bonding of assemblies with poor contact between mating surfaces. Resilient bond, shock resistant. Serv temp from −65 to 400°F. Coated parts may be stored for one year @ r.t. Resistant to oils, brake fluid, water.
FROM: 15 min @ 350°F To: 5 min @ 400°F (Allow to dry @ r.t. until free of solvent before cure)	250-1000 psi	St/St 2200 @ r.t. St/St 1500 @ 250°F St/St 1008 @ 400°F (disc shear)	As Ray-BOND R-81001.
10 min @ 300°F or 5 min @ 350°F (Allow to dry @ r.t. until tack-free before curing)	250-1000 psi	Mat. N.S. 2500 plus @ r.t. 2080 @ 500°F 1130 @ 650°F	Friction material to metal, friction material to itself. For assemblies with poor contact between mating surfaces. Serv temp from below 0°F to 650°F. Resistant to oils, solvents, water.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
186	Ray-BOND R-84029	Modified phenolic	1	Liquid, 2370-2650 cps	Reddish brown	Brush Roller Spray	90 days @ 80°F 6 mos @ 45-60°F
187	Ray-BOND R-86001	Epoxy	2	Liquid, 10,000-15,000 cps	Tan, light	Brush Knife Extruder	4 hrs
188	Ray-BOND R-86004	Epoxy	2	Liquid, 15,000 cps	White	Spatula Brush	40 min (100-600 gram mass)
189	Ray-BOND R-86024	Epoxy	2	Paste, buttery	Gray	Spatula	2½ hrs
190	Ray-BOND R-86044	Epoxy	2	Paste	White	Spatula Brush	1 hr (200 gram mass)
191	RESILITH	Epoxy-polysulfide (solvent containing)	3	Trowelling visc	Available in Gray, Brick red or Forest green	Trowel	1 hr
192	RESI-WELD #2	Epoxy	2	Fluid, medium viscosity	Amber, clear	Spatula Trowel Knife Brush Extruder	1 to 2 hrs
193	RESI-WELD #3	Epoxy	2	Liquid, flow-resistant	*Resin:* Gray *Cur Agt:* Amber, clear	Spatula Trowel Stiff brush Caulking gun	1½ to 2½ hrs

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
10 min @ 300°F or 5 min @ 350°F (Allow to dry @ r.t. until tack-free before curing)	250-1000 psi	St/St 2500 plus @ r.t. St/St 1345 @ 250°F	Rubber to metal, friction material to metal, friction material to itself. Intimate contact between mating surfaces essential. (Allowable gap .01″ max.) Resistant to oils, solvents, water. Serv temp from below 0°F to 250°F.
FROM: 7 days @ 77°F To: 15 min @ 300°F	2-2½ psi	Al/Al 2250 @ 77°F	Cured natural rubber, cured neoprene rubber, cured GR-S rubber, cured Buna-N. Cyclizing recommended for optimum results. With natural, neoprene and GR-S rubbers point of failure is within rubber stock. Serv temp from below 0°F to 125°F.
72 hrs @ r.t. or 2 hrs @ 200°F	2-5 psi	Mat. N.S. 3000-4000 @ r.t.	Etched Teflon to metal. Good peel strength. Serv temp from below 0°F to 200°F.
FROM: 17 hrs @ 73°F (max strength after 7 days) To: 1 hr @ 220°F	2-2½ psi	Al/Al 3600 @ r.t (1½ hr cure @ 180°F)	Rubber to metal, plastics to metal or ceramic, metal to metal, glass to metal, wood to metal. Resistant to most solvents, acids and alkalis. Serv temp from below 0°F to 220°F.
72 hrs @ 74°F or 2 hrs @ 200°F	2-5 psi	Mat. N.S. 3500 @ r.t.	Etched Teflon to metal. Good peel strength. Serv temp from −67°F to 300°F.
4-12 hrs @ r.t.	Contact	St/Concrete 1000 (aver) @ r.t.	Resurfacing old and new wood, concrete, steel and glazed concrete surfaces. Resistant to shock, thermal shock, abrasion, acids, alkalis and solvents. Serv temp from 0°F to 350°F. Product unit consists of 3 components: resin, curing agent and dry aggregate.
FROM: 5 days @ r.t. To: 1 to 3 min at 400°F	Contact	Al/Al 3740 @ r.t. Al/Al 1370 @ 180°F Al/Al 3720 @ −104°F	Metals including aluminum, steel, brass, copper, zinc, iron, tin and lead. Glass, wood, ceramics, concrete, rubber and most plastics. Flexibility can be adjusted by varying resin-to-cur agt ratio. Relatively non-toxic. Serv temp range from −104° to 180°F.
FROM: 3 to 5 days @ r.t. To: 3 to 5 min @ 400°F	Contact	Al/Al 4000 @ r.t. Al/Al 1450 @ 180°F	Primarily for aluminum and steel. Also iron, tin, lead, brass, copper, zinc, glass, wood, ceramics, concrete and many plastics. Good resistance to mechanical impact and thermal shock. High tensile, flexural and compressive strength. Resists flow and sagging in thin films and seams. Flexibility can be adjusted by varying resin-to-cur agt ratio. Easy to use. Minimum toxicity. Serv temp range from −104° to 180°F.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
194	RESI-WELD #4	Epoxy	2	Liquid, medium viscosity	Amber, clear	Spatula Trowel Knife Brush Caulking gun	½ to 1 hr
195	RESI-WELD #6	Epoxy	2	Liquid, flow-resistant	Amber	Spatula Trowel Brush Caulking gun	1-2 hrs
196	RESI-WELD #8	Epoxy	2	Liquid, flow resistant	Amber	Trowel Knife Pressure gun	4 hrs
197	RESI-WELD #30	Modified Epoxy	2	Liquid, very low viscosity 1200 cps	Black	Spatula Roller Stiff brush Spray gun	30 min
198	RESI-WELD #31	Modified Epoxy	2	Liquid, very low viscosity, 800 cps	Black	Spatula Roller Stiff brush Spray gun	4 hrs
199	RESI-WELD #32	Modified Epoxy	2	Liquid, viscosity, 3000 cps	Black	Spatula Stiff brush Roller	40 min
200	RESI-WELD #33	Modified Epoxy	2	Med high visc, 15,200 cps	Black	Spatula Trowel	75 min

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 2 to 4 days @ r.t. To: 3 to 5 min @ 400°F	Contact	Al/Al 3240 @ r.t. Al/Al 2850 @ 180°F St/St 2830 @ room temp St/St 2800 @ 180°F	For flexible and rigid materials. Metals and other materials as RESI-WELDS #2 & 3 including magnesium. Flexibility can be adjusted by varying resin-to-cur agt ratio. Easy to use. Minimum toxicity. Serv temp range from −104° to 180°F. Used in bonding neoprene gaskets to aluminum & outboard motor assemblies, etc. Resists impact, vibration & thermal shock.
FROM: 3 to 5 days @ r.t. To: 5 to 10 min @ 300°F	Contact	Al/Al 2500 @ r.t.	Specifically designed for bonding vinyl plastic to metals & other construction materials. Will also bond acrylonitrile & other plastics to themselves & to metals. Not for highly plasticized vinyl. Impact resistant bonds with good weathering properties. For serv temp below 200°F.
3 hrs @ 180°F or 1½ hrs @ 200°F	Contact	Al/Al 3600 @ 77°F Al/Al 3350 @ 180°F Al/Al 1200 @ 250°F Al/Al 2600 @ −70°F (1″ wide specimens—½″ overlap)	Specifically designed for metal to metal. Formulated to meet specifications MIL-A-5090B and MIL-A-8623A. Does not run when applied in thin films. Gives strong bonds at service temperatures up to 250°F to most metals, glass and heat-resistant plastics. Resists moisture, most solvents & chemicals.
3 to 5 days @ room temp or 40 min @ 150°F	Contact	Al/Al 1700 @ room temp St/St 1500 @ room temp (1″ wide specimens—½″ overlap)	Low-cost systems for steel, aluminum, polystyrene foam, glass, concrete and wood. Semi-flexible bond. Not to be used on high stress loading applications where contin serv temp above approx 160°F are encountered. Good peel & impact strength.
6 to 10 days @ room temp or 3 hrs @ 150°F	Contact	Al/Al 1400 @ room temp St/St 1300 @ room temp (1″ wide specimens—½″ overlap)	As RESIWELD #30. Specially suitable for panel construction.
3 to 5 days @ room temp or 50 min @ 150°F	Contact	Al/Al 1500 @ room temp St/St 1400 @ room temp (1″ wide specimens—½″ overlap)	As RESIWELD #30. Recommended for porous & nonporous flat sheet bonding.
3 to 5 days @ room temp or 50 min @ 150°F	Contact	Al/Al 2800 @ room temp St/St 2700 @ room temp (1″ wide specimens—½″ overlap)	As RESIWELD #30, more rigid. Resistant to cold and hot water. Serv temp up to 200°F.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
201	RESI-WELD #34	Modified Epoxy	2	Med high visc, 32,500 cps	Black	Knife Roller	4 hrs
202	RESI-WELD #35	Modified Epoxy	2	Thixotropic visc, 6200 cps	Black	Spatula Trowel Roller	30 min
203	RESI-WELD #69	Epoxy-"Thiokol" polysulfide	2	Liquid, visc N.S.	Amber	Brush Spray gun	2½ to 5 hrs between 70° and 40°F resp.
204	RESI-WELD #70	Epoxy-"Thiokol" polysulfide	2	Liquid, visc N.S.	Amber	Brush Spray gun	2 to 6 hrs between 90° and 70°F resp.
205	RESI-WELD #105	Epoxy	1	Liquid, high visc	Metallic	Spatula Trowel Knife Caulking gun	1 yr at 70°F
206	RESI-WELD #109	Epoxy	1	Form N.S., high visc	N.S.	Spatula Trowel Knife Caulking gun	2 yrs
207	S-16840	Epoxy	2	Liquid, med visc	Gray-green	Spatula	25 min or 3 hrs dep on curing agent used

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
6 to 10 days @ room temp or 3 hrs @ 150°F	Contact	Al/Al 2200 @ room temp St/St 2000 @ room temp (1″ wide specimens—½″ overlap)	As RESIWELD #33.
3 to 5 days @ room temp or 40 min @ 150°F	Contact	Al/Al 1900 @ room temp St/St 1600 @ room temp (1″ wide specimens—½″ overlap)	As RESIWELD #30, but flow-resistant yet easy to spread and apply. Clings to surfaces.
FROM: 20 hrs @ 40°F To: 8 hrs @ 70°F	Contact	Strength of bond exceeds that of concrete @ 80°F	Concrete to metal and to itself. Can be used on damp surfaces. For applic at temp under 70°F but not below 40°F. Serv temp range from 0° to 150°F.
FROM: 19 hrs @ 70°F To: 8 hrs @ 90°F	Contact	Strength of bond exceeds that of concrete @ 80°F	As RESIWELD #69. For use when temp at applic time is 70°F or above.
FROM: 2 hrs @ 300°F To: 15 min @ 400°F	Contact Clamping	Al/Al 5110 @ room temp Al/Al 2950 @ 180°F Al/Al 1360 @ 220°F St/St 5980 @ room temp St/St 2440 @ 180°F St/St 1440 @ 220°F (1″ wide specimens—½″ overlap)	Particularly high strength bond on alum and steel. Also good bond strength on stainless, brass, nickel and chrome plate. Good impact strength. Serv temp up to 220°F. Can be used for roll coaters and pressure-feed applicators if warmed, e.g. @ 140°F visc is lowered to 20,000 cps and pot life is over 2 weeks. Resistant to salt spray, water, anti-icing fluid, hydraulic oil, JP-4 fuel & other hydrocarbon fluids.
FROM: 4 hrs @ 300°F To: 30 min @ 400°F	Contact Clamping	Al/Al 3300 @ 77°F Al/Al 3800 @ 180°F Al/Al 1200 @ 300°F Al/Al 3100 @ −70°F (1″ wide specimens—½″ overlap)	Formulated to meet spec MIL-A-8623A. Designed for aircraft manuf. Alum, steel and other metals and heat-resistant nonmetals. Good impact strength. Service temp range from −70° to 300°F. Can be used for roll coaters and pressure-feed applicators if warmed to lower visc. Chemical resistance similar to RESIWELD #105.
24 hrs @ r.t. (70°F) or 1 hr @ 160°F OR 24 hrs @ r.t. (70°F) plus 1 hr @ 200°F	Contact Clamping	Teflon/Teflon 1000 @ −70°F to r.t. (etched)	Spec designed for bonding sodium etched Teflon to other materials & to itself. Available with two different curing agents for modification of pot life & curing cycle.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
208	SCOTCH-WELD AF-6	Phenolic-nitrile	1	Film, unsupported 5 to 8 mils	Yellow (changes to brown when cured)	Cut to size and place	At least 3 months @ 75°F. Storage below 45°F lengthens life to 6 months or more.
209	SCOTCH-WELD AF-10	Phenolic-nitrile	1	Film, unsupported 9 to 11 mils	Yellow (changes to brown when cured)	Cut to size and place	At least 3 months @ 75°F. Storage below 45°F lengthens life to 6 months or more.
210	SCOTCH-WELD AF-13	Phenolic-nitrile	1	Film, unsupported 3 mils	Yellow (changes to brown when cured)	Cut to size and place	At least 3 months @ 75°F. Storage below 45°F lengthens life to 6 months or more.
211	SCOTCH-WELD AF-30 AF-30/ EC-1459 (AF-5930 System)	Thermo-setting resin-elastomer Base, NS	1 or 2	Film, unsupported With or without liquid primer 9-11 mils	Tan, light	Cut to size and place Primer: (if used) Brush or spray or dip	6 months or more @ 40°F *Primer:* 6 months or more between 32-50°F
212	SCOTCH-WELD AF-30/ EC-1593 (AF-9330 System)	Thermo-setting resin-elastomer Base, NS	1	Film, unsupported and liquid primer 9-11 mils	*Film:* Tan, light *Primer:* Cream	Primer: Flow coat Film: Cut to size and place	6 months or more @ 40°F *Primer:* 3 months @ room temp

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 8 hrs @ 275°F To: 80 min @ 325°F	100-150 psi	Al/Al 3400 @ 70-80°F Al/Al 1650 @ 180°F Al/Al 3400 @ −67°F (1 hr cure @ 350°F and 125 psi) (1″ wide specimens—½″ overlap)	Metal/metal, aircraft applications. Simultaneous bonding & sealing of integral fuel tanks. Bonding metal helicopter rotor blades. Flexible bond with good peel strength, resistant to salt spray, high humidity and fuel, ethyl glycol, anti-icing, hydraulic & hydrocarbon fluid. Serv temp up to 180°F.
2 hrs @ 350°F	100-150 psi	Al/Al 3000 @ 70-80°F (1″ wide specimens—½″ overlap)	As SCOTCH-WELD AF-6.
FROM: 8 hrs @ 275°F To: 80 min @ 325°F	100-150 psi	Al/Al 2810 @ 70-80°F Al/Al 1325 @ 180°F Al/Al 2810 @ −67°F (1 hr cure @ 350°F and 125 psi) (1″ wide specimens—½″ overlap)	As SCOTCH-WELD AF-6.
Primer: (if used) Air dry 1 hr then bake for 30 min @ 150°F *Assembly:* 1 hr @ 350°F or 1 hr @ 325°F	25-150 psi	Al/Al 3978 @ room temp Al/Al 2317 @ 180°F Al/Al 1680 @ 300°F Al/Al 3270 @ −67°F (Primed, 1 hr cure @ 350°F, 150 psi) Al/Al 3475 @ room temp Al/Al 2135 @ 180°F Al/Al 1210 @ 300°F Al/Al 3060 @ −67°F (Primed, 1 hr cure @ 325°F, 25 psi) Al/Al 3718 @ room temp Al/Al 2660 @ 180°F Al/Al 1432 @ 300°F Al/Al 4073 @ −67° (Without primer, 1 hr cure @ 350°F, 150 psi) (1″ wide specimens—½″ overlap)	Metal to metal. Qualified under MIL-A-5090B, Class E if used with primer EC-1459 (Designated as AF-5930 System). Structural sealing of integral fuel tanks. Good peel strength. Chemical resistance as SCOTCH-WELD AF-6. Serv temp from −65°F to 300°F.
Primer: Air dry 30 min then bake 90 min @ 180 to 200°F *Assembly:* 35 min @ 320°F Grad incr to above temp not exceed 12°F/min	Alum: 40 psi Magnes: 22.5 psi	Al/Al 3095 @ room temp Al/Al 1592 @ 180°F Al/Al 4005 @ −67°F Magnes/Magnes 2436 @ room temp Magnes/Magnes 1392 @ 180°F Magnes/Magnes 2000 to 2300 @ −67°F (1″ wide specimens—½″ overlap)	Developed for bonding zinc chromate primed magnesium. Aircraft applic. and serv temp as AF-30/EC-1459. Chemical resistancc as SCOTCH-WELD AF-6.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
213	SCOTCH-WELD AF-31 AF-31/ EC-1459 (AF-5931 System)	Phenolic-Nitrile	1 or 2	Film, unsupported with or without liquid primer 9-11 mils	Tan	Primer: (if used) Brush Spray Dip Film: Cut to size and place	At least 6 months @ 40°F *Primer:* At least 6 months @ 32-50°F
214	SCOTCH-WELD AF-32 AF-32/ EC-1459 (AF-5932 System)	Phenolic-Epoxy	1 or 2	Film, unsupported with or without liquid primer 9-11 mils	Tan	Primer: (if used) Brush Spray Dip Film: Cut to size and place	At least 6 months @ 40°F *Primer:* At least 6 months @ 32-50°F
215	SCOTCH-WELD AF-102 AF-102/ EC-1459 (AF-59102 System)	Phenolic-Nitrile	1 or 2	Film, fabric supported 18-23 mils With or without liquid primer	Tan, light	Primer: (if used) Brush Spray Dip Film: Cut to size and place	At least 6 months @ 40°F *Primer:* At least 6 months @ 32-50°F
216	TYGO-WELD PB-I Type I	Alloyed Epoxy	1	Powder, fine, 200 mesh spreadable @ 194-212°F	Aluminum	Melt on Dusting Flame-spray Air blowing	No limit @ 70°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
Primer: (if used) Air dry 30 min then bake 30 min @ 250°F *Assembly:* 1-2 hrs @ 350°F	100-150 psi	Al/Al 3800 @ 77°F Al/Al 2600 @ 180°F Al/Al 2100 @ 300°F Al/Al 1150 @ 400°F Al/Al 3900 @ −67°F } 1 hr cure @ 350°F 150 psi Al/Al 4203 @ room temp Al/Al 2487 @ 300°F Al/Al 3953 @ −67°F } 2 hr cure @ 350°F, 150 psi Al/Al 3776 @ room temp Al/Al 2348 @ 300°F Al/Al 3807 @ −67°F } Primed with EC-1459 and cured 2 hrs @ 350°F, 100 psi (1″ wide specimens—½″ overlap)	Metal to metal. Retains good flexibility and peel strength at elevated temp. May be used in many applic without a primer. Structural sealing of integral fuel tanks. Resistant to salt spray, high humidity and fuel. Serv temp from −65°F to 350°F.
Primer: (if used) Air dry 1 hr then bake 30 min @ 150°F *Assembly:* 1 hr @ 350°F	150 psi	Al/Al 3337 @ room temp Al/Al 1601 @ 250°F Al/Al 4125 @ −67°F } Without primer Al/Al 3783 @ room temp Al/Al 1337 @ 250°F Al/Al 4578 @ −67°F } With primer EC-1459 (1″ wide specimens—½″ overlap)	Metal to metal. Very flexible. High peel strength at low temp. Aircraft applic and other assemblies. Resistant to salt spray, high humidity and fuel.
Primer: (if used) Air dry 1 hr then bake 30 min @ 150°F *Assembly:* 1-2 hrs @ 350°F	150 psi	Al/Al 3300 @ 80°F Al/Al 2250 @ 180°F Al/Al 1750 @ 300°F Al/Al 2800 @ −65°F } 1 hr cure @ 350°F Al/Al 3100 @ room temp Al/Al 1780 @ 300°F Al/Al 2890 @ −67°F } Primed with EC-1459 and cured 2 hrs @ 350°F (1″ wide specimens—½″ overlap)	Honeycomb sandwiches. Metal to metal. For use where spacer is desired. Flexible bond, resistant to salt spray, high humidity & fuel.
FROM: 80 min or longer @ 338°F To: 2 to 4 min @ 530°F	Contact Clamping	Al/Al 4900 @ 68°F after 10 days exposure @ 212°F Al/Al 4950 @ 68°F after 10 days exposure @ 302°F Al/Al 4150 @ 68°F after 1 yr exposure @ 212°F Al/Al 4000 @ 68°F after 1 yr exposure @ 302°F (All cured 1 hr @ 392°F)	Dissimilar metals, carbide tool assembly, metal inserts in ceramics and other materials including aluminum, cast iron, copper, brass, steel, stainless, chrome, magnesium, sintered metals, titanium, treated Teflon and glass. Rigid bond. Serv temp up to 350°F. Resist to water, oil, gasoline & methyl alcohol.

Key #	Designation of Adhesive	Type or Base	Number of Components	Form, Viscosity or Consistency	Color	Application Method	Work Life of Adhesive
217	TYGO-WELD PB-I Type I-C	Alloyed Epoxy	1	Powder, fine, 200 mesh spreadable @ 194-212°F	Light green before cure; opaque amber after cure	Melt on Dusting Flame-spray Air blowing	No limit @ 70°F
218	TYGO-WELD PB-I Type II	Alloyed Epoxy	1	Rod, spreadable @ 194-212°F	Aluminum	Melt on	No limit @ 70°F
219	TYGO-WELD PB-I Type III	Alloyed Epoxy	1	Rod, spreadable @ 194-212°F	Green before cure; aluminum gray after cure	Melt on	No limit @ 70°F
220	TYGO-WELD PB-I Type IV	Alloyed Epoxy	1	Rod, spreadable @ 194-212°F	Dark green before cure; opaque amber after cure	Melt on	No limit @ 70°F
221	TYGO-WELD 33-B	Alloyed Epoxy	2	Paste, heavy	Aluminum	Knife Pressure gun	2½-3½ hrs
222	TYGO-WELD 36-B	Alloyed Epoxy	2	Paste, medium	Aluminum	Knife Roller Pressure gun	2½-3½ hrs
223	TYGO-WELD 38-C	Alloyed Epoxy	2	Paste, medium	Clear	Knife Roller Pressure gun	2½-3½ hrs
224	TYGO-WELD F-52-A	Phenolic-synthetic rubber	1	Tape, unsupported 10-12 mils	Black	Cut to size and place	6-9 mos @ temp not over 80°F

Typical Curing Cycle or Range	*Pressure Required*	* *Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 80 min or longer @ 338°F To: 2 to 4 min @ 530°F	Contact Clamping	N.S.	As TYGOWELD PB-I, Type I. Will denote the correct cure temp range @ 482°F (plus or minus 5°) by change of color. Chem resist as TYGOWELD PB-I, Type I.
FROM: 80 min or longer @ 338°F To: 2 to 4 min @ 530°F	Contact Clamping	As TYGOWELD PB-I, Type I	As TYGOWELD PB-I, Type I. Low flow properties. Chem resist as TYGOWELD PB-I, Type I.
FROM: 80 min or longer @ 338°F To: 2 to 4 min @ 530°F	Contact Clamping	As TYGOWELD PB-I, Type I	As TYGOWELD PB-I, Type I. Cure indicator will denote when optimum cure is achieved by color change from green to aluminum gray, at 482°F (plus or minus 5°F). Medium flow properties. Chem resist as TYGOWELD PB-I, Type I.
FROM: 80 min or longer @ 338°F To: 2 to 4 min @ 530°F	Contact Clamping	N.S.	As TYGOWELD PB-I, Type I-C.
FROM: 6 days @ r.t. To: 1 hr @ 220°F	Contact Clamping	Al/Al 4000 @ 77°F Al/Al 3550 @ 180°F Al/Al 3150 @ −70°F } 1 hr cure @ 200°F (½″ overlap)	Ferrous and nonferrous metals, glass, fibreglass, ceramics and thermosetting plastics; also polyester glass and epoxy glass fibre laminates. Moderately flexible bond. Serv temp from −60°F to 180°F. Good resist to ethyl glycol, Skydrol, JP-4 & most solvents & chemicals.
FROM: 6 days @ r.t. To: 1 hr @ 220°F	Contact Clamping	Al/Al 3700 @ 77°F Al/Al 2200 @ 180°F	Primarily designed for sandwich construction. Semi-rigid bond. High peel strength. For metals and rigid dissimilar materials. Serv temp up to 160°F. Chemical resist as TYGOWELD 33-B.
FROM: 6 days @ r.t. To: 1 hr @ 220°F	Contact Clamping	N.S.	For sandwich construction and electrical applic. Semi-rigid bond. Good flexural and peel strength. Serv temp up to 160°F. Chem resist as TYGOWELD 33-B.
FROM: 20 min @ 335°F To: 1 min @ 500°F	100 psi	Al/Al 2700 @ 70°F Al/Al 2100 @ 180°F Al/Al 1330 @ 325°F Al/Al 788 @ −65°F (1 sq in. overlap)	Brake linings and other friction materials. Shell halves in shell molding, phenolic laminates to metal, synthetic rubber to metal and metal to metal. Abrasive wheels and tools to supporting members. Good electrical properties and peel strength. Serv temp up to 350°F. Resist to water, oil, brake fluids & most solvents.

Key #	*Designation of Adhesive*	*Type or Base*	*Number of Components*	*Form, Viscosity or Consistency*	*Color*	*Application Method*	*Work Life of Adhesive*
225	TYGO-WELD 114	Alloyed Epoxy	1	Liquid, medium viscosity	Green before cure, Amber after cure	Flow-on Dip Eye-dropper Brush	6 mos between 60°F and 75°F

Typical Curing Cycle or Range	*Pressure Required*	*Typical Shear Strength (lbs/psi) of Cured Bond and Temperature at Time of Test*	*Main Uses Special Properties General Information*
FROM: 5 hrs @ 220°F To: 45 sec to 2 min @ 400-450°F	Contact Clamping	Al/Al 1500-2000 @ r.t.	For metal to metal and electronic applic. Does not possess gap-filling qualities. For applic where thin, neutral colored bond line is desired. Color change when cure complete or @ 450°F. Serv temp up to 275°F. Careful surf prep required.

7. ALPHABETICAL CROSS-REFERENCE INDEX OF SPECIFIED STRUCTURAL BONDS AND LISTED ADHESIVES (By key numbers)

The key numbers listed here can be identified in Column 1 of the Adhesives Identification and Properties Chart.

The purpose of this index is to offer wide choice of materials from which to select adhesives for experimentation and use. Since the bonding capabilities of structural adhesives are so varied and dependent upon the conditions under which they are used, it is recommended that their suitability for intended application be determined by thorough tests.

Adhesives for bonding materials to themselves do not appear since, for example, any capable of bonding aluminum to copper can be considered also for aluminum to aluminum or copper to copper applications.

It should be emphasized that many of the adhesives are suited not only for the materials indicated but for other bond combinations not stated in manufacturers' literature. For certain specific applications only a few adhesives are listed although others can be used. Many of these can be found under General-Purpose Applications.

Specific Applications

Alnico/Aluminum (and Alloys)	11, 23, 24, 25, 26
Alnico/Steel	9(R), 23, 24, 25, 26
Alnico/Zinc Castings	11, 23, 24, 25, 26
Aluminum (and Alloys)/Asbestos Board	23, 24, 25, 26, 42(R), 166, 171(R), 172(H), 183(H), 184(H), 224(H)

Note: L—Below room temperature (68°F) curing.
R—Room temperature curing (approximately 68°-86°F).
H—Recommended curing temperatures of 300°F and above. Cures at lower temperatures are possible in some cases.
HH—Curing temperatures of 600°F and above.
HHH—Curing temperatures of over 1000°F.
no indication—Heat curing at temperatures below 300°F.

Specific Applications [a] (cont.)

[a] See Note, p. 118.

Specific Applications[a] (cont.)

ALUMINUM (and ALLOYS)/FIBROUS GLASS	4(R), 11, 12(R), 13(R), 14(R), 23, 24, 25, 26, 45(R), 53(R), 55(R), 56, 58(H), 62(H), 63(H), 66(R), 68(R), 71(R), 80, 81(R), 82, 83(H), 85(R), 92(R), 93, 94(R), 97(R), 110(R), 114(H), 117(R), 118(R), 119(R), 121(R), 122(R), 123(H), 126(H), 131(R), 132(R), 139(R), 141(R), 142(R), 143, 144(H), 145, 156(R), 157(R), 158(R), 159(R), 166, 167, 172(H), 179(R), 188(R), 189(R), 192(R), 193(R), 194(R), 196, 197(R), 198(R), 199(R), 200(R), 201(R), 202(R), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)
ALUMINUM (and ALLOYS)/GOLD	77, 79(H), 80, 81(R), 83(H), 84(H), 85(R), 86(R), 91(H)
ALUMINUM (and ALLOYS)/IRON	4(R), 6(R), 77, 79(H), 80, 81(R), 82, 83(H), 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 93, 94(R), 96(R), 97(R), 98(H), 100(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 138(R), 170(H), 192(R), 194(R), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)
ALUMINUM (and ALLOYS)/MAGNESIUM (and ALLOYS)	10(H), 11, 17(R), 23, 24, 25, 26, 45(R), 79(H), 96(R), 98(H), 110(R), 135, 136(R), 137(R), 138(R), 140(R), 147(H), 174(H), 194(R), 212(H), 216(H), 217(H), 218(H), 219(H), 220(H)
ALUMINUM (and ALLOYS)/NICKEL (and ALLOYS)	77, 79(H), 80, 81(R), 82, 83(H), 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 135, 136(R), 137(R), 205(H)
ALUMINUM (and ALLOYS)/NYLON	9(R), 50(R), 52(R), 53(R), 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 112(R), 120(R), 167, 168
ALUMINUM (and ALLOYS)/PHENOLICS (and LAMINATES)	11, 45(R), 59(H), 60(R), 80, 81(R), 82, 83(H), 85(R), 99(H), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 118(R), 127(H), 131(R), 141(R), 143, 145, 167, 171(R), 172(H), 183(H), 184(H), 192(R), 206(H), 224(H)
ALUMINUM (and ALLOYS)/POLYESTER FIBROUS GLASS LAMINATES	7(R), 8(R), 10(H), 11, 12(R), 13(R), 19, 20, 45(R), 50(R), 51(R), 52(R), 79(H), 80, 81(R), 82, 83(H), 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 117(R), 119(R), 131(R), 145, 150(H), 152(H), 161(H), 179(R), 206(H), 221(R)

[a] See Note, p. 118.

Specific Applications[a] (cont.)

[a] See Note, p. 118.

Specific Applications [a] (cont.)

ALUMINUM (and ALLOYS)/ STEEL (*cont'd*)	125, 126(H), 128, 130(R), 131(R), 132(R), 133(R), 134(R), 135, 136(R), 137(R), 138(R), 139(R), 140(R), 141(R), 142(R), 143, 144(H), 146(H), 152(H), 153(HHH), 154(H), 155(H), 156(R), 157(R), 158(R), 159(R), 160(H), 161(H), 164(H), 165(H), 166, 167, 170(H), 171(R), 172(H), 173(H), 174(H), 175(H), 176(H), 177(H), 179(R), 183(H), 184(H), 189(R), 192(R), 193(R), 194(R), 196, 197(R), 198(R), 199(R), 200(R), 201(R), 202(R), 205(H), 206(H), 208(H), 209(H), 210(H), 211(H), 213(H), 214(H), 215(H), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R), 222(R), 223(R), 224(H)
ALUMINUM (and ALLOYS)/TEFLON, TREATED	85(R), 99(H), 110(R), 118(R), 135, 188(R), 190(R), 207(R), 216(H), 217(H), 218(H), 219(H), 220(H)
ALUMINUM (and ALLOYS)/TITANIUM (and ALLOYS)	23, 24, 25, 26, 77, 79(H), 80, 81(R), 82, 83(H), 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 135, 136(R), 137(R), 146(H), 148(H), 216(H), 217(H), 218(H), 219(H), 220(H)
ALUMINUM (and ALLOYS)/WOOD	4(R), 7(R), 8(R), 21(R), 42(R), 45(R), 51(R), 52(R), 74(R), 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 117(R), 118(R), 119(R), 122(R), 134(R), 135, 139(R), 145, 156(R), 157(R), 158(R), 159(R), 167, 179(R), 189(R), 192(R), 193(R), 194(R), 197(R), 198(R), 199(R), 200(R), 201(R), 202(R)
ALUMINUM (and ALLOYS)/ZINC	23, 24, 25, 26, 93, 94(R), 96(R), 97(R), 98(H), 100(R), 159(R), 174(H), 192(R), 194(R)
ASBESTOS BOARD/COPPER (and ALLOYS)	23, 24, 25, 26, 166, 171(R), 183(H), 184(H), 224(H)
ASBESTOS BOARD/STAINLESS STEEL	23, 24, 25, 26, 166, 171(R), 172(H), 183(H), 184(H), 224(H)
ASBESTOS BOARD/STEEL	23, 24, 25, 26, 42(R), 166, 170(H), 171(R), 172(H), 183(H), 184(H), 224(H)
BERYLLIUM/COPPER (and ALLOYS)	77, 79(H), 80, 81(R), 82, 83(H), 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 146(H)
BERYLLIUM/GOLD	77, 79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 91(H)

[a] See Note, p. 118.

Specific Applications[a] (cont.)

BERYLLIUM/IRON	77, 79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H)
BERYLLIUM/NICKEL (and ALLOYS)	77, 79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H)
BERYLLIUM/POLYESTER FIBROUS GLASS LAMINATES	79(H), 80, 81(R), 82, 85(R)
BERYLLIUM/POLYSTYRENE FOAM	79(H), 80, 81(R), 82, 85(R)
BERYLLIUM/SILVER	79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 91(H)
BERYLLIUM/STAINLESS STEEL	79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 146(H), 182(HH)
BERYLLIUM/STEEL	77, 79(H), 80, 81(R), 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 146(H)
BERYLLIUM/TITANIUM (and ALLOYS)	77, 79(H), 80, 81(R), 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 146(H)
CARBIDE/STEEL	11, 131(R), 205(H), 216(H), 217(H), 218(H), 219(H), 220(H)
CERAMICS/COPPER (and ALLOYS)	17(R), 23, 24, 25, 26, 53(R), 54(R), 55(R), 56, 58(H), 63(H), 64, 65, 66(R), 68(R), 69(R), 92(R), 93, 94(R), 97(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 114(H), 123(H), 126(H), 135, 143, 144(H), 145, 153(HHH), 189(R), 192(R), 193(R), 194(R), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)
CERAMICS/IRON	93, 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 192(R), 194(R), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)
CERAMICS/MAGNESIUM (and ALLOYS)	23, 24, 25, 26, 135, 194(R), 216(H), 217(H), 218(H), 219(H), 220(H)
CERAMICS/STAINLESS STEEL	23, 24, 25, 26, 53(R), 54(R), 55(R), 56, 58(H), 62(H), 63(H), 64, 65, 66(R), 68(R), 69(R), 92(R), 93, 94(R), 97(R), 114(H), 123(H), 126(H), 135, 143, 144(H), 153(HHH), 182(HH), 189(R), 193(R), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)

[a] See Note, p. 118.

Specific Applications[a] (cont.)

Ceramics/Steel	7(R), 8(R), 11, 21(R), 23, 24, 25, 26, 53(R), 54(R), 55(R), 56, 58(H), 63(H), 64, 65, 66(R), 68(R), 69(R), 92(R), 93, 94(R), 97(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 114(H), 121(R), 123(H), 126(H), 135, 143, 144(H), 153(HHH), 189(R), 192(R), 193(R), 194(R), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)
Ceramics/Titanium (and Alloys)	23, 24, 25, 26, 135, 216(H), 217(H), 218(H), 219(H), 220(H)
Concrete/Copper (and Alloys)	35(R), 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 179(R), 192(R), 194(R), 203(L), 204(R)
Concrete/Iron	35(R), 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 192(R), 194(R)
Concrete/Stainless Steel	35(R), 85(R), 179(R), 193(R), 203(L), 204(R)
Concrete/Steel	21(R), 35(R), 50(R), 52(R), 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 169(R), 179(R), 191(R), 192(R), 193(R), 194(R), 197(R), 198(R), 199(R), 200(R), 201(R), 202(R), 203(L), 204(R)
Copper (and Alloys)/Epoxy Fibrous Glass Laminates	131(R), 152(H), 161(H), 206(H), 221(R)
Copper (and Alloys)/Fibrous Glass	71(R), 139(R), 194(R), 221(R)
Copper (and Alloys)/Glass	11, 23, 24, 25, 26, 53(R), 55(R), 56, 58(H), 63(H), 66(R), 68(R), 71(R), 80, 81(R), 82, 85(R), 93, 94(R), 97(R), 110(R), 114(H), 117(R), 119(R), 122(R), 123(H), 126(H), 131(R), 132(R), 139(R), 141(R), 142(R), 143, 144(H), 145, 156(R), 157(R), 158(R), 166, 167, 179(R), 188(R), 189(R), 192(R), 193(R), 194(R), 196, 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)
Copper (and Alloys)/Gold	77, 79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 91(H)
Copper (and Alloys)/Iron	77, 79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 93, 94(R), 96(R), 97(R), 98(H), 100(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 170(H), 192(R), 194(R), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)

[a] See Note, p. 118.

Specific Applications [a] (cont.)

[a] See Note, p. 118.

Specific Applications [a] (cont.)

Copper (and Alloys)/ Stainless Steel (*cont'd*)	137(R), 139(R), 143, 144(H), 146(H), 152(H), 153(HHH), 154(H), 155(H), 156(R), 157(R), 158(R), 160(H), 161(H), 164(H), 165(H), 166, 167, 170(H), 171(R), 173(H), 174(H), 175(H), 176(H), 177(H), 179(R), 183(H), 184(H), 189(R), 196, 205(H), 206(H), 208(H), 209(H), 210(H), 211(H), 213(H), 214(H), 215(H), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R), 222(R), 223(R), 224(H), 225
Copper (and Alloys)/Steel	17(R), 23, 24, 25, 26, 27(R), 30(R), 31(R), 34(R), 45(R), 46(H), 47, 53(R), 54(R), 55(R), 56, 58(H), 59(H), 60(R), 61(R), 62(H), 63(H), 64, 65, 66(R), 67, 69(R), 71(R), 72, 73(R), 77, 78(H), 79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 92(R), 93, 94(R), 96(R), 97(R), 98(H), 100(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 108(H), 110(R), 114(H), 116(H), 124(H), 125, 126(H), 128, 130(R), 131(R), 132(R), 133(R), 134(R), 135, 136(R), 137(R), 139(R), 140(R), 141(R), 142(R), 143, 144(H), 146(H), 152(H), 153(HHH), 154(H), 155(H), 156(R), 157(R), 158(R), 161(H), 164(H), 166, 167, 170(H), 171(R), 173(H), 174(H), 175(H), 176(H), 177(H), 179(R), 183(H), 184(H), 189(R), 192(R), 194(R), 196, 205(H), 206(H), 208(H), 209(H), 210(H), 211(H), 213(H), 214(H), 215(H), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R), 222(R), 223(R), 224(H)
Copper (and Alloys)/Teflon, Treated	85(R), 99(H), 110(R), 135, 188(R), 190(R), 207(R), 216(H), 217(H), 218(H), 219(H), 220(H)
Copper (and Alloys)/Titanium (and Alloys)	23, 24, 25, 26, 77, 79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 135, 136(R), 137(R), 146(H), 216(H), 217(H), 218(H), 219(H), 220(H)
Copper (and Alloys)/Wood	45(R), 74(R), 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 117(R), 119(R), 122(R), 134(R), 135, 139(R), 145, 156(R), 157(R), 158(R), 167, 179(R), 189(R), 192(R), 193(R), 194(R)
Copper (and Alloys)/Zinc	93, 94(R), 96(R), 97(R), 98(H), 100(R), 174(H), 192(R), 194(R)

[a] See Note, p. 118.

Specific Applications [a] (cont.)

Epoxy Fibrous Glass Laminates/ Stainless Steel	131(R), 152(H), 161(H), 206(H), 221(R)
Epoxy Fibrous Glass Laminates/ Steel	50(R), 52(R), 131(R), 152(H), 161(H), 206(H), 221(R)
Fibrous Glass/Stainless Steel	71(R), 139(R), 221(R)
Fibrous Glass/Steel	42(R), 71(R), 76, 139(R), 194(R), 221(R)
Glass/Gold	80, 81(R), 82, 85(R)
Glass/Iron	80, 81(R), 82, 85(R), 93, 167, 170(H), 192(R), 194(R), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)
Glass/Magnesium (and Alloys)	23, 24, 25, 26, 45(R), 110(R), 194(R), 216(H), 217(H), 218(H), 219(H), 220(H)
Glass/Silver	80, 81(R), 82, 85(R), 117(R), 119(R)
Glass/Stainless Steel	12(R), 13(R), 23, 24, 25, 26, 53(R), 55(R), 56, 58(H), 62(H), 63(H), 66(R), 68(R), 71(R), 80, 81(R), 82, 85(R), 92(R), 93, 94(R), 97(R), 110(R), 114(H), 117(R), 118(R), 119(R), 122(R), 123(H), 126(H), 131(R), 132(R), 139(R), 143, 144(H), 156(R), 157(R), 158(R), 167, 170(H), 172(H), 179(R), 188(R), 189(R), 193(R), 196, 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)
Glass/Steel	23, 24, 25, 26, 45(R), 53(R), 55(R), 56, 58(H), 63(H), 66(R), 68(R), 71(R), 80, 81(R), 82, 85(R), 92(R), 93, 94(R), 97(R), 110(R), 114(H), 118(R), 121(R), 122(R), 123(H), 126(H), 131(R), 132(R), 139(R), 141(R), 142(R), 143, 144(H), 156(R), 157(R), 158(R), 167, 170(H), 172(H), 179(R), 188(R), 189(R), 192(R), 193(R), 194(R), 196, 197(R), 198(R), 199(R), 200(R), 201(R), 202(R), 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)
Glass/Titanium (and Alloys)	23, 24, 25, 26, 80, 81(R), 82, 85(R), 216(H), 217(H), 218(H), 219(H), 220(H)
Gold/Nickel (and Alloys)	77, 80, 81(R), 82, 84(H), 85(R), 86(R), 91(H)
Gold/Stainless Steel	77, 80, 81(R), 82, 84(H), 85(R), 86(R), 91(H), 166, 182(HH)

[a] See Note, p. 118.

Specific Applications [a] (cont.)

Gold/Titanium (and Alloys)	77, 80, 81(R), 82, 84(H), 85(R), 86(R), 91(H)
Iron/Magnesium (and Alloys)	79(H), 96(R), 98(H), 100(R), 138(R), 194(R), 216(H), 217(H), 218(H), 219(H), 220(H)
Iron/Nickel (and Alloys)	77, 79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H)
Iron/Nylon, Molded	85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 167
Iron/Phenolics (and Laminates)	1(R), 3(R), 80, 81(R), 82, 85(R), 99(H), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 167, 192(R)
Iron/Polyester Fibrous Glass Laminates	79(H), 80, 81(R), 82, 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 221(R)
Iron/Polystyrene Foam	79(H), 80, 81(R), 82, 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R)
Iron/Rubber, Hard	101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R)
Iron/Titanium (and Alloys)	77, 79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 216(H), 217(H), 218(H), 219(H), 220(H)
Iron/Wood	85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 167, 170(H), 192(R), 194(R)
Iron/Zinc	93, 94(R), 96(R), 97(R), 98(H), 100(R), 192(R), 194(R)
Magnesium (and Alloys)/Stainless Steel	9(R), 12(R), 13(R), 17(R), 23, 24, 25, 26, 79(H), 96(R), 98(H), 100(R), 110(R), 135, 136(R), 137(R), 174(H), 212(H), 216(H), 217(H), 218(H), 219(H), 220(H)
Magnesium (and Alloys)/Steel	10(H), 17(R), 23, 24, 25, 26, 45(R), 78(H), 79(H), 96(R), 98(H), 100(R), 110(R), 135, 136(R), 137(R), 138(R), 140(R), 174(H), 194(R), 212(H), 216(H), 217(H), 218(H), 219(H), 220(H)
Magnesium (and Alloys)/Titanium (and Alloys)	23, 24, 25, 26, 79(H), 135, 136(R), 137(R), 216(H), 217(H), 218(H), 219(H), 220(H)

[a] See Note, p. 118.

Specific Applications [a] (cont.)

[a] See Note, p. 118.

Specific Applications[a] (cont.)

POLYESTER FIBROUS GLASS LAMINATE/ TITANIUM (and ALLOYS)	79(H), 80, 81(R), 82, 85(R)
POLYSTYRENE FOAM/MAGNESIUM (and ALLOYS)	11, 12(R), 13(R), 15(R), 17(R)
POLYSTYRENE FOAM/SILVER	79(H), 80, 81(R), 82, 85(R), 117(R), 119(R)
POLYSTYRENE FOAM/STAINLESS STEEL	12(R), 13(R), 17(R), 79(H), 80, 81(R), 82, 85(R), 117(R), 118(R), 119(R), 152(H), 159(R)
POLYSTYRENE FOAM/STEEL	11, 12(R), 13(R), 17(R), 42(R), 79(H), 80, 81(R), 82, 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 152(H), 159(R), 197(R), 198(R), 199(R), 200(R), 201(R), 202(R)
POLYSTYRENE FOAM/TITANIUM (and ALLOYS)	79(H), 80, 81(R), 82, 85(R)
RUBBER, NITRILE/STAINLESS STEEL	12(R), 13(R), 19, 20, 69(R), 85(R), 87(R), 93, 94(R), 95(R), 97(R), 110(R), 122(R), 134(R), 135, 171(R), 183(H), 184(H), 186(H), 187(R), 189(R), 224(H)
RUBBER, HARD/STEEL	101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 122(R)
RUBBER, NITRILE/STEEL	19, 20, 42(R), 45(R), 69(R), 85(R), 87(R), 93, 94(R), 95(R), 97(R), 110(R), 122(R), 134(R), 135, 171(R), 183(H), 184(H), 186(H), 187(R), 189(R), 192(R), 194(R), 224(H)
SILVER/STAINLESS STEEL	77, 80, 81(R), 82, 84(H), 85(R), 86(R), 91(H), 117(R), 119(R)
SILVER/STEEL	84(H), 85(R), 86(R), 91(H)
SILVER/TITANIUM (and ALLOYS)	77, 80, 81(R), 82, 84(H), 85(R), 86(R), 91(H)
STAINLESS STEEL/TEFLON, TREATED	85(R), 99(H), 110(R), 118(R), 135, 188(R), 190(R), 207(R), 216(H), 217(H), 218(H), 219(H), 220(H)
STAINLESS STEEL/TITANIUM (and ALLOYS)	23, 24, 25, 26, 77, 80, 81(R), 82, 84(H), 85(R), 86(R), 87(R), 88(H), 89(R), 90(H), 91(H), 135, 136(R), 137(R), 146(H), 148(H), 151(HH), 216(H), 217(H), 218(H), 219(H), 220(H)

[a] See Note, p. 118.

Specific Applications[a] (cont.)

STAINLESS STEEL/WOOD	12(R), 13(R), 74(R), 85(R), 117(R), 118(R), 119(R), 122(R), 134(R), 135, 139(R), 156(R), 157(R), 158(R), 167, 170(H), 179(R), 189(R), 193(R)
STAINLESS STEEL/ZINC	93, 94(R), 96(R), 97(R), 98(H), 100(R), 159(R), 174(H)
STEEL/TEFLON, TREATED	85(R), 99(H), 110(R), 118(R), 135, 188(R), 190(R), 207(R), 216(H), 217(H), 218(H), 219(H), 220(H)
STEEL/TITANIUM (and ALLOYS)	23, 24, 25, 26, 77, 80, 81(R), 82, 84(H), 85(R), 86(R), 87(R), 88(H), 89(H), 90(H), 91(H), 135, 136(R), 137(R), 146(H), 216(H), 217(H), 218(H), 219(H), 220(H)
STEEL/TUNGSTEN CARBIDE	1(R), 3(R), 23, 24, 25, 26
STEEL/WOOD	7(R), 8(R), 21(R), 42(R), 45(R), 52(R), 74(R), 85(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 118(R), 122(R), 134(R), 135, 139(R), 156(R), 157(R), 158(R), 167, 170(H), 179(R), 189(R), 192(R), 193(R), 194(R), 197(R), 198(R), 199(R), 200(R), 201(R), 202(R)
STEEL/ZINC	93, 94(R), 96(R), 97(R), 98(H), 100(R), 159(R), 174(H), 192(R), 194(R)

[a] See Note, p. 118.

General-Purpose Applications

ALNICO/OTHER METALS	11, 23, 24, 25, 26
ALUMINUM (and ALLOYS)/PLASTICS *	4(R), 6(R), 7(R), 8(R), 14(R), 50(R), 53(R), 54(R), 55(R), 57(R), 58(R), 62(H), 63(H), 66(R), 69(R), 72, 73(R), 80, 81(R), 82, 83(H), 85(R), 87(R), 92(R), 93, 95(R), 100(R), 110(R), 126(R), 132(R), 133(R), 134(R), 135, 136(R), 137(R), 139(R), 143, 156(R), 167, 168, 172(H), 179(R), 183(H), 184(H), 189(R), 192(R), 194(R), 206(H)

* Not recommended for highly plasticized vinyls, untreated polyethylene, untreated "Teflon," or untreated "Kel-F" type plastics.

NOTE:
L—Below room temperature (70°F) curing.
R—Room temperature curing (approx. 70°-80°F).
H—Recommended curing temperatures of 300°F and above. Cures at lower temperatures are possible in some cases.
HH—Curing temperatures of 600°F and above.
HHH—Curing temperatures of over 1000°F.
NO INDICATION—Heat curing at temperatures below 300°F.

General-Purpose Applications[a] (cont.)

Asbestos Board/Metals	23, 24, 25, 26, 27(R), 31(R), 41, 166, 171(R), 183(H), 184(H)
Beryllium/Plastics *	80, 81(R), 82, 85(R), 87(R)
Ceramics/Metals	27(R), 30(R), 31(R), 34(R), 36, 37, 38(R), 40, 53(R), 54(R), 55(R), 56, 58(H), 62(H), 63(H), 64, 65, 66(R), 68(R), 69(R), 92(R), 93, 94(R), 97(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 114(H), 118(R), 121(R), 123(H), 126(H), 135, 143, 144(H), 153(HHH), 180(HHH), 181(HH), 182(H), 189(R), 192(R), 194(R), 216(H), 217(H), 218(H), 219(H), 220(H)
Ceramics/Rubber †	12(R), 13(R), 27(R), 30(R), 31(R), 34(R)
Concrete/Metals	35(R), 52(R), 101(R), 102(R), 103, 104(R), 105(R), 106(R), 107(R), 179(R), 192(R), 194(R), 203(L), 204(R)
Copper (and Alloys)/Plastics *	9(R), 53(R), 54(R), 55(R), 57(R), 66(R), 69(R), 72, 73(R), 85(R), 87(R), 92(R), 93, 95(R), 100(R), 110(R), 117(R), 119(R), 126(H), 132(R), 135, 136(R), 137(R), 139(R), 143, 156(R), 167, 168, 179(R), 183(H), 184(R), 189(R), 192(R), 194(R)
Electrically Conductive Cements	56, 57(R), 58(H), 59(H), 60(R), 61(R)
→ Friction Materials and Brake Linings/Metals	39, 170(H), 171(R), 172(H), 183(H), 184(H), 185(H), 186(H), 224(H)
Glass/Metals	1(R), 3(R), 9(R), 17(R), 18(H), 38(R), 53(R), 55(R), 56, 58(H), 62(H), 63(H), 66(R), 68(R), 71(R), 80, 81(R), 82, 85(R), 92(R), 93, 94(R), 97(R), 110(R), 114(H), 120(R), 122(R), 123(H), 126(H), 131(R), 132(R), 134(R), 139(R), 143, 144(H), 156(R), 157(R), 158(R), 159(R), 166, 167, 168, 179(R), 180(HHH), 181(HH), 182(HH), 188(R), 189(R), 192(R), 194(R), 196, 216(H), 217(H), 218(H), 219(H), 220(H), 221(R)
Gold (and Plate)/Other Metals	77, 79(H), 80, 81(R), 82, 84(H), 85(R), 86(R), 91(H), 166
Gold (and Plate)/Plastics *	79(H), 80, 81(R), 82, 85(R)

[a] See Note, p. 131.

* Not recommended for highly plasticized vinyls, untreated polyethylene, untreated "Teflon," or untreated "Kel-F" type plastics.

† Not recommended for silicone rubber.

General-Purpose Applications [a] (cont.)

[a] See Note, p. 131.

* Not recommended for highly plasticized vinyls, untreated polyethylene, untreated "Teflon," or untreated "Kel-F" type plastics.

† Not recommended for silicone rubber.

General-Purpose Applications [a] (cont.)

* PLASTICS/STEEL	1(R), 3(R), 7(R), 8(R), 50(R), 53(R), 54(R), 55(R), 57(R), 58(H), 62(H), 63(H), 66(R), 69(R), 72, 73(R), 80, 81(R), 82, 85(R), 87(R), 92(R), 93, 95(R), 100(R), 110(R), 126(H), 132(R), 133(R), 134(R), 135, 136(R), 137(R), 139(R), 143, 156(R), 167, 168, 170(H), 179(R), 183(H), 184(H), 189(R), 192(R), 194(R), 196, 206(H)
* PLASTICS/TITANIUM (and ALLOYS)	80, 81(R), 82, 85(R), 135, 136(R), 137(R)
* PLASTICS/ZINC	93, 95(R), 100(R), 192(R), 194(R)

[a] See Note, p. 131.

* Not recommended for highly plasticized vinyls, untreated polyethylene, untreated "Teflon," or untreated "Kel-F" type plastics.

APPENDIX I

FEDERAL TEST METHOD STANDARD NO. 175

METHODS OF TESTING ADHESIVES

Authority.—*This standard is issued pursuant to the Federal Property and Administration Services Act of 1949, as amended, and its application to the purchase of commodities referred to herein is mandatory on all Federal agencies.*

1. SCOPE AND NUMBERING SYSTEM

1.1 Scope.—The methods in this standard shall be used officially in the routine sampling, inspection, and testing of adhesives and constructions made with adhesives purchased under Federal specifications. This standard does not include test methods applicable only to a specific product; such test methods are included in the material specifications. In case of conflict between the provisions of this standard and those of the material specification for a particular material or product, the provisions of the latter shall take precedence.

1.2 Numbering system.—The various test methods are designated by numbers, assigned in accordance with the following system. The number of times any given test method has been revised is indicated by the number following the decimal point.

1.2.1 *Class of test.*—Any given class of tests is assigned a series of basic numbers covering one millenary. For example, the permanence class of tests is designated by the numbers 2000 to 2999, inclusive, with others shown below:

1000—Strength Properties.
2000—Permanence Properties.
3000—Working Properties.
4000—Analytical Tests.

2. NOTES

2.1 (Activities outside the Federal Government may obtain copies of Federal Specifications and Standards as outlined under General Information in the Index of Federal Specifications and Standards and at the prices indicated in the Index. The Index, which includes cumulative monthly supplements as issued, is for sale on a subscription basis by the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

(Single copies of product specifications required by activities outside the Federal Government for bidding purposes are available without charge at the General Services Administration Regional Offices in Boston, New York, Atlanta, Chicago, Kansas City, Mo., Dallas, Denver, San Francisco, Los Angeles, Seattle, and Washington, D. C.)

(Federal Government activities may obtain copies of Federal Specifications and Standards and the Index of Federal Specifications and Standards from established distribution points in their agencies.)

PUBLISHER'S NOTE: The spellings used are identical with the original specifications.

Patent notice.—When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

3. GENERAL REQUIREMENTS

3.1 Inspection and sampling.—Unless otherwise specified in the invitation for bids, purchases shall be inspected and samples for test taken either at the place of manufacture or at the point of delivery. If the inspection and tests, whether preliminary or final, are to be made on the premises of the contractor or subcontractor, the contractor shall furnish, without additional charge, all reasonable facilities and assistance for the safe and convenient performance of the inspection and tests. The manufacturer and/or the contractor shall notify the purchasing officer sufficiently in advance of the completion of manufacture of material to permit arrangement for inspection and taking of samples.

3.1.1 *Number of samples.*—The number of samples to be taken from each lot shall be as specified in the material specification. The number of specimens to be tested in each method of test shall be as specified in the material specification; if not so specified, the number of specimens specified in the method of test shall be used.

3.1.2 *Taking of samples.*—Samples shall be obtained if possible from the products to be tested, taken at random, and in such case shall be taken in accordance with the requirements of the specification covering the particular material. In case it is not practical to obtain suitable test specimens from the finished article, the manufacturer shall furnish bonded test specimens suitable for the tests specified. The manufacturer shall furnish an affidavit that the material submitted for test is made from the same materials under the same or equivalent conditions as those used in the manufacture of the commodity.

3.2 Preparation of test specimens.

3.2.1 *Bonding.*—The accuracy of the results of strength tests of adhesive bonds will depend upon the conditions under which the bonding process is carried out. Unless otherwise specified in the material specification, the bonding conditions shall be prescribed by the manufacturer of the adhesive. To insure that complete information is available to the individual conducting the tests, the manufacturer of the adhesive shall furnish numerical values and other specific information for each of the following variables:

(1) Procedure for preparation of surfaces prior to application of the adhesive, including the moisture content of wood, the cleaning and drying of metal surfaces, and special surface treatments such as sanding which are not specifically limited by the pertinent test method.

(2) Complete mixing directions for the adhesive.

(3) Conditions for application of the adhesive, including the rate of spread or thickness of film, number of coats to be applied, whether to be applied to one or both surfaces, and the conditions of drying where more than one coat is required.

(4) Assembly conditions before application of pressure, including the room temperature, and open and closed assembly time.

(5) Curing conditions, including the amount of pressure to be applied, the length of time under pressure, and the temperature of the assembly when under pressure. It should be stated whether this temperature is that of the adhesive layer or of the atmosphere at which the assembly is to be maintained.

(6) Conditioning procedure before testing, including the length of time, temperature, and relative humidity.

A range may be prescribed for any variable by the manufacturer of the adhesive if it can be assumed by the test operator that any arbitrarily chosen value within such a range or any combination of such values for several variables will be acceptable to the manufacturer and the purchaser of the adhesive.

3.2.2 *Machining.*—When it is necessary to machine specimens, cutting tools shall be used in such a manner that the possibility of overheating is minimized. Unless otherwise specified herein, all machined surfaces of specimens shall be finished with 3/0 emery paper to eliminate all irregularities such as tool marks, etc. When a more perfect finish is desired, a suitable polishing compound shall be used.

3.2.3 *Treatment prior to test.*—Samples and specimens for tests shall not be heated, immersed in water, or subjected to any mechanical or chemical treatment prior to test except as specifically described herein or in the material specification.

3.3 Testing conditions.—Unless otherwise specified in detail method of test, the atmospheric conditions surrounding the specimen prior to and during test shall be 23° ± 1.1°C. (73.5° ± 2°F.) and 50 ± 4 percent relative humidity in accordance with Fed. Std. No. 1, Laboratory Atmospheric Conditions For Testing; the conditioning period prior to test shall be 48 hours for specimens of 1/8 inch or less in thickness and 96 hours for thicker specimens.

3.3.1 *Testing for temperature effects.*—When the relation of properties to temperature is to be determined, it is recommended, as a matter of standardization, that tests be performed at one or more of the following atmospheric temperatures: −55°C. (−67°F.), −40°C. (−40°F.), −25°C. (−13°F.), 0°C. (32°F.), 50°C. (122°F.), 70°C. (158°F.), or 77°C. (171°F.). In all cases specimens should be conditioned at the testing temperature and humidity for at least 24 hours immediately prior to test, unless otherwise specified. The temperature, the relative humidity, and the period of time for conditioning should all be recorded.

3.4 Apparatus.—Unless otherwise specified, properties shall be determined in any stardard type of testing machine properly calibrated and accurate to 1 per cent in the range used.

3.5 Results of tests.—Unless otherwise specified, the average of the results for the specimens tested shall be used to determine conformance of materials tested under this specification. Unless otherwise specified, results for specimens that break at some obvious flaw or that do not break between the predetermined gage marks shall be discarded. Unless otherwise specified, results that deviate from the mean value of all tests shall be rejected if the deviation of the doubtful value is more than five times the average deviation from the mean obtained by excluding the doubtful value. Additional specimens shall be tested in place of any for which the results are discarded in accordance with these provisions.

3.6 Test reports.—Unless otherwise specified, the report on each test shall include the following:

(1) The name of the Government agency requesting the test.

(2) The name of the contractor and the number and date of the contract covering the material and/or parts.

(3) The title, number, and date of the applicable material specification.

(4) Description of the material, including type, source, manufacturer's code numbers, etc.

(5) Type and dimensions of specimens.

(6) Location and direction of specimens in the original sample.

(7) Temperature, humidity, and length of conditioning period.

(8) Such additional data as are stated herein under the individual test methods.

(9) Such additional data as may be required under the material specification.

(10) Any further information that may be considered pertinent, particularly with reference to unexpected behavior.

(11) A brief description of the testing apparatus, sufficient to identify it.

METHOD 1011.1: TENSILE PROPERTIES OF ADHESIVES

1. SCOPE

1.1 This method of test is intended for determining the comparative tensile properties of adhesives when tested on standard-shape specimens and under defined conditions of pretreatment, temperature, and testing machine speed. It is not suitable for testing specimens made with flexible or nonrigid adherends. Tensile strength is the maximum tensile load per unit area of original cross section carried by a test specimen of the types herein described during a tension test. It is expressed in pounds per square inch.

2. SPECIMENS

2.1 Test specimens for wood-to-wood adhesives shall conform to the form and dimensions shown in figure 1A. Unless otherwise specified in

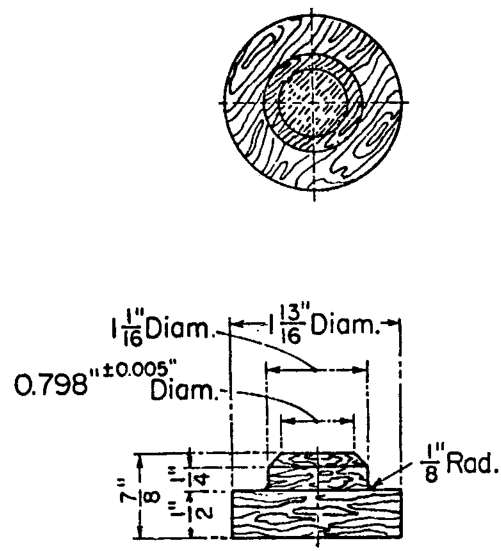


FIGURE 1A.—*Wood and glass test specimen.*

the material specification, hard maple (Acer saccharum or Acer nigrum) having a minimum specific gravity of 0.65 based on oven-dry weight and volume shall be used. This wood shall be of straight grain and free from defects including small knots, birdseye, short grain, and unusual discolorations within the test area. Blocks 2½ inches in width, 11 inches in length, and ⅞ inch in thickness, from which test specimens are to be made, shall be surfaced immediately before bonding and may be conditioned prior to surfacing as recommended by the manufacturer, unless otherwise specified in the material specification. If no moisture conditioning process is given in the material specification or recommended by the manufacturer, blocks at the time of surfacing shall be at equilibrium condition, resulting from exposure to a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.). The blocks shall be surfaced by the standard procedure as follows: Blocks shall be weighed and assembled in pairs so that blocks of approximately the same specific gravity are bonded together. The blocks shall be planed smooth, preferably with a hand-feed jointer, and the surfaced faces laid together. The surfaces shall be planed just before bonding, left unsanded, and shall be free from dirt. Blocks shall then be bonded and conditioned to their original moisture content by restoring them at the equilibrium condition, after which test specimens conforming to figure 1A shall be prepared. For machining to the dimensions specified in figure 1A, pieces 2 by 2 inches shall be sawed from the bonded hard maple block.

2.2 Test specimens for metal-to-metal adhesives shall conform to the form and dimensions shown in figure 1B. Metal specimens may be reused after testing by resurfacing by grinding flat and parallel those areas that contain the adhesive. Suggestions regarding metals for use in this test method are given in note 1.

2.3 Test specimens for plastic-to-plastic adhesives and plastic-to-metal adhesives shall conform to the form and dimensions shown in figure 1B. The surface shall be prepared in accordance with the recommendations of the manufacturer of the adhesive, unless otherwise specified in the material specification (note 2).

2.4 Test specimens for glass-to-glass adhesives shall conform to the form and dimensions shown in figure 1A. The surface shall be prepared in accordance with the recommendations of the manufacturer of the adhesive, unless otherwise specified in the material specification. Glass surfaces may be reused after testing by resurfacing by grinding flat and parallel those areas that contain the adhesive.

2.5 At least 10 and preferably 20 specimens shall be tested for each adhesive in the case of wood adhesives. At least 10 test specimens shall be tested for each adhesive in the case of metal-to-metal, plastic-to-plastic, plastic-to-metal, and glass-to-glass adhesives.

2.6 Specimens that break at some obviously fortuitous flaw remote from the adhesive line shall be discarded and retest made, unless such flaws constitute a variable the effect of which it is desired to study.

2.7 Bonding shall be done in accordance with the procedure as outlined by the manufacturer of the adhesive. If no rate of spread is recommended, 3 to 4 grams of adhesive shall be applied to each contacting

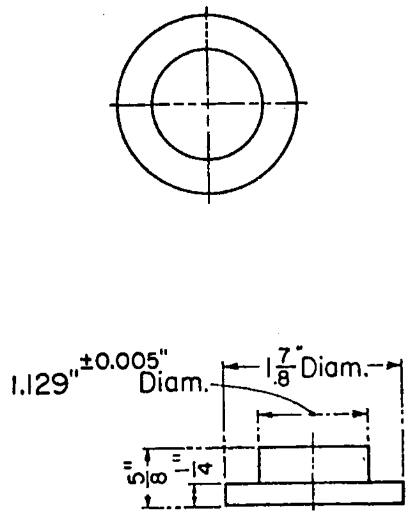


FIGURE 1B.—*Metal and plastic test specimen.*

surface. For wood specimens a pair of maple blocks, selected as described in 2.1, 2½ inches in width, 11 inches in length, and ⅞ inch in thickness, shall be bonded together with the grain of the wood parallel in each piece. For metal, plastic, and glass specimens preparation of areas that are to be bonded shall be in accordance with the recommendations of the manufacturer of the adhesive.

NOTE.—Surfaces of all specimens shall be ground flat and parallel. It is preferable to grind all metal specimens at the same time.

3. APPARATUS

3.1 The testing machine shall be capable of maintaining a specified rate of loading. It shall have a fixed or essentially stationary member, carrying one grip, and a movable member, carrying a second grip. The grips shall be used to hold a test specimen between the fixed member and the movable member. These shall be of the self-alining type. That is, they shall be attached to the fixed and movable member, respectively, in such a way that they will move into alinement as soon as any load is applied, so that the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly. While the design of grips of this type is optional, one that has been found satisfactory is shown in figures 2 and 3.

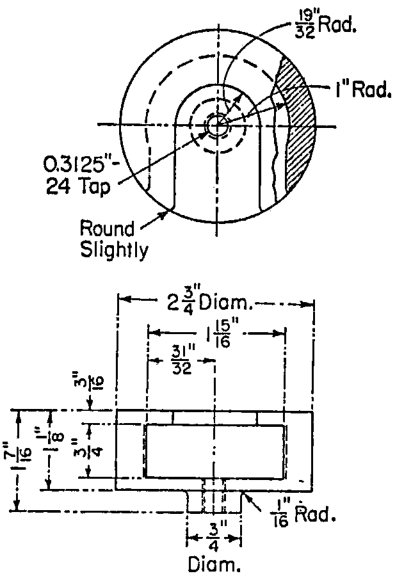


FIGURE 2.—*Test grips (cold-rolled steel).*

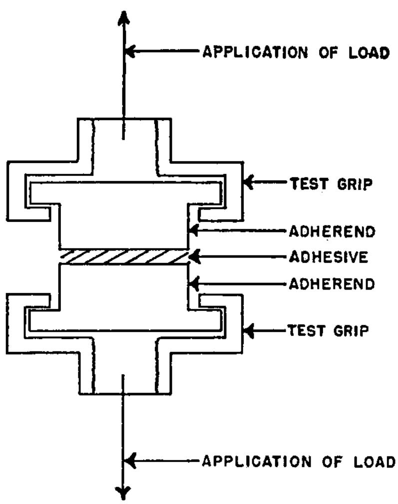


FIGURE 3.—*Cross section of test specimen in test grip.*

3.2 A conditioning room capable of maintaining a relative humidity of 50 ± 4 per cent at $23° \pm 1.1°C.$ $(73.5° \pm 2°F.)$, or desiccators filled with a saturated salt solution to give a relative humidity of 50 ± 4 per cent at $23° \pm 1.1°C.$ $(73.5° \pm 2°F.)$ (note 3).

4. PROCEDURE

4.1 Unless otherwise specified in the material specification the adhesive and the wood and plastic specimens shall be preconditioned by exposure to a relative humidity of 50 ± 4 per cent at $23° \pm 1.1°C.$ $(73.5° \pm 2°F.)$ until they reach equilibrium, as determined by no progressive change in weight. Metal and glass specimens shall be preconditioned for at least 4 hours or to temperature equilibrium. The specimens shall be bonded with the adhesive in accordance with General Requirements, section 3, paragraph 3.2.

4.2 After the bonded specimens are made they shall be conditioned and tested as described in General Requirements, section 3, paragraph 3.3.

4.3 The specimen shall be placed in the grips of the testing machine, care being taken to aline the specimen and the grips with an imaginary line joining the points of attachment of the grips to the machine. Wood-to-wood specimens shall be inserted so that the grain direction is at right angles to the long horizontal axis of the slots in the grip.

4.4 Tension tests for all materials shall be made under one of the following conditions: (a) by applying a load to the specimen of 600 to 700 pounds per square inch of bonded area per minute, or (b) at a rate of grip separation crosshead speed of the testing machine such that the load can be accurately weighed but shall not exceed 0.050 inch per minute (1.27 millimeters per minute) when the machine is running idle. In case the material specification does not specify a rate, the 600 to 700 pounds per square inch of bonded area per minute rate shall be used.

4.5 Record the maximum load carried by the specimen at failure and also the following:

(1) In the case of wood specimens record the percentage of wood failures, bond failures, and contact failures (note 4). This shall be based on a visual inspection.

(2) In the case of metal, plastic, and glass specimens record the percentage of cohesion, adhesion, and contact failures (note 4). This shall be based on visual inspection.

4.6 Tensile strength of wood and glass specimens shall be calculated by multiplying the breaking load by 2. This result shall be expressed in pounds per square inch and if possible reported to three significant figures. Tensile strength of the metal and plastic specimens shall be the breaking load and shall be expressed in pounds per square inch and, if possible, reported to three significant figures. For each series of tests, the arithmetic mean of the values obtained shall be calculated and reported as the average value. The standard error, s, of the reported average value shall be calculated as follows:

$$s = \sqrt{\frac{\Sigma x^2 - N\bar{x}^2}{N(N-1)}}$$

where s = standard error of the average,
x = value of a single observation,
N = number of observations, and
$\bar{x}$ = arithmetic mean of the set of observations.

5. REPORT

5.1 Unless otherwise specified, the report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Test room conditions.
(2) Number of specimens tested.
(3) Rate of loading or rate of grip separation.
(4) Average value and standard error of the tensile strength, with an average value of the percentages of wood failure, bond failure, and contact failure for wood specimens, and of cohesion, adhesion, and contact failures for metal, plastic, and glass specimens.

Note 1.—Metals conforming to the following specifications are suggested for making bonded metal-to-metal specimens for use in this method:

Metal	Federal Specification	ASTM Designation
Aluminum	QQ–A–267 or QQ–A–268	B 211, alloy CG42A.
Brass	QQ–B–626, comp. 22	B 16.
Copper	QQ–C–502	B 133, type A.
Magnesium	QQ–M–31, alloy AZ61A	B 107, alloy AZ61A.
Nickel silver	QQ–C–586, alloy 2	B 151, alloy B.
Phosphor bronze	QQ–P–330, comp. A	B 139, alloy A.
Steel	QQ–S–633, alloy FS 1020	A 108, grade 1020.

Note 2.—Plastic materials used in the test specimens shall be as specified in the material specification, invitation to bid, or the order.

Note 3.—A saturated solution of calcium nitrate will give approximately 52-per cent relative humidity at 23°C.

Note 4.—Failure in the adhesive layer itself denotes cohesive failure. One-hundred-per cent cohesive failure is obtained when adhesive adheres to the two separated test pieces at all points and no voids are visible. Adhesion or bond failure refers to the separation of the adhesive from the adherend. Contact failure refers to lack of contact of the adhesive with the adherend surfaces because of lack of planeness, low pressure, nonuniform distribution of the adhesive, insufficient adhesive, etc.

METHOD 1012: TENSILE PROPERTIES OF ADHESIVES FOR RUBBERLIKE MATERIALS

1. SCOPE

1.1 This method of test is intended for determining the comparative tensile properties of adhesives for rubberlike materials when tested on standard-shape specimens and under defined conditions of pretreatment, temperature and testing machine speed. Tensile adhesion strength is the maximum tensile load per unit area of original cross section required to break a test specimen of the types herein described during a tension test. It is expressed in pounds per square inch.

2. SPECIMENS

2.1 Test specimens for rubber-to-rubber adhesives shall consist of two 1-inch cubes of vulcanized rubber bonded together with the test adhesive. Each cube shall have a hole drilled through the center of two opposite faces for the insertion of a ⅛-inch pin. One of the other faces of each cube shall be buffed, washed with toluene, and coated with the adhesive in the manner specified. The two cubes shall then be carefully pressed together with the coated surfaces in contact. A ten-pound weight shall be placed on them and allowed to remain for 24 hours or longer as required.

2.2 Test specimens for rubber-to-metal adhesives shall be prepared for cold-set type and hot-set type adhesives as described in 2.2.1 and 2.2.2, respectively. Circular metal plates having the configuration shown in figure 1 shall be machined from rolled bar steel conforming to alloy

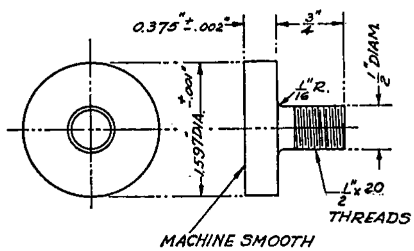


FIGURE 1.—*Metal part of specimen for testing metal-to-rubber adhesives.*

FS 1020 in Federal Specification QQ–S–633 (grade 1020 in ASTM Designation A 108). The stud is used for attaching the test piece to the loading fixture in the testing machine. The smoothly machined faces of the metal plates shall be brass plated, sand blasted, ground or prepared by a procedure required to give a good bond with the particular adhesive being tested.

2.2.1 *Cold-set type adhesive.*—The test specimen shall be prepared from vulcanized rubber of the type specified by cutting cylinders 0.500 ± 0.005 inch in thickness and 1.597 ± 0.005 inch in diameter, and buffing the circular faces to parallel planes. The circular faces of the rubber cylinders shall be coated with a uniform film of the test adhesive, 0.001 to 0.005 inch in thickness. The faces of the metal plates shall be freshly sand-blasted or ground and washed free of dust and grease with toluene. The metal faces shall also be coated with the test adhesive in a manner similar to that used to coat the rubber cylinders. When the adhesive films have dried to the point where there is still aggressive tackiness but no tendency for the film to lift when touched with a finger, each rubber cylinder shall be bonded firmly by hand between the coated faces of two metal plates and the assembly shall be clamped in a suitable loading fixture under a compressive load of 10 pounds for at least 24 hours at 23° ± 1.1°C. (73.5° ± 2°F.) and 50 ± 4 per cent relative humidity.

2.2.2 *Hot-set type adhesive.*—The specimen for determining adhesive strength in tension for hot-set adhesives shall be prepared and conditioned as specified in 2.2.1. The curing conditions for the adhesive shall be in accordance with the manufacturer's instructions unless otherwise specified in the material specification. After curing, the loading fixture containing the specimen shall be placed in an oven at 100° ± 3°C. (212° ± 5°F.) for three hours, following which the fixture and the specimens shall be removed from the oven and allowed to stand at room temperature for an additional 48 hours under the 10-pound load. The specimens shall then be removed from the fixture and allowed to stand at 23° ± 1.1°C. (73.5° ± 2°F.) and 50 ± 4 per cent relative humidity for at least 48 hours.

2.3 Before sampling, the adhesive to be tested shall be thoroughly agitated to uniform consistency throughout in such a manner that large amounts of air are not stirred into the sample. A sample of sufficient quantity for performance of the required tests shall then be taken.

2.4 At least 10 specimens shall be tested for each adhesive.

2.5 Specimens that break at some obviously fortuitous flaw remote from the glue line shall be discarded and retest made, unless such flaws constitute a variable the effect of which it is desired to study.

3. APPARATUS

3.1 The testing machine shall be capable of maintaining a specified rate of loading. It shall have a fixed or essentially stationary member, carrying one grip, and a movable member, carrying a second grip. The grips shall be used to hold a test specimen between the fixed member and the movable member. These shall be of the self-alining type. That is, they shall be attached to the fixed and movable member, respectively, in such a way that they will move into alinement as soon as any load is applied, so that the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly. While the design of grips of this type is optional, one that has been found satisfactory is shown in figure 2. The assembly of the grips and the test specimen prior to test are shown in figure 3.

3.2 A conditioning room capable of maintaining a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ±2°F.), or desiccators filled with a saturated salt solution to give a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.) (note 1).

4. PROCEDURE

4.1 Unless otherwise specified in the material specification, the specimens shall be conditioned by exposure to a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.) until they reach equilibrium, as determined by no progressive change in weight and tested under these conditions as described in General Requirements, section 3, paragraph 3.3.

4.2 The specimen shall be placed in the grips of the testing machine, care being taken to aline the specimen and the grips with an imaginary line joining the points of attachment of the grips of the machine.

4.3 Tension tests for all rubberlike materials shall be made under one of the following conditions: (a) by applying a load to the specimen of 600 to 700 pounds per square inch of bonded area per minute, or (b) at a rate of grip separation of 1 inch per minute when the machine is running idle. In case the material specification does not specify a rate, the 600 to 700 pounds per square inch of bonded area per minute rate shall be used.

4.4 The maximum load carried by the specimen at failure and the estimated percentage of cohesion, adhesion, and contact failures shall be recorded (note 2). This shall be based on a visual inspection.

4.5 The tensile adhesion strength shall be expressed in pounds per square inch obtained by dividing the load causing failure by the original area of the bonded surface. With the standard rubber-to-metal test specimen the strength value is the load divided by two. For each series of tests the arithmetic mean of all values obtained shall be calculated and reported as the average value. The standard error, s, of the reported average value shall be calculated as follows:

$$s = \sqrt{\frac{\Sigma x^2 - N\bar{x}^2}{N(N-1)}}$$

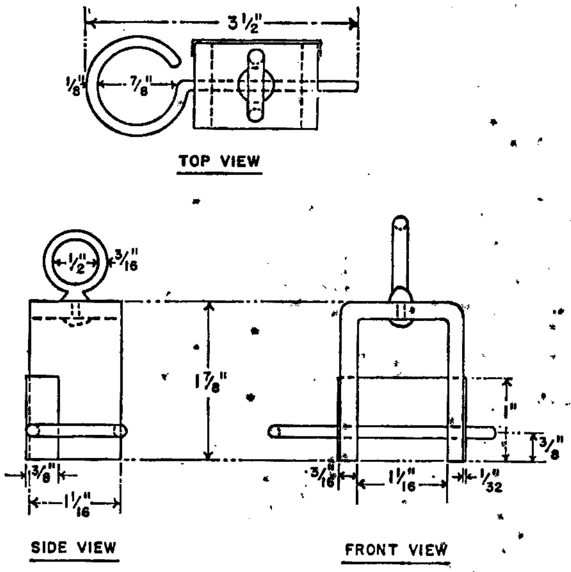


FIGURE 2.—*Test grips (steel).*

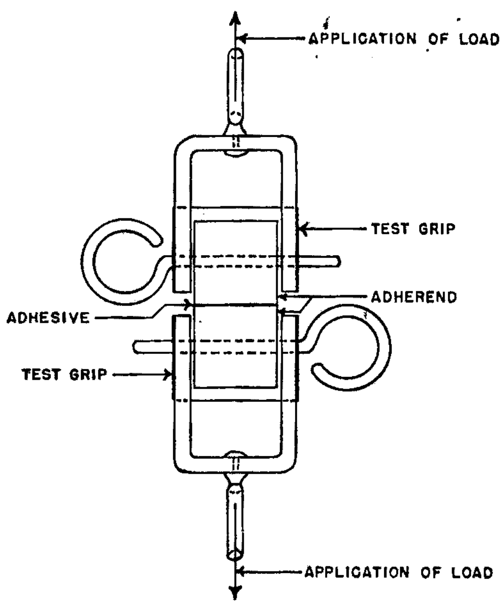


FIGURE 3.—*Cross section of test specimen in test grip.*

where: s = standard error of the average,
x = value of a single observation,
N = number of observations, and
$\bar{x}$ = arithmetic mean of the set of observations.

NOTE 1.—A saturated solution of calcium nitrate will give approximately 52 per cent relative humidity at 23°C.

NOTE 2.—Failure in the adhesive layer itself denotes cohesive failure. One-hundred-per cent cohesive failure is obtained when adhesive adheres to the two separated test pieces and no voids are visible. Adhesion or bond failure refers to the separation of the adhesive from the adherend. Contact failure refers to lack of contact of adhesive with the adherend surfaces because of lack of planeness, low pressure, nonuniform distribution of adhesive, insufficient adhesive, etc.

5. REPORT

5.1 Unless otherwise specified, the report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following, where applicable:

(1) Test room conditions.
(2) Number of specimens tested.
(3) Rate of loading or rate of grip separation.
(4) Average value and standard error of the tensile adhesion strength with an average value of the percentage of bond failure.

METHOD 1021: SHEAR STRENGTH PROPERTIES OF ADHESIVES BY FLEXURAL LOADING

1. SCOPE

1.1 This method of test is intended for determining the comparative properties of adhesive assemblies when subjected to flexural stresses with standard-shaped specimens and under defined conditions of pretreatment, temperature, relative humidity, and testing technique. The test specimen and testing technique were designed to develop a large portion of shear forces between the laminae of the test piece when the load is applied rather than to reduce shear stress to a minimum as is done in other methods of test for flexural properties. This method is not applicable to nonrigid adherends. The flexural-shear strength is the apparent maximum shear stress sustained by the specimen, as calculated by the formula in 4.5.1. It is recognized that this formula does not apply rigidly to tests made in the manner described in this method, but it does serve to reduce the data to a more comparable basis.

2. SPECIMENS

2.1 General.—The specimen shall be a rectangular piece 1 to 1.5 inches long and 0.75 to 1 inch wide. The length of the specimen shall be sufficient to allow an overhang of about 0.1 inch or more on each end. The specimens shall be machined from laminated panels made by bonding together eight plies of 0.01-inch-thick adherend material, each ply coated with adhesive with an even spread on both sides. The mixing procedure, weight of spread, drying conditions, and assembly time shall conform to the manufacturer's directions.

2.2 Wood specimens.—Unless otherwise specified in the material specification, birch shall be used. The wood panels shall be prepared from 0.01-inch-thick quarter-cut veneers. Only straight grain veneers shall be selected. Veneers shall be conditioned at 50 ± 4 per cent relative humidity and 23° ± 1.1°C. (73.5° ± 2°F.) for at least 2 weeks before bonding. Panels shall be constructed by arranging the grains of the veneers symmetrically about the center so that the two core veneers are parallel, and the two face veneers perpendicular to the core and to the next outer veneers and parallel to each other and to the veneers next to the core.

2.3 Metal specimens.—Unless otherwise specified in the material specification, aluminum alloy conforming to Federal Specification QQ–A–355 shall be used. The metal panels shall be prepared from 0.01-inch-thick sheets.

2.4 Three panels shall be prepared with each adhesive-adherend combination and at least three specimens shall be cut from each panel for this test.

3. APPARATUS

3.1 Testing machine.—A properly calibrated testing machine capable of maintaining a specified rate of approach of the two loading parts shall be used. The error for indicated loads shall not exceed plus or minus 1 per cent. The stiffness of the testing machine shall be such that the total elastic deformation of the system does not exceed 1 per cent of the total deflection of the test specimen. The load indicating mechanism shall be essentially free from inertia lag at the specified rate of testing.

3.2 Loading piece.—The center loading piece which is attached to one loading part of the testing machine shall have a radius of at least $\frac{1}{32}$ inch. The rounded nose shall be at least 1 inch long. If significant indentation occurs, a radius of one and one-half times the specimen depth for a chord length of not less than twice the specimen depth shall be used.

3.3 Supports.—A pair of round-nosed supports of the same radius as that on the loading piece shall be used. The span shall be adjustable to plus or minus 0.005 inch within the range of 8 times the thickness of the test specimens (usually 0.5 to 1.5 inches). The support device shall be mounted on the one loading part of the testing machine so that the rounded-nose of the loading piece on the other loading part is centered between the supports.

3.4 Deflection indicator.—A suitable instrument for measuring the deflection of the test specimen at the center directly beneath the line of application of the load, at any time during the test, shall be used. It is desirable, but not essential, that this instrument record the center deflection (or any change in it) as a function of the load on the test specimen or of the elapsed time from the start of the test or both. This instrument shall be essentially free from inertia lag at the specified rate of loading and shall be accurate to plus or minus 1 per cent of strain or better.

3.5 Micrometers.—Suitable calibrated micrometers, reading to at least 0.001 ± 0.000 inch, shall be used for measuring the width and thickness of the test specimens.

3.6 Conditioning room or desiccators.—A conditioning room capable of maintaining a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.) or desiccators filled with a saturated salt solution to give a relative humidity of 50 ± 4 per cent at 23° ±1.1°C. (73.5° ± 2°F.) (note 1).

4. PROCEDURE

4.1 The specimen shall be tested as a simple beam loaded at midspan. The span-depth ratio shall be 8 to 1. The span length shall be measured to the nearest 0.01 inch. The width and thickness of the specimen shall be measured to the nearest 0.001 inch at the center of the span.

4.2 Rate of loading.—The rate of approach of the loading parts for testing the specimens shall be calculated in accordance with the following formula:

$$N = \frac{ZL^2}{6d}$$

where:

N = rate of approach of the loading parts in inches per minute,
L = span in inches,
d = depth of beam in inches, and
Z = unit rate of fiber strain in inches per inch of outer fiber length per minute, which constant shall be 0.01.

For the conditions of the test described in this method, this formula reduces to: $N = 0.107\,d$.

The rate of approach of the loading parts shall be as near as possible but shall not exceed the value calculated from this formula. This permits the use of a constant rate of stressing provided the resultant rate of approach does not exceed the value calculated from the above formula.

4.3 Load-deflection curves may be plotted to determine the modulus of elasticity (note 2), offset yield strength, and the total work measured by the area under the load-deflection curve. The deflection shall be measured with a dial gage or other suitable apparatus located under the specimen in contact with it at the center of the span, or by measuring the deflection of the neutral axis of the specimen. Data obtained by measuring the head travel are not acceptable.

4.4 When load-deflection data are being taken, the rate of approach of the loading parts shall be low enough so that deflection gage readings can be made accurately.

4.5 Shear strength properties.

4.5.1 *Flexural-shear strength.*—The maximum shear stress of a specimen tested as a simple beam of rectangular cross section loaded at midspan is as follows:

$$S = \frac{3P}{4bd}$$

where:

S = maximum shear stress in pounds per square inch,
P = breaking load in pounds,
b = width of beam tested in inches,
d = depth of beam tested in inches.

The flexural-shear strength shall be calculated from the load sustained by the specimen at the moment of break, using the formula given for maximum shear stress.

4.5.2 *Modulus of elasticity.*—The modulus of elasticity of material tested as a simple beam of rectangular cross section loaded at midspan shall be calculated as follows:

$$E_b = \frac{L^3}{4bd^3} \cdot \frac{P}{Y}$$

where:

E_b = modulus of elasticity in bending in pounds per square inch,
L = distance between points of support in inches,
b = width of beam tested in inches,
d = depth of beam tested in inches, and
$\frac{P}{Y}$ = slope of initial straight line portion of load-deformation curve in pounds per inch of deflection.

4.6 For each series of tests, the arithmetic mean of all values obtained shall be calculated to three significant figures and reported as the average value for the particular property in question.

4.7 The deviation of each value from the average value shall be calculated and the arithmetic mean of these deviations determined. This arithmetic mean shall be reported to two significant figures as the average deviation of the particular series of results.

4.8 Unless otherwise specified in the material specification, all specimens shall be conditioned prior to test at 23° ± 1.1°C. (73.5° ± 2°F.) and 50 ± 4 per cent relative humidity for 48 hours.

NOTE 1.—A saturated solution of calcium nitrate will give approximately 52 per cent relative humidity at 23°C.

NOTE 2.—The modulus of elasticity is the ratio of stress to the corresponding strain within the elastic limit of the material. It is calculated in accordance with the formula in 4.5.2.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 6.3, and the following where applicable:

(1) Method of preparing test specimens.
(2) Direction of cutting and loading specimens.
(3) Radius of supports and nose.
(4) Rate of approach of loading parts in inches per minute.
(5) Maximum deflection at center of span in inches or millimeters.
(6) Flexural-shear strength calculated in accordance with 4.5.1, average value and average deviation.
(7) Modulus of elasticity in bending in pounds per square inch, calculated in accordance with 4.5.2, average value and average deviation.
(8) Type of failure; i.e., delamination, breaking, or buckling.

METHOD 1031: SHEAR STRENGTH PROPERTIES OF ADHESIVES BY COMPRESSION LOADING

1. SCOPE

1.1 This method of test is intended for determining the comparative shear strengths of adhesives, used for bonding wood and other similar materials, when tested on a standard specimen under specified conditions of preparation, conditioning, and loading in compression. This method is intended primarily as an evaluation of adhesives for wood.

2. SPECIMENS

2.1 Test specimens shall conform to the form and dimensions shown in figure 1.

2.2 At least 10 specimens shall be tested, representing at least 2 different joints.

2.3 Hard maple blocks (*Acer saccharum* or *Acer nigrum*), having a minimum specific gravity of 0.65 based on oven-dry weight and volume shall be selected (note 1). These blocks shall be of straight grain and free from defects including knots, birdseye, short grain, decay, and any unusual discolorations within the shearing area. The blocks shall be of suitable size, preferably so that five test specimens may be cut from one test joint as shown in figure 2. Blocks approximately ¾ by 2½ by 12

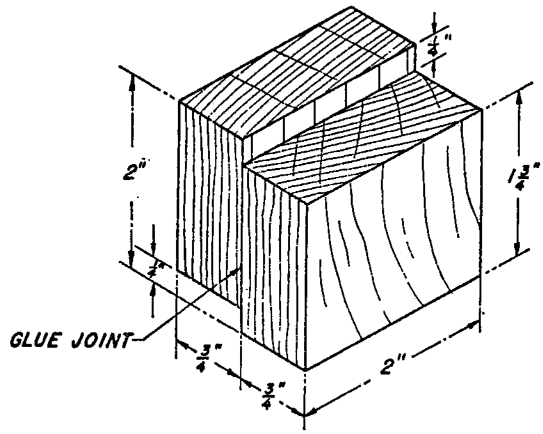


FIGURE 1.—*Form and dimensions of test specimen.*

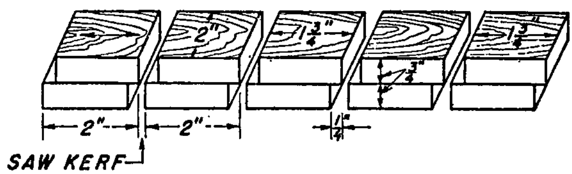


FIGURE 2.—*Test joint showing method of cutting five test specimens.*

inches have been found to be satisfactory for this purpose. The grain direction shall be parallel to the longest dimension of the block. The blocks shall be at the equilibrium moisture content recommended by the manufacturer of the adhesive. In the absence of such recommendation, the moisture content shall be from 10 to 12 per cent based on oven-dry weight as determined on representative samples (note 2). The blocks shall be surfaced, just prior to bonding, preferably with a hand-feed jointer, and the blocks weighed and assembled in pairs so that blocks of approximately the same specific gravity are bonded together. The surfaces shall remain unsanded and shall be free from dirt.

2.4 The adhesive shall be prepared and applied to the blocks in accordance with the procedure recommended by the manufacturer of the adhesive. If no rate of spread is recommended, 3 to 4 grams of adhesive mix shall be applied to each contacting surface. The adhesive-coated blocks shall then be assembled and pressed, likewise in accordance with the recommendations of the manufacturer of the adhesive.

2.5 The specimens shall be cut as shown in figure 2 so that the grain direction is parallel to the direction of loading during test. Care shall be taken in preparing the test specimens to make the loaded surfaces smooth and parallel to each other and perpendicular to the height. When sawing the bonded assembly into five separate test specimens, care shall also be exercised in reducing the lengths of the laminations to 1¾ inches to insure that the saw cuts extend to, but not beyond, the adhesive line. The width and height of the specimen at the adhesive line shall be measured to the nearest 0.010 inch to determine the shear area.

2.6 Specimens shall be retained in the conditioning atmosphere.

3. APPARATUS

3.1 The testing machine shall be fitted with a compression shearing tool containing a self-alining seat to insure uniform lateral distribution of the load. The machine shall be capable of maintaining a uniform rate of grip separation such that the load may be applied with a continuous motion of the movable head to maximum load at a rate of 0.015 inch per minute with a permissible variation of plus or minus 25 per cent. The shearing tool shown in figure 3 has been found satisfactory. The testing

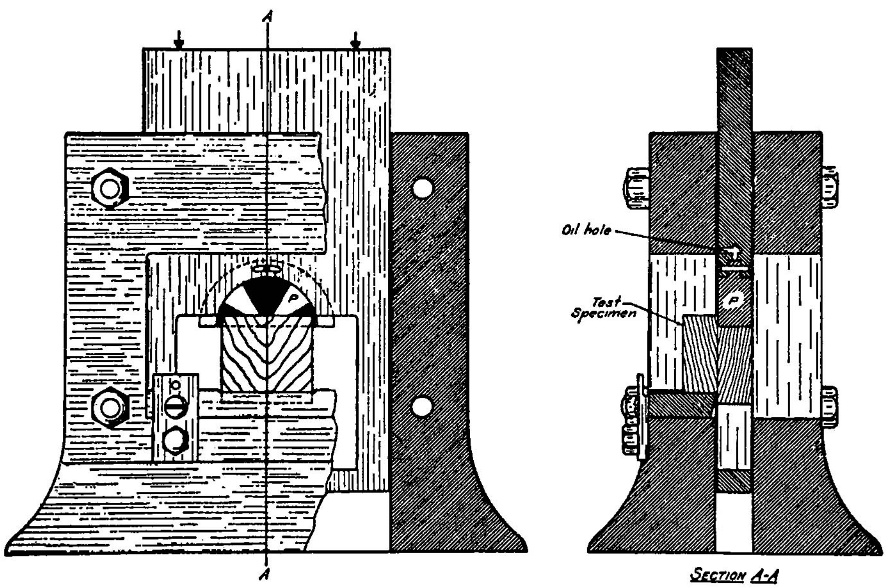


FIGURE 3. *Shearing tool.*

machine shall be located in an atmosphere such that the moisture content of the specimens developed under the conditions prescribed in 4.1 is not noticeably altered during testing.

4. PROCEDURE

4.1 The joints upon removal from pressure shall be conditioned at a relative humidity of 50 ± 4 per cent (note 3) and at a temperature of 23° ± 1.1°C. (73.5° ± 2°F.) either for a period of 7 days or until specimens reach equilibrium as indicated by no progressive changes in weight, whichever is the shorter period. The length of this period of conditioning may be extended beyond this limit in the material specification.

4.2 The test specimen shall be placed in the shearing tool so that the load may be applied as described in 3.1. The position of the specimen in one type of shearing tool is shown in figure 3. The loading shall be applied with a continuous motion of the movable head at a rate of 0.015 inch per minute to failure as prescribed in 3.1.

4.3 The shear stress at failure shall be calculated in pounds per square inch, based on the adhesive line area between the two laminations measured to the nearest 0.01 square inch, and shall be reported for each specimen together with the estimated percentage of wood failure.

NOTE 1.—A convenient method for determining the specific gravity of blocks of wood will be found in section 115 of the Tentative Methods of Testing Small Clear Specimens of Timber (A. S. T. M. designation: D 143–52) of the American Society for Testing Materials.

NOTE 2.—Convenient methods for determining the moisture content by oven drying procedures will be found either in sections 122 to 125 of the Tentative Methods of Testing Small Clear Specimens of Timber (A. S. T. M. designation: D 143–52) of the American Society for Testing Materials or in Military Specification MIL–W–6110 for Determination of Moisture Content of Wood.

NOTE 3.—A saturated solution of calcium nitrate will give approximately 52 per cent relative humidity at 23°C.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Application and bonding conditions used in preparing the specimens.

(2) Temperature and relative humidity in the test room.

(3) Number of specimens tested.

(4) Number of joints represented.

(5) Maximum and minimum shear stresses at failure and percentages of wood failure. The standard deviation or all individual test values, or both, for the failing load values and wood failure values may be included in the report, as specified in the material specification.

(6) The average shear stress at failure and the average percentage of wood failure.

METHOD 1032: SHEAR STRENGTH PROPERTIES OF ADHESIVES IN PLYWOOD TYPE CONSTRUCTION BY TENSION LOADING

1. SCOPE

1.1 This method of test is intended for determining the comparative shear strengths of adhesives in plywood-type construction, when tested on a standard specimen and under specified conditions of preparation, conditioning, and testing. This method is intended to be applied only to adhesives used in bonding wood to wood.

1.2 The requirements in the material specification will indicate whether or not both the dry and wet tests shall be made. The procedure for the wet tests shall be specified from method 2031.

2. SPECIMENS

2.1 The test specimen shall conform to the form and dimensions shown in figure 1.

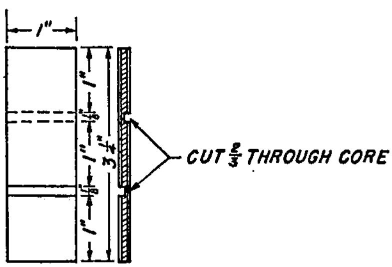


FIGURE 1.—*Form and dimensions of test specimen.*

2.2 At least 20 specimens shall be tested, representing at least four different panels for the dry test and a like number for the wet test.

2.3 Sweet or yellow birch veneer (*Betula lenta* or *Betula lutea*), either rotary cut or sliced, $\frac{1}{16}$ inch in thickness, shall be selected so that it is free from defects such as knots, cracks, short grain, or any unusual amount of discoloration which would indicate decay. The surfaces shall be unsanded. The veneer shall be cut into suitable sizes and assembled in groups of three sheets, the grain of the center sheet running at right angles to the grain of the other two sheets. The grain in all sheets shall be parallel to one edge. A size which has been found to be convenient is shown in figure 2, in which case the grain in the face ply should be parallel to the shorter dimension. The veneer shall be at the moisture content

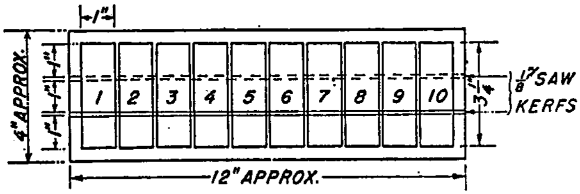


FIGURE 2.—*Size of test panel.*

recommended by the manufacturer of the adhesive. In the absence of such a recommendation, the moisture content shall be from 10 to 12 per cent based on oven-dry weight as determined on representative samples in the material specification. Any other species of veneer may be designated by the material specification.

2.4 The adhesive shall be prepared in accordance with the procedure outlined by the manufacturer of the adhesive.

2.5 The adhesive shall be applied to the veneers as prescribed by the manufacturer of the adhesive. After the prescribed time has elapsed, the veneers shall be assembled into three-ply panels so that the grain in the center ply is at right angles to the grain in the two outer plies. The panel shall then be bonded in accordance with the recommendations of the manufacturer of the adhesive.

2.6 The panels, after bonding, shall be aged in accordance with the recommendations of the manufacturer of the adhesive.

2.7 The test specimens shall be cut as shown in figure 1. This is best accomplished by cutting the notches to the proper width, depth, and location in the test panel, using a hollow ground grooving saw or any other method that will give equally satisfactory results. The individual test specimens shall then be cut from the panel. The cutting of individual specimens is shown for one size of panel in figure 2. The width of the specimen and the distance between notches shall be measured to the nearest 0.010 inch to determine the shear area.

3. APPARATUS

3.1 The testing machine shall be capable of maintaining a rate of loading of 600 to 700 pounds per square inch per minute. It shall be provided with suitable grips and jaws so that the specimen can be gripped tightly and held in alinement as the load is applied. The grips and jaws shown in figure 3 have been found satisfactory.

4. PROCEDURE

4.1 The finished specimens shall be conditioned at a relative humidity of 50 ± 4 per cent and at a temperature of 23° ± 1.1°C. (73.5° ± 2°F.)

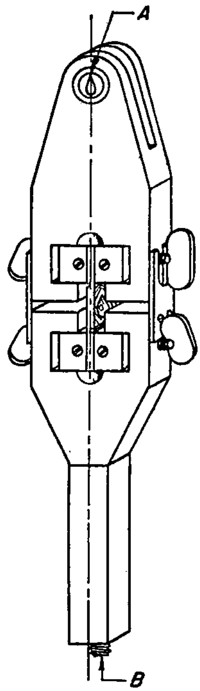


FIGURE 3.—*Grips and jaws.*

either for 7 days or until the specimens reach equilibrium as indicated by no progressive changes in weight, whichever is the shorter period. The length of this period may be extended beyond this limit in the material specification.

4.2 Dry test.—The specimens shall be tested in an atmosphere maintained at 50 ± 4 per cent relative humidity and $23° \pm 1.1°C$. ($73.5° \pm 2°F$.).

4.3 Wet test.—The test specimens shall be subjected to one or more of the procedures given in method 2031 if wet strength values are required.

4.4 The test specimen shall be placed in the jaws of the grips in the testing machine and gripped tightly so that the specimen is perfectly alined and the jaws are directly above each other and in such a position that an imaginary straight vertical line would pass through the center of the bonded area and through the points of suspension A and B, as shown in figure 3. Specimens shall be placed in the jaws alternately so that in one case the upper notch is to the left and in the other case toward the right. The load shall then be applied at a rate of 600 to 700 pounds per square inch per minute until failure.

4.5 The load at failure and the estimated per cent of wood failure shall be recorded for each test specimen. All failing loads shall be expressed in pounds per square inch of shear area, calculated to the nearest 0.01 square inch.

NOTE 1.—Convenient methods for determining the moisture content by oven drying procedures will be found either in sections 122 to 125 of the Tentative Methods for Testing Small Clear Specimens of Timber (A.S.T.M. designation: D 143–52) of the American Society for Testing Materials or in Military Specification MIL–W–6110 for determination of moisture content of wood.

NOTE 2.—By making three-ply panels with other materials, such as wood and metal, adhesives for other materials may be tested by this method.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Application and bonding conditions used in preparing the specimens.

(2) Temperature and relative humidity in the test room.

(3) Number of specimens tested.

(4) Number of panels represented.

(5) Maximum and minimum loads at failure and percentages of wood failure. The standard deviation or all individual test values, or both, for the failing load values and wood failure values may be included in the report, as requested in the material specification.

(6) The average load at failure and the average percentage of wood failure.

TENTATIVE STANDARD METHOD 1032.1–T: SHEAR STRENGTH PROPERTIES OF ADHESIVES IN PLYWOOD-TYPE CONSTRUCTION BY TENSION LOADING

1. SCOPE

1.1 This method of test is intended for determining the comparative shear strengths of adhesives in plywood-type construction, when tested on one of two standard specimens and under specified conditions of preparation, conditioning, and testing. This method is intended to be applied only to adhesives used in bonding wood to wood (note 1).

1.2 The requirements in the material specification will indicate whether or not both dry and wet tests shall be made. The procedure for the wet tests shall be one of those specified in method 2031 or method 2031.1–T.

2. SPECIMENS

2.1 The test specimen shall conform to the form and dimensions shown in figure 1a for veneer of 1/16 inch or greater in thickness. The test specimen for veneer 1/20 inch or less in thickness shall conform to the form and dimensions shown in figure 1b.

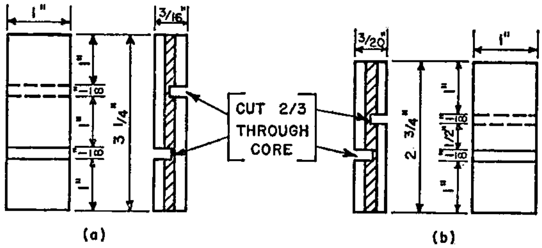


FIGURE 1.—*Form and dimensions of test specimens.*

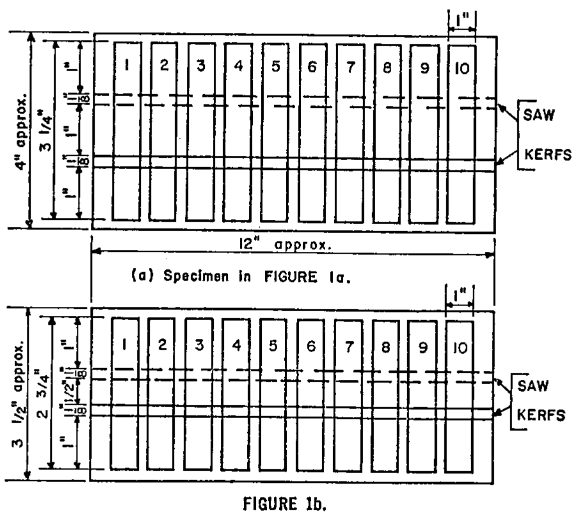


FIGURE 2.—*Size of test panels.*

2.2 At least 20 specimens shall be tested, representing at least four different panels for the dry test and a like number for the wet test.

2.3 Sweet or yellow birch veneer (Betula lenta or Betula lutea), either rotary cut or sliced, 1/16 or 1/20 inch in thickness, shall be selected so that it is free from defects such as knots, cracks, short grain, or any unusual amount of discoloration which would indicate decay. The surfaces shall be unsanded. The veneer for each thickness shall be cut into suitable sizes and assembled in groups of three sheets, the grain of the center sheet running at right angles to the grain of the other two sheets. The grain in all sheets shall be parallel to one edge. Sizes which have been found to be convenient are shown in figures 2a and 2b; in these cases the grain in the face ply should be parallel to the shorter dimension. The veneer shall be at the moisture content recommended by the manufacturer of the adhesive. In the absence of such a recommendation, the moisture content shall be from 10 to 12 per cent based on oven-dry weight as determined on representative samples in the material specification (note 2). Any other species of veneer may be designated by the material specification.

2.4 Bonding shall be done in accordance with the procedure outlined in General Requirements, section 3, paragraph 3.2.1.

2.5 The test specimens shall be cut as shown in figure 1a or figure 1b. This is best accomplished by cutting the notches to the proper width, depth, and location in the test panel, using a hollow ground grooving saw or any other method that will give equally satisfactory results. The individual test specimens shall then be cut from the panel. The cutting of individual specimens is shown for two sizes of panels in figures 2a and 2b. The width of the specimen and the distance between notches shall be measured to the nearest 0.010 inch to determine the shear area.

3. APPARATUS

3.1 The testing machine shall be capable of maintaining a rate of loading of 600 to 700 pounds per square inch per minute. It shall be provided with suitable grips and jaws so that the specimen can be gripped tightly and held in alinement as the load is applied. The grips and jaws shown in figure 3 have been found satisfactory.

4. PROCEDURE

4.1 The finished specimens shall be conditioned at a relative humidity of 50 ± 4 per cent and at a temperature of 23° ± 1.1°C. (73.5° ± 2.0°F.), either for 7 days or until the specimens reach equilibrium as indicated by no progressive change in weight, whichever is the shorter period. The length of this period may be extended beyond this limit in the material specification.

4.2 **Dry test.**—The specimens shall be tested in an atmosphere maintained at 50 ± 4 per cent relative humidity and 23° ± 1.1°C. (73.5° ± 2.0°F.).

4.3 **Wet test.**—The test specimens shall be subjected to one or more of the procedures given in methods 2031 or 2031.1–T if wet strength values are required.

4.4 The test specimen shall be placed in the jaws of the grips in the

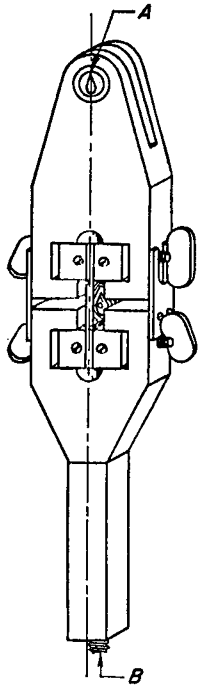


Figure 3.—*Grips and jaws.*

testing machine and gripped tightly so that the specimen is perfectly alined so that one jaw is directly above the other in such a position that an imaginary straight vertical line would pass through the center of the bonded area and through the points of suspension A and B, as shown in figure 3. Specimens shall be placed in the jaws alternately so that in one case the upper notch is to the left and in the other case toward the right. The load shall then be applied at a rate of 600 to 700 pounds per square inch per minute until failure.

4.5 The load at failure and the estimated per cent of wood failure shall be recorded for each test specimen. All failing loads shall be expressed in pounds per square inch of shear area, calculated to the nearest 0.01 square inch.

NOTE 1.—By making three-ply panels with other materials, such as wood and metal, adhesives for other materials may be tested by this method.

NOTE 2.—Convenient methods for determining the moisture content by oven drying procedures will be found either in sections 122 to 125 of the Standard Methods for Testing Small Clear Specimens of Timber (ASTM Designation: D143–52) of the Society for Testing Materials or in Military Specification MIL–W–6110 for determination of moisture content of wood.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Application and bonding conditions used in preparing the specimens.

(2) Temperature and relative humidity in the test room.

(3) Number of specimens tested.

(4) Number of panels represented.

(5) Maximum and minimum loads at failure and percentages of wood failure. The standard error or all individual test values, or both, for the failing load values and wood failure values may be included in the report, as requested in the material specification.

(6) The average load at failure and the average percentage of wood failure.

METHOD 1033: SHEAR STRENGTH PROPERTIES OF ADHESIVES DETERMINED WITH SINGLE-LAP CONSTRUCTIONS BY TENSION LOADING

1. SCOPE

1.1 This method of test is intended for use in determining the comparative shear strengths of adhesives for bonding adherends when tested on a standard specimen and under specified conditions of preparation and testing.

1.2 A variation in thickness of the adherends will likely influence the test values. For this reason, the thickness of the sheets used to make the test specimen shall be specified in the material specification. When no thickness is specified, sheets of adherends 0.064-inch thick are recommended.

2. SPECIMENS

2.1 The test specimens shall conform to the form and dimensions shown in figure 1.

2.2 At least 20 specimens shall be tested, representing at least four different panels.

2.3 Sheets of the adherend materials (metal, wood, plastic, etc.) shall be cut to 6- by 6-inch squares. The sheets shall be cleaned and dried carefully according to the procedure prescribed by the manufacturer and assembled into the specified pairs. When wood is used, the moisture con-

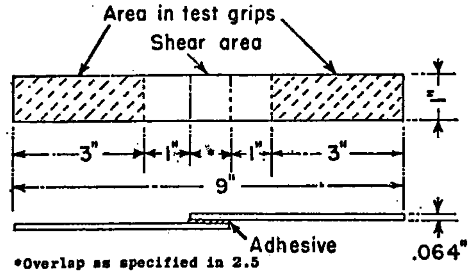


FIGURE 1.—*Specimen placement for shear strength test.*

tent shall be a value recommended by the manufacturer of the adhesive. In the absence of such a recommendation, the moisture content shall be from 10 to 12 per cent based on oven-dry weight as determined on representative samples (note 1).

2.4 The adhesive shall be prepared and applied, in accordance with the recommendations of the manufacturer of the adhesive, to an area 0.25 inch wider than the overlap to be used and 6 inches long across the end of one or both sheets of each pair. The sheets shall then be assembled and held rigidly so that the length of the overlap shall be as calculated in 2.5 and the adhesive allowed to cure as prescribed by the manufacturer of the adhesive.

2.5 The length of the overlap shall be based on the thickness of the material being bonded. The ratio of $\frac{\sqrt{t}}{L}$ shall be 0.5 or greater for metal specimens where t is the thickness of the adherend in inches and L the overlap in inches. For nonmetallic materials the overlap shall be 1 inch for adherends ⅛ inch or thicker and ½ inch for adherends less than ⅛ inch thick.

2.6 Test specimens, as shown in figure 1, shall be cut from the joints. This cutting operation must be done so as to avoid overheating or mechanical damage to the bonds. The width of the specimen and the length of the overlap shall be measured to the nearest 0.010 inch to determine the shear area.

2.7 The finished specimens shall be conditioned at a relative humidity of 50 ± 4 per cent and at a temperature of 23° ± 1.1°C. (73.5° ± 2°F.) either for a period of 7 days or until specimens reach equilibrium as indicated by no progressive changes in weight, whichever is the shorter period. The length of this period of conditioning may be extended beyond this limit in the material specification.

2.8 Specimens shall be retained in the conditioning atmosphere until tested.

3. APPARATUS

3.1 The testing machine shall be capable of maintaining a rate of loading of 600 to 700 pounds per square inch per minute. It shall be provided with suitable grips and jaws so that the specimen can be gripped tightly and held in alinement as the load is applied.

4. PROCEDURE

4.1 Dry test.—The specimens shall be tested in an atmosphere maintained at 50 ± 4 per cent relative humidity and 23° ± 1.1°C. (73.5° ± 2°F.).

4.2 Wet test.—The test specimens shall be subjected to one or more of the procedures given in method 2031 if wet strength values are required.

4.3 The test specimen shall be placed in the jaws of the grips in the testing machine and gripped tightly so that the specimen is perfectly alined and the jaws are directly above each other and in such a position that an imaginary straight vertical line would pass through the center of the bonded area and through the points of suspension. The load shall then be applied at a rate of 600 to 700 pounds per square inch per minute until failure.

4.4 The load at failure shall be recorded. All failing loads shall be expressed in pounds per square inch of shear area, calculated to the nearest 0.01 square inch. The nature and amount of the failure (such as cohesion in adherend, or adhesion) shall be recorded for each specimen.

NOTE 1.—A convenient method for determining the moisture content of wood will be found in sections 122 to 125 of the Tentative Methods for Testing Small Clear Specimens of Timber (ASTM designation: D 143–52) of the American Society for Testing Material.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Complete identification of the adherends used, their thickness, and the methods of cleaning and preparing their surfaces prior to bonding.

(2) Application and bonding conditions used in preparing the specimens.

(3) Number of specimens tested.

(4) Number of panels represented.

(5) Temperature and relative humidity in the test room.

(6) Maximum and minimum loads at failure and percentages of wood failure, if any. The standard deviation or all individual test values, or both, for the failing load values and wood failure values may be included in the report as requested in the material specification.

(7) The average load at failure and the average percentages of failure in cohesion or adhesion.

TENTATIVE STANDARD METHOD 1033.1–T: SHEAR STRENGTH PROPERTIES OF ADHESIVES BY TENSION LOADING

1. SCOPE

1.1 This method of test is intended for use in determining the comparative shear strength of adhesives for bonding rigid adherends when tested on a standard specimen and under specified conditions of preparation and testing.

1.2 A variation in thickness of the adherends and the length of the overlap will likely influence the test value and make direct comparison of data questionable. For this reason, in comparative or specification tests, the thickness of metal adherends should preferably be 0.064 ± 0.005 inch and the thickness of plastic adherends 0.125 ± 0.010 inch; the length of the overlap for metal specimens should preferably be 0.5 ± 0.05 inch and the length of the overlap for plastic specimens should preferably be 0.25 ± 0.02 inch. Thickness and length of overlap should not be in excess of the value computed in 2.3. For development tests these values could be different, but should then be constant.

2. SPECIMENS

2.1 The test specimens shall conform to the form and dimensions shown in figure 1.

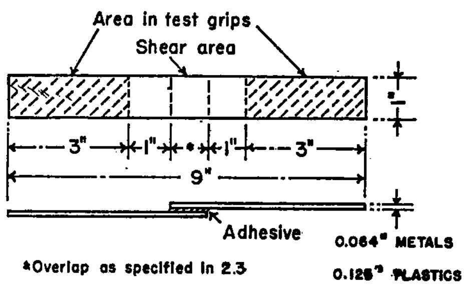


FIGURE 1.—*Specimen placement for shear strength test.*

2.2 At least 20 specimens shall be tested representing at least four different joints. These shall be cut from test joints prepared as specified in 2.4. The recommended thickness of metal sheets is 0.064 ± 0.005 inch, that of plastic sheets 0.125 ± 0.010 inch. The recommended length of the overlap for most metals of 0.064-inch thickness is 0.5 ± 0.05 inch, while the recommended length of the overlap for most plastics of 0.125-inch thickness is 0.25 ± 0.02 inch (note 1).

2.3 Since it is undesirable to exceed the yield point of the adherend in tension during test, the permissible length of overlap in the specimen will vary with the thickness and type of adherend and on the general level of strength of the adhesive being investigated. The maximum permissible length may be computed from the following relationship:

$$L = \frac{Yt}{r}$$

where:

L = length of overlap in inches,
t = thickness of adherend in inches,
Y = yield point of adherend (or the stress at proportional limit), and
r = 150 per cent of the estimated average shear strength in adhesive bond in pounds per square inch.

2.4 It is recommended that test specimens be made up in multiples of at least 5 specimens, and then cut into individual test specimens (note 2). Sheets of adherends of the thickness and with the length of overlap as prescribed in 2.2 and 2.3 shall be cut to suitable size. A size of 4 by 6 inches has been found convenient. The sheets shall be cleaned and dried carefully according to the procedure prescribed by the manufacturer of the adhesive and assembled in pairs. The adhesive shall be prepared and applied in accordance with General Requirements, section 3, paragraph 3.2. The adhesive shall be applied to a sufficient length in area across the end of one or both adherend sheets so that the adhesive will cover a space approximately ¼ inch longer than the overlap selected in 2.2 or 2.3. The sheets shall then be assembled and held rigidly so that the length of the overlap will be controlled as indicated in 2.2 or 2.3 within ± 0.05 inch for metals and within ± 0.02 inch for plastics.

2.5 Test specimens, as shown in figure 1, shall be cut from the joints. The cutting operation shall be done so as to avoid overheating or mechanical damage to the joints (note 3). At least 0.25 inch of the joint shall be discarded from each edge of the panel. The width of the specimen and the length of the overlap shall be measured to the nearest 0.05 inch to determine the shear area.

3. APPARATUS

3.1 The testing machine shall conform to the requirements of the Tentative Methods of Verification of Testing Machines (ASTM Designation E 4–5T, 1955 Book of Standards, Part 7). The testing machines shall be so selected that the breaking load falls between 15 and 85 per cent of the full-scale capacity. The machine shall be capable of maintaining a rate of loading of 600 to 700 pounds per minute, or, if the rate is dependent on crosshead motion, the machine should be set to approach this rate of loading. It shall be provided with a suitable pair of self-alining grips to hold the specimen. It is recommended that the jaws of these grips shall engage the outer 2½ inch of each end of the test specimen firmly (note 4). The grips and attachments shall be so constructed that they will move into alinement with the test specimen as soon as the load is applied, so that the long axis of the test specimen will coincide with the direction of the applied pull through the center line of the grip assembly.

4. PROCEDURE

4.1 Specimens, prepared as prescribed in 2.5, shall be tested as soon after preparation as possible. The tests shall be in accordance with General Requirements, section 3, paragraph 3.3.

4.2 Specimens shall be placed in the grips of the testing machine so that the outer 2½ inches of each end are in contact with the jaws (note 4) and so that the long axis of the test specimen shall coincide with the direction of applied pull through the center line of the grip assembly. The loading shall be applied at a rate of 600 to 700 pounds per square inch of the shear area per minute. The load shall be continued to failure.

4.3 The load at failure and the nature and amount of this failure (cohesion in adhesive or adherend, or adhesion) shall be recorded for each specimen. All failing loads shall be expressed in pounds per square inch of shear area, calculated to the nearest 0.01 square inch.

5. REPORT

5.1 The report shall include the data specified under General Requirements section 3, paragraph 3.6, and the following where applicable:

(1) Complete identification of the adherend used, its thickness, and the method of cleaning and preparing its surfaces prior to bonding.

(2) Application and bonding conditions used in preparing the specimens.

(3) Length of overlap used.

(4) Number of specimens tested.

(5) Number of joints represented.

(6) Maximum, minimum, and average values for the failing load. The standard deviation or all individual test values, or both, for the failing load values may be included in the report as requested in the material specification.

(7) The nature of the failure, including the average estimated per-

centages of failure in the cohesion of the adhesive, contact failure, and adhesion to the adherend.

NOTE 1.—Metals conforming to the specifications listed below are suggested for making the bonded metal-to-metal specimens for use in this method:

Metal	Federal Specification	ASTM designation
Aluminum	QQ–A–355, T3 temper .	B 209, alloy CG42A, T3 temper.
Brass	QQ–B–626, Comp. 1	B 36, alloy 8.
Copper	QQ–C–576	B 152, type A.
Steel	QQ–S–636, #2 half-hard.	A 109, grade 2.
Steel, corrosion-resisting	QQ–S–766, class 2	A 167, grade 2.

NOTE 2.—Bonding specimens in multiple panels is believed to give more representative specimens. However, individual specimens may be prepared if recommended by the manufacturer of the adhesive or specified in the material specification.

NOTE 3.—A fine-tooth typesetter's circular saw has been found suitable for such purposes.

NOTE 4.—The length of the overlap in the specimen and the length of the specimen in the jaws may be varied where necessary. The distance from the end of the lap to the end of the jaws should be at least 1 inch in all tests.

METHOD 1041.1: PEEL OR STRIPPING STRENGTH OF ADHESIVES

1. SCOPE

1.1 This method of test is intended for use in determining the comparative peel or stripping characteristics of adhesives when tested on standard-size specimens and under specified conditions of preparation and testing.

1.2 Peel or stripping strength.—The average load per unit width of bond line required to separate progressively one member from the other over the adherend surfaces at a separation angle of approximately 180° and at a separation rate of 6 inches per minute. It is expressed in pounds per inch of width.

1.3 Flexible.—The designation "flexible" in this test indicates a material of the proper flexural modulus of elasticity and thickness to permit a turn-back of an approximate 180° angle by application of a load less than that required to subsequently peel the adherend. At least one of the adherend materials must be flexible.

2. SPECIMENS

2.1 The test specimen, shown in figure 1A, shall consist of one piece of flexible material, 1 by 12 inches, bonded for 6 inches at one end to one

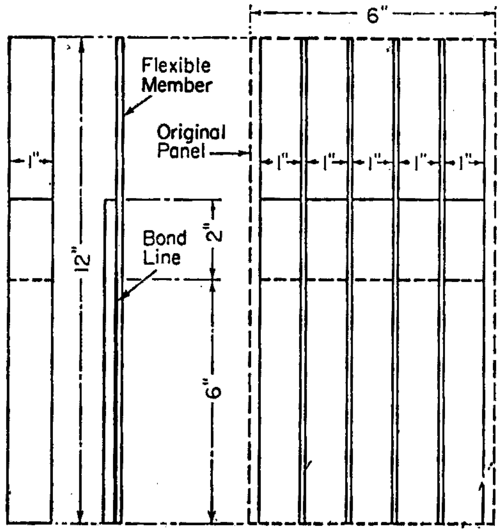


FIGURE 1A.—*Test specimen.*

FIGURE 1B.—*Specimens from bonded panel.*

piece of flexible or rigid material, 1 by 8 inches, with the unbonded portions of each member being face to face.

2.2 To maintain a separation rate of 6 inches per minute, the specimen shall be relatively nonextensible in the expected loading range. Where a material is sufficiently extensible to lessen radically the separation rate, it shall be backed up with a suitable nonextensible material. In reporting such a test, the backing material and method of backing shall be completely identified.

2.3 Test materials shall be thick enough to withstand the expected tensile pull. Wherever possible, the standard thickness or weight of adherend material used to make the specimens shall be: metals, $\frac{1}{16}$ inch; plastics, $\frac{1}{16}$ inch; woods, $\frac{1}{8}$ inch; rubber compounds, 0.075 inch; and cotton duck, 30 ounces per square yard. Other special materials, as well as the standard materials, shall be completely identified in the test report.

2.4 At least 10 test specimens shall be tested for each adhesive.

2.5 Any specimen whose test result is out of line because of some obvious flaw shall be discarded and retest made.

2.6 All bonding shall be done in accordance with the procedure and recommendations outlined by the manufacturer of the adhesive.

2.7 While individual specimens may be prepared, it is recommended, where possible, that specimens be cut from bonded panels approximately

6 inches in width as shown in figure 1B, so that five standard 1-inch-wide specimens may be obtained from each panel.

2.8 All specimens shall be conditioned for 7 days by exposure to a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.) or until equilibrium is reached.

3. APPARATUS

3.1 Testing machine.—The tests shall be made with a power-driven machine, which shall fulfill the following requirements:

3.1.1 The applied tension as measured and recorded shall be accurate within plus or minus 1 per cent.

3.1.2 Specimens shall be held in the testing machine by grips that clamp firmly and prevent slipping at all times.

3.1.3 The rate of travel of the power-actuated grip shall be 12 inches per minute. This rate, which provides a separation of 6 inches per minute shall be uniform throughout the tests.

3.1.4 The machine shall be operated without any device for maintaining maximum load indication. In pendulum-type machines, the weight lever shall swing as a free pendulum without engagement of pawls.

3.1.5 The machine shall be autographic, giving a chart having the inches of separation as one axis and applied tension as the other axis of coordinates.

3.1.6 The machine shall be of such capacity that the maximum applied tension during test shall not exceed 85 per cent nor be less than 15 per cent of the rated capacity.

3.2 Conditioning room or desiccators.—A conditioning room capable of maintaining a relative humidity of 50 ± 4 per cent at 23° ±1.1°C. (73.5° ± 2°F.), or desiccators filled with a saturated salt solution (note 1) to give a relative humidity of 50 ± 4 per cent at 23° ±1.1°C. (73.5° ± 2°F.) are required for the conditioning of such specimens.

4. PROCEDURE

4.1 Tests shall be conducted as soon as possible after removal of the test specimens from the conditioning atmosphere and preferably under the same conditions.

4.2 The free end of the 1-inch-wide flexible member shall be separated by hand from the other member for a distance of about 1 inch. The specimen shall then be placed in the testing machine by clamping the free end of the 8-inch-long member in one grip, turning back the free end of the flexible member, and clamping it in the other grip as shown in figure 2. Care shall be used to adjust the specimen symmetrically in order that the

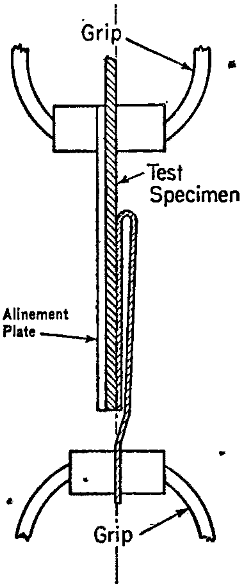


FIGURE 2.—*Specimen under test*

tension shall be distributed uniformly. Provision shall be made to maintain the specimen during test approximately in the plane of the clamps. This may be done either by attaching the minimum weight required to the free end of the specimen or by holding the specimen against an alinement plate (fig. 2) attached to the stationary clamp. In either case the added weight shall be taken into account in determining the load causing separation. The 1-inch-wide flexible member shall be gripped symmetrically and firmly without twisting in the power-actuated clamp. The autographic mechanism and chart shall be adjusted to zero and the machine started. The separating member shall be stripped from the specimen approximately at an angle of 180° and the separation continued for a sufficient distance to indicate the peel or stripping value. At least one-half of the bonded area shall be peeled even though a peel or stripping value may be indicated before this point.

4.3 The actual peel or stripping strength shall be determined by drawing on the autographic chart the best average load line which will accommodate the recorded curve. The load so indicated, corrected for any tare weight which may have been used with the specimen as described in 4.2, expressed in pounds per inch of width for separation at 6 inches per minute, shall be reported as the peel or stripping strength for the particular specimen under test.

4.4 For each series of tests, the arithmetic mean of the values obtained shall be calculated and reported as the average value. The standard error, s, of the reported average value shall be calculated as follows:

$$s = \sqrt{\frac{\Sigma x^2 - N\bar{x}^2}{N(N-1)}}$$

where: s = standard error of the average,
x = value of a single observation,
N = number of observations, and
$\bar{x}$ = arithmetic mean of the set of observations.

NOTE 1.—A saturated solution of calcium nitrate will give approximately 52-per cent relative humidity at 23°C.

NOTE 2.—Cohesion or adhesive failure may be determined by observation. A cohesive failure is one which has occurred in the adhesive or specimen material itself. Adhesive failure refers to the lack of adherence to the materials being bonded.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Method of preparing test specimens.
(2) Testing room conditions.
(3) Number of specimens tested.
(4) Identity and thickness of adherends.
(5) Rate of loading.
(6) Average value and standard error of peel or stripping strength.
(7) Maximum and minimum strength values of the series.
(8) Individual test values, individual autographic charts, and other statistical data as specified by the material specification.
(9) Type of failure; whether in adhesion, cohesion in the adhesive, or in the material being bonded (note 2).

TENTATIVE STANDARD METHOD 1042–T: PEEL STRENGTH OF ADHESIVES (CLIMBING DRUM APPARATUS)

1. SCOPE

1.1 This method of test is intended for use in determining the comparative peel or stripping characteristics of adhesive bonds between metal facings and cores of sandwich constructions and between metal laminates when tested on standard-size specimens and under specified conditions of preparation and testing. This method is applicable when the face being peeled is flexible. The peeling torque calculated includes the forces required to break the bond and to bend the face.

1.2 Peel or stripping strength.

(1) The average load per unit width of bond required to separate progressively the facing from the core at a separation rate of 6 inches per minute.

(2) The average peeling torque in inch-pounds per inch width of specimen.

1.3 **Flexible.**—The designation "flexible" in this test indicates a facing material of the proper flexural modulus and thickness to require a low torque for bending the facings.

2. SPECIMENS

2.1 Test specimens for the sandwich constructions shall conform to the form and dimensions shown in figure 1. Unless otherwise specified in the material specification, a facing of 24 ST–3 clad aluminum alloy 0.020 inch thick and a core 0.50 inch thick shall be used. These specimens may be cut from larger bonded panels.

2.2 Test specimens for the metal laminates shall conform to the form and dimensions shown in figure 2. Unless otherwise specified in the material specification the strippable metal shall be 0.020 inch 24 ST–3 clad aluminum alloy bonded to 0.064 inch thick 24 ST–3 clad aluminum alloy. These specimens may be cut from larger bonded panels. Holes shall be drilled and tapped along the outer edges of each laminated metal specimen, as shown in figure 2, to attach the metal backing sheet prior to testing.

2.3 At least 10 specimens, 3 or more from each of 3 bonded panels, shall be tested for each adhesive sample.

2.4 Specimens that break at some obviously fortuitous flaw in the metal shall be discarded and retest made, unless such flaws constitute a variable, the effect of which it is desired to study.

2.5 Bonding shall be done in accordance with the procedure outlined in General Requirements, section 3, paragraph 3.2. The specimens shall be cut from the sandwich panels or the laminated panels in such a way as to avoid overheating or mechanical damage to the adhesive bond (note 1).

2.6 All specimens shall be conditioned for 7 days by exposure to a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.) or until equilibrium is reached.

3. APPARATUS

3.1 **Testing machine.**—The tests shall be made with a power-driven machine, which shall fulfill the following requirements:

3.1.1 The applied tension as measured and recorded shall be accurate within plus or minus 1 per cent (note 2).

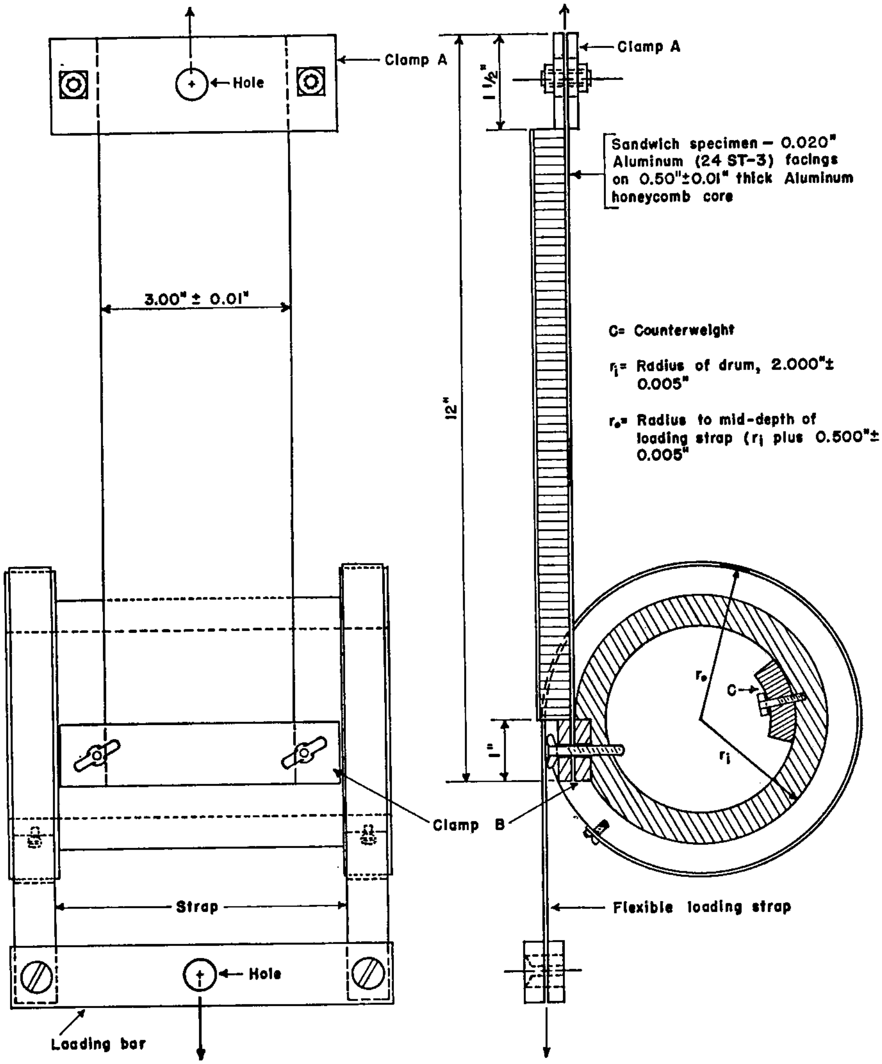


FIGURE 1.—*Apparatus and specimen suitable for making sandwich peel test.*

3.1.2 Specimens shall be held by an upper grip and the lower end of the specimen attached to a suitable clamp on the flanged drum. Flexible loading straps or cables connect the drum to the lower grip of the testing machine. The drum as shown in figures 1 and 2 has been found satisfactory. The outside radius of the drum shall be 2.000 inches ± 0.005 inch, and the radius of the flange, including one half of the thickness of the loading straps or cables, shall be 0.500 ± 0.005 inch larger than the radius

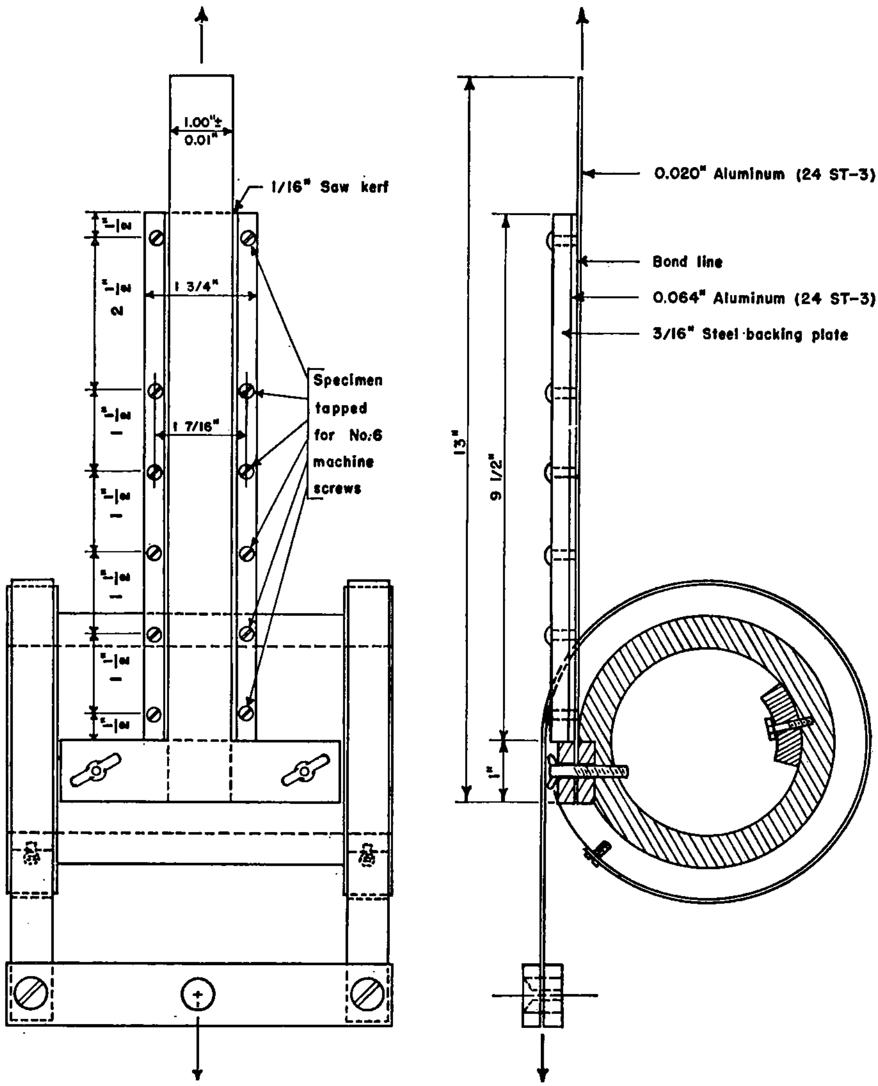


FIGURE 2.—*Apparatus and specimen suitable for making peel test of laminated metal bonds.*

of the drum. This 0.500 ± 0.005 inch is the effective torque arm of the apparatus. The specimen shall be attached tangent to the drum by the clamp B. The drum shall be balanced about its axis by use of a weight placed diametrically opposite clamp B to compensate for the weight of this clamp. The combined weight of the drum with flange, clamp B, and the compensating weight shall not exceed 8 pounds. A lighter weight facilitates handling of the apparatus.

3.1.3 The rate of travel of the testing machine head shall be 1.50 ± 0.10 inch per minute. This will separate the metal facing at a rate of 6 inches per minute with the apparatus shown in figures 1 and 2.

3.1.4 The machine shall be operated without any device for maintaining maximum load indication. In pendulum-type machines, the weight lever shall swing as a free pendulum without engagement of pawls.

3.1.5 The machine shall be autographic, giving a chart having the inches of separation as one axis and the applied tension as the other axis of coordinates.

3.1.6 The machine shall be of such capacity that the maximum applied tension during the test shall not exceed 85 per cent nor be less than 15 per cent of the rated capacity.

3.2 Calibration of test apparatus.—The load necessary to overcome the resisting torque of each particular drum, clamp B, and the counter weight shall be determined. This may be done by inserting a strip of thin fabric having negligible stiffness in place of a test specimen, and applying a load sufficient to roll the drum upward around the fabric. This load, with the radius of flange 0.500 inch larger than the radius of the drum, will be about 4 times the total weight of the drum, clamp B, and the compensating weight.

3.3 Conditioning room or desiccators.—A conditioning room capable of maintaining a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 1.8°F.), or desiccators filled with a salt solution (note 3) to give a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.) are required for the conditioning of such specimens.

4. PROCEDURE

4.1 Tests shall be conducted as soon as possible after removal of the test specimens from the conditioning atmosphere and preferably under the same conditions.

4.2 The test specimen shall be clamped securely to the drum by clamp B as shown in figures 1 and 2. The other end of the specimen shall be clamped securely by clamp A. A suitable metal backing sheet shall be attached to each laminated metal specimen by screws as shown in figure 2. The specimen assembly shall then be suspended from the top head of the testing machine by a pin through the hole in clamp A or by the use of a test grip. The weighing apparatus shall be balanced to zero. At least 6 inches of the bonded area shall be peeled, even though a peel or stripping value may be indicated before this point.

4.3 The peel or stripping strength, average peeling torque, and the maximum peeling torque shall be determined.

4.3.1 The peel or stripping strength shall be determined by drawing on the autographic chart the best average load line which will accommodate the recorded curve for the test specimen between 1 and 6 inches, corresponding to ¼ to 1½ inches of head travel. The load so indicated, minus the load necessary to overcome the resisting torque of the drum, expressed in pounds per inch of width shall be reported as the peel or stripping strength for the particular specimen under test.

4.3.2 The average and maximum peeling torque shall be obtained. The average peeling torque (T) in inch-pounds per inch of specimen width for peeling the strip of facing shall be calculated as follows:

where: $T = \mathrm{PL}$
$P =$ the peel or stripping strength and
$L =$ length of the torque arm (0.5 in. as indicated in 3.1.2).

4.4 For each series of tests the arithmetic mean of the values obtained shall be calculated and reported as the average value. The standard error, s, of the reported average value shall be calculated as follows:

$$s = \sqrt{\frac{\Sigma x^2 - N\bar{x}}{N(N-1)}}$$

where $s =$ standard error of the average,
$x =$ value of a single observation,
$N =$ number of observations, and
$\bar{x} =$ arithmetic mean of the set of observations

NOTE 1.—A metal cutting bandsaw, with proper setting and spacing of teeth and operated at the proper speed has been found to be adequate for cutting aluminum alloy specimens of the types shown in figures 1 and 2. The kerfs in the laminated metal specimen in figure 2 may be cut with a metal-cutting circular saw.

NOTE 2.—It is difficult to meet the accuracy requirement when loads are measured with a spring-type or pendulum-type weighing device.

NOTE 3.—A saturated salt solution of calcium nitrate will give approximately 52 per cent relative humidity at 23°C.

NOTE 4.—Cohesion or adhesive failure may be determined by observation. A cohesive failure is one which has occurred in the adhesive or specimen material itself. Adhesive failure refers to the lack of adherence to the materials being bonded.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Methods of preparing test specimens.
(2) Testing room conditions.
(3) Number of specimens tested.
(4) Number of test panels represented.

(5) Identity and thickness of adherends.

(6) Load required to overcome the resisting torque of the peeling drum used.

(7) Rate of peel.

(8) Average value of peel or stripping strength.

(9) Average peeling torque values in inch pounds per inch of specimen width.

(10) The standard error, the maximum and minimum peel strength, and the maximum and minimum peel torque for the sample.

(11) Type of failure, whether in adhesion, cohesion within the adhesive, or within the material being bonded (note 4).

(12) Average radius (approximate) of the facing for each sample after peeling.

(13) Individual test values, individual autographic charts, individual radius of facings, and other statistical data as specified by the material specification.

METHOD 1051: IMPACT STRENGTH OF ADHESIVES

1. SCOPE

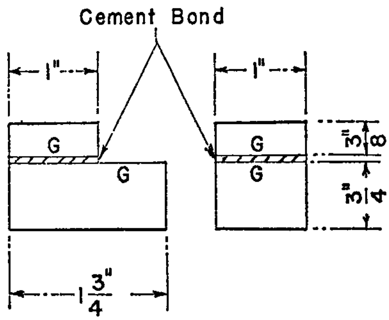
1.1 This method of test is intended for determining the comparative impact strength of adhesives in shear, when tested on standard specimens under specified conditions of preparation, conditioning, and testing.

1.2 Impact strength is the minimum force that, when applied as shock to a standard specimen, will cause failure of the specimen in a single blow. Impact strength is expressed in foot-pounds per square inch.

2. SPECIMENS

2.1 The specimen size shall be such as to give impact strengths that fall somewhere near the middle of the range of the testing machine, since readings in the highest and lowest parts of the range are often unreliable. The specimen shall be assembled so that the face receiving the impact load is at the point of maximum velocity of the impact head. The impact face of the specimen shall be square and flat, perpendicular to the plane of the adhesive line, and parallel to the striking face of the pendulum. The surfaces of the specimens which come in contact with the metal surfaces of the vise shall be plane and smooth so that a good fit is obtained between the faces of the specimens and the metal surfaces.

2.2 The test specimen for metal-to-metal adhesives shall conform to the dimensions given in figure 1A, whenever possible. In cases where this specimen cannot be fractured in the testing machine available, the square dimensions of the 1- by 1-inch block may be reduced to a smaller square, keeping the dimensions of the 1- by 1¾-inch block constant. Tests on adhesives with high impact strength preferably should be run on steel to minimize deformation. Specimens may be reused after testing, provided that the face receiving the impact is not deformed. Suggestions regarding metals for use in this test method are given in note 1.

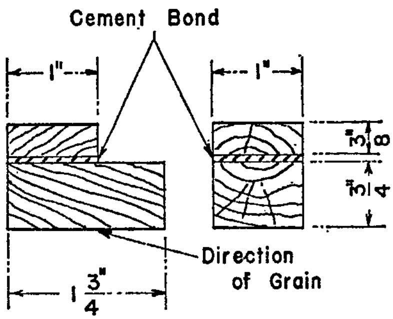


METAL TO METAL

FIGURE 1A.—*Specimen arrangement for impact strength test (metal-to-metal).*

2.3 Test specimens for wood-to-wood adhesives shall conform to the dimensions shown in figure 1B. The specimens may be prepared by gluing blocks ⅜ by 1 by *L* inches to blocks ¾ by 1¾ by *L* inches, where the 1-inch and 1¾-inch dimensions, respectively, are those in the direction of the grain and *L* is a convenient length. Specimens, each 1 inch in width, may then be cut across the *L* dimension. Hard maple (*Acer saccharum* or *Acer nigrum*) having a minimum specific gravity of 0.65 based on oven-dry weight and volume, shall be used. This wood shall be of straight grain and free from defects, including small knots, birdseye, short grain, and unusual discolorations within the test area. The wood shall be at an equilibrium condition, resulting from exposure to 50 ± 4 per cent relative humidity at 23° ± 1.1°C. (73.5° ± 2°F.) at the time of surfacing, unless another moisture conditioning process is recommended by the manufacturer. Blocks of approximately the same specific gravity shall be paired and planed smooth, preferably with a hand-feed jointer and the surfaced faces laid together. The surfaces shall be planed just before bonding, shall be left unsanded, and shall be free from dirt. Blocks shall then be bonded as described in 2.4, after which test specimens conforming to figure 1B shall be prepared.

2.4 Bonding shall be done in accordance with the procedure outlined by the manufacturer of the adhesive. For metal-to-metal specimens, preparation of areas that are to be bonded shall be in accordance with the recommendations of the manufacturer of the adhesive. For wood-to-wood specimens, the grain of the wood shall be parallel in the two pieces and parallel to the adhesive line as shown in figure 1B. If, due to circumstances, wood with a slight taper in the grain must be used, the pieces shall be assembled so the grain runs toward the adhesive line. Thus, failures that start in the wood will be directed toward the adhesive line.



WOOD TO WOOD

FIGURE 1B.—*Specimen arrangement for impact strength test (wood-to-wood).*

2.5 At least 10 test specimens shall be tested for each adhesive in the case of metal-to-metal specimens. At least 20 specimens shall be tested, representing at least four different joints, in the case of wood-to-wood adhesives. Specimens that break at some obviously fortuitous flaw remote from the adhesive line shall be discarded and retests made, unless such flaws constitute a variable, the effect of which it is desired to study.

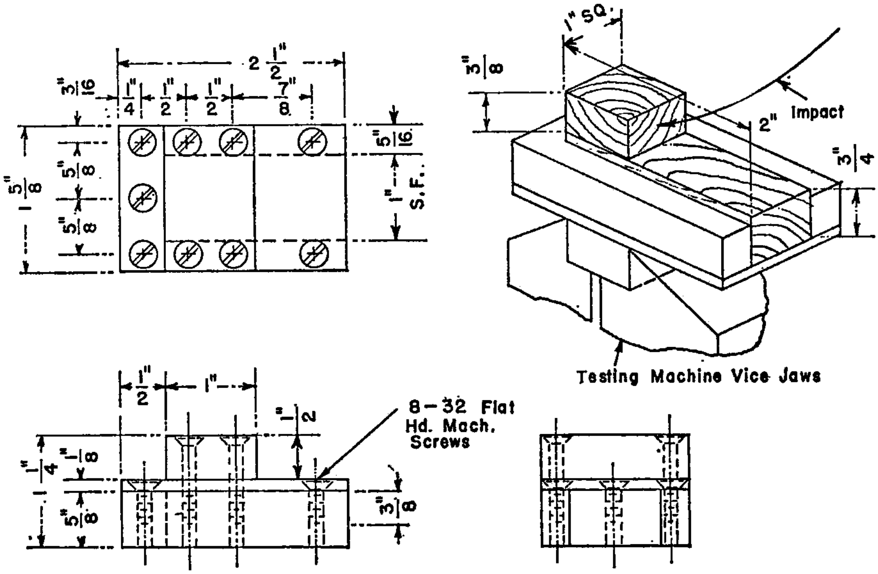
3. APPARATUS

3.1 Testing machines.—A pendulum-type impact machine with a head velocity of 11 feet per second, comprising essentially the following:

3.1.1 An impact head equipped with a flat striking face slightly wider than the test specimen, alined to strike the specimen full-face.

3.1.2 A jig to hold the test specimen as shown in figure 2. The jig shall be square so that the specimen will fit snugly and butt squarely against the retaining end of the jig. The jig shall be so located that the specimen will be struck at the point of maximum head velocity.

3.1.3 A vise to hold the jig rigid and immobile under the impact loads. The total height of the vise, jig, and test specimen shall be such that the lower edge of the striking face of the impact head strikes the specimen as near the adhesive line as possible, preferably within $1/32$ inch.



MATERIAL C.R.S OR M.S.

FIGURE 2.—*Jig for holding test specimen, impact strength test.*

3.2 Conditioning room or desiccators.—A conditioning room capable of maintaining a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.) or desiccators filled with a saturated salt solution to give a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.) (note 2).

4. PROCEDURE

4.1 Metal-to-metal specimens shall be preconditioned for at least 4 hours at the specified temperature. The adhesive is ready for test purposes when it has been applied in accordance with 2.4, unless otherwise specified in the material specification. All wood specimens shall be conditioned at a humidity of 50 ± 4 per cent, and at a temperature of 23° ± 1.1°C. (73.5° ± 2°F.) either for a period of 7 days or until specimens reach equilibrium as indicated by no progressive changes in weight, whichever is the shorter period. Special conditioning procedures may be specified by the material specification.

4.2 Testing shall be done in an atmosphere such that the moisture content of the wood specimens developed under the conditions prescribed in 4.1 is not noticeably altered during testing, and such testing shall be done as soon as possible after the conditioning period prescribed in 4.1.

4.3 The specimen shall be placed in the jig in the vise of the impact machine so that the specimen butts squarely against the retaining end of the jig. The impact head of the machine shall be rested gently against the specimen and the jig adjusted so that the head fits squarely against the impact face of the specimen.

4.4 The impact head shall then be raised to a predetermined height and the safety catch released. The impact load absorbed by the specimen may then be read directly.

4.5 The following information shall be recorded:

4.5.1 Record foot-pounds of energy absorbed in producing failure of the specimen.

4.5.2 Record bonded area of specimen.

4.5.3 In case of metal-to-metal adhesives, record the percentages of cohesion, adhesion, and contact failures (note 3). This will be based on visual inspection.

4.5.4 In case of wood-to-wood adhesives, record the percentages of wood, adhesive, and contact failures. This will be based on visual inspection.

4.6 Impact strength of the specimen shall be calculated as the energy absorbed in producing failure of the specimen divided by the bonded area of the specimen, and shall be expressed in foot-pounds per square inch. Values shall be reported to the nearest tenth of a foot-pound.

4.7 For each series of tests, the arithmetic mean of values obtained shall be calculated and reported as the average value.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Method of preparing test specimens, dimensions of specimens, and materials bonded.

(2) Atmospheric conditions in test room.

(3) Number of specimens tested.

(4) Maximum, minimum, and average value of impact strength, with an average value of the percentages of wood, adhesive, and contact failures for the wood specimens, or cohesion, adhesion, and contact failures for the metal specimens.

NOTE 1.—Metals conforming to the following specifications are suggested for making bonded metal-to-metal specimens for use in this method:

Metal	Federal Specification	ASTM designation
Aluminum	QQ-A-267 or QQ-A-268 ...	B 211, alloy CG42A.
Brass	QQ-B-626, comp. 22	B 16.
Copper	QQ-C-502	B 133, type A.
Magnesium	QQ-M-31, alloy AZ61A	B 107, alloy AZ61A or M1A.
Nickel silver	QQ-C-586, alloy 2	B 151, alloy B.
Phosphor bronze ...	....	B 139, grade B2.
Steel	QQ-S-633, grade FS 1020 ...	A 108, grade 1020.

NOTE 2.—A saturated solution of calcium nitrate will give approximately 52 per cent relative humidity at 23°C.

NOTE 3.—Cohesion failure may be obtained by observing how much of the failure has occurred in the adhesive itself. That is, if the adhesive has adhered to the metal test pieces and no voids are visible, it represents a 100-per cent cohesion failure. Adhesion failure refers to the lack of adhering to metals being fastened. Contact failure refers to lack of adhesive lines being in contact due to uneven surfaces, poor pressure distribution, etc.

TENTATIVE STANDARD METHOD 1051.1–T: IMPACT VALUE OF ADHESIVES

1. SCOPE

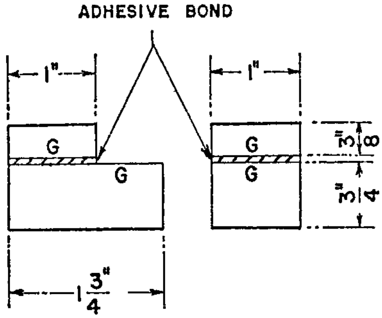
1.1 This method of test is intended for determining the comparative impact value of adhesives in shear, when tested on standard specimens under specified conditions of preparation, conditioning, and testing.

1.2 Impact value is the energy absorbed by a specimen of standard design when sheared by a single blow of a testing machine hammer. Impact value is expressed in foot-pounds per square inch.

2. SPECIMENS

2.1 The specimen size shall be such as to give impact values that fall somewhere near the middle of the range of the testing machine, since readings in the highest and lowest parts of the range are often unreliable. The specimen shall be assembled so that the face receiving the impact load is at the point of maximum velocity of the impact head. The impact face of the specimen shall be square and flat, perpendicular to the plane of the adhesive line, and parallel to the striking face of the pendulum.

2.2 The test specimen for metal-to-metal adhesives shall conform to the dimensions given in figure 1A, whenever possible. In cases where this specimen cannot be fractured in the testing machine available, the square



METAL TO METAL

FIGURE 1A.—*Specimen for impact test.*

dimensions of the 1- by 1-inch block may be reduced to a smaller square, keeping the dimensions of the 1- by 1¾-inch block constant. The dimensions of the specimen and bonded area shall be clearly stated in the report (section 5). Tests on adhesives with high impact values preferably should be run on steel to minimize deformation. Specimens may be reused after testing, provided that the face receiving the impact is not deformed. Suggestions regarding metals for use in this test method are given in note 1.

2.3 Test specimens for wood-to-wood adhesives shall conform to the dimensions shown in figure 1B. The specimens may be prepared by bonding blocks ⅜-inch thick by 1-inch wide of convenient length to blocks ¾-inch thick by 1¾-inch wide of the same convenient length, where the 1-inch and the 1¾-inch dimensions, respectively, are those in the direction of the grain. Specimens, each 1 inch in width, may then be cut from the bonded assembly by cutting across the long dimensions, in the grain direction. Hard maple (Acer saccharum or Acer nigrum) having a minimum specific gravity of 0.65 based on oven-dry weight and volume, shall be used (note 2). These blocks shall be of straight grain and free from defects, including knots, birdseye, short grain, decay, and any unusual discolorations within the test area. The blocks shall be at the equilibrium moisture content recommended by the manufacturer of the adhesive. In the absence of such recommendation, the moisture content shall be from 10 to 12 per cent, based on oven-dry weight as determined on representative samples (note 3). Just prior to bonding, the blocks shall be surfaced, preferably with a hand-feed jointer and then weighed and assembled in pairs so that blocks of approximately the same specific gravity are bonded together. The surfaces shall remain unsanded and shall be free from dirt. Blocks shall be bonded as described in 2.4 after which test specimens conforming to figure 1B shall be prepared.

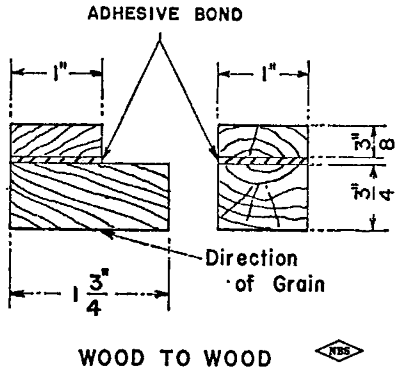


FIGURE 1B.—*Specimen for impact test.*

2.4 Bonding.—Bonding shall be done in accordance with General Requirements, section 3, paragraph 3.2.1.

(1) For wood specimens, the grain of the wood shall be parallel in the two pieces and parallel to the adhesive line as shown in figure 1B. If, due to circumstances, wood with a slight taper in the grain must be used, the pieces shall be assembled so the grain runs toward the adhesive line.

(2) Excess adhesive at the impact face should be removed carefully to insure proper striking of the impact head. Also squeeze-out should be removed when necessary to insure proper positioning of the specimen in the jig.

2.5 Number of test specimens.

(1) At least 10 specimens shall be tested for each adhesive in the case of metal specimens.

(2) At least 20 specimens shall be tested, representing at least four different joints, in the case of wood adhesives.

(3) Specimens that break at some obviously fortuitous flaw remote from the adhesive line shall be discarded and retests made, unless such flaws constitute a variable, the effect of which it is desired to study.

3. APPARATUS

3.1 Testing machine.—A pendulum-type impact machine with a head velocity of 11 feet per second, comprising essentially the following:

3.1.1 An impact head equipped with a flat striking face slightly wider than the test specimen, alined to strike the specimen full-face.

3.1.2 Jig to hold the test specimen, as shown in figure 2. The jig illustrated is not suitable for use with all impact machines and vises. Dimensions and design of the jig may be varied as required for adaptation to machines and vises available, provided the following general require-

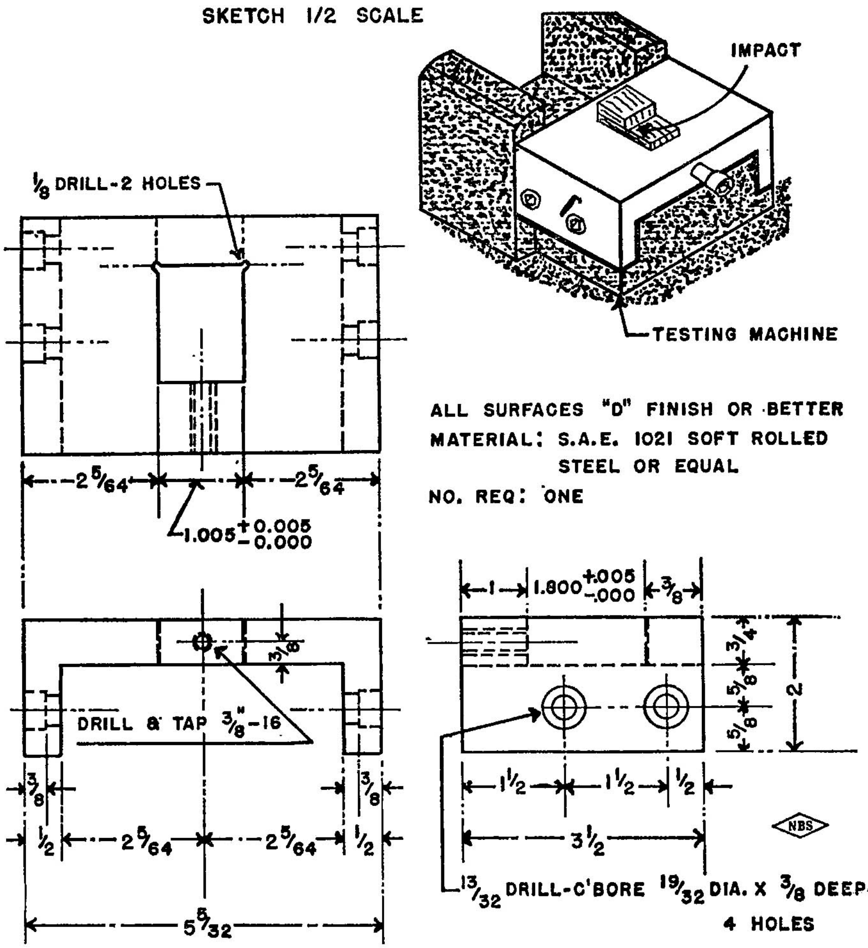


FIGURE 2.—*Adapter jig for impact machines.*

ments are met: It is necessary that the jig be machined from a solid piece of steel and be solidly bolted to the base of the testing machine. Corners shall be drilled to ensure that the test specimen sets flush against the retaining end of the jig; the drilled corners are required to minimize dirt collection at the corners which could hold the end of the specimen away from the face of the jig. The jig shall be provided with a screw to tighten the specimen in the jig, to minimize the tendency of the specimen to overturn when struck. To prevent the holding screw from splitting specimens of wood, a metal plate shall be placed between the end of the wood block and the end of the screw. The jig shall be so located that the specimen will be struck at the point of maximum head velocity.

3.1.3 Vise or bolts to hold the jig rigid and immobile under the stress of the testing machine hammer. The total height of the vise, jig, and test specimen shall be such that the lower edge of the striking face of the impact head strikes the specimen as near the adhesive line as possible, preferably within $\frac{1}{32}$ inch. Ordinarily the distance between the top of the jaws of the vise of the machine and the bottom of the striking face of the head is 0.866 inch, and proper height of the specimen may be obtained by adjusting its height in the jig (note 4).

3.2 Conditioning room or desiccators.—A conditioning room capable of maintaining a relative humidity of 50 ± 4 per cent at $23° \pm 1.1°C$. ($73.5° \pm 2°F$.) or desiccators filled with a saturated salt solution to give a relative humidity of 50 ± 4 per cent at $23° \pm 1.1°C$. ($73.5° \pm 2°F$.) (note 5).

4. PROCEDURE

4.1 Conditioning.

(1) Metal-to-metal specimens shall be conditioned for at least 4 hours at the specified temperature. The adhesive is ready for test purposes when it has been applied in accordance with 2.4.

(2) All wood-to-wood specimens shall be conditioned at a humidity of 50 ± 4 per cent, and at a temperature of $23° \pm 1.1°C$. ($73.5° \pm 2°F$.) either for a period of 7 days or until specimens reach equilibrium as indicated by no progressive changes in weight, whichever is the shorter period. Special conditioning procedures may be specified by the material specification.

4.2 Testing shall be done in an atmosphere such that the moisture content of the wood specimens developed under the conditions prescribed in 4.1 is not noticeably altered during testing, and such testing shall be done as soon as possible after the conditioning period prescribed in 4.1.

4.3 The specimen shall be placed in the jig in the vise of the impact machine so that the specimen butts squarely against the retaining end of the jig. The impact head of the machine shall be rested gently against the specimen and the jig adjusted so that the head fits squarely against the impact face of the specimen.

4.4 The impact head shall then be raised to a predetermined height and the safety catch released. The impact energy absorbed by the specimen may then be read directly.

4.5 The following information shall be recorded:

4.5.1 Record foot-pounds of energy absorbed in producing failure of the specimen.

4.5.2 Record bonded area of specimen.

4.5.3 In case of metal-to-metal adhesives, record the percentages of cohesion, adhesion, and contact failures (note 6). This will be based on visual inspection.

4.5.4 In case of wood-to-wood adhesives, record the percentages of wood, adhesive, and contact failures. This will be based on visual inspection.

4.6 Impact strength of the specimen shall be calculated as the energy absorbed in producing failure of the specimen divided by the bonded area of the specimen, and shall be expressed in foot-pounds per square inch. Values shall be reported to the nearest tenth of a foot-pound. Unit results cannot be extended to different areas than those tested.

4.7 For each series of tests, the arithmetic mean of values obtained shall be calculated and reported as the average value.

NOTE 1.—Metals conforming to the following specifications are suggested for making bonded metal-to-metal specimens for use in this method of test:

Metal	Federal Specification	ASTM designation
Aluminum	QQ–A–355, QQ–A–267, or QQ–A–268	B 211, alloy CG42A or 24St.
Brass	QQ–B–626, comp. 22	B 16.
Copper	QQ–C–502	B 133, type A.
Magnesium ...	QQ–M–31, alloy AZ61A	AZ61A.
Nickel silver ..	QQ–C–586, alloy 2	B 151, alloy B.
Phosphor bronze	QQ–P–330 comp. A	B 139, alloy A.
Steel	QQ–S–633, grade FS 1020	A 108, grade 1020.

NOTE 2.—A convenient method of selecting maple blocks of satisfactory specific gravity is described in the Appendix to the Standard Method of Test for Strength Properties of Adhesives in Shear by Compression Loading (ASTM designation D 905–49, 1955 Book of ASTM Standards, Part 7).

NOTE 3.—Convenient methods for determining the moisture content by oven drying procedures will be found either in section 122 to 125 of the Tentative Methods of Testing Small Clear Specimens of Timber (ASTM designation: D 143–52, 1952 Book of ASTM Standards, Part 4) or in the Military Specification MIL–W–6110 for Determination of Moisture Content in Wood.

NOTE 4.—Additional information on impact testing machines and their calibration may be found in Tentative Methods of Impact Testing of Metallic Materials (ASTM designation E 23, 1955 Book of ASTM Standards, Parts 1 and 2).

NOTE 5.—A saturated solution of calcium nitrate will give approximately 52-per cent relative humidity at 23°C.

NOTE 6.—Cohesion failure may be obtained by observing how much of the failure has occurred in the adhesive itself. That is, if the adhesive has adhered to the metal test pieces and no voids are visible, it represents a 100-per cent cohesion failure. Adhesion failure refers to the lack of adhering to metals being fastened. Contact failure refers to lack of adhesive lines being in contact due to uneven surfaces, poor pressure distribution, etc.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Method of preparing test specimens, dimensions of specimens, and materials bonded.

(2) Atmospheric conditions in test room.

(3) Number of specimens tested.

(4) Actual bonded area.

(5) Maximum, minimum, and average value of impact strength, with an average value of the percentages of wood, adhesive, and contact failure for the wood specimens, or cohesion, adhesion, and contact failures for the metal specimens. The standard deviation or all individual test values, or both, for the failing load values may be included in the report as requested in the material specification.

METHOD 1061: FATIGUE STRENGTH OF ADHESIVES

1. SCOPE

1.1 This method is intended for use in determining at constant load the comparative fatigue strength of adhesives for bonding adherends when tested on a standard specimen and under specified conditions of preparation and testing.

1.2 A variation in the thickness of the adherends will likely influence the test values. For this reason, the thickness of the sheets used to make the test specimens shall be specified in the material specification. When no thickness is specified, sheets of metal adherends 0.064 inch thick are recommended.

2. SPECIMENS

2.1 The test specimens shall be the same as those described in method 1033, except for overlap and gripping. Grip ends shall be suitable for use in the particular testing machine.

2.2 At least 15 specimens shall be tested, representing at least four different panels.

2.3 Specimens shall be prepared, cut, finished, and conditioned in the same manner as for method 1033. The length of the overlap shall be 0.375 inch for aluminum alloys. Dimensions of other materials shall be such that the majority of failures occur in the bond. An overlap of 0.050 inch for 0.125-inch-thick nonmetals should be used if possible.

3. APPARATUS

3.1 Testing machine.—The testing machine shall be capable of applying a cyclic axial load. The maximum rate shall be 3,600 cycles per minute. The machine shall be provided with suitable grips and jaws so that the specimen can be gripped tightly and held in alinement as the load is applied. Loads shall be accurate within plus or minus 1 per cent.

4. PROCEDURE

4.1 The specimens shall be tested in an atmosphere maintained at 50 ± 4 per cent relative humidity and 23° ± 1.1°C. (73.5° ± 2°F.). Metal-to-metal specimens shall be preconditioned for at least 4 hours.

4.2 The specimen shall be placed in the jaws of the testing machine and gripped tightly so that the specimen and the jaws are perfectly alined in such a position that an imaginary vertical line would pass through the center of the bonded area and through the points of suspension (fig. 1).

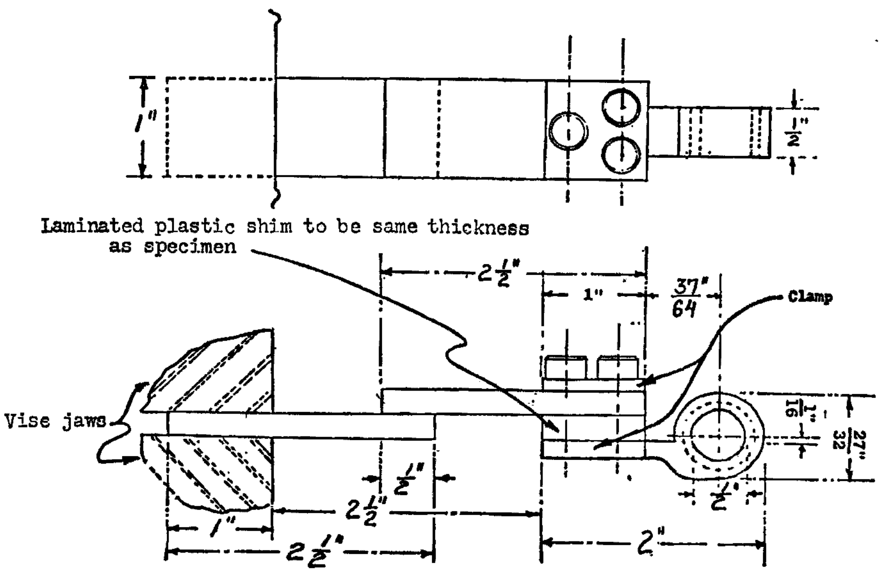


FIGURE 1.—*Specimen and mounting.*

The edge of the lap shall be 1 inch from the edge of the grip. The cyclic load shall then be applied and checked periodically. This load shall range from a maximum to approximately 10 per cent of the maximum. The maximum load selected will depend upon the strength of the adhesive and the desired life.

4.3 A total of 15 specimens shall be tested at 5 or more maximum loads which shall be selected such that failures occur with regular spacing over a range varying from at least 10,000,000 cycles to not less than 5,000 cycles.

4.4 The numbers of cycles to failure and the corresponding loads, calculated in pounds per square inch, shall be recorded. The specimen bond dimensions shall be measured accurately enough to calculate the area to the nearest 0.01 square inch. The nature, adhesive or joint material, and the amount of failure if in the adhesive, shall be recorded for each specimen. Amounts shall be listed for cohesion, adhesion, or contact failures.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Complete identification of the adherends used, their thickness, and the methods of cleaning and preparing their surfaces prior to bonding.

(2) Application and bonding conditions used in preparing the specimens.

(3) Number of specimens tested.

(4) Thickness of adhesive layer.

(5) Number of panels represented.

(6) Temperature and relative humidity in the test room.

(7) Fatigue strength at 10,000,000 cycles.

(8) The average percentages of failure in cohesion, adhesion, or contact at each maximum load.

TENTATIVE STANDARD METHOD 1071-T: CLEAVAGE STRENGTH OF METAL-TO-METAL ADHESIVES

1. SCOPE

1.1 This method of test is intended for determining the comparative cleavage properties of adhesives when tested on standard shape metal specimens under specified conditions of preparation and testing. It may be used also to compare adhesives used with other metallic materials having any specified surface treatment.

2. SPECIMENS

2.1 The test specimens shall consist of metal pieces conforming to the dimensions and conditions shown in figure 3 and bonded together as specified in 2.3. Various metallic materials and surface treatments may be specified to simulate surface conditions. The metal pieces may be reused after testing provided the adhesive is completely removed from the adhering surfaces and the surfaces are reconditioned. The grades of metal recommended for the test specimen as being representative of a wide range of metallic materials are given in note 1.

2.2 At least 10 specimens shall be tested for each adhesive.

2.3 Preparation of the areas that are to be bonded and the bonding operations shall be done in accordance with the procedure outlined by the manufacturer of the adhesive. It is important that all flash be carefully removed from the edges of the specimens (note 2).

2.4 Unless otherwise specified in the material specification the adhesive is ready for test when it has been applied in accordance with 2.3.

3. APPARATUS

3.1 The testing machine shall be capable of maintaining the rate of loading specified in 4.3. It shall have a fixed or essentially stationary member, carrying one grip, and a movable member, carrying a second grip. The grips shall be used to hold a test specimen between the fixed member and the movable member. They shall be of the self-alining type. That is, they shall be attached to the fixed and movable member, respectively, in such a way that they will move into alinement as soon as any load is applied, so that the direction of pull is at right angles to the point of adhesion. While the design of grips of this type is optional, grips that have been found satisfactory are shown in figures 1 and 2.

3.2 A conditioning room capable of maintaining a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.).

4. PROCEDURE

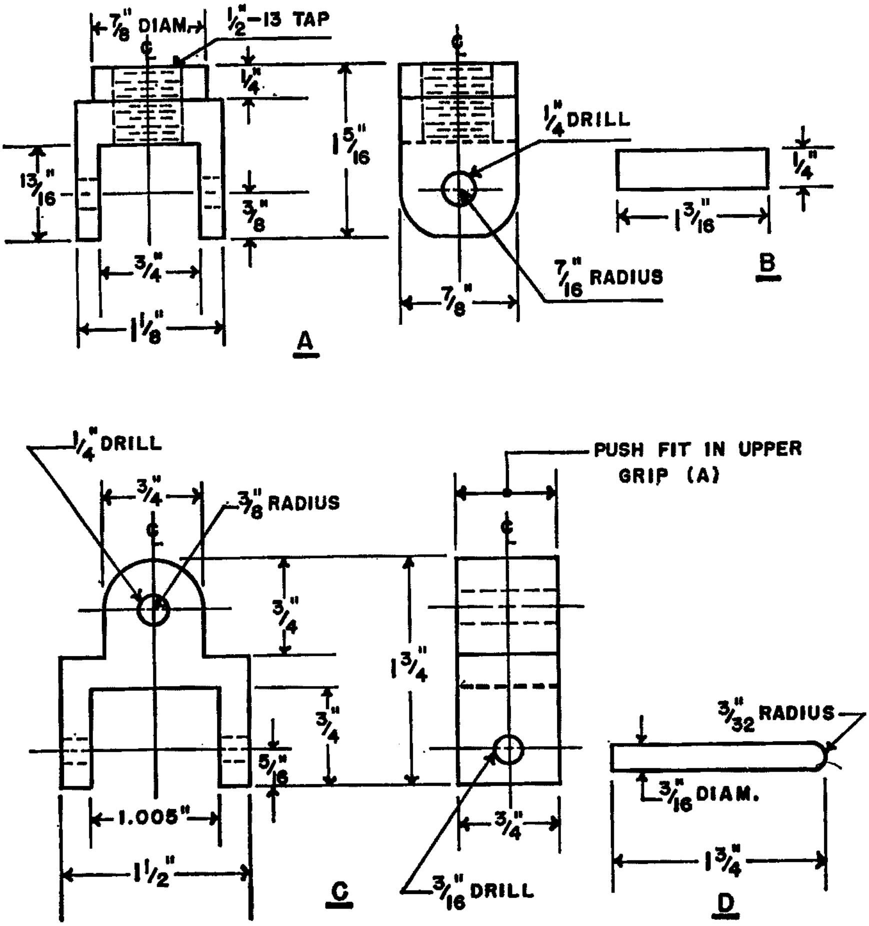
4.1 Unless otherwise specified in the material specification, the test specimens shall be preconditioned for at least four hours or to temperature equilibrium by exposure to a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.) and tested under these conditions.

4.2 The specimens shall be placed in the grips of the testing machine, care being taken to aline the specimens as indicated in figure 2.

4.3 Tensile load shall be applied at the rate of 600 to 700 pounds per square inch of bonded area per minute or the crosshead speed of the testing machine shall be such that the load can be accurately weighed but shall not exceed 0.050 inch per minute (1.27 millimeter per minute) when the machine is running idle.

4.4 Record the maximum load in pounds carried by the specimen at failure. The percentages of cohesion, adhesion, and contact failure shall also be recorded.

NOTE 1.—Metals conforming to the specifications listed below are suggested for making bonded metal-to-metal specimens for use in this method:



A. UPPER GRIP
B. PIN CONNECTING UPPER AND LOWER GRIPS
C. LOWER GRIP
D. PIN FOR ATTACHING GRIP TO SPECIMEN

FIGURE 1.—*Details of test grips for cleavage test.*

Metal	Federal Specification	ASTM designation
Aluminum	QQ-A-267 or QQ-A-268	B 211, alloy CG42A.
Brass	QQ-B-626, comp. 22	B 16.
Copper	QQ-C-502	B 133, type A.
Magnesium	QQ-M-31, AZ61A	B 107, alloy AZ61A.
Nickel silver	QQ-C-586, alloy 2	B 151, alloy B.
Phosphor bronze	QQ-P-330, comp. A	B 139, alloy A.
Steel	QQ-S-633, grade FS 1020	A 108, grade 1020.

NOTE 2.—The one-inch-square surface to be bonded shall be ground flat and parallel with the opposite surface.

4.5 Cleavage strength shall be the breaking load expressed in pounds per inch. This is obtained by dividing the breaking load by the width of the bonded area. Whenever possible the results shall be reported to three significant figures.

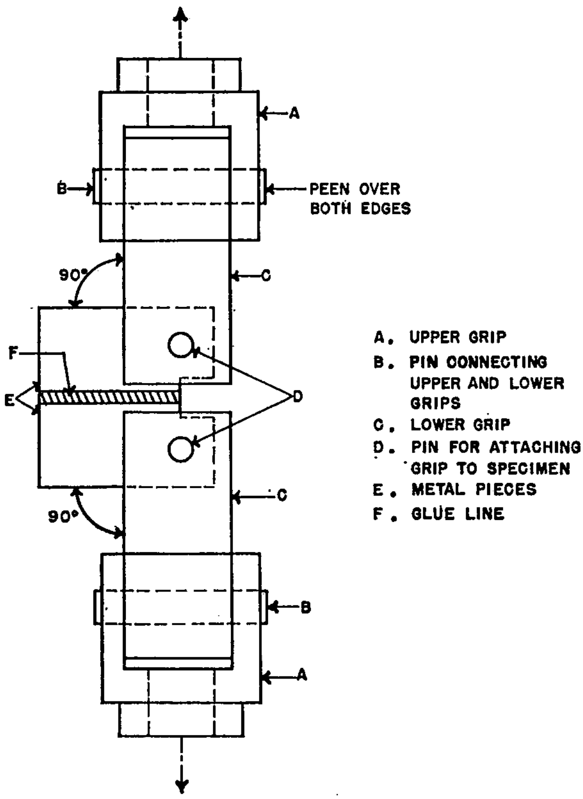
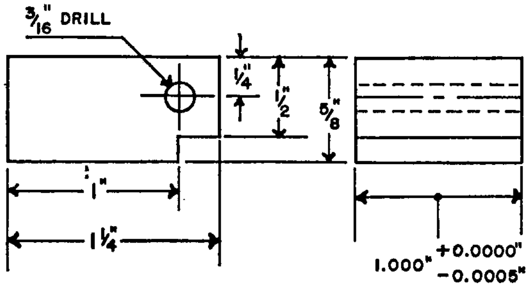


FIGURE 2.—*Assembly of grips and test specimen for cleavage test.*



NOTE.—The 1"-inch square surface to be glued shall be ground flat and parallel with the opposite surface.

FIGURE 3.—*Metal pieces for use in cleavage test specimen.*

5. REPORT

5.1 Unless otherwise specified, the report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Method of preparing test specimen.

(2) Conditions of testing room.

(3) Number of specimens tested.

(4) Rate of loading or rate of grip separation.

(5) Maximum, minimum, standard deviation, and average value of cleavage strength.

(6) Average value of the percentage of cohesion failure.

6. DEFINITIONS

6.1 Cleavage strength is the tensile load in terms of pounds per inch of width required to cause separation of a test specimen one inch in length as described by this method of test.

6.2 Cohesion failure is that failure which occurs in the adhesive itself. That is, if the adhesive has adhered to the metal test pieces and no voids are visible, and failure is completely in the adhesive layer then 100 per cent cohesive failure is obtained.

6.3 Adhesion failure occurs when no bond is formed between adhesive and metal.

6.4 Contact failure occurs when no adhesive layer is present over an area intended to be bonded. This may be caused by uneven surfaces, lack of uniform pressure distribution, or insufficient adhesive.

METHOD 2011.1: RESISTANCE OF ADHESIVE BONDS TO CHEMICAL REAGENTS

1. SCOPE

1.1 This method is intended for the testing of all types of adhesives for resistance to chemical reagents. It includes provisions for reporting loss in strength in accordance with methods of test for strength properties of adhesives.

1.2 Care shall be exercised in choice of materials with respect to adherends and containers in that they are unaffected by the chemicals and solvents used in the test.

1.3 A short-time test is permissible for the purpose of elimination of those materials which are unsuitable or unduly affected by the reagents. The screening test may be performed on films or suitable specimens of the adhesive prepared according to the manufacturer's instructions with regard to drying time, cure, etc.

2. SPECIMENS

2.1 The test specimens shall be identical with those required in the method of test for the strength properties to be measured.

2.1.1 For the required strength properties see the following method of test numbers in this publication: Tensile Properties of Adhesives, No. 1011.1; Shear Strength Properties of Adhesives by Flexural Loading, No. 1021; Shear Strength Properties of Adhesives by Compression Loading, No. 1031; Shear Strength Properties of Adhesives in Plywood-Type Construction by Tension Loading, No. 1032; Shear Strength Properties of Adhesives Determined with Single-Lap Constructions by Tension Loading, No. 1033; Peel or Stripping Strength of Adhesives, No. 1041.1; Impact Strength of Adhesives, No. 1051; Fatigue Strength of Adhesives, No. 1061. Other methods of test covering strength properties may also be used.

3. APPARATUS AND REAGENTS

3.1 The apparatus shall consist of containers for test specimens and a cabinet for maintaining a temperature of 23° ± 1.1°C. (73.5° ± 2°F.).

3.1.1 Freshly prepared distilled water shall be used wherever water is specified in this method.

3.2 Apparatus for making strength tests is specified in the method for the property to be measured.

3.3 Standard reagents

3.3.1 *Sulfuric acid (30 per cent).*—Slowly add 199 milliliters (366 gm.) of H_2SO_4 (sp. gr. 1.84) to 853 milliliters of water.

3.3.2 *Sulfuric acid (3 per cent).*—Slowly add 16.6 milliliters (30.6 gm.) of H_2SO_4 (sp. gr. 1.84) to 988 milliliters of water.

3.3.3 *Sodium hydroxide solution (10 per cent).*—Dissolve 111 grams of NaOH in 998 milliliters of water.

3.3.4 *Sodium hydroxide solution (1 per cent).*—Dissolve 10.1 grams of NaOH in 999 milliliters of water.

3.3.5 *Ethyl alcohol (95 per cent).*—Undenatured ethyl alcohol.

3.3.6 *Ethyl alcohol (50 per cent).*—Add 598 milliliters (482 gm.) of 95 per cent undenatured ethyl alcohol to 434 milliliters of water.

3.3.7 *Acetone, c. p.*

3.3.8 *Ethyl acetate, c. p.*

3.3.9 *Ethylene dichloride, c. p.*

3.3.10 *Carbon tetrachloride, c.p.*

3.3.11 *Toluene, c. p.*

3.3.12 *Heptane.*—Commercial grade, boiling range 90° to 100°C.

3.3.13 *Sodium chloride solution (10 per cent).*—Add 107 grams of NaCl to 964 milliliters of water.

3.3.14 *Distilled water.*—Freshly prepared.

3.4 Supplementary Reagents

3.4.1 *Nitric acid (10 per cent).*—Add 108 milliliters (153 gm.) of HNO_3 (sp. gr. 1.42) to 901 milliliters of water.

3.4.2 *Hydrochloric acid (10 per cent).*—Add 239 milliliters (283 gm.) of HCl (sp. gr. 1.19) to 764 milliliters of water.

3.4.3 *Acetic acid (5 per cent).*—Add 48 milliliters (50.5 gm.) of glacial acetic acid (sp. gr. 1.05) to 955 milliliters of water.

3.4.4 *Oleic acid, c. p.*

3.4.5 *Ammonium hydroxide (10 per cent).*—Add 375 milliliters (336 gm.) of NH_4OH (sp. gr. 0.90) to 622 milliliters of water.

3.4.6 *Sodium carbonate solution (2 per cent).*—Add 55 grams of $Na_2CO_3 \cdot 10H_2O$ to 964 milliliters of water.

3.4.7 *Hydrogen peroxide solution (3 per cent, or U. S. P. 10 volume).*—Add 98 milliliters (108 gm.) of commercial grade (100 volume or 28 per cent) hydrogen peroxide to 901 milliliters of water (note 1).

NOTE 1.—Additional reagents may be substituted for or supplement those listed in 3.4, as specified by the material specification, provided such reagents are within the general scope of this method.

4. PROCEDURE

4.1 Each specimen shall be placed in a separate glass container and totally immersed in a sufficient quantity of the reagent for 7 days at a temperature of 23° ± 1.1°C. (73.5° ± 2°F.). The volume of the reagent used shall be at least ten times the volume of the specimen. The specimen shall be placed on edge in the container in the case of flat specimens so that it is supported at an angle from the bottom and side wall of the container. The reagent shall be stirred every 24 hours by moderate manual rotation of the container (note 2).

NOTE 2.—The directions given in 3.3 and 3.4 for preparation of reagents are for approximately 1-liter quantities. All percentages are by weight.

4.2 The individual specimen shall be removed from the reagent, the aqueous solution rinsed off with distilled water, and wiped with a clean dry cloth. The strength of the specimen shall then be determined immediately at a temperature of $23° \pm 1.1°$C. ($73.5° \pm 2°$F.), in accordance with the specified method. When specified, additional specimens shall be allowed to dry for a specified period and then tested.

5. REPORT

5.1 Report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Strength property of each specimen.

(2) Percentage change in average strength during immersion for 7 days calculated to the nearest 0.01 per cent, taking the average strength property of untreated test specimens as 100 per cent.

(3) General appearance and behavior of each specimen during and after immersion.

(4) Type of specimen.

(5) Trade name and type of adhesive used.

(6) Designation of materials and test procedure used.

(7) Application, drying, and curing conditions used in preparing specimens.

METHOD 2021: DELAMINATION

1. SCOPE

1.1 This method is an accelerated test intended for determining the resistance of adhesive bonds to delamination on exposure to alternate dry and wet conditions.

Procedure A (4.1) is intended for testing adhesives used in plywood and wood constructions, although it can be used for other constructions, particularly in sheet form.

Procedure B (4.2) is intended for testing adhesives in metal or plastic constructions. This procedure is not applicable when the adhesive or the adherend used softens appreciably at temperatures below 100°C. (212°F.).

2. SPECIMENS

2.1 Specimen I.—Test specimen I shall be approximately 6 inches by 6 inches by the thickness of the test panel. When sufficient sample is available, five test specimens shall be cut from each test panel; one shall be cut from each end, approximately at midwidth of the panel, and from each side, approximately at midlength of the panel, and from somewhere near the center of the panel.

2.2 Specimen II.—Test specimen II shall be approximately 0.5 inch wide by 1 inch long by the thickness of the test panel. Test panels of wood shall be made in accordance with the procedure described in 2.2 of method 1021. Test panels of all other materials, including metals and plastics, shall be prepared from 0.01-inch-thick sheets. Three panels shall be prepared with each adhesive-adherend combination and at least three specimens shall be taken from different parts of each panel.

2.3 The mixing, weight of spread, method of applying, drying conditions, and assembly time shall be in accordance with the recommendation of the manufacturer.

3. APPARATUS

3.1 The apparatus shall consist of test tubes, containers, water baths maintained at boiling, water bath maintained at 60° ± 3°C. (140° ± 5°F.), distilled water with a pH between 5.6 and 7.0, a circulating-air oven maintained at 60° ± 3°C. (140° ± 5°F.), and a mandrel with an 8-inch radius.

4. PROCEDURE

4.1 Procedure A.—Test specimen I shall be used for this test. The specimens shall be immersed in water at 23° ± 1.1°C. (73.5° ± 2°F.) for 4 hours followed by drying at 35° ± 2°C. (96° ± 4°F.) for 20 hours. The procedure described above shall constitute 1 cycle of the test. The number of cycles to which the specimens shall be subjected shall be specified in the material specification. One cycle shall be used unless otherwise specified in the material specification.

4.2 Procedure B.—Test specimen II shall be used for this test. The test tubes, one for each specimen, shall be filled with distilled water to a depth of 4 inches, placed in the water bath maintained at boiling, and allowed to come to temperature equilibrium. A test specimen shall then be placed in each tube so that it is completely immersed in the water for 1 hour. At the end of this period the specimens shall be removed and immersed in distilled water at 23° ± 1.1°C. (73.5° ± 2°F.) for 30 minutes. The specimens shall then be dried at 60° ± 3°C. (140° ± 5°F.) in a circulating-air oven for 20 hours. The specimens shall be removed from the oven and allowed to cool for 2 hours. The specimens shall then be bent over a mandrel with an 8-inch radius in 3 to 6 seconds until the entire specimen is in contact with the mandrel. The procedure described above shall constitute 1 cycle of the test. The number of cycles to which the specimens shall be subjected shall be specified in the material specification. Unless otherwise specified in the material specification, 5 cycles shall be used for a complete test.

NOTE 1.—As in all accelerated tests, care must be used in the interpretation and use of the results obtained in the tests.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Type of specimen and procedure used.
(2) Number of cycles to which the specimens were subjected.
(3) The pH of the distilled water.
(4) The temperature of the bath.
(5) Description of the failures as evidenced by delamination, cracking, or splitting of the specimen.
(6) Extent of failure.

METHOD 2031: RESISTANCE OF ADHESIVE BONDS TO WATER (WET STRENGTH)

1. SCOPE

1.1 This method of test is intended for use in determining the wet strength values of adhesives used in assemblies, when tested on a standard specimen and under specified conditions of preparation, conditioning, and testing. The procedures are intended primarily for adhesives used in bonding wood, although they may be used for other constructions.

2. SPECIMENS

2.1 The test specimens shall be identical with those required in the method of test for the strength properties to be measured or as specified in the material specification.

3. APPARATUS

3.1 The apparatus shall consist of suitable containers for test specimens and a cabinet or room for maintaining a temperature of 23° ± 1.1°C. (73.5° ± 2°F.).

3.2 Apparatus for making the strength tests is specified in the method for the property to be measured.

3.3 Unless otherwise specified, distilled water with a pH between 5.6 and 7.0 shall be used for the tests.

3.4 Water bath maintained at boiling (97° to 100°C.).

4. PROCEDURE

4.1 Continuous immersion test.—The test specimens shall be immersed in distilled water for 48 ± 2 hours and the strength test made immediately upon removal from the water. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers. The temperature of the water shall be maintained at 23° ± 1.1°C. (73.5° ± 2°F.).

4.2 Water boil test.—The test specimens shall be immersed in boiling water (97° to 100°C.) for 3 hours ± 10 minutes, removed, and immersed in water at 23° ± 1.1°C. (73.5° ± 2°F.) for 0.5 hour ± 5 minutes and then tested immediately upon removal from the water. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers.

4.3 Wet and dry cyclic test.—The test specimen shall be subjected to the following cycles of conditions:

Cycle	Period	Temperature	Wet condition
	Hours	°*C.*	
1	48	23 ± 1.1	Immersion in water.
	8	60 ± 3	Less than 10 per cent relative humidity.
2	16	23 ± 1.1	Immersion in water.
	8	60 ± 3	Less than 10 per cent relative humidity.
3	16	23 ± 1.1	Immersion in water.
	8	60 ± 3	Less than 10 per cent relative humidity.
4	16	23 ± 1.1	Immersion in water.

The specimens shall be tested immediately upon removal from the water. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers.

4.4 Water boil and dry cyclic test.—The test specimen shall be subjected to following cycles of conditions:

Cycle	Period	Temperature	Wet condition
	Hours	°*C.*	
1	4	97 – 100	Immersion in boiling water.
	20	60 ± 3	Less than 10 per cent relative humidity.
2	4	97 – 100	Immersion in boiling water.
	4	23 ± 1.1	Immersion in water.

The specimens shall be tested immediately upon removal from the water. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers.

4.5 Vacuum-pressure accelerated wet and dry cyclic test.—The test specimen shall be subjected to the following cycles of conditions:

Cycle	Period	Wet or dry condition	Pressure
	Hours		
1	2	Dry	Vacuum of 20–25 inches of mercury.
2	2	Immersed in water	75 lb./in.^{2}.
	2	do	Vacuum of 20–25 inches of mercury.
3	2	do	75 lb./in.^{2}.
	16	do	Atmospheric.
	144	In circulating air at 26°C. and 30 per cent relative humidity.	Do.

This procedure shall be repeated twice, making a test of 21 days duration. The specimens shall be tested immediately. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Complete identification of the adhesive tested including type, source, manufacturer's code numbers, form, etc.

(2) Application and bonding conditions used in preparing the specimens.

(3) Conditioning procedure used for the specimens.

(4) The procedure or procedures used.

(5) Number and size of specimens tested in each procedure.

(6) Number of panels represented.

(7) Maximum and minimum loads at failure and percentages of adherend failure. The standard deviation of all individual test values, for the failing load values and adherend failure values may be included in the report if specified by the material specification.

(8) The average load at failure and the average percentage of wood failure.

(9) Extent of delamination.

TENTATIVE STANDARD METHOD 2031.1-T: RESISTANCE OF ADHESIVE BONDS TO WATER (WET STRENGTH)

1. SCOPE

1.1 This method of test is intended for use in determining the wet strength values of adhesives used in a standard specimen and under specified conditions of preparation, conditioning, and testing. The procedures are intended primarily for adhesives used in bonding wood, although they may be used for other constructions.

2. SPECIMENS

2.1 The test specimens shall be identical with those required in the method of test for the strength properties to be measured or as specified in the material specification.

3. APPARATUS

3.1 The apparatus shall consist of suitable glass containers for test specimens and a cabinet or room for maintaining a temperature of 23° ± 1.1°C. (73.5° ± 2°F.)

3.2 Apparatus for making the strength tests is specified in the method for the property to be measured.

3.3 Unless otherwise specified, distilled water with a pH between 5.6 and 7.0 shall be used for the tests.

3.4 Water bath maintained at boiling (97° to 100°C.).

4. PROCEDURE

4.1 **Continuous immersion test.**—The test specimens shall be immersed in distilled water for 48 ± 2 hours and the strength test made immediately upon removal from the water. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers. The temperature of the water shall be maintained at 23° ± 1.1°C. (73.5° ± 2°F.).

4.2 **Water boil test.**—The test specimens shall be immersed in boiling water (97° to 100°C.) for 3 hours ± 10 minutes, removed, and immersed in running water and cooled to 23° ± 1.1°C. (73.5° ± 2°F.). The specimens are then immersed in water at this temperature for 0.5 hour ± 5 minutes and then tested immediately upon removal from the water. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers.

4.3 **Wet and dry cyclic test.**—The test specimen shall be subjected to the following cycles of conditions (note 1):

Cycle	Period	Temperature	Wet or dry condition
	Hours	*°C.*	
1	64	23 ± 1.1	Immersion in water.
	8	60 ± 3	Less than 10 per cent relative humidity.
2	16	23 ± 1.1	Immersion in water.
	8	60 ± 3	Less than 10 per cent relative humidity.
3	16	23 ± 1.1	Immersion in water.
	8	60 ± 3	Less than 10 per cent relative humidity.
4	16	23 ± 1.1	Immersion in water.

The specimens shall be tested immediately upon removal from the water. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers.

4.4 Water boil and dry cyclic test.—The test specimens shall be subjected to the following cycles of conditions (note 1):

Cycle	Period	Temperature	Wet or dry condition
	Hours	*°C.*	
1	4	97 – 100	Immersion in boiling water.
	20	60 ± 3	Less than 10 per cent relative humidity.
2	4	97 – 100	Immersion in boiling water.
	1	23 ± 1.1	Cool to temperature rapidly by immersion in running water followed by 1 hour immersion in water.

The specimens shall be tested immediately upon removal from the water. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers.

4.5 Vacuum-pressure accelerated wet and dry cyclic test.—The test specimens shall be subjected to the following conditions (note 1):

Cycle	Period	Wet or dry condition	Pressure
	Hours		
1	2	Immersed in water at 23°C.	Vacuum of 20–25 inches of mercury.
	2	do	75 ± 5 p.s.i.
2	2	do	Vacuum of 20–25 inches of mercury.
	2	do	75 ± 5 p.s.i.
3	88	In circulating air at 27°–30°C. and 25–30 per cent relative humidity.	Atmospheric.

The test shall consist of three exposures (total of 12 days) to the above cyclic conditions. The specimens shall be tested immediately upon completion of the cyclic exposure. Test specimens from the same sample may be immersed in one container but specimens from different samples shall be immersed in separate containers.

NOTE 1.—All end-grain surfaces shall have free access to water during immersion. The end-grain surfaces shall be parallel to the air stream during exposure to forced air circulation.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Application and bonding conditions used in preparing the specimens.

(2) Conditioning procedure used.

(3) The test procedure or procedures used.

(4) Number and size of specimens tested in each procedure.

(5) Number of panels represented.

(6) Maximum and minimum loads at failure and percentages of adherend failure. The standard error for the failing load values and adherend failure values may be included in the report if specified by the material specification.

(7) The average load at failure and the average percentage of wood failure.

(8) Extent of delamination.

METHOD 2041: BLOCKING POINT OF POTENTIALLY ADHESIVE LAYERS

1. SCOPE

1.1 This method is intended for use in determining the blocking point of a thermoplastic, a hygroscopic layer, or a coating of potentially adhesive material.

1.2 Potentially adhesive materials comprise those materials in a substantially nonadhesive state which may be activated to an adhesive state by application of heat or solvents. Since some potentially adhesive materials are both thermoplastic and hygroscopic this method provides means for estimating thermoplastic and hygroscopic blocking on the same material.

1.3 Blocking.—Because some requirements are more strict than others two varying degrees of blocking are recognized, first and second degree blocking. Two types of blocking are recognized and defined, cohesive and adhesive blocking.

1.3.1 *Blocking.*—The adhesion between touching layers of similar or dissimilar material, such as occurs under moderate pressures during storage or use.

1.3.2 *Cohesive blocking.*—The blocking of two similar, potentially adhesive faces.

1.3.3 *Adhesive blocking.*—The blocking of a potentially adhesive face and a standard test paper.

1.3.4 *First degree blocking.*—An adherence between the surfaces under test of such degree that when the upper specimen is lifted the lower specimen will cling thereto but may be parted with no evidence of damage to either surface.

1.3.5 *Second degree blocking.*—An adherence of such degree that when the surfaces under test are parted one surface or the other will be found to be damaged.

1.3.6 Other degrees of blocking which may be specified by the material specification shall be defined in the material specification.

1.3.7 *Critical temperature.*—The lowest temperature at which blocking of a given degree occurs.

1.3.8 *Critical humidity.*—The lowest humidity at which blocking of a given degree occurs.

2. SPECIMENS

2.1 Eighteen test specimens 1½ inch square shall be cut from each sample for each series of tests. Twelve specimens shall be used for cohesive tests and six specimens for adhesive tests in both thermoplastic and hygroscopic blocking.

2.2 Adhesive specimens shall be prepared to conform closely with commercial practice in respect to adhesive thickness, backing material, and method of preparation.

2.3 Test specimens and standard paper for determining thermoplastic blocking shall be conditioned in a desiccator over anhydrous calcium chloride at 38° ± 1°C. (100° ± 2°F.) for 24 hours.

2.4 Test specimens and standard paper for determining hygroscopic blocking shall be conditioned at the required relative humidity at 38° ± 1°C. (100° ± 2°F.) for 24 hours.

3. APPARATUS

3.1 The apparatus shall consist of a constant temperature oven, capable of maintaining temperatures up to 85°C. (185°F.) within ± 1°C.

(2°F.) and of sufficient size to hold one or more desiccators of the type described in 3.2.

3.2 Desiccators used as humidity chambers shall have a minimum diameter of 150 mm. The desiccators shall be made of glass with ground flanges and fitting covers. Ground edges shall be clean and well lubricated with stopcock grease.

3.3 Salts for maintaining constant humidity conditions within the desiccators (note 1).

(1) Anhydrous calcium chloride ($CaCl_2$) for low humidity.

(2) The following salts shall be used in saturated solutions:

Salt	Approximate relative humidity over saturated solution at 38° C. (100° F.)
	Percent
Sodium dichromate ($Na_2Cr_2O_7 \cdot 2H_2O$)	50
Sodium bromide ($NaBr$)	54
Sodium nitrite ($NaNO_2$)	62
Sodium acetate ($NaC_2H_3O_2 \cdot 3H_2O$)	68
Sodium chloride ($NaCl$)	75
Potassium chloride (KCl)	83
Ammonium monophosphate ($NH_4H_2PO_4$)	91

3.4 Weights of 1 pound each having a flat base one square inch in area.

3.5 Pieces of plate glass measuring 1½ by 1½ inches.

3.6 **Standard paper.**—Filter paper such as Whatman's No. 1 which may be obtained in sheets 47½ by 57 centimeters or an equivalent paper cut in squares 1½ by 1½ inches (note 2).

4. PROCEDURE

4.1 **Cohesive blocking.**—For cohesive blocking two conditioned test specimens shall be placed on a glass plate, adhesive face to adhesive face. A one-pound weight as specified in 3.4 shall be placed on top of the alined assembly in the center of the 1½-inch-square area. Six assemblies shall be prepared, three for the thermoplastic blocking test and three for the hygroscopic blocking test.

4.2 **Adhesive blocking.**—For adhesive blocking three squares of standard paper as specified in 3.6 shall be superimposed on the adhesive face of a conditioned test specimen and placed on a glass plate. The test specimen, standard paper, and glass plate shall be alined so that the edges are flush. A one-pound weight as specified in 3.4 shall be placed on top of the alined assembly in the center of the 1½-inch-square area. Six assemblies shall be prepared, three for the thermoplastic blocking test and three for the hygroscopic blocking test.

4.3 Thermoplastic blocking.—For thermoplastic blocking the test assemblies shall be placed immediately in a desiccator over anhydrous calcium chloride at 38° ± 1°C. (100° ± 2°F.) for 24 hours.

4.4 Hygroscopic blocking.—For hygroscopic blocking the test assemblies shall be placed immediately in a desiccator at approximately 50 per cent relative humidity at 38° ± 1°C. (100° ± 2°F.) for 24 hours.

4.5 The test assemblies shall be removed and promptly examined at room temperature, noting the degree of adherence.

4.6 The degree of blocking shall be classified as follows:

(1) Free,

(2) First degree blocking,

(3) Second degree blocking, or

(4) Any other degree of blocking as specified by the material specification.

4.7 If the classification is "free," the test shall be repeated with new test assemblies at successively higher temperatures in increments of 5°C. (9°F.) for thermoplastic blocking, or successively higher humidities in increments shown in 3.3 (2) for hygroscopic blocking, until the first or second degree blocking is found, or until a prescribed high temperature or humidity is reached.

Note 1.—Desiccators made up with salt solutions shall be prepared and held at the designated temperatures a sufficient time in advance of use to insure humidity equilibrium within the desiccators. An excess of salt shall be maintained in the solution throughout the period of testing.

Note 2.—In cases where the standard paper listed in 3.6 is deemed inadequate a different paper or material other than paper may be substituted as specified by the material specification, provided such materials are within the scope of this method.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Complete identification of the adhesive tested, including thickness or weight per unit area, and method of application to supporting carrier, if any.

(2) Any alternate material employed under note 2.

(3) Type of test used, whether for cohesive or adhesive blocking, thermoplastic or hygroscopic blocking.

(4) Degree of blocking, whether free, first degree, second degree, or other.

(5) Results of all determinations made, including the critical temperature or, alternatively, the highest temperature employed for thermoplastic blocking; the critical humidity or, alternatively, the highest humidity employed for hygroscopic blocking, and any other phenomena.

TENTATIVE STANDARD METHOD 2051–T: RESISTANCE OF ADHESIVES FOR WOOD TO CYCLIC LABORATORY AGING CONDITIONS

1. SCOPE

1.1 This method of test is intended for determining the resistance of adhesives to cyclic laboratory aging conditions by exposing bonded wood specimens to conditions of high and low temperatures and high and low humidities. The extent of degradation is determined from changes in strength properties as a result of exposure to the test conditions. Although this method is intended primarily for use with the plywood shear specimens described in method 1032 Shear Strength Properties of Adhesives in Plywood-Type Construction by Tension Loading, other strength properties can be used. It is recognized that no laboratory aging procedure for degrading materials correlates perfectly with actual service conditions, and that no single or small group of laboratory test conditions will simulate all actual service conditions. Consequently, care must be exercised in the interpretation and use of data obtained in this test. The test procedure, the number of cycles of the test procedure to be used to determine the extent of degradation and whether test specimens or test panels are to be used, shall be specified in the material specification.

2. SPECIMENS

2.1 The number and type of test specimens shall meet the requirements of the particular strength method of test used to evaluate the extent of degradation. Test panels may also be exposed to those conditions, after which the specified test specimen shall be cut from the panels. One set of specimens shall be tested without exposure to the laboratory aging tests and another after exposure.

3. APPARATUS

3.1 The apparatus shall consist of circulating air ovens, capable of being controlled at the required temperatures.

3.2 Rooms, cabinets, or desiccators with means for controlling the relative humidity of the air in them at the required values (see note 1).

3.3 Glass vessels with water for immersion tests.

3.4 Substitute ocean water with the following composition:

Compound:	Composition — Grams per liter
NaCl	24.53
$MgCl_2.6H_2O$	11.11
Na_2SO_4	4.09
$CaCl_2$	1.16
KCl	.695
$NaHCO_3$	.201
KBr	.101
H_3BO_3	.027
$SrCl_2.6H_2O$	.042
NaF	.003

3.5 Other apparatus as specified by the test method number for the particular strength property used to evaluate the extent of degradation.

4. PROCEDURE

4.1 All specimens shall be conditioned for 7 days by exposure to a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.).

4.2 The test specimens or panels shall be placed in containers so that free access of the controlled atmosphere is obtained for at least 75 per cent of the total area of each test specimen or panel (note 2).

4.3 The test specimens or panels shall be subjected to the number of cycles of one of the test procedures listed in table I, as specified in the material specification.

4.4 After completion of the exposure of the test specimens or panels to one of the procedures in table I, the test specimens or panels shall be conditioned for seven days by exposure to a relative humidity of 50 ± 4 per cent at 23° ± 1.1°C. (73.5° ± 2°F.) and then tested immediately for the specified strength properties, unless otherwise specified in the material specification.

4.5 The average strength value determined in accordance with the designated method of test shall be used to calculate the change in strength, as follows:

$$R = \frac{Y - X}{X} \times 100$$

where R = percentage change in strength as a result of exposure to the test conditions,
X = initial strength, and
Y = strength after exposure to test conditions.

The sign of the result will indicate whether there is a gain (+) or loss (−) in strength.

TABLE I.—*Test procedures*

Procedure designation	Name	Period	Temperature		Relative humidity
			°C.	°F.	
		Hours			*Percent*
A	Interior	24	23±1.1	73.5±2	85 to 90.
		24	48.5±3	120±5	<25.
		72	23±1.1	73.5±2	85 to 90.
		48	48.5±3	120±5	<25.
B	Interior	48	60±3	140±5	<15.
		48	38.5±2	100±3.5	85 to 90.
		8	−18±2	0±3.5	about 100.
		64	38.5±2	100±3.5	85 to 90.
C	Exterior, land and air.	48	71±3	160±5	<10.
		48	23±1.1	73.5±2	Immersed in water.
		8	−57±3	−70±5	About 100.
		64	38.5±2	100±3.5	About 100.
D	Exterior, marine	48	71±3	160±5	<10.
		48	23±1.1	73.5±2	Immersed in substitute ocean water.
		8	−57±3	−70±5	About 100.
		64	23±1.1	73.5±2	Immersed in substitute ocean water.

4.6 Specimens or panels which delaminate during the tests have a change in strength of −100 per cent. Specimens which delaminate during the test before the final strength test can be made to have a strength of 0, and this value shall be included in calculating the average strength and standard deviation.

NOTE 1.—The following saturated salt solutions give 85 to 90 per cent relative humidity: potassium chloride at 23°C. (73.5°F.) and manganous sulfate at 38.5°C. (101.3°F.).

NOTE 2.—The vessels used for the immersion tests shall contain a volume of water not less than 10 times the volume of the test specimen.

5. REPORT

5.1 Unless otherwise specified, the report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Title and designation of strength method of test used.
(2) Information required in particular strength method used.
(3) Test procedure.
(4) Number of cycles.

(5) Whether test specimens or panels were used.
(6) Percentage change in strength.
(7) Changes in appearance of test specimens or panels.
(8) Number of specimens which delaminated during the test before the strength tests were made.
(9) Standard deviation.
(10) Average wood failure in per cent.

TENTATIVE STANDARD METHOD 2052–T: DETERMINING THE EFFECT OF MOISTURE AND TEMPERATURE ON ADHESIVE BONDS

1. SCOPE

1.1 This method of test is intended to define conditions for determining the performance of adhesive bonds when subjected to continuous exposure at specified conditions of moisture and temperature. The performance is expressed as a percentage based on the ratio of strength retained after exposure to the original strength.

1.2 This method of test may be used to determine the performance, for suitable materials, in terms of any desired strength property of adhesive bonds. Test conditions of temperature and moisture only are specified herein. The duration of exposure is dependent upon the nature of the adhesive and the type of specimens and will, therefore, be covered by the material specification.

2. SPECIMENS

2.1 The test specimens shall be prepared in accordance with the procedure outlined in General Requirements, section 3, paragraphs 3.2.1, 3.2.2 and 3.2.3. The specimens shall be of a suitable form and number to meet the requirements of the investigation. They shall conform in detail with the requirements prescribed in the test methods covering the desired property, as follows:

Test Method No.:	*Title of Test Method*
1011.1	Tensile Properties of Adhesives.
1032 (or 1032.1–T).	Shear Strength Properties of Adhesives in Plywood-Type Construction by Tension Loading.
1033 .... or	Shear Strength Properties of Adhesives Determined with Single-Lap Construction by Tension Loading.
1033.1–T	Shear Strength Properties of Adhesives by Tension Loading.
1041.1	Peel or Stripping Strength of Adhesives.

and any other method of test prescribed in Fed. Test Method Std. No. 175 pertaining to strength properties of adhesives for the desired strength test.

2.2 Matched specimens shall be selected for control and exposure treatments, the number to be fixed by the variability inherent in the method.

3. APPARATUS

3.1 The apparatus shall consist of conditioning cabinets or ovens with temperature and humidity control.

4. PROCEDURE

4.1 Preconditioning.—All test specimens shall be conditioned for 7 days by exposure to 50 ± 4 per cent relative humidity at 23° ± 1.1°C. (73.5° ± 2°F.) immediately prior to exposure or prior to testing in the case of control specimens. Prior history of the test specimens should be known and recorded.

4.2 Exposure conditions.—The exposure conditions shall conform to one of the standard test exposures given in table I.

4.3 The control specimens shall be tested for strength by the appropriate method immediately after the conditioning period. The values obtained shall be averaged and recorded as the *original strength* against which the strength after exposure shall be compared in calculating performance.

4.4 The conditioned test specimens shall be subjected to the designated exposure conditions for the length of time prescribed by the specifications for the adhesive being tested. At the end of this time the specimen shall either:

(1) be tested as conditioned by exposure with the exception that temperature-specimens shall be brought to and tested at room temperature after exposure, or

(2) be conditioned again for 7 days by exposure to 50 ± 4 per cent relative humidity at 23° ± 1.1°C. (73.5° ± 2°F.) and tested immediately hereafter. For conditions under which the exposed test specimens shall be tested, see note 1.

4.5 The strength values obtained on the exposed specimens shall be averaged and recorded as the *strength after exposure.*

4.6 Calculations.—The performance of the adhesive under test shall be calculated as follows:

$$\text{Performance } A = \frac{A}{C} \times 100$$

or

$$\text{Performance } B = \frac{B}{C} \times 100$$

where:

$A =$ average strength after exposure when determined in accordance with paragraph 4.4 (1),

$B =$ average strength after exposure when determined in accordance with paragraph 4.4 (2).

$C =$ original strength determined in accordance with paragraph 4.3, see note 2.

NOTE 1.—The conditions under which the exposed specimens are tested will depend on the nature of the adhesive, the adherend, and the strength property being investigated. This will be prescribed by the material specification.

NOTE 2.—Alternative methods of expressing results may be used.

5. REPORT

5.1 Unless otherwise specified, the report shall include the data specified in General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Bonding conditions used in preparing the test specimens and history of the specimens prior to testing.

(2) Description of test specimens, including materials, size, shape, and designation of method of test number in Federal Test Method Standard No. 175 covering the detailed requirements.

TABLE I.—*Standard test exposures*

Test exposure number	Temperature [1]		Moisture conditions
	°*C.*	°*F.*	
1	−57	−70	As conditioned.
2	−34	−30	As conditioned.
3	−34	−30	Presoaked.[2]
4	0	32	As conditioned.
5	23	73.5	50 per cent relative humidity.
6	23	73.5	Immersed in water.
7	38	100	88 per cent relative humidity.
8	63	145	Oven, <10 per cent relative humidity.
9	63	145	Over water.
10	63	145	Immersed in water.
11	79	175	Oven, <10 per cent relative humidity.
12	79	175	Over water.
13	100	212	Immersed in water.
14	105	221	Oven, <10 per cent relative humidity.

[1] The tolerance for test temperature shall be ± 1.1°C. or ± 2°F.

[2] Presoaking shall consist of submerging specimens in water and applying vacuum at 20 ± 1 inch of mercury until equilibrium (constant weight) is reached.

(3) Test conditions used, including any deviation from conditions listed in Table I, duration of exposure, and condition of specimens at test (paragraph 4.4 (1) or 4.4 (2)).

(4) Number of specimens tested, strength of each specimen, and average strength for both control and exposed specimens, including the types of failure and amounts of each type.

(5) Performance expressed as percentage in accordance with 4.6.

METHOD 3011: APPLIED WEIGHT PER UNIT AREA OF DRIED ADHESIVE SOLIDS

1. SCOPE

1.1 This method of test covers a procedure for determining the quantity of adhesive solids applied in a spreading or coating operation.

2. SPECIMENS

2.1 Adherend test specimens shall be selected from portions of the actual material to be coated or spread, or shall be selected from the same, or a similar lot, having the same physical characteristics such as thickness, density, texture, etc.

2.2 The size of the test specimen may vary with the nature of the material to which the adhesive is to be applied. Materials of low porosity may normally require larger test specimens than materials of high porosity.

2.3 Test specimens shall be of simple geometric shape to facilitate precise measurement of dimensions.

2.4 For operations involving the coating or spreading of sheeted stock, individual plies or laminae of the adherend, a minimum of five coated and uncoated duplicate specimens shall be required for determining the average weight of adhesive solids applied.

2.5 For operations wherein the adherend test specimen is in continuous form such as roll stock of paper, fabric, etc., the total area of test specimens required shall be sufficient to reflect accurately the average weight of adhesive solids applied per thousand square feet of coated surface.

3. APPARATUS

3.1 The apparatus shall consist of a balance capable of weighing the material accurately to the nearest 1 per cent, and a suitable instrument for measuring the linear dimensions of the specimens to the same degree of precision.

3.2 Equipment capable of satisfactorily drying the spread or coated specimens to the solvent-free condition shall be employed.

4. PROCEDURE

4.1 The test specimens shall be exposed so as to reach equilibrium with the atmospheric conditions prevailing under actual, or contemplated, operational use, prior to the application of the adhesive.

4.2 The linear dimensions of the test specimens shall be determined and their areas calculated to an accuracy of 1 per cent. The weight of the test specimens shall be determined to the nearest 1 per cent.

4.3 The adhesive shall be applied in accordance with the procedure recommended by the manufacturer.

4.4 Only test specimens reflecting a normal uniform application of adhesive (by visual inspection) shall be used in calculating the weight of adhesive solids applied.

4.5 Both coated and uncoated test specimens shall be simultaneously dried to the solvent-free condition using the procedure recommended by the adhesive manufacturer.

4.6 The solvent-free coated and uncoated specimens shall be reweighed. For continuous operations (where adherend test specimens are fed from roll stock) the dried, solvent-free, coated specimens shall be weighed. The weight of an equal area of identical uncoated stock shall be established.

4.7 The weight of adhesive solids applied, where it is possible to provide exact duplicate specimens for this determination, shall be calculated as follows:

When W_2 and W_1 are expressed in grams:

$$D = \frac{(W_2 - W_1) \times 317.5}{N \times A}$$

When W_2 and W_1 are expressed in ounces:

$$D = \frac{(W_2 - W_1) \times 9000}{N \times A}$$

where:

D = weight of adhesive solids applied, expressed in pounds per thousand square feet of joint or surface areas,

W_2 = weight of the specimen after application of the adhesive and elimination of solvents,

W_1 = weight of the duplicate uncoated specimen,

A = area of test specimen in square inches, and

N = number of surfaces spread.

4.8 The weight of adhesive solids applied, where it is not possible to provide exact duplicate specimens for this determination, shall be calculated as follows:

When W_2 and W_1 are expresed in grams:

$$D = \frac{W_2 - W_1(1-k) \times 317.5}{N \times A}$$

When W_2 and W_1 are expressed in ounces:

$$D = \frac{W_2 - W_1(1-k) \times 9000}{N \times A}$$

where:

D = weight of adhesive solids applied, expressed in pounds per thousand square feet of joint or surface area,
W_2 = weight of the specimen after application of the adhesive and elimination of solvents,
W_1 = original uncoated weight of the specimen,
A = area of test specimen in square inches,
N = number of surfaces spread, and
k = a factor applied to correct for changes in specimen weight that occur during the solvent elimination process. It is obtained by weighing a duplicate specimen and then exposing it simultaneously with the original coated specimen to the solvent evaporation procedure.

k is calculated as follows:

$$k = \frac{M_0 - M_1}{M_0}$$

where

M_0 = original weight of duplicate specimen, and
M_1 = weight after exposure to solvent elimination.

NOTE 1.—Spreading or coating weight per unit area is the total quantity of adhesive solids uniformly applied, expressed in pounds per thousand square feet of joint or surface area.

NOTE 2.—Total quantity of adhesive solids applied is the solvent-free gross weight of adhesive on the surface or at the glue joint, whether resulting from a single spread, double spread (both contacting surfaces spread), or multiple applications of adhesive.

NOTE 3.—Test specimen or adherend is that material which is to be spread or coated with adhesive.

NOTE 4.—For spreading or coating operations where both contacting surfaces of the joint are spread, or where successive coatings of adhesive are applied, the formulas above should be used for each surface spread or successive coating applied, and the combined weight shall equal the total weight of adhesive solids applied.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Method of applying the adhesive and drying the test specimens.

(2) Complete description of the adherend test specimens (composition or type, moisture content, size, source, etc.).

(3) Number of test specimens used (or total area of test specimens if from a continuous operation) and calculated weight of adhesive solids applied to each specimen.

(4) The average calculated weight of adhesive solids applied per thousand square feet of joint or surface area.

(5) Any qualifying remarks concerning the test procedure.

METHOD 3012: APPLIED WEIGHT PER UNIT AREA OF LIQUID ADHESIVE

1. SCOPE

1.1 This method of test covers a procedure for determining the quantity of liquid adhesive applied in a spreading or coating operation.

2. SPECIMENS

2.1 Adherend test specimens shall be selected from portions of the actual material to be coated or spread, or shall be selected from the same, or a similar lot, having the same physical characteristic such as thickness, density, texture, etc.

2.2 The size of the specimen may vary with the nature of the material to which the adhesive is to be applied. Materials of low porosity may normally require larger test specimens than materials of high porosity.

2.3 Test specimens shall be of simple geometric shape to facilitate precise measurement of dimensions.

2.4 For operations involving the coating or spreading of sheeted stock, individual plies or laminae of the adherend, a minimum of five test specimens shall be required for determining the average weight of liquid adhesive applied.

2.5 For operations wherein the adherend test specimen is in continuous form, such as roll stock of paper, fabric, etc., the total area of test specimens required shall be sufficient to reflect accurately the average weight of liquid adhesive applied per thousand square feet of coated surface.

3. APPARATUS

3.1 The apparatus shall consist of a balance capable of weighing the material accurately to the nearest 1 per cent, and a suitable instrument for measuring the linear dimensions of the specimens to the same degree of precision.

4. PROCEDURE

4.1 The test specimens shall be exposed so as to reach equilibrium with the atmospheric conditions prevailing under actual, or contemplated, operational use, prior to the application of the adhesive.

4.2 The linear dimensions of the test specimens shall be determined and their areas calculated to an accuracy of 1 per cent. The weight of the test specimens shall be determined to the nearest 1 per cent.

4.3 The adhesive shall be applied to the test specimens in accordance with the procedure recommended by the manufacturer, and the specimens immediately reweighed.

4.4 Only test specimens reflecting a normal uniform application of adhesive (by visual inspection) shall be used in calculating the weight of liquid adhesive applied.

4.5 The weight of liquid adhesive applied shall be calculated as follows:

When W_2 and W_1 are expressed in grams:

$$S = \frac{(W_2 - W_1) \times 317.5}{N \times A}$$

When W_2 and W_1 are expressed in ounces:

$$S = \frac{(W_2 - W_1) \times 9000}{N \times A}$$

where:

S = weight of liquid adhesive applied, expressed in pounds per thousand square feet of joint or surface area,
W_2 = weight of specimen immediately after application of the adhesive,
W_1 = weight of specimen before applying the adhesive,
A = area of test specimen in square inches, and
N = number of surfaces spread.

NOTE 1.—Spreading or coating weight per unit area is the total quantity of liquid adhesive uniformly applied, expressed in pounds per thousand square feet of joint or surface area.

NOTE 2.—Total quantity of liquid adhesive uniformly applied is the gross weight of adhesive on the surface or at the adhesive joint, whether resulting from a single spread, double spread (both contacting surfaces spread), or multiple applications of adhesive.

NOTE 3.—Test specimen or adherend is that material which is to be spread or coated with adhesive.

NOTE 4.—For bonding operations where both contacting surfaces or the joint are spread with adhesive, the formulas above should be used for each surface spread and the combined weight shall equal the total weight of adhesive applied.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Method of applying the adhesive and drying the test specimens.

(2) Complete description of the adherend test specimens (composition or type, moisture content, size, source, etc.).

(3) Number of test specimens used (or total area of test specimens if from a continuous operation) and calculated weight of adhesive solids applied to each specimen.

(4) The average calculated weight of liquid adhesive applied per thousand square feet of joint or surface area.

(5) Any qualifying remarks concerning the test procedure.

METHOD 4011: pH OF ADHESIVES AND BONDED ASSEMBLIES

1. SCOPE

1.1 This method is useful for determining the pH (acidity or alkalinity) of adhesives and bonded assemblies. The pH of an adhesive may be a factor where the adherend or the adhesive itself may be adversely affected in time by the acidity or alkalinity. These conditions often arise from the catalysts used to cure the adhesive.

2. SPECIMENS

2.1 For adhesives which form dry films at room temperature, the adhesive shall be mixed in accordance with the recommendations of the manufacturer, cast on glass, and allowed to dry at $23° \pm 1.1°$C. ($73.5° \pm 2°$F.). The resin film shall be removed from the glass and ground so that all the particles pass through a 40-mesh sieve. Two grams of this powder shall comprise the test specimen.

2.2 For adhesives which require heat to form dry films, the adhesive shall be mixed in accordance with the recommendations of the manufacturer, cast on glass, and cured in accordance with the recommendations of the manufacturer. The adhesive film should be less than 0.020 inch in thickness. In case the manufacturer makes no recommendation regarding cure of the adhesive, the following is suggested: Place the films on the glass plates in a circulating-air oven at 65°C. (150°F.) until most of the solvent is evaporated; this process usually requires about 4 hours. Then raise the temperature to 150°C. (302°F.) and heat the films until they are cured; this process usually requires less than 1 hour. The dry resin film shall be removed from the glass and ground so that all the particles pass through a 40-mesh sieve. Two grams of this powder shall comprise the test specimen.

2.3 For bonded materials, a section of the sample including both adherend and adhesive shall be ground so that all the particles pass through a 40-mesh sieve. Two grams of this powder shall comprise the test specimen.

3. APPARATUS

3.1 A suitable pH meter capable of making measurements to plus or minus 0.05 pH unit with a glass electrode.

3.2 Distilled water with a pH between 5.6 and 7.0 at 23° ± 1.1°C. (73.5° ± 2°F.).

4. PROCEDURE

4.1 The pH shall be measured at 23° ± 1.1°C. (73.5° ± 2°F.).

4.2 Two grams of the powdered sample shall be suspended in 10 milliliters of distilled water. The pH shall be measured after 15 minutes and then every 24 hours until the values are constant within 0.05 pH unit. Samples shall be kept in glass vessels which do not have an acid or alkaline reaction, such as Pyrex or other heat-resistant glass. The vessels shall be kept tightly stoppered except when measurements are actually being made.

4.3 At least three specimens from each sample shall be tested.

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) The pH and the time required to reach equilibrium of each test specimen.

(2) The pH of the distilled water used.

METHOD 4021: TOTAL SOLIDS CONTENT

1. SCOPE

1.1 Procedure A (4.1) describes a method for determining the total solids content of adhesives containing low-boiling volatile organic solvents.

1.2 Procedure B (4.2) describes a method for determining the total solids content of adhesives containing higher-boiling volatile organic solvents and/or water.

2. SPECIMENS

The test specimen shall consist of 10 grams of the sample in the as-received condition.

3. APPARATUS

3.1 The apparatus shall consist of low-form ground glass-stoppered glass weighing bottles, an oven maintained at 70° ± 3°C. (158° ± 5°F.), desiccator, and analytical balance. An explosion-proof oven should be used when the volatile materials are likely to burn or explode.

4. PROCEDURE

4.1 Procedure A.—The test specimen shall be weighed accurately in a covered low-form weighing bottle, the cover removed, and the bottle heated to 70° ± 3°C. (158° ± 5°F.) until the bottle reaches constant weight. The bottle with the specimen shall be cooled in a desiccator over a drying agent before weighing. The percentage of total solids shall be calculated as follows:

$$\text{Total solids, per cent} = \frac{\text{weight of residue}}{\text{weight of specimen}} \times 100$$

Unless otherwise specified in the material specification, two specimens of each sample shall be tested.

4.2 Procedure B.—This test shall be made in accordance with the instructions given for Procedure A except that the temperature shall be 103° ± 3°C. (217° ± 5°F.).

5. REPORT

5.1 The report shall include the data specified under General Requirements, section 3, paragraph 3.6, and the following where applicable:

(1) Procedure used (temperature of drying).
(2) Number of specimens tested.
(3) Total solids content of each specimen.
(4) Average total solids content of the sample.

FED. TEST METHOD STD. NO. 175: NUMERICAL INDEX OF TEST METHODS

NOTE.—The American Society for Testing Materials designations are given for reference only; there may be a difference between the ASTM method and the method specified herein, but in most cases the methods are identical.

Method	Fed. Std. Method No.	ASTM No.[1]
STRENGTH PROPERTIES		
Tensile Properties of Adhesives	1011.1	D 897–49.
Tensile Properties of Adhesives for Rubberlike Materials	1012	
Shear Strength Properties of Adhesives by Flexural Loading	1021	D 1184–55.
Shear Strength Properties of Adhesives by Compression Loading	1031	D 905–49.
Shear Strength Properties of Adhesives in Plywood-Type Construction by Tension Loading.	1032	D 906–49.
Shear Strength Properties of Adhesives in Plywood-Type Construction by Tension Loading.	1032.1–T	D 906–49.
Shear Strength Properties of Adhesives Determined with Single-Lap Constructions by Tension Loading.	1033	D 1002–53T.
Shear Strength Properties of Adhesives by Tension Loading	1033.1–T	D 1002–53T.
Peel or Stripping Strength of Adhesives	1041.1	D 903–49.
Peel Strength of Adhesives (Climbing Drum Apparatus)	1042–T	
Impact Strength of Adhesives	1051	D 950–54.
Impact Value of Adhesives	1051.1–T	D 950–54.
Fatigue Strength of Adhesives	1061	
Cleavage Strength of Metal-to-Metal Adhesives	1071–T	D 1062–51.
PERMANENCE PROPERTIES		
Resistance of Adhesive Bonds to Chemical Reagents	2011.1	D 896–51.
Delamination	2021	
Resistance of Adhesive Bonds to Water (Wet Strength)	2031	
Resistance of Adhesive Bonds to Water (Wet Strength)	2031.1–T	
Blocking Point of Potentially Adhesive Layers	2041	D 1146–53.
Resistance of Adhesives for Wood to Cyclic Laboratory Aging Conditions	2051–T	D 1183–55T.
Determining the Effect of Moisture and Temperature on Adhesive Bonds	2052–T	D 1151–56T.
WORKING PROPERTIES		
Applied Weight per Unit Area of Dried Adhesive Solids	3011	D 898–51.
Applied Weight per Unit Area of Liquid Adhesive	3012	D 899–51.
ANALYTICAL TESTS		
pH of Adhesives and Bonded Assemblies	4011	
Total Solids Content	4021	

[1] ASTM publications are available for reference in most technical libraries, as well as in some public libraries.

FED. TEST METHOD STD. NO. 175: ALPHABETICAL INDEX OF TEST METHODS

NOTE.—The American Society for Testing Materials designations are given for reference only; there may be a difference between the ASTM method and the method specified herein, but in most cases the methods are identical.

Method	Fed. Std. Method No.	ASTM No.[1]
Applied Weight per Unit of Dried Adhesive Solids	3011	D 898-51.
Applied Weight per Unit Area of Liquid Adhesive	3012	D 899-51.
Blocking Point of Potentially Adhesive Layers	2041	D 1146-53.
Cleavage Strength of Metal-to-Metal Adhesives	1071-T *	D 1062-51.
Delamination	2021	
Determining the Effect of Moisture and Temperature on Adhesive Bonds	2052-T *	D 1151-56T.
Fatigue Strength of Adhesives	1061	
Impact Strength of Adhesives	1051	D 950-54.
Impact Value of Adhesives	1051.1-T *	D 950-54.
Peel or Stripping Strength of Adhesives	1041.1	D 903-49.
Peel Strength of Adhesives (Climbing Drum Apparatus)	1042-T *	
pH of Adhesives and Bonded Assemblies	4011	
Resistance of Adhesive Bonds to Chemical Reagents	2011.1	D 896-51.
Resistance of Adhesive Bonds to Water (Wet Strength)	2031	
Resistance of Adhesive Bonds to Water (Wet Strength)	2031.1-T *	
Resistance of Adhesives for Wood to Cyclic Laboratory Aging Conditions	2051-T *	D 1183-55T.
Shear Strength Properties of Adhesives by Compression Loading	1031	D 905-49.
Shear Strength Properties of Adhesives by Flexural Loading	1021	D 1184-55.
Shear Strength Properties of Adhesives by Tension Loading	1033.1-T *	D 1002-53T.
Shear Strength Properties of Adhesives Determined with Single-Lap Construction by Tension Loading.	1033	D 1002-53T.
Shear Strength Properties of Adhesives in Plywood-Type Construction by Tension Loading.	1032	D 906-49.
Shear Strength Properties of Adhesives in Plywood-Type Construction by Tension Loading.	1032.1-T *	D 906-49.
Tensile Properties of Adhesives	1011.1	D 897-49.
Tensile Properties of Adhesives for Rubberlike Materials	1012	
Total Solids Content	4021	

[1] ASTM publications are available for reference in most technical libraries, as well as in some public libraries.

* Tentative Methods were compiled by the National Bureau of Standards. They are for optional use by all Federal agencies. Comments should be submitted to the Organic and Fibrous Materials Division.

APPENDIX II

MILITARY SPECIFICATIONS

MIL-A-14042A(ORD) SUPERSEDING MIL-A-14042(ORD): ADHESIVE EPOXY

1. SCOPE

1.1 This specification covers an epoxy adhesive to be used for hot or cold bonding of metals (such as projectiles and missile parts and assemblies) phenolic, polyester, epoxy laminates; glass, or wood; to each other, and in combination.

2. APPLICABLE DOCUMENTS

2.1 The following documents of the issue in effect on date of invitation for bids, form a part of this specification:

Specifications

FEDERAL

O-C-141	— Carbon Tetrachloride, Technical.
O-T-634	— Trichloroethylene, Technical.
QQ-A-355	— Aluminum Alloy, Plate and Sheet 2024.
QQ-S-OO640	— Steel, Carbon: Sheet and Strip.
PPP-C-96	— Cans, Metal, 28 Gage and Lighter.
PPP-D-729	— Drums: Metal, 55 Gallon (for Shipment of Noncorrosive Materials).
PPP-D-760	— Drums and Pails, Metal (5 and 16.64 Gallon).

MILITARY

MIL-S-3136	— Standard Test Fluids Hydrocarbon and Iso-octane.
MIL-B-5634	— Blasting Grit, Soft (for Carbon Removal).

Standards

FEDERAL

Fed. Test Method Std. No. 141 — Paint, Varnish, Lacquer, and Related Materials; Methods of Inspection, Sampling, and Test-Testing.

Fed. Method Std. No. 175 – Adhesives: Methods of Testing.

MILITARY

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes.

MIL-STD-129 — Marking for Shipment and Storage.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

PUBLISHER'S NOTE: The spellings used are identical with the original specifications.

2.2 *Other publications.*—The following documents form a part of this specification. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

Consolidated Classification Committee

Uniform Freight Classification Rules

(Application for copies of these freight classification rules should be addressed to the Consolidated Classification Committee, 202 Chicago Union Station, Chicago 6, Illinois.)

3. REQUIREMENTS

3.1 *Material.*—The adhesive furnished under this specification shall consist of two parts: base polymer, and accelerator. The base polymer, accelerator and finished adhesive shall conform to the requirements of this specification (see 6.2).

3.1.1 *Base polymer.*—The base polymer shall contain a thermosetting resin of the epoxy type as the basic ingredient, and shall be a translucent, odorless liquid.

3.1.2 *Accelerator.*—The accelerator shall be a liquid amine.

3.2 *Test requirements.*—The materials shall conform to all test requirements of this specification. At the discretion of the procurement agency check tests may be limited to working life, shear strength (see 3.2.2) and any other tests (see 3.2.3) considered necessary to determine conformance of the materials with the requirements of this specification.

3.2.1 *Working life.*—The maximum average viscosity values for the working life of the adhesive shall be as specified in table I, when determined as specified in 4.5.2.1.

TABLE I.—*The viscosity of room temperature epoxy adhesive, used as criterion for its working life.*

Time elapsed after mixing accelerator with base polymer, minutes *	Temperature of adhesive immersed in cold bath, °F.	Average values, centipoises, maximum.
0	64.4	30,000
30	64.4	75,000
60	64.4	160,000

* NOTE: Each specimen shall be thoroughly mixed every 10 minutes.

3.2.2 *Minimum tests for shear strength.*—Adhesive specimens shall have shear strengths as specified in table II when determined as specified in 4.5.2.2. The minimum test for shear strength shall be method 1 or 2 of table II and tested at 73.5° ± 2°F. and 50 ± 2 per cent relative humidity.

TABLE II.—*Shear strength of room temperature epoxy adhesive*

Method No.	Conditions of the bonded panels: Method & Length of time of curing	Conditions of the bonded panels: Treatment of bonded panels prior to shear strength tests	Shear strengths of the adhesive, Lbs. per sq. inch: Conditioned 30 minutes at −65 ± 2°F then tested at −65 ± 2°F		Tested at 73.5° ± 2°F and relative humidity 50 ± 2 per cent		Conditioned one hour at 160 ± 2°F then tested at 160° ± 2°F	
			Minimum	Minimum average	Minimum	Minimum average	Minimum	Minimum average
(1)	Seven days at 73.5° ± 2°F and relative humidity 50 ± 2 per cent		1150	1330	1900	2450	485	600
(2)	One hour at 160° ± 2°F		1500	1800	3000	3160	700	950
(3)	Seven days at 73.5° ± 2°F and relative humidity 50 ± 2 per cent	Seven days immersion in aromatic (mixed) hydrocarbon fluid, type II			2000	2450		
(4)	One hour at 160° ± 2°F	Seven days immersion in aromatic (mixed) hydrocarbon fluid, type II			2500	2850		
(5)	Seven days at 73.5° ± 2°F and relative humidity 50 ± 2 per cent	168 hours conditioning in weatherometer			1200	1800		
(6)	One hour at 160° ± 2°F	168 hours conditioning in weatherometer			1500	2300		
(7)	Seven days at 73.5° ± 2°F and relative humidity 50 ± 2 per cent	176 hours salt spray			1250	1550		
(8)	One hour at 160° ± 2°F	176 hours salt spray			1750	2000		

3.2.3 *Additional requirements.*—The material shall conform to the following requirements. Tests to determine conformance of the material with these additional requirements shall be made at the discretion of the procuring agency.

3.2.3.1 *Shear strength of bonded joints under different conditions.*—Adhesive specimens shall have shear strengths as specified in table II, when determined as specified in 4.5.2.2.

3.2.3.2 *Curing.*—The maximum time required for cure shall be seven days at room temperature (73.5° ± 2°F.) and relative humidity 50 ± 2 per cent or one hour at 160° ± 2°F., when determined as specified in 4.5.2.3.1.1.

3.2.3.3 *Per cent of non-volatile matter.*—The average non-volatile matter of the adhesive shall be 99.5 per cent, minimum, when determined as specified in 4.5.2.3.1.2.

3.2.3.4 *Specific gravity.*

3.2.3.4.1 *Base polymer.*—The specific gravity of the base polymer shall be 1.21 ± 0.01, when determined as specified in 4.5.2.3.1.3.1.

3.2.3.4.2 *Accelerator.*—The specific gravity of the accelerator shall be 0.95 ± 0.01, when determined as specified in 4.5.2.3.1.3.2.

3.2.3.5 *Ash content.*

3.2.3.5.1 *Base polymer.*—The average ash content of the base polymer shall be 0.12 per cent, maximum, when determined as specified in 4.5.2.3.1.4.

3.2.3.5.2 *Accelerator.*—The average ash content of the accelerator shall be 0.01 per cent, maximum, when determined as specified in 4.5.2.3.1.4.

3.2.3.6 *pH value.*

3.2.3.6.1 *Base polymer.*—The pH value of the base polymer shall be 6.3 ± 0.2, when determined as specified in 4.5.2.3.1.5.

3.2.3.6.2 *Accelerator.*—The pH value of the accelerator shall be 6.3 ± 0.2, when determined as specified in 4.5.2.3.1.5.

3.2.3.7 *Suitability for use with explosives.*—When suitability for use with a particular explosive is required, a special test shall be conducted at a designated Government laboratory to determine compliance of the adhesive in this respect (see 6.2). The procuring agency shall request this test to be conducted and shall specify the particular explosive to be used in this test.

3.3 *Instruction sheet.*—A dated instruction sheet shall be provided with each shipment container of the component ingredients of epoxy adhesive, outlining instructions for mixing and use of the adhesive. The instruction sheet shall cover the following:

a. Name and type of base resin used in the adhesive.

b. Maximum usable storage and working life of the base polymer, with and without the addition of accelerator, at various temperatures between 32°F. and 100°F.

c. Mixing instructions, including recommended type and percentage of accelerator, maximum and minimum per cent of accelerator allowed, and temperature control necessary during mixing and use of the adhesive.

d. Complete recommended pre-bonding treatment and metal cleaning processes, including proportions of materials necessary to prepare cleaning media.

e. Complete recommended procedure including method of application of adhesive, recommended film thickness, drying or curing time, recommended temperature and pressure.

f. Any other pertinent information relative to the preparation, use, and storage of the component ingredients or adhesive.

3.4 *Workmanship.*—The component ingredients shall be free from foreign matter, homogeneous, intimately compounded, and processed as required in accordance with the best practice for high quality material.

4. QUALITY ASSURANCE PROVISIONS

4.1 Unless otherwise specified herein the supplier is responsible for the performance of all inspection requirements prior to submission for Government inspection and acceptance. Except as otherwise specified, the supplier may utilize his own facilities or any commercial laboratory acceptable to the Government. Inspection records of the examinations and tests shall be kept complete and available to the Government as specified in the contract or order.

4.2 *Lot.*—A lot of epoxy adhesive shall consist of that number of batches of base polymer of epoxy adhesive and that number of batches of accelerator of epoxy adhesive which have been subjected to the same processing operations and conditions. A batch, in all cases, shall be defined as that quantity of material which has been subjected to some unit chemical or physical mixing process intended to make the final product substantially uniform.

4.3 *Sampling.*

4.3.1 *For examination.*—A random sample of filled containers shall be selected for examination in accordance with level 1 of Standard MIL–STD–105.

4.3.2 *For tests:* A one quart sample (with necessary accelerator) shall be selected at random from each lot. Each sample shall be divided into two parts. One-half shall be used to conduct the necessary test. The other half shall be held for referee test, if necessary. Additional samples may be taken if considered necessary by the procuring agency to determine compliance of the adhesive with the requirements of this specification.

4.4 *Examination.*

4.4.1 *Visual.*—Sample units selected in accordance with 4.3.1 shall be examined for the defects and at the Acceptable Quality Level shown in table III.

4.4.2 *Examination of packaging and packing.*—Sample units selected in accordance with 4.3.1 shall be examined for the defects and at the Acceptable Quality Level shown in table III.

TABLE III.—*Method of examination.*

Material	AQL per cent	Classification of defects	Defect	Method of inspection
Base Polymer (see 3.1.1 and 3.4).	2.5	Major 1 Major 2 Major 3 Major 4 Major 5	Not translucent Foreign matter Not intimately compounded Not homogeneous Not odorless	Visual Visual Visual Visual Olfactory
Accelerator (see 3.4).	2.5	Major 1 Major 2 Major 3	Foreign matter Not intimately compounded Not homogeneous	Visual Visual Visual
Container, open (see 4.4.2 and 5.1).	2.5	Major 1 Major 2	Improper type Improper fill	Visual Visual
Container, closed (see 4.4.2 and 5.1).	2.5	Major 1 Major 2	Leakage Improper closure	Visual Visual
Box, open (see 4.4.2 and 5.2).	2.5	Major 1 Major 2	Improper type Lack of, or improper strapping	Visual Visual
Box, closed (see 4.4.2 and 5.2).	2.5	Major 1 Major 2 Major 3	Gross weight, max. Marking misleading or unidentifiable Improperly closed	Approved scale [1] Visual Visual

[1] Approved by procuring agency

4.5 *Tests.*

4.5.1 *Preparation for tests.*

4.5.1.1 *Preparation of adhesive.*—The adhesive shall be prepared, in a room at 73.5 ± 2°F. with a relative humidity of 50 ± 2 per cent, by thoroughly mixing 100 parts (by weight) of base polymer with 7 ± 0.2 parts (by weight) of accelerator. Only the base polymer shall be cooled to 55° ± 2°F. prior to mixing. The temperature of the adhesive shall be between 65° and 68°F. during mixing and working periods. This temperature can be maintained by immersing the container in a cold water bath of approximately 55°F. It is recommended that not more than 107 gm be prepared at one time, except for the amount required for the working life test (see 4.5.2.1).

4.5.1.2 *Preparation of adherend materials.*

4.5.1.2.1 *Aluminum strips.*—Aluminum Alloy 24S, Condition O, complying with Specification QQ–A–355, shall be used to fabricate at least 120 strips, 1 inch by 4 inches by ⅛ inch. A surface area of 1 square inch shall be sand blasted at one end by particles of 60 to 70 mesh sand (see Specification MIL–B–5634) under 50 to 70 psi air pressure. The strips shall be wiped with a cloth soaked in a solvent such as acetone, carbon tetrachloride (see Specification O–C–141), or trichloroethylene (see Specification O–T–634), and immersed in an acid bath for 3 to 5 minutes at 185°F. (The acid bath shall consist of 6 oz. of sodium dichromate, 32 oz. of concentrated sulfuric acid, and sufficient distilled water to make 1 gallon of solution.) The strips shall be rinsed in cold running water followed by hot distilled water, then dried by hot air or in an oven and stored in a desiccator until ready for use.

4.5.1.2.2 *Steel strips.*—Steel panels, FS, 1022, No. 4 soft, complying with Specification QQ–S–00640, shall be used to fabricate at least 120 strips, 1 inch by 4 inches by ⅛ inch. An area of 1 square inch, on one end of the strip, shall be sand blasted by particles of 60 to 70 mesh sand under 50 to 70 psi air pressure. The strips shall then be wiped with a cloth soaked in a solvent such as carbon tetrachloride or trichloroethylene and immersed in clean solvent for 2 to 5 minutes. The strips shall then be oven or air dried, and stored in a desiccator until ready for use.

4.5.1.2.3 *Assembling the strips.*—Strips of steel to aluminum shall be assembled as follows: The overlap shall be determined as specified in 4.5.1.2.4 and the length of the overlap marked with a pencil along the width (sand blasted side) of one of the strips. A thin layer of adhesive (see 4.5.1.1) shall be applied, with a brush or spatula, on an area of approximately 1 inch square on each strip. A 2 inch long, ¾ inch wide, piece of pressure sensitive cellophane tape, shall be placed across the inner end of the deeper trough of the assembling apparatus, figure 1. The strip, with the marking of the length of overlap, shall be laid into this trough, face upward, with its opposite surface in contact with the adhesive or tape. The second strip, with the adhesive on, shall be placed so the adhesive coated surfaces of both strips face each other. The adhesive coated transverse edge of the top strip shall be aligned with the marking of the length of overlap on the bottom strip. The strips shall be held in position and aligned by pressing with the little finger of each hand, on each strip. The remaining fingers of each hand shall be used to fold the free ends of the pressure sensitive cellophane tape over the strip.

4.5.1.2.4 *Length of overlap.*—The length of overlap shall be based upon the thickness of the metal being bonded. (See figure 2.)

The value of $\sqrt{\frac{t}{L}}$ shall be 0.5, or greater, for metal specimens.

where:

t = thickness of the adherend in inches.

L = overlap in inches.

For example, when t = 1/8 inch, the length of overlap shall not be greater than 0.5 inch.

4.5.2 *Test methods.*

4.5.2.1 *Working life.*

4.5.2.1.1 *Apparatus.*—The apparatus shall consist of a Brookfield Synchrolectric Viscometer (Model HBF, Volts 110, freq. −60), or approved substantial equal. It shall be mounted on a platform which is attached to stand in such a manner that the viscometer is lowered at the rate of 1 inch per minute by means of a motor-driven buttress-type screw. A spindle attached to the viscometer, bears a notch and disc on its shaft. The notch indicates the depth of penetration. A beaker (200 ml, 5 inches tall, 2¼ inch diameter) shall serve to weigh the mix and base polymer with the accelerator, and to suspend it in a cold bath. The cold bath shall serve as the source of refrigeration; the temperature (50° to 53°F.) shall maintain the thermal equilibrium (65° to 68°F.) of the adhesive during the test period.

4.5.2.1.2 *Procedure.*—One hundred seventy-five grams of the base polymer shall be weighed in the beaker, and suspended in a cold bath to bring the base polymer temperature to 55° ± 2°F. An accurately weighed portion of 12.25 gm of accelerator shall be thoroughly mixed, in small portions, with the refrigerated base polymer for 15 minutes. The temperature of the adhesive, during and at the end of mixing, shall be between 65° and 68°F. The beaker, with its contents shall be removed from the cold bath, and the viscosity of the adhesive shall be determined within 3 minutes with the Brookfield Synchroletric Viscometer, using Spindle #3, at a speed of 5 rpm. The beaker and its contents shall be placed back in the cold bath, and after a lapse of 30 minutes, the viscosity shall again be determined. The viscosity determination shall be repeated again after a second 30-minute period, and the reading on the scales recorded. The adhesive shall be mixed every 10 minutes during the entire viscosity test. When the readings on the scales surpass the 500 to 1000 marks, the spindle in use shall be replaced by a refrigerated spindle of smaller diameter. The recorded readings on the scales shall be converted to centipoises in accordance with the instructions of the Brookfield Synchrolectric Viscometer. Three separate tests shall be conducted, and the respective test results tabulated. The maximum of the averages, in centipoises, shall be recorded as listed in table I.

4.5.2.2 *Shear strength tests under different conditions.*—Sixty specimens shall be assembled as specified in 4.5.1.2. Thirty of these specimens shall be cured as specified in 4.5.2.3.1.1.1 and the remaining 30 specimens shall be cured as specified in 4.5.2.3.1.1.2. The specimens prepared as specified above shall be used for the following tests:

4.5.2.2.1 *Low temperature.*—Five specimens cured at room temperature and five specimens cured at elevated temperature shall be conditioned in a chamber at $-65° \pm 2°$F. for 30 minutes. They shall then be tested at $-65° \pm 2°$F. in accordance with Standard No. 175, method 1033, except that the load shall be applied at the rate of 800 psi per minute.

4.5.2.2.2 *Room temperature.*—Five specimens cured at room temperature and five specimens cured at elevated temperature shall be conditioned at $73.5° \pm 2°$F. and a relative humidity of 50 ± 2 per cent. The specimens shall then be tested at $73.5° \pm 2°$F. and a relative humidity of 50 ± 2 per cent, in accordance with Standard No. 175, method 1033, except that the load shall be applied at a rate of 800 psi per minute.

4.5.2.2.3 *Elevated temperature.*—Five specimens cured at room temperature and five specimens cured at elevated temperature shall be conditioned at $160° \pm 2°$F. for 1 hour. They shall then be tested at $160° \pm 2°$F., in accordance with Standard No. 175, method 1033, except that the load shall be applied at a rate of 800 psi per minute.

4.5.2.2.4 *Accelerated weathering.*—Five specimens cured at room temperature and five specimens cured at elevated temperature shall be subjected to accelerated weathering for 168 hours in accordance with Standard No. 141, method 6152, and then tested in accordance with Standard No. 175, method 1033, except that the load shall be applied at the rate of 800 psi per minute.

4.5.2.2.5 *Salt spray.*—Five specimens cured at room temperature and five specimens cured at elevated temperature shall be exposed to salt spray for 176 hours in accordance with Standard No. 141, method 6061. The specimens shall then be tested in accordance with Standard No. 175, method 1033, except that the load shall be applied at the rate of 800 psi per minute.

4.5.2.2.6 *Immersion in hydrocarbon fluid.*—Five specimens cured at room temperature and five specimens cured at elevated temperature shall be immersed in fluid complying with Specification MIL–S–3136, type II, for 7 days at a temperature of 73.5° ± 2°F. and relative humidity of 50 ± 2 per cent. Immediately after removal from the fluid, the specimens shall be tested in accordance with Standard No. 175, method 1033, except that the load shall be applied at a rate of 800 psi per minute.

4.5.2.3 *Methods for additional tests.*

4.5.2.3.1 *Certification.*—The contractor shall certify that the adhesive meets the additional test requirements, and that such samples or specimens that have been tested were taken from the lot, as described herein, being submitted for acceptance. The certificate presented to the Government inspector, prior to or at the time of delivery of the lot, shall show the tests performed and the results obtained. This certificate shall be signed by a responsible agent of the certifying organization and shall be accompanied by evidence of this agent's authority to bind his principal. The Government reserves the right to check test the material submitted by the contractor under certification.

4.5.2.3.1.1 *Curing.*

4.5.2.3.1.1.1 *Room temperature.*—Bonded specimens, as prepared in 4.5.1.2.3 shall be cured for 7 days, in a room having a temperature of 73.5° ± 2°F., and a relative humidity of 50 ± 2 per cent.

4.5.2.3.1.1.2 *Elevated temperature.*—Bonded strips, as prepared in 4.5.1.2.3 shall be cured for 1 hour, in an oven at 160° ± 2°F. (see 6.3).

4.5.2.3.1.2 *Non-volatile matter.*—Approximately 7 gm of the adhesive shall be prepared as specified in 4.5.1.1 and cooled at room temperature until the exothermic reaction ceases. The specimen shall then be tested as specified in Standard No. 141, method 4041. Three specimens shall be tested, and the average reported.

4.5.2.3.1.3 *Specific gravity.*

4.5.2.3.1.3.1 *Base polymer.*—The specific gravity of the base polymer shall be determined as specified in Standard No. 141, method 4183, except that an 83.3-milliliter aluminum pycnometer, with a glass stoppered thermometer shall be used, and the temperature shall be 25°/25°C. (77°/77°F.).

4.5.2.3.1.3.2 *Accelerator.*—The specific gravity of the accelerator shall be determined as specified in Standard No. 141, method 4183, except that an 83.3-milliliter aluminum pycnometer shall be used and the temperature shall be 25°/25°C. (77°/77°F.).

4.5.2.3.1.4 *Percentage of ash.*—The percentage of ash of the base polymer and the accelerator shall be determined as specified in Standard No.

141, method 5264. Three specimens of each shall be tested and the average reported.

4.5.2.3.1.5 *Determination of pH value.*—The pH value of base polymer and accelerator shall be determined as specified in Standard No. 175, method 4011. Three specimens of each shall be tested and the average reported.

4.6 *Resubmission and retest.*—If the sample submitted for test, fails to pass the test, the lot shall be rejected subject to reworking and resubmission. The lot shall be considered acceptable on retest provided that a new sample, selected in accordance with 4.3.2 passes all the tests required by this specification.

5. PREPARATION FOR DELIVERY

5.1 *Packaging.*—Packaging shall be level A or C as specified (see 6.1).

5.1.1 *Level A.*

5.1.1.1 *Base polymer.*—Unless otherwise specified, base polymer shall be furnished in 1-gallon multiple friction top cans conforming to type V, class 2 of Specification PPP–C–96; in 5-gallon lug-cover steel pails conforming to type II, class 1 of Specification PPP–D–760; or in 55-gallon steel drums conforming to type III of Specification PPP–D–729, as specified.

5.1.1.2 *Accelerator.*—Unless otherwise specified, the accelerator shall be furnished in 1-gallon multiple friction top cans conforming to type V, class 2 of Specification PPP–C–96.

5.1.2 *Level C.*

5.1.2.1 *Base polymer.*—Unless otherwise specified, the base polymer shall be packaged in accordance with the suppliers commercial practice. Protection shall be such as to prevent deterioration during shipment and subsequent interval prior to use.

5.1.2.2 *Accelerator.*—Unless otherwise specified, the accelerator shall be packaged in accordance with the suppliers commercial practice. Protection shall be such as to prevent deterioration during shipment and subsequent interval prior to use.

5.2 *Packing.*—Packing shall be level A or C as specified (see 6.1).

5.2.1 *Level A.*—The base polymer and accelerator packaged as specified in 5.1.1 shall be packed in accordance with the overseas shipment requirements of Specification PPP–C–96, Appendix. Five-gallon pails and 55-gallon drums will require no overpacking.

5.2.2 *Level C.*—The base polymer and accelerator packaged as specified in 5.1.2 shall be packed in a manner to ensure carrier acceptance and safe delivery at destination. Containers shall be in accordance with Uni-

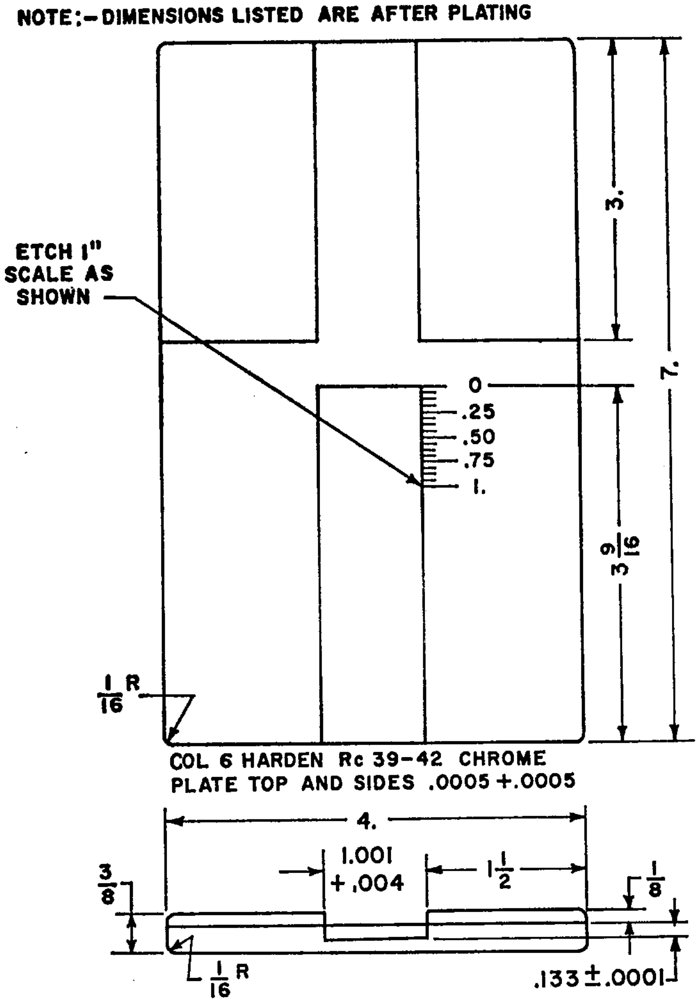


Figure 1. Assembly apparatus.

form Freight Classification Rules, or regulations of other carriers applicable to the mode of transportation.

5.3 *Marking.*—In addition to marking in accordance with Standard MIL–STD–129, interior packages and exterior containers shall be marked with the following:

Material: Base Polymer or Accelerator (as applicable).
Batch Number.
Flash Point.
Storage.

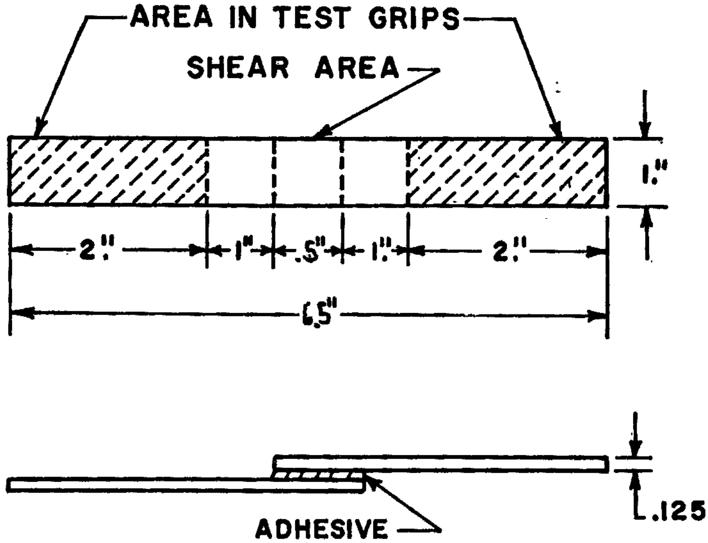


Figure 2. Specimen placement for shear strength test.

a. *Base polymer.*—The base polymer should be stored in tightly closed tinplated containers in a cool dry place at a temperature range of 35° to 60°F.

b. *Accelerator.*—The accelerator must be kept in a tightly closed glass or tinplated steel container. The stopper of the container should be lined with tin foil.

"*CAUTION:* Prolonged contact of the base polymer, or the accelerator, with the skin, clothing, etc., should be avoided. These materials should be removed from any such contact area with a solvent such as toluene or acetone, then washed with soap and water. Special care should be taken to avoid inhaling the accelerator."

The marking shall be protected by a coat of clear transparent varnish to ensure identification after storage.

5.4 *Storage.*—The storage requirements should not vary with the packaging requirements as to the type of containers which are specified for the different levels of packaging.

6. NOTES

6.1 Ordering data.—Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Levels of packaging and packing required.

(c) Size of container required (see 5.1.1).
(d) Unit, intermediate and exterior package quantities, when applicable.
(e) Any other desired options offered herein (see 3.2.3.2, 4.5.1.1 and 4.5.2.1.1).
(f) Whether suitability with an explosive is required (see 3.2.3.7).

6.2 Use with explosives.—Information pertaining to the use of the adhesive, procured under this specification, with explosives may be obtained from the Commanding Officer, Picatinny Arsenal, Dover, New Jersey, Attention Director, Feltman Research and Engineering Laboratories, Plastics and Adhesives Research Section.

6.3 Elevated temperature curing.—The curing temperature of 160° ± 2°F. refers to the glue line temperature and can be determined by inserting thermocouple leads onto one specimen adjacent to the bonded joint. A Leeds and Northrup potentiometer indicator using chromel-alumel leads is satisfactory.

Notice: When Government drawings, specifications or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

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MIL-A-9067B [SUPERSEDING MIL-A-9067A, MIL-M-9269 (USAF)]: ADHESIVE BONDED METAL; PROCESS AND INSPECTION REQUIREMENTS

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 This specification establishes requirements for the processing and inspection of structural and nonstructural metal parts, including sandwich constructions, bonded with airframe structural metal-to-metal adhesives. This specification is particularly adaptable to airframe parts.

2. APPLICABLE DOCUMENTS

2.1 The following standard, of the issue in effect on date of invitation for bids, forms a part of this specification:

Standards

MILITARY

MIL-STD-105 — Sampling Procedures and Tables for Inspection by Attributes

2.1.1 Specifications governing the bonding materials and the materials to be bonded shall be as stipulated or approved by the procuring Service. They shall be of the issue in effect on the date of invitation for bids and shall form a part of this specification.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Contractor's process specification, engineering report, and drawings. —The contracting fabricator shall submit a titled, numbered, and dated process specification to the procuring Service for approval. After approval, the process specification shall form a part of this specification and copies shall be made available by the contractor for use by authorized Government inspectors at the contractor's plant. The materials and processes used in production shall conform to the requirements of the process specification in addition to the requirements of this specification, and shall not be changed in production without approval of a new superseding process specification. The process specification shall be applicable only for the adhesives, metals, and, if applicable, sandwich core materials for which it is written and for the contractor preparing it. Changes shall not be made without written approval of the procuring Service. The process specification shall contain all necessary procedures, controls, precautions, and inspection methods to insure the production of a fully satisfactory product. An engineering report, prepared by the fabricator, shall be furnished with the process specification submitted for approval, and shall describe all tests which are used as a basis for specification requirements. After receiving approval of the process specification, the contractor shall submit engineering drawings, prepared in accordance with applicable Government specifications, detailing the design of the proposed specific end item parts utilizing adhesive bonded metal to the procuring Service for end item approval. These drawings shall reference the approved process specification. However, where the process specification is not general, but is for specific parts and references drawings for such parts, these drawings shall be submitted along with the process specification. The following specific requirements, processes, inspection methods, and precautions shall all be included and completely described in the process specification.

3.1.1 *Materials.*—All materials used in the processes covered by this specification shall conform to applicable Government specifications or other specifications as stipulated or approved by the procuring Service.

3.1.1.1 Adhesive to be used in the production bonding of parts shall be sampled and tested within 96 hours preceding its use to determine its conformance with the normal (room) temperature shear strength requirements to be found in the applicable and stipulated specification governing its use. The metal for the test specimens shall be cleaned by the same method and materials as will be used on production parts. Adhesive not conforming to this requirement shall not be used in the production of parts. No acceptable lot of adhesive shall be used in the production of parts later than 96 hours after it was sampled for such test unless it is again sampled, tested, and passed on the above requirements for the same usable period of time.

3.1.2 *Bonding procedure.*—All operations connected with bonding, from the drying and storage of cleaned parts to be bonded through their assembly for final bonding, shall be conducted in an area where cleanliness is carefully maintained and controlled by policing of the area and filtering of all incoming air. Temperature of the area shall be controlled to stay within the range of 65° to 75°F.; the relative humidity of the area shall be maintained at 40 to 65 per cent. The following specific steps in the bonding procedure shall be completely described in the contractor's process specification.

3.1.2.1 *Prefitting of parts.*—The surfaces shall have good contact over the entire area to be bonded and shall be free of burrs, waves, and other surface imperfections. When practicable, the surfaces shall be prefitted. Surfaces not prefitted shall conform to the applicable drawings.

3.1.2.2 *Cleaning of contact surfaces.*—All parts to be bonded shall be thoroughly cleaned by a suitable and approved procedure. The precautions to be taken to eliminate contamination of cleaned surfaces awaiting application of adhesive shall be specified in the contractor's process specification. The time cleaned parts may remain uncoated shall also be specified, and shall be substantiated by tests described in the contractor's engineering report.

3.1.2.2.1 *Wrought aluminum and aluminum alloys.*—The surfaces to be bonded of all wrought aluminum and aluminum alloy parts or test specimens shall be thoroughly cleaned using the following cleaning procedure, unless otherwise specified in the process specification and approved by the procuring Service.

3.1.2.2.1.1 Degrease with an organic solvent, followed by immersion in a chromic acid solution of approximately the following composition by weight for 10 minutes at 150° to 160°F. (65.6° to 71.1°C.):

30 parts water
10 parts concentrated sulfuric acid (1.84 specific gravity)
1 part sodium dichromate

Rinse in water at a temperature no higher than 150°F. Parts or specimens cleaned shall be observed for water breaks on the surfaces. If water breaks occur, the parts or specimens shall be recleaned. Cleaned parts or specimens shall be allowed to dry for at least 30 minutes at a temperature no greater than 150°F. before having the adhesive applied.

3.1.2.2.2 *Other metals.*—The cleaning process for metals other than wrought aluminum shall require specific approval from the procuring Service. The request for approval shall be substantiated by test data in the contractor's engineering report showing the bond to have adequate strength and durability.

3.1.2.2.3 All cleaning solutions shall be tested daily and maintained at their required strengths. Procedures for such maintenance shall be described in the contractor's process specification.

3.1.2.3 *Handling of parts.*—Clean, white gloves shall be worn by all personnel handling parts already cleaned.

3.1.2.4 *Application of adhesive.*—The exact procedures to be followed in applying the adhesive to the metal shall be described in the contractor's process specification. These procedures shall conform to the general requirements of such an approved adhesive manufacturer's instruction sheet as may be required by the applicable and stipulated adhesive specification. However, the process specification shall contain the specific and detailed application procedures applicable to the specific adhesive bonded parts to be made and process equipment to be used. After application of the adhesive, the parts shall be kept dry and free from dirt, grease, oil, wax, or other foreign material, and shall not be handled with the bare hands. The length of time adhesive coated parts are allowed to stand before bonding shall not exceed the open assembly life of the adhesive and shall be specified in the contractor's process specification. Precautions to be taken to eliminate physical contamination of the adhesive coatings shall also be specified therein.

3.1.2.5 *Assembly of parts.*—Care shall be taken in assembling parts in the curing fixture or jig to assure that the adhesive is not disturbed and that excessive residual stresses are avoided. Parts shall be assembled in such a manner that the requirements of the applicable adhesive manufacturer's instruction sheet are fulfilled, and the procedures to be used shall be described in the contractor's process specification.

3.1.2.6 *Curing of adhesive.*—The exact curing procedures shall be described in the contractor's process specification. These procedures shall conform to the general curing requirements of the approved adhesive manufacturer's instruction sheet as required by the applicable and stipulated adhesive specification. However, heat curing cycles shall be chosen such that, as a result of processing through the maximum number of cycles that may occur during fabrication, there shall be no reduction in either the mechanical or the corrosion-resistance properties of the metals or alloys employed to values below the minimums of the applicable material specifications. Data substantiating compliance with this requirement shall be included in the contractor's engineering report (see 3.1). The contractor's process specification shall contain the specific and detailed curing procedures applicable to the specific adhesive bonded parts and process equipment to be used.

3.1.2.7 *Temperature and pressure requirements and controls.*—Temperature and pressure requirements and the details of procedures to be followed for their measurement and control during production bonding of parts shall be included in the contractor's process specification. The adequacy of such requirements shall be determined by bonding experimental parts under variable conditions of temperature and pressure until a satisfactory product is obtained as judged by subsequent destructive testing and disassembly of these parts. Those conditions of temperature and pressure control and those temperatures and pressures which thus give the best and most satisfactory parts shall thereafter be used in production and shall be those stipulated in the contractor's process specification. Such optimum conditions shall be determined with thermocouples and pressure gauge so placed and spaced as to insure that adequate temperatures and pressures and even distributions thereof are being obtained over all the areas and subareas to be bonded.

3.1.2.8 *Bonding of subassemblies.*—If bonded subassemblies are to be bonded again into complete assemblies, a description of precautions to be taken to assure that the second cleaning and bonding operations cause no ill effects on the initially bonded parts shall be included in the contractor's process specification.

3.1.3 *Protection of bonded joints.*—In specific cases, when bonded joints are to be protected by coatings or other means against corrosion or other deteriorating factors, because of the particular application or metal used, complete details of the materials and procedures to be used shall be included in the contractor's process specification.

3.1.4 Any other processes or precautions required for proper storage, control of film thickness, control of application, control of humidity during metal cleaning, adhesive application, tooling, etc., which may be applicable to the particular adhesive or to the conditions of fabrication being employed, shall be included in the contractor's process specification.

3.1.5 The contractor's process specification shall contain all the specific and detailed requirements for sampling, lot size, inspection, and testing. These specific requirements shall be in accordance with the requirements specified in 4.3 through 4.6.

4. QUALITY ASSURANCE PROVISIONS

4.1 General.—All the tests of this specification are classified as acceptance tests, for which the necessary sampling techniques, inspection procedures, and methods of testing are specified in this section, and shall be performed during the fabrication of adhesive bonded metal airframe parts which are to be submitted for acceptance under a contract or order.

4.2 Process specification.—The primary and continuing purpose of the acceptance tests shall be to see that all the requirements and procedures of the approved contractor's process specification specified in 3.1 are continuously complied with during production of parts. This shall be accomplished by periodic inspection of the production processes, controls, and other items covered by the process specification.

4.3 Sampling of parts.

4.3.1 Production bonded parts shall incorporate, where possible, extensions or coupons which can be cut from the parts after bonding and which will be representative of the bonds obtained in the parts proper. Where extensions cannot be incorporated in the parts, standard specimens shall be fabricated to simulate such extensions. These shall be bonded at the same time, with the same adhesive, and in the same equipment and under the same conditions as for the assembly they represent. Complete details of such incorporation or fabrication procedures shall be included in the contractor's process specification. Such extensions or specimens shall be inspected and tested in accordance with the provisions of 4.4.1.

4.3.2 Completely fabricated parts shall be taken periodically from production for inspection and testing in accordance with the provisions of 4.4.2. Unless otherwise specified, sampling shall be in accordance with Standard MIL–STD–105.

4.4 Inspection and test of parts.

4.4.1 Destructive quantitative strength tests shall be made of the adhesive bonds in the extensions or specimens prepared in accordance with the provisions of 4.3.1 above. Full details concerning the number of extensions or specimens to be prepared, the test procedures to be used, and the requirements to be met shall be contained in the contractor's process specification.

4.4.2 Destructive inspection tests shall be made on at least the first completed production part and on a sufficient number of succeeding parts (to be approved by the procuring Service) to insure proper fabrication of parts throughout the production run. Any evidence of improper cure, adhesion, alignment, etc., shall be immediately corrected by making indicated adjustments in cure pressures, temperatures, or cycles, or in tooling. If any changes are made in established curing or tooling or if new tooling is introduced, even though it is identical to the already established tooling, new qualitative tests shall be made. Bonded assemblies affected by such changes shall be subjected to rejection and retest in accordance with 4.8. Control and test instruments shall be periodically checked and calibrated. Full details concerning the percentage and frequency of parts to be tested and inspected, the procedures to be used, and the requirements to be met, shall be contained in the contractor's process specification. The types of tests performed to fulfill this requirement shall be quantitative, at least in part, and shall be static destruction tests on the entire production part or specimens cut from the production part. The frequency of the proposed tests shall be predicated on tool life expectancy and on an adequate learning curve. Estimates of tool life shall be included in the contractor's specification. Checks of tool dimensions and alignment shall be performed after every assembly is completed. Whatever the quantitative tests used to satisfy this specification, each production part shall be checked and inspected visually for bond quality. Details pertaining to the fulfillment of the requirements of this paragraph shall be included in the contractor's process specification and shall be submitted to the procuring Service for approval.

4.5 Sampling and inspection of adhesive.—Adhesive to be used in the production bonding of parts shall be sampled and tested within 96 hours preceding its use to determine its conformance to the provisions of 3.1.1.1.

4.6 Sampling and inspection procedures differing from the above will be considered for approval in specific cases where justified, and shall be described in the contractor's process specification and justified in the contractor's engineering report.

4.7 The materials and methods covered by this specification, the articles fabricated thereby, and the tests made thereon shall be subject to the inspection and supervision of authorized Government inspectors. Reports of tests performed under Government inspection and supervision shall be furnished the authorized inspectors.

4.8 Rejection and retest.—Adhesive bonded assemblies not meeting the requirements of this specification shall be rejected. Rejected assemblies shall not be resubmitted for inspection without the contractor furnishing full particulars concerning previous rejection and measures taken to overcome the defects.

5. PREPARATION FOR DELIVERY

5.1 There are no applicable requirements.

6. NOTES

6.1 Intended use.—The process and inspection requirements in this specification are intended for use in the manufacture of adhesive bonded airframe structural and nonstructural metal parts.

Notice. When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:
Army—Ordnance Corps
Navy—Bureau of Aeronautics
Air Force

Other Interest:
Navy—OrMd

Preparing Activity:
Air Force

MIL–A–9067B AMENDMENT 1: ADHESIVE BONDED METAL; PROCESS AND INSPECTION REQUIREMENTS

This amendment forms a part of Military Specification MIL–A–9067B, 8 May 1957, has been approved by the Department of Defense, and is mandatory for use by the Departments of the Army, the Navy and the Air Force.

Page 4, paragraph 3.1.3. Add: "Bonded joints at the exposed edges of sandwich components, access doors, windows, et cetera must be protected against the entrance of liquids (water, fuel, oil, et cetera) into the core of the sandwich. The contractor's process specification shall contain a specific and detailed proof-test to prove the adequacy of panel sealing against the entrance of moisture, such as to draw a vacuum on the interior of the sandwich part while immersed in water. Repeated simulated service loads should be applied during immersion. Weight changes, if any, should be observed at intervals and recorded over a period of at least 192 hours. If weight changes are noticed, the exact location of the water can be found by X-ray examination. Completely fabricated parts shall be taken periodically from production for inspection and testing for water penetration by a method similar to that outlined in this paragraph. Any parts which have been damaged and repaired during fabrication shall be fully proof-tested for water penetration."

Custodians:
Army—Ordnance Corps
Navy—Bureau of Aeronautics
Air Force

Preparing activity:
Air Force

Other interest:
Navy—OrMd

MIL-A-25463(ASG): ADHESIVE, METALLIC STRUCTURAL SANDWICH CONSTRUCTION

This specification has been approved by the Department of the Air Force and by the Navy Bureau of Aeronautics.

1. SCOPE

1.1 *Scope.*—This specification covers adhesives for bonding metal facings to metal cores and to metal components of sandwich panels which are intended for use in primary and secondary structural airframe parts that may be exposed to temperatures up to 500°F. (260°C.).

1.2 *Classification.*—The adhesives shall be of the following types and classes, as specified (see 6.2):

Type I —For long-time exposures to temperatures from −67° to +180°F. (−55° to +82°C.).

Type II —For long-time exposures to temperatures from −67° to +300°F. (−55° to +149°C.).

Type III—For long-time exposures from −67° to +300°F. (−55° to +149°C.) and short-time exposures from 300° to 500°F. (149° to 260°C.).

Type IV —For long-time exposures from −67° to +500°F. (−55° to +260°C.).

Class 1 —For bonding metal facings to metal cores only.
Class 2 —For bonding metal facings to metal cores, inserts, edge attachments, and other components of completed sandwich structures.

2. APPLICABLE DOCUMENTS

2.1 The following specifications and standards, of the issue in effect on date of invitation for bids, form a part of this specification to the extent specified herein:

Specifications

FEDERAL	
QQ-A-355	Aluminum Alloy (24S), Plate and Sheet
QQ-A-362	Aluminum Alloy (Clad 24S); Plate and Sheet
PPP-C-96	Cans, Metal, 28 Gage and Lighter
MILITARY	
MIL-S-3136	Standard Test Fluids Hydrocarbon and Iso-Octane
MIL-A-5090	Adhesive; Airframe Structural, Metal to Metal
MIL-C-7438	Core Material, Aluminum, for Sandwich Construction
MIL-A-8431	Adhesives, Heat Resistant, Airframe Structural, Metal to Metal
MIL-S-25043	Steel Plate, Sheet, and Strip, 17-7 PH, Corrosion Resistant, Precipitation Hardening

Standards

FEDERAL	
Fed. Test Method Std. No. 151	Metals; Test Methods
MILITARY	
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-401	Sandwich Constructions and Core Materials; General Test Methods

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 *Qualification.*—The material furnished under this specification shall be a product which has been tested and has passed the Qualification tests specified herein.

3.1.1 Qualification of the adhesive shall be in accordance with its type, class, and physical form. Qualification of one form (liquid, solid, film, etc.) shall not constitute qualification of a different form in the same type and class.

3.1.2 Adhesives that produce optimum results using nonperforated core shall be qualified for use only with such core (see 3.7 and 4.2.1.2).

3.2 *Materials.*—The adhesive shall be thermosetting and shall meet the strength requirements of this specification. The adhesive shall not cause a deleterious effect on the metal surfaces being bonded over the range of temperatures at which the adhesive will be used. There shall be no restrictions on the ingredients used in the adhesives other than those imposed by the technical requirements specified herein. Class 2 adhesives shall consist of an adhesive conforming to Specification MIL–A–5090 or MIL–A–8431, as applicable, plus the requirements specified herein.

3.2.1 *Formulation changes.*—The adhesive shall be approved only for the formulation for which qualification tests are made. Any modification, such as the adding of pigments, hardeners, or fillers; change in carrier or method of manufacture; change in weight per square foot in excess of the tolerance specified in 3.2.2, etc., shall be cause for designating the adhesive as a new material which shall not be considered approved. The changed adhesive shall be given a new code number and shall be submitted for approval under this specification.

3.2.2 *Code number.*—Each adhesive shall be identified by a trade name and a code number which shall indicate its type, class, form, and type of core with which to be used. For film adhesives the weight in pounds per square foot ± 0.020, or the weight range (see 3.2.3.2.1), and the carrier, when applicable (see 3.2.3.2), shall be indicated also.

3.2.3 *Physical form.*—There shall be no restriction of the physical form in which the adhesive is supplied except those imposed by the technical requirements specified herein.

3.2.3.1 *Liquid form.*—Liquid-form adhesives shall be capable of being mixed to a smooth homogeneous solution or suspension of a consistency suitable for application.

3.2.3.1.1 *Catalyst, hardener, or modifier.*—If necessary, a catalyst, hardener, or modifier shall be supplied in powder or liquid form for mixing with the adhesive.

3.2.3.2 *Film form.*—Film-form adhesives shall consist either entirely of adhesive or of a carrier impregnated with adhesive(s).

3.2.3.2.1 Manufacturers of a film adhesive supplying the adhesive in a weight range exceeding ± 0.020 pound per square foot shall submit for qualification the maximum and minimum weights of the adhesive. Approval of the maximum and minimum film adhesive weights shall constitute automatic qualification approval of the weights within the qualified range.

3.2.4 *Solvent.*—A solvent, if used as an additive for the adhesive, shall be furnished as a liquid. An activating solvent may be furnished and used with the adhesive in film form.

3.2.5 *Filler.*—If necessary, a filler may be incorporated in the adhesive. Any such filler shall remain uniformly dispersed and suspended in the mixed adhesive during its normal pot life.

3.3 *Application.*—Unless otherwise approved by the activity responsible for qualification, the adhesive shall be suitable for application to metal facings and core materials in accordance with the manufacturer's instructions at temperatures between 60° and 100°F. (16° and 38°C.) and relative humidities of 30 to 80 per cent.

3.4 *Curing.*—The time, temperature, and pressure used to cure the adhesive shall be within the range specified herein. An adhesive not producing satisfactory bonds under these curing conditions will be acceptable, at the option of the activity responsible for qualification, if it is capable of meeting the strength requirements when bonded under other conditions.

3.4.1 *Curing time and temperature.*—Types I and II adhesives shall meet the requirements of this specification when cured for not longer than 2 hours at a bond line temperature not exceeding 350°F. (177°C.). Curing temperatures used with types III and IV adhesives in stainless steel constructions shall not exceed 800°F. (426°C.) for more than 3 hours.

3.4.2 *Curing pressure.*—In the preparation of sandwich constructions fabricated in accordance with 4.4, the pressure required for curing the adhesive shall not exceed 75 psi for aluminum core constructions and 100 psi for steel core constructions.

3.5 *Storage life.*—The adhesive manufacturer shall determine the optimum and maximum temperature and the storage period (from date of manufacture) for those temperatures at which the adhesive, when stored in airtight containers or wrapped in suitable vapor barriers, will retain its capabilities of meeting the minimum strength requirements specified in 3.6. These storage conditions shall be included in the instruction sheet (3.7) and the test report (4.2.1.2) and shall constitute the storage conditions for the storage life test specified in 4.6.15.

3.6 *Mechanical properties.*

3.6.1 *Class 1.*—When tested in accordance with the applicable paragraph in section 4, class 1 adhesive shall develop the minimum average and minimum individual properties specified in tests 1 through 15 in table I, as applicable to the type.

TABLE I.—*Mechanical properties of bonded joints*

Test No.	Applicable to adhesive type	Condition and type of test	Method paragraph reference	Requirements[1] Minimum average value	Requirements[1] Minimum individual value
		Sandwich peel strength			
1	I and II III and IV	Normal temperature	4.6.1	8.5 lb in./in. of width 3.5 lb in./in. of width	7 lb in./in. of width 2 lb in./in. of width
2	I and II III and IV	180° ± 2°F (82° ± 1°C)	4.6.2	5 lb in./in. of width 3.5 lb in./in. of width	3 lb in./in. of width 2 lb in./in. of width
3	I, II, III, and IV	−67° ± 2°F (−55° ± 1°C)	4.6.3	2 lb in./in. of width	1 lb in./in. of width
		Flatwise tensile strength			
4	I, II, III, and IV	Normal temperature	4.6.4	450 psi	400 psi
5	I II III and IV	180° ± 2°F (82° ± 1°C) 300° ± 5°F (149° ± 3°C) 500° ± 5°F (260° ± 3°C)	4.6.5	270 psi 350 psi 270 psi	240 psi 315 psi 240 psi
6	I, II, III, and IV	−67° ± 2°F (−55° ± 1°C)	4.6.6	350 psi	315 psi
		Flexural strength (total load)			
7	I, II, III, and IV	Normal temperature	4.6.7	1,750 lb	1,575 lb
8	I II III and IV	180° ± 2°F (82° ± 1°C) 300° ± 5°F (149° ± 3°C) 500° ± 5°F (260° ± 3°C)	4.6.8	1,200 lb 1,500 lb 1,200 lb	1,080 lb 1,350 lb 1,080 lb
9	I, II, III, and IV	−67° ± 2°F (−55° ± 1°C)	4.6.9	1,750 lb	1,575 lb
		Flexural strength after 192 hours exposure (total load)			
10	I II and III IV	180° ± 2°F (82° ± 1°C) 300° ± 5°F (149° ± 3°C) 500° ± 5°F (260° ± 3°C)	4.6.8	1,000 lb 1,200 lb 600 lb	900 lb 1,080 lb 540 lb
		Creep deflection in flexure when loaded for maximum of 192 hours			
11	I, II, III, and IV	Normal temperature	4.6.10	0.025 in. max deflection under 1,000-lb load	

TABLE I.—*Mechanical properties of bonded joints* (Continued)

Test No.	Applicable to adhesive type	Condition and type of test	Method paragraph reference	Minimum average value	Minimum individual value
12	I	180° ± 2°F (82° ± 1°C)	4.6.11	0.05 in. max deflection under 800-lb load	
	II and III	300° ± 5°F (149° ± 3°C)		0.05 in. max deflection under 1,000-lb load	
	IV	500° ± 5°F (260° ± 3°C)		0.05 in. max deflection under 500-lb load	
		Flexure strength after 30 days exposure (total load)			
13	I, II, III, and IV	To 90 to 100 per cent relative humidity and 120° ± 2°F (49° ± 1°C)	4.6.12	1,500 lb	1,350 lb
14	I, II, III, and IV	To salt spray (Fed. Test Method Std. No. 151, Method 811)	4.6.13	1,500 lb	1,350 lb
15	I, II, III, and IV	To hydrocarbon fluid (Spec MIL–S–3136, type III)	4.6.14	1,500 lb	1,350 lb

[1] The number of specimens required by each qualifying test shall be tested and the results shall meet the minimum average and minimum individual value requirements. All strength values, including the average, and all data upon which these values are based, from both the initial tests and any retests, shall be reported.

3.6.2 *Class 2.*—The mechanical properties of class 2 adhesive shall conform to those specified in Specification MIL–A–5090 or MIL–A–8431, as applicable. In addition, when tested in accordance with the applicable paragraphs in section 4, class 2 adhesives shall develop the minimum average and minimum individual properties specified in tests 1 through 12 in table I, as applicable to the type.

3.7 *Instruction sheet.*—The manufacturer shall provide an approved, dated, coded, and titled instruction sheet with each package of adhesive outlining instructions for its use in bonding metal facings to metal cores and metal components. The instruction sheet shall also be provided to authorized Government Inspectors at the contractor's plant. The instruction sheet shall include the following information:

(a) The general chemical type of the base resin used in the adhesive, such as phenolic-neoprene, vinyl-phenolic, etc.
(b) The type of core with which adhesive is to be used (perforated vs nonperforated).
(c) The type and treatment of carrier used in supported film adhesive.

(d) Information required in 3.5.
(e) Instructions on the use of a thinner or solvent with the adhesive, including optimum and maximum amount allowable.
(f) Mixing instructions, where necessary, including recommended type and percentage of catalyst, filler, and other additives with maximum percentages allowed, and temperature control necessary during mixing.
(g) Complete recommended metal-preparation processes and treatments, including proportions of materials necessary to prepare treatment media. These shall include those approved by the activity responsible for qualification.
(h) Application instructions, including spread method, number of coats, weight range, and liquid adhesive or primer film thickness range. Application temperature and relative humidity, if other than specified in 3.3.
(i) Drying time between coats and after last coat. If forced drying is required, the time and temperature shall be tested.
(j) Maximum allowable storage life of adhesive-coated metal prior to assembly and curing.
(k) Recommended and maximum and minimum times, temperatures, and pressures for each segment of the complete curing cycle and the number of permissible re-cures for multiple bonding of assemblies.
(l) The necessary safety precautions to be taken when using the adhesive.

3.8 *Workmanship.*—The adhesive shall be free of foreign matter and shall be prepared in accordance with the best commercial practices for this type of material.

4. QUALITY ASSURANCE PROVISIONS

4.1 *Classification of tests.*—The inspection and testing of the adhesive shall be classified as follows:

(a) Qualification tests	(See 4.2)
(b) Acceptance tests	(See 4.3)

4.2 *Qualification tests.*

4.2.1 *Sampling instructions.*—Qualification test samples shall consist of 2 quarts of liquid adhesive, or an equivalent amount in weight or measure if of another form, from each of three different batches of the adhesive being presented for qualification. These samples are in addition to the number of specimens specified in 4.4.1 through 4.4.3 and may or may not be from the same three batches used in preparing the qualification sample specimens. Samples shall be identified by the manufacturer's own adhesive number, type of core (perforated or nonperforated), and any additional identification required and forwarded to the activity responsible for qualification, designated in the letter of authorization from that activity. (See 6.3.1).

4.2.1.1 *Test report.*—In addition to the Qualification test samples, the manufacturer shall furnish a dated and numbered test report, certified by affidavit, which shall include the results of all tests listed in table I, as applicable to the type and class (see 4.2.2). The individual and average values for the tests shall be reported. The test report shall cover all the requirements in section 3 except 3.7. The type of core (perforated or nonperforated) and actual adhesive spread, assembly condition, pressure, and time of curing used in the preparation of the test panels shall be reported. The report shall certify that the preparation of the adhesive and test specimens conforms to the descriptions required in the instruction sheet.

4.2.1.2 *Instruction sheet.*—The manufacturer shall submit for approval two copies of an instruction sheet conforming to 3.7.

4.2.2 *Tests.*

4.2.2.1 *Class 1 adhesive.*—Class 1 adhesives shall be subjected to all the tests specified in table I, as applicable to the adhesive type.

4.2.2.2 *Class 2 adhesive.*—In addition to meeting the mechanical property requirements specified in Specification MIL–A–5090 or MIL–A–8431, as applicable, class 2 adhesives shall be subjected to tests 1 through 12 specified in table I, as applicable to the adhesive type. Adhesives already qualified under either of the above specifications need not be reevaluated thereto.

4.3 *Acceptance tests.*—Acceptance tests shall consist of Sampling tests.

4.3.1 *Lot.*—A lot shall consist of 500 pounds of adhesive, or fraction thereof, of one type and class forming part of one contract or order, manufactured from one batch, and submitted for acceptance at one time and place.

4.3.1.1 *Batch.*—A batch shall consist of a homogeneous unit of finished adhesive manufactured at one time or representing a blend of several manufactured units of finished adhesive of the same formulation.

4.3.2 *Sampling tests.*—A single sample of not less than 2 quarts of liquid adhesive or an equivalent amount in weight or measure if of another form shall be taken at random from each lot and tested. Each sample shall be divided into two equal parts; one part shall be available for required acceptance tests and the other part shall be retained for retests, if necessary. The storage condition for the retained sample shall be that recommended by the adhesive manufacturer (see 3.5), and samples shall not be retained beyond the storage life, as recommended by the adhesive manufacturer.

4.3.3 *Tests.*—Acceptance tests shall consist of the normal temperature peel test (4.6.1) and the normal temperature flexure test (4.6.7). For the peel test, three 3- by 12-inch specimens shall be prepared from panels fabricated in accordance with 4.4 and 4.4.1. For the flexure test for type I and II adhesives, three 3- by 8-inch specimens shall be prepared from aluminum sandwich panels fabricated in accordance with 4.4, 4.4.3, and 4.4.3.1. For the flexure test for types III and IV adhesives, three 3- by 8-inch specimens shall be prepared from steel sandwich panels fabricated in accordance with 4.4, 4.4.3, and 4.4.3.2.

4.3.4 *Rejection and retest.*—If the results of any of the acceptance tests are less than the applicable minimum requirements in table I, another set of specimens shall be prepared and tested to the same procedure as the rejected specimens. The retest specimens for the acceptance tests shall be selected from panels prepared with part of the adhesive sample retained (see 4.3.2) for retests. Failure of the retest specimens to meet the respective requirements in table I shall then be cause for rejection of the adhesive. Rejected adhesive, except as specified herein, shall not be resubmitted by the manufacturer for retest without furnishing full particulars concerning previous rejections and measures taken to overcome the defects.

4.4 *Preparation of test specimens for qualification testing.*—Specimens shall be prepared as described in the following subparagraphs for the peel, tension, flexure, and creep tests. Each third of the panels or specimens shall be representative of one of the three batches of adhesive being presented for qualification. All panels and specimens shall be so marked that each specimen and panel can be identified with the particular batch of adhesive from which it was bonded in order that any failures may be traced to either the adhesive or the machines or equipment for bonding. For sandwich panels, the total weight (both facings) of the adhesive system used to prepare the test panels shall be the minimum recommended by the adhesive manufacturer, +5 per cent −0 per cent, and shall not exceed 0.25 pound per square foot of sandwich panel for types I and II adhesives nor 0.40 pound per square foot of sandwich panel for types III and IV adhesives.

4.4.1 *Panels for peel tests.*—A sufficient number of sandwich panels shall be prepared to provide for at least eighteen 3- by 12-inch specimens for the peel tests. The sandwich panels shall be prepared using 0.020-inch ± 0.002, 2024–T3, clad aluminum alloy facings conforming to Specification QQ–A–362 bonded to 0.50-inch thick, perforated (unless otherwise specified), aluminum core conforming to Specification MIL–C–7438, code 7.9-1/4-40P(3003). The panels shall be fabricated and cut so the ribbon direction of the core is the same as the 12-inch dimension of the test specimen.

4.4.2 *Specimens for flatwise tensile tests.*—At least 27 sections of core measuring 2 by 2 inches shall be cut for bonding to two 2- by 2-inch cross section by 1.5-inch thick loading blocks. The dimensions of the specimens shall be measured to at least 0.5 per cent accuracy. For types I and II adhesives, the specimens shall consist of 0.50-inch thick, perforated (unless otherwise specified), aluminum core conforming to Specification MIL–C–7438, code 7.9-1/4-40P(3003), bonded directly with the adhesive submitted for qualification to 2024–T4 aluminum alloy loading blocks conforming to Specification QQ–A–355. For types III and IV adhesives, the specimens shall consist of 0.50-inch thick, ¼-inch cell size, perforated (unless otherwise specified), 0.002-inch foil size, type 17-7 PH, condition TH 1050, stainless steel (Specification MIL–S–25043) honeycomb core with continuous welded nodes bonded directly with the adhesive submitted for qualification to stainless steel loading blocks conforming to Specification MIL–S–25043, type 17-7 PH, condition TH 1050. In lieu of stainless steel welded core, cores with adhesive-bonded nodes may be used, but it shall be so specified in the test report. The node-bonding adhesive shall be either the adhesive being submitted for qualification or an equivalent type conforming to Specification MIL–A–8431. The bolt holes in the loading blocks shall be 0.25 inch in diameter and the axis of the hole shall be parallel to the bonding face, 1.0 ± 0.020 inch from the bonding face, and equidistant (tolerance ± 0.02 inch) between the adjacent sides. The specimens shall be assembled so the holes in the two loading blocks on opposite sides of the core are at 90 degrees to each other and so the sides of the blocks are in alinement (maximum effect tolerance of 0.015 inch). See 6.4.3 for recommended bonding and alinement procedures. Tension specimens and apparatus are shown in figure 1.

4.4.3 *Panels for flexure and creep tests.*—Sufficient sandwich panels shall be prepared to provide at least fifty-four 3- by 8-inch specimens for class 1 adhesives and thirty-six 3- by 8-inch specimens for class 2 adhesives. All test specimens shall be cut from the panels so the ribbon direction "L" of the cores is the same as the 8-inch lengthwise dimension of the specimen.

4.4.3.1 *Types I and II adhesives.*—Sandwich panels shall be prepared using 0.063 ± 0.003 inch, 2024-T3, clad aluminum alloy facings conforming to Specification QQ–A–362 bonded to 0.50-inch thick, perforated (unless otherwise specified), aluminum core conforming to Specification MIL–C–7438, code 7.9-1/4-40P(3003). Core materials for use with type

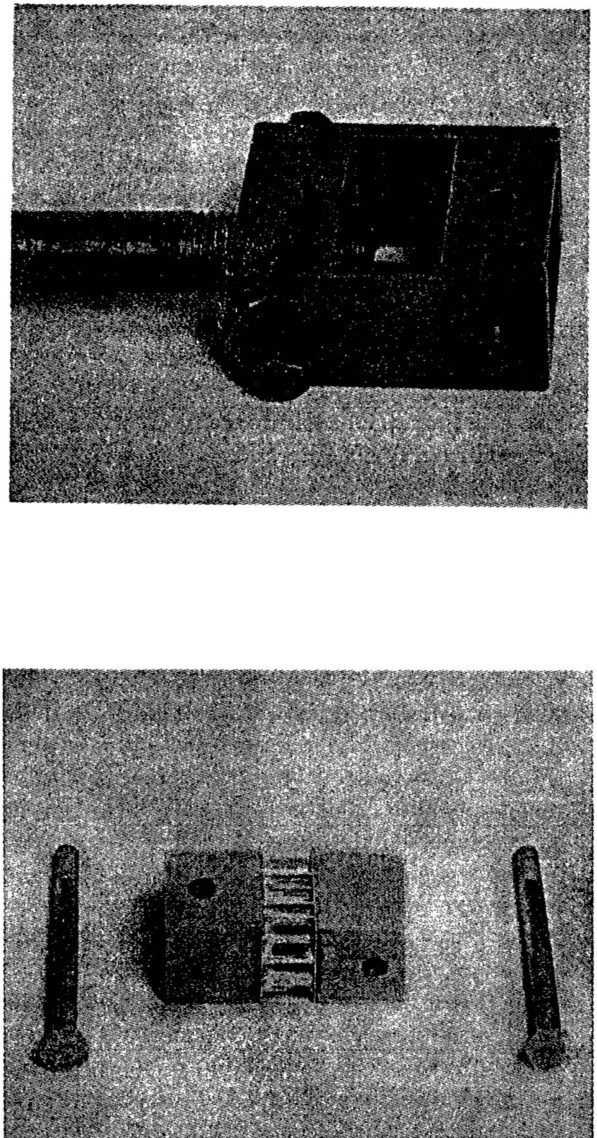


Figure 1. Flatwise tensile test specimens and apparatus.

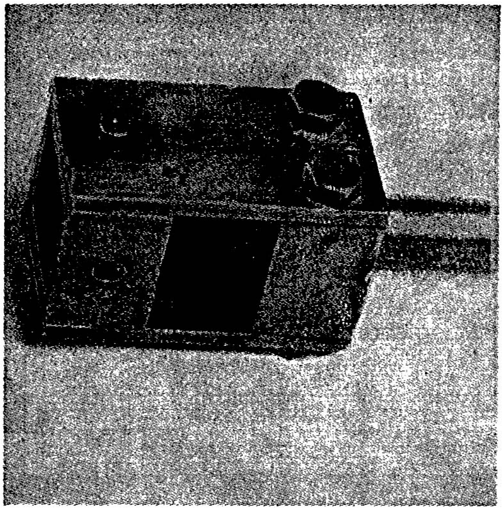


Figure 1. (*Continued*)

II adhesives shall be node bonded with the adhesive submitted for qualification or an equivalent type conforming to Specification MIL–A–8431.

4.4.3.2 *Types III and IV adhesives.*—Sandwich panels shall be prepared using 0.050 ± 0.005 inch, type 17-7 PH, condition TH 1050 stainless steel facings conforming to Specification MIL–S–25043 bonded to 0.50-inch thick, 0.25-inch cell size, perforated (unless otherwise specified), 0.002-inch foil size, condition TH 1050, stainless steel (Specification MIL–S–25043) honeycomb core with continuous welded nodes. See 4.4.2 for exception to core with continuous welded nodes.

4.5 *Test conditions.*

4.5.1 *Normal temperature.*—Normal temperature tests shall be conducted at 70° to 80°F. (21° to 27°C.) 10 minutes after the specimens have reached equilibrium at this temperature. The required time for the specimens to reach normal temperature equilibrium shall be no less than 10 minutes nor more than 30 minutes. If the validity of the property values determined within the above specified temperature is questionable, the test shall be repeated at 73° ± 2°F. (23° ± 1°C.) and 50 ± 4 per cent relative humidity 10 minutes after the specimens have reached equilibrium at such temperature.

4.5.2 *Elevated temperature.*—The final testing temperatures for all specimens for elevated temperature tests shall be those of the surface of the metal as close to the bonded area as possible. The temperature shall be determined with a thermocouple firmly attached as above in order to insure accuracy of the testing temperature and reproducibility of data.

If radiant heating devices are used, the thermocouples shall be properly shielded. Specimens for the long-time elevated temperature tests may be placed in circulating air ovens for the 192-hour period, after which they shall be immediately transferred to the heating unit of the testing machine. Elevated temperature tests shall be conducted 10 minutes after the specimens in the testing chamber have reached temperature equilibrium at the specified temperature. The time required for the specimens to reach the specified temperature equilibrium shall not exceed the schedule specified in table II.

TABLE II.—*Time required for specimens to reach temperature equilibrium in the test chamber*

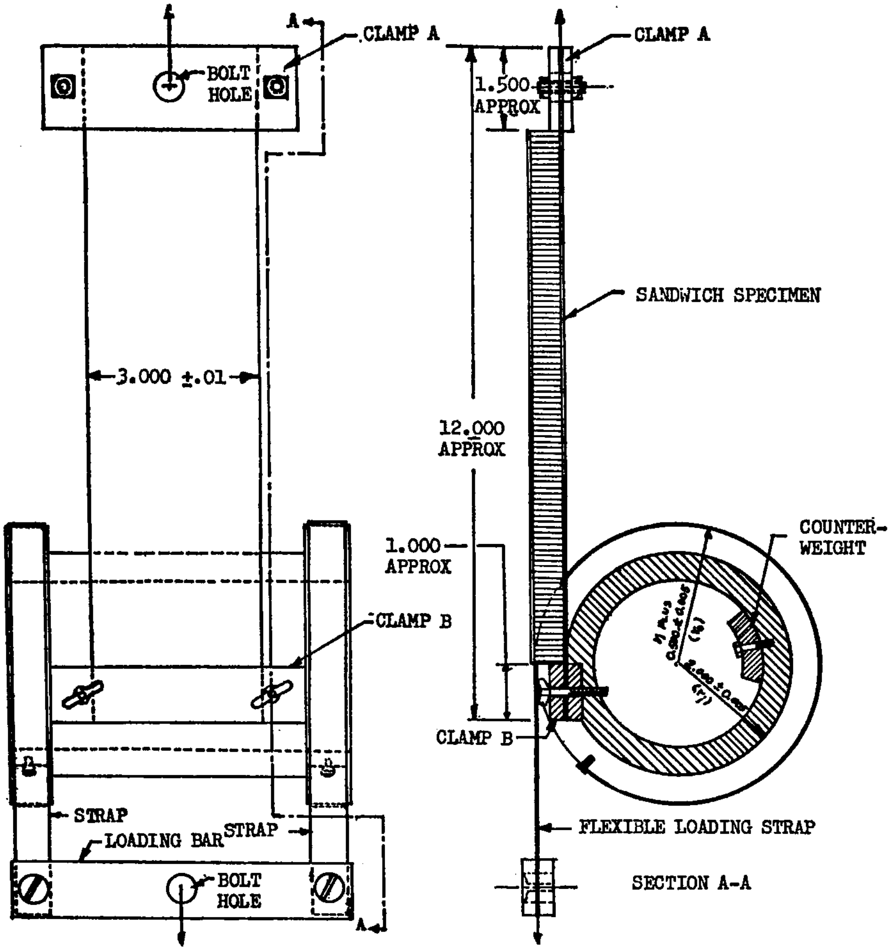
Temperature	Short-time exposure (minutes)	After long-time exposure (minutes)
$-67° \pm 2°F$ ($-55° \pm 1°C$)	30 ± 10	20 ± 10
$120° \pm 2°F$ ($49° \pm 1°C$)	30 ± 10	20 ± 10
$180° \pm 2°F$ ($82° \pm 1°C$)	30 ± 10	20 ± 10
$300° \pm 5°F$ ($149° \pm 3°C$)	45 ± 10	20 ± 10
$500° \pm 5°F$ ($260° \pm 3°C$)	60 ± 10	20 ± 10

4.5.3 *Low temperature.*—Low temperature tests shall be conducted at $-67° \pm 2°F$. ($-55° \pm 1°C$.) 10 minutes after the specimens have reached equilibrium at that temperature. The method for determining the temperature of the specimens and the time required for the specimens to reach temperature equilibrium shall be in accordance with 4.5.2.

4.6 *Test methods.*

4.6.1 *Normal temperature sandwich peel.*—Six specimens prepared in accordance with 4.4 and 4.4.1 shall be tested in conformance to table I. One facing of the test specimen shall be undercut at both ends and the core and one facing removed as shown in figure 2. For testing bonds having high-peel strengths in sandwich panels with low stiffness, additional stiffness may be added to the back face of the sandwich panel (see 6.4.3). The test specimens shall be tested at normal temperature, 4.5.1, in a climbing peel test apparatus of the type shown in figure 2.

4.6.1.1 The peel test apparatus shall consist of a drum with flanges and flexible loading straps or cables and clamps for holding the test specimen as specified in figure 2. The weight shall be placed diametrically opposite clamp B and shall be of such mass as to balance the drum about its axis. The drum and flange with clamp B and its compensating weight shall not weigh more than 8 pounds; a lighter weight is preferable to facilitate handling of the apparatus.



DIMENSIONS IN INCHES. NOT COMPLETELY DIMENSIONED.
r_1= RADIUS OF DRUM TO MID-DEPTH OF SPECIMEN FACING.
r_0= RADIUS TO MID-DEPTH OF STRAP.

Figure 2. Type of apparatus suitable for making sandwich peel test.

4.6.1.2 The tests shall be made by clamping the sandwich specimen securely in place and loading the apparatus in tension at a head speed of 1 inch ± 0.01 inch per minute. A head speed of 1 inch per minute will peel the sandwich facing at a rate of 4 inches per minute. A suitable testing machine that is capable of measuring load accurately within 1 per cent shall be used.

4.6.1.3 Prior to the start of the peeling test, the specimen and apparatus shall be suspended from the top head of the testing machine and the weighing apparatus balanced to zero. The loading bar shall then be pinned to the lower fixed fitting and an initial load (F_o) shall be applied that is equal to that required to overcome the resisting torque exerted by the weight of the drum and that required to bend the facing. This load (F_o) can be determined by inserting a strip of metal of the same width, thickness, and material used in the facing of the sandwich panel to be tested in place of the sandwich specimen and applying a load sufficient to roll the drum upward around the metal sheet.

4.6.1.4 During the peel test, an autographic recording shall be made on the load (F_p) versus head movement or of the load versus distance peeled. The average load required for peeling shall be taken from the autographic curve for the 5 inches of peeling of the sandwich specimen between 1 and 6 inches, corresponding to 1¼ inches of head travel after the first ¼ inch. The average load shall be determined by scaling the curve by means of a planimeter. If autographic equipment is not available for acceptance testing, the approximate average may be obtained by averaging recorded loads at fixed increments of time after the start of the test. The load shall be recorded 15 seconds after the start of the test and at each 5-second interval thereafter until 6 inches of the specimen are peeled.

4.6.1.5 The peeling torque (T) in pound-inches per inch of specimen width shall be reported. The torque required to peel the adhesive bond shall be calculated as $\frac{T = (F_p - F_o)(r_o - r_i)}{W}$ in which the difference between the two radii, r_o and r_i, is approximately ½ inch for the apparatus, shown in figure 2, and W is the width of the specimen measured to the nearest 0.010 inch.

4.6.2 *Elevated temperature peel test.*—Six specimens conforming to 4.4 and 4.4.1 shall be subjected to the peel test in accordance with the general requirements specified in 4.6.1 except that the testing temperature shall be 180° ± 2°F. (82° ± 1°C.). The entire test apparatus and specimen shall be placed within the heating chamber. The length of straps and fittings may be reduced to fit within standard ovens. The test conditions shall be as specified in 4.5.2.

4.6.3 *Low temperature peel test.*—Six specimens conforming to 4.4 and 4.4.1 shall be subjected to the peel test in accordance with the general requirements specified in 4.6.1 and 4.6.2 except that the testing temperature and conditions shall be in accordance with 4.5.3.

4.6.4. *Normal temperature flatwise tensile test.*—Nine flatwise tensile specimens prepared in accordance with 4.4 and 4.4.2 shall be tested to failure for conformance to table I in accordance with the sandwich tension method specified in Standard MIL–STD–401. The tensile load shall be applied to the fixture at a constant rate of movement of the movable head of the testing machine of not less than 0.015 and not more than 0.020 inch per minute until failure. Tests shall be made at the normal temperature conditions specified in 4.5.1. The maximum load and type of failure shall be recorded. All failing loads shall be expressed in pounds per square inch of actual test area, calculated to the nearest 0.01 square inch.

4.6.5 *Elevated temperature flatwise tensile test.*—Nine specimens shall be subjected to the flatwise tensile test in accordance with the general requirements specified in 4.6.4. The testing temperature shall be as specified for the applicable type in table I, and the test conditions shall be in accordance with 4.5.2.

4.6.6 *Low temperature flatwise tensile test.*—Nine specimens shall be subjected to the flatwise tensile test in accordance with the general requirements specified in 4.6.4. The test conditions shall be in accordance with 4.5.3.

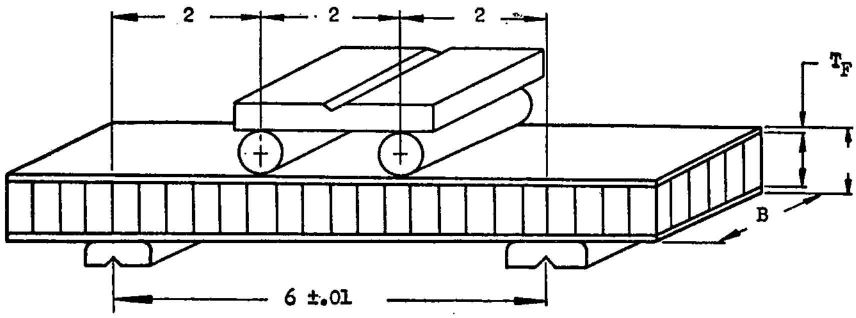


Figure 3. Method of loading for sandwich flexture tests.
B—Specimen width T_F—Facing thickness
T—Specimen thickness

End support plates are 1 by 3 by .250 inches with grooves for alinement.
Loaded edges are rounded to .06 inch radius.
Load bars are .500 inch round.
Dimensions in inches. Tolerances: as indicated.

4.6.7 *Normal temperature sandwich flexure test.*—Six specimens prepared in accordance with 4.4 and 4.4.3 shall be subjected to the sandwich flexure test for conformance to table I. The test method shall be generally in accordance with the sandwich flexure test specified in Standard MIL–STD–401. The specimens shall be tested in flexure over a 6-inch span with the load applied at the two third-span points as shown in figure 3. The round steel rods or pipes used to apply loads shall have a diameter not less than ¼ nor more than ¾ inch. The end support of the rounded knife edges shall swivel and be used with metal plates having rollers that will permit these plates to move during the flexure of the specimen. Span and third points shall be accurately located to within 0.01 inch. The specimens shall be loaded at a constant rate of the movable head of the testing machine of not less than 0.015 nor more than 0.020 inch per minute until failure. Tests shall be made at the normal temperature conditions specified in 4.5.1. Only the maximum load required to fail the 3-inch wide specimen need be measured. The maximum load and type of failure shall be recorded.

4.6.8 *Elevated temperature sandwich flexure test.*—Six specimens shall be subjected to both short-time and long-time exposure sandwich flexure tests in accordance with the general requirements specified in 4.6.7. The test conditions shall be in accordance with 4.5.2 for the temperature and exposure time specified for the applicable type in table I.

4.6.9 *Low temperature sandwich flexure test.*—Six specimens shall be subjected to the sandwich flexure test in accordance with the general requirements specified in 4.6.7. The test conditions shall be in accordance with 4.5.3.

4.6.10 *Normal temperature creep deflection and flexure test.*—Six sandwich specimens shall be prepared in accordance with 4.4 and 4.4.3 and tested for conformance to table I. Creep deflection measurements shall be determined using either an apparatus as specified for the flexure test (see 4.6.7) or other loading devices which will exert a constant load on the test specimen. Ten minutes after the specimens have reached temperature equilibrium (see 4.5.1) a load as specified in table I shall be applied to the flexure specimen. Within 25 to 35 seconds after loading, the center beam deflection shall be accurately measured to the nearest 0.001 inch. Creep deflection shall be measured at increments in time to establish creep deflection time curves not to exceed 192 hours. The difference between the initial and final deflection readings shall be recorded as the creep deflection.

4.6.11 *Elevated temperature creep deflection and flexure tests.*—Six sandwich specimens shall be subjected to the creep deflection test in accordance with the general requirements specified in 4.6.10. The entire assembly shall be placed in a heating chamber maintained at the temperature specified in table I, test 12, as applicable to the type.

4.6.12 *High humidity and flexure test.*—Six sandwich flexure specimens prepared in accordance with 4.4 and 4.4.3 shall be conditioned for 30 days $\pm$ 2 hours at 97 to 100 per cent relative humidity and 120° $\pm$ 2°F. (49° $\pm$ 1°C.). The specimens shall be mounted vertically with the 8-inch edges of the test specimens parallel to the base of the exposure chamber. The specimens shall also be so mounted that there is no metallic contact between adjacent specimens or between the specimens and the holding devices or the exposure chamber that would contribute to corrosion. The humidity condition shall be obtained by using distilled water contained at the bottom of a vapor-tight chamber, thermostatically controlled within the prescribed limits. Normal flexure tests (4.6.7) shall be made on the specimens immediately after removal from the high humidity exposure.

4.6.13 *Salt-water spray and flexure test.*—Six sandwich flexure specimens prepared in accordance with 4.4 and 4.4.3 shall be conditioned for 30 days ± 2 hours in a salt-water spray chamber operated in accordance with the requirements of Federal Test Method Standard No. 151, method 811. The specimens shall be mounted in the same manner as that prescribed in 4.6.12. Normal temperature flexture tests (4.6.7) shall be made on the specimens immediately after removal from the salt-spray exposure.

4.6.14 *Test fluid immersion and flexure test.*—Six sandwich flexure specimens prepared in accordance with 4.4 and 4.4.3 shall be completely immersed for 30 days ± 2 hours at 70° to 80°F. (21° to 27°C.) in hydrocarbon test fluid conforming to Specification MIL–S–3136, type III. The specimens shall then be removed from the test fluid and the excess fluid removed, as is practical. Normal temperature flexure tests (4.6.7) shall be made on the specimens immediately upon removal from the fluid.

4.6.15 *Storage life test.*—One each minimum-sized package of the three batches of the adhesive submitted for qualification shall be stored under the temperature-time conditions established in 3.5. At the end of the storage period, the adhesive shall be used in preparation of test specimens as required for tests 1, 4, and 7 of table I, as applicable to the adhesive type. All individual specimen results shall be reported. The respective average strengths of the specimens shall equal or exceed the applicable minimum strength requirements specified in table I.

5. PREPARATION FOR DELIVERY

5.1 *Packaging.*

5.1.1 *Level A.*—Liquid adhesives for metals shall be packaged in metal containers conforming to Specification PPP–C–96. The type, class, shape, and size of the container and type of closure, when required, shall be as specified by the procuring activity (see 6.2). Film adhesive shall be packaged, using a suitable membrane to prevent deterioration. Packaging shall be accomplished in accordance with the appendix to Specification PPP–C–96.

5.1.2 *Level C.*—Adhesives shall be packaged in accordance with manufacturer's commercial practice.

5.1.3 A copy of the manufacturer's instruction sheet (see 3.7) shall be attached to each interior package.

5.2 *Packing.*

5.2.1 *Level A.*—Adhesive packaged as specified in 5.1.1 shall be packed in accordance with overseas shipment requirements of the appendix to Specification PPP–C–96.

5.2.2 *Level B.*—Adhesives packaged as specified in 5.1.1 shall be packed in accordance with the domestic shipment requirements of the appendix to Specification PPP–C–96.

5.2.3 *Level C.*—Adhesives packaged as specified in 5.1.2 shall be packed in exterior-type shipping containers in a manner that will insure safe transportation at the lowest rate to the point of delivery. Containers shall meet Consolidated Freight Classification Rules or other common carrier regulations, as applicable to the mode of transportation.

5.3 *Marking.*—Interior and exterior containers shall be marked in accordance with Standard MIL–STD–129.

6. NOTES

6.1 Intended use.—Adhesives conforming to this specification are intended for bonding sandwich constructions of metal facings to metal core for use in structural airframe parts. Included in this bonding is the bonding of the metal facings to metal components within the sandwich panels which must be cured under the same conditions as the sandwich panel. Fabrication and inspection will be in accordance with the requirements of Specification MIL–A–9067. Parts or assemblies requiring the use of adhesives covered by this specification should be designed with consideration for the heat and pressure required during the bonding operations. The maximum curing pressures specified in 3.4.2 are necessary requirements for determining the suitability of an adhesive for general production use. However, shop facilities permitting higher pressure in accordance with the manufacturer's instructions should be used wherever practicable.

6.1.1 Any adhesive covered by this specification can be used for sandwich constructions other than metal to metal provided the use of the adhesive is substantiated by the tests specified herein using the combination of the materials in question. For example, an adhesive covered by this specification can be used for bonding metal core to plastic facings, plastic core to plastic facings, plastic inserts and edge members to plastic or metal facings, etc.

6.2 Ordering data.—Procurement documents should specify the following:

- (a) Title, number, and date of this specification.
- (b) Type and class of adhesive (see 1.2).
- (c) Code number (see 3.2.2).
- (d) Curing conditions (if other than specified in 3.4).

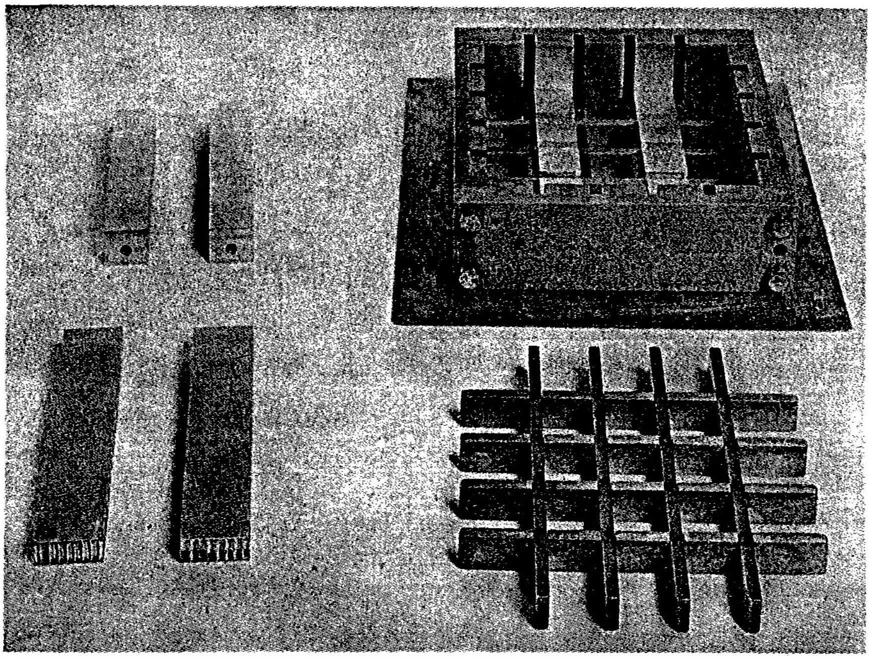


Figure 4. Suitable alinement jig for fabrication of specimens for flatwise tensile test.

(e) Type, class, shape, and size of containers and type of closure, when required (see 5.1).
(f) Selection of applicable levels of packaging and packing for containers.

6.3 Qualification.—With respect to products requiring qualification, awards will be made only for such products as have, prior to the bid opening date, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date.

6.3.1 The attention of suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. Requests for information pertaining to qualification of products covered by this specification should be addressed to the Commander, Wright Air Development Center, ATTN: WCLTR–4, Wright-Patterson Air Force Base, Ohio, the activity responsible for qualification, with a copy to the Bureau of Aeronautics, Navy Department, Washington 25, D. C.

6.4 Fabrication and testing notes.

6.4.1 Cutting of test panels and specimens.—Test panels and specimens should be cut in such a manner that vibration and heating of the specimen are kept to a minimum.

6.4.2 Type of fabrication of core.—The expanded type of honeycomb core is preferable for the fabrication of the sandwich test panels in 4.4 because of its normally sharper edges and better bonding properties, but tests made with the corrugated type of core, smoothly cut, are acceptable.

6.4.3 Prevention of bending sandwich specimen in peel test.—If, after a trial test, the peel resistance of the bond is found to be so high that the sandwich specimen bends appreciably during the test (4.5.1), a piece of ½-inch thick plywood can be suitably attached to the back face of the sandwich specimen to stiffen it.

6.4.4 Bonding of tension loading cubes to core specimens.—A suitable jig for alining the loading cubes is shown in figure 4.

6.4.5 Prevention of local failures in flexure test.—If, after a trial test, it is found that local failure occurs under the load points during the sandwich flexure tests (4.6.7 through 4.6.9), 1-inch-wide strips of thin plywood or other suitable thin materials may be used under these load points.

Notice: When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:
Navy—Bureau of Aeronautics
Air Force

MIL–A–8623A [SUPERSEDING MIL–A–8623(Aer), MIL–A–14042(Ord)]: ADHESIVE, EPOXY RESIN, METAL-TO-METAL STRUCTURAL BONDING

This specification has been approved by the Department of Defense, and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 Scope.—This specification established the requirements for epoxy resin adhesives intended for structural bondings such as the fabrication and repair of airframe parts, components and other applications requiring bonding of a similar quality.

1.2 Classification.—Adhesives covered by this specification shall be furnished in the following types, as specified:

Type I—Room Temperature Setting (will harden at a bond line temperature between 20 and 30°C. (68 and 86°F.) and if subjected to a bond line temperature between 70 and 74°C. (158 and 164°F.) will cure in 1 hour.)

Type II—Intermediate Temperature Setting (will harden at a bond line temperature between 31 and 99°C. (87 and 210°F.))

Type III—High Temperature Setting (will harden at a bond line temperature above 99°C. (210°F.))

2. APPLICABLE DOCUMENTS

2.1 The following specifications, standards, drawings and publications, of the issue in effect on date of invitation for bids, shall form a part of this specification:

Specifications

FEDERAL

NN-P-515	—Plywood, Container Grade
NN-B-591	—Boxes, Fiberboard, Wood Cleated (For Domestic Shipment)
QQ-A-355	—Aluminum Alloy (24S) Plate and Sheet
QQ-A-362	—Aluminum Alloy (Clad 24S); Plate and Sheet
TT-P-141	—Paint, Varnish, Lacquer, and Related Materials; Methods of Inspection, Sampling, and Testing
LLL-B-631	—Boxes, Fiber Corrugated (For Domestic Shipment)
LLL-B-636	—Boxes, Fiber, Solid (For Domestic Shipment)
MMM-A-175	—Adhesives; Methods of Testing
PPP-C-96	—Cans, Metal, 28 Gage and Lighter
PPP-B-585	—Boxes, Wood, Wirebound
PPP-B-601	—Boxes, Wood-Cleated-Plywood
PPP-B-621	—Boxes, Wood, Nailed and Lock-Corner
PPP-D-760	—Drums and Pails, Metal (5 and 16.64 gallon)
PPP-C-843	—Cushioning Materials, Cellulosic

MILITARY

JAN-P-106	—Packaging and Packing for Overseas Shipment—Boxes, Wood, Nailed
MIL-F-5566	—Fluid, Anti-icing (Isopropyl Alcohol)
MIL-H-3136	—Hydrocarbon-Fluid, Standard Test
MIL-O-5606	—Oil; Hydraulic, Aircraft, Petroleum Base

MIL–F–5624 —Fuel; Aircraft Turbine and Jet Engine
MIL–B–10377 —Box, Wood, Cleated Veneer, Paper Overlaid

Standards

MIL–STD–105 —Sampling Procedures and Tables for Inspection by Attributes
MIL–STD–129 —Marking for Shipment and Storage

(Copies of specifications, drawings, standards and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other Publications.—The following documents form a part of this specification. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

American Society for Testing Materials Standards

D1062—Metal to Metal Adhesives

(Copies of ASTM standards may be obtained from the American Society for Testing Materials, 1916 Race Street, Philadelphia, Pa.)

3. REQUIREMENTS

3.1 Qualification.—Any adhesive furnished for acceptance under this specification shall be a product which has passed the qualification tests specified herein.

3.2 Materials.—The adhesives shall contain thermosetting resin of the epoxy type as the basic ingredient, compounded to be capable of meeting the requirements specified herein. Fillers may be included. Adhesives shall be noncorrosive to the metal surfaces being bonded.

3.2.1 Type I and Type II adhesives may be two part materials having an activator separate from the base adhesive. An amine type material may be used as the activator.

3.2.2 Type III adhesive shall be a one part material having an activator incorporated.

3.2.3 *Liquid Phases.*—Adhesives or portions of adhesive combinations of liquid form shall be, or be capable of hand mixing to, a smooth solution or suspension of a consistency suitable for application and shall be free of lumps. Component parts shall not separate in any way within the span of a normal working day.

3.2.4 *Film Types.*—Film type adhesives shall consist either entirely of adhesive or a carrier impregnated with adhesive. The material and treatment of the carrier shall be designated.

3.2.5 *Accelerator, Hardener or Modifier.*—If necessary, an accelerator, hardener or modifier shall be supplied in powder or liquid form for mixing with the adhesive.

3.2.6 *Solvent.*—A solvent, if used as an additive for the adhesive, shall be furnished as a liquid. If necessary, an activating solvent shall be furnished and used with adhesive in film form.

3.2.7 *Filler.*—If necessary, a filler may be incorporated in or furnished for addition to the adhesive. Any such filler must remain uniformly dispersed and suspended in the mixed adhesive during its normal pot life. If contained in the adhesive as furnished, the filler must be readily dispersible throughout the adhesive during its entire usable storage life. The filler must be highly moisture and corrosion resistant and must withstand the maximum curing temperature.

3.2.8 *Formulation Changes.*—The adhesive shall be approved only for the formulation which has passed the qualification tests and shall be used by the fabricator as approved. Any changes such as the adding of pigments, hardeners, or fillers, or changing the type or method of manufacture, change in formulation of the base resin or any other changes, shall be cause for designating the adhesive as a new material which shall not be considered approved. The changed adhesive shall be given a new code number and shall be resubmitted for approval under this specification. Recommendations of the manufacturer for changes in the instruction sheet should be submitted to the qualifying activity for approval.

3.2.8.1 The manufacturer shall designate each adhesive, and in case of film adhesives, each film thickness, by a code number which shall be used to identify the adhesive. A trade name if accompanied by the code number, may also be used.

3.3 Working Characteristics.

3.3.1 *Working Life.*—The adhesives, when mixed and ready for use, shall remain spreadable or sprayable for the interval specified below, at a temperature of 23 ± 1.1°C. (73.5 ± 2°F.). Type I and Type II adhesives shall be considered to have reached the end of their working lives when the viscosity reaches 160,000 centipoises as specified in 4.5.4.11.

Type I	At least ½ hour
Type II	At least 2½ hours
Type III	At least 1 year

3.3.2 *Curing.*—Unless otherwise approved by the procuring agency, the maximum curing time shall be as specified below at the indicated temperatures.

Type I	7 days at 30°C. (86°F.) or 1 hour at 74°C. (164°F.)
Type II	2 hours at 99°C. (210°F.) followed by 7 days at 23 ± 1.1°C. (73.5 ± 2°F.)

Type III 7 hours at 177°C. (350°F.)

3.3.3 *Curing Pressure.*—The pressure required during the curing of adhesive bonded metal to metal joints shall be not more than 10 pounds per square inch. Type I adhesive shall be capable of curing and making satisfactory bonded joints as described within this specification, when only contact pressure is applied during the period of cure.

3.3.4 *Storage Life.*—The adhesives as furnished by the manufacturer shall be capable of meeting the specified requirements for shear strength at 23 ± 1.1°C. (73.5 ± 2°F.) and at 82° ± 1.1°C. (180 ± 2°F.), and working life after storage for one year at standard test conditions in the absence of sunlight.

3.4 Strength Characteristics.—Adhesive specimens prepared and tested as described in Section 4 shall develop the minimum average mechanical properties listed in Table I.

3.5 Instruction Sheet.—The manufacturer shall provide a suitably identified and dated instruction sheet for each "Unit Package" in the shipment, outlining instructions for use of the adhesive. The instruction sheet shall also cover the following:

(a) Manufacturer's description of base polymer, modifier, filler and pigment, if any, used in the adhesive.

(b) Maximum usable storage and pot life of the adhesive, with and without the addition of activators, at 23 ± 1.1°C. (73.5 ± 2°F.) and at various temperatures between 0°C (32°F.) and 37°C. (98.6°F.). The pot life of the adhesive, after the addition of the activator shall be based on definite quantities of the adhesive.

(c) Mixing instructions including recommended type and percentage of activator, maximum per cent of activator allowed, and temperature control necessary when mixing and thinning, including recommended solvent, when necessary.

(d) Complete recommended pre-bonding treatments and metal cleaning processes including proportions of materials necessary to prepare cleaning media.

(e) Complete recommended application procedure including film thickness range, spread method, spread rate, number of coats, and method of cleaning equipment.

(f) Drying time between coats (if more than 1 coat is necessary) and after last coat. If a force dry is required, the time and temperature shall be stated.

(g) Maximum allowable shelf life of adhesive coated metal prior to assembly and curing.

(h) Curing cycle including recommended (optimum and range) time, temperature, and pressure for each assembly.

(i) Any other pertinent information relative to the use, storage, and precautionary measures necessary in the handling of the adhesive with emphasis on the toxicity of the material or ingredients.

(j) The instruction sheet shall contain the following statement: "The fabricator using this adhesive shall not alter the material in any manner whatsoever."

3.6 Workmanship.—The component ingredients shall be intimately assembled and processed as required in accordance with the best practice for a high-quality material which is stable and not subject to change with age in a sealed container.

3.7 Suitability for Use with Explosives.—When suitability for use with a particular explosive is required, a special test shall be conducted at a designated Government laboratory to determine compliance of the adhesive in this respect. The procuring agency shall request this test to be conducted, shall specify the particular explosive to be used and designate the qualifying laboratory.

4. QUALITY ASSURANCE PROVISIONS

4.1 Lot.—A lot shall consist of adhesive of one type, manufactured at one time in one batch, forming part of one contract or order, and submitted for inspection at the same time and place. A batch shall be defined as that quantity of material which has been subjected to some unit chemical or physical mixing process intended to make the final product substantially uniform.

4.2 Sampling.

4.2.1 *For Qualification.*—The qualification test samples shall consist of at least 4 one quart containers of each type of adhesive (or equivalent amount, if in another form) (with necessary activators) on which qualification is desired. All samples shall be identified as to name of manufacturer, manufacturer's designation, date of manufacture, base polymer or accelerator, (as applicable), the date of submittal, identification of the activity submitting the sample and forwarded to the Naval Air Experimental Station. (See 6.3.) In addition, a statement indicating that the products have not been rebranded or, if rebranded, indicating the names of the original manufacturers and original designations of the products shall accompany the samples. All information submitted will be treated as commercially confidential.

4.2.2 *For Acceptance Testing.*—A one-quart sample (with necessary activators) shall be taken at random from each lot. Each sample shall be divided into two parts. One-half shall be used to conduct the necessary tests. The other half shall be sealed in a separate air-tight container and shall be held for referee tests, if necessary. Additional samples may be taken if considered by the Government Inspector to determine conformance of the product to the requirements of this specification.

4.2.3 *For Inspection of Filled Containers.*—A random sample of filled containers shall be selected from each lot by the Government Inspector in accordance with Standard MIL–STD–105 at inspection level I, and at acceptance quality level (AQL)—2.5 per cent defective, to verify conformance to all requirements of this specification regarding fill, closure, marking and other requirements not involving tests.

4.3 Inspection.

4.3.1 *Filled Containers.*—Each sample filled container, selected in accordance with 4.2.3 shall be examined by the Government Inspector for defects of the container and closure, for evidence of leakage, and for unsatisfactory markings; each sample filled container shall also be weighed to determine the amount of the contents. Any container in the sample, having one or more defects, or under required fill, shall be rejected and if the number of defective containers in any sample exceeds the acceptance number for the specified sampling plan of Standard MIL–STD–105, the lot represented by the sample shall be rejected. Rejected lots may be resubmitted for acceptance tests provided that the contractor has removed or repaired all non-conforming containers.

4.4 Classification of Tests.—The testing of the adhesive shall be classified as follows:

(a) Qualification tests: Qualification tests are those accomplished on samples submitted for qualification as a satisfactory product.

(b) Acceptance tests: Acceptance tests are those tests accomplished on individual lots of adhesive manufactured and submitted for acceptance under contract.

4.5 Qualification Tests.

4.5.1 *Prior Qualification.*—Unless otherwise specified by the procuring agency, adhesives which have not passed the qualification tests, or adhesives which have passed the qualification tests and have been modified in any manner, shall satisfactorily pass the qualification tests prior to acceptance of any adhesive. Qualification tests may be repeated on material previously found satisfactory at any time at the option of the agency responsible for qualification approval.

4.5.2 *Tests.*—Qualification tests of adhesives shall consist of all the tests of this specification including approval of the manufacturer's instructions. The qualification tests will be conducted by the Naval Air Experimental Station, Naval Air Material Center, Naval Base, Philadelphia 12, Pennsylvania.

TABLE I.—*Mechanical Properties of Bonded Joints*

Property	Conditioning of Test Panels (4.5.3.1)	No. of Specimens to be Tested	Test Temperature	*Min. Average Requirements* Type I	Type II	Type III
Shear Strength (psi)	30 min. at −55°C (−67°F)	10	−55 ± 1.1°C (−67 ± 2°F)	1300	2500	2500
Shear Strength (psi)		10	23 ± 1.1°C (73.5 ± 2°F)	2500	2500	2500
Shear Strength (psi)	30 min. at 82°C (180°F)	10	83.3 ± 1.1°C (180 ± 2°F)	1250	1250	1500
Shear Strength (psi)	1 hour at 71°C (160°F) 30 min. at −55°C (−67°F)	10	−55 ± 1.1°C (−67 ± 2°F)	1800	2000	2500
Shear Strength (psi)	1 hour at 71°C (160°F)	10	23 ± 1.1°C (73.5 ± 2°F)	3150	3150	3150
Creep-Rupture Strength (psi)		10	23 ± 1.1°C (73.5 ± 2°F)	1600	1600	1600
Creep-Rupture Strength (psi)		10	83.3 ± 1.1°C (180 ± 2°F)	300	300	300
Fatigue Strength (psi)		10	23 ± 1.1°C (73.5 ± 2°F)	650	600	600
Cleavage Strength (lbs.)		5	23 ± 1.1°C (73.5 ± 2°F)	1000	1000	1500
Shear Strength (psi)	250 hours salt spray	10	23 ± 1.1°C (73.5 ± 2°F)	2250	2250	2250
Shear Strength (psi)	168 hours of accelerated weathering	10	23 ± 1.1°C (73.5 ± 2°F)	2000	2000	2000
Shear Strength (psi)	7 days immersion in fluids of Table II	5 *	23 ± 1.1°C (73.5 ± 2°F)	2400	2500	2500

* Each fluid.

4.5.2.1 *Manufacturer's Instructions.*—Two copies of the mixing, application, and curing instructions for the adhesive shall also be furnished for approval with the qualification test samples (see 3.5).

4.5.2.2 *Test Report.*—All reports shall be appropriately identified by the manufacturer's own adhesive number and any additional identification required by the authorizing letter. A report, certified by affidavit, shall be furnished including the results of all tests. The individual and average values for all tests and the information required by paragraph 3.5 shall be reported. The actual pressure, temperature and time of curing used in the preparation of the test panels shall be reported. The preparation of the adhesive and of the test panels shall conform to the provided instructions and the requirements of this specification and the report shall so state.

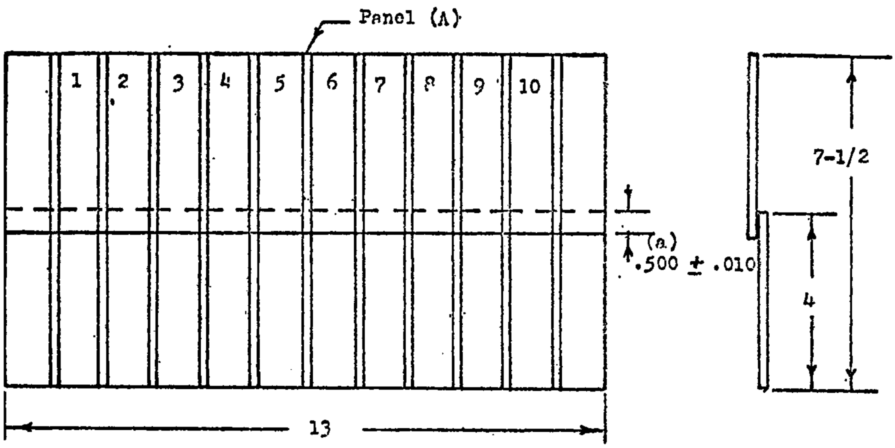
4.5.3 *Test Procedures.*

4.5.3.1 *Test Conditions.*—Unless otherwise specified in the detail method of test, all specimens shall be conditioned at 23° ± 1.1° (73.5 ± 2°F.) and 50 ± 2 per cent relative humidity for a period of at least 7 days. Other conditioning shall be as prescribed in Table I. Preparation of test specimens shall be in accordance with Section 6 of Specification MMM–A–175 and as described herein. The open assembly period shall be zero in the preparation of ½ of the required panels and shall be 30 minutes or the maximum open assembly period specified by the manufacturer, if greater than 30 minutes, for the remaining panels.

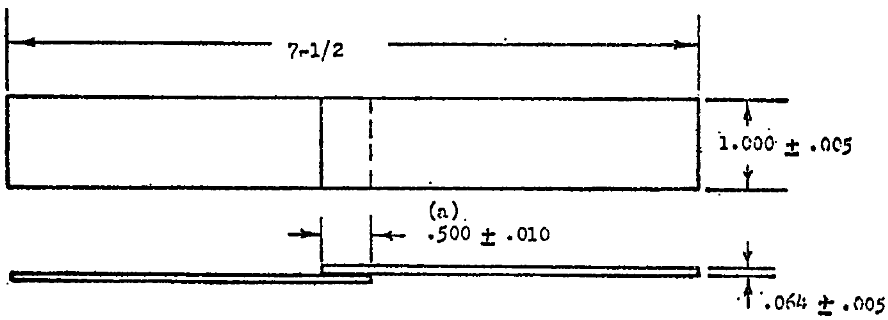
4.5.3.2 *Test Panels.*—For qualification tests, 15 panels as shown in Figure 1 or a number of panels as shown in Figure 2, to produce an equivalent number of specimens, shall be prepared to furnish specimens for all tests listed in Table I except for fatigue and cleavage tests. The panels shall be bonded and prepared in accordance with Section 6 of Specification MMM–A–175 from 0.064 inch thick aluminum alloy sheet conforming to Specification QQ–A–362. Each panel shall be divided into ten one-inch wide specimens and the specimens numbered consecutively, the specimens shall then be randomly selected for the specific tests as illustrated:

No. of Specimens	Test
10	Shear Strength at −55 ± 1.1°C (−67 ± 2°F)
10	Shear Strength at 23 ± 1.1°C (73.5 ± 2°F)
10	Shear Strength at 83.3 ± 1.1°C (180 ± 2°F)
10	Shear Strength at −55 ± 1.1°C (−67 ± 2°F) (Preheat at 71°C (160°F)
10	Shear Strength at 23 ± 1.1°C (73.5 ± 2°F) (Preheat at 71°C (160°F)
10	Creep-Rupture Strength at 23 ± 1.1°C (73.5 ± 2°F)
10	Creep-Rupture Strength at 82 ± 1.1°C (180 ± 2°F)
10	Salt Spray Exposure
10	Accelerated Weathering
5 Each	Fluid Immersion

MARKING FOR SAWING SPECIMENS



ASSEMBLED PANEL



TEST SPECIMEN

Figure 1. Panel and specimen.
(a) .375 ± .010 lap for fatigue specimens.
Dimensions in inches.

Precautions against overheating in cutting specimens shall be observed. Specimens cut from the panels shall have a one-half inch over-lap. The edges of all specimens shall be smoothly finished. For acceptance tests 2 panels as shown in Figure 1 or an equivalent number of panels shown in Figure 2 shall be bonded and prepared. Each panel shall be divided into ten one-inch wide specimens and the specimens shall be numbered to identify them for the shear strength tests. Three fatigue panels shall be prepared as above except for the over-lap which shall be ⅜ inch. Cleavage specimens shall be bonded metal as specified in ASTM Method D1062.

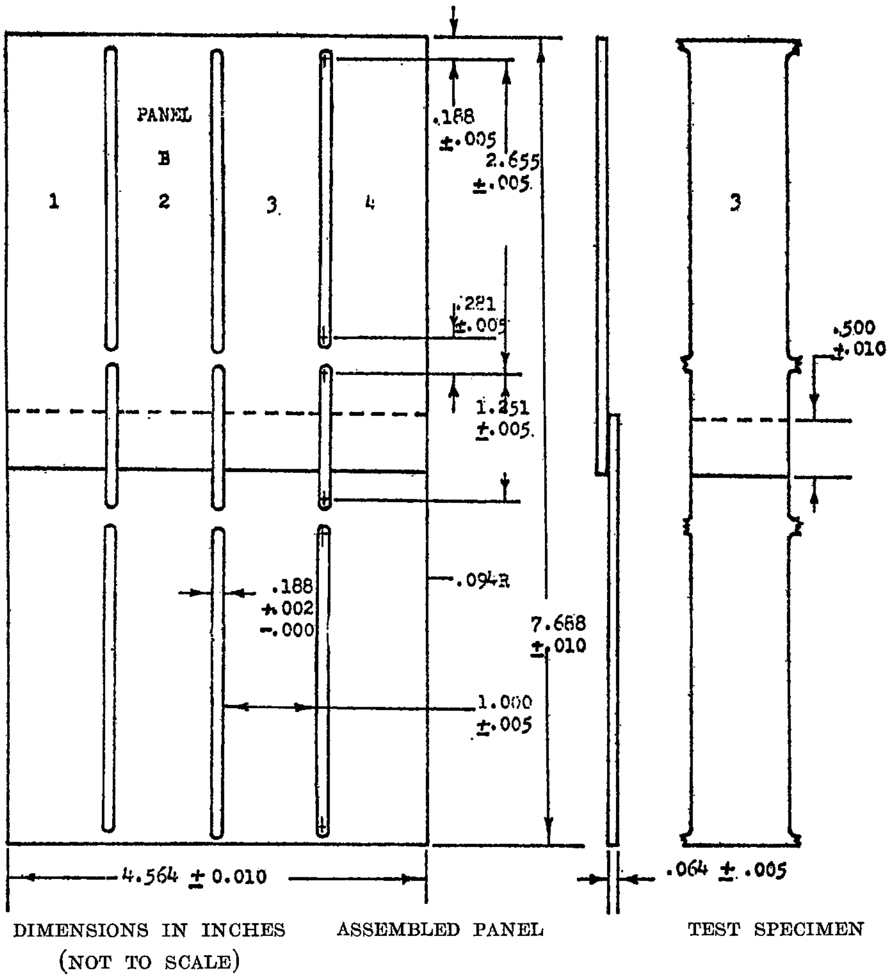


Figure 2. Panel and specimen.

4.5.3.3 *Examination of Product.*—Adhesive shall be examined to determine conformance with the requirements of this specification for which no test method is stated below.

4.5.4 *Test Methods.*

4.5.4.1 *Shear Strength.*—The shear strength tests shall be performed in accordance with Method 1033 of Specification MMM–A–175 and as specified herein. The number and dimensions of specimens shall be as specified in 4.5.3.2. The test specimen shall be placed in a testing machine, accurate within ± 1 per cent, having self aligning grips. The distance from the ends of the lap to the ends of the grips shall be two inches. The load shall be applied and increased at a rate of 600 to 700 pounds per square inch of bond area per minute until failure.

4.5.4.2 *Shear Strength, High Temperature.*—For the elevated temperature shear strength tests a suitable oven shall be provided to maintain the specimen at ± 1.1°C. (± 2°F.) of specification temperature during conditioning and testing. Each specimen shall be conditioned as prescribed in Table I prior to testing. The load shall be applied and increased at a rate of 600 to 700 pounds per square inch of bond area per minute until failure.

4.5.4.3 *Shear Strength, Low Temperature.*—For the low temperature shear strength test a suitable test chamber shall be provided for maintaining the specimen at −55 ± 1.1°C. (−67 ± 2°F.) during conditioning and testing. Each specimen shall be conditioned for 30 minutes prior to testing. Where conditioning at 71°C. (160°F.) is specified the specimen shall be placed in the cold temperature from the conditioning temperature. The load shall be applied and increased at a rate of 600 to 700 pounds per square inch of bond area per minute until failure.

4.5.4.4 *Creep-Rupture Strength at 23 ± 1.1°C. (73.5 ± 2°F.).*—After conditioning, the bonded specimen shall be tested in a dead weight loading apparatus capable of applying loads accurate within ± 1 per cent. The specimen shall be gripped tightly and be held in alignment as the load is applied. At least 3 random specimens shall be tested at the minimum strength requirements of Table 1. Specimens shall remain loaded until failure occurs or until the load has been applied 200 hours. Specimens which do not fail in 200 hours shall in that time deform no more than 0.025 inch under the load specified in Table I. This deformation shall be measured by observing with a suitable microscope or similar measuring device, the offset of a fine line scribed across the edge of the bonded joint, at the center of the lap, in a direction normal to the plane of the sheet material. Other specimens shall be utilized to determine specific creep-rupture strengths of the material. The hours to failure and the corresponding loads, calculated in pounds per square inch, shall be recorded and plotted on stress-log time coordinates. The stress point at which a smooth curve connecting the points of failure crosses the 200 hour ordinate shall be listed as the long time strength. The specimen bond dimensions shall be measured accurately enough to calculate the area to the nearest 0.01 square inch. Values shall be listed for the per cent of adhesive, cohesive, and contact failure and also the adhesive film thickness. The measurement of the thickness of the adhesive film shall be accurate to 0.0005 inch. Length and width shall be measured to the nearest 0.01 inch. If one or more of the three random specimens fail, three more of such specimens shall be tested. If any of these fail, the adhesive shall be rejected.

4.5.4.5 *Creep-Rupture Strength at 83.3 ± 1.1°C. (180 ± 2°F.)*.—After conditioning, the specimen shall be maintained at a temperature of 82 ± 1.1°C. (180 ± 2°F.) and long time strength shall be determined as in 4.5.4.4 except that the deformation requirement shall not be considered.

4.5.4.6 *Fatigue Strength.*—Fatigue strength of the adhesive shall be determined by testing a total of six of the fatigue specimens described in 4.5.3.2, two from each panel, taken at random, in accordance with Method 1061 of Specification MMM–A–175. The specimens shall be tested at the minimum strength requirements of Table I for 10 million cycles. If one or more should fail to meet these requirements, six additional specimens, two from each panel, shall be tested. If any one of these fail, the adhesive shall be rejected. The adhesive film thickness shall be listed. The measurement of the thickness of the adhesive film shall be accurate to the nearest .0005 inch.

4.5.4.7 *Cleavage Strength.*—Cleavage strength of the adhesive shall be determined by testing at least five specimens in accordance with ASTM Tentative Method D1062. The results shall be recorded in pounds.

4.5.4.8 *Shear Strength After Salt Spray Exposure.*—The bonded test specimens shall be exposed to salt spray in accordance with Method 606.1 of Specification TT–P–141 for 250 hours. Immediately after removal from the salt spray, the specimen shall be examined, significant effects of the treatment on the joint shall be noted, and the specimens shall be tested for shear strength in accordance with 4.5.4.1 and without further conditioning.

4.5.4.9 *Shear Strength After Accelerated Weathering.*—The bonded test specimens shall be exposed to accelerated weathering for 168 hours in accordance with Method 615.2 of Specification TT–P–141. Immediately after removal from the weathering device, the specimens shall be examined and tested for shear strength as in 4.5.4.1.

4.5.4.10 *Shear Strength After Immersion.*—Bonded test specimens shall be immersed in fluids as enumerated in Table II at standard temperature for seven days. Immediately after removal from the fluid, the specimens shall be examined and tested for shear strength as in 4.5.4.1. The average strength for specimens from each exposure shall not be less than that specified in Table I.

TABLE II

Fluid	Specifications	No. of Specimens
Distilled Water	None	5
Anti-Icing	MIL–F–5566	5
Hydraulic Oil	MIL–O–5606	5
JP–4	MIL–F–5624	5
Hydrocarbon Fluid	MIL–H–3136, Type III	5

4.5.4.11 *Working Life (Types I and II).*

4.5.4.11.1 *Apparatus.*—The apparatus shall consist of a Brookfield Synchrolectric Viscometer, (Model HBF, Volts 110, Freq. −60), or approved equivalent. It shall be mounted on a platform which is attached to stand in such a manner that the viscometer is lowered at the rate of 1 inch per minute by means of a motor-driven buttress-type screw. A spindle, attached to the viscometer, bears a notch and disc on its shaft. The notch indicates the depth of penetration. A beaker, (200 ml. 5 inches tall, 2¼ inches diameter), shall serve to weigh and mix the base adhesive with the accelerator and suspend it in a cold bath. The cold bath shall serve as the source of refrigeration. The temperature of the bath 10° ± 1.1°C. (50 ± 2°F.) shall be used to maintain the thermal equilibrium 19 ± 1.1°C. (66 ± 2°F.) of the adhesive during the test period.

4.5.4.11.2 *Procedure.*—One hundred seventy five grams of the epoxy resin shall be weighed in the beaker, and suspended in a cold bath to bring the base adhesive temperature to 13 ± 4°C. (55° ± 2°F.). An accurately weighed portion of accelerator, as specified by the adhesive manufacturer, shall be thoroughly mixed, in small portions, with the refrigerated epoxy resin for 15 minutes. Readings shall be taken every 30 minutes until a viscosity of 160,000 centipoises to determine compliance with paragraph 3.3.1.

4.5.4.12 *Storage Life.*—A suitable amount of adhesive in an original unopened container shall be stored under the conditions specified in Section 3. At the end of the storage period, the adhesive shall be subjected to the tests for shear strength at 23 ± 1.1°C. (73.5 ± 2°F.) and at 83.3 ± 1.1°C. (180 ± 2°F.) and working life.

4.5.5 *Referee Tests.*—If adhesive submitted for inspection fails to meet the requirements of this specification, the remainder of the sample shall be tested. If the sample fails on these tests, the entire lot of adhesive represented by the sample shall be rejected. If, in the opinion of the Inspector failure of any sample or specimen to meet the requirements of this specification is possibly due to poor bonding technique, a retest shall be allowed.

4.6 Acceptance Tests.—The manufacturer shall furnish all samples and shall be responsible for accomplishing the required tests. When inspection is conducted at the manufacturers plant, all inspection and testing shall be under the supervision of the Government Inspector. Manufacturers not having laboratory testing facilities satisfactory to the Government shall engage the services of a commercial testing laboratory acceptable to the Inspector. The manufacturer shall furnish test reports, in duplicate, showing quantitative results for all tests required by this specification, and signed by an authorized representative of the manufacturer or laboratory, as applicable. Acceptance or approval of material during course of manufacture shall in no case be construed as a guaranty of the acceptance of the finished product.

4.6.1 *Tests.*—The acceptance tests of adhesives shall consist of the following tests, as described herein:

Inspection (Paragraph 4.3)
Examination of Product (Paragraph 4.5.3.3)
Working Life (Paragraphs 3.3.1, 4.5.4.11)
Shear Strength at 23 ± 1.1°C. (73.5 ± 2°F.) (Paragraph 4.5.4.1, Table I)

In addition, the adhesive shall be subject to any of the other tests specified herein which the Inspector considers necessary to determine conformance with the requirements of this specification.

4.7 Rejection and Retest.—Adhesive which has been rejected may be reworked to correct the defects and resubmitted for acceptance. Before resubmitting, full particulars concerning previous rejection and the action taken to correct the defects found in the original shall be furnished the Inspector. Material rejected after retest shall not be resubmitted without specific approval of the procuring agency.

5. PREPARATION FOR DELIVERY

5.1 Packaging.

5.1.1 *Unit Packaging.*—The adhesive may be furnished in tinplate cans or pails, or glass jars with metal caps containing aluminum foil coated innerseals, as specified by the procuring activity. If seams of cans or pails are soldered, they shall be coated with a suitable coating which is non-reactive to the adhesive and activator. Activators may be furnished in similar tinplate containers which will meet the requirements of Specification PPP–C–96 insofar as tinplate and interior coating is concerned, or preferably in glass ampules. Terneplate containers shall not be used. If activators are required to be furnished in glass ampules, the capacity of ampules may be specified by the procuring activity to contain the quantity of activator recommended for either one ounce, ½ pound, or one pound of adhesive. If the adhesives and activator are packaged separately, the container of the adhesive and the equivalent proportion of activator required shall be included in a unit fiberboard box; the quantities of the adhesive and activator so packaged, when mixed according to the manufacturer's instructions, shall produce the specified quantity of adhesive. The fiberboard boxes shall conform to Specification LLL–B–631. If pails are used, adhesive and activator shall be packed together by utilizing multiple compartment metal containers, or suitable modified single compartment containers. When shipment is to be made in a modified single compartment container, it will be necessary to submit the proposed container or a drawing of same to the procuring activity for approval prior to shipment. The kind and capacity of all adhesive containers shall be as specified by the procuring activity. If liquid adhesive is furnished in cans, the constructions and dimensions of cans shall conform to Type V, Class 2, of Specification PPP–C–96. Powdered, stick, or jelly type materials shall be furnished in cans or pails conforming to cans, Type V, Class 2 of Specification PPP–C–96 or pails, Type II, (5 gallon pails with lug closures) of Specification PPP–D–760.

5.1.2 *Cushioning.*—Unless otherwise specified by the procuring activity, when unit fiberboard boxes are required, the contents shall be secured snugly by means of vertical separators, fiberboard or corrugated paper to fill voids and/or cushioning material conforming to Specification PPP–C–843. The fiberboard shall be made of single or double wall corrugated board, and the corrugated paper shall be flexible and single faced.

5.2 Packing.

5.2.1 *Level A.*—When specified by the procuring activity, the unit packages shall be packed in wood cleated plywood (overseas type), nailed wood, wirebound wood (Style 3 for type 2 load) boxes conforming to Specification PPP–B–601, PPP–B–621 or PPP–B–585 respectively. Box closures shall be as specified in the applicable box specification or appendix thereto. The gross weight of wood boxes shall not exceed 200 pounds.

5.2.2 *Level B.*—Unless otherwise specified by the procuring activity, the unit packages shall be packed in wood cleated fiberboard, nailed wood, wirebound wood (for type 2 load) corrugated or solid fiberboard, wood cleated plywood (domestic type), or wood cleated paper overlaid (domestic type) boxes conforming to Specifications NN–B–591, PPP–B–621, PPP–B–585, LLL–B–631, LLL–B–636, PPP–B–501 or MIL–B–10377, respectively. Closures shall be as specified in the box specification or appendix thereto. Fiberboard boxes shall conform to the special requirements of the applicable box specification.

5.2.3 *Level C.*—When specified by the procuring activity, the unit packages shall be packed in containers in a manner to insure safe delivery and acceptance at destination. Containers shall comply with the Consolidated Freight Classification Rules or other carrier regulations applicable to the mode of transportation.

5.3 Marking.

5.3.1 *Marking of Packages.*—Each unit package, can, pail, ampule, etc., as applicable, shall be marked in accordance with Standard MIL–STD–129 and with the following notes:

Caution: Special care should be taken to avoid inhaling the activator fumes. Avoid contact of the epoxy resin or the accelerator with the skin.

Note: Uncured epoxy resin or accelerator may be removed from contact area by washing with toluol or acetone, then with soap and water.

5.3.2 *Marking of Shipping Containers.*—In addition to any special marking required by the contract or order, shipping containers shall be marked in accordance with Standard MIL–STD–129, and with the following note on storage:

Storage. Whenever practicable, adhesive conforming to this specification should be stored at a temperature of 20-30°C. (68-86°F.) in the absence of sunlight. If transit and/or normal storage conditions necessitate exposure of the adhesives for prolonged periods to temperatures in excess of 86°F., it can be expected that the storage life of the adhesive will be proportionately reduced.

6. NOTES

6.1 Intended use.—The adhesives covered by this specification are used in the structural bonding of metal to metal parts of aircraft to produce high strength joints when cured under specified conditions. They are also suitable for use in bonding wood, glass, phenolic, polyester and epoxy resin laminates to each other or in combination.

6.1.1 Designers are cautioned that shear strength values specified herein are based on tests performed with clad aluminum alloy. For use with other materials, strength values of the adhesive should be further investigated.

6.2 Ordering data.—Requisitions, contracts, and orders shall state the type of adhesive, capacity and kind of containers, the quantity desired, and applicable level of packaging and packing (see section 5).

6.2.1 *Application.*—The packaging, packing, and marking requirements specified herein apply only to direct purchases by or direct shipments to the Government.

6.3 Qualification testing.

6.3.1 *Provisions for qualification tests.*—With respect to products requiring Qualification, awards will be made only for such products as have, prior to the bid opening date, been tested and approved for inclusion in Qualified Products List QPL–8623, whether or not such products have actually been so listed by that date. Manufacturers are urged to request authorization of tests, and information as to the marking and forwarding of samples, and test fees, if any, and to subsequently submit test reports showing conformance with all the requirements of this specification to the Director, Naval Air Experimental Station, Naval Air Material Center,

U. S. Naval Base, Philadelphia 12, Pennsylvania. Test reports shall show individual and average results, and certify that the test specimens were prepared in accordance with the instruction sheet.

6.3.2 It is to be understood that upon receipt of the Letter of Authorization, samples shall be furnished at no cost to the Government, and that the manufacturer shall pay the transportation charges to and from the designated point where tests are to be made. In the case of failure of the sample or samples submitted, consideration will be given to the request of the manufacturer for additional tests only after it has been clearly shown that changes have been made in the product which the Government considers sufficient to warrant additional tests.

6.3.3 Applications for tests of suitability for use with explosives, may be made to the Commanding Officer, Picatinny Arsenal, Dover, New Jersey, Attention: Samuel Feltman Ammunition Laboratories, Ordnance Corps Plastic Laboratory.

6.4 Unapproved changes.—It is to be understood that adhesive supplied under contract shall be identical in every respect to the samples tested and found satisfactory. Any unapproved changes from the qualification sample such as changes in formulation, code designator or place of manufacture shall constitute cause for rejection of material submitted and for removal from the list of qualified suppliers.

6.5 Miscellaneous notes.—Although Type I adhesive must meet the requirements of this specification when cured at room temperature, in use the curing rate may be increased by curing at elevated temperatures in accordance with manufacturer's instructions.

Custodians:

Army—Ordnance Corps
Navy—Bureau of Aeronautics

Other interest:

Army—E Sig T C
Navy—Sh Or

Preparing activity:

Navy—Bureau of Aeronautics

MIL–A–5090D SUPERSEDING MIL–A–005090C(ASG), MIL–A–5090B, MIL–A–8431(USAF): ADHESIVES, HEAT-RESISTANT, AIRFRAME STRUCTURAL, METAL-TO-METAL

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 Scope.—This specification covers the requirements for heat resistant adhesives for use in bonding primary and secondary structural and external metallic airframe parts which will be exposed to temperatures within the range of −67° to 500°F. (−55° to 260°C.). (See 6.1.)

1.2 Classification.—Adhesives covered by this specification shall be furnished in one of the following types as specified by the procuring activity. (See 6.4.)

Type I —For long-time (192 hours) exposures to temperatures from −67° to 180°F. (−55° to 82°C.).

Type II —For long-time (192 hours) exposures to temperatures from −67° to 300°F. (−55° to 149°C.).

Type III —For long-time (192 hours) exposures to temperatures from −67° to 300°F. (−55° to 149°C.) and short-time (10 minutes) exposures to temperatures from 300° to 500°F. (149° to 260°C.).

Type IV —For long-time (192 hours) exposures to temperatures from −67° to 500°F. (−55° to 260°C.).

See 6.2 for definition of long-time and short-time exposures.

1.2.1 There shall be no restrictions, other than those imposed by the technical requirements of this specification, on the classes or physical forms (such as liquid, film, powder, or multiple or mixed systems thereof) in which the adhesives are submitted. However, the manufacturer shall fully identify each product submitted under this specification according to its type number and physical form.

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on the date of invitation for bids, form a part of this specification to the extent specified herein:

Specifications

FEDERAL

QQ–A–362	—Aluminum Alloy Plate and Sheet, Alclad 2024.
PPP–C–96	—Cans, Metal, 28 Gage and Lighter.

MILITARY

MIL–S–3136	—Standard Test Fluids, Hydrocarbon and Iso-Octane.
MIL–F–5566	—Fluid; Anti-Icing (Isopropyl Alcohol).
MIL–H–5606	—Hydraulic Fluid; Petroleum Base, Aircraft and Ordnance.
MIL–J–5624	—Jet Fuel, Grades JP–3, JP–4, and JP–5.
MIL–A–9067	—Adhesive Bonded Metal; Process and Inspection Requirements.
MIL–S–25043	—Steel Plate, Sheet, and Strip, 17–7 PH, Corrosion Resistant, Precipitation Hardening.

Standards

FEDERAL

Federal Test Methods
Standard No. 151 —Metals: Test Methods.
Federal Test Methods
Standard No. 175 —Adhesives: Methods of Testing.

MILITARY

MIL–STD–10	—Surface Roughness, Waviness and Lay.
MIL–STD–105	—Sampling Procedures and Tables for Inspection by Attributes.
MIL–STD–129	—Marking for Shipment and Storage.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 Other publications.—The following document forms a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply:

CONSOLIDATED CLASSIFICATION COMMITTEE

Uniform Freight Classification Rules.

(Application for copies of the above publication should be addressed to the Consolidated Classification Committee, 202 Chicago Union Station, Chicago 6, Illinois.)

3. REQUIREMENTS

3.1 Qualification.—The adhesive furnished under this specification shall be a product which has been tested and has passed the qualification tests specified herein, and has been listed on or approved for listing on the applicable Qualified Products List.

3.2 Materials.—The adhesives shall be thermosetting. There shall be no restrictions on the chemical types or physical nature of materials used in the adhesives except those imposed by these and other technical requirements of this specification.

3.2.1 Specifications and standards for all materials and parts, and Government certification and approval of processes and equipment which are not specifically designated herein and which are necessary for the execution of this specification, shall be as designated by the procuring activity.

3.2.2 *Liquid form.*—Adhesives in liquid form shall mix readily to a smooth solution or suspension of consistency suitable for application and shall be free of lumps. The components shall not settle out or separate during a normal working day.

3.2.3 *Film form.*—Film adhesives shall consist either entirely of adhesive or adhesive with a carrier. The film thickness (in mils) and corresponding weight (in pounds per square foot to the nearest 0.001 pound) shall be stated. Film adhesives of a given type and composition manufactured in more than one weight range shall be submitted for separate testing and qualification approval. Films within a range of $\pm$ 20 per cent of the medial weight shall be considered within one weight range when more than two weight ranges of a product are available. Approval of both the maximum and minimum weight products will then convey automatic approval of products of same type and composition with weights between the maximum and minimum.

3.2.4 *Curing agents.*—If necessary, curing agents may be used and shall be supplied in powder or liquid form for mixing with the adhesive.

3.2.4.1 Curing agents and solvents (3.2.5) shall be noncorrosive to the surfaces bonded. Specimens tested in accordance with 4.3.5 shall not show corrosion attributable to the bonding materials.

3.2.5 *Solvent.*—If a solvent is required as a separate thinner or activator, it shall be furnished by the adhesive manufacturer. The solvent shall be noncorrosive to the surfaces bonded.

3.2.6 *Filler.*—If necessary, a filler may be incorporated in or furnished for addition to the adhesive. Any such filler shall be considered as a part of the adhesive system and shall remain uniformly dispersed and suspended in the mixed adhesive during its normal pot life. If contained in the adhesive as furnished, the filler shall be readily dispersible throughout the adhesive during its entire usable storage life. The filler shall be highly moisture and corrosion resistant and shall withstand the maximum temperature to which the particular type of adhesive in which it is used is subjected both during cure and in end use.

3.2.7 *Formulation changes.*—An adhesive shall be approved only for the formulation on which qualification tests are made. Approval of an adhesive as a type II, III, or IV adhesive does not convey automatic approval of same as an adhesive of lower type number nor does approval of a given form of adhesive within a given type convey automatic approval of another form of the same type even though the two forms may be of the same basic chemical composition. Film adhesives of a given basic chemical composition and type, but with different fillers or carriers, shall be considered as different forms of that adhesive and shall require specific and separate qualification approval. Any changes by the manufacturer, such as the adding of materials, pigments, hardeners, carriers, dyes, and fillers, or changing the type or form of the adhesive or the method of manufacture or changing the mixing, application (including metal treatment) or curing procedures, or any other change, shall be cause for designating the adhesive as a new product which shall not be considered approved and which shall require specific and separate qualification testing and approval. The changed adhesive shall be given a new code number and shall be resubmitted for approval under this specification.

3.2.8 *Identification of product.*

3.2.8.1 *Trade name and code number.*—The manufacturer shall designate each adhesive by a trade name and code number which shall be used to identify the adhesive.

3.2.8.2 *Use of MIL designations.*—MIL designations shall not be applied to a product, except for qualification test samples, nor referred to in correspondence, until notice of approval has been received from the activity responsible for qualification.

3.3 Working characteristics.

3.3.1 *Application.*—The adhesives shall be capable of being readily applied to treated surfaces of the metals (see 6.1) in accordance with the manufacturer's instructions, at room temperatures at least between 60° and 100°F. (16° and 38°C.), and at relative humidities at least up to 75 per cent.

3.3.2 *Pot life.*—The minimum pot life of the mixed adhesive, ready and usable for bonding, shall be of practical length for production fabrication applications, preferably 8 hours or longer.

3.3.3 *Curing conditions.*—Unless otherwise approved by the procuring activity, the curing time, temperature, and pressure shall be within the limitations specified herein.

TABLE I.—*Mechanical properties of bonded joints*

Test number	Property	Test conditions	Number of specimens to be tested[1]	Paragraph reference	Minimum average strength requirements (PSI)[1]			
					Type I adhesive[2]	Type II adhesive[2]	Type III adhesive[2]	Type IV adhesive[2]
1	Tensile shear	Normal temperature, 75° ± 5°F	6	4.5.5.1	[3]2,500	[3]2,250	[3]2,250	[3]2,250
2	Tensile shear	10 minutes at 180° ± 5°F	6	4.5.5.2	[3]1,250	....	....	....
3	Tensile shear	10 minutes at 300° ± 5°F	6	4.5.5.2	....	[3]2,000	[3]2,000	[3]2,000
4	Tensile shear	192 hours at 300° ± 5°F	6	4.5.5.2	....	2,000	2,000	2,000
5	Tensile shear	10 minutes at 500° ± 5°F	6	4.5.5.2	....	....	[3]1,850	[3]1,850
6	Tensile shear	192 hours at 500° ± 5°F	6	4.5.5.2	....	....	....	1,000
7	Tensile shear	10 minutes at −67° ± 5°F	6	4.5.5.3	2,500	2,250	2,250	2,250
8	Fatigue strength	Normal temperature, 75° ± 5°F	15	4.5.5.4	750 at 10^6 or 600 at 10^7 cycles			
9	Creep-rupture	1,600 PSI at normal temperature, 75° ± 5°F	6	4.5.5.5 and 4.5.5.7	192 hours, 0.015 inch (max) deformation			
10	Creep-rupture	800 PSI at 180° ± 5°F	6	4.5.5.6 and 4.5.5.8	192 hours 0.015 inch (max) deformation	....	....	....
11	Creep-rupture	800 PSI at 300° ± 5°F	6	4.5.5.6 and 4.5.5.8	....	192 hours 0.015 inch (max) deformation	192 hours 0.015 inch (max) deformation	....
12	Creep-rupture	800 PSI at 500° ± 5°F	6	4.5.5.6 and 4.5.5.8	....	....	....	192 hours 0.015 inch (max) deformation

13	Tensile shear	Normal temperature, 75° ± 5°F after 30 days salt-water spray	6	4.5.5.9	[3]2,250	[3]2,100	[3]2,100	[3]2,100
14	Tensile shear	Normal temperature, 75° ± 5°F after 30 days at 120° ± 5°F, 95 to 100 per cent relative humidity.	6	4.5.5.9	2,250	2,100	2,100	2,100
15	Tensile shear	Normal temperature, 75° ± 5°F after 7 days immersion in the respective fluids of table II, except 30 days immersion in tap water.[4]	6	4.5.5.9	2,250	2,100	2,100	2,100

[1] Of the six specimens, two shall be from each of the batches of adhesive (4.5.2). Of the 15 specimens, five shall be from each of the batches of adhesive (4.5.2). The average strength shall meet the respective minimum average requirement, and the strength of any individual specimen shall be not less than 80 per cent of this minimum average requirement.

[2] Tests applicable to types I and II adhesives are to be made with aluminum-alloy specimens and tests applicable to types III and IV adhesives are to be made with corrosion-resisting steel specimens (see 4.4.).

[3] These strength requirements also apply to storage life tests (see 4.5.5.10).

[4] See table II.

3.3.3.1 *Curing time and temperature.*—Type I and type II adhesives shall require not longer than 2 hours for curing at a temperature not to exceed 350°F. (177°C.) at the glue line, and type III and type IV adhesives shall require not longer than 2 hours for curing at a temperature not to exceed 700°F. (371°C.) at the glue line. If lower curing temperatures are specified, increasingly longer curing periods may be used.

3.3.3.2 *Curing pressure.*—The pressure required for curing the bonded test panels described in this specification shall not exceed 200 pounds per square inch (PSI) (see 6.1).

3.3.3.3 *Post-curing.*—Post-curing (curing beyond the regular time-temperature-pressure cycle at a reduced temperature or pressure, or both,) is not desirable but will be acceptable for type III and type IV adhesives which attain all the respective minimum strength requirements of this specification only through such post-curing.

3.3.4 *Storage life.*—The adhesive manufacturer shall determine and report the optimum temperature at which the adhesive and curing agents, when stored in airtight containers or wrapped in suitable vapor barrier material, will retain their capabilities of conforming to the applicable minimum strength requirements of table I (see also 4.5.5.10) for the longest period of time from date of manufacture. Both such temperature and time shall be reported (see 3.5). The maximum time during which the adhesive, packaged as specified above, will retain such capabilities when stored at 75° ± 2°F. (24° ± 1.1°C.) shall also be determined and reported. The two so reported conditions of storage temperature and time shall then constitute the respective conditions under which the submitted adhesive shall be stored in preparation for the storage life tests specified in 4.5.5.10.

3.4 Mechanical properties.—Mechanical properties of test specimens prepared and tested as specified in section 4 shall conform to the respective requirements listed in table I.

3.5 Instruction sheet.—The manufacturer shall provide a dated, coded, and titled instruction sheet with the test report supplied when requesting qualification (see 4.5.4) and also with each shipment of adhesive (see 5.1.3) outlining instructions for its use on aluminum alloy or corrosion-resisting steel alloy sheets, or both. The instruction sheet shall include the following information:

(a) The general chemical type of the base resin used in the adhesive, such as phenolic-neoprene, epoxy, or vinyl-phenolic. The carrier (for a film adhesive), if used, shall also be identified. Each part of a multiple-part adhesive system shall be separately and fully described.

(b) Instructions on the use of a thinner or solvent with the adhesive, including minimum, optimum, and maximum amounts to be used.

TABLE II.—*Fluids for panel immersion tests*

Fluids	Specifications	Immersion
Water	Distilled or not containing more than 200 parts per million of total solids	30 days ± 2 hours
Jet engine fuel JP-4	MIL-J-5624	7 days ± 2 hours
Anti-icing fluid	MIL-F-5566	7 days ± 2 hours
Hydraulic oil	MIL-H-5606	7 days ± 2 hours (for types I and II adhesives)
Standard test fluids	MIL-S-3136, type III	7 days ± 2 hours

(c) Mixing instructions, including type and percentage of curing agents, filler, and temperature controls necessary during mixing, and maximum pot life of the mixed adhesive.

(d) Complete processes and treatments for preparing the metal faying surfaces prior to their bonding with the submitted adhesive. These shall include a parts-by-weight listing of all ingredients of mixed cleaning media and etches, and full details of mixing and using procedures, temperatures, times, rinsing media, and drying requirements; also maximum allowable storage time and necessary temperature-humidity controls and protective measures necessary during storage before application of the adhesive. (See also 3.5(i).)

(e) Application instructions including spread method, number of coats, spread rate, weight range, application temperature and relative humidity (if other than those specified in 3.3.1) and acceptable glue-line (bond) thickness range before and after cure. (See also 3.5(i).)

(f) Drying time between coats and after last coat. If a force dry is required, the time and temperature shall be stated.

(g) Maximum allowable open assembly time and temperature-humidity controls and protective measures necessary during storage for adhesive-coated metal prior to assembly.

(h) Maximum allowable closed assembly time and temperature-humidity controls and protective measures necessary during storage for adhesive-coated and assembled parts prior to cure.

(i) Typical time, temperature, and pressure for each segment of the complete curing cycle giving maximum and minimum limits for each condition.

(j) Information required by 3.3.4.

(k) Necessary safety precautions to be observed throughout all operations.
(l) Any other pertinent information relative to the use and storage of the adhesive or curing agent, or both.

3.6 Workmanship.—Liquid adhesives shall be free of foreign matter and shall be prepared in accordance with the best commercial practices for this material. Film adhesives shall be substantially free of folds, foreign matter, wrinkles, and shall have not more than two holes of ⅛-inch maximum diameter per square inch which penetrate through the film.

4. QUALITY ASSURANCE PROVISIONS

4.1 Inspection responsibility.—The supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize his own or any other inspection facilities and services acceptable to the Government. Inspection records of the examination and tests shall be kept complete and available to the Government as specified in the contract or order. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of tests.—The inspection and testing of the adhesives shall be classified as follows:

(a) Qualification tests (see 4.5).
(b) Acceptance tests (see 4.6).

4.3 Test conditions.

4.3.1 *Normal (room) temperature conditions.*—Strength properties shall be determined for types I, II, III, and IV adhesives at 75° ± 5°F. (24° ± 2.8°C.), no sooner than 10 minutes after specimens have reached equilibrium at such temperature. If the validity of property values determined within this range is questionable, the test shall then be repeated under a standard 73.4° ± 2°F. (23° ± 1°C.), and 50 ± 4 per cent relative humidity. Specimens shall then be tested only after being exposed for 4 days to this temperature and humidity.

4.3.2 *Elevated temperature conditions.*—Strength properties of type I adhesives shall be determined at 180° ± 5°F. (82° ± 2.8°C.), dry heat; those of types II, III, and IV adhesives shall be determined at 300° ± 5°F. (149° ± 2.8°C.), dry heat; and those of types III and IV shall be determined at 500° ± 5°F. (260° ± 2.8°C.), dry heat, 10 minutes after the specimens have reached equilibrium at those respective temperatures. No less than 3 minutes nor more than 10 minutes shall be required to bring the bonded area of the test specimen to the required temperature after the specimen has been placed in the conditioning chamber. Strength properties of types II, III, and IV adhesives shall be determined at 300° ± 5°F. (149° ± 2.8°C.), dry heat; and those of type IV adhesives shall be determined at 500° ± 5°F. (260° ± 2.8°C.), 192 hours after the specimens for these long-time elevated temperature strength tests (tests Nos. 4 and 5 of table I) have reached equilibrium at those respective temperatures. These specimens for the long-time elevated temperature tests may be placed in circulating air ovens for the 192-hour period, after which they shall be transferred to the preheated heating unit of the testing machine. Specimens should not be subjected to thermal shock while being transferred between test ovens. The final testing temperatures of all elevated temperature test specimens shall be of the surface of the metal in the approximate center of the bonded area and shall be determined with a thermocouple attached to the specimen in order to insure accuracy of testing temperature and reproducibility of data. The junction of the thermocouple shall be firmly attached to the specimen in immediate contact with the metal in the position shown in figure 1. A prototype specimen, located as near to the test specimen as is practicable, may be used as an alternate method to establish specimen temperature. In this alternate method, thermocouples shall be bonded in the joint in the area shown in figure 1, in both prototype specimen and a specimen located in normal test position in the test fixture. Correlation between the two temperature readings shall then be determined as a guide for subsequent tests.

4.3.3 *Low temperature condition.*—Strength properties shall be determined at −67° ± 5°F. (−55° ± 2.8°C.) for types I, II, III, and IV adhesives, 10 minutes after specimens have reached equilibrium at the temperature. The surface of the metal of the bonded area shall be −67° ± 5°F. (−55° ± 2.8°C.) as determined with a thermocouple attached to the specimen. The junction of the thermocouple shall be firmly attached to the specimen in immediate contact with the metal in the position shown in figure 1. The prototype specimen technique described in 4.3.2 may be used for these temperature measurements. No longer than 10 minutes shall be required to bring the bonded area to the required temperature after the specimen has been placed in the conditioning chamber.

4.3.4 *Salt water spray condition.*—Resistance to salt spray shall be determined by exposure of the panels for 30 days, ± 2 hours in accordance with the requirements of Federal Test Method Standard No. 151, except as hereby modified. The bonded test panels shall be vertically suspended from the top by means of glass hooks, waxed strings, or other nonmetallic materials through holes as indicated in figure 2 with the plane of the panel parallel to the principal direction of flow of the salt spray through the

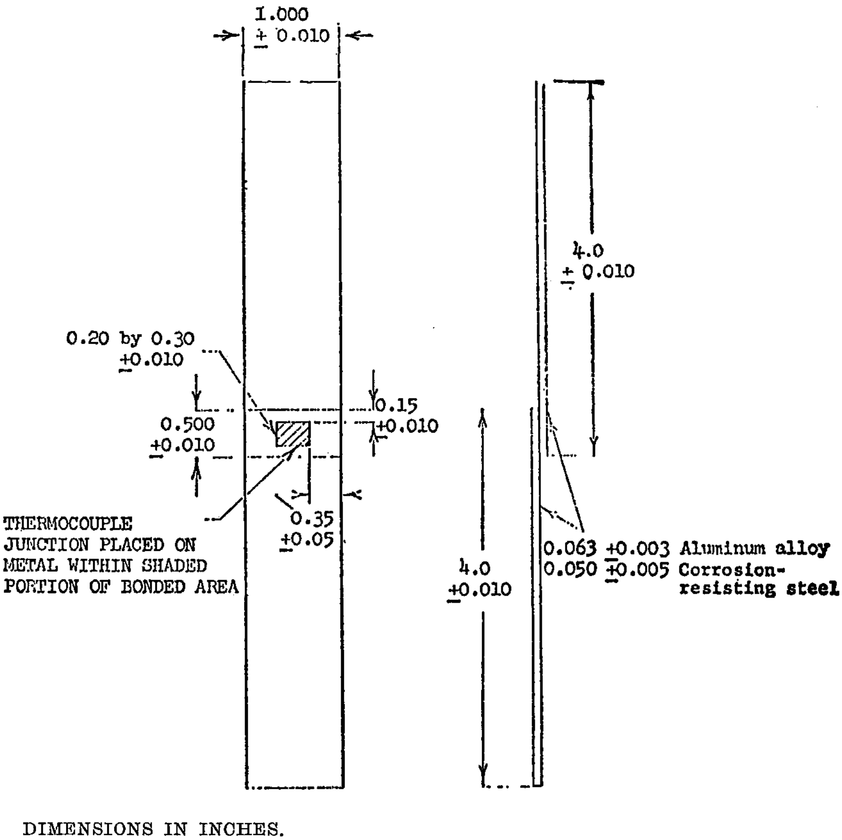
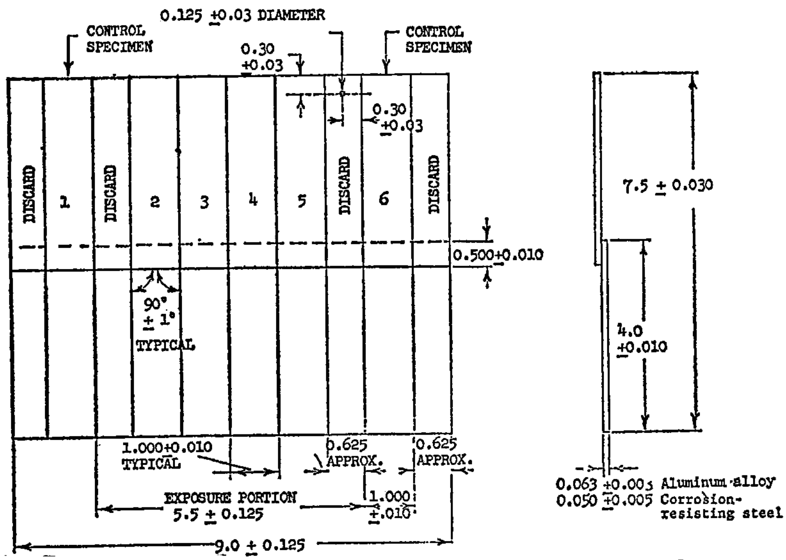


Figure 1. Location of thermocouples on the shear test specimens.

chamber. Individual panels shall not contact each other or any metallic material.

4.3.5 *High humidity condition.*—Resistance to humidity exposure shall be determined after 30 days ± 2 hours exposure of the panels in a humidity cabinet in which the exposure zone of the closed humidity chamber is maintained at 120° ± 5°F. (49° ± 2.8°C.) and 95 to 100 per cent relative humidity. The temperature in the chamber shall be recorded at least twice each working day. Condensate from one panel shall not drip upon any other panel. Distilled water or water containing not more than 200 parts per million of total solids shall be used to maintain the humidity. The test shall be continuous for the duration of the 30-day period. Continuous operation means that the chamber shall be closed and the humidity maintained continuously except for short daily interruptions necessary to in-



DIMENSIONS IN INCHES.

NOTE: All discards to be of uniform and common width. Width of exposure panel to depend on width of saw kerfs.

Figure 2. Exposure test panel.

spect, rearrange, or remove test panels, or to check or replenish the water in the reservoir. The panels shall be suspended as specified in 4.3.4 and shall not contact the water used to maintain the humidity, each other, any metallic material, or any material that may act as a wick.

4.3.6 *Fluid immersion conditions.*—Panels shall be immersed in the respective fluids listed in table II for 7 days ± 2 hours, except that 30 days ± 2 hours shall be used for the water immersions. The temperature of these fluids should be maintained at 70° to 80°F. (21° to 27°C.). The water immersion panels shall also be suspended from the edge of a hole as shown in figure 2. The remaining panels need not be so suspended. However, all panels must be so suspended or set in the containers as to insure full contact of the respective fluids with the bonded area of the test panels. Faces of panels immersed in the same container of fluid shall not contact each other; panels shall contact the container only at the panel corners or the 9-inch edges.

4.3.7 All panels to be exposed to the conditions specified in 4.3.4, 4.3.5, and 4.3.6, except those specimens taken from the ends of the panels for control-strength test purposes (4.4.2.3), shall be immersed as bonded (complete, preslotted, or prepunched) (see 4.4 and figures 3 and 4) edges unprotected and prior to being cut into specimens.

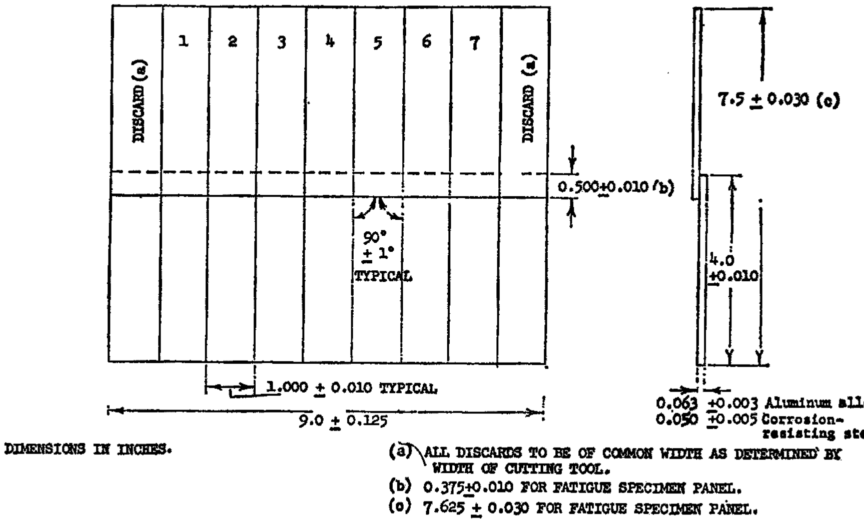


Figure 3. Standard test panel.

4.4 Preparation of test panels and specimens.—Lap joint panels as shown in figure 2, 3, or 4 shall be prepared in sufficient quantities (see 4.4.2), from a given type of adhesive to furnish the necessary number of specimens for all the tests applicable to that particular type of adhesive listed in table I. Lap joint panels for testing types I and II adhesives for all applicable table I properties shall be prepared from 0.063-inch clad 2024–T3 aluminum-alloy sheet conforming to Specification QQ–A–362 (2024–T3 clad aluminum alloy is the same material formerly designated as 24S–T3). Lap joint panels for testing types III and IV adhesives for all applicable table I properties shall be prepared from 0.050 inch 17–7 PH corrosion-resisting steel, condition TH–1050, conforming to Specification MIL–S–25043, with finish equivalent to No. 2 dull of type 301 corrosion-resisting steel. These corrosion-resisting steel specimens shall be made either in the form of complete lap joint panels (figures 2 and 3) or preslotted or prepunched panels of the general type shown in figure 5 to eliminate sawing of the specimens after bonding (see 4.4.1 and 6.3).

4.4.1 All edges of the metal panels and specimens which will be within (or which will bound) the lap joints shall be machined true (without burrs or bevels and at right angles to faces) and smooth (RHR 140 maximum, in accordance with Standard MIL–STD–10) before the panels are surface treated and bonded. The metal treating and bonding procedures employed shall be in accordance with the adhesive manufacturer's instruction sheet. All test panels shown in figures 2 and 3 shall have an overlap of 0.500 ±

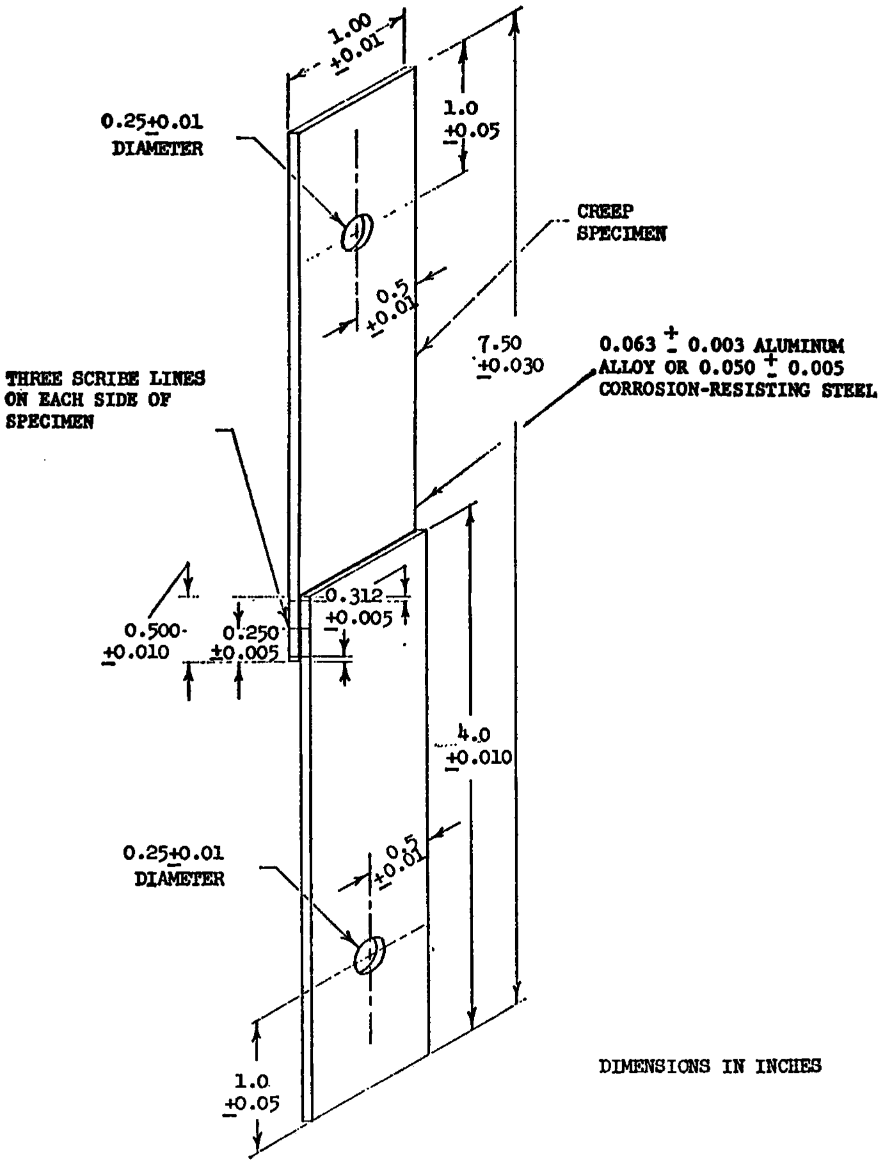


Figure 4. Creep rupture test specimen showing location of scribe lines.

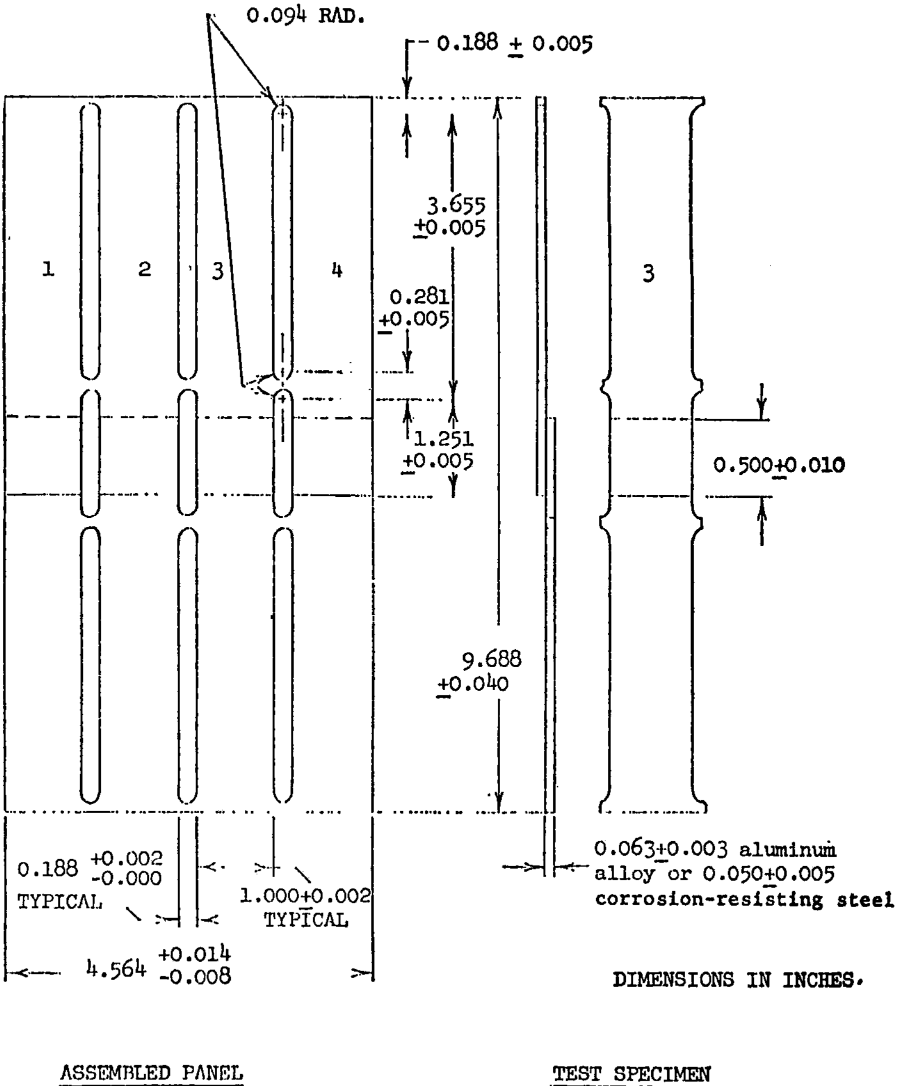


Figure 5. Optional panel.

0.010 inch except the figure 3 fatigue test panels, which shall have an overlap of 0.375 ± 0.010 inch. Panels so prepared shall be cut into 1-inch-wide specimens for testing in accordance with the provisions of applicable tests. Panels shall not be cut into specimens until at least 24 hours after bonding. Aluminum-alloy panels may be sawed with a bandsaw, with the setting and spacing of teeth and operational speed adjusted to hold frictional heating of the bond to a minimum. Corrosion-resisting steel panels (figures 2 and 3) may be cut with a water-cooled abrasive wheel, bandsaw, or a staggered-tooth milling tool with suitable cutting fluid at such operational speed as will hold frictional heating of the bond to a minimum (see 6.3). All panels and specimens shall be so marked that each specimen can be identified at any time with the particular panel from which it was cut and with the particular batch of adhesive with which it was bonded so that any failure may be properly traced to either the adhesive or the mechanics or equipment of bonding.

4.4.2 *Number of panels and specimens required for test.*

4.4.2.1 *Tensile shear and creep-rupture strength* (*tests Nos. 1 through 7, and 9 through 12 of table I*).—Three panels conforming to the dimensions and marking shown in figure 3 (with ½-inch lap joint) shall be prepared from each of three different batches of the adhesive being presented for qualification. Each of the resultant 9 panels shall be cut as shown in figure 3 into seven 1-inch-wide specimens. Each of the resultant 63 specimens shall be identified with the particular panel from which it was cut and with the particular batch of adhesive with which it was bonded so that any failure may be traced to either the adhesive or the mechanics or equipment of bonding. Specimens for each of tests Nos. 1 through 7, and 9 through 12, when applicable, of table I and necessary retest specimens shall be taken from the 63 specimens. Respective test procedures and numbers of specimens to be tested by each procedure are specified in 4.5.5.1 to 4.5.5.3 and in 4.5.5.5 to 4.5.5.8. If prepunched panels of corrosion-resisting steel (figure 5) having less than seven specimens per panel are used, the number of panels will need to be modified to have an equivalent total number of specimens.

4.4.2.2 *Fatigue* (*test No. 8 of table I*).—One panel conforming to the dimensions and marking shown in figure 3 shall be prepared with a ⅜-inch lap joint from each of the same three batches of the adhesive used in the preparation of the panel specified in 4.4.2.1. Each of these panels shall be cut as shown in figure 3 into seven 1-inch-wide (± 0.010 inch) (after machining) specimens. The edges of the specimens shall be machined smooth. Selection and testing of these specimens shall be as specified in 4.5.5.4.

4.4.2.3 *Salt water spray, high humidity, and fluid immersion* (*test Nos. 13 through 15 of table I*).—Eight panels shall be prepared as shown in figure 2 with each of the same three batches of adhesive used in the preparation of the panels specified in 4.4.2.1 and 4.4.2.2. Control specimens Nos. 1 and 7 shall be cut according to the procedure specified in 4.4.1 from each panel and shall be identified as to panel number as well as specimen number. These control specimens shall be tested at the applicable elevated temperature, 180°F. (82°C.) for type I adhesive, 300°F. (149°C.) for type II adhesive, and 500°F. (260°C.) for types III and IV adhesives after 10 minutes of temperature conditioning as specified in 4.5.5.2. Failure of any one control specimen to meet the specified minimum elevated temperature shear strength requirement of test No. 2, 3, or 5 (as applicable) shall void the panel from which that specimen was cut for use in these exposure tests and a replacement panel shall be prepared. The resultant 24 panels (part-panels) shall then be exposed at the conditions specified in 4.3.4 through 4.3.7, three panels (one panel representative of each batch of adhesive) shall be exposed at each of the conditions. After exposure, the panels shall be cut into individual specimens and tested in accordance with 4.5.5.9. If prepunched panels of corrosion-resisting steel (figure 5) having less than seven specimens per panel are used, the number of panels exposed will need to be changed to have an equivalent total number of specimens.

4.5 Qualification tests.

4.5.1 *Prior qualification.*—Unless otherwise specified by the procuring activity, adhesives which have not passed the qualification tests, or adhesives which have passed the qualification tests and have been modified in any manner, shall satisfactorily pass the qualification tests prior to acceptance of any adhesive. Qualification tests may be repeated on material previously found satisfactory at any time at the option of the activity responsible for qualification approval.

4.5.2 *Sampling instructions.*—The manufacturer shall submit a duplicate set of bonded panels and specimens which shall be prepared as specified in 4.4 and subparagraphs thereto. These panels shall be prepared with adhesive samples from the same three batches of adhesive and shall be code marked the same as the panels upon which the data given in the test report (4.5.3) were obtained. The manufacturer shall also submit four 1-pint samples of liquid adhesive together with necessary thinners and curing agents, or an equivalent amount of material in weight or measure if of another form, from each of three different numbered batches of the adhesive being presented for qualification. These adhesive samples shall each be from batches of most recent production-scale manufacture, and may be from different batches than those used in preparing the above specified set of duplicate panels. Part of the adhesive samples from each batch will be used in preparing test panels for qualification tests and the balance will be used for storage life tests (4.5.5.10). All samples shall be identified as to name of manufacturer, manufacturer's designation, date of manufacture, base polymer and curing agents (as applicable), the date of submittal, and identification of the activity submitting the samples, and forwarded to the Naval Air Material Center (see 6.6). In addition, a statement indicating that the products have not been rebranded shall accompany the samples. If rebranded, the names of the original manufacturers and original designations of the products shall be indicated. All information submitted will be treated as confidential.

4.5.3 *Test report.*—Prior to conducting the qualification tests (4.5.5), a dated and numbered report, certified by notarized affidavit, shall be furnished giving the results of all applicable tests listed in table I. The individual specimen and average values for each test shall be reported (see 6.6.2). Each value reported shall be shown as being for a definitely numbered specimen, the numbering of which shall be coded in the report in such a manner as to definitely establish the particular panel from which the specimen was cut and the particular batch of adhesive with which said panel was bonded and the date of bonding. Coded identification of the adhesive batches shall include the respective dates of manufacture and sizes of batch. Dates on which the different tests were performed shall be shown in the test report. The test report shall also cover all the requirements of paragraphs in section 3 (except 3.5). The actual pressure, temperature, and time of curing used in the preparation of the test panels shall be reported. The preparation of the adhesive and of the test panels shall conform to the description given in the instruction sheet and the report shall so state.

4.5.4 *Instruction sheet.*—The manufacturer shall submit, attached to the test report, (4.5.3) an instruction sheet in accordance with 3.5.

4.5.5 *Tests.*—The qualification tests shall consist of all the tests of this specification, and shall include approval of the manufacturer's instructions. These tests will be conducted by the Naval Air Material Center (see 6.6.1). Any changes shall be subject to the approval of that activity.

4.5.5.1 *Normal temperature tensile shear test (test No. 1 of table I).*—The test specimen shall be gripped tightly and uniformly across the ends in the jaws of the testing machine with the jaws and specimen so aligned that the jaws are directly opposite each other, and in such a position that an imaginary straight line will pass through the center of the bonded area and through the points of suspension. The specimen shall be gripped 2 inches ± 1/4 inch from each edge of the lap joint. The load shall then be applied at a rate of 1,200 to 1,400 pounds per square inch per minute or at an equivalent head speed per minute until failure. The load at failure shall be recorded. The testing machine accuracy shall be within 1 per cent. Length and width of shear area shall be measured to the nearest 0.01 inch and shall be recorded. All failing loads shall be expressed in pounds per square inch of actual shear area, calculated to the nearest 0.01 square inch. The nature and per cent of failure, such as cohesive failure (failure within the adhesive), adhesion failure (adhesive peeling from the metal), or contact failure (lack of complete adhesive-to-metal contact during bonding), and the adhesive thickness shall also be recorded for each specimen. Adhesive thickness shall be the micrometer thickness, measured to the nearest 0.001 inch, of the overall thickness of lap joint less the combined micrometer thickness of the individual pieces of surface-treated metal or the adhesive thickness can be measured with a traveling comparator microscope or an equivalent measuring apparatus. A total of 6 specimens, 2 specimens representative of each of the three batches of adhesive from the lots of specimens prepared as specified in 4.4.2.1, shall be tested. The average and minimum strengths of these 6 specimens shall equal or exceed that specified for test No. 1 in table I. If the strengths, either average or minimum, are less than that specified in table I, two more specimens from each of the three batches of adhesive shall be tested as a retest. If both specimens from the same batch of the adhesive fail to meet the minimum requirements in this retest and those from the other two batches of adhesive are satisfactory, a retest using 3 specimens from that same batch of adhesive shall be run. Like failure in the retest shall cause rejection of the adhesive. The normal temperature shear strengths of all ½-inch lap joint specimens tested in accordance with the qualification tests of this specification, except values voided and replaced by retest values, shall be averaged for use in determining the acceptance-test-required normal temperature shear strength (4.6.3.1).

4.5.5.2 *Elevated temperature tensile shear test* (*tests Nos. 2 through 6 of table I*).—The 180°F. (82°C.), 300°F. (149°C.), and 500°F. (260°C.) tensile shear tests shall be in accordance with 4.5.5.1 with the added requirement that a suitable oven or furnace shall be provided to maintain the specimens at the specified test temperature (see 4.3.2). Six specimens, selected as specified in 4.5.5.1, shall be tested for tensile shear strength at 180°F. (82°C.), 300°F. (149°C.), or at 500°F. (260°C.), as applicable, for each elevated temperature shear test listed in table I (tests Nos. 2 to 6). The average and minimum shear strength of each set of specimens tested shall equal or exceed that specified in the applicable test of table I. Retest provisions shall be as specified in 4.5.5.1.

4.5.5.3 *Low temperature tensile shear test* (*test 7 of table I*).—The low temperature tensile shear test shall be in accordance with 4.5.5.1, with the added requirement that a suitable chamber shall be provided for maintaining the specimen at $-67° \pm 5°$F. ($-55° \pm 2.8°$C.) (see 4.3.3). Six specimens, selected as specified in 4.5.5.1, shall be tested for tensile shear strength at $-67° \pm 5°F.$ $(-55° \pm 2.8°C.)$. The average and minimum shear strength of these specimens shall equal or exceed that specified for test No. 8 in table I. Like failure in the retest shall cause rejection of the adhesive.

4.5.5.4 *Normal temperature fatigue test (test No. 8 of table I)*.—This test shall be performed in accordance with the general provisions of Method 1061 of Federal Test Method Standard No. 175. Specimens having ⅜-inch overlap (see 4.4.2.2) shall have cyclic axial loads applied by a testing machine at a rate not to exceed 3,600 cycles per minute. The specimens shall be held tightly and in alignment as the load is applied by suitable grips, and these grips shall extend to within 1 ± ⅛ inch from the edge of the lap joint. The applied cyclic load shall always be in tension and shall range from the maximum selected to 10 per cent of the maximum. The loads shall be accurate to ± 1 per cent. Length and width of the shear area shall be measured to the nearest 0.01 inch and shall be recorded. The test shall be run until the specimen fails or until the maximum required number of repeated stresses have been applied (see 4.5.4.1). The number of cycles to failure shall be recorded. The nature and per cent of failure, such as cohesive failure (failure within the adhesive), adhesion failure (adhesive pulling from metal), contact failure (lack of complete adhesive-to-metal contact), or tensile metal failure, and the adhesive thickness shall be recorded for each specimen. Adhesive thickness shall be the micrometer thickness, measured to the nearest 0.001 inch, of the overall thickness of the lap joint less the combined micrometer thickness of the individual pieces of surface-treated metal, or the adhesive thickness can be measured with a traveling comparator microscope.

4.5.5.4.1 From each panel prepared as specified in 4.4.2.2, two properly identified control specimens shall be taken, one from the center and one from the end, and these specimens shall be subjected to the normal temperature shear test specified in 4.5.5.1. The normal temperature shear strength results obtained on these fatigue control specimens with ⅜-inch overlap shall be reported with the fatigue data. A total of 15 specimens, 5 from each panel, shall be tested in fatigue using maximum selected loads such that failures occur, with approximately regular spacing over a range from 10,000 to 10,000,000 cycles.

NOTE.—The number of cycles of testing to failure at the upper end of the range (10 million) may be reduced, in order to simplify the testing procedure, to 1 million cycles providing the applicable fatigue strength, as determined, conforms to test No. 8 of table I.

The number of cycles to failures and corresponding loads, calculated in pounds per square inch, shall be recorded on stress-log cycle coordinates and a smooth curve drawn. The point at which the smooth curve intercepts the 10-million cycle ordinate or 1-million cycle ordinate (see note above), is the fatigue strength. This fatigue strength shall equal or exceed that specified for test No. 8 in table I. If the fatigue strength value fails below that specified, another set of 6 specimens shall be prepared and tested, each with a 600-pound-per-square-inch maximum alternating stress. If any one of these specimens fails to conform to the 10-million cycle requirement, the adhesive shall be rejected.

4.5.5.5 *Normal temperature creep-rupture test (test No. 9 of table I).*—The lap joint specimens (see 4.4) shall be tested in a dead-weight loading test apparatus capable of applying loads accurate within 1 per cent. The specimens shall be gripped or suspended by means of 0.250-inch-diameter pins placed through drilled holes in the ends of specimens. The drilled hole shall be centered ($\pm$ 0.01 inch) in the width of the specimen and placed with its center 1 inch from the end of the specimen. Care must be exercised to avoid eccentricity in the loading of the adhesive joint. The entire assembly of specimen and loading mechanism must be checked for alignment prior to test. Long pull rods will facilitate obtaining proper alignment. Specimens shall remain loaded with a 1,600-pound-per-square-inch stress until rupture occurs or until the stress has been applied for 192 hours. The length and width of the shear area shall be measured to the nearest 0.01 inch and shall be recorded. The specimen bond areas shall be calculated to the nearest 0.01 square inch. Creep shall be measured during test in accordance with 4.5.5.7. The time to failure and the amount of creep of each specimen shall be recorded, as well as the nature and per cent of joint failure, if any, and the adhesive film thickness. The type of failure shall be determined and the adhesive film thickness measured as specified in 4.5.5.1 and 4.5.5.4. Six specimens, selected as specified in 4.5.5.1, shall be tested at the 1,600-pound-per-square-inch stress. If one or more of these specimens fails the 192-hour test No. 9 of table I, another set of 6 specimens shall be selected and tested. If any one of these retest specimens fails the test, the adhesive shall be rejected.

4.5.5.6 *Elevated temperature creep-rupture test (tests Nos. 10 to 12 of table I).*—The 180°F. (82°C.), 300°F. (149°C.), and 500°F. (260°C.) creep-rupture tests shall be in accordance with 4.5.5.5, with the added requirement that a suitable furnace or oven, which does not influence the application of load, shall be provided to maintain the temperature as required. Creep shall be measured on the specimen under stress in accordance with 4.5.5.8. Six specimens, selected as specified in 4.5.5.1, shall be tested with an 800-pound-per-square-inch stress. If one or more of these specimens fails the 192-hour tests Nos. 10 to 12, as applicable, of table I, 6 more specimens (2 specimens from each of the 3 adhesive batches) shall be tested as a retest. Like failure in the retest shall cause rejection of the adhesive.

4.5.5.7 *Normal temperature total creep deformation.*—As a part of the creep-rupture tests specified in 4.5.5.5, measurements of total deformation (including that due to initial loading) shall be made while the specimen is under stress. The deformation shall be measured to an accuracy of 0.0001 inch at such intervals of time that a smooth time deformation curve may be plotted. The exact time intervals will depend upon the adhesive being tested and the creep rate of the joint. The deformation may be measured directly by observing the displacement of fine scribe lines across both edges of the specimen near each end and at the center of the lap joint (figure 4), using a traveling comparator microscope capable of measuring displacement, as required, to the nearest 0.0001 inch or an equivalent measuring apparatus. The deformation of each specimen shall be determined by averaging the deformation measurements at the six prescribed points on the joint. If an extensometer is used, the gage length multiplied by a value equal to the stress in the metal, divided by the modulus of the metal used (10.5 times 10^6 pounds per square inch for aluminum alloy or 26.0 times 10^6 pounds per square inch for corrosion-resisting steel) shall be subtracted from all extensometer readings. The average total deformation of the 6 specimens at 192 hours shall be no greater than that specified in table I. All measurements shall be reported. Rejection and retest provisions shall be as specified in 4.5.5.5.

4.5.5.8 *Elevated temperature total creep deformation.*—The elevated temperature total deformation tests shall be made during the elevated temperature creep-rupture tests, 4.5.5.5. The procedure for deformation measurements shall be as specified in 4.5.5.7, except that the testing temperature shall be 180° ± 5°F. (82° ± 2.8°C.), 300° ± 5°F. (149° ± 2.8°C.), and 500° ± 5°F. (260° ± 2.8°C.) (see 4.5.5.2), as required in table I. Care shall be taken to insure that these temperatures have no effects on the accuracy of the method of measuring the deformation. Rejection and retest provisions shall be as specified in 4.5.5.6.

4.5.5.9 *Salt spray, humidity, and fluid exposure (tests Nos. 13 through 15 of table I).*—The partial panels (figure 2) which have been exposed to high humidity or salt spray conditions or immersed in fluids as specified in 4.3.4, 4.3.5, and 4.3.6 shall each be cut into four individual specimens as shown in figure 2. The cutting and marking of these specimens shall be done as specified in 4.4.1. Two specimens randomly selected from each panel (3 panels per exposure condition, 1 panel being prepared with each of the 3 batches of adhesive, see 4.4.2.3) shall be tested in tensile shear at normal temperature (tests 13, 14, and 15 of table I) following the procedures specified in 4.5.5.1. Tests shall be made within 6 hours after removal from the exposure condition. The strengths of the specimens tested at each condition shall equal or exceed that specified in tests Nos. 13 through 15 of table I, as applicable. If original test set fails in this regard, another group of 3 test panels may be exposed at the particular condition at which the quality was found to be less than that required. Six specimens shall be tested as retest. Like failure in the retest shall cause rejection of the adhesive.

4.5.5.10 *Storage life tests.*—One pint package of liquid adhesives, or equivalent amount properly packaged (see 5.1), if of another form, of each of the 3 batches of adhesive being submitted for qualification under this specification shall be stored under each of the two temperature and time conditions specified in 3.3.4. At the ends of the respective storage periods, these samples shall be used in the preparation of bonded lap joint panels as required by tests Nos. 1, 2, 3, 5, and 13 of table I, which are applicable to the particular type of adhesive being submitted. Six specimens, 2 specimens from each of the 3 adhesive batches, shall be tested at each of the applicable test conditions, except for test No. 13 for which 1 partial panel (figure 2) from each of the 3 adhesive batches shall be exposed and tested. The strengths of these specimens shall equal or exceed that specified for the applicable tests in table I. If the original test set fails in this regard, another set of specimens may be prepared with the remainder of the sample and tested. Like failure in the retest shall cause rejection of the adhesive or a modification of maximum storage life statement as furnished by the adhesive manufacturer. (See 3.3.4 and 6.6.3.)

4.6 Acceptance tests.

4.6.1 *Sampling.*

4.6.1.1 *Adhesive.*—A single sample of not less than 2 quarts of liquid adhesive or an equivalent amount in weight or measure, if of another form, shall be taken at random from each lot and tested. Each sample shall be divided into two equal parts; one part shall be available for required acceptance tests and the other part shall be retained for retests, if necessary. The storage condition for the retained sample shall be that recommended by the adhesive manufacturer (see 3.3.4), and samples shall not be retained beyond the storage life, as recommended by the adhesive manufacturer. Additional samples may be taken if considered necessary by the Government inspector to determine conformance of the product to this specification.

4.6.1.2 *Filled containers.*—A random sample of filled containers shall be selected from each lot by the Government inspector in accordance with Standard MIL–STD–105 at inspection level I, and at acceptance quality level (AQL) of 2.5 per cent defective, to verify conformance to all requirements of this specification regarding fill, closure, and marking.

4.6.2 *Lot.*—A lot shall consist of 500 pounds or fraction thereof of adhesive of one type, manufactured at one time in one batch, forming part of one contract or order, and submitted for inspection at the same time and place. A batch shall be defined as that quantity of material which has been manufactured at one time or subjected to some unit chemical or physical mixing process intended to make the final product homogeneous.

4.6.3 *Tests.*—Samples of each submitted lot of adhesive delivered on contract or order shall be subjected to the following acceptance tests. Test reports, in duplicate, shall be furnished for all acceptance tests specified in this specification, and shall be signed by an authorized representative of the laboratory making the tests. Acceptance or approval of material during course of manufacture shall in no case be construed as a guaranty of the acceptance of the finished products.

4.6.3.1 *Normal temperature tensile shear test (acceptance).*—The normal temperature tensile shear test shall be in accordance with 4.5.5.1. Two panels as shown in figure 3 (except the panel width shall be 6 inches instead of 9 inches) or two panels as shown in figure 5 shall be prepared. The cleaning and bonding of these panels shall be done in accordance with the approved manufacturer's instructions. All available specimens therefrom shall be tested. The average normal temperature shear strength value shall equal or exceed the applicable acceptance requirements of this specification or the process specification prepared by the processing activity in accordance with Specification MIL–A–9067, whichever is higher.

4.6.3.2 *Elevated temperature tensile shear tests (acceptance).*—The elevated temperature tensile shear tests shall be in accordance with 4.5.5.2. Two panels as specified in 4.6.3.1, shall be prepared for each of tests Nos. 2 through 6 of table I as applicable to the type of adhesive being tested. All available specimens therefrom shall be tested. The respective average test values shall equal or exceed the applicable acceptance requirements of this specification or the process specification prepared by the processing activity in accordance with Specification MIL–A–9067, whichever is higher.

4.6.3.3 *Filled containers.*—Each sample-filled container, selected in accordance with 4.6.1.2, shall be examined by the Government inspector for defects of the container and closure, for evidence of leakage, and for unsatisfactory markings. Each sample-filled container shall also be weighed to determine the amount of the contents. Any container in the sample having one or more defects or under required fill, shall be rejected, and if the number of defective containers in any sample exceeds the acceptance number for the specified sampling plan of Standard MIL–STD–105, the lot represented by the sample shall be rejected. Rejected lots may be resubmitted for acceptance tests provided that the contractor has removed or repaired all nonconforming containers.

4.6.4 *Packaging, packing and marking.*—Preparation for delivery shall be examined for conformance with section 5.

4.6.5 *Rejection and retest.*—If the results of the acceptance tests show failure to conform to 4.6.3.1 or 4.6.3.2, another set of specimens for both normal and elevated temperature tests shall be made with the remaining adhesive sample held for retest (4.6.1.1). Both types of tests shall be repeated. Failure of the retest specimens to conform to the respective requirements shall then be cause for rejection of the adhesive. Adhesive which has been rejected may be reworked to correct the defects and resubmitted for acceptance. Before resubmitting, full particulars concerning previous rejection, and the action taken to correct the defects found in the original shall be furnished the Government inspector. Material rejected after retest shall not be resubmitted without specific approval of the procuring activity.

5. PREPARATION FOR DELIVERY

5.1 Packaging.

5.1.1 *Level A.*—Liquid adhesives for metals shall be packaged in metal containers conforming to Specification PPP–C–96. The type, class, shape, and size of the container and type of closure, when required, shall be as specified by the procuring activity (see 6.5). Film adhesive shall be packaged, using a suitable membrane to prevent deterioration. Packaging shall be accomplished in accordance with the appendix to Specification PPP–C–96.

5.1.2 *Level C.*—Adhesives shall be packaged in accordance with manufacturer's commercial practice.

5.1.3 Three copies of the manufacturer's instruction sheet (see 3.5) shall be included with each shipment, unless more are requested by the procuring activity.

5.2 Packing.

5.2.1 *Level A.*—Adhesive packaged as specified in 5.1.1 shall be packed in accordance with overseas shipment requirements of the appendix to Specification PPP–C–96.

5.2.2 *Level B.*—Adhesives packaged as specified in 5.1.1 shall be packed in accordance with the domestic shipment requirements of the appendix to Specification PPP–C–96.

5.2.3 *Level C.*—Adhesives packaged as specified in 5.1.2 shall be packed in exterior-type shipping containers in a manner that will insure safe transportation at the lowest rate to the point of delivery. Containers shall meet Uniform Freight Classification Rules or other common carrier regulations, as applicable to the mode of transportation.

5.3 Marking of shipments.—Interior and exterior containers shall be marked in accordance with Standard MIL–STD–129. Exterior containers shall also be marked with a note relative to storage, such as:

> "Adhesives conforming to this specification should be stored at a temperature of less than 86°F. (30°C.) in the absence of direct sunlight. If transit or normal storage conditions, or both, necessitate exposure of the adhesive to temperatures in excess of 86°F. (30°C.) the life of the adhesive will be proportionally reduced."

6. NOTES

6.1 Intended use.—Adhesives conforming to this specification are intended for use in bonding airframe structural components. However, fabricators are required by the procuring activity to obtain approval of the component and of a process specification applicable to the adhesive and component prior to use of the adhesive on parts procured on contract. Fabrication and inspection must be made in accordance with the requirements of Specification MIL–A–9067. Types I and II adhesives are intended principally for use on clad aluminum alloys, and types III and IV adhesives are intended principally for use on corrosion-resisting steel alloys. Use of either on other metals or combination of metals must be substantiated by tests. Parts or assemblies requiring the use of adhesives covered by this specification should be designed with consideration for the heat and pressure required during the bonding operations. The maximum curing pressure specified in 3.3.3.2 is a necessary requirement for determining the suitability of an adhesive for general production use, however, shop facilities permitting higher pressures in accordance with the manufacturer's instructions may be used whenever practicable.

6.1.1 Some of the adhesives covered by this specification can be used for bonding other constructions such as metal-to-plastic or plastic-to-plastic, provided the use of the adhesive is substantiated by the tests specified herein, using the combination of the materials in question.

6.1.2 Adhesives covered by this specification are not intended for use in bonding sandwich constructions unless they conform to specification MIL–A–25463.

6.2 Definition.—The terms "long-time exposures" and "short-time exposures" as used in 1.2 and other paragraphs are relative terms, which for the purpose of this specification are defined as 192-hours duration and 10-minutes duration, respectively. Adhesives are not qualified in this specification on the basis of their ability to withstand extremely high temperatures for "ultra short-time exposures," such as 1,000°F. (538°C.) for 2 minutes, because testing techniques under these conditions have not been satisfactorily standardized. Fabricators concerned with elevated temperature exposures for these ultra short periods will need to provide substantiating data of the adequacy of the adhesives for the intended use.

6.3 Precaution.—Severe damage has been obtained in cutting corrosion-resisting steel specimens from bonded panels using saws and lubricating fluids. Certain of the fluids penetrate adhesive bonds under these conditions. Damage might also be caused by vibration or heating from the cutting operation. Shop tests should be made to determine that the sawing techniques used will not harm the bonds. If satisfactory sawing techniques are not readily available, preslotted or prepunched specimens of type shown in figure 5 should be used.

6.4 It should be noted that type IV adhesives, although maintaining substantial strength properties for 192 hours at 500°F. (260°C.), may not retain adequate properties very much beyond that time, and therefore, they may not be, and in general are not suitable for continuous use at 500°F. (260°C.). Their strengths and serviceability for periods beyond 192 hours must be determined by tests by the user. In general, type II adhesives will be suitable for use beyond the 192-hour period, and possibly will be suitable for continuous use at 300°F. (149°C.), depending on stress conditions. However, this must also be determined by actual tests by the user.

6.5 Ordering data.—Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Type of adhesive (see 1.2), adhesive code number (see 3.2.8.1).
(c) Capacity and kind of container and quantity desired.
(d) Applicable levels of packaging and packing (see section 5).

6.6 Qualification testing.

6.6.1 *Qualification.*—With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening bids, been tested and approved for inclusion in the applicable Qualified Products List whether or not such products have actually been so listed by that date. The attention of the supplier is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government, tested for qualification, in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. The activity responsible for the Qualified Products List is the Bureau of Naval Weapons, Navy Department, Washington 25, D.C.; however, information pertaining to qualification may be obtained from the Naval Air Material Center, Philadelphia 12, Pennsylvania, Attention: Director, Aeronautical Materials Laboratory.

6.6.2 In authorizing qualification tests, it should be stated in the Letter of Authorization that the following information and samples should be furnished at no cost to the Government:

(a) Notarized test report (4.5.3) listing all data obtained with three separate batches of the adhesive in evaluation tests performed in accordance with this specification.

(b) A duplicate set of bonded test panels prepared with the same three batches of adhesive and under the same bonding conditions as used to obtain the data given in the test report. Twelve lap-joint panels (11 with a ½-inch overlap and one with a ⅜-inch overlap) with each of the three batches of adhesives and two peel test specimens with each of the three batches of adhesive will be required. (See 4.4, 4.4.2, and 4.5.2 for panel construction and identification of panels with adhesive batch.)

(c) Instruction sheet (4.5.4) listing all of the information as required in 3.5 and including storage life recommendations (3.3.4).

(d) Four 1-pint samples of liquid adhesive together with necessary thinners and curing agents, or an equivalent amount of material in weight and measure if of another form, from each of three different batches of adhesive. These adhesive samples shall be from batches of recent production scale manufacture and may be from different batches from those used in preparing the above test panels. These samples should each be properly packaged for storage (see section 5) and shall be properly identified (see 4.5.2).

(e) If the recommended method of preparing the metal surface for bonding requires the use of chemicals other than standard commercial acids, solvents, or sodium chromate, the manufacturer shall include enough of such chemicals to make 2 gallons of solution.

(f) The manufacturer shall pay the transportation charges to and from the designated point where tests are to be made. In the case of failure of the sample or samples submitted, consideration will be given to the request of the manufacturer for additional tests only after it has been clearly shown that changes have been made in the product which the Government considers sufficient to warrant additional tests.

6.6.3 Adhesives conforming to the other requirements of this specification may, at the option of the qualifying activity, be placed on Qualified Products List QPL–5090 (see 6.6.1) prior to the completion of the storage life tests. Modification of the manufacturer's storage life recommendations or removal of the adhesive from the Qualified Products List will be necessary, if subsequently, the adhesive does not pass the life storage test.

Notice.—When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Army—Ordnance Corps
Navy—Bureau of Naval Weapons
Air Force

Preparing activity:

Navy—Bureau of Naval Weapons

MIL-A-13883A (ORD) SUPERSEDING MIL-A-13883 (ORD): ADHESIVE, RUBBER RESIN, SYNTHETIC (HOT OR COLD BONDING)

1. SCOPE

1.1 Scope.—This specification covers two types of general purpose synthetic rubber adhesives for hot or cold bonding (see 6.1).

1.2 Classification.—Adhesive covered by this specification shall be of the following types and classes:

Type I—Thermoplastic
- Class 1—High solids
- Class 2—Low solids

Type II—Thermosetting
- Class 1—High solids

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids, form a part of this specification.

Specifications

FEDERAL

CCC-C430	—Cloth, Cotton Sheeting.
PPP-C-96	—Cans, Metal, 28 gauge and lighter.
PPP-D-760	—Drums and Pails, Metal (5 and 16.64 gallon).

MILITARY

JAN–T–171 —Toluene

Standards

FEDERAL

Fed. Test Method
Std. No. 175 —Adhesives: Methods of Testing.

MILITARY

MIL–STD–105 —Sampling Procedures and Tables for Inspection by Attributes.

MIL–STD–129 —Marking for Shipment and Storage.

Publications

ORDNANCE CORPS

ORD–M608–11 —Procedures and Tables for Continuous Sampling by Attributes.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

2.2 *Other publications.*—The following documents form a part of this specification. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

CONSOLIDATED CLASSIFICATION COMMITTEE PUBLICATION

Consolidated Freight Classification Ratings, Rules and Regulations

(Application for copies should be addressed to the Consolidated Classification Committee, 202 Chicago Union Station, Chicago 6, Illinois.)

AMERICAN TRUCKING ASSOCIATION

National Motor Freight Classification Rules and Container Regulations

(Application for copies of rules should be addressed to the National Classification Board, 1424 Sixteenth Street N. W. Washington 6, D.C.)

INTERSTATE COMMERCE COMMISSION

49 CFR 71–78—Interstate Commerce Commission Rules and Regulations for the Transportation of Explosives and Other Dangerous Articles.

(The Interstate Commerce Commission Regulations are now a part of the Code of Federal Regulations (1949 Edition-Revised 1950) available from the Superintendent of Documents, Government Printing Office, Washington 25, D.C. Orders for the above publication should cite "49 CFR 71-78 (Rev. 1950)".)

3. REQUIREMENTS

3.1 *Quality.*—The adhesive shall meet all requirements of this specification, shall contain no lumps of any size, be ready for use, and have no deleterious effect on metal surfaces.

3.2 *Nonvolatile matter.*—The per cent of nonvolatile matter in the adhesive shall not be less than 28 per cent nor more than 32 per cent for type I, class 1 and type II materials when tested in accordance with 4.4.1. The nonvolatile matter in the type I, class 2, material shall not be less than 18 per cent or more than 22 per cent when tested as specified in 4.4.1.

3.3 *Ash content of nonvolatile matter.*—The ash content of the nonvolatile matter in the adhesive shall not exceed 18 per cent when tested in accordance with 4.4.2.

3.4 *pH of the adhesive water mixture.*—The pH of the mixture shall not be less than 5.5 nor more than 9.0 when tested in accordance with 4.4.3.

3.5 *Solvent, boiling point.*—The boiling point of the solvent in the adhesive shall not be less than 70 degrees nor more than 135 degrees Centigrade when tested in accordance with 4.4.4.

3.6 *Specific gravity.*—The specific gravity of the adhesive shall not be less than 0.80 nor more than 0.98 when tested in accordance with 4.4.5.

3.7 *Viscosity.*—The viscosity of the adhesive shall not be less than 5 seconds nor more than 70 seconds when tested in accordance with 4.4.6.

3.8 *Shear strength.*—The material shall conform to the shear strength requirements listed in table I, when tested in accordance with 4.4.7.

3.9 *Peel strength.*—The adhesive shall have a minimum peel strength average of 12 pounds per linear inch and a minimum individual value of 10 pounds per linear inch when tested in accordance with 4.4.8.

3.10 *Suitability for use with explosives.*—When suitability for use with a particular explosive is required, special tests shall be conducted at a designated Government Laboratory to determine if the adhesive is suitable in this respect (see 6.7). The procuring agency shall request these tests to be conducted, and shall specify the particular propellant or explosive to be used in these tests.

3.11 *Toxicity.*—When used for its intended purpose, the adhesive shall have no adverse effect on the health of personnel (see 6.3).

4. QUALITY ASSURANCE PROVISIONS

4.1 *Lot.*—A lot shall consist of adhesive from the same manufacturer's batch. A batch is defined as that quantity of material which has been subjected to some unit chemical, or physical mixing process intended to make the final product substantially uniform.

4.2 *Sampling.*

Table I.—*Shear Strength*

Conditioning time and temperature	Temperature	*Type I Adhesives*		*Type II Adhesives*	
		Average value lbs. per sq. in. min.	Min. individual value lbs. per square inch	Average value lbs. per sq. inch minimum	Min. individual value lbs. per square inch
24 hrs. at 25° C.	25° C.	1200	1000	2700	2500
24 hrs. at 77° C. then 2 hrs. at 25° C.	25° C.	1200	1000	2700	2500
24 hrs. immersion in toluene at 25° C.	25° C.	1200	1000	2700	2500
2 hrs. at 50° C.	50° C.	700	500	1700	1500

4.2.1 *Sampling for inspection of filled containers.*—A random sample of filled containers shall be selected by the inspector, in accordance with Standard MIL–STD–105 at inspection level I with Acceptance Quality Level equal to 2.5 per cent defective, to verify compliance with all stipulations of this specification in regard to fill, closure, and other requirements not involving tests.

4.2.2 *Sampling for acceptance testing.*—An eight (8) ounce sample shall be selected at random from each lot by the Government inspector. The sample shall be placed in an airtight container and labeled to show the name of the material, manufacturer, plant, contract or purchase description.

4.3 *Inspection of filled containers.*—Each sample filled container selected in accordance with 4.2.1 shall be examined by the Government inspector for defects in the container and the closure, for evidence of leakage, and for unsatisfactory markings; each sample filled container shall also be weighed to determine the amount of the contents. Any container in the sample, having one or more defects, or under required fill, shall be rejected and if the number of defective containers in any sample exceeds the acceptance number for appropriate sampling plan of Standard MIL–STD–105, the lot represented by the sample shall be rejected. Rejected lots may be resubmitted for acceptance tests provided that the contractor has removed all nonconforming containers.

4.4 *Acceptance test procedures.*—The following acceptance tests shall be performed by or for the contractor (see 6.7).

4.4.1 *Nonvolatile matter.*—A weighing bottle (approximately 2.25 inches inside diameter and 1.25 inches deep) shall be heated for one hour at 100° ± 5° Centigrade, then cooled in a desiccator, and weighed. All weighings shall be to the nearest one-hundredth gram. Approximately 20 grams of the sample shall be placed in the prepared weighing bottle, the bottle immediately covered, and weighed. The cover shall be removed, and the weighing bottle placed on a steam bath until most of the solvent has evaporated. (CAUTION: Care should be taken to remove as much of the solvent as is practicable by this method in order to eliminate any fire hazard which might otherwise exist when subjecting the material to the subsequent drying operation.) The weighing bottle and contents shall then be placed in an oven at 100 degrees ± 5 degrees Centigrade, heated for 5 hours, cooled in a desiccator, and weighed. This heating and weighing procedure shall be continued by heating for periods of ½ hour at 100° ± 5°C. until the loss in weight is less than 0.2 grams. This percentage of nonvolatile matter shall be calculated by the following equation to determine compliance with the requirements in 3.2.

$$\text{Per cent nonvolatile matter} = \frac{(a - b) \times 100}{c}$$

where:

a = weight of weighing bottle plus sample after heating.
b = weight of weighing bottle.
c = weight of sample for determination.

4.4.2 *Ash content.*—Approximately 20 grams of the sample shall be placed in a tared, 150 milliliter capacity, high-form porcelain crucible. The crucible and contents shall be placed on a steam bath until the solvent has been evaporated. (CAUTION: Care should be taken to remove as much of the solvent as is practicable by this method in order to eliminate any fire hazard which might otherwise exist when subjecting the material to the subsequent drying operation.) Then the crucible and contents shall be placed in an oven at 100 degrees to 105 degrees Centigrade for five (5) hours, cooled in a desiccator, and weighed. The weight shall be recorded as the weight of the nonvolatile matter in this sample. A 25 milliliter portion of concentrated nitric acid shall be added to the crucible containing the dried material. The crucible shall be covered with a watch glass to prevent loss by spattering, and heated on an open steam bath until the vigorous reaction which first ensues has subsided. The addition of 25 milliliters of concentrated nitric acid and heating on the steam bath shall be repeated until no solid material remains in the crucible. The watch glass shall be removed, and the crucible and contents continued to be heated on the open steam bath until all excess nitric acid has been removed. The crucible and contents shall then be placed on an electric hot plate, at medium heat, and heated until all volatile matter has been driven off, and the contents of the crucible have been charred. The crucible and contents shall be ignited to constant weight in a muffle furnace at 600 degrees plus or minus 25 degrees Centigrade. The ash content of the nonvolatile matter shall be calculated by means of the following equation to determine compliance with the applicable requirement of 3.3.

$$\text{Per cent ash} = \frac{a \times 100}{b}$$

where:

a = weight of ash.
b = weight of nonvolatile matter in sample.

4.4.3 *pH of adhesive water mixture.*

4.4.3.1 *Preparation of reagents.*—A 10 gram portion of chromic acid (CrO_3), shall be dissolved in 1000 milliliters of distilled water. The mixture shall be distilled, the first 100 milliliters of the distillate discarded, and the next 600 milliliters of the distillate retained for use.

4.4.3.2 *Determination.*—Approximately 10 grams of the sample shall be placed in a 100 milliliter beaker. Then 50 milliliters of pH water prepared as specified in 4.4.3.1 shall be added, the beaker covered with a watch glass, and the mixture allowed to stand at room temperature for one hour. The mixture shall be stirred every ten (10) minutes. The electrodes of a Beckman pH meter (Model M), or other similar electrometer, shall be inserted into the beaker so that the mixture of the water and sample covers the active surfaces of the electrodes. The contents of the beaker shall be allowed to remain in contact with the electrodes of the pH water for fifteen (15) minutes before taking the first measurement. A measurement shall be taken every succeeding five (5) minutes until a total of four (4) values have been obtained. The pH value of the adhesive-water-mixture shall be recorded as the average of the four (4) values, to determine compliance with the applicable requirements in 3.4.

4.4.4 *Solvent boiling point.*—Approximately 250 grams of the sample shall be transferred to a 500 milliliter distilling flask, and the flask connected to a water condenser. The flask shall be gently heated, by means of an oil bath heated to about 130 degrees Centigrade, and the distillate collected in a clean bottle or flask. When no more solvent comes over, the distillate shall be transferred to a 250 milliliter distilling flask. A thermometer (0 degrees to 110 degrees Centigrade range, graduated in 0.2 degrees Centigrade) shall be placed in the flask so that the top of the bulb is approximately one half (½) inch below the side arm. The flask shall be placed in the apparatus shown in figure 1. Heat shall be cautiously applied by means of the Bunsen Burner, with a flame so regulated that the distillation continues at the rate of approximately two (2) drops per second. The thermometer shall be read when ten (10) milliliters of the liquid has been collected. This value, corrected for variation in barometric pressure, shall be reported as the solvent boiling point, to determine compliance with the applicable requirement of 3.5.

4.4.5 *Specific gravity.*—The sample shall be thoroughly stirred, and the temperature adjusted to 25 degrees plus or minus 2 degrees Centigrade. The sample shall be poured into a tared 100 millimeter graduated cylinder to the 100 milliliter level, being careful to eliminate any air bubbles by tapping the cylinder on a large rubber stopper. The cylinder and contents shall be weighed to the nearest 0.1 grams. The specific gravity shall be calculated by dividing the change in weight of the cylinder by 100, to determine compliance with the applicable requirement of 3.6.

4.4.6 *Viscosity.*—For type I, class 1, and type II, the consistency cup (see 6.4) with the 0.25 inch orifice shall be used, and for type I, class B,

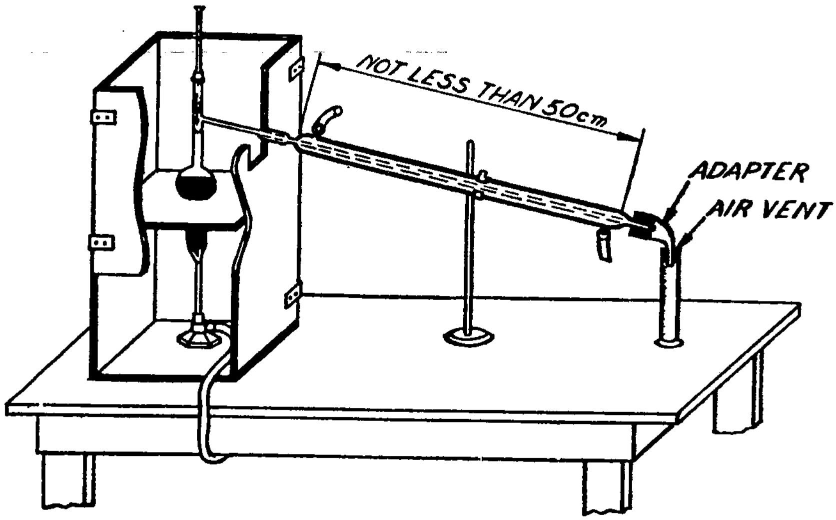


Figure 1. Assembly of apparatus for the determination of distillation range.

the consistency cup with the 0.15 inch orifice (see figure 2) shall be used. The temperature of the material to be tested and the consistency cup shall be adjusted to 25 degrees plus or minus 2 degrees Centigrade. The cup shall be mounted in the support provided for the purpose, and the receiving cylinder placed in position. The outlet of the cup shall be closed by placing the finger over it. Then, a sample of the well mixed material shall be poured into the cup until an overflow occurs. The excess material above the rim of the cup shall be struck off by means of a straight edge. The finger shall be withdrawn from the outlet and a stop watch started simultaneously. When the top of the meniscus of the liquid in the receiving cylinder has reached the 50 milliliter mark, the watch shall be stopped. The time, in seconds, for the 50 milliliters of material to flow into the cylinder shall be recorded as the viscosity, to determine compliance with the applicable requirement of 3.7.

4.4.7 *Shear strength.* (See 6.4, 6.5, 6.6).

4.4.7.1 *Preparation of shear test specimens.*—A total of forty (40) panels shall be prepared from 1020 cold rolled steel measuring 1 inch by 4 inches by .064 inch. One face of each panel shall be thoroughly cleaned by buffing with fine emery cloth. The panels shall be degreased by immersing them in a solution prepared as follows:

Sodium orthosilicate	30 grams
Sodium alkylaryl sulfonate	3 grams
Water to make	1 liter

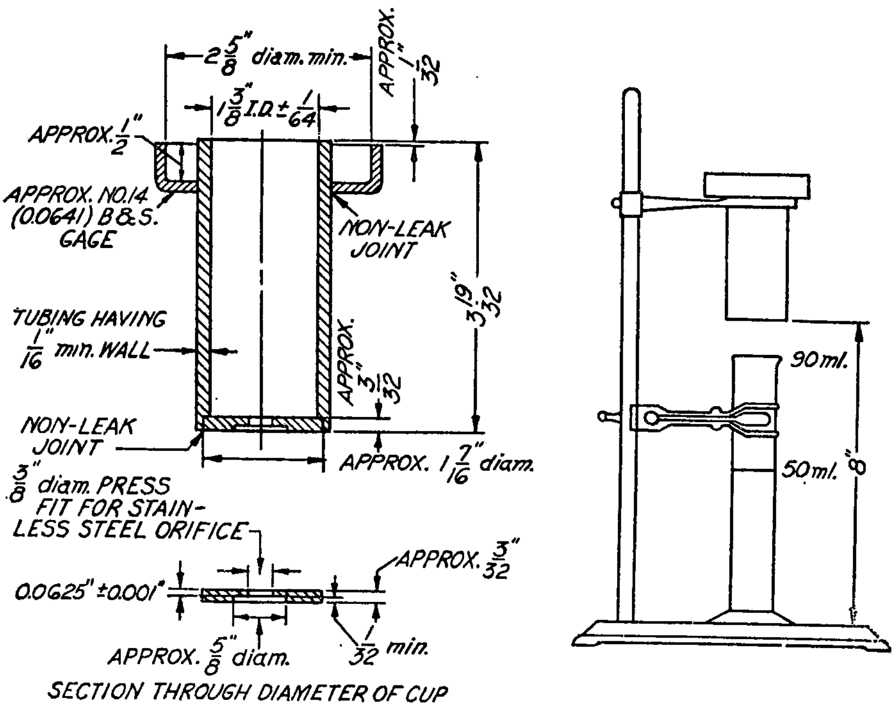


Figure 2. Test apparatus for determining viscosity.

NOTE 1.—Four consistency cups constitute a set, as follows:

	Diameter of Orifice, in.
First Cup	0.07 ± 0.0001
Second Cup	0.10 ± 0.0001
Third Cup	0.15 ± 0.0001
Fourth Cup	0.25 ± 0.0001

NOTE 2.—Cups made of brass or bronze. Orifice disks made of 18 per cent chromium, 8 per cent nickel stainless steel. The diameter of the orifice pressed in the cup shall be stamped on the cup.

NOTE 3.—Fractional dimensions subject to permissible variations of plus or minus 0.01 in.; unless otherwise specified.

The panels shall be immersed in this solution for five (5) minutes at 60 to 65 degrees Centigrade, and rinsed with hot distilled water, then dried in an oven at 100 to 105 degrees Centigrade. Using a stiff bristled brush, a thin coating of the adhesive material shall be applied to one end of each of the panels for a length of about one and one quarter of an inch (1¼"). The adhesive shall be dried in an oven for one (1) hour at 77° ± 2°C.

Then, the two panels shall be placed together so that the adhesive coated faces are together, and the panels overlap over an area of exactly 1 square inch. The panels shall be bonded by applying and maintaining a pressure of five hundred (500) pounds per square inch, and a temperature of 145 degrees to 150 degrees Centigrade for 30 ± 2 minutes. A hot press shall be used for the bonding.

4.4.7.2 *Testing of shear specimens.*—The shear strength tests shall be performed to determine compliance with 3.9. Five of the panels prepared as specified in 4.4.7.1 shall be allowed to cool at 25 degrees ± 2 degrees Centigrade, and 50 ± 4 per cent relative humidity for 24 hours. The specimens shall be tested in accordance with Fed. Test Method Std. No. 175, method 1033. Five of the specimens, prepared as specified in 4.4.7.1 shall be placed in an oven at 77 degrees ± 2 degrees Centigrade, for 24 hours. They shall be allowed to cool to 25 degrees ± 2 degrees Centigrade and tested as indicated above. Five of the specimens shall be immersed in toluene, complying with the requirements of Specification JAN–T–171, grade B at 25 degrees, ± 2 degrees Centigrade for 24 hours. The specimens shall be wiped dry with a towel, and an immediate determination of the shear strength made as indicated above. Five of the specimens shall be placed in a test chamber heated at 50 degrees ± 2 degrees Centigrade for 2 hours, and the shear strength determined at this temperature. The average shall be calculated and recorded as the sample value.

4.4.8 *Peel strength.*

4.4.8.1 *Preparation of peel test specimens.*—A total of ten (10) panels of cold rolled steel measuring one inch (1″) by eight inches (8″) by one sixteenth (1/16″), and a total of ten (10) strips of cotton cloth conforming to Specification CCC–C–430 and measuring one inch (1″) by twelve inches (12″) shall be prepared. The metal panels shall be wiped with a clean cloth dampened with acetone, and then thoroughly vapor degreased with perchloroethylene. The degreasing time will be a minimum of twenty (20) minutes. The panels shall be allowed to cool to 25 degrees ± 2 degrees Centigrade. Adhesive shall be applied to a five inch (5″) length of one side of each metal panel, and to a five inch length of one side of each cloth strip. The number of coats of adhesive and the drying between coats, shall be as specified by the manufacturer, however, no more than two (2) coats shall be applied to each faying surface. The adhesive shall not be thinned. All cementing operations shall be made at 25 ± 2 degrees Centigrade, and at 50 ± 4 per cent relative humidity. The bonding surfaces shall be brought together immediately after coating with adhesive. The unbonded ends of the adherends shall be adjacent to each other. Intimate contact shall be accomplished by hand pressure and all wrinkles shall be removed. The specimens shall be air dried for 18 hours at 25 degrees ± 2 degrees

Centigrade, then oven dried for 24 hours at 50 ± 2 degrees Centigrade in air circulating oven.

4.4.8.2 *Testing of peel specimens.*—The peel specimens prepared in 4.4.8.1 shall be conditioned at 25 degrees ± 2 degrees Centigrade and 50 ± 4 per cent relative humidity for 4 hours. The specimens shall be tested in accordance with Fed. Test Method Std. No. 175, method 1041. The average shall be calculated and recorded as the sample value.

4.4.9 *Rejection.*—Should any portion of the sample tested fail to comply with the requirements of section 3, the lot shall be rejected by the Government or its assigned agent.

5. PREPARATION FOR DELIVERY

5.1 *Preservation and packaging.*

5.1.1 *Level A.*

5.1.1.1 *Unit packaging.*—Synthetic rubber adhesive shall be packaged either in metal cans, complying with the requirements of PPP–C–96, type V, class 2, or in metal drums and pails complying with the requirements of Specification PPP–D–760 type 1, as applicable. In addition to the requirements of Specification PPP–C–96, type V, class 2, or Specification PPP–D–760, type 1, the container shall comply with the applicable requirements of Regulations for Transportation of Explosives and Other Dangerous Articles, etc. of the Interstate Commerce Commission for Cement, Rubber.

5.1.1.2 *Intermediate packaging.*—Synthetic rubber adhesive packaged in accordance with 5.1.1.1 shall be intermediately packaged, when required, in accordance with applicable paragraphs of Appendix to Specification PPP–C–96 and with applicable requirements of Regulations for Transportation of Explosives and Other Dangerous Articles, etc., of the Interstate Commerce Commission for Cement, Rubber. Unless otherwise specified five gallon drums require no overpacking.

5.2 *Packing.*

5.2.1 *Level A.*—Synthetic rubber adhesive, packaged as in 5.1.1, shall be packed in accordance with applicable paragraphs of Appendix to Specification PPP–C–96 and with applicable requirements of Regulations for Transportation of Explosives and Other Dangerous Articles, etc., of the Interstate Commerce Commission for Cement, Rubber. Unless otherwise specified, five gallon drums require no overpacking.

5.2.2 *Level C.*—The adhesive shall be packed to ensure carrier acceptance and safe delivery in compliance with Consolidated Freight Classification Rules and Container Specifications or with National Motor Freight Classification Rules and Container Specifications or with other carrier rules and regulations applicable to the mode of transportation.

5.3 *Marking.*—In addition to any special marking required by the contract or purchase order, unit and intermediate packages and exterior containers shall be marked in accordance with Standard MIL–STD–129, with applicable paragraphs of Appendix to Specification PPP–C–96 and with applicable requirements of Regulations for Transportation of Explosives and other Dangerous Articles, etc. of the Interstate Commerce Commission for Cement, Rubber.

6. NOTES

6.1 *Intended use.*—While it is intended that this type of material be suitable for use as a general purpose adhesive, the user should satisfy himself by preparing and testing specimens of the intended adherends. It is not possible to test the numerous varieties of materials under all conditions for specification purposes.

6.1.1 The type I adhesive is a thermoplastic material and is not recommended for applications where it will be subjected to either continuous high stress or to stress at elevated temperatures. The type II adhesive may be considered for certain high continuous stress applications or for applications involving stress at elevated temperature only when adequately heat cured.

6.2 *Ordering data.*—Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Type required (see 1.2).
(c) Maximum shelf life recommended by manufacturer.
(d) Selection of applicable levels of packaging, and packing.

6.3 Any question raised regarding toxicity should be referred to appropriate medical authority. In the case of Army procurement, the Surgeon General of the Army will act as advisor to the procuring agency.

6.4 The consistency cups used for determining viscosity are the same as the ASTM number 15, and number 25 cups (ASTM Procedure D333–40).

6.5 A Tinius Olsen Plastiversal Testing Machine, or approved substantial equal, is suitable for testing the shear strength.

6.6 Shear tests were conducted on elevated temperature cured specimens to obtain maximum strength values.

Peel tests were conducted on essentially room temperature cured specimens to obtain short term and room temperature cured strength values. All values are for specification testing only.

6.7 Information on suitability or unsuitability of some polymeric materials and adhesives for use with explosives is available at Picatinny

Arsenal. Application for tests to determine the suitability of adhesives with explosives or propellants should be made to the

Commanding Officer, Picatinny Arsenal, Dover, New Jersey
Attention:
Director, Samuel Feltman Ammunition Laboratories, Chemical & Plastics Research Laboratory.

Notice.—When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation or conveying any rights or permission to manufacture, use, or sell any patented invention that may be related thereto.

Custodian:
Army—Ordnance Corps

Preparing activity:
Army Ordnance Corps

Other interest:
Army—CEMQSigT

MIL-A-1154B SUPERSEDING MIL-A-1154A: ADHESIVE, VULCANIZED SYNTHETIC RUBBER TO METAL AND TO VULCANIZED SYNTHETIC RUBBER BONDING

This specification has been approved by the Department of Defense and is mandatory for use by the Departments of the Army, the Navy, and the Air Force.

1. SCOPE

1.1 This specification covers material for bonding vulcanized synthetic rubber material as gaskets, matting and similar items, to steel and to vulcanized synthetic rubber.

2. APPLICABLE DOCUMENTS

2.1 The following specifications and standards, of the issue in effect on date of invitation for bids, form a part of this specification:

Specifications

FEDERAL

QQ-S-693	—Steel, Sheet, Hot-Rolled.
PPP-C-96	—Cans, Metal, 28 Gage and Lighter.

MILITARY

MIL–R–1149 —Rubber Sheets, Strips, and Gaskets; Solid, Synthetic, Medium and Medium Hard.

Standards

MILITARY

MIL–STD–105 —Sampling Procedures and Tables for Inspection by Attributes.

MIL–STD–129 —Marking for Shipment and Storage.

(Copies of specifications, standards, drawings, and publications required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

2.2 Other publications.—The following document forms a part of this specification. Unless otherwise indicated, the issue in effect on date of invitation for bids shall apply.

CONSOLIDATED CLASSIFICATION COMMITTEE
Consolidated Freight Classification Rules.

(Application for copies should be addressed to the Consolidated Classification Committee, 202 Chicago Union Station, Chicago 6, Ill.)

3. REQUIREMENTS

3.1 Qualification.—Adhesive furnished under this specification shall be a product which has been tested and has passed the qualification tests specified herein (see 6.2).

3.2 Material.—The material shall be of the best commercial quality, ready for use, and shall have no deleterious effect on the metal surfaces or synthetic rubber materials to which it is applied. The adhesive shall be free from material which will be toxic to personnel under normal conditions of use.

3.3 Viscosity.—The material shall have a viscosity of not more than 150 nor less than 110 seconds when tested as specified in 4.5.1. Based on the value for viscosity obtained in the qualification test, the viscosity for succeeding lots shall not vary more than 10 per cent.

3.4 Solids content.—Based on the percentage value of solids content obtained in the qualification test, the solids content of succeeding lots shall not vary more than 10 per cent when tested as specified in 4.5.2.

3.5 Wet adhesive strength.—The material shall have a wet adhesive strength of not less than 1.5 pounds per inch of width of specimen when tested as specified in 4.5.3.

3.6 Stability.—After the material has been subjected to the aging condition specified in 4.5.4, the wet adhesive strength, as defined in 3.5, shall be not less than 1.5 pounds per inch of width of specimen (see 6.3).

3.7 Strip adhesion.

3.7.1 The initial strip adhesive strength of the material shall be not less than 5 pounds per inch of width of specimen when tested as specified in 4.5.5.

3.7.2 After immersion in 5 per cent sodium chloride water solution, the strip adhesive strength of the material shall be not less than 4 pounds per inch of width when tested as specified in 4.5.5.

3.7.3 The strip adhesive strength of the adhesive at 140° ± 2°F., using the specified classes of synthetic rubber (see 4.5.5.1) shall be such that the test specimen shall not strip more than 3 inches in 3 minutes under a load of 1 pound when tested as specified in 4.5.5.

3.8. Marking.—Each container of material shall be provided with a label giving adequate instructions for its use and application. The name of the manufacturer, specification number and month and year of manufacture shall also be indicated on the label.

3.9 Weight.—The weight of a filled pint container of material shall not vary more than one ounce from the weight of the qualified material, as determined by 4.5.6.

4. QUALITY ASSURANCE PROVISIONS

4.1 Qualification tests.—Qualification tests shall be conducted at a laboratory designated by the Bureau of Ships. These tests shall consist of the tests specified in 4.5.

4.2 Sampling.

4.2.1 *Inspection lot.*—For purposes of sampling, inspection and tests, a lot shall consist of material from one batch offered for delivery at one time.

4.2.2 *Sampling for lot acceptance.*

4.2.2.1 *One pint containers.*—From each lot offered for Government inspection, four containers shall be selected at random and forwarded to the testing laboratory designated by the bureau or agency concerned.

4.2.2.2 *Half pint containers.*—From each lot offered for Government inspection, eight containers shall be selected at random and forwarded to the testing laboratory designated by the bureau or agency concerned.

4.2.3 *Sampling for inspection of containers (at the contractor's plant).* —A random sample of filled containers shall be selected by the Government inspector in accordance with Standard MIL-STD-105 at inspection level I and acceptable quality level = 2.5 per cent defective to verify compliance with all stipulations of this specification regarding fill, closure, marking and other requirements not involving tests.

4.3 Inspection.

4.3.1 *Inspection of filled containers.*—Each sample filled container shall be examined for defects of construction of the container and the closure, for evidence of leakage, and for markings. Each sample filled container shall also be weighed. Any sample filled container that is found not in conformance with the requirements of 3.9 and section 5 shall be rejected, and if the number of defective filled containers in the sample exceeds the acceptance number for the appropriate sampling plan of Standard MIL–STD–105, the entire lot represented by the sample shall be rejected. Rejected lots may be resubmitted for inspection, provided the contractor has removed (or reworked) all nonconforming containers.

4.4 Lot acceptance tests.

4.4.1 *Place of test.*—Lot acceptance tests shall be conducted at the place of manufacture if facilities are available, otherwise they shall be conducted at a laboratory designated by the bureau or agency concerned.

4.4.2 The containers of material selected in accordance with 4.2.2 shall be formed into two test samples of one quart each. (Two one-pint or 4 half-pint containers making one test sample.) Each test sample shall be separately subjected to the following tests:

Test	*Reference*
Viscosity	4.5.1
Solids content	4.5.2
Wet adhesive strength	4.5.3

4.4.3 *Rejection.*—If any sample representing a lot is found to be not in conformance with this specification, the entire lot shall be rejected. A rejected lot may be resubmitted for Government inspection (and testing) provided the manufacturer, after having been informed of the reasons for rejection, has reworked the lot to remove the deficiency noted.

4.5 Tests.

4.5.1 *Viscosity test.*

4.5.1.1 *Specimen.*—A sufficient quantity of material to fill the cup shall be used.

4.5.1.2 *Apparatus.*—A cup of the type shown on figure 1 [1] equipped with a $\frac{1}{4}$ inch orifice.

4.5.1.3 *Procedure.*—Both the sample of adhesive to be tested and the apparatus shall be adjusted to the testing temperature (74° ± 2°F.) before starting the test. Stir the material thoroughly allowing a minimum of solvent to evaporate. Level the apparatus and then place one finger over

[1] Commonly called the Ford cup.

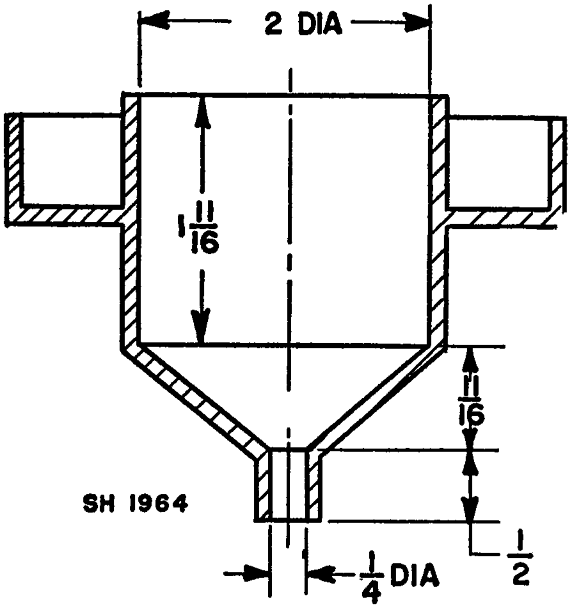


Figure 1—*Schematic sketch of viscosity cup.*

the orifice of the cup and rapidly fill with the material. Allow a moment or two for air bubbles to rise and then wipe the finger away from the orifice of the cup, and simultaneously start a stop watch. Observe the stream of material flowing from the orifice of the cup, and at the first break in the stream, stop the watch. This test shall be run in duplicate using a new sample of material for each determination.

4.5.1.4 *Report.*—A report shall be kept of the following:

(a) The time in seconds for each of the two quantities of material.
(b) The temperature of the testing room.

4.5.2 *Solids content.*

4.5.2.1 *Specimens.*—Approximately 10 grams of thoroughly stirred material shall be poured into a tared container.

4.5.2.1.1 *Procedure.*—A suitable container and cover shall be weighed, and the sample poured into the tared container, covered and weighed. After removing the cover, the container shall be placed in the oven and the temperature maintained at 158° ± 2°F. until the sample reaches a constant weight. The container, cover, and sample shall then be cooled in a desiccator and weighed. The test shall be run in duplicate.

4.5.2.1.2 Total solids shall be expressed as a percentage of nonvolatile matter present in the material. It shall be calculated as follows:

$$\text{Total solids, per cent} = \frac{\text{the weight of the residue}}{\text{the original weight of the sample}} \times 100$$

and the two determinations shall be reported.

4.5.3 *Wet adhesive strength.*

4.5.3.1 *Specimens.*—One set of specimen panels shall be prepared as specified in 4.5.5.1.

4.5.3.2 *Procedure.*—The wet adhesive strength shall be determined 1 hour plus or minus 5 minutes after the bond has been accomplished using the same test procedure and equipment as used in the strip adhesion test specified in 4.5.5.2 and 4.5.5.3.1. Likewise, the values shall be reported in the same units.

4.5.4 *Stability test.*—Approximately 1 pint of material shall be placed in an oven in an unopened container of the same construction as used by the manufacturer, for 2 weeks at a temperature of 120° ± 2°F. It shall then be removed from the oven and allowed to cool for 3 hours. After the material has cooled, the wet adhesive strength test specified in 4.5.3 shall be conducted with the material.

4.5.5 *Strip adhesion.*

4.5.5.1 *Specimens.*—The synthetic rubber gasket materials used for this test shall conform to type I, classes 1, 2 or 5 of Specification MIL–R–1149 and the sheet steel panels to which the synthetic rubber strips are bonded shall conform to class A of Specification QQ–S–693. Strips of synthetic rubber material measuring 1 inch by ¼ inch by at least 6 inches long shall be bonded to steel panels for strip adhesion tests which shall be conducted in triplicate on specimens prepared from each of the classes 1, 2 and 5 synthetic rubber gasket materials for each of the following test conditions: (1) initial adhesive strength (2) adhesive strength after immersing specimens in salt water solution and (3) adhesive strength tests at 140°F. ± 2°. The synthetic rubber strips shall be roughened by buffing on a coarse grinding wheel or other suitable means and the steel panels shall be ground smooth and then cleaned with a suitable solvent. When the solvent has evaporated completely, one brush coat of the adhesive material shall be applied to the prepared surfaces of the synthetic rubber strips and panels. The adhesive material shall be permitted to air dry on the strips and panels for 1 hour (at 74° ± 2°F. and 50 ± 3 per cent relative humidity) before bonding unless the manufacturer of the adhesives specifically recommends a shorter drying time. Immediately after the strips have been bonded to the panels, they shall be rolled down with six single passes of a 10 pound roller, 2 inches wide, requiring about 2 seconds per pass. The panels to which the synthetic rubber strips are bonded shall be preconditioned and tested as shown in table I. The rubber strips shall be used only once for adhesion tests.

4.5.5.2 *Apparatus.*—The initial adhesion tests, and those after immersion shall be made on a power driven apparatus, preferably of the inclination balance or pendulum type, although a spring-balance apparatus may be used. The machine shall fulfill the requirements specified as follows:

(a) The applied load as measured and recorded shall be accurate within plus or minus 1 per cent.
(b) Strip specimens shall be held in the testing machine by grips which clamp firmly and prevent slipping at all times during the test.
(c) The rate of travel of the power-actuated grip shall be 1 inch per minute.
(d) The machine shall be operated without any device for maintaining maximum load indication. In pendulum type machines, the weight lever shall swing as a free pendulum without engagement of the pawls.
(e) The machine shall be autographic giving a chart having the inches of separation as one axis and applied load as the other axis of coordinates.
(f) The machine shall be of such capacity that the maximum applied load during the test shall not exceed 85 per cent nor less than 15 per cent of the rated capacity.

TABLE I.—*Conditioning and testing schedule*

Strip adhesion test	Elapsed time, hours			
	0 to 48	48 to 96	96 to 120	120
Initial tests	L	R	R	T
Tests after immersion	L	I	R	T
At 140°F.	L	R	R	T(1)

NOTES:
L—Dead weight load of 2.5 pounds per square inch of synthetic rubber gasket area shall be applied at room temperature (74° ± 2°F.) as a loading pressure on the strips bonded to the steel panel.
R—Rest time under no load at room temperature (74° ± 2°F.)
I —Specimens shall be immersed in 5 per cent sodium chloride salt water solution, under no load at room temperature (74° ± 2°F.).
T—Tests shall be conducted at room temperature (74° ± 2°F.).
T(1)—Strip adhesion test shall be conducted at 140° ± 2°F.

4.5.5.3 *Procedure.*

4.5.5.3.1 *Procedure for determining strip adhesive strength initially and after immersion.*—The specimen panels, conditioned as specified in table I shall be secured to the orthogonal strip adhesion apparatus as shown on figure 2. One end of the synthetic rubber strip shall be pulled loose from the steel panel for a distance of about 2 inches and secured to the clamp which is suspended from a chain attached to the loading head of the testing machine. The crank of the apparatus shall be rotated to position the steel panel during the test and thus maintain a 90 degree separation angle of the synthetic rubber strip from the panel. In addition, the machine shall be adjusted to draw an autographic plot of the adhesive strength of bond of the synthetic rubber gasket material to the steel panel. The strip adhesive strength, in pounds per inch of width of the synthetic rubber strip, shall be determined by drawing the best average line of the adhesive strength recorded on the autographic chart omitting the load build-up and decay portions where the rubber strip is stretching or contracting without separating from the steel panel. The average of three such values (three specimens per test required) shall be considered as the strip adhesive strength for the test condition.

4.5.5.3.2 *Procedure for determining strip adhesive strength at 140° ± 2°F.*—The specimen panel, conditioned as specified in table I, shall be supported at the ends in a horizontal position in an oven operating at a temperature of 140° ± 2°F. The panel shall be positioned with the synthetic rubber strips facing down and conditioned for 20 minutes. After the conditioning period, and while still in the oven, one end of a strip shall be pulled loose for a distance of about 2 inches and a 1-pound weight shall be suspended from the free end of the strip. The weight shall be allowed to act on the strip for 3 minutes, and the average distance of stripping of the specimen from the panel under the influence of the weight shall be recorded.

4.5.6 *Weight.*—The weight of a filled pint container of material shall be determined by averaging the weights of material submitted for qualification.

5. PREPARATION FOR DELIVERY

5.1 Packaging.

5.1.1 *Level A.*—The adhesive shall be furnished in ½-pint or 1 pint multiple friction top cans conforming to Specification PPP–C–96. The exterior of the cans shall be coated in accordance with plan B.

5.1.2 *Level C.*—The adhesive shall be packaged in accordance with commercial practice.

5.2 Packing.

5.2.1 *Levels A and B.*—The adhesive shall be packed for level A or level B as specified (see 6.1) in accordance with the Appendix of Specification PPP–C–96.

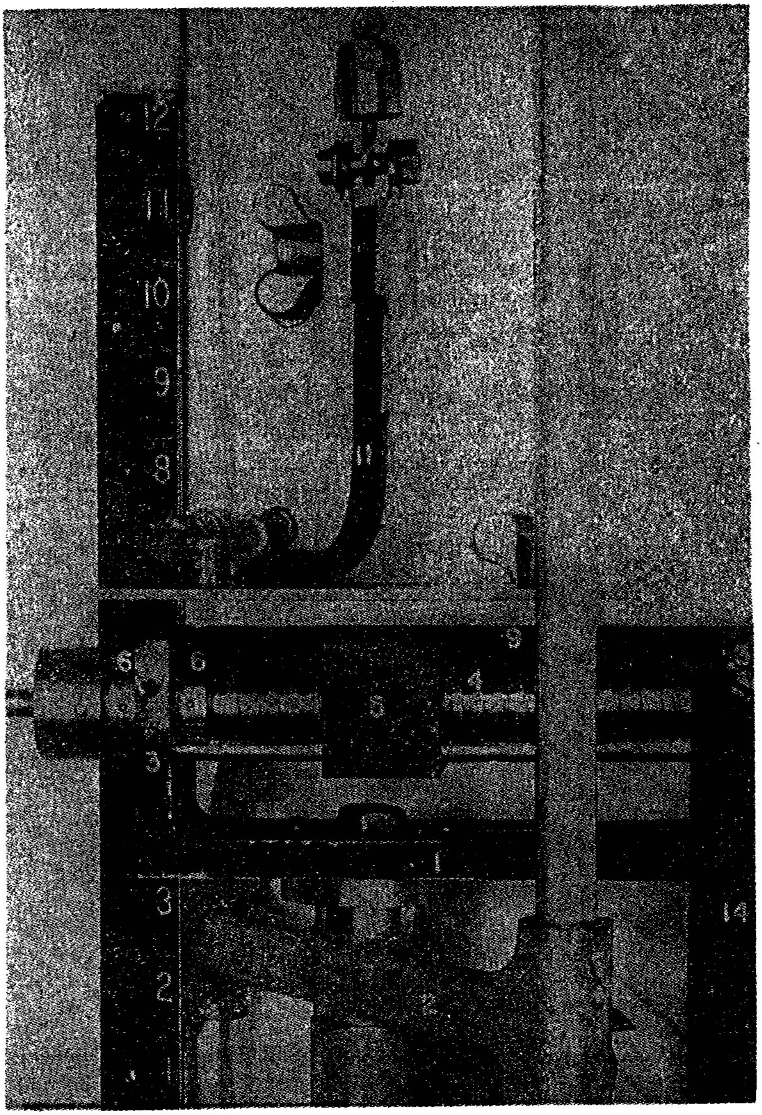


Figure 2. Close-up of orthogonal strip adhesion device mounted on Scott tensile machine.

5.2.2 *Level C*.—The adhesive shall be packed to insure carrier acceptance and safe delivery to destination at the lowest applicable rate. Containers shall comply with the Consolidated Freight Classification Rules or other carrier regulations applicable to the mode of transportation.

5.3 Marking.—In addition to any special marking required in the contract or order, marking of the packages and shipping containers shall be in accordance with Standard MIL–STD–129.

6. NOTES

6.1 Ordering data.—Procurement documents should specify the following:

(a) Title, number, and date of this specification.
(b) Unit quantity per container (see 5.1).
(c) Whether the adhesive shall be packaged for level A or C and packed for level A, B or C (see 5.1 and 5.2).

6.2 Qualification.—With respect to products requiring qualification, awards will be made only for such products as have, prior to the time set for opening of bids, been tested and approved for inclusion in Qualified Products List QPL–1154, whether or not such products have actually been so listed by that date.

6.2.1 The attention of suppliers is called to this requirement, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government, tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. Information pertaining to qualification of products covered by this specification may be obtained from the Chief of the Bureau of Ships, Department of the Navy, Washington 25, D. C.

6.3 The adhesive should still be usable after being stored in unopened containers for 1 year at room temperature (74° ± 2°F.).

Custodians:

Army—Ordnance Corps
Navy—Bureau of Ships

Other interest:

Army—E SigT
Navy—AOrY

Preparing activity:

Navy—Bureau of Ships

MIL–A–1154B AMENDMENT–1: ADHESIVE, VULCANIZED SYNTHETIC RUBBER TO METAL AND TO VULCANIZED SYNTHETIC RUBBER BONDING

This amendment forms a part of Military Specification MIL–A–1154B, 19 March 1957, has been approved by the Department of Defense, and is mandatory for use by the Department of the Army, the Navy, and the Air Force.

Page 2, paragraph 3.3. Delete and substitute:

"**3.3 Viscosity.**—The material shall have a viscosity of not more than 150 seconds when tested as specified in 4.5.1."

Page 2, paragraph 3.6: Delete "(see 6.3)".

Page 2. Add as paragraph 3.6.1:

"**3.6.1** The adhesive material shall be still usable after being stored in unopened containers for 1 year at room temperature (74° ± 2°F.) (see 4.5.1.)."

Page 2, paragraph 3.7.1. Delete and substitute:

"**3.7.1** The initial strip adhesive strength of the gasket material (see 4.1.1) shall be not less than 5 pounds per inch of width of specimen for classes 1 and 2 and 4 pounds per inch of width of specimen for class 5 material when tested as specified in 4.5.5.1."

Page 2, paragraph 3.9. Delete and substitute:

"**3.9 Weight.**—The weight of the adhesive contained in a filled one pint can shall not vary more than one ounce from the weight of the qualified material, as determined by 4.5.6."

Page 2. Add as paragraph 4.1.1:

"**4.1.1** Standard gasket stocks conforming to type I, class 1, 2, or 5 of Specification MIL–R–1149 and having the following recipes shall be used to evaluate adhesive materials:

Class 1, formula number 156-616

Neoprene WRT	100	Cure for ¼ inch thickness—30 min. at 310°F.
Stearic acid	2	
XLC magnesia	2	
Medium thermal carbon black (Thermax)	10	
Clay (dixie clay)	45	
Phenyl-alpha-naphthylamine (Neozone A)	2	
Paraffin	2	
Petrolatum	2	
Whiting (crown filler)	60	
Circo light process oil	15	
Zinc oxide	2	
NA22	0.5	

Class 2, formula number 162-1778		
GR–S1500	100	Cure for ¼ inch thickness—20 min. at 310°F.
Fine furnace carbon black (Statex B)	20	
Sulfur	2	
Stearic acid	2	
Zinc oxide	5	
Fine thermal carbon black (P33)	20	
Whiting (crown filler)	70	
Califlux 510	25	
Tetramethyl thiuram disulfide (methyl tuads)	0.4	

Class 5, formula number 194-542		
Paracril B	100	Cure for ¼ inch thickness—20 min. at 310°F.
Medium thermal carbon black (Thermax)	91.5	
Whiting (crown filler)	27.7	
Zinc oxide	5	
Stearic acid	1	
Coumarone indene softener (cumar P10)	20	
Dibutyl phthalate	10	
Phenyl-beta-naphthylamine (agerite powder)	1	
Tetramethyl thiuram disulfide	0.3	
Sulfur	1.5	

Page 4, paragraph 4.5.5.1, first sentence: Delete and substitute "The synthetic rubber gasket materials used for this test shall be prepared as specified in 4.1.1, and the sheet steel panels to which the synthetic rubber strips are bonded shall conform to type A of Specification QQ–S–693."

Page 5, paragraph 4.5.6. Delete and substitute:

"**4.5.6** *Weight.*—The weight of adhesive in a filled pint container shall be determined by averaging the weights of material submitted for qualification."

Page 5. Add as a new paragraph 4.5.7:

"**4.5.7** *Storage.*—The adhesive material after being stored in unopened containers for one year at room temperature (74° ± 2°F.) shall be examined to determine the brushability of the adhesive."

Page 6, paragraph 6.3: Delete.

Figure 2: Delete Scott from title.

Custodians:

Army—Ordnance Corps
Navy—Bureau of Ships

Preparing activity:

Navy—Bureau of Ships
(Project 8040–0001)

MIL–A–928A SUPERSEDING MIL–A–928(AER): ADHESIVE; METAL TO WOOD, STRUCTURAL

This specification was approved by the Departments of the Army, the Navy, and the Air Force for the use of procurement services of the respective Departments.

1. SCOPE

1.1 Scope.—This specification covers synthetic resin adhesives for the structural bonding of clad aluminum alloy to wood.

1.2 Classification.

1.2.1 *Types.*—The adhesives covered by this specification shall be furnished in the following types, as specified:

Type I —Single adhesive system
Type II—Two adhesive system

1.2.2 *Conditions.*—The type II adhesive shall be furnished in the following conditions, as specified:

Condition A—Primary adhesive with room temperature (75°–90°F.) setting secondary adhesive.
Condition B—Primary adhesive with intermediate temperature (90°–180°F.) setting secondary adhesive.
Condition C—Primary adhesive with a high temperature (180°–325° F.) setting secondary adhesive.

2. APPLICABLE SPECIFICATIONS, AND OTHER PUBLICATIONS

2.1 The following publications, of the issue in effect on date of invitation for bids, shall form a part of this specification to the extent specified herein:

2.1.1 *Specifications.*

Federal

QQ–A–362 —Aluminum Alloy (Clad 24S); Plate and Sheet.
QQ–M–151 —Metals; General Specification for Inspection of.
UU–C–843 —Cushioning Materials, Cellulosic.
MMM–A–175 —Adhesives; Methods of Testing.

Military

MIL–A–397 —Adhesive, Room-Temperature and Intermediate-Temperature Setting Resin (Phenol, Resorcinol, and Melamine Base).

MIL-C-124 —Containers (Cans, Pails, and Drums) Metal.
MIL-H-3136 —Hydrocarbon-Fluid, Standard Test.
MIL-P-6070 —Plywood and Veneer; Aircraft Flat Panel.
MIL-W-6110 —Wood, Determination of Moisture Content of.
JAN-P-105 —Packaging and Packing for Overseas Shipment—Boxes, Wood, Cleated, Plywood.
JAN-P-106 —Packaging and Packing for Overseas Shipment—Boxes; Wood, Nailed.
JAN-P-108 —Packaging and Packing for Overseas Shipment—Boxes, Fiber-board (V-board and W-Board) Exterior and Interior.
JAN-P-139 —Packaging and Packing for Overseas Shipment—Plywood, Container Grade.

2.1.2 *Other Publications.*

MILITARY STANDARDS (BOOK)

MIL-STD-129 —Marking of Shipments.
MIL-STD-105 —Sampling Procedures and Tables for Inspection by Attributes.

NAVY DEPARTMENT

General Specifications for Inspection of Material.

INTERSTATE COMMERCE COMMISSION REGULATIONS

37D—Steel Drums.

(Information as to the availability of these Regulations may be obtained from the Interstate Commerce Commission, Washington 25, D. C.)

(Copies of specifications, standards, and drawings required by contractors in connection with specific procurement functions should be obtained from the procuring agency or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 Materials.—The adhesive shall consist of a resin or resins furnished in liquid form, with or without hardener, or in the solid form as stick, powder, or film.

3.1.1 *Liquid form.*—Adhesives in liquid form shall mix readily to a smooth solution or suspension of a consistency suitable for application and shall be free of lumps. The components shall not settle out during a normal working day.

3.1.1.1 *Working life.*—The liquid adhesive shall have a minimum working life of $2\frac{1}{2}$ hours at $73.5 \pm 2°F.$ when determined as specified in paragraph 4.5.6.

3.1.2 *Film form.*—Adhesives in the film form shall consist either entirely of adhesive or a carrier impregnated with adhesive. The material and treatment of the carrier shall be designated. If necessary, an activating solvent shall be furnished and used with adhesive in film form.

3.1.3 *Accelerator, hardener, or modifier.*—If necessary, an accelerator, hardener, or modifier shall be supplied in powder or liquid form for mixing with the adhesive.

3.1.4 *Formulation changes.*—The adhesive or adhesives shall be approved only for the formulation for which qualification tests are made and shall be used by the fabricator as approved. Any changes such as adding of pigments, hardeners, or fillers, or changing the type shall be cause for designating the adhesive as a new adhesive which shall not be considered approved. The changed adhesive shall be given a new code number and resubmitted for approval under this specification. No changes or additions shall be allowed unless the new code number adhesive has also been approved.

3.1.4.1 *Code Number.*—The manufacturer shall designate each adhesive by a code number which shall be used to identify the adhesive. A trade name, if accompanied by a code number, may also be used.

3.1.5 *Solubility.*—The adhesives shall be capable of being thinned with water or with commercially available solvents specified by the manufacturer. Adhesives, before curing, shall be easily dissolved and removed from spreading equipment.

3.2 Application.

3.2.1 *Type I.*—Adhesives shall be capable of being readily applied to aluminum or aluminum alloy and to wood surfaces in accordance with the manufacturer's instructions at temperatures between 16° and 38°C. (60° and 100°F.), at relative humidities of 30 to 75 per cent.

3.2.2 *Type II.*—The primary adhesives shall adhere to aluminum or aluminum alloys. The secondary adhesives shall adhere the wood member to the primary coated metal, resulting in a metal to wood joint. The adhesives shall be capable of being readily applied to the surfaces in accordance with the manufacturer's instructions at temperatures between 16° and 38°C. (60° and 100°F.) at relative humidities of 30 to 75 per cent.

3.3 Curing.—The time, temperature, and pressure shall be as specified herein, unless otherwise approved by the procuring agency.

3.3.1 *Type I.*

3.3.1.1 *Curing temperature.*—The adhesives shall require not longer than 20 minutes at a temperature not exceeding 168°C. (335°F.) at the bonding line. If a lower temperature is specified for curing, the curing period may be proportionately longer.

3.3.1.2 *Curing pressure.*—The pressure required for curing the bonded metal-to-metal assembly described in section 4 shall not exceed 50 pounds per square inch.

3.3.2 *Type II.*

3.3.2.1 *Curing temperature.*

3.3.2.1.1 *Primary.*—Primary adhesives shall require not longer than 20 minutes at a temperature not exceeding 168°C. (335°F.) at the adhesive line. If a lower temperature is specified for curing, the curing period may be proportionately longer.

3.3.2.1.2 *Secondary.*

Condition A.—Condition *A* secondary adhesives shall require not longer than 8 hours to cure when exposed to a temperature of 75° to 90°F. measured in the adhesive line.

Condition B.—Condition *B* secondary adhesives shall require not longer than 5 hours to cure when exposed to a temperature between 90° and 180°F. measured in the adhesive line.

Condition C.—Condition *C* secondary adhesives shall require not longer than 30 minutes to cure when exposed to a temperature between 180° to 325°F. measured in the adhesive line.

3.3.2.2 *Curing pressure.*—The pressure required for curing the bonded metal-to-metal assembly described in section 4 shall not exceed 50 pounds per square inch.

3.4 Shear strength of bonded joints.

3.4.1 *Type I.*—Adhesive specimens prepared and tested as described in section 4 shall develop the minimum average shear strengths shown in table I.

3.4.2 Adhesive specimens prepared and tested as described in section 4 shall develop the minimum average shear strengths shown in table II.

TABLE I.—*Average shear strengths of bonded joints type I adhesive*

Condition	Strength lbs. sq. in. (min.)
Initial Shear Strength at 20° ± 1°C. (77° ± 2°F.).	900
Shear Strength at 82° ± 1°C. (180° ± 2°F.).	700
Shear Strength after immersion in fresh water for 7 days at 25° ± 1°C. (77° ± 2°F.).	700
Shear Strength after immersion in salt water for 7 days at 25° ± 1°C. (77° ± 2°F.).	700
Shear Strength after immersion in hydrocarbon test fluid for 7 days at 25° ± 1°C. (77° ± 2°F.).	700

3.5 Storage life.

3.5.1 *Type I.*—The adhesive as furnished by the manufacturer shall be capable of meeting all of the type I requirements of this specification after being stored for 3 months from date of manufacture at a temperature of 25° ± 1°C. (77° ± 2°F.), or 6 months from date of manufacture at a temperature between 5° and 10°C. (41° and 50°F.) in airtight containers.

TABLE II.—*Average shear strengths of bonded joints type II adhesive*

Condition	Strength lbs. sq. in. (min.)
Initial Shear Strength at 25° ± 1°C. (75° ± 2°F.).	900
Shear Strength at 82° ± 1°C. (180° ± 2°F.).	700
Shear Strength after immersion in fresh water for 7 days at 25° ± 1°C. (77° ± 2°F.).	500
Shear Strength after immersion in salt water for 7 days at 25° ± 1°C. (77° ± 2°F.).	500
Shear Strength after immersion in hydrocarbon Test fluid for 7 days at 25° ± 1°C. (77° ± 2°F.).	700

3.5.2 *Type II.*—The primary adhesive as furnished by the manufacturer shall be capable of meeting all of the type II requirements of this specification after being stored for 3 months from date of manufacture at a temperature of 25° ± 1°C. (77° ± 2°F.), or 6 months from date of manufacture at a temperature between 5° and 10°C. (41° and 50°F.) in airtight containers. The condition A secondary adhesive as furnished by the manufacturer shall be capable of meeting all of the type II requirements of this specification after being stored for 1 year from date of manufacture at a temperature of 25° ± 1°C. (77° ± 2°F.) in airtight containers. The condition B and C secondary adhesives as furnished by the manufacturer shall be capable of meeting all of the type II requirements of this specification after being stored for 6 months from date of manufacture at a temperature of 25° ± 1°C. (77° ± 2°F.) in airtight containers.

3.6 Instruction sheet.—The manufacturer shall provide a dated instruction sheet with each shipment of the adhesive outlining instructions for its use on clad aluminum-alloy sheet. The instruction sheet shall also cover the following:

(a) The general chemical type of the base resin used in the adhesive.
(b) Maximum usable storage life of the adhesive, with and without the addition of accelerators, at various temperatures between 41°F. and 100°F.

(c) Mixing instructions including recommended type and percentage of accelerator, maximum per cent of accelerator allowed, and temperature control necessary during mixing.
(d) Complete recommended metal cleaning processes and treatments including proportions of materials necessary to prepare cleaning media.
(e) Application instructions including spread method, number of coats, spread rate, and film thickness range.
(f) Drying time between coats and after last coat. If a force dry is required, the time and temperature shall be stated.
(g) Maximum allowable life of adhesive coated metal prior to assembly and cure.
(h) Curing cycle including recommended time, temperature, and pressure for each assembly.
(i) Any other pertinent information relative to the use and storage of the adhesive.

3.7 pH Value—secondary adhesives (type II).—The set secondary adhesive film shall develop a pH value of not less than 3.5 nor more than 11.0 when determined as described in section 4.

3.8 Workmanship.—Workmanship shall be in accordance with high-grade practice covering this class of material.

4. SAMPLING, INSPECTION, AND TEST PROCEDURES

4.1 Classification of tests.—The inspection and testing of adhesives shall be classified as follows:

(a) Qualification tests: Qualification tests are those tests accomplished on samples submitted for qualification as a satisfactory product.
(b) Inspection tests: Inspection tests are those tests accomplished on adhesive manufactured and submitted for acceptance under contract.

4.2 Qualification tests.

4.2.1 *Sampling instructions.*—The Qualification test samples shall consist of at least 1 gallon of each type and condition of adhesive (type II materials require 1 gallon each of primary and secondary adhesives) on which qualification is desired. Samples shall be forwarded to the Supply and Fiscal Officer, Naval Air Material Center, Naval Base, Philadelphia 12, Pa., Attention Superintendent, Aeronautical Materials Laboratory, plainly and durably marked with the following information:

Sample for Qualification Test
ADHESIVE; METAL TO WOOD, STRUCTURAL
Type and Condition

Name of Manufacturer
Manufacturer's Designation
Date of Manufacture
Submitted by (name) (date) for qualification test in accordance with Specification MIL–A–928A under authorization (reference authorizing letter).

4.2.1.1 *Manufacturer's instructions.*—Two copies of the mixing, application, and curing instructions for the adhesive shall also be furnished for approval with the qualification test samples.

4.2.2 *Tests.*—The Qualification tests of adhesives shall consist of all the tests of this specification, and shall include approval of the manufcaturer's instruction sheet.

4.3 Inspection tests.—The contractor shall furnish all samples and shall be responsible for accomplishing the required tests. When inspection is conducted at the contractor's plant, all inspection and testing shall be under the supervision of the Government inspector. Contractors not having laboratory facilities satisfactory to the Government shall engage the services of a commercial testing laboratory acceptable to the procuring agency. The contractor shall furnish test reports, in duplicate, showing quantitative results for all tests required by this specification, and signed by an authorized representative of the contractor or laboratory, as applicable. Acceptance or approval of material during course of manufacture shall in no case be construed as a guaranty of the acceptance of the finished product.

4.3.1 *Navy Department inspection.*—When procurement is inspected under the supervision of the Navy Department, the general inspection procedures shall be in accordance with the Navy Department General Specifications for Inspection of Material.

4.3.2 *Sampling instructions (adhesives).*—Two separate 1-quart samples of adhesive from different containers shall be taken from each lot. Each sample shall be divided into two parts. One-half of each sample shall be used to conduct the necessary tests. The other halves shall be sealed in separate airtight containers and shall be held for referee tests for a period not exceeding that of the actual storage life of the materials. Additional samples may be taken if considered necessary by the Government inspector to determine conformance of the product to the requirements. For type II materials, 2 quarts of the primary and secondary adhesives, together with sufficient accelerator, if required, shall be taken from each lot. A lot shall consist of adhesive of one type and condition, manufactured at one time in one batch, forming part of one contract or order, and submitted for inspection at the same time and place.

4.3.3. *Tests.*—Samples of adhesives shall be subjected to the following tests as described under "Test Methods" of this specification.

(a) Examination of Product
(b) Initial Shear Strength
(c) Shear Strength after Immersion in Fresh Water

4.3.3.1 In addition, the adhesive shall be subjected to any of the other tests specified herein which the inspector considers necessary to determine conformance with the requirements of this specification.

4.3.4 *Sampling for inspection of containers (at contractor's plant).*—A random sample of filled containers shall be selected by the Government inspector in accordance with Standard MIL–STD–105 at inspection level I and acceptable quality level—2.5 per cent defective to verify compliance with this specification regarding fill, closure, marking, and other requirements not involving tests. Each sample-filled container shall be examined for defects of construction of the container and the closure, for evidence of leakage, and for unsatisfactory markings. Each filled container shall also be weighed to determine the amount of contents. Any container in the sample having one or more defects, or under required fill, shall be rejected, and if the number of defective containers in any sample exceeds the acceptance number for the appropriate sampling plan of Standard MIL–STD–105, the lot represented by the sample shall be rejected. Rejected lots may be resubmitted for acceptance tests, provided the contractor has removed (or reworked) all nonconforming containers.

4.3.5 Rejection and retest.—If any of the samples of adhesives selected to represent a particular lot of material fails to meet the requirements of this specification, the remainder of the sample shall be tested. If the sample fails on the retest, the entire lot of adhesive represented by the sample shall be rejected. If, in the opinion of the inspector, failure of any sample or specimen to meet the requirements of this specification is possibly due to poor bonding technique, a retest shall be allowed. Rejected material shall not be resubmitted for approval without full particulars being furnished to the inspector concerning previous rejection and measures taken to overcome the defects.

4.4. Test Conditions.

4.4.1 *Preparation of specimens.*—Specimen preparation shall be identical for both types of adhesive except where otherwise indicated.

4.4.1.1 *Mixing and thinning of adhesive.*—The adhesive shall be mixed and thinned, if necessary, in accordance with the manuacturer's instructions.

4.4.1.2 *Shear specimens.*—The test specimens shall conform to the form and dimensions shown in method 1032 of Specification MMM–A–175. The test specimens shall have a one-sixteenth of an inch thick yellow birch veneer core and 0.032 inch thick faces of aluminum clad aluminum alloy conforming to the requirements of Specification QQ–A–362. The birch veneer shall have a moisture content of 6 to 12 per cent determined in accordance with Specification MIL–W–6110. The veneer shall conform to the requirements of Specification MIL–P–6070. The shear specimens shall be prepared as follows:

Type I adhesives	*Type II adhesives*
1. Twenty pieces of aluminum alloy shall be cut to the dimensions 4 by 12 inches.	
2. Ten pieces of yellow birch veneer shall be cut to the same dimensions, with grain running parallel to the short dimensions.	
3. The aluminum-alloy pieces shall be cleaned in accordance with the manufacturer's instructions.	
4. The adhesive shall be applied to both surfaces of the birch core, and to the one contacting surface of each metal face or as specified in the approved manufacturer's instructions. The adhesives shall then be air-dried and precured in accordance with the manufacturer's instructions.	4. The primary adhesive shall be applied to one side of the aluminum-alloy sheets, air-dried, precured, and cured in accordance with the approved instructions of the manufacturer.
5. Not applicable to type I. See step 6.	5. The secondary adhesive shall be applied to both contacting surfaces of the veneer and to the cured primary adhesive-coated aluminum-alloy sheet. (The amount of secondary adhesive applied to each surface is usually between 6 and 7.5 grams. This is based on 40–50 lbs/1,000 sq ft of single adhesive line.)
6. The panels shall be assembled by placing one yellow birch veneer core between two aluminum-alloy sheets so that the adhesive-coated surfaces of both the birch core and the aluminum alloy-sheets are in contact. Type II, condition A, adhesive test specimens shall be thus assembled within the maximum open assembly time specified by the manufacturer.	
7. The assembly shall be placed in a heated press and cured at the temperature and for the time interval specified by the manufacturer. The pressure applied shall not exceed 50 pounds per square inch.	7. A pressure not exceeding 50 pounds per square inch shall be applied to the assembly. For condition A, the assembly shall be allowed to remain under pressure for 8 to 16 hours at 25° ± 1°C. (77° ± 2°F.). For conditions B and C, the assembly shall be cured under pressure at the temperature and for the interval specified by the manufacturer in his written instructions. The assembly shall be allowed to cool

to room temperature under pressure. Conditions A, B, and C, assemblies shall be allowed to condition for 6 to 7 days at 25° ± 1°C. (77° ± 2°F.) before cutting into specimens.

8. After the specified curing cycle, the bonded panels shall be removed and allowed to cool to room temperature.

9. The 10 panels shall be: (a) cut and, (b) numbered 1 through 100 according to method 1032 of Specification MMM-A-175.

4.5 Test methods.—Test methods shall be identical for both types of adhesive, except where otherwise indicated.

4.5.1 *Examination of product.*—The adhesive shall be examined to determine conformance with the requirements of this specification with respect to materials and workmanship.

4.5.2 *Shear strength of bonded joints.*—Tests shall be conducted in accordance with the methods prescribed in Specification MMM-A-175. If the wood utilized for the test is not capable of yielding the minimum strengths specified, a new lot of wood shall be selected for tests. The specimens shall be tested as follows:

4.5.2.1 *Initial shear strength.*—Specimens numbered 1, 6, 11, 16, etc., shall be placed in distilled water at the temperature specified in section 3 and allowed to remain therein for 1 hour. They shall then be allowed to dry overnight at 24° to 27° C. (75° to 80° F.) and a relative humidity of 50 to 70 per cent and tested in the dry state.

4.5.2.2. *Shear strength at elevated temperature.*—Specimens numbered 2, 7, 12, 17, etc., shall be conditioned at the temperature specified in section 3 for 1 hour and shall then be tested in a heat chamber at that temperature.

4.5.2.3 *Shear strength after immersion in fresh water.*—Specimens numbered 3, 8, 13, 18, etc., shall be allowed to remain in distilled water under the conditions specified in section 3, and shall then be tested in the wet state.

4.5.2.4 *Shear strength after immersion in salt water.*—Specimens numbered 4, 9, 14, 19, etc., shall be allowed to remain in a 3 per cent salt solution under the conditions specified in section 3 and shall then be tested in the wet state.

4.5.2.5 *Shear strength after immersion in hydrocarbon test fluid.*—Specimens numbered 5, 10, 15, 20, etc., shall be allowed to remain in hydrocarbon test fluid conforming to Specification MIL-H-3136, type II, under the conditions specified in section 3, and shall then be tested immediately after being removed from the test fluid.

4.5.3 *Storage life.*

4.5.3.1 *Type I adhesive.*—A suitable amount of the type I adhesive being tested shall be stored under the conditions specified in section 3. At the end of the specified storage period, the adhesive shall be capable of meeting the type I requirements of this specification for Initial Shear and Shear Strength after Immersion in Salt Water (10 specimens each).

4.5.3.2 *Type II adhesives.*—A suitable amount of the type II primary adhesive and the designated secondary adhesive shall be stored under the conditions specified in section 3. After the specified time interval has passed, the adhesive combination shall meet the type II requirements of this specification for Initial Shear and Shear Strength after Immersion in Salt Water (10 specimens each). To expedite qualification tests, type II, condition A, secondary adhesives that have been qualified under the requirements of Specification JAN–A–397 need not be subjected to the 1-year storage life tests.

4.5.4 *Solubility.*—The spreading equipment (brushes, etc.) shall be washed in the specified solvent and examination made for evidence of nonsolubility.

4.5.5 *pH value.*—The adhesive shall be prepared and tested in accordance with method 4011 of Specification MMM–A–175.

4.5.6 *Working life.*—Pour approximately 200 grams of freshly mixed adhesive into a large glass test tube or beaker approximately 35 mm in diameter, provided with a glass stirring rod, and immerse the tube with contents in a water bath held at 73.5° ± 2°F. Stir the adhesive frequently with the rod, and note the time at which the adhesive is considered to be definitely no longer spreadable on a wood surface with stiff bristle brush. The time to reach this consistency after mixing is the liquid working life of the adhesive at 73.5° ± 2°F.

5. PREPARATION FOR DELIVERY

5.1 Application.—The requirements specified herein apply only to direct purchases by or direct shipments to the Government.

5.2 Packaging.

5.2.1 *Unit packaging.*—Unless otherwise specified, all adhesives and accelerators, shall be furnished in cans, pails, or drums. If packaged in cans and an accelerator or a two-part adhesive is required, the metal containers for both the adhesive or adhesives, and the equivalent proportions of accelerator required shall be included in a unit fiberboard box; the quantities of the adhesive or adhesives and accelerator so packaged, when mixed according to the manufacturer's instructions, shall produce the specified quantity of adhesive. The fiberboard boxes shall conform to Specification JAN–P–108. If adhesive is packaged in pails or drums it will be necessary that the pails or drums, with their proportionate additional containers of adhesive or accelerator, if applicable, be packaged together. This may be accomplished through the utilization of multiple compartment metal containers or suitable modified single compartment containers. When shipment is to be made in a modified single compartment container, it will be necessary to submit the proposed container or a drawing of the same to the procuring agency, prior to shipment. The capacity of all adhesive containers shall be as specified by the procuring agency. The metal containers shall be in accordance with the following requirements, as applicable:

5.2.1.1 *Liquid materials.*—Liquid materials shall be packaged in type IV cans conforming to Specification MIL–C–124 or in 6- to 55-gallon metal drums (open top style with bolted ring closures and with side seams welded), conforming to Interstate Commerce Commission Regulations, Specification 37D.

5.2.1.2 *Powdered and jelly-type materials.*—Powdered or jelly-type materials shall be packaged in type IV cans or type VI 5-gallon pails with lug closures conforming to Specification MIL–C–124; or in 6- to 55-gallon open top style metal drums with bolted ring seal closures and with side seams welded, conforming to Interstate Commerce Commission Regulations, Specification 37D.

5.2.2 *Cushioning.*—Unless otherwise specified by the procuring agency, when unit fiberboard boxes are required, the contents shall be secured snugly by means of vertical separators, fiberboard, or corrugated paper to fill voids and cushioning material conforming to Specification UU–C–843. The fiberboard shall be made of single- or double-wall corrugated board, and the corrugated paper shall be flexible and single-faced.

5.3 Packing.—Unless otherwise specified, all materials shall receive domestic packing. Shipping containers shall contain an identical number of like packages and shall be of a uniform size and designed to inclose the contents in a snug, tight-fitting manner. The gross weight of exterior shipping containers containing cans, when packed for shipment, shall not exceed 200 pounds. When adhesives are packaged in metal pails or drums, they shall require no overpacking for domestic or oversea shipment.

5.3.1 *Domestic packing.*—Unless otherwise specified by the procuring agency, unit packages or one part adhesive cans without accelerators, as applicable, shall be packed in substantial commercial shipping containers so constructed as to insure acceptance by common or other carrier for safe transportation, at the lowest rate, to the point of delivery. Except as specified herein, the shipping container shall conform to the requirements of Consolidated Freight Classification Rules in effect at the time of shipment. The use of corrugated or solid fiberboard having a minimum Mullen test of less than 275 pounds is prohibited. Containers shall be able to withstand storage, rehandling, and reshipment, without the necessity of repacking.

5.3.2 *Oversea packing.*—Unless otherwise specified by the procuring agency, for oversea packing, unit packages of two part adhesive or cans of single adhesive without accelerators, as applicable, shall be packed in cleated plywood, nailed wood or wirebound wood boxes conforming to Specification JAN–P–105, JAN–P–106 or JAN–P–107, respectively. Plywood, if used, shall conform to Specification JAN–P–139, type A or B, condition I.

5.4 Marking and labeling.

5.4.1 *Packages.*—Each unit package, can, pail, drum, etc., as applicable, shall be marked in accordance with MIL–STD–129. Each package shall have "Storage Precautions" printed thereon. Secondary adhesives shall have the following information marked thereon: "Use only with primary adhesive, Manufacturer's Designation ...."

5.4.2 *Shipping containers.*—In addition to any special marking required by the contract or order, shipping containers shall be marked in accordance with MIL–STD–129.

6. NOTES

6.1 Intended use.

6.1.1 *Type I adhesives.*—The type I adhesive covered by this specification is intended primarily for use in the structural bonding of aluminum alloy to wood. It shall not be used in aircraft for the fabrication of primary structure or for adhering wood to any metal other than aluminum alloy without the specific approval of the procuring agency.

6.1.2 *Type II adhesives.*—Type II adhesives covered by this specification are intended primarily for use in fabricating aluminum-wood-aluminum structural sandwich panel constructions, particularly where low density wood cores are used, as well as for the structural bonding of aluminum to wood attachments not of sandwich type construction. It shall not be used in aircraft for the fabrication of primary structure or for adhering wood to any metal other than aluminum alloy with specific approval of the procuring agency. Type II, condition A adhesive is intended for applications where small areas are involved or where heat cannot be used in the final assembly operation. Type II, condition B and C adhesive is intended for use in cases where the fabrication of large items necessitates a final assembly time exceeding that permissible with the condition A adhesive.

6.2 General.—In the design of parts and assemblies requiring the use of adhesives covered by this specification, consideration should be given to the heat and pressure required during the bonding operation. The curing of the bonded joint in the case of type I bonding, or the prime coat in the case of type II bonding, may be expected to require a curing temperature as high as 325°F. The curing pressure of 50 psi specified in section 3 is a necessary requirement for determining the suitability of an adhesive or adhesive combination for general production use. However, shop facilities permitting higher pressures in accordance with the manufacturer's instructions may be used wherever practicable.

6.3 Storage.—Wherever practicable, adhesive conforming to this specification should be stored at a temperature of 5° to 10°C. (41° to 50°F.). If transit and normal storage conditions necessitate exposure of the adhesive for prolonged periods to temperatures in excess of 80°F., it can be expected, in general, that the storage life of the adhesive will be proportionally reduced.

6.4 Ordering data.—Requisitions, contracts, and orders should state the type, condition, and form of adhesive desired, the capacity of containers, the quantity desired, and whether oversea packing shall be furnished, if applicable (see sec. 5). Due to the age deterioration characteristics of these adhesives, they should not be procured in quantities the use of which will require longer than 6 months.

6.5 Provisions for qualification tests.—The right is reserved to reject bids on products that have not been subjected to the required tests and found satisfactory. The attention of suppliers and manufacturers is called to this requirement and they are urged to request authorization for tests of the adhesives which they propose to offer to the Air Force or Navy under this specification. Requests for authorization of tests, together with certified test reports showing conformance of the product with all of the requirements of this specification should be addressed to the Director, Naval Air Experimental Station, Naval Air Material Center, Naval Base, Philadelphia 12, Pa.

6.5.1 It is to be understood that upon receipt of the letter of authorization, samples shall be furnished at no cost to the Government, and that the manufacturer shall pay the transportation charges to and from the designated point where tests are to be made. In the case of failure of the sample or samples submitted, consideration will be given to the request of the manufacturer for additional tests only after it has been clearly shown that changes have been made in the product which the Government considers sufficient to warrant additional tests.

Notice.—When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodians:

Army—Signal Corps
Navy—Bureau of Aeronautics
Air Force

Other interests:

Army—CEOQT
Navy—OrShS

MIL-A-928A AMENDMENT-1: ADHESIVE; METAL TO WOOD, STRUCTURAL

This amendment forms a part of Military Specification MIL-A-928A, 6 August 1952, and has been approved by the Department of Defense for use by the Departments of the Army, the Navy, and the Air Force.

Pages 1 and 2, paragraph 2.1.1: Add to the listed Federal Specifications: "NN-P-515 Plywood, Container Grade." Delete Specification JAN-P-139 from the listed Military Specifications. Delete the Navy Department General Specifications for Inspection of Material.

Page 3, paragraph 3.5.1, lines 3 and 4: Delete lines 3 and 4 and insert "meeting Type I requirements for initial Shear Strength, Shear Strength after Immersion in Salt Water, and Working Life after being stored for 3 months."

Page 4, paragraph 3.5.2, lines 3, 11 and 18: Delete "all of."

Page 4, paragraph 3.5.2, lines 4, 12 and 19: Delete "of this specification" and insert "for Initial Shear Strength, Shear Strength after Immersion in Salt Water, and Working Life."

Page 5, paragraph 4.2.1: Add new subparagraph as follows: "4.2.1.2. In addition, quantitative basic formulation data (ingredients identified by chemical and trade names and specification numbers, if any) of the material(s) shall accompany the samples. All information submitted will be treated as commercially confidential."

Page 5, paragraph 4.3.1: Delete the paragraph.

Page 8, paragraph 4.5.3.1, line 7: Between "for" and "initial" add "Working Life."

Page 8, paragraph 4.5.3.2, line 8: Between "for" and "initial" add "Working Life," *Page 9, paragraph 5.3.2, penultimate and last line:* Delete "JAN–P–139, type A or B, condition I" and insert "NN–P–515, Type I or II, Class 2."

Page 10, paragraph 6.5, line 11: After "showing" add "the results (individual and average) indicating."

Page 11, paragraph 6.5, line 13: After "specification" add "and certifying that test specimens were prepaid in accordance with the Instruction Sheet."

Custodians:

Army—Signal Corps
Navy—Bureau of Aeronautics
Air Force

Other interests:

Army—GEOQ
Navy—OrSh

APPENDIX III

DIRECTORY OF ADHESIVE AND EQUIPMENT MANUFACTURERS

PART A: MANUFACTURERS AND KEY NUMBERS OF PRODUCTS LISTED IN THE "ADHESIVE IDENTIFICATION AND PROPERTIES CHART"

PART B: ALPHABETICAL LISTING OF ADDITIONAL MANUFACTURERS WITH TRADE NAME DESIGNATIONS

PART C: EQUIPMENT MANUFACTURERS

PART A

MANUFACTURERS AND KEY NUMBERS OF PRODUCTS LISTED IN THE "ADHESIVE IDENTIFICATION AND PROPERTIES CHART"

Key Number	Manufacturer
1, 2, 3, 4, 5, 6, 7, 8	ARMSTRONG PRODUCTS CO. Argonne Road Warsaw, Indiana
9	APPLIED PLASTICS CO., INC. 130 Penn St. El Segundo, Calif.
10, 11, 12, 13, 14, 15, 16, 17	RUBBER AND ASBESTOS CORP. 225 Belleville Ave. Bloomfield, N. J.
18	B. B. CHEMICAL CO. 784 Memorial Drive Cambridge 39, Mass.
19, 20	BLOOMINGDALE RUBBER CO. Box 453 Aberdeen, Maryland
21, 22	CARBOLINE CO. 32 Hanley Industrial Court St. Louis 17, Missouri
23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34	POLYMER INDUSTRIES, INC. Springdale Connecticut
35	ADHESIVE ENGINEERING Div. of Hiller Aircraft Corp. 1411 Industrial Road San Carlos, Calif.
36, 37, 38, 39, 40	CYCLEWELD PRODUCTS DIV. Chrysler Corp. 5437 W. Jefferson Ave. Trenton, Mich.

Key Number	Manufacturer
41, 42, 43, 44	STRUCTURAL PRODUCTS DIV. National Starch Products, Inc. 750 Third Ave. New York 17, N. Y.
45	EASTMAN CHEMICAL PRODUCTS, INC. Kingsport Tennessee
46, 47, 48, 49, 50, 51, 52	MINNESOTA MINING AND MFG. CO. Adhesives, Coatings and Sealers Div. 900 Bush Ave. St. Paul 6, Minn.
53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66	EMERSON & CUMING, INC. 869 Washington St. Canton, Mass.
67, 68, 69, 70, 71, 72, 73, 74, 75	FURANE PLASTICS, INC. 4516 Brazil St. Los Angeles 39, Calif.
76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91	INDUSTRIAL CHEMICALS DIV. Shell Chemical Co. 17500 West Eight Mile Rd. Detroit 35, Mich.
92	H. V. HARDMAN CO. 571 Cortlandt St. Belleville 9, N. J.
93, 94, 95, 96, 97, 98, 99, 100	THE EPOXYLITE CORP. 10829 East Central Ave. El Monte, Calif.
101, 102, 103, 104, 105, 106, 107	CO-POLYMER CHEMICALS, INC. 12350 Merriman Rd. Livonia, Mich.
108, 109	BLOOMINGDALE RUBBER CO. Box 453 Aberdeen, Maryland
110, 111, 112, 113, 114, 115	CARL H. BIGGS CO., INC. 1547 Fourteenth St. Santa Monica, Calif.
116	BLOOMINGDALE RUBBER CO. Box 453 Aberdeen, Maryland

Key Number	Manufacturer
117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129	HYSOL CORP. 322 Houghton Ave. Olean, New York
130, 131, 132	ARMSTRONG CORK CO. Lancaster Pennsylvania
133, 134, 135, 136, 137	LEFFINGWELL CHEMICAL CO. P.O. Box 1187, Perry Annex Whittier, Calif.
138	MOBAY CHEMICAL CO. 1815 Washington Road Pittsburgh 34, Penna.
139, 140	THE MARBLETTE CORP. 37-31 30th St. Long Island City 1, N. Y.
141, 142, 143, 144, 145	MERECO PRODUCTS DIV. Metachem Resins Corp. 530 Wellington Ave. Cranston 10, R. I.
146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165	MATERIALS DIVISION Narmco Industries, Inc. 600 Victoria St. Costa Mesa, Calif.
166	MIRACLE ADHESIVES SALES CORP. 250 Pettit Ave. Bellemore, L. I., New York
167, 168	H. V. HARDMAN CO. 571 Cortlandt St. Belleville 9, N. J.
169	BORDEN CHEMICAL CO. Div. of the Borden Co. 350 Madison Ave. New York 17, N. Y.
170, 171, 172, 173, 174, 175, 176, 177, 178	ADHESIVES DIV. B. F. Goodrich Industrial Products Co. 500 S. Main St. Akron 18, Ohio
179	COAST PRO-SEAL & MFG. CO. 2235 Beverly Blvd. Los Angeles 57, Calif.

Key Number	Manufacturer
180, 181, 182	CORNING GLASS WORKS Corning New York
183, 184, 185, 186, 187, 188, 189, 190	RAYBESTOS-MANHATTAN INC. Adhesives Dept. Bridgeport 2, Conn.
191	BORDEN CHEMICAL CO. Div. of the Borden Co. 350 Madison Ave. New York 17, N. Y.
192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206	H. B. FULLER CO. 255 Eagle St. St. Paul 2, Minn.
207	W. S. SHAMBAN & CO. Polytex Div. 11617 W. Jefferson Blvd. Culver City, Calif.
208, 209, 210, 211, 212, 213, 214, 215	MINNESOTA MINING AND MFG. CO. Adhesives, Coatings and Sealers Div. 900 Bush Ave. St. Paul 6, Minn.
216, 217, 218, 219, 220, 221, 222, 223, 224, 225	THE U. S. STONEWARE CO. Adhesives Div. Akron 9, Ohio

PART B

ALPHABETICAL LISTING OF ADDITIONAL MANUFACTURERS WITH TRADE NAME DESIGNATIONS

Manufacturer	Trade Name
Acme Resin Corp. 1401 Circle Ave. Forest Park, Ill.	ACME
Adhesive Products Corp. 1660 Boone Ave. New York 60, N. Y.	ADLOK, POLYWELD
Aerojet-General Corp. Structural Materials Div. P. O. Box 296 Azusa, Calif.	AEROREZ
American Latex Products Corp. 3341 W. El Segundo Blvd. Hawthorne, Calif.	STABOND, VULCABOND
American-Marietta Co. Adhesive, Resin & Chemical Div. 3400 13th Ave., S.W. Seattle 4, Wash.	AMRES
American Metaseal Corp. 607 - 65th St. West New York, N. J.	FIX-MIX
Atlas Mineral Products Co. Mertztown Pennsylvania	AMPHESIVE
Bond Adhesives Co. 120 Johnston Ave. Jersey City, N. J.	BOND CEMENT
Catalin Corp. 1 Park Ave. New York 16, N. Y.	CATALIN
Chemical Coatings & Engineering Co., Inc. 221 Brooke St. Media, Penna.	CORROCOTE

MANUFACTURER	TRADE NAME
Chemical Industries (Unit of E. F. Van Winkle Co.) 557 Walnut St. Pasadena, Calif.	RESLOCK
Ciba Products Corp. Fairlawn New Jersey	ARALDITE, REDUX
Compo Chemical Co., Inc. Waltham Massachusetts	COMPO
Cordo Chemical Corp. 34 Smith St. Norwalk, Conn.	CORDOBOND
Dennis Chemical Co. 2701 Papin St. St. Louis 3, Mo.	DENNIS
Devcon Corp. Danvers Massachusetts	CEPOS, CD CEMENT, DEVCON
Dow Chemical Co., The Midland Michigan	D.E.N., D.E.R.
Dreyfus Co., L. A. South Plainfield New Jersey	LADCO
Farrington Texol Corp. Walpole Massachusetts	FARRINGTON
Fybrglas Industries Div. of Schramm Fiberglass Products, Inc. 3010 Montrose Ave. Chicago 18, Ill.	TWIN WELD
Goodyear Tire & Rubber Co. Chemical Division Akron 16, Ohio	PLIBOND, PLIBOND HT, PLIOGRIP, PLIOTAC
Gordon-Lacey Chemical Products Co. Maspeth New York	PLASTIBOND
Homalite Corp., The Wilmington Delaware	HOMALITE

Manufacturer	Trade Name
Isochem Resins Co. 221 Oak St. Providence 9, R. I.	ISOCHEM GEL, ISOCHEM REZ, ISOCHEM BOND
Lebec Chemical Corp. Paramount California	LEBEC
Leon Chemical Industries, Inc. 2841 E. Eleven Mile Rd. Warren, Mich.	LEOPOX
Lithgow Chemical Co. Div. of Reinhold Eng. and Plastics Co. 12827 E. Imperial Highway Norwalk, Conn.	LITHGOW
Marbon Chemical Div. Borg-Warner Corp. Washington, W. Va.	TY-PLY
Midland Adhesive and Chemical Corp. Detroit 20 Michigan	MIDLAND
Monsanto Chemical Co. Plastics Div. Springfield 2, Mass.	LAUXITE
Morningstar Paisley, Inc. 630 W. 51 St. New York 19, N. Y.	PAISLEY
Multiplastics Div. Curd Enterprises, Inc. 3337 Lincoln St. Franklin Park, Ill.	MULTIPLASTICS
National Polychemicals, Inc. Wilmington Massachusetts	POLYPHEN
Nureco, Inc. Cranston 10 Rhode Island	NURECO
Ohio Adhesives Corp. New Philadelphia Ohio	OHIO
Permacel New Brunswick New Jersey	PERMACEL

MANUFACTURER	TRADE NAME
Plastics Engineering Co. Sheboygan Wisconsin	PLENCO
Polymer Chemical Co. 5920 Carthage Ave. Cincinnati, Ohio	PERMABOND
Randolph Products Co. Carlstadt New Jersey	RANDOLPH
Reichhold Chemicals Inc. RCI Bldg. White Plains, N. Y.	EPOTUF, POLYOX, POLYLITE, PLYOPHEN
Ren Plastics, Inc. 5422 S. Cedar Lansing 9, Mich.	REN
Rezolin, Inc. 1651 18th St. Santa Monica, Calif.	REZOLIN, EPOLOY, EPOLITE
Rubba, Inc. 1015 E. 173rd St. New York 60, N. Y.	RUBBAGRIP
Schwartz Chemical Co., Inc. 50-01 Second St. Long Island City 1, N. Y.	REZ-N-GLUE
Steelcote Mfg. Co. 3418 Gratiot St. Louis, Mo.	EPO-LUX, THIOBOND, STEELCOTE "500"
Synco Resins Inc. Bethel Connecticut	SYNCO
Tylene Plastics, Inc. P. O. Box 343 Michigan City, Ind.	TYLENE
UBS Chemical Corp. Div. of A. E. Staley Mfg. Co. 491 Main St. Cambridge 42, Mass.	FLEXWELD
Union Carbide Plastics Co. Div. of Union Carbide Corp. 270 Park Ave. New York, N. Y.	BAKELITE

Manufacturer	Trade Name
U. S. Plywood Corp. 55 W. 44th St. New York 18, N. Y.	PLYCOZITE
Williamson Adhesives, Inc. 8220 Kimball Ave. Skokie, Ill.	PLASTIC MASTIC
Xylos Rubber Co. Div. of The Firestone Tire & Rubber Co. Akron 1, Ohio	LOXITE

PART C

EQUIPMENT MANUFACTURERS

Application Equip.

(Caulking guns, spraying equip. etc.)

American Type Founders
200 Elmora Ave.
Elizabeth, New Jersey

B. B. Chemical
Bostik Dept.
784 Memorial Drive
Cambridge, Mass.

Binks Manufacturing Co.
3114 Carroll Ave.
Chicago 12, Illinois

Black Bros.
Mendota
Illinois

De Vilbiss Co.
Toledo 1
Ohio

Emhart Manufacturing Co.
Portland Div.
Portland, Conn.

John P. Fox
1107 S. Mountain Ave.
Monrovia, Calif.

New Plastic Corp.
1026 N. Sycamore Ave.
Los Angeles 38, Calif.

Plasmadyne Corp.
3839 S. Main St.
Santa Ana, Calif.

Plaster Supply House
Box 551
Chicago 90, Illinois

Plastic Welding Corp.
841 Frelinghuysen Ave.
Newark 12, New Jersey

Potdevin Machine Co.
297 North St.
Teterboro, New Jersey

Semco Sales & Service, Inc.
1313 W. Florence Ave.
or
3141 W. Century Blvd.
Inglewood, Calif.

Sta-Warm Electric Co.
Ravenna
Ohio

Union Tool Corp.
Warsaw
Indiana

United Shoe Machinery Corp.
140 Federal St.
Boston, Mass.

Metering and Mixing Equip.

Baker-Perkins Co.
1000 Hess St.
Saginaw, Mich.

Binks Manufacturing Co.
3114 Carroll Ave.
Chicago 12, Ill.

Coleman Instruments
42 Madison St.
Maywood, Ill.

Conn & Co.
James St.
Warren, Penna.

Dake Corp.
Grand Haven
Michigan

J. H. Day
4932 Beech St.
Cincinnati 12, Ohio

Delsen
719 W. Broadway
Glendale 4, Calif.

H. V. Hardman Co., Inc.
577 Cortland St.
Belleville 9, N. J.

Industrial Enterprises
Edmund and Shelmire Sts.
Philadelphia 36, Penna.

Jiffy Mixer Co.
515 Market Bldg.
San Francisco 5, Calif.

Lapp Insulator Co.
Process Equip. Div.
102 Hall St.
Le Roy, New York

J. M. Lehmann Co.
Lyndhurst
New Jersey

Mixing Equip. Co. Inc.
170 Mt. Read Blvd.
P.O. Box 1370
Rochester 3, N. Y.

Munson Mill
Seward Ave. & Lasher
Utica 1, New York

Norcross Corp.
247 Newtonville Ave.
Newton 58, Mass.

NoVo Industrial
Mitchell Specialty Div.
Holmesburg
Philadelphia 36, Penna.

E. T. Oakes
Commack Rd.
Islip, L. I., New York

Plaster Supply House
Box 551
Chicago 90, Ill.

Richardson Scale
668 Van Houten Ave.
Clifton, N. J.

Schutte & Koerting
Cornwells Heights
Bucks County, Penna.

Semco Sales & Service, Inc.
1313 W. Florence Ave.
Inglewood, Calif.
or
3141 W. Century Blvd.
Inglewood, Calif.

Ovens

De Vilbiss Co.
Toledo 1
Ohio

Blue M Electric Co.
138 and Chatham Sts.
Blue Island, Ill.

The Girdler Co.
High Frequency Curving
76 Beaver St.
New York, N. Y.

R. C. Mahon
Industrial Equipment Div.
Detroit, Mich.

Modern Lab Equip. Co., Inc.
1811–1st Ave.
New York, N. Y.

Ramco Equipment Corp.
Div. of Randall Mfg.
801 Edgewater Rd.
New York, N. Y.

Trent Inc.
211 Leverington Ave.
Philadelphia 27, Penna.

Testing Equip.

Amasco Products
79-22 71st Ave.
Glendale, New York

Bulova Research & Development Laboratories, Inc.
62-10 Woodside Ave.
Woodside, New York

M B Electronics
Div. of Textron Electronics, Inc.
781 Whalley Ave.
New Haven, Conn.

Sika Chemical Corp.
Passaic
New Jersey

Standard Cabinet Co., Inc.
56 Washington Ave.
Carlstadt, N. J.

Tenney Engineering, Inc.
1090 Springfield Rd.
Union, N. J.

Testing Machines, Inc.
72 Jericho Turnpike
Mineola, New York

Tinius Olsen Testing Machine Co.
East Road
Willow Grove, Penna.

GLOSSARY

A-Stage: Primary phase in the reaction of thermosetting mixtures during which the material is still soluble and fusible. This stage is characterized by an initial lowering of viscosity.

Accelerator: A material that triggers or speeds up polymerization, vulcanization or condensation reactions. It differs from a catalyst in that it becomes a part of the resultant compound and loses its chemical identity.

Adherend: A body held to another body by an adhesive.

Adhesion: State in which surfaces are held together by the action of interfacial forces, which may consist of valence forces (chemical adhesion), interlocking action (mechanical adhesion) or both.

Adhesive: Substance capable of maintaining a surface bond between materials.

Adhesive, Cold-Curing: Adhesive capable of curing at temperatures below 68°F. approx.

Adhesive, Heat-Curing: Adhesive capable of curing at temperatures above 212°F. approx.

Adhesive, Intermediate Temperature Curing: Adhesive capable of curing at temperatures between 87° and 211°F., approx.

Adhesive, Room Temperature Curing: Adhesive capable of curing at temperatures between 68°–86°F. approx.

Adhesive Failure: Bond failure at interfaces.

Adhesive, Separate Application: A two-part adhesive which is used by applying one part to one adherend and one part to the other and bringing them together to form a bond.

Assembly: Parts or surfaces put together for bonding or already bonded.

Autoclave: A heavy vessel for controlled heat and pressure application.

B-Stage: Intermediate phase in the reaction of thermosetting mixtures during which the material gels and is not completely fused. This stage is characterized by a progressive increase in viscosity.

Bend Test: Method of testing the ability of an adhesive to maintain a bond under flexing.

Bonding: Joining materials by the use of adhesives.

C-Stage: Final phase in the reaction of thermosetting mixtures at which the material is fully cured and has become relatively insoluble and infusible.

Catalyst: A substance added in minor quantities to the adhesive mixture in order to speed up its cure. It does not lose its chemical identity in the reaction.

Cohesion: The state in which the particles of the adhesive or adherend are held together by primary or secondary valence forces.

Cohesive Failure: Bond failure within the adhesive layer.

Crazing: Breaking up into cracks, either under surface or throughout entire adhesive layer.

Creep (or Cold Flow): Dimensional deformation of material under load developing with time.

Cure: Development of the bonding properties of an adhesive by chemical reaction, such as condensation, polymerization or vulcanization, usually induced by the action of heat, and/or catalysts or accelerators, alone or in combination, with or without pressure.

Curing Agent: General term used for accelerators, catalysts and resins added to adhesive mixtures for promoting or controlling the curing reaction.

Cyclizing: Hardening and toughening of a rubber surface by chemical means, usually sulfuric acid, to render it more suitable for bonding. Fissures on surface are usually formed in this process.

Dielectric Strength: The amount of voltage necessary to break down the electric insulating properties of an adhesive film of one mil (one thousandth of an inch) thickness.

Dimensional Stability: Retention of the exact shape of a part or material.

Doctor Blade: Mechanism which by scraping off excess material controls the amount of adhesive on spreader roll or on the surface being coated.

Elasticity, Modulus of: Stress/strain ratio in an elastically deformed material.

Exotherm: Heat given off by chemical reaction.

Faying Surface: Surface of a body which comes in contact with another body to which it is fastened.

Filler: Nonadhesive material added to an adhesive to improve its properties.

Fillet: Used to describe junction formed by skin and core in honeycomb constructions.

Gel: Semi-solid material formed from colloidal dispersions on standing.

Glue Line: Area containing adhesive layer.

Glue Line, Starved: A glue line which has an insufficient amount of adhesive to produce a satisfactory bond.

Honeycomb Core: Sheet metal or resin impregnated sheet material formed into hexagonal cells and used for sandwich construction.

Joint: The area where two adherends are held together by an adhesive layer.

Joint, Lap: Joint produced by placing one adherend partly over another and bonding the overlaid portions.

Joint, Scarf: Joint produced by fitting the bevelled parts of two adherends and bonding them.

Laminate: Two or more layers of material or materials bonded together.

Pick Up Roll: A device for picking up adhesive from a reservoir and transferring it to a spreading mechanism.

Polymerization: A chemical reaction in which several simpler molecules are linked together to form a more complex molecule (polymer) having the same empirical formula as the simpler ones and whose molecular weight is a multiple of that of the original substance.

Pot Life: The period during which a thermosetting adhesive mixture remains usable after the addition of a curing agent.

Primer: A special coating applied to an adherent surface prior to the application of an adhesive to improve bond performance.

Resin: Solid or semi-solid organic substance of natural or synthetic origin, nonvolatile and generally of high molecular weight.

Roll Coater: Equipment for the mechanical application of adhesives to flexible materials.

Room Temperature: For nonmilitary applications generally defined as being between 68°–86°F.; for military 70°–80°F.

Sagging: Running or flowing off adherent surface by adhesive; caused by application of excess material or material too low in viscosity.

Sandwich Panel: Assembly made up of a light weight core to which metal skins or "facings" have been bonded on both sides.

Setting: Chemical or physical action by which an adhesive changes to a hardened state.

Shelf Life: The storage period during which an adhesive remains usable.

Strength, Impact: Ability of the glue line to resist shock by a physical blow directed against it, measured in terms of foot/pound.

Strength, Peel: Ability to resist peel stress; point of failure under peel stress usually expressed in weight per unit area.

Strength, Shear: Ability to resist shear stress; point of failure under shear stress usually expressed in weight per unit area.

Strength, Tensile: Ability to resist tensile stress; point of failure under tensile stress usually expressed in weight per unit area.

Stress: Mutual forces between surfaces of bodies.

Stress, Cleavage: Encountered when forces exerted on the joint are concentrated at the edge of a rigid bonded area.

Stress, Peel: Encountered when forces exerted on the joint tend to pull away or strip off one of the adherent surfaces.

Stress, Shear: Encountered when forces exerted on the joint are in same plane as the adhesive layer.

Stress, Tensile: Encountered when forces exerted on the joint are perpendicular to the adhesive layer.

Surface Preparation: Physical or chemical methods, such as abrading, solvent cleaning, anodizing or etching used to render adherent surface suitable for bonding.

Tape: Adhesive in dry film form with or without supporting fabrics.

Tests, Accelerated: Testing materials by exposure to intensified duplication of service conditions, such as aging, weathering, etc.

Tests, Destructive: Tests in which assemblies are destroyed in order to evaluate the maximum performance of the bond under specific conditions and stresses.

Tests, Non-destructive: Tests used for inspection purposes in which the quality of the bond is evaluated without destruction of the assembly.

Thermoplastic: Ability to repeatedly soften under heat and harden by cooling.

Thermosetting: Capable of hardening to a relatively infusible state by a chemical reaction induced by the action of heat, curing agents, ultraviolet light, etc.

Thixotropic: Pertaining to adhesives whose viscosity can be lowered by isothermal agitation and which will regain their original viscosity upon rest.

Viscosity: The property of resistance to flow due to internal friction caused by cohesion in fluids.

INDEX

GUTTMANN

CONCISE GUIDE TO STRUCTURAL ADHESIVES.