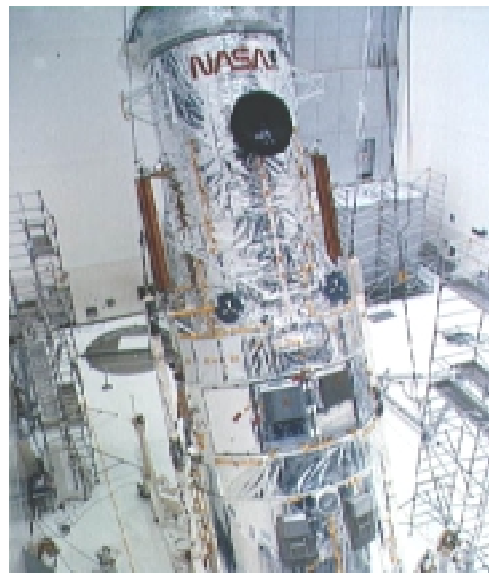
In Accordance With
NAS 5300.4 (3J-1)
MAY 1996

NASA Training Program



Student Workbook for Polymeric Applications & Inspection

May 2000

NASA

National Aeronautics and
Space Administration

In Accordance With
NAS 5300.4 (3J-1)
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NASA Training Program
Student Workbook for
Polymeric Applications and Inspection

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May 2000

National Aeronautics and
Space Administration

This document was prepared by Hernandez Engineering (HEI) under a contract with the National Aeronautics and Space Administration (NASA).

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INTRODUCTION

NASA has designated Goddard Space Flight Center/Unisys/Hernandez Engineering, Inc. and the Jet Propulsion Laboratory as the Training Centers for the Eastern Region and Western Region, respectively, of the United States. The NASA Training Centers specialize in the development and implementation of technical training courses for space flight and ground support equipment.

The courses conform to released NASA Technical Standards and are recognized by NASA.

The purpose of this course is to assure that each individual who fabricates or inspects is appropriately skilled in the types of applications involved in his/her work. This course provides the student with the theory and hands-on experience to produce or inspect Polymeric Applications. Hands-on training programs with qualified instructors are essential in training personnel to perform these tasks consistently.

POLICY MATTERS ON TRAINING

Questions regarding policy matters on training should be directed to the attention of the Manager of the Jet Propulsion Laboratory Training Center or the Goddard Space Flight Training Center, whichever is appropriate.

ENTRANCE REQUIREMENTS

A vision and color test is required as a prerequisite to the polymeric program. All personnel who perform or inspect staking and conformal coating applications must meet the minimum vision requirements as described in paragraph 3J201.

COMPLETION OF TRAINING

Upon completion of the course, students will be issued a diploma and a wallet-size card showing completion of training. A document will also be issued to the student's supervisor for employee records. All documents contain information as to the type of course, classification (operator, inspector, or instructor) date of expiration, and authorizing signatures.

Certification of trained personnel shall be provided by the supplier based upon successful completion of training.

RETRAINING

Retraining is based on performance and application of theory, with passing grades of classroom work in accordance with course requirements. Retraining shall be accomplished prior to the training expiration date shown on the wallet-size identification card. Failure to successfully complete retraining requires the student to attend a full training course.

TRAINING RESOURCES

1. Training of Level B instructors is available at either the Goddard Space Flight Center (GSFC) or Jet Propulsion Laboratory (JPL). The NASA Generic Staking and Conformal Coating Training Plan will be supplied to instructors at the time of course completion.

   a. GSFC
   Training Center
   Code 300.1
   Greenbelt, MD 20771
   (301) 731-8632
   FAX (301) 731-8628

   b. JPL
   Training Center
   MS83-204
   4800 Oak Grove Drive
   Pasadena, CA 91109
   (818) 354-6730
   FAX (818) 393-0090

2. Suppliers may train operator or inspector personnel in-house for certification or recertification utilizing certified instructors and approved training programs, or arrange for this training at one of the NASA conducted schools.

3. A fee is required. Contact either training center for information.

COURSE REQUIREMENTS

This document specifies the requirements for training personnel in the techniques of Polymeric Applications & Inspection techniques for space flight hardware. Instruction is accomplished through video presentations, written documentation, hands-on experience, and sample inspection. Attendees are required to successfully complete all exercises and tests, as directed by the instructor, in order to pass this course.

RELATED DOCUMENTS

NASA Documents

JPL D-4330	Conformal Coating and Staking Training Handbook
NHB 8060.1C	Flammability, Odor and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion
IPC-6011	Generic Performance Specification for Printed Wiring Boards
IPC-6012	Qualification and Performance Specification for Rigid Printed Boards – Supplemented [at project option] with GSFC approval. Code 312 document S312-P-003, Rev. B
IPC-2221	Generic Standard on Printed Board Design
IPC-2222	Sectional Design Standard for Rigid Organic Printed Boards

NAS-5300.4 (3J-1)	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electric Assembly
MSFC 527/JSC 090604	Materials Selection List for Space Hardware Systems

Other Documents

ASTM-D-2240	Standard Method of Test for Rubber Property Durometer Hardness
ASTM-D-2651-67	Preparation of Metal Surfaces for Adhesive Bonding
OSHA Standards	Occupational Safety and Health Standards 29 CRF Part 1910
MIL-A-8625E,II,2	Anodic Coatings, For Aluminum and Aluminum Alloys
MIL-C-554 lD	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-C-28809	Circuit Card Assemblies, Rigid, Flexible, and Rigid-Flex

References

Beach, Norman E. — Glossary of Plastics Terms: A Consensus. Plastics Technical Evaluation Center, Dover, NJ December 1966.

Budinski, Kenneth G. — Engineering Materials Properties and Selection, 3rd ed., Prentice Hall, Inc. New Jersey, 1989.

Walter, Neil A.; Scialdone, John — Outgassing Data for Selecting Spacecraft Materials, NASA Reference Publication 1124, Revision 4, June 1997.

Clatterbuck, Carroll H. — "Radio Frequency Shielding of Cables Using a & John J. Park Protective and Conductive Polymer", GSFC, Greenbelt, Maryland 1975.

Clatterbuck, Carroll H. — "Materials Processing Document MPD-313-008. Conformal Coating of Printed Wiring Boards with a Two Part Room Temperature Curing Urethane-Uralane 5750-LV", Office of Flight Assurance, NASA/GSFC.

Clatterbuck, Carroll H. — Materials Processing Document MPD-313-023. A Pressure Applied Urethane Resin Insulation for Potting Cable Connectors

Clatterbuck, Carroll H. — Materials Processing Document MPD-313-015. Adhesive Bonding of Epoxy Fiberglass Thermal Blanket Fasteners to Substrate Surfaces

Clatterbuck, Carroll H. — Materials Processing Document MPD-313-017. Adhesive Bonding Thermostat Switches to Substrate Surfaces

Clatterbuck, Carroll H. Materials Processing Document MPD-313-022. Adhesive Bonding Kapton Thermofoil Heaters to Substrate Surfaces

Clatterbuck, Carroll H. Materials Processing Document MPD-313-027. Adhesive Bonding of Thermistor Board Assembly to Substrate Surfaces

POLYMERIC INSPECTION AGENDA

Day One	
8:00 - 8:15	Introduction
8:15 - 9:00	3J-1 Requirements
9:00 - 9:15	Break
9:15 -10:30	Typical Staking
10:30 - 11:30	Typical Conformal Coating
11:30 – 12:00	Quality Assurance – Chapter 8
12:00 – 1:00	Lunch
1:00 - 2:15	Hands On/Demonstrations/Review GSFC Student Workbook pages 33-45, Bonding, Connector Potting, and RF Shielding Criteria (Not in 3J-1)
2:15 - 2:30	Break
2:30 - 3:45	Written Exam Inspection Test
3:45 - 4:00	Clean-up

POLYMERIC INSPECTION GRADING

Written Exam	85%
Inspection Test	85%

NOTE:
Instructors for this course must attend the Polymeric Application Course. (See next page).

POLYMERIC APPLICATIONS AGENDA

Day One	Day Two
Introduction Review Slides/Requirements to 3J-1 ESD Cleaning PWA's and Connectors • Batch • Spray Demoisturizing of PWA's and Connectors PWA Making and Connector Molds Surface Preparation for Bonding	PWA Masking, Conformal Coating, Connector Potting, Bonding } Slide Review **Practical:** Staking, Connector Potting and Bonding

Day Three	Day Four
Quiz Inspection Slides Practical: Staking, Conformal Coating, Connector Potting, Bonding	Written Exam Inspection Test Self Inspection

Day Five (Instructors Only)
Instructor Slide Presentation Review Requirements/Hands-on Instructor Exam

POLYMERIC APPLICATIONS GRADING

	Fabricator	Inspector	Instructor Score
Written Test	80%	80%	90%
Inspection Test	80%	85%	90%
Fabrication Test	85%	80%	90%

COMMONLY USED GSFC MATERIALS FOR POLYMERIC APPLICATION

For a complete listing of NASA approved materials, see NASA Reference Publication 1124, "Outgassing Data for Selecting Spacecraft Materials."

Solvents

Acetone, ACS Grade
Alcohol, Ethyl (200 proof), ACS Grade
Heptane, ACS Grade
Hexane, ACS Grade
Toluene, ACS Grade
Trichloroethane, I,I,I, ACS Grade
Xylene, ACS Grade
Isopropyl Alcohol

* A list of approved solvents and cleaners can be found in 3J-1.

Polymerics	**Manufacturers**
Adhesive A-3 1	Armstrong
Catalyst 9	Emerson and Cummings
Catalyst 50	Emerson and Cummings
Conathane EN-ll	Conap
Eccosil 4952	Emerson and Cummings
Eccosil 4954	Emerson and Cummings
EA 934NA	Hysol
CV-2946	McGhan-Nusil
Resin, Epon 828	Shell Chemical
Stycast 2850 FT	Emerson and Cummings
Stycast 2850	Emerson and Cummings
Uralane 5750LV	Ciga Geigy
Uralane 5753LV	Ciga-Geigy
Versamid 140	General Mills
Frozen Materials	Appli-Tec

Other

Boron Nitride Powder SHP-325	Caborundum Co. (SOHIO)
Cab-O-sil M-5	Cabot
Silflake 135	Handy and Harman
Titanium Dioxide	
Ti-Pure, R-960-28	Dupont
VYAC Luminescer 174	Bever Cloth Cutting Machine, Inc.

SAFETY PRECAUTIONS

The use of solvents, fillers, and resin compounds dictate adherence to the OSHA Standard 29 CFR Part 1910, and to the recommendations found in the "Material Safety Data Sheet" (MSDS) for each material.

The foremost concern facing the operator, inspector and instructor is the handling of the solvents and resins from a biological, biochemical, and flammability hazard standpoint. Since the chemicals can be used either as cleaning agents or diluents in the resin formulation, they can be inhaled or come in contact with exposed skin and eyes. Fillers are the greatest threat via inhalation. Therefore, all safety precautions must be strictly followed as outlined below:

1. Safety goggles must be worn at all times around the area of active processing.
2. Suitable protective gloves must be worn when working with chemicals.
3. At a minimum, tested half-mask facepiece respirators must be worn around volatile organic compounds.
4. Dust masks must be used around fillers and during abrasion processes.
5. All moderate hazard chemical processing must be done under a fumehood rated at a full face velocity of 100 feet per minute (fpm) maximum sash is fully opened and 125 fpm minimum closed.
6. Absolutely no smoking, eating or drinking is allowed in the laboratory, chemical storage area, or in the vicinity of the processing area when in the field.
7. Follow the relevant MSDS recommendations on how to treat exposure to specific chemicals.
8. Never sniff chemicals as a method of identifying them.
9. Never touch chemicals with bare hands.
10. Never stir chemicals with bare or gloved hands.
11. Never wear slippers or open-toed footwear around chemicals.
12. Open flames are forbidden next to or in the vicinity of solvents or processing area.
13. Do NOT touch anything without the permission of the lab technician.

BASIC PRINCIPLES OF MATERIALS ENGINEERING

The background information supplied here is intended to help the student of this polymeric applications workmanship course understand essential details about polymer science, specifically the field of advanced adhesive and elastomer technology. The treatment of materials engineering given here will be relatively brief.

Materials engineering is based on the principles of chemistry and physics. Therefore, the use of chemical and physical terms is unavoidable. However, they are defined in Appendix A - Definitions, or explained during the class.

The materials called plastics are more correctly designated as polymers. Substances that are made up of many chemical units are called "mers". These mers are the links in the long molecular chains that form the polymers. An example of this is polyethylene. The polymer, polyethylene, is comprised of long chain- repeating ethylene molecules or mers. Most polymers are solids.

In this training class the groups of materials on which we will be focusing are the urethanes, silicones, and epoxies.

Urethanes are used to pot connectors, stake parts on a printed wiring assemblies (PWA), encapsulate power supplies, and conformally coat PWA's.

Silicones are applied as adhesives, sealants and gaskets, made into molds; and used as a heat dissipating material between heat generating objects and passive sinks (such as batteries mounted on an aluminum panel).

Epoxies serve primarily as structural adhesives, but they can also serve as heat conductors for structurally bonded parts like thermostats, thermistors, and platinum resistance thermometers (PRT's).

OBSERVATION OF THE SUBSTANCE PROPERTIES

Different types of materials tend to have their own distinguishing characteristics, which we will place in four categories for purposes of discussion:

> **Chemical**, such as oxidation resistance, acid resistance, and compound formation. These cannot be identified by visual observation but must undergo rigorous analysis.
>
> **Physical**, which include electrical conductivity, thermal conductivity, color, density and phase change. These often pertain to interaction of materials with various forms of energy and can frequently be measured without destroying or changing the sample.
>
> **Mechanical**, involving elastic behavior (hardness strength, modulus of elasticity, and brittleness). Measurement of these properties typically causes destruction of the sample.
>
> **Dimensional**, is a category relating to the shape of an object and its surface characteristics. Surface roughness is an example that is measurable and important for structural bonding applications.

Importance of Outgassing and Offgassing. A product that outgasses can contaminate optical assemblies thus destroying optically transmitted data. Outgassing materials can also deposit conductive condensates on electronic equipment. Outgassing is the release of a volatile part(s) from a substance when placed in a vacuum environment simulating that of outer space. All compounds used in polymeric applications must meet the following outgassing criteria.

1. The percentage of collectable, volatile, condensable material (CVCM) for the substance must be less than 0.1%.
2. The total mass loss (TML) for the substance must be less than 1%. See Table 1 for Outgassing Data of selected materials.

Table 1. Material Selection: Sample Outgassing Data
NASA Reference Publication 1124, Rev 4, June 1997

	MATERIAL	MFR CODE	% TML	% CVCM	°C CURE TEMP	CURE TIME	ENVIRON	APPLI-CATION	COLOR
1[A]	Armstrong A-12 A/B 3/2 BW Epoxy	APC	.87	.00	25	24H	Air	Adhesive	Brown
1[B]	Armstrong 1-12 A/B 3/2 BW Epoxy	APC	.65	.00	54	8H	Air	Adhesive	Brown
2	Armstrong A- 3 1 A/B 6/4 BW Epoxy	APC	.44	.01	25	7D	Air	Adhesive	Tan
3	Hysol EA 934 A/B 100/33 BW Epoxy	HYS	.87	.00	25	7D	Air	Adhesive	Gray
4	Hysol EA 934 NA A/B 100/33 BW Epoxy	HYS	.54	.01	25	7D	Air	Adhesive	Gray
5	Eccosil 4952/Cat 50 10/.02 BW Filled Sil.	EMC	.42	.17	66	4H	Air	Thermal control	Red
6	Epon 815/V 140 3/1.8 BW Epoxy	GSC	.51	.02	25	7D	Air	Adhesive	
7	Epon 828/V 140 Bn3 1/1/2 BW Epoxy	GSC	.74	.03	25	7D	Air	Thermal Cond. Adhsv	
8	Epox-Patch Kit IC EQ. Lights from tubes	HYS	.81	.02	25	24H	Air	Adhesive Sealant	White
9	Stycast 2850 fl/1 I	MC	.38	.01	85	12H	Air	Adhesive	Black
10	Stycast 2850 ft/24 LV 100/7 BW Epoxy	EMC	.39	.00	25	24H	Air	Adhesive	Black
11	Uralane 5753 LV A/B 1/5 B@W/Cabosil TS-720	GSC	.80	.02	25	7D	Air	Staking Compound	
12[A]	Uralane 5753 A/B 1/5 BW Poly-Urethane	FPI	.62	.01	25	7D	Air	Conformal Coating	
12[B]	Uralane 5753 LV A/B 1/5 BW Poly-Urethane	FPI	.60	.01	60	24H	Air	Conformal Coating	
13	Uralane 5750 LV A/B 18/100 w/mek/tol	GSC	.48	.01	25	7D	Air	Conformal Coating	
14[A]	Conathane En 11A/B 100/55 BW Pur	GSC	.45	.03	25	10D	Air	Potting	
14[B]	Conathane En 11A/B 100/55 BW Pur	GSFC	.38	.01	50	24H	Air	Potting	
14[C]	Conathane En 11A/B 100/55 BW Pur	GSFC	.43	.02	55	24H	Air	Potting	
BW = By Weight A/B = Parts A & B Sil = Silicone V = Versamid									

Materials that will be placed in the crew compartment must meet offgassing standards. The offgassing test addresses flammability, odor, and toxic hazards requirements. For example, a burning product can give off life threatening toxic gasses or an odor that can be nauseating or just distracting.

Polymer Storage. Polymeric material shall be stored in accordance with the manufacturer's specifications. This is to ensure that the stated shelf life and use of the material is not compromised. Proper storage usually indicates a definite temperature for a suitably sealed container. (Ref. NAS5300.4 (3J-1) 3J306)

General Surface Preparation. Before any polymer application processing can begin, mixing utensils, tools, assemblies, parts, and working surfaces must be properly cleaned. Approved solvents must be used and correct cleaning procedures for substrates must be followed, or else reliable adhesion will be compromised. All surfaces must be free from solder, flux and other ionic, oily, or particulate contaminants. Any trapped contaminants will interfere with the performance of the polymeric application and will degrade the function of the assembly. After cleaning, the substrate shall be thoroughly dried to remove all residual solvents and moisture. The parts to be processed shall be kept clean and dry until processing with polymerics is initiated.

The effectiveness of the cleaning will depend on the proper execution of the approved cleaning procedure and the consistent use of a fresh and residue free solvent for the final cleaning step. Cotton and foam-tipped swabs, and lint-free fabric shall be soxhlet-extracted to ensure a contaminant free condition. A soxhlet extractor is pictured in Figure 1. Soxhlet extraction is operated for a minimum period of 48 hours, and the load (e.g. cotton fabric, swabs) shall then be dried in a contaminant-free environment.

Curing. Polymeric material shall be allowed to cure in accordance with the cure schedule specified for the material by the manufacturer. A tack-free cure can usually be expected in a minimum of 24 hours. Complete cure for urethanes usually requires a time frame of 5 to 7 days, at room temperature (25-27°C/77-80.6°F). For complete cure at elevated temperatures, consult the technical data on the compounded resin.

Caution: The resin should not be allowed to experience high temperatures before a 24 hour cure at room temperature has been completed.

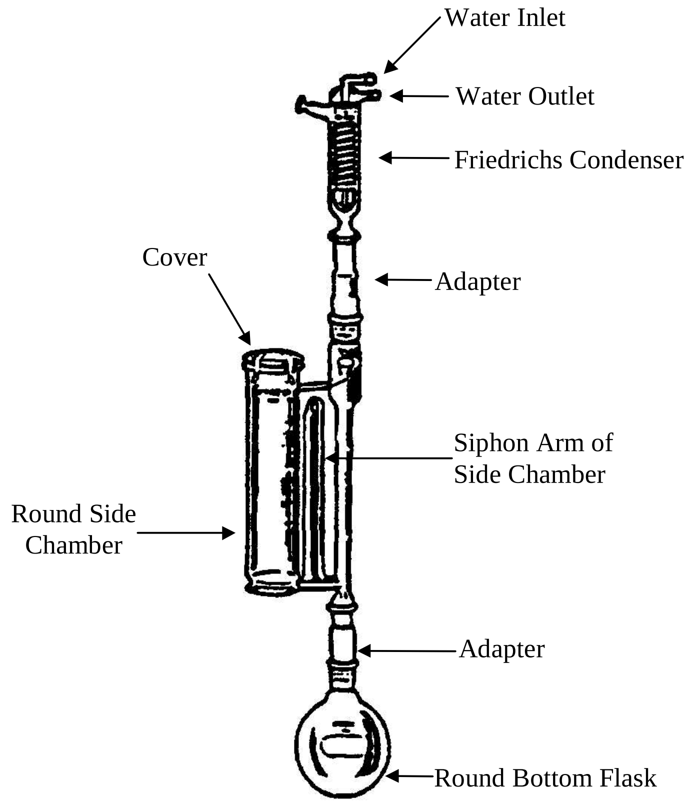


Figure 1. Soxhlet Extractor

INTRODUCTION TO POLYMERIC APPLICATIONS

Inspectors, fabricators and instructors need to be aware of the requirements to be met by the completed work including functionality, conformance to specifications, and aesthetic appeal.

Conformance to specifications is mandatory. Specifications will be found either in the written procedure for the relevant polymeric application, the engineering drawing, certification log, or with written approval by the materials engineer. The polymer technician is required to complete a mixing record for each mix batch date and procedure. **This mixing record shall be examined for completeness by the inspector.** In addition, the polymer technician is required to prepare one witness sample (1.0 inch in diameter and 1/4 inch in depth) per lot of "in-use" two-part system polymeric material (i.e., part A/part B) at the moment of first use. The witness sample shall be used primarily for hardness tests; it shall also be available for thermal analyses if deemed necessary. These tests and/or analyses shall not be performed before the full period has passed. The witness sample shall be kept with the mixing record(s) for a minimum of 5 years, or as specified by contract. A sample mixing record is illustrated in Figure 2.

NASA TRAINING CENTER POLYMERICS APPLICATION LABORATORY MATERIALS PROCESSING MIXING RECORD		DCN:
Date Received:	Received by:	Work Req. #:
Requestor:	Code/Contractor:	Phone: ( )
Project:	Hardware I.D.:	Type: Flight ❑ Non-Flight ❑
Work Performed by:	Date Completed:	
Work Desired:		

FORMULATION DATA							
Material I.D.:							
Ingredients	**Lot #**	**Exp. Date**	**PBW**	**Gram Wt.**	**Vol. (ml.)**	**Rec'd Date**	**Mfg. Date**

Degassed: ❑ Yes ❑ No	Component/Substrate Preparation:			
Cure Schedule:	Cure Temp:	Control Sample		H.T. Sample
		RCN:		RCN:
		Batch #:		Batch #:
Remarks:				
QA				
Pick-up Date:	Signature:			
Delivery Date:	Signature:			

Figure 2. A Sample Mixing Record

Functionality is of critical importance to the operator and inspector. The tack-free test (optional) gives the first indication whether a polymer is meeting its cure schedule (i.e., whether the resin mix is becoming functional as a polymer or the chemical reaction toward a full cure is going or has gone awry). If curing is proceeding as planned, the second step is to search for evidence of defects in the polymeric application(s). It is then the inspector's responsibility to reject the article under consideration if there is a problem.

After the article passes inspection and the proper amount of time has lapsed, a hardness test is performed on a **witness sample** of the fully cured mix. A common hardness test for polymers is the Shore Durometer test. Hardness is measured by pushing a spring-loaded indentor into the witness sample. (Remember to check for valid calibration stickers on the Durometer). Generally, a Shore A test is used as a measure for the polyurethanes and silicones. The Shore D is the measure for epoxies and harder polymers. The hardness measurement result should be within +/-5 units of the manufacturer's recommended value. Table 2 is an example of a hardness scale.

Table 2. Typical Hardness Values

Polymeric Material	Shore	Hardness
Conathane EN- 11	A	65
Eccosil 4952	A	70
Eccosil 4954	A	78
Hysol EA-934 NA	D	85
McGhan-Nusil CV-2946	A	70
Stycast 2850 FT CAT9	D	94
Uralane 5750LV	A	50
Uralane 5753LV	A	45

Aesthetic appeal is not a requirement, however, good appearance of polymeric application does not mean it is functionally sound. Therefore, the inspector must regard aesthetic appeal not as a requirement, but only as a preferred quality in the finished product. The inspector should criticize poor quality work. The responsibilities of the technician and inspector are illustrated in Figure 3.

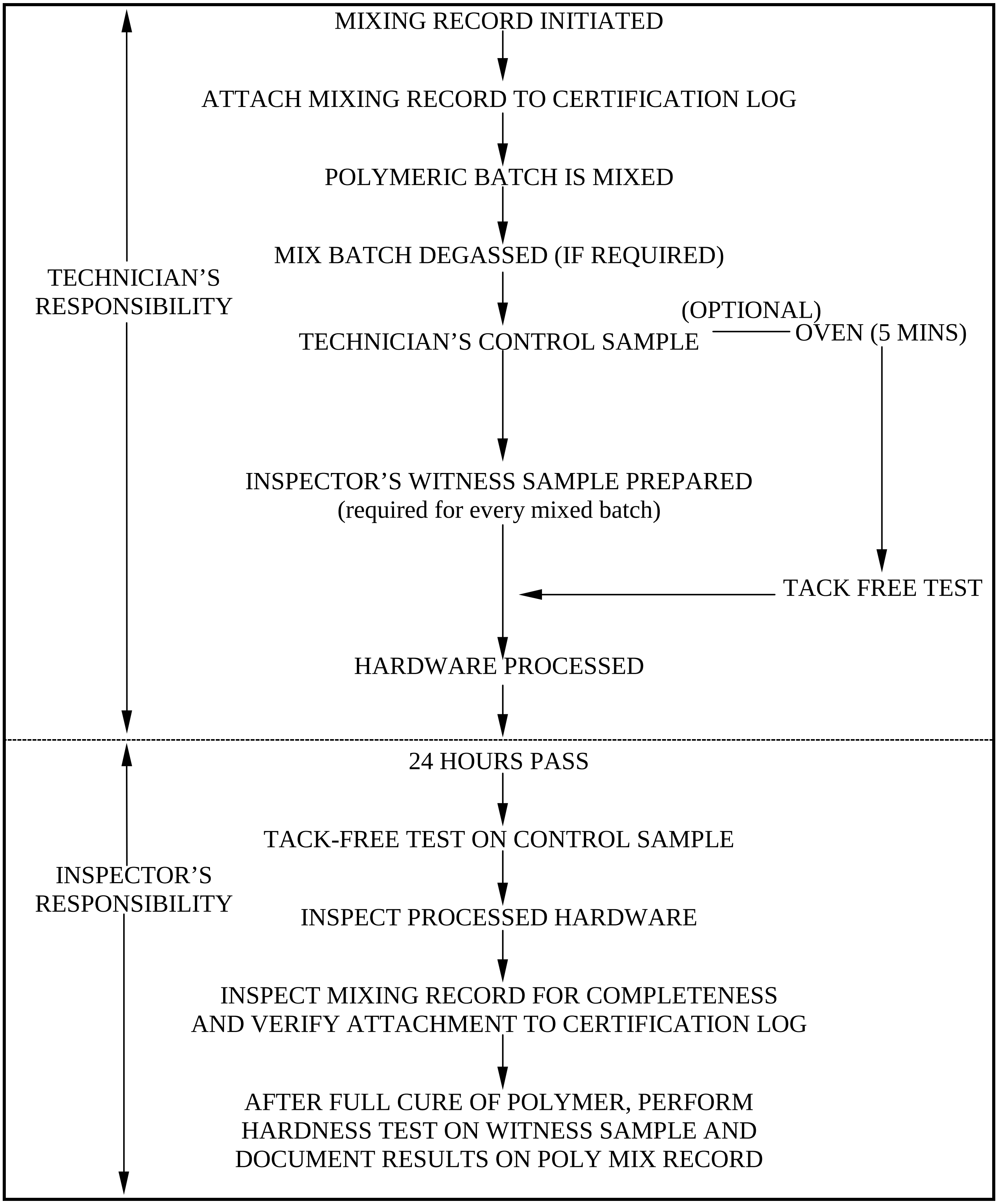


Figure 3. Responsibilities of the Technician and Inspector

STAKING

Definition: Staking is the process of bonding and securing components or parts to PWA's and electronic assemblies by means of an adhesive material.

Purpose: The main purpose for staking is to protect and support parts that may be damaged by vibration, shock, or handling.

PRINCIPLES OF RELIABLE STAKING

Factors Controlling Reliability. Reliable staking results from proper design, control of equipment, materials, work environments, and careful workmanship by trained and certified personnel.

Design Considerations for Staking. These staking material shall meet the following basic design considerations.

1. The staking material shall be a noncorrosive, electrically insulative material, with dielectric properties (permittivity and dissipation factor) that will not change or adversely affect the performance characteristics of the parts being staked or their associated circuitry.
2. The staking material selected shall provide adequate mechanical support to allow the item to survive vibration levels imposed during end-item use. Rigid staking material with a low thermal expansion coefficient is generally desirable. For special cases where parts, sensitive to thermal/mechanical stress are used, application of resilient materials may be required.
3. The staking material must be compatible with, and adhere to, the printed wiring assembly (PWA) or substrate, the part staked, and the conformal coating to be applied.
4. The staking material shall exhibit hydrolytic and thermal stability under high-vacuum and thermal-vacuum conditions. The material shall meet program and contractual outgassing, offgassing, and flammability requirement.
5. The staking compound selected must not negate the stress relief in parts leads or on jumper wires.
6. Staking material selection shall take into consideration the system operating temperatures and the material glass transition temperatures as specified on the approved engineering documentation in order to minimize stress on parts and jumper wiring during operational thermal cycling.
7. Staking material must not be applied to areas where induced stress will cause damage, such as under a dual-in-line (DIP) integrated circuit or flat pack device.
8. The staking material selected shall be curable under temperature conditions compatible with the PWA on which it is located.

Staking Formulation. The manufacturer's specification for the parts-by- weight (PBW) mixing of the two-part resin system shall be followed. If the required weight of filler added to a formulation is not listed in a manufacturer's specification; it is determined by the materials engineer. Only the weight in grams of the filler is entered on the Mixing Record. For example, Table 3 is the formulation for GSFC approved staking-grade resin mix that would appear on the mixing record. Approved fluorescent dyes may be added into the staking formulation.

Table 3. Resin Formulation for Staking

Material	Function	PBW (gms)
Uralane 5753-B	Prepolymer Resin	30.0
Uralane 5753-A	Curing Agent	6.0
*Cab-O-Sil, M-5	SiO2 Thickener	2.75

After the formulation has been mixed, it should be degassed or deaerated until all entrapped air is removed.

*Must be kept at 125°C for at least forty-eight (48) hours before use. Cab-O-Sil is hygroscopic.

INSPECTION METHODS FOR STAKING

Workmanship and Adhesion Requirements. Satisfaction of requirements shall be verified by visual inspection using 4X to 10X power magnification. Higher magnification may be used, as necessary, to inspect suspected anomalies or defects.

Tackiness and Adhesion. Gentle pressure shall be used to inspect for tackiness and adhesion. For this purpose, lint free gloves or finger cots shall be worn.

Hardness. When applicable, hardness shall be measured in accordance with ASTM-D-2240, "Standard Method of Test for Rubber Property Durometer Hardness."

ACCEPTANCE CRITERIA FOR STAKING

1. The staking material shall be tack-free when cured as per paragraph 3J601-5.
2. The staking material shall adhere to the intended surfaces as per paragraph 3J601-1.
3. Staking material shall be free from contamination as per paragraph 3J601-3b.
4. A mixing record shall be completed for each mix batch date and procedure as per paragraph 3J503-6.
5. The staking compound shall not enclose the part lead as per paragraph 3J601-3a.
6. Jumper wires shall be staked a minimum of 2.54 cm (1 inch) and at every change of direction, outside the radius of curvature as per paragraph 3J601-4.
7. All axial lead solid slug tantalum capacitors shall be staked as per paragraph 3J601-4.

8. Glass bodied parts shall be covered with resilient material prior to staking with rigid material as per paragraph 3J601-3C.
9. Staking material shall not bridge between the PWB and the bottom of DIPs or flatpacks as per paragraph 3J601-1.
10. Staking material shall not be used after shelf life expiration as per paragraph 3J306-1b.

REJECTION CRITERIA FOR STAKING

1. Staking material used after shelf life expiration as per paragraph 3J306-1b.
2. Staking material bridges between the PWB and the bottom of the DIP's or flatpacks as per paragraph 3J601-1.
3. Staking material fills the stress relief areas as per paragraph 3J601-3a.
4. Staking material encloses the part lead as per paragraph 3J601-3a.
5. Rigid staking has been applied directly to glass bodied parts as per paragraph 3J601-3c.

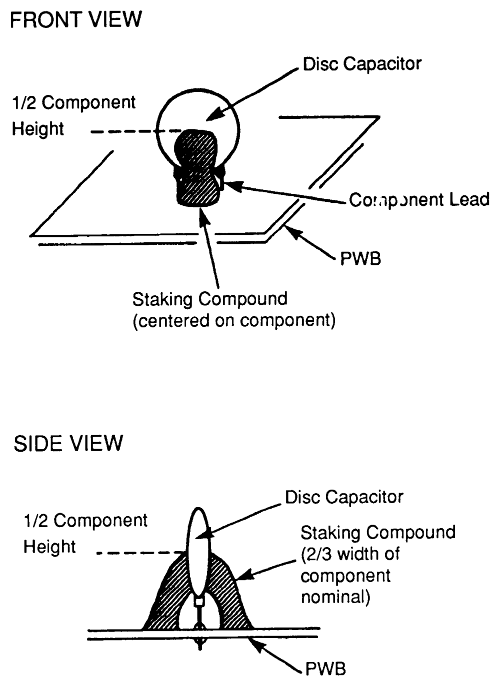


Figure 4. Typical Staking of a Single Disc-Type Component

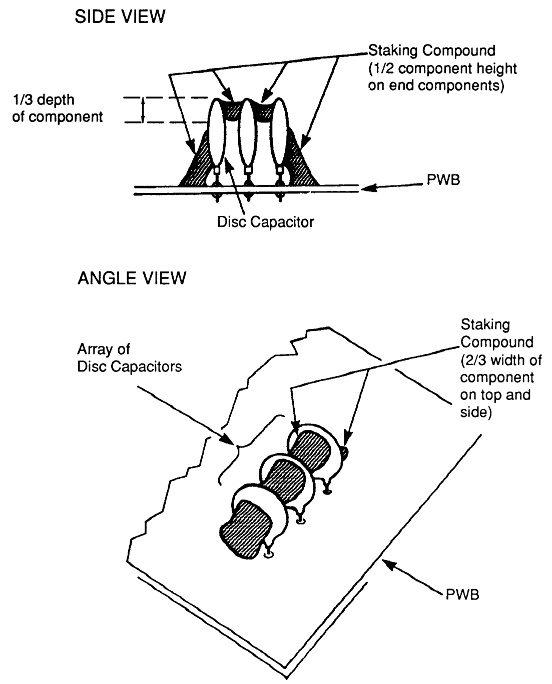


Figure 5. Typical Staking for an Array of Disc-Type Component

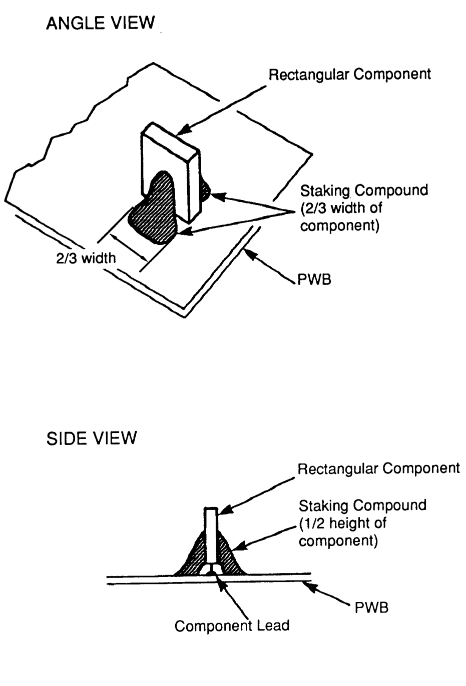


Figure 6. Typical Staking of a Single Vertically Mounted Rectangular Component

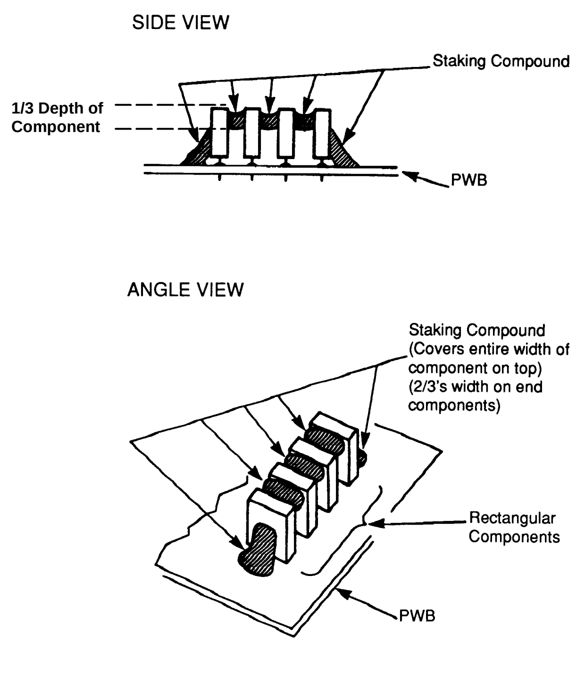


Figure 7. Typical Staking for an Array of Vertically Mounted Rectangular Component

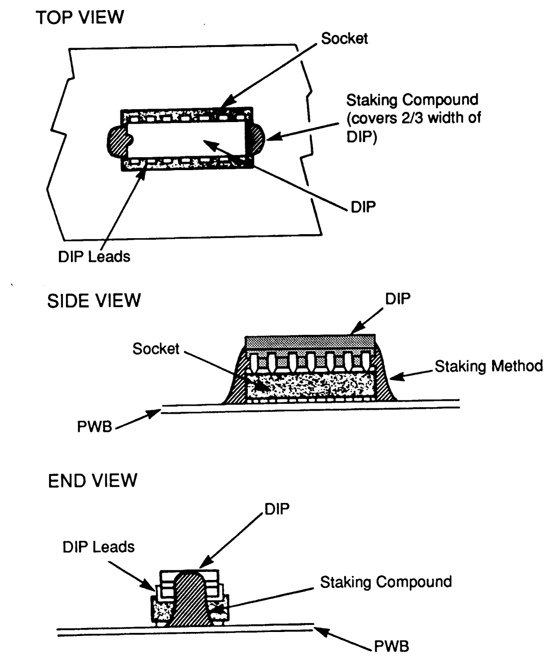


Figure 8. Typical Staking for a Dual-In-Line (DIP) Integrated Circuit in a Socket

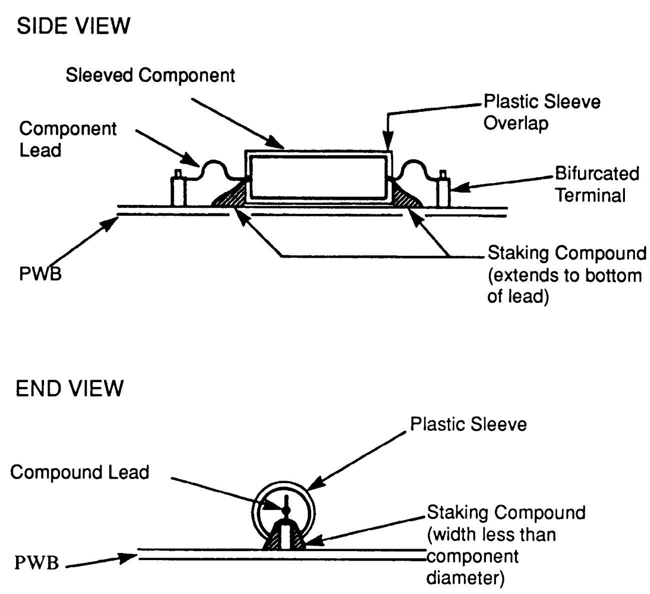


Figure 9. Typical Staking for Horizontally Mounted Sleeved Cylindrical Component

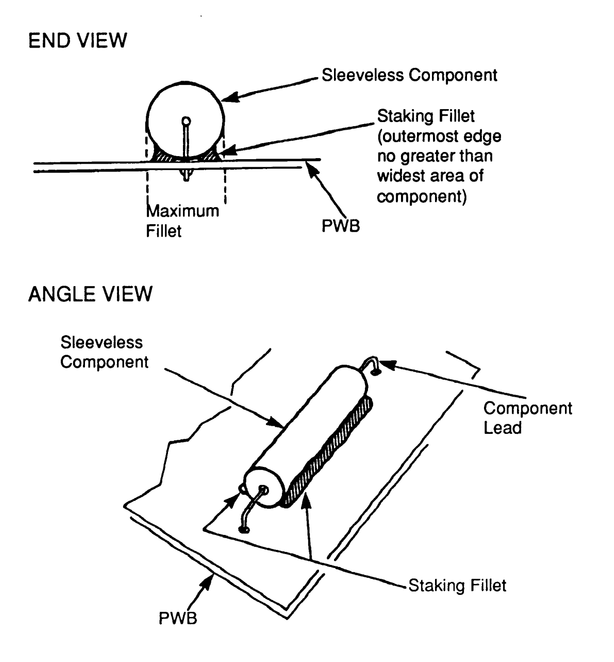


Figure 10. Typical Staking for Horizontally Mounted Sleeveless Cylindrical Components

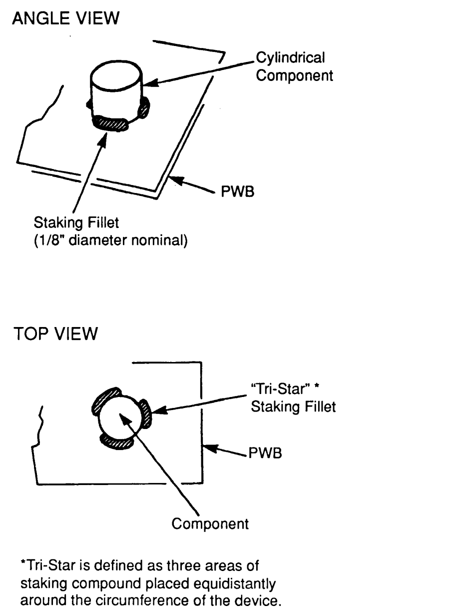


Figure 11. Typical Staking of Flush Mounted Cylindrical Components

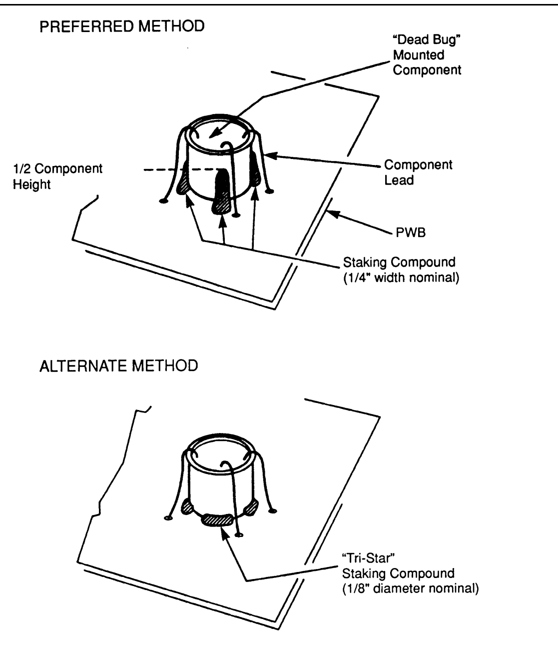


Figure 12. Typical Staking of "Dead Bug" Cylindrical Components

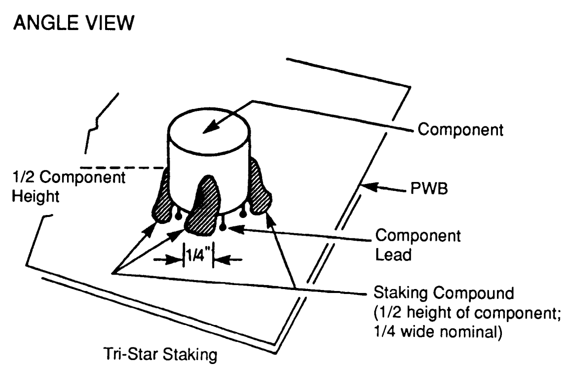


Figure 13. Typical Staking of Vertically Mounted Cylindrical Components

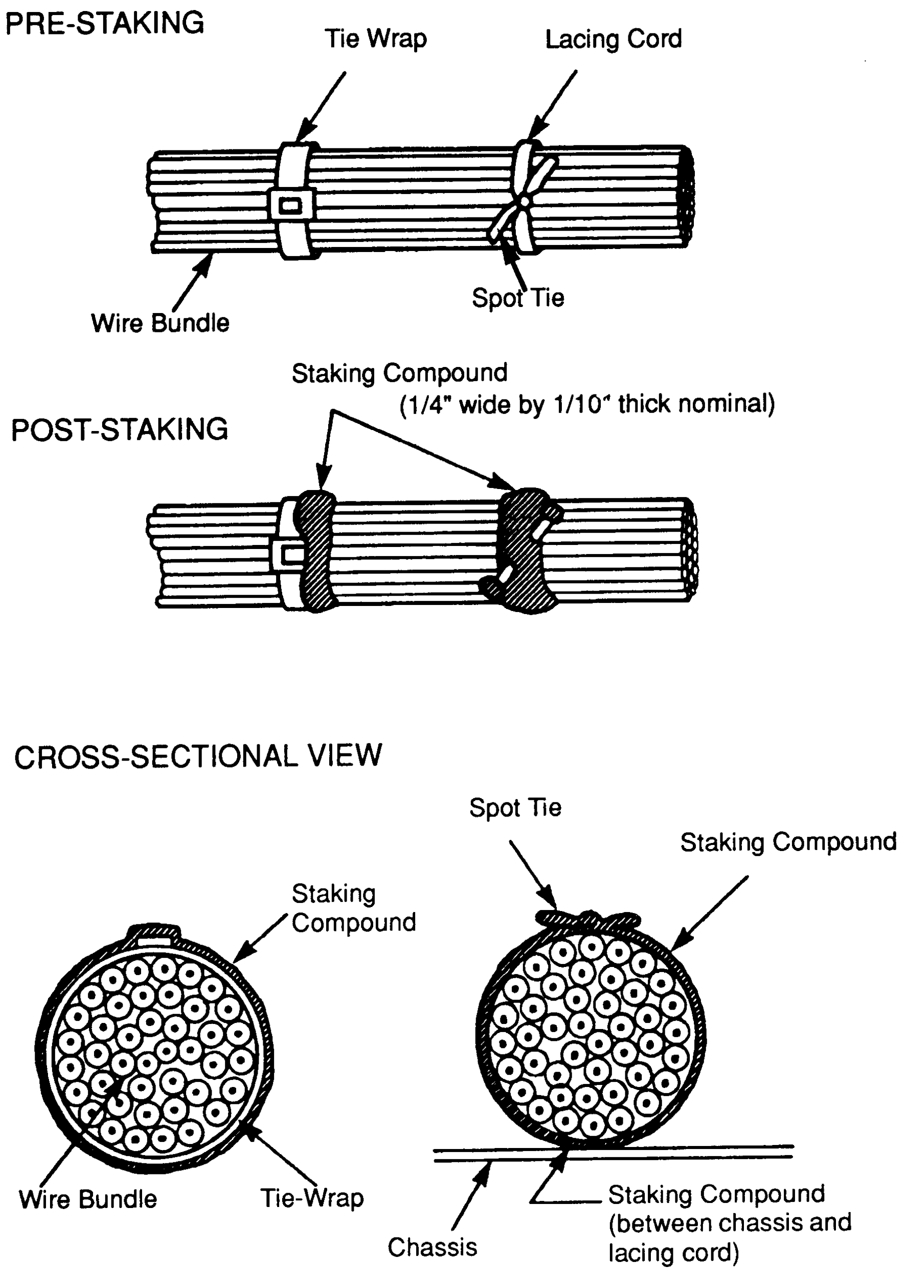


Figure 14. Typical Wire Bundle Staking

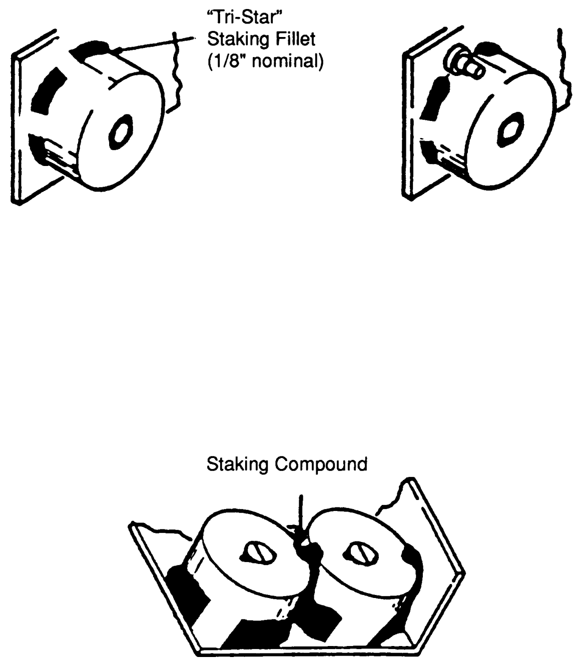


Figure 15. Typical Staking of Large Toroids to a Subchassis

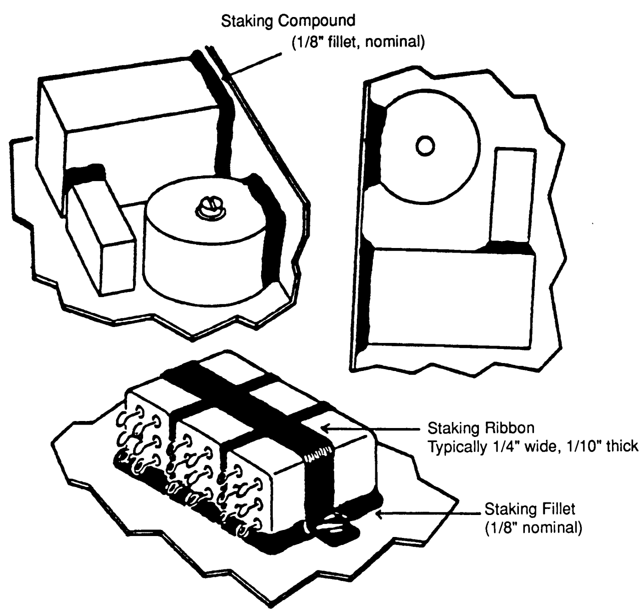


Figure 16. Typical Staking of Other Component Arrangements

CONFORMAL COATING

Definition: A conformal coating is a thin, electrically nonconductive, and protective coating that will conform to the configuration of the board or other assembly.

Purpose: Conformal coatings are intended to provide electrical insulation and environmental protection, thus minimizing the performance degradation of electronic assemblies by humidity, handling, debris, and contamination.

PRINCIPLES OF RELIABLE CONFORMAL COATING

Factors Controlling Reliability. Reliable conformal coatings result from proper design, control of equipment, materials, work environments, and from careful workmanship by trained and certified personnel.

Design Considerations for Conformal Coating. Conformal coating material shall be specified on the approved engineering drawing, and shall be suited to the complexity of the assembly, and shall be capable of covering the circuitry.

1. Have excellent dielectric properties that will meet the minimum circuit requirements in all anticipated environments.
2. Not cause excessive stress to the PWA, its parts, or its electrical interconnections, or to the assembly during thermal or mechanical tests.
3. Meet outgassing requirements.
4. Have maintainability properties (repair and rework) compatible with the parts and board or other substrates.
5. Be compatible with and adherent to all materials used in PWA's and electronic assemblies.
6. Be hydrolytically and thermally stable as required.
7. Meet offgassing requirements if assembly is to be placed in crew compartment.
8. Be noncorrosive and curable under conditions compatible with the parts on the boards and assemblies, including their temperature limits.

APPROVED APPLICATION METHODS FOR CONFORMAL COATING

Conformal coating is applied using methods designed to yield complete coverage without excessive filleting or runs. The preferred application methods are spraying and brushing. NAS 5300.4 (3J-1) describes dipping and pouring methods that are also acceptable.

INSPECTION

Coating coverage and location shall be determined by visual inspection. An ultraviolet (UV) lamp with adequate intensity shall be used to compare fluorescent areas to uncoated portions. A UV lamp shall be used to inspect the fluorescent cured urethane to ensure that all the surfaces and electrical parts are well coated. Inspection shall also be done using 4X to 10X power magnification.

Interpretation of Conformal Coating Under Ultraviolet Light:

1. An even blue glow indicates a uniform surface coating.
2. Dark spots indicate voids and dry spots.
3. Splotches of blue glow indicate nonuniform coating.
4. Small dark spots point to pinholes or debris.
5. Glowing rings with dark centers indicate bubbles.
6. Lumps are highlighted by small intensely glowing areas.
7. A large dark area shows absence of coating.
8. Large, elongated, intensely glowing areas indicate runs.
9. Straight dark lines indicate bristles or debris, especially in a brush coating.

Adhesion. The resin will not adhere to sharp points, sharp edges, teflon surfaces, or silicone surfaces. "Pull-Back" occurs at the edges of silicone surfaces that have squeezed out from under heat generating parts.

Operator Workmanship Inspection. The following steps are completed by the operator immediately after the conformal coating has been applied to the PWA. This inspection may be witnessed by the inspector if required.

Step 1 A lighted magnifier having a 4X to 10X magnification shall be used to inspect the florescent cured urethane to ensure that all the surfaces and electrical parts are well coated. Higher magnification may be used, as necessary, to inspect suspected anomalies or defects (e.g. bubbles and bubble sizes) and contaminants.

Step 2 Coating coverage shall be determined by the UV lamp. The wavelength range of the UV lamp shall be between 300 to 400 nanometers (nm), long wave (UV), and adequate in intensity to allow comparison of fluorescent areas to uncoated portions.

Step 3 Thickness measurements. Thickness measurements shall be made on coupons processed at the same time and under the same conditions as the PWA.

Final Inspection. The inspector shall examine the PWA after the resin has become tack-free, for compliance to the following criteria. Both sides of a conformally coated PWA shall meet these requirements. Workmanship and adhesion requirements shall be verified by visual inspection using 4X to 10X power magnification. Higher magnification may be used, as necessary, to inspect suspected anomalies or defects (e.g., bubbles and bubble sizes) and contaminants.

ACCEPTANCE CRITERIA FOR CONFORMAL COATING

1. Coating shall be tack-free and fully cured as per paragraph 3J701-5a.
2. Coating shall have good adhesion to the PWA and electrical parts with no visible lifting or peeling of the coating as per paragraph 3J701-5a.
3. Coating shall have a smooth continuous surface and follow the contours of the PWA as per paragraph 3J701-5b.
4. Coating shall be free of contamination as paragraph 3J701-5c.
5. A mixing record shall be completed for each mix batch date and procedure as per paragraph 3J503-6.
6. Coating material that bridges between adjacent part leads must not negate stress relief as per paragraph 3J701-5e.
7. Coatings shall not exhibit excess runs, fish eyes, or peeling as per Figure 7-5 in 3J-1.
8. Coating shall not bridge between the underside of DIPs or flatpacks, and the PWA's surface as per paragraph 3J701-4b.
9. Scratches in the coating shall not expose any conductive area as per Figure 7-3 in 3J-1.
10. Terminals shall be conformal coated encapsulated, including the insulation gap of the wire, unless it is a solder ball connection (as in high voltage connection) as per paragraph 3J701-5d.

For rejection criteria see Figure 17 through 22.

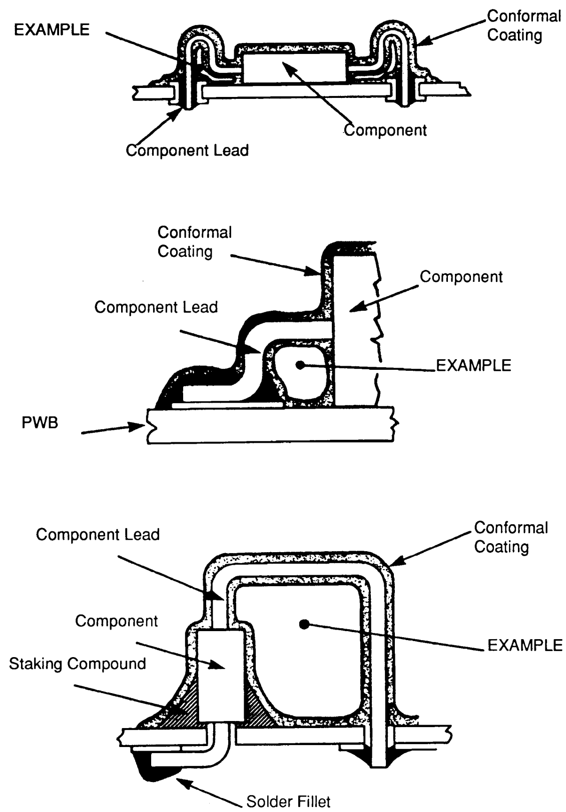
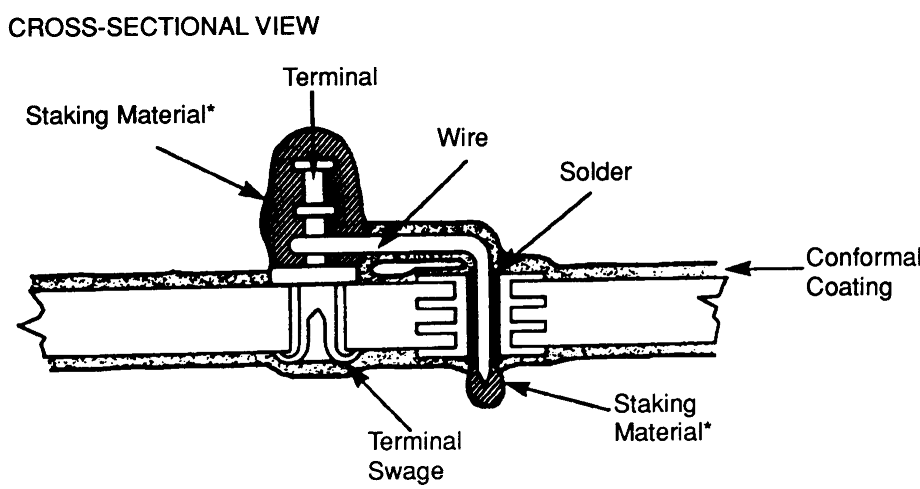
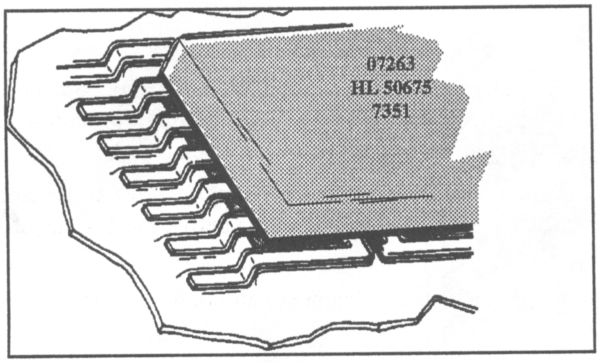


Figure 17. Examples of Where Conformal Coating is Not Allowed



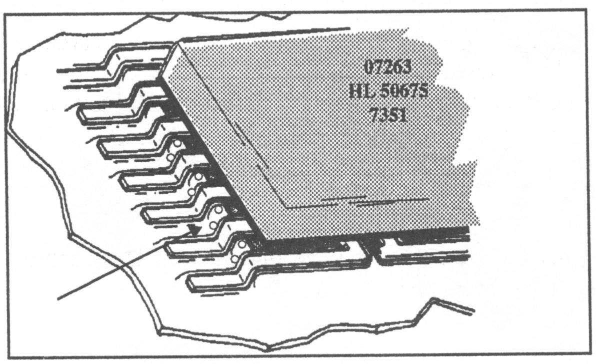
*This method is referred to as "Conformal Coating Encapsulation" (CCE)

Figure 18. Examples of Areas That Are Staked After Conformal Coating Has Been Completed



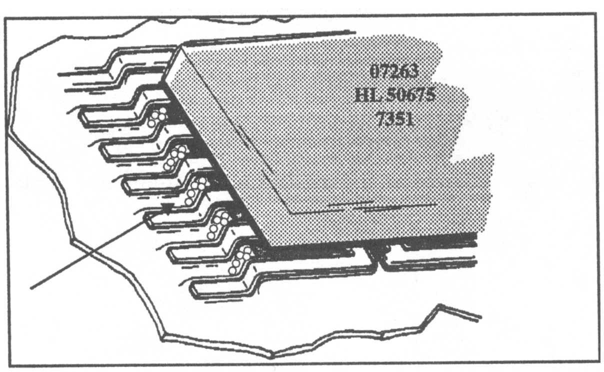
PREFERRED

Complete uniform coverage with no visual bubbles



ACCEPTABLE

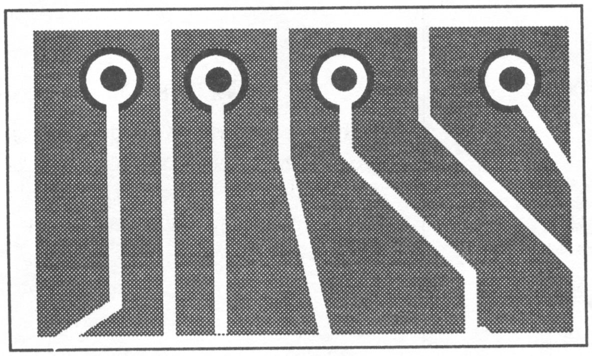
Small bubbles, but they do not bridge between uncommon conductors, expose a bare conductor surface, or exceed 0.76mm (0.03 inch) in any dimension.



UNACCEPTABLE

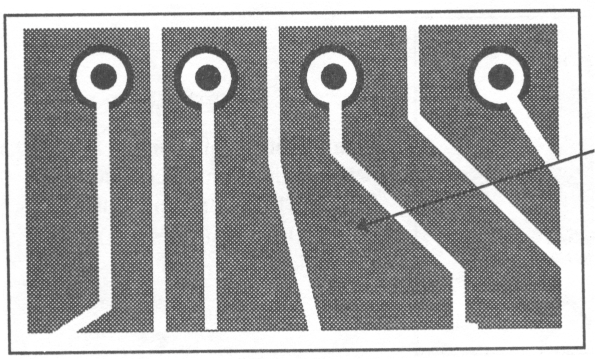
Excessive bubbling.

Figure 19. Conformal Coating - Bubbles



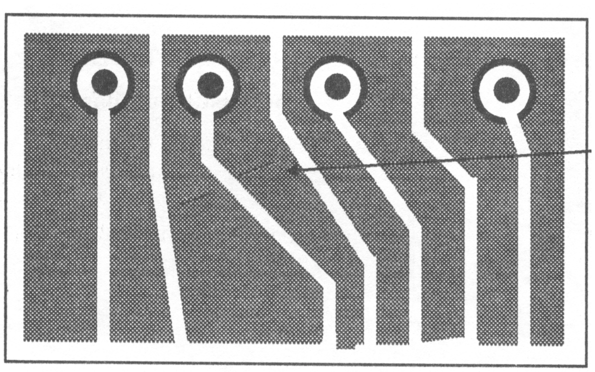
PREFERRED

No defects.



ACCEPTABLE

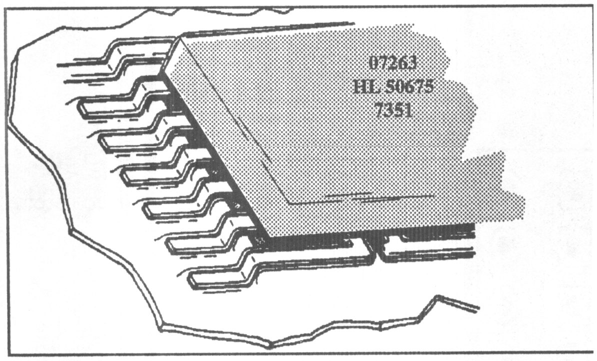
Scratch does not expose any conductive area.



UNACCEPTABLE

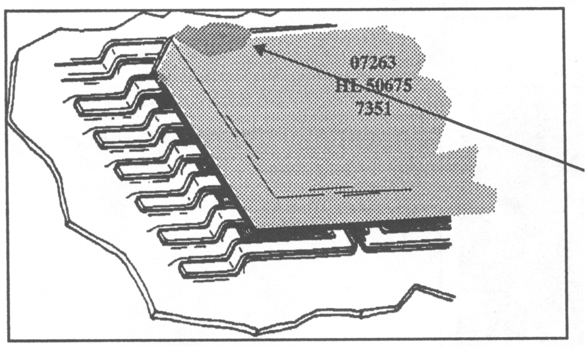
Scratch exposes conductive areas.

Figure 20. Conformal Coating - Scratches



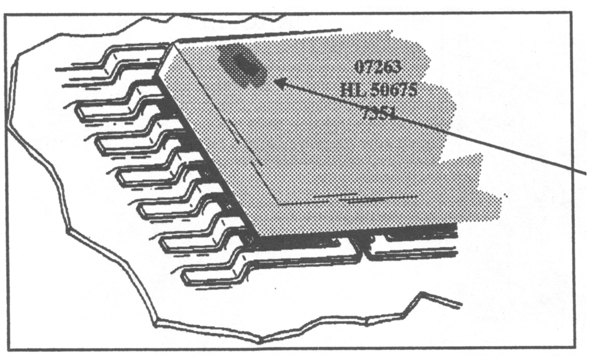
PREFERRED

Uniform color, texture, and thickness with apparent good adhesion on parts and board surface. The coating should show uniform fluorescence under a UV light.



ACCEPTABLE

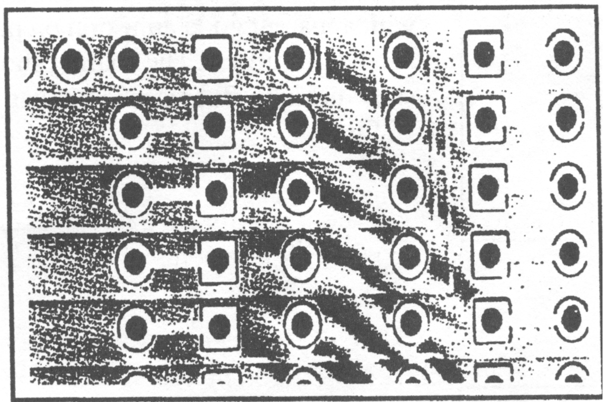
Some evidence of variation in coating thickness. Minor lifting on nonconductive areas.



UNACCEPTABLE

Excessive lifting and peeling indicating improper surface cleaning or excessive thickness. Any lifting on conductive areas is nonconforming.

Figure 21. Conformal Coating - Lifting and Peeling



Conformal Coating - Runs

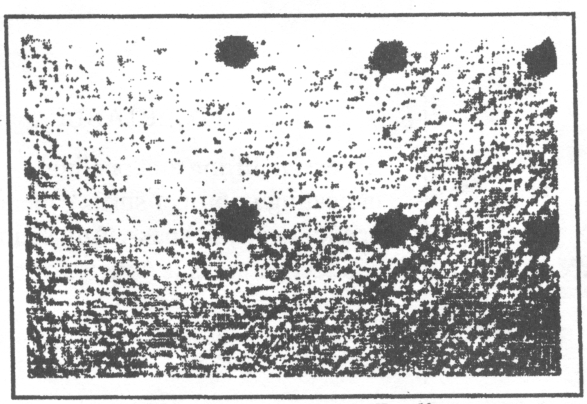
ACCEPTABLE

Not to exceed 5% of PWB surface area.

Conformal Coating - Fish Eyes

ACCEPTABLE

Not to exceed 5% of PWB surface area.



Conformal Coating - Peeling

UNACCEPTABLE

Loss adhesion.

Figure 22. Conformal Coating - Coverage Defects

THIS SECTION OF THE STUDENT WORKBOOK COVERS CONNECTOR POTTING, RF SHIELDING AND BONDING CRITERIA IN ACCORDANCE WITH THE GODDARD SPACE FLIGHT CENTER.

THE DESCRIBED PROCESSES AND CRITERIA ARE NOT COVERED IN NAS-5300.4(3J-1).

CONNECTOR POTTING

Definition: Potting is the embedment of a part or module in a resin.

Purpose: Potting is used to provide any or all of the following: mechanical support, abrasion resistance, electrical insulation, thermal conduction, and environmental isolation.

SURFACE PREPARATION

The approved cleaning solvent is isopropy alcohol. The connectors to be potted, connector savers and molds must be thoroughly cleaned and the mold put in place before the appropriate procedure for the application can begin.

METHODS OF APPLICATION

Potting is done either freehand or by using a mold. Freehand is usually the method for mated connectors or where molding is difficult or freehand is specified. Molding is the preferred method of potting. For example, fused connectors are generally molded for Cannon D type connectors.

CONNECTORS

In the general case of potting, the wires and their insertion points must be fully encapsulated. Where the insertion points or holes are large, a sufficiently viscous resin mix should be used to avoid capillary filling of the holes.

ACCEPTANCE CRITERIA FOR CONNECTOR POTTING

1. Potting shall be tack-free and fully cured.
2. There shall be no cracks, cavities, blisters, tears, burns, or discolorations in the material. The material shall not have pulled away from the connector, solder joints, or wire.
3. Bubbles greater than 0.025 inch diameter and greater than 25% of the total potting volume are not acceptable.
4. No bubbles or voids shall be allowed against electrically conductive surfaces.
5. There shall be no surface voids.
6. All potting material shall be free of contamination.
7. A mixing record and witness sample shall be completed for each mix batch date and procedure.
8. There shall be no potting material on the exterior surfaces or in any area of the connector or wires outside of the potting area.
9. Floating connector contacts shall not be locked in place by the potting material.

10. Crimp and solder type connectors shall be potted only when a connector saver is installed to ensure connector alignment.

11. Potting material shall extend at least 1/8 inch above the top of insulation gap. See Figure 23.

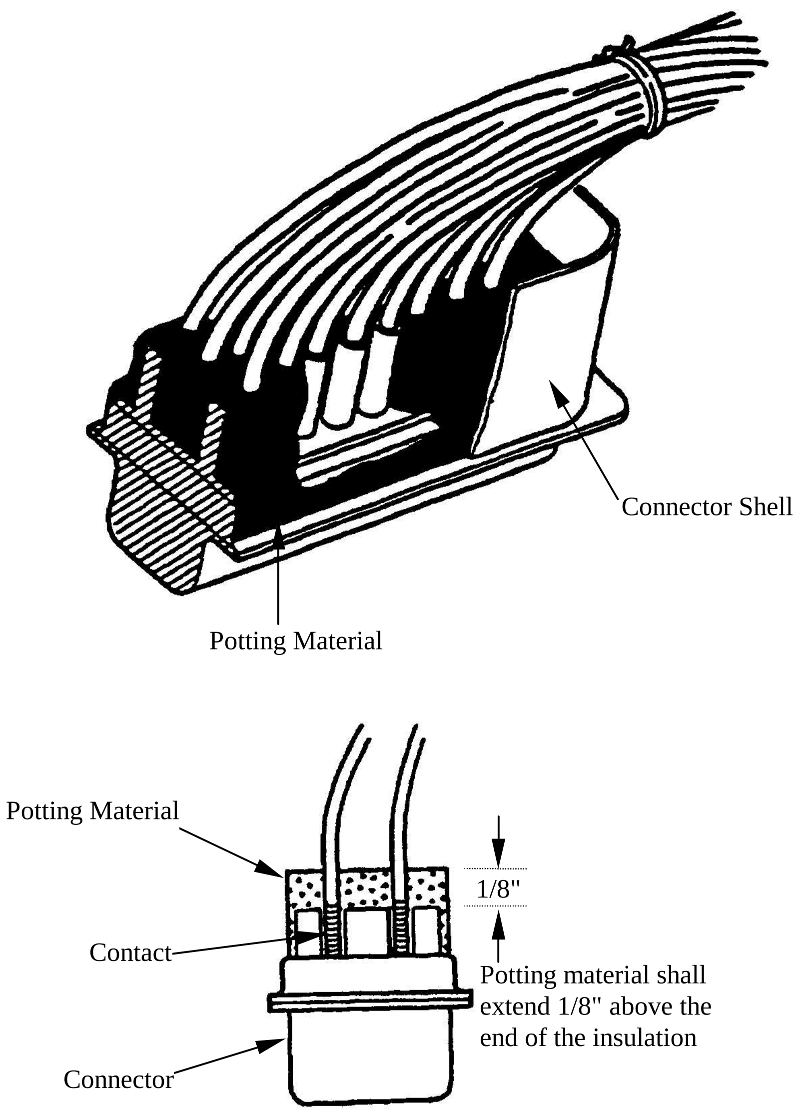


Figure 23. Cross-Sectional View of Connector Potting Process

CONNECTOR SHIELDING

Definition: Shielding is the process where three layers of polymer material are applied to the unprotected junction between the braided cable shield and the connector housing; one such layer having been made electrically conductive by adding a metallic filling to the resin mix.

Purpose: Shielding is applied to bridge and provide radio frequency interference (RFI) and electromagnetic interference (EMI) protection at the junction between the cable shield and the connector housing, replacing the removed insulation jacket. It also provides continuity through the applied conductive coating, thus completing the grounding circuit.

RADIO FREQUENCY (RF) SHIELDING OF CONNECTORS

The polymeric shielding process addresses the problem of providing total RFI and EMI shielding in the area where the cable shield joins with the connector housing, since the metallic cable braid must be terminated above the connector. This creates an unprotected area that is not shielded by a conductive path. Such a condition will allow extraneous electromagnetic and RF signals to be picked up by the internal wires. This is not acceptable.

To provide total RFI and EMI shielding electrical protection to that exposed junction, the polymeric shielding process places a nonconductive layer as a replacement for the previously removed wire insulation. It also provides an electrically conductive layer between the connector metal housing and the metal shielding braid covering the wires, thus completing the grounding circuit. Finally, a protective pigmented layer is applied over the conductive layer, as well as the metallic braid end and connector housing to protect the shielding system. See Figure 24.

INSPECTION REQUIREMENTS

It is the project or inspector's decision whether or not to inspect each step of the RF shielding application. Inspection shall be accomplished by using 4X to 10X magnification.

ACCEPTANCE CRITERIA

1. Potting shall be fully tack-free.
2. There shall be no cracks, cavities, blisters, tears, burns, or discolorations in any layer of the material. The material shall not have pulled away from the connector, solder joints, or wire.
3. Bubbles or pinholes are not acceptable.
4. All potting material shall be free of contamination.
5. A mixing record and witness sample shall be completed for each mix batch date and procedure.
6. There shall be no potting material on the exterior surfaces or in any area of the connector or wires outside of the potting area.

7. There shall be no voids between two electrical conductive elements.
8. The resistance of the conductive layer between the connector body and braid shall be 100 milliohms or less.
9. There shall not be a conductive path between any connector pin and the shield and/or connector body.
10. Connector savers must be in place during processing.

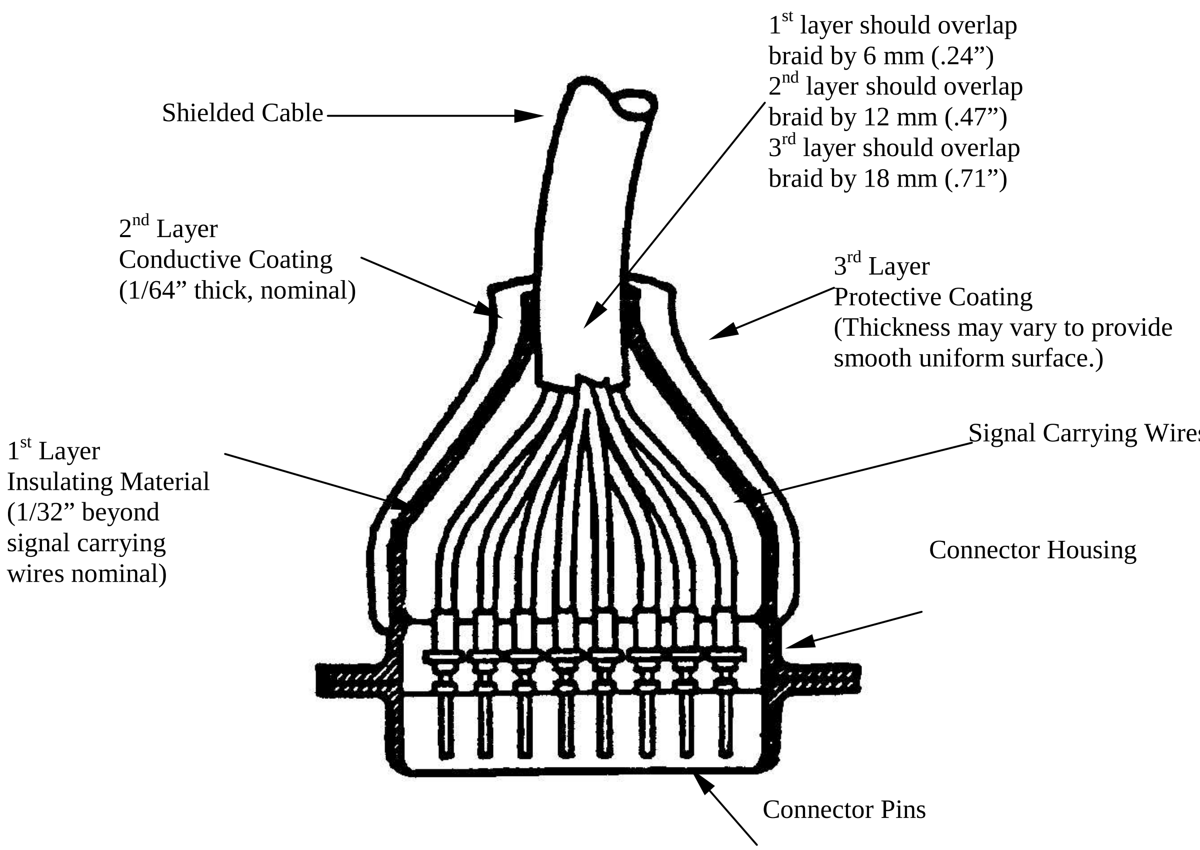


Figure 24. Cross-Sectional View of RF Shielded Connector

BONDING

<u>Definition:</u> Bonding is the process of establishing a firm chemical bond using an adhesive material for securing mechanical and electronic parts to a mounting surface.

<u>Purpose:</u> Bonding provides a cost effective method for reducing total structural weight while reinforcing strength.

SURFACE PREPARATION

The substrate surfaces to be bonded must be abraded to impart sufficient roughness to the area. This is a critical step in effecting reliable adhesion and maximum strength to the bond. The cleaning solvents are acetone and alcohol. Acetone is used to remove oils, waxes, and greases from the substrate surface. Alcohol is employed for the final cleaning. The surfaces are usually cleaned before and always after the abrasion process. The solvents are then gently baked out by heating the surfaces in a convection oven. Heat guns may be used in cases where oven use is not feasible.

Black anodized aluminum is generally not abraded for bonding applications. G-10 epoxy fiberglass (heat resistant) blanket stand-off buttons and Kapton blankets (multilayer insulation) are substrates that require abrasion prior to bonding. Z306 paint and iridite coating must be removed from the aluminum surface, followed by abrasion before bonding can be effected.

Cleaning the abraded surface with an approved clean solvent is mandatory.

Aluminum Surface Preparation. Kapton or Mylar tape (1/2 inch) is used to frame the area for abrasion. First, cleaning is done with a precleaned cotton fabric and ethyl alcohol (200 proof). The surface is then abraded with aluminum oxide sandpaper or with a wire-wheel brush (using a drill or dremel tool). A deep cleaning is then given to the abraded surface using a lint-free cloth with acetone as the solvent. This is followed by a cleaning with a lint-free cloth using 200 proof ethyl alcohol as the solvent. The abraded surface is dried using an oven or heat gun. The aluminum is allowed to cool before polymeric applications are performed. Where drying is inappropriate, sufficient time must be allowed for it to dry out at room temperature.

PART BONDING

Thermally nonconducting epoxy adhesive is applied to bond parts that function only as structural enhancements. Cable tie-down metal clips, blanket buttons, velcro, and various kinds of fasteners fit the category of structural aids.

Thermal sensing parts are structurally bonded with a thermally conductive epoxy adhesive. PRT's, thermostats, thermistors, and heaters are bonded in this way. Normally, foil heaters are bonded with an approved acrylic pressure sensitive adhesive. Special high temperature applications are usually bonded with high temperature epoxy adhesive. Figures 31 and 32 depict other configurations that are bonded.

ACCEPTANCE CRITERIA (GENERAL)

Each acceptance criterion listed under this heading (General) pertains to all types of bonding.

1. Bonding shall be tack-free and fully cured.
2. The adhesive must have good adhesion between the part to be bonded and substrate surface, with no visible lifting or peeling.
3. The bonding material shall be free of air bubbles.
4. All bonding shall be free of contamination and foreign material.
5. A mixing record and witness sample shall be completed for each batch of polymeric material.
6. Excess material shall be removed from edges of the bonded area. Any smears of adhesive on the parts shall be removed.
7. Clips, PRT's, thermostats, thermistors, blanket buttons, and velcro shall show evidence of 100% squeeze out.
8. There shall be no bonding material on terminals.

ACCEPTANCE CRITERIA FOR BONDING

Fasteners Locking (see Figure 25)

9. If a nut is part of the fastener combination, the nut shall be spot bonded (staked) at the 6 o'clock and 12 o'clock position.
10. Bolt locking shall have 75% to 100% of the bolt head's circumference covered with resin.
11. Screw and screw combinations associated with electronic part mounting shall have 50% to 75% of the screw head's circumference covered with resin.

Torque Striping (see Figure 25)

12. There shall be evidence of a torque strip on every torqued fastener.
13. Torque striping shall show no evidence of having been disturbed. Torque stripes shall be applied from the center of the screw or bolt head to at least 1/8 inch onto the substrate surface.

Heater (see Figure 26)

14. Heaters shall show no evidence of bubbles, voids, and delamination.
15. Kapton tape shall secure the edges.
16. The electrical lead wires must be staked 1 inch, at a minimum, from the edge of Kapton tape with an approved staking compound.

Metal Clips (see Figure 27)

17. There shall be no evidence of a break in the perimeter bond line.
18. There shall be complete filling of fastener holes with adhesive.

Platinum Resistance Thermometer (PRT) (see Figure 28)

19. The PRT must be in contact with and parallel to the substrate surface.
20. The adhesive around the PRT must be no greater than 1/16 inch from the edge and overlapping onto the PRT's flange.
21. The adhesive shall not cover the center raised portion of the PRT.
22. The electrical lead wires must be staked 1 inch, at a minimum, from the sensor with an approved staking compound.

Thermistors (see Figure 29)

23. The thermistor body must be in contact with the substrate.
24. The acceptance dot shall be on top and shall not be covered by bonding material.
25. The adhesive surrounding the thermistor shall be no greater than 1/16 inch from the body.
26. The electrical lead wires must be staked 1 inch, at a minimum, from the sensor with an approved staking compound.

Velcro (Hook and Loop Fastener) (see Figure 30)

27. There shall be evidence of an unbroken bond line around the entire perimeter.
28. There shall be no adhesive material on the unbonded surface (i.e., velcro locking surface and margin).

Blanket Buttons (see Figure 31)/**Thermal Switch Bonding** (see Figure 32)

29. There shall be no evidence of a break in the perimeter bond line.

30. The adhesive surrounding the device shall be no greater than 1/16 inch from the body.

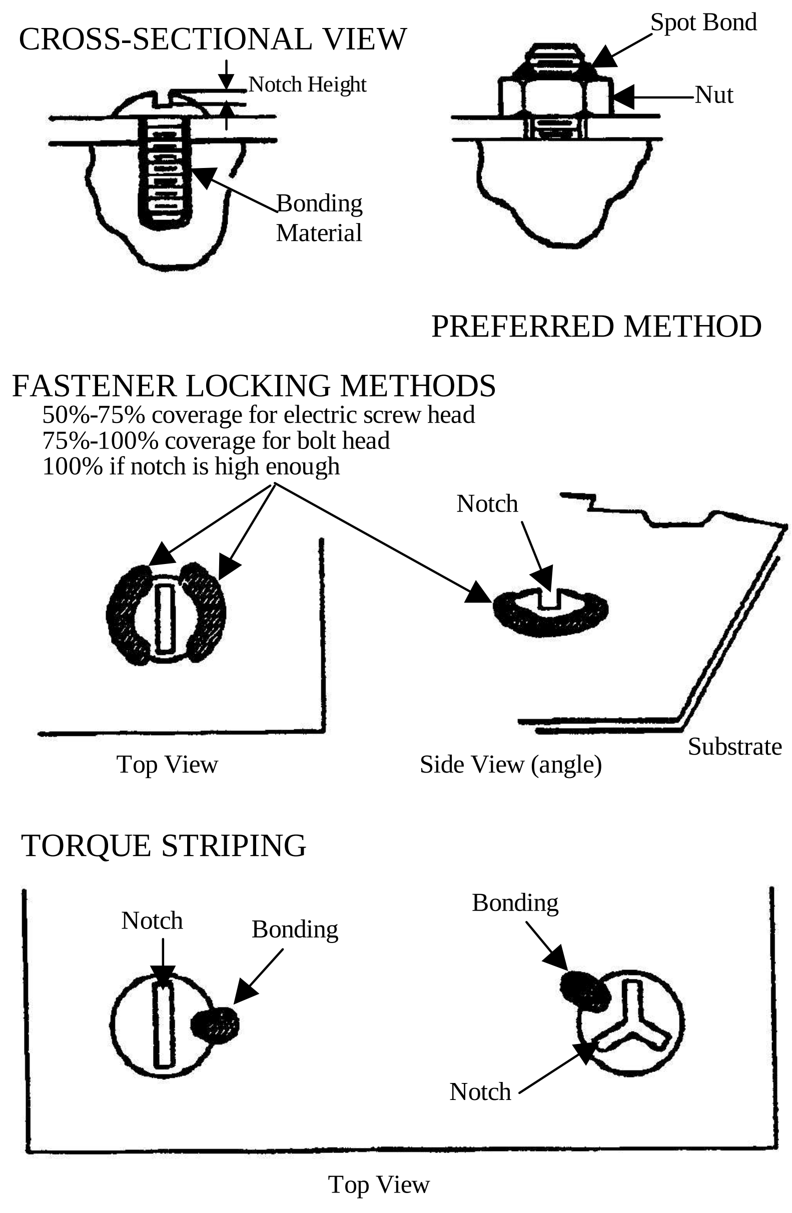


Figure 25. Typical Methods of Faster Bonding

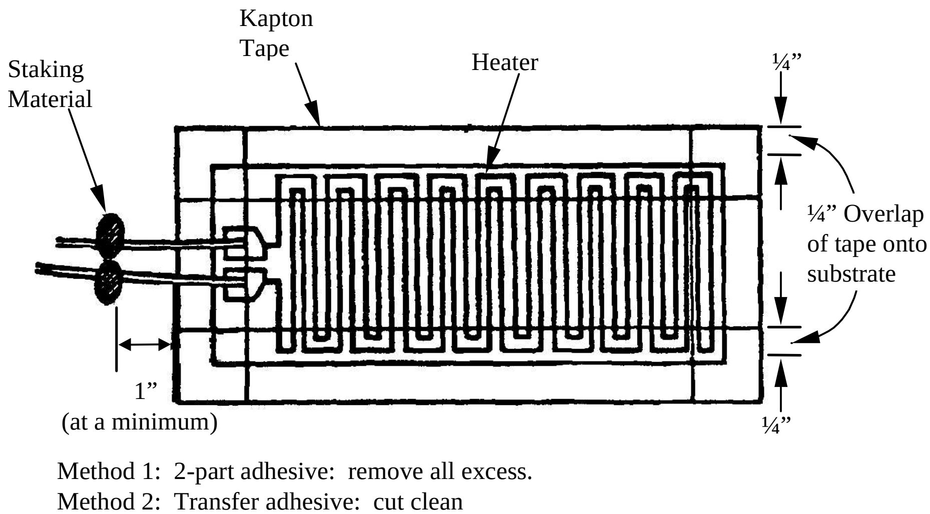


Figure 26. Typical Heater Bonding

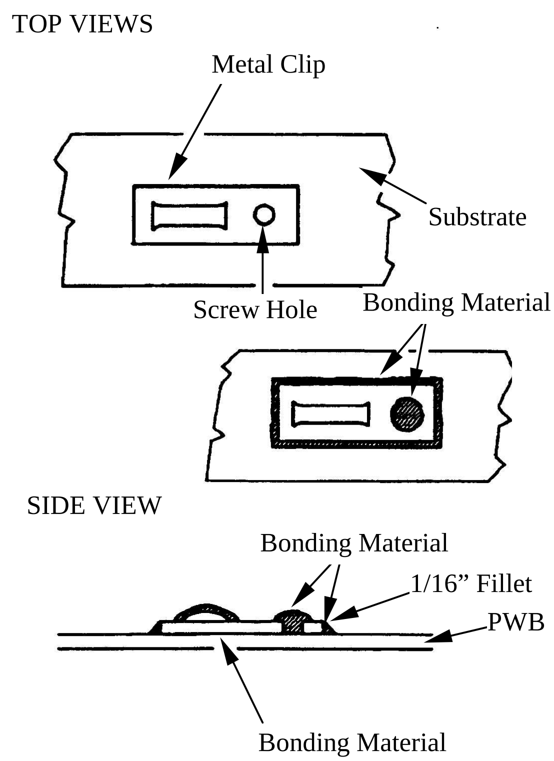


Figure 27. Metal Clip Bonding

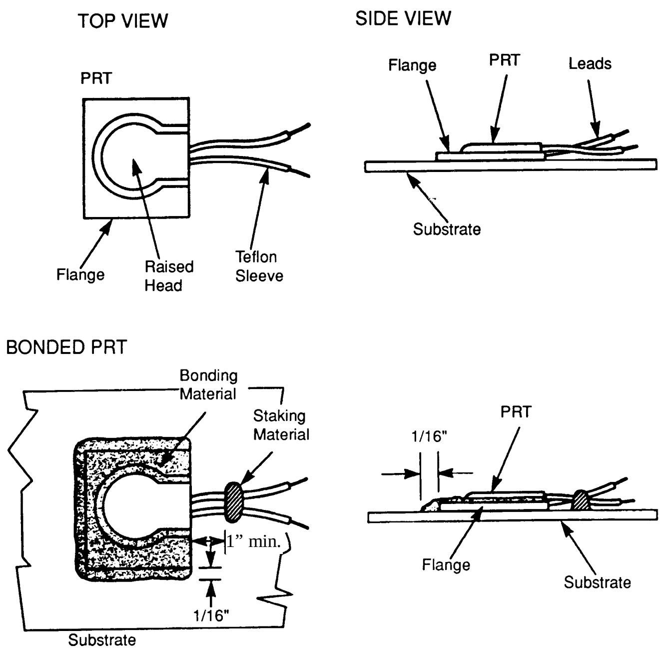


Figure 28. PRT Bonding

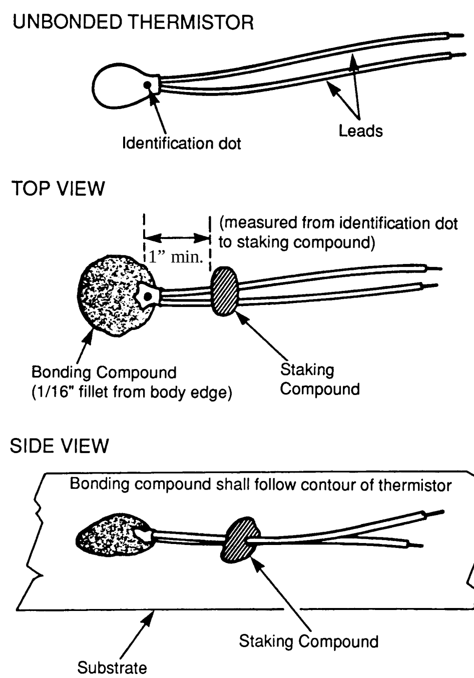


Figure 29. Typical Thermistor Bonding

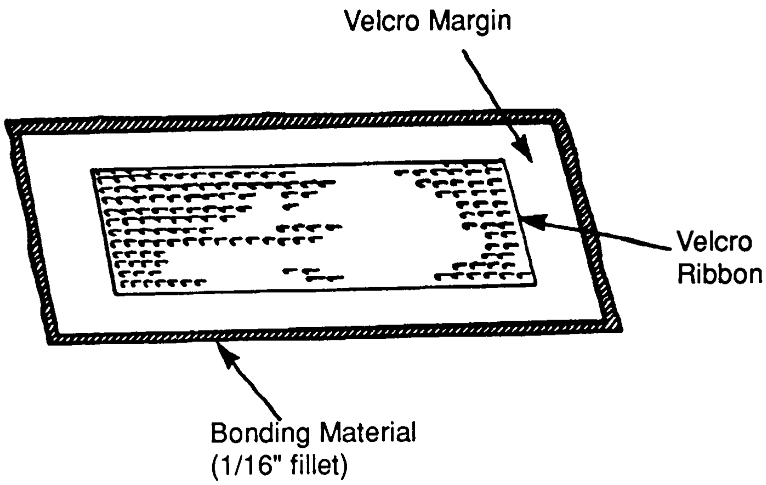
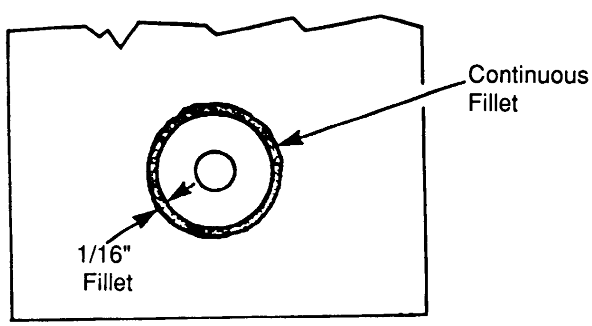


Figure 30. Typical Velcro Bonding



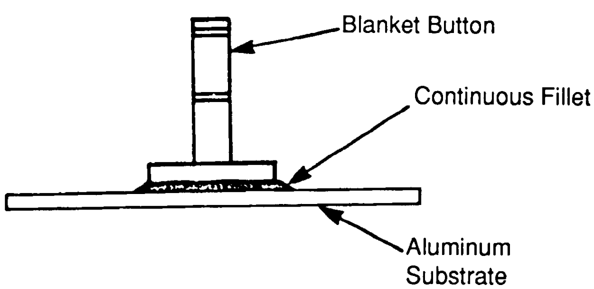


Figure 31. Typical Bonding of Blanket Buttons

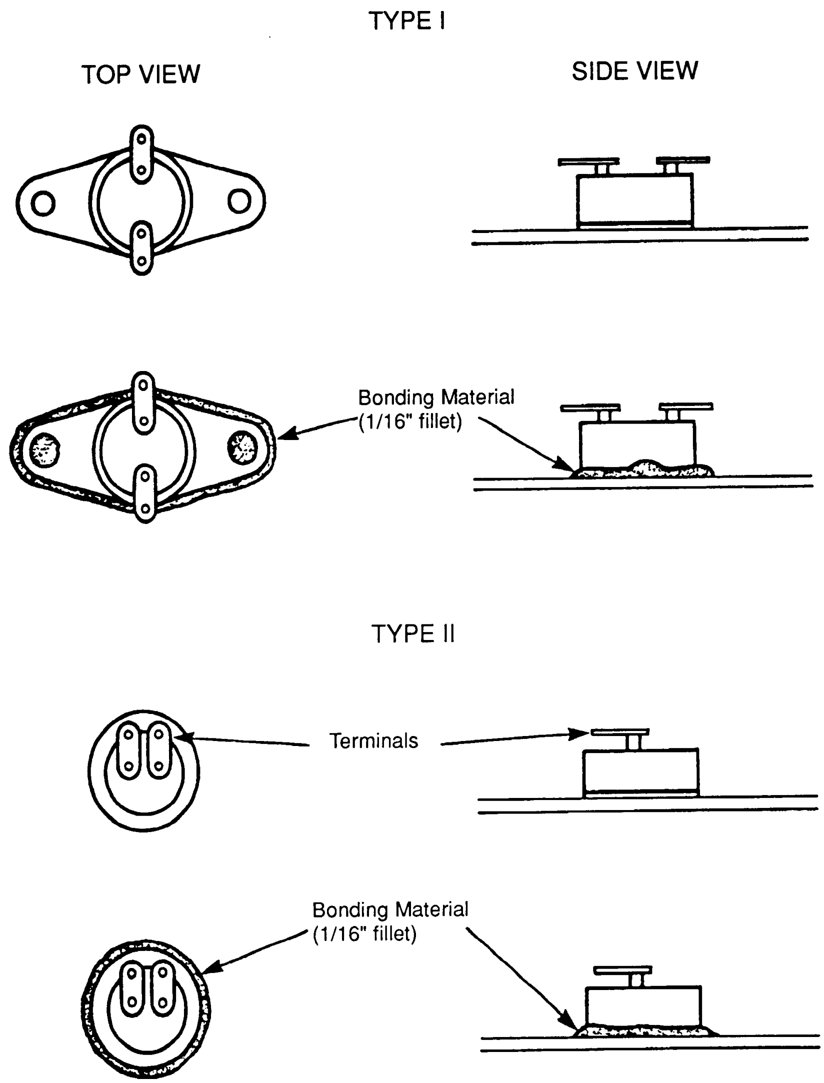


Figure 32. Thermal Switch Bonding

APPENDIX A

Definitions

DEFINITIONS

Blister. Undesirable rounded elevation of the surface of a plastic, whose bound- areas may be more or less sharply defined, resembling in shape a blister on the human skin. The blister may burst and become flattened.

Catalyst. A substance that changes the rate of a chemical reaction without undergoing permanent change in its composition; a substance that markedly speeds up the cure of a compound when added in minor quantity as compared to the amount of primary reactants.

Chemical Properties. Characteristics that relate to the molecular structure of a material and its formation from the elements.

Colloid. A state of matter in which finely divided particles of one substance are suspended in another where the electrical and surface properties acquire special importance. [Gk. "kolla" means glue.

Composite. A combination of two or more materials that has properties that the component materials do not have by themselves.

Conversion Coating. The production of an adherent coating on a metallic surface by changing the chemical nature of the surface of the material through chemical means.

Crazing. Fine cracks that may extend in a network or under the surface of a plastic material.

Curing Agent. A catalytic or reactive agent, similar to a hardener, that when added to a resin causes polymerization.

Copolymer. A long chain molecule formed by the reaction of two or more dissimilar monomers.

CVCM. Collectable, volatile, condensable material.

Dielectric Strength. The highest potential difference (voltage) that an insulating material of a given thickness can withstand for a specified time without electrical breakdown through its bulk.

Diluent. Any material which reduces the concentration of the fundamental resin:

- usually a liquid added to resin to afford lower viscosity in order to facilitate working with the system;
- an inert powdered substance added to the elastomer to increase its volume;
- in an organosol, a liquid component which has little or no solvating action on the resin, its purpose being to modify the action of the dispersant.

Dimensional Properties. The size, shape, finish, and tolerance of a material.

These are not listed in the property handbooks, and are not a legitimate category by most standards but are very important.

DIP. Dual-in-line package. A flat, molded IC package having terminal lugs along both long edges.

Encapsulation. The enclosure of an item in plastic; something used specifically in reference to the enclosure of capacitors or modules. (Also see "potting").

Elongation. Deformation caused by stretching; the fractional increase in length of a material stressed in tension.

Electrical Resistivity. The electrical resistance of a material per unit length and cross section area or per unit length and unit weight.

Extractor. An all-glass apparatus used in the removal of soluble contaminants with a solvent such as ethyl alcohol (200 proof) by a combined process of fractional distillation, reflow condensation, and gravity siphon.

Filler. A relatively inert material added to a plastic mixture to reduce cost, modify mechanical properties, improve surface texture, or to serve as a base for color effects.

fpm. feet per minute.

Gel. A colloidal dispersion of a solid in a liquid, typically having a jelly-like consistency.

Glass Transition Temperature. The temperature above which an amorphous polymer displays viscous behavior caused by chain slip. Below the Tg, the material behaves like a glass-brittle solid.

Hardener. A substance or mixture added to a plastic composition to promote or control the curing action by taking part in it. Also, a substance added to control the degree of hardness of the cured film.

Hardness. The resistance of a material to permanent plastic deformation, usually by indentation or abrasion.

Hydrolysis. Decomposition of a compound by water.

Hygroscopic. Having a tendency to absorb moisture.

Impact Strength. The amount of energy required to fracture a given volume of material by mechanical shock.

Inhibitor. A substance that retards a chemical reaction; used in certain types of monomers and resins to prolong storage life.

Mechanical Properties. The characteristics of a material that are displayed when a force is applied to the material.

Mold. The cavity or matrix into or on which the plastic composition is placed and from which it takes its form. Also, to shape plastic parts or finished articles by heat and pressure, or the assembly of all parts that function collectively in the molding process.

MSDS. Material Safety Data Sheet.

nm. nanometers. A unit of wavelength.

Out of Flat. The deviation of a surface from a flat plane, usually over a macroscopic area.

PBW. Parts-by-weight.

Physical Properties. The characteristics of materials that pertain to the interaction of those materials with various forms of energy and with other forms of matter.

Pot Life. The length of time that a catalyzed resin system takes to double its original viscosity.

Potting. Similar to encapsulating, except that steps are taken to insure complete penetration of the voids in the object before the resin polymerizes.

Prepolymer. A chemical structure intermediate between that of the monomers and the final polymer or resin.

Promoter. A chemical, itself a catalyst, that greatly increases the activity of a given catalyst.

PRT. Platinum Resistance Thermometer.

PWA. Printed Wiring Assembly.

PWB. Printed Wiring Board.

Resin. Generally, any synthetic plastic material produced by polymerization.

Roughness. Relatively finely spaced surface irregularities, the height, width, and direction of which establish a definite surface pattern.

Shear Strength. The stress required to produce fracture in the plane of the cross section of a material. The conditions of bonding are such that the directions of force and resistance are parallel and opposite.

Squeeze-out. The resin and/or reinforcement that create flash.

Structural Bond. A bond that joins basic load-bearing parts of an assembly. The load may be either static or dynamic.

Tensile Strength (ultimate strength). The ratio of the maximum load in a tension test to the original cross-sectional area of the test bar.

Thermal Conductivity. Ability of a material to conduct heat. Also, the physical constant for the quantity of heat that passes through unit thickness across unit area of a substance, for unit difference in temperature.

Thermal Expansion (linear coeff., of). The rate that a material elongates when heated. The rate is expressed as a unit increase in length per unit rise in temperature within a specified temperature range per unit length.

Thermoplastic. Capable of being repeatedly softened and hardened by an increase and decrease of temperature respectively. This change is substantially physical rather than chemical.

Thermoset. A plastic, which when cured by application of heat or by chemical means, changes into a substantially infusible and insoluble material.

Thixotropic. Materials that are gel-like at rest but are fluids when agitated.

TML. Total mass loss.

UV. Ultra-violet.

Voids. Gaseous pockets that have been trapped and cured into a laminate.

Wetting. The thorough impregnation of a material by a liquid. A condition of reduced surface tension that promotes adhesion to a surface.

Yield Strength. The stress that a material exhibits at a specified deviation from proportionality of stress and strain.