

National Aeronautics and
Space Administration

HYBRID

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August 6, 1999

WORKMANSHIP STANDARD FOR STAKING AND CONFORMAL COATING OF PRINTED WIRING BOARDS AND ELECTRONIC ASSEMBLIES

NASA TECHNICAL STANDARD

PREFACE

Effective Date: 6 August 1999

This document has been issued to make available to project managers a technical standard for staking and conformal coating of printed wiring boards and electronic assemblies.

The document:

Prescribes NASA's requirements, procedures, and documenting requirements for staking and conformal coating of printed wiring boards and electronic assemblies. These may be tailored to the program applications to obtain the most cost effective, best quality product.

Describes basic considerations necessary to ensure reliable staking and conformal coating of printed circuit boards and electronic assemblies.

Establishes the responsibility for documentation of those fabrication and inspection procedures to be used for NASA work including supplier innovations, special processes, and changes in technology. For the purpose of this document the term supplier is defined as in-house NASA, NASA contractors, and subtier contractors.

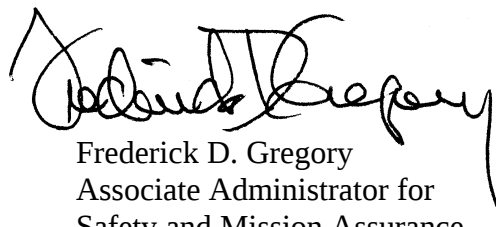
Procuring NASA Enterprise Programs or Centers shall review this document for applicability to NASA contracts as well as for applicability to internal activities.

Questions concerning the application of this publication to specific procurements or requests should be referred to the NASA Enterprise Program or Center.

Comments and suggestions for improving this publication may be submitted using the form "NASA Standard Improvement Proposal." A copy of this form is included at the end of the document.

This Standard cancels NASA Assurance Standard 5300.4 (3J-1), Workmanship Requirements for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies.

Other processes such as soldering or cabling and harnessing, not covered by this document may be required to fabricate hardware involving staking and coating. The design, materials, and processes not covered shall be defined in engineering documentation.



Frederick D. Gregory
Associate Administrator for
Safety and Mission Assurance

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SDL1 (SIQ)

NASA TECHNICAL STANDARDS FOR FLIGHT HARDWARE WORKMANSHIP

NASA Technical Standards can be found on the World Wide Web at URL address
<http://www.hq.nasa.gov:80/office/codeq/doctree/qdoc.pdf>.

Title	Number
Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies	NASA-STD-8739.1
Workmanship Standard for Surface Mount Technology	NASA-STD-8739.2
Soldered Electrical Connections	NASA-STD-8739.3
Crimping, Interconnecting Cables, Harnesses, and Wiring	NASA-STD-8739.4
Fiber Optic Terminations, Cable Assemblies, and Installation	NASA-STD-8739.5
Standard for Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)	NASA-STD-8739.7

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CHAPTER 1 - SCOPE

1.1 Scope

This Standard prescribes NASA's requirements, procedures, and documenting requirements for staking and conformal coating of printed wiring boards (PWBs) and electronic assemblies. These requirements may be tailored to the program applications to obtain the most cost effective, best quality product.

1.2 Purpose

This publication sets forth requirements for staking and conformal coating of printed wiring assemblies (PWA's).

1.3 Applicability

This publication is applicable to NASA programs involving staking and conformal coating applications for flight hardware, mission critical ground support equipment, and elements thereof, and wherever invoked contractually.

1.4 Special Requirements

Special requirements may exist that are not in conformance with the requirements of this publication. Engineering documentation shall contain the details for such requirements, including modifications to existing equipment, and shall take precedence over appropriate portions of this publication when approved in writing by the procuring NASA Center.

1.5 Approval of Departures From This Standard

1. Departures from this publication require written approval from the cognizant NASA contracting officer. The supplier is responsible for assuring that any departures from this publication are evaluated by, coordinated with, and submitted to the procuring NASA Center for approval prior to use or implementation.
2. For in-house NASA projects, this publication requires written approval by the in-house NASA project management to deviate from the provisions herein.

CHAPTER 2 - APPLICABLE DOCUMENTS

2.1 Related Documents

1. **Applicable Specifications.** Copies of the following specifications, when required in connection with a specific procurement, can be obtained from the procuring NASA Center or as directed by the contracting officer. Unless otherwise specified, the issue in effect on the date of invitation for bids or requests for proposal shall apply. The following related documents form a part of this publication to the extent specified herein.

FEDERAL SPECIFICATIONS:

O-E-760	Ethyl Alcohol (Ethanol) Denatured Alcohol; Proprietary Solvents and Special Industrial Solvents
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IT-I-735	Isopropyl Alcohol
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MILITARY SPECIFICATIONS:

MIL-I-46058	Insulating Compound, Electrical (for Conformal Coating Printed Circuit Assemblies)
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QPL-46058	Qualified Product List for MIL-I-46058
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MIL-STD-1246	Product Cleanliness Levels and Contamination Control Program
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NASA SPECIFICATIONS:

NASA-STD-8739.9	Standard for Electrostatic Discharge Control (Excluding Electrically Initiated Explosive Devices)
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NASA-STD-6001	Flammability, Odor, Offgassing and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion
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INDUSTRY SPECIFICATIONS:

ANSI/NCSL Z540-1-1994	General Requirements for Calibration Laboratories and Measuring and Test Equipment
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ASTM-D-2240	Standard Test Method for Rubber Property - Durometer Hardness
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ASTM-E-595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials From Outgassing in a Vacuum Environment
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OSHA Standards

Occupational Safety and Health Administration (OSHA),
Title 29, Code of Federal Regulations (CFR), Part 1910,
Occupational Safety and Health Standards.

CHAPTER 3 - DEFINITIONS AND ACRONYMS

3.1 Terms and Definitions

The following definitions apply to terms used in conformal coating and staking.

Accelerator. A chemical used to speed up a reaction or cure.

Batch. That quantity of material that was subjected to unit chemical processing or physical mixing, or both, designed to produce a product of substantially uniform characteristics.

Blister. Undesirable rounded elevation of the surface of a polymer, whose boundaries may be more or less sharply defined.

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.

Certification. The act of verifying and documenting that personnel have completed the required training and have demonstrated specified proficiency and have met other specified requirements.

Conductor. A lead or wire, solid, stranded, or printed wiring path serving as an electrical connection.

Conformal Coating. A thin electrically nonconductive protective coating that conforms to the contours of the PWA.

Connection. An electrical termination that was soldered. A solder joint.

Contaminant. An impurity or foreign substance present in a material that affects one or more properties of the material. A contaminant may be either ionic or nonionic. An ionic, or polar, compound forms free ions when dissolved in water, making the water a more conductive path. A nonionic substance does not form free ions, nor increase the water's conductivity. Ionic contaminants are usually processing residue such as flux activators, finger prints, and etching or plating salts.

Cure. A chemical reaction that hardens and changes the physical properties of a material.

Diluent. Any material that reduces the concentration of the fundamental resin; usually a liquid added to the resin to afford lower viscosity.

Filler. A material added to polymers in order to reduce cost or modify physical properties.

Fillet. A smooth, generally concave, buildup of material between two surfaces (e.g., a buildup of conformal coating material between a part and a PWB).

Fisheyes. A small area of a fabric that resists resin wetting that can be caused by the resin system, fabric, and treating.

Flatpack. A part with two straight rows of leads (normally on 1.27mm (0.050 inch) centers) that are parallel to the part body.

Flux. A chemically-active compound which, when heated, removes minor surface oxidation, minimizes oxidation of the basis metal, and promotes the formation of an intermetallic layer between solder and basis metal.

Gelling. Formation of a semi-solid system consisting of a network of solid aggregates in which liquid is held; the initial gel-like solid phase that develops during the formation of a resin from a liquid.

Glass Transition Temperature (T_g). The polymer's characteristic temperature below which a glassy state forms and, above which a rubbery state is produced. Below T_g, free rotations around chemical bonds cease due to intra-molecular energy barriers (i.e. the polymer stiffens). Above T_g, chain slippage is possible.

Hygroscopic. Capable of absorbing moisture from air.

Lifting. The separation of conformal coating from the PWA, usually due to improper preparation. Lifting is distinguished from peeling in that the layer of conformal coating is continuous.

Measling. A condition at the interface of the conformal coating and base material, in the form of whitish spots or patches which reveal a separation of the conformal coating from the surface of the printed wiring board or from the surface of attached components or from both.

Module. A separable unit in a packaging scheme.

Offgassing. Deaeration or other gaseous emission from a liquid or solid material when exposed to reduced pressure, heat, or both that may affect crew members.

Outgassing. Gaseous emission from a liquid or solid material when exposed to reduced pressure, heat, or both.

Part Lead. The conductor attached to a part.

Peeling. The separation of conformal coating from the PWA, usually due to improper preparation or abrasion. Peeling is distinguished from lifting in that the layer of conformal coating is not continuous.

Plasticizer. A material incorporated in a polymer to increase its work ability and its flexibility or distensibility. Normally used in thermoplastics.

Printed Wiring Assembly. The PWA consists of the PWB, components, and associated hardware and materials.

Printed Wiring Board. A pattern of conductors printed (screened) onto the surface of an insulating base to provide interconnection for parts.

Staking. The process of bonding and securing components or parts to PWB's and electronic assemblies by means of an adhesive material.

Staking Compound. An electrically nonconductive adhesive material used for additional support after a part has been attached by mechanical or soldering process.

Stress Relief. The formed portion of a conductor that provides sufficient length to minimize stress between terminations.

Substrate. That surface upon which an adhesive is spread for any purpose, such as coating; a broader term than "adherend".

Supplier. All in-house NASA, NASA contractors, and subtier contractors.

Touch-up. The addition of conformal coating to correct conformal coating deficiencies.

Viscosity. A measure of the resistance of a fluid to flow.

Witness Sample. A portion of mixed polymer material that is processed at the same time and under the same conditions as the end item product.

3.2 Acronyms

The following acronyms apply to terms used in this Standard.

CFR	Code of Federal Regulations
CVCM	Collected Volatile Condensable Material
CVD	Chemical Vapor Deposition
DIP	Dual-In-Line Package
DOT	Department of Transportation
EEE	Electrical, Electronic, and Electromechanical
EPA	Environmental Protection Agency
ESD	Electrostatic Discharge
GSFC	Goddard Space Flight Center
JPL	Jet Propulsion Laboratory
MSDS	Material Safety Data Sheet
NASA	National Aeronautics and Space Administration

OSHA	Occupational Safety and Health Administration
PWA	Printed Wiring Assembly
PWB	Printed Wiring Board
QPL	Qualified Products List
RM&QA	Reliability, Maintainability, and Quality Assurance
RMS	Root Mean Square
TML	Total Mass Loss
UV	Ultraviolet

CHAPTER 4 - GENERAL

4.1 General

1. **Implementation.** NASA quality assurance personnel will advise and assist suppliers, NASA personnel, and delegated agencies in the proper and effective implementation of the provisions of this publication. Effective implementation includes establishing a system that will identify each inspection point and provide records.
2. **Changes in Requirements.** When related requirements or changes in requirements are specified, NASA quality assurance personnel will assure that the Government agency delegated to inspect at the supplier's site of fabrication has received full instructions so that the work will be inspected to actual contract requirements.
3. **Nonstandard Processes, Materials, or Parts.** When the supplier intends to use processes, materials, or parts not covered by this publication, the supplier shall document the details of fabrication and inspection, including acceptance and rejection criteria, and shall provide appropriate test data. Such documentation shall be approved by the procuring NASA Center prior to use.
4. If at any time during any phase of staking or conformal coating, a condition should arise that the operator feels may damage or in any way affect the reliability of the hardware, the work shall be halted until that condition has been reviewed and resolved.
5. The prime contractors are responsible for delegating the requirements herein to their subtier suppliers as required.

4.2 Documentation

1. The supplier shall document the methods and procedures proposed to incorporate the requirements of this Standard into the design, fabrication, and inspection of staking and conformal coating applications involved in the contract or purchase order.
2. Documents required herein, except as specified by paragraph 4.1-3, shall be submitted to the procuring NASA Center, or its designated representative, as required by the contract or purchase order. Applicable supplier staking and conformal coating program documents, or portions thereof, accepted on other NASA contracts shall be included to avoid duplication of effort.

4.3 Rework and Repair

1. **Rework.** Rework is permissible unless excluded by other provisions of the contract. All rework shall meet the requirements of this publication and approved engineering documentation.
2. **Repair is not Rework.** Repairs shall be made only in compliance with applicable contractual requirements and after authorization for each incident by the procuring

NASA Center. Repairs shall be accomplished using documented methods previously approved by the procuring NASA Center. For in-house NASA projects, repairs shall be authorized for each incident by the Project Office and Quality Management.

4.4 Principles of Reliable Staking and Conformal Coating

1. **Factors Controlling Reliability.** Reliable staking and conformal coating results from proper design, control of equipment, materials, work environments, and careful workmanship by trained and certified personnel.
2. **Fabrication Principles.** All fabrication shall be performed to meet governing engineering documentation.
3. **Design Considerations for Staking.** Staking material shall be specified on the approved engineering documentation. The basic design considerations to assure reliable staking materials are as follows:
 - a. 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.
 - b. 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.
 - c. The staking material must be compatible with, and adhere to, the PWB or substrate, the part staked, and the conformal coating to be applied.
 - d. 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 requirements.
 - e. The staking compound selected must not negate stress relief in part leads or on jumper wires.
 - f. 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.
 - g. Staking material must not be applied to areas where induced stress will cause damage, such as under a dual-in-line package (DIP) integrated circuit or flat pack device.

- h. The staking material selected shall be curable under temperature conditions compatible with the PWA on which it is located.
4. **Design Considerations for Conformal Coating.** Conformal coating material shall be specified on the approved engineering documentation. The basic design considerations to assure reliable conformal coatings are as follows:
- a. The conformal coating material and process selected shall be suited to the complexity of the assembly and shall be capable of covering the circuitry.
 - b. The conformal coating material selected shall have dielectric properties that will meet the minimum circuit requirements in all anticipated environments. The material shall be noncorrosive and curable under conditions compatible with the parts on the PWA, including their temperature limits.
 - c. The conformal coating material shall not cause damaging stress to the PWA, electronic assembly, or electrical interconnections.
 - d. The coating material shall exhibit stability under high-vacuum and thermal-vacuum conditions. The material shall meet program and contractual outgassing, offgassing, and flammability requirements.
 - e. The coating material selected shall have maintainability properties (repair and rework) compatible with the parts and PWB or other substrates.
 - f. The coating material selected shall be compatible with, and adherent to, all materials used in PWA's and electronic assemblies.
 - g. The coating material selected shall be hydrolytically and thermally stable, as required.
 - h. The coating thickness shall be within the range specified for each type of material unless otherwise specified.

CHAPTER 5 - TRAINING AND CERTIFICATION PROGRAM

5.1 General

1. The supplier is responsible for maintaining a documented training program that meets the requirements of this Standard.
2. The supplier shall assure that design personnel are familiar with the requirements of this Standard, staking and conformal coating techniques, and other pertinent requirements of the contract. The supplier shall implement and document a training program that provides the necessary training of staking and conformal coating fabrication and inspection personnel in techniques, use of equipment, and procedures pertinent to their responsibilities in performance of the contract requirements. The supplier is responsible for certifying and maintaining the certification of each individual who fabricates, inspects, or instructs.
3. Operators, inspectors, and instructors shall be qualified to fulfill all requirements of this Standard involved in their assigned tasks. Demonstration of proficiency and understanding of the requirements is a requisite for certification and recertification. Evidence of certification status shall be maintained in the work area.

5.2 Vision Requirements

1. The supplier is responsible for ensuring that all personnel who perform or inspect staking or conformal coating applications meet the following vision test requirements as a prerequisite to training, certification, and recertification. The vision requirements may be met with corrected vision (personal eyeglasses). The vision tests shall be administered every 2 years by a qualified eye examiner, accepted by the procuring supplier, using standard instruments and techniques. Results of the visual examinations shall be maintained and available for review.
2. The following are minimum vision requirements:
 - a. **Far Vision.** Snellen Chart 20/50.
 - b. **Near Vision.** Jaeger 1 at 355.6 mm (14 inches), or reduced Snellen 20/20, or equivalent.
 - c. **Color Vision.** Ability to distinguish red, green, blue, and yellow colors as prescribed in Dvorine Charts, Ishihara Plates, or AO-HRR Tests.

NOTE: *A PRACTICAL TEST, USING COLOR CODED WIRES AND/OR COLOR CODED ELECTRICAL PARTS, AS APPLICABLE, IS ACCEPTABLE FOR COLOR VISION TESTING.*

5.3 Certification Levels

1. Level A NASA instructors are certified by the NASA Training and Certification Board. Level A NASA instructors have the authority to train Level B instructors, operators, and inspectors. Upon successful course completion, a certificate shall be issued.
2. Certification of Level B instructors shall be provided by the supplier based on successful completion of training by a Level A NASA instructor. Level B instructors are authorized to train operators and inspectors employed at their organization and subtier contractors.
3. Certification of inspectors shall be provided by the supplier based on successful completion of training by a Level A NASA instructor or Level B supplier instructor. An inspector is trained and certified to inspect for conformance with the requirements of this Standard.
4. Certification of operators shall be provided by the supplier based on successful completion of training by a Level A NASA instructor or Level B supplier instructor. An operator is trained and certified to apply polymeric materials in conformance with the requirements of this Standard. When operators are certified to perform limited operations or processes, it shall be stated on the certification card.

5.4 Training Program Requirements

1. The supplier is responsible for training and certification of operators and inspectors in the staking and conformal coating processes and associated processing equipment.
2. The supplier training program documentation shall be submitted to the procuring NASA Center as directed by the contract. A NASA Generic Staking and Conformal Coating Training Plan from the NASA Workmanship Training Centers is available for use as a guideline.
3. The training program shall:
 - a. Identify the criteria for qualification and certification of Level B instructors, inspectors, and operators.
 - b. Document the methods and procedures proposed to fulfill the requirements of this Standard.
 - c. Utilize visual standards consisting of satisfactory work samples or visual aids that clearly illustrate the quality characteristics of polymeric applications applicable to the contract.
 - d. Utilize applicable illustrations in this Standard, supplemented as necessary, for visual standards. Standards of unacceptable conditions may also be used for clarification or comparison.

- e. Make applicable standards readily available.

5.5 Documentation

1. The supplier training program documentation shall describe the training and certification program proposed to satisfy the requirements herein for the staking and conformal coating applications. This description shall include the following, as applicable:
 - a. Qualification of instructors.
 - b. Procedures for training, including who will be trained and for what purpose, (e.g., operator, inspector).
 - c. Lesson plan(s)/student standards.
 - d. Hours of instruction.
 - e. Procedures for certification and recertification.
 - f. Procedures for recording training, recertification, and a method of identifying/recalling trained personnel.
 - g. Certification criteria.
2. Records of training and certification shall become part of the supplier's quality data and shall be retained for a minimum of 5 years.
3. Evidence of certification status, including limitations, shall be available in the work area.

5.6 Maintenance of Certification Status

1. Maintenance of certification for instructors, operators, and inspectors requires continuous proficiency.
2. Recertification of Level B instructors shall include the successful completion of retraining by a Level A NASA instructor. Recertification of operators and inspectors shall include successful completion of retraining by a Level A NASA instructor or a Level B supplier instructor.
3. Recertification shall be required when:
 - a. Proficiency requirements herein are not met.
 - (1) Instructors - proficiency unacceptable.
 - (2) Operators - unsatisfactory quality of articles fabricated.

- (3) Inspectors - unsatisfactory quality of inspection.
- (4) Quality/quantitative data demonstrates a need for recertification.
- b. New staking or conformal coating application or inspection techniques have been approved that require different skills.
- c. Work period interruption of greater than 6 months occurs.
- d. Two years have elapsed since the last certification.
- 4. Certification shall be revoked when:
 - a. Certificate holder fails recertification.
 - b. Certificate holder fails to meet visual acuity requirements of paragraph 5.2.
 - c. Employment is terminated.
 - d. Supplier training program fails to meet requirements set forth herein or those set forth otherwise in the contract.

5.7 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, CA91109
(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.

CHAPTER 6 - FACILITIES, TOOLS, AND MATERIALS

6.1 Safety

1. **General.** Personal protective equipment shall be provided as appropriate to the work being performed. At a minimum, protective equipment shall include eye protection, gloves, and ventilation systems. Protective equipment shall comply with the requirements of Occupational Safety and Health Administration (OSHA), 29 CFR Part 1910, personal protective equipment.
2. **Protective Gloves.** Staking and conformal coating materials may affect skin; hence, protective gloves shall be worn during processing. Rubber or other approved protective gloves shall be free of plasticizers or other contaminants.
3. **Protective Glasses.** Protective glasses shall be worn during processing.
4. **Handling of Staking and Conformal Coating Materials.** Staking and conformal coating material may be flammable or contain harmful solvents. No smoking or open flame shall be allowed within 7.6 meters (25 feet) of the staking or conformal coating operation and storage areas.

WARNING: *ALL SOLVENTS AND CHEMICALS MAY PRESENT HEALTH AND SAFETY PROBLEMS. FOLLOW DOT/EPA/OSHA PRECAUTIONS AND GUIDELINES FOR HANDLING, TRANSPORTING, STAGING, AND DISPOSAL OF HAZARDOUS WASTE. THESE ACTIVITIES SHALL BE PERFORMED IN ACCORDANCE WITH APPLICABLE HOST GOVERNMENT OR COUNTRY REGULATIONS.*

5. **Exposure to Solvents.** Personnel exposure to solvents and vapor of solvents shall be minimized and controlled in accordance with OSHA, 29 CFR Part 1910.
6. **Exposure to Carcinogenic, Mutagenic, and Toxic Agents.** Polymeric materials may contain carcinogenic, mutagenic, and toxic agents. OSHA restrictions, 29 CFR Part 1910, on exposure shall be followed. See the applicable Material Safety Data Sheet (MSDS) for each material. The supplier shall ensure that the hazards of all chemicals used are evaluated, and that information concerning their hazards is transmitted to employees. This transmittal of information shall be accomplished by means of a comprehensive hazard communication program, to include container labeling and other forms of warning, MSDS's, and employee training. MSDS's shall be available for reference at the work area.

6.2 Facility Cleanliness

The work area shall be maintained in a clean and orderly condition. Smoking, eating, and drinking materials in staking and conformal coating areas and at individual work stations shall not be permitted. Nonessential tools and materials shall not be permitted at the work station.

WARNING: *SMOKING, EATING, AND DRINKING MATERIALS MAY ABSORB CHEMICALS THAT ARE HARMFUL TO PERSONNEL.*

6.3 Environmental Conditions

1. **Controlled Environment.** The staking and conformal coating area shall have a controlled environment that limits the entry of contamination. The temperature and humidity of this area shall be monitored and maintained within the limits defined as the working zone in Figure 6-1.

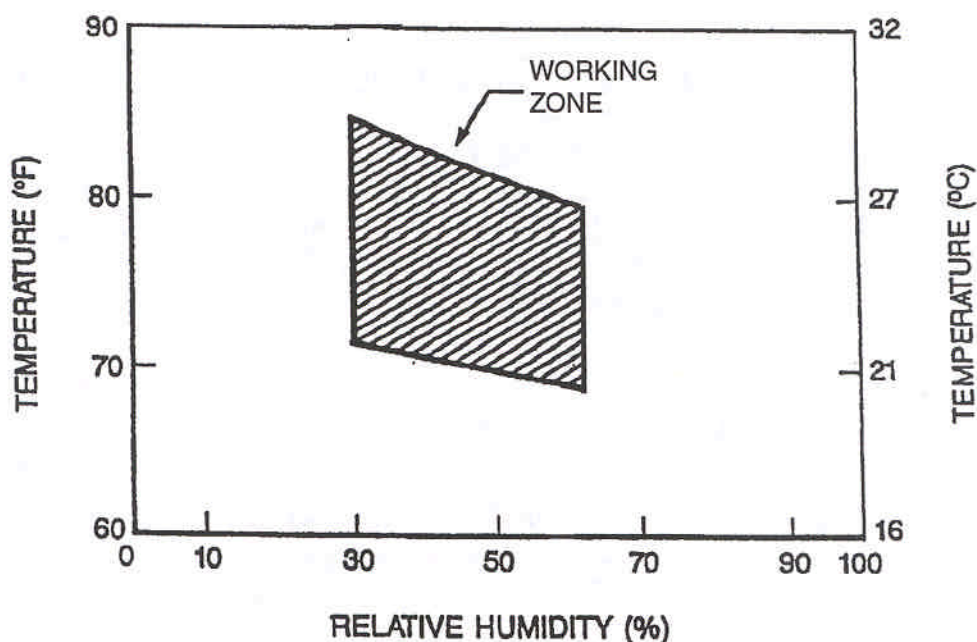


FIGURE 6-1. Working Zone - Temperature versus Humidity Requirements

2. **Special Environmental Requirements.** Parts or equipment being processed that require more stringent control of environmental conditions than those stated above shall have these requirements and controls identified and specified on the engineering documentation.
3. **Ventilation System.** Areas used for cleaning parts, and areas where toxic or volatile vapors are generated, shall have an adequate ventilation system for removing air contaminants. The ventilation system shall comply with the recommendations and guidelines of the OSHA 29 CFR Part 1910.
4. **Field Operations Requirement.** In field operations where the required controlled conditions cannot be effectively achieved, special precautions shall be taken to minimize the effects of the uncontrolled environment on the operation being performed on the hardware. These precautions shall be identified in the appropriate documentation.

5. **Lighting Requirements.** Light intensity shall be a minimum of 1077 Lumens per square meter (Lm/m²) (100 foot - candles) on the surface being staked, conformally coated, or inspected. Supplemental lighting may be used to achieve the required levels.

6.4 Electrostatic Discharge Requirements

Electrostatic Discharge (ESD) requirements shall be in accordance with NASA-STD-8739.7.

6.5 Tool and Equipment Control

1. Each supplier shall:
 - a. Select tools to be used in staking, conformal coating, and in work preparation areas appropriate to their intended function.
 - b. Clean and properly maintain all tools and equipment.
 - c. Examine all elements of tools used in polymeric applications for physical damage.
 - d. Prohibit unauthorized, defective, or uncalibrated tools in the work area.
 - e. Document detailed operating procedures and maintenance schedules for tools and equipment requiring calibration or set up. Maintain records of tool and equipment calibration and functional testing.
2. The supplier shall have a documented calibration system in accordance with ANSI/NCSL Z540-1-1994. The minimum standard shall be:
 - a. Measurement standards used for calibrating tools must be traceable to the National Institute of Standards and Technology. Calibration of tools shall be performed in an environment compatible with the environmental requirements of the tools.
 - b. Calibration intervals shall be based on the type of tool and records of the tool's calibration. Intervals may be lengthened or shall be shortened on the basis of stability demonstrated over previous calibration periods.
 - c. Procedures shall be generated and utilized for the calibration of all tooling stated herein. Procedures shall include, as a minimum, standards to be used, parameters to be measured, accuracy, tolerances, environmental factors, and steps in the calibration process. The procedures may be manufacturer's specifications if judged adequate, and need not therefore be rewritten, but must be documented.
 - d. Records shall be maintained that document the data for each tool calibration.

- e. Tools shall be labeled to indicate, as a minimum:
 - (1) Date of calibration.
 - (2) Calibration due date.
 - (3) Any limitation of use. If placing the label directly on the tool is not practical, then the label shall be affixed to the tool container.
 - (4) The identification of the organization performing the calibration.
 - (5) Tool identification.
 - (6) Traceability on the tool to the container if the container contains the calibration label.
 - f. Power tools used during the staking and conformal coating process shall comply to the tool requirements herein and have a three-wire grounded power cord or be double insulated. The area making contact with the workpiece shall be grounded. When measured from the workpiece contact point to ground, the resistance shall not exceed 2.0 ohms and the potential difference shall not exceed 2 millivolts root mean square (RMS) using methods indicated on the supplier's engineering documentation.
3. The supplier's process documentation for tool control is subject to review and approval by the procuring NASA Center. Suppliers may elect to use tools not mentioned in this Standard provided the engineering documentation is reviewed and approved by the procuring NASA Center.

6.6 Staking and Conformal Coating Material Selection

- 1. Staking and conformal coating materials shall be selected from the Qualified Products List (QPL) of MIL-I-46058 or other sources specified in writing by the procuring NASA Center. Staking materials are to be applied as identified on the engineering documentation. To facilitate examination for coverage, conformal coating materials with a fluorescent indicator are preferred.

CAUTION: *ULTRAVIOLET (UV) SENSITIVE EQUIPMENT MAY BE ADVERSELY AFFECTED BY USING FLUORESCENT INDICATORS.*

- 2. All materials used in vacuum or low-pressure compartments shall not release greater than 1.0 percent total mass loss (TML) or 0.1 percent collected volatile condensable material (CVCM) when tested in accordance with ASTM-E-595. All materials used in habitable areas of spacecraft, stowed equipment, and experiments shall be evaluated for flammability, odor, and offgassing characteristics in accordance with NHB 8060.1. Materials used shall be subjected to NASA approval. All material shall be selected to conform to the project contamination control requirements plan.

6.7 Material Storage

1. Shelf Life.

- a. **Shelf Life Stickers.** Material storage shall be controlled by shelf life stickers attached to each material container.
- b. **Expired Shelf Life.** Staking and conformal coating material shall not be used if the shelf life has expired. Shelf life extension may be granted on an individualized basis when adequate data is provided to the procuring supplier in advance of actual use.
- c. **Shelf Life.** The material shelf life shall be as stated by the manufacturer and in accordance with the manufacturer's specifications governing the usable life of the product.

2. Materials.

- a. **Solvents.** All cleaning and diluent solvents shall be stored in accordance with imposed safety regulations.
- b. **Staking and Conformal Coating Materials.** Materials shall be stored in accordance with the manufacturer's recommendations. All stored containers shall be sealed.
- c. **Moisture Sensitive Material.** Many materials are hygroscopic or moisture sensitive. Their storage shall be such as to minimize moisture exposure. All such material shall be stored in a dry nitrogen atmosphere whenever possible.
- d. **Material in Use.** The staking and conformal coating material shall be free of foreign matter and shall not show any signs of apparent deterioration or prior catalytic action.

3. Records.

- a. **Purchase Date Recording.** Records of manufacturing date, lot number, receiving date, and manufacturer's certification of compliance of each material shipment shall be maintained.
- b. **Container Markings.** Material containers shall be marked in accordance with the following:
 - (1) Manufacturer's identification.
 - (2) Manufacturer's product designation.
 - (3) Batch number (if applicable).
 - (4) Storage temperature range (if applicable).

- (5) Expiration date of guaranteed product life or use.
 - (6) Caution notes (where applicable).
4. **Storage Requirements.** The conditions for material storage shall be as specified by the manufacturer.

6.8 Inspection Optics

Visual inspection shall be performed using magnification aids conforming to the following:

- 1. Inspection magnification aids that permit simultaneous viewing with both eyes are preferred but single eye viewing devices are acceptable.
- 2. Magnification aids shall be capable of rendering true colors, proportional dimensions, and adequate resolution at the chosen magnification to perform the specified inspection.
- 3. The light source shall provide shadowless illumination of the area being viewed.
- 4. Magnification aids shall utilize only glass optical elements.

6.9 In-Process Storage and Handling

- 1. Each supplier performing staking and conformal coating operations shall develop and implement requirements and procedures that control conditions to prevent damage to and degradation of parts and deliverable items. In particular, means shall be provided to prevent damage or contamination of printed wiring terminating areas, terminals, connectors, wire ends, and part leads during handling or storage. Containers shall be compatible with materials stored therein.
- 2. Contact with bare hands shall be avoided. When handling metal surfaces, printed wiring terminating areas, terminals, connectors, wire ends, or part leads is unavoidable, clean, lint free gloves or finger cots shall be used. Gloves or finger cots shall not generate a static charge.

6.10 Solvents

- 1. The solvents or aqueous cleaners used to remove grease, oil, dirt, flux, and other debris shall be selected for their ability to remove both ionic and nonionic contamination. The solvents or cleaners used shall not degrade the materials or parts being cleaned. A list of approved solvents and cleaners is provided in Table 6-1. Mixtures of the approved solvents may be used. Solvent containers shall be properly labeled. The use of any other solvents requires the approval of the procuring NASA Center and shall be identified in the supplier's process documentation. MSDS's for solvents and cleaners shall be available for personnel review at the work area. Also see paragraph 6.3-3.

TABLE 6-1. Solvent and Cleaners

Solvent & Cleaners	Specification
Ethyl Alcohol	O-E-760, Types III, IV, or V
Isopropyl Alcohol	TT-I-735
Methyl Alcohol (See paragraph 6.10-2)	O-M-232, Grade A
Butyl Alcohol, Secondary (See paragraph 6.10-2)	ASTM-D-1007
Water	1 megohm-cm, minimum resistivity (See paragraph 6.10-3)
Detergent cleaners and saponifiers	(See paragraph 6.10-4)

CAUTION: *CLEANERS AND SOLVENTS SHALL NOT BE USED IN ANY MANNER THAT WILL CARRY TO OR DEPOSIT RESIDUE ON ELECTRICAL CONTACT SURFACES SUCH AS THOSE IN SWITCHES, POTENTIOMETERS, OR CONNECTORS.*

2. Methyl alcohol and secondary butyl alcohol shall be used only when purchased as a constituent of an already blended solvent. Pure methyl alcohol or secondary butyl alcohol shall not be used alone as a solvent.
3. When deionized water is used, care shall be exercised to ensure that proper drying is accomplished immediately after its use.
4. Water based saponifier and detergent systems as per Table 6-1 shall require the approval of the procuring NASA Center.
5. Solvent and cleaning systems have the potential of removing marking information from parts. Appropriate marking permanency testing shall be performed as part of the evaluation procedure for any solvent or cleaning system.

WARNING: *SOLVENTS USED IN THE STAKING AND CONFORMAL COATING PROCESS CAN BE HAZARDOUS AND VOLATILE. THESE MATERIALS SHALL BE USED IN ACCORDANCE WITH THE RECOMMENDATIONS AND GUIDELINES OF THE INDUSTRIAL VENTILATION MANUAL OF RECOMMENDED PRACTICES AND OSHA, CFR29. THE MSDS'S FOR EACH SOLVENT SHALL BE READILY AVAILABLE FOR ALL USERS.*

6.11 Personnel Protection

Personnel protective equipment shall be provided as appropriate for the work being performed. At a minimum, protective equipment shall include eye protection, gloves, and ventilation systems. Protective equipment shall comply with the requirements of OSHA, 29 CFR Part 1910 and any applicable state or local regulations.

CHAPTER 7 - CLEANLINESS REQUIREMENTS

7.1 General

All cleaning procedures shall be specified in the supplier's process documentation.

1. **Monitoring.** The effectiveness of the cleaning process depends upon the proper execution of the approved cleaning procedure. To assure the effectiveness of the cleaning method, a system for monitoring the purity of the cleaning solvents shall be established. Solvents used in degreasing systems shall be periodically checked and replaced when contamination exceeds established levels.
2. **Compatibility of Solvent With Hardware.** The cleaning solvent shall be chemically benign to the hardware and in accordance with Table 6-1. The solvent used shall not degrade the reliability of the hardware being cleaned.
3. **Protection of Unsealed Parts.** Unsealed parts shall not be completely immersed in the cleaning solvent. Hardware containing unsealed parts shall be immersed in the solvent only after these parts have been sealed or masked prior to cleaning.
4. **Ultrasonic Cleaning.** Ultrasonic cleaning shall not be used for cleaning assemblies that contain electronic parts.
5. **Rework Cleaning.** The rework area shall be cleaned and dried prior to application of rework staking and conformal coating. Conformal coated assemblies shall not be immersion cleaned.

7.2 Cleanliness Testing

Cleanliness testing is used to monitor the effectiveness of PWA cleaning processes. All PWA's shall be tested prior to conformal coating.

1. Two basic test methods are recommended.
 - a. Resistivity of solvent extract (paragraph 7.5).
 - b. Sodium chloride (NaCl) salt equivalent ionic contamination test (paragraph 7.6).
2. Other test methods must be approved by the procuring supplier before use.

7.3 Testing Frequency

1. Testing shall be performed with sufficient frequency to ensure compliance with the requirements of paragraph 7.4 test limits. At a minimum, this shall consist of once per shift, and immediately prior to changing the cleaning solvent solution.

2. It is recommended that statistical process control methods be used to control continuous solvent cleaning processes. Records of relevant readings shall be maintained for early detection of a trend towards an out-of-specification condition.
3. In the event that the result of a test is unacceptable, all the PWA's that were cleaned between the previous passed test and this failed test are considered unacceptable.
4. Failed PWA's shall not be recleaned until appropriate corrective actions have been performed on the cleaning system to ensure its correct operation.

7.4 Test Limits

1. **Resistivity Of Solvent Extract.** The resistivity of the solvent extract shall have a final value greater than 2,000,000 ohm-cm.
2. **Sodium Chloride Salt Equivalent Ionic Contamination Test.** The final value for this test must be less than 1.55 micrograms per sq. cm (10 micrograms per square inch) of PWB surface area.

7.5 Resistivity of Solvent Extract

Solvent extract resistivity shall be measured as follows (also, see Table 7-1):

1. Prepare a test solution of 75 percent by volume isopropyl alcohol and 25 percent by volume deionized water. Pass this solution through a mixed bed deionizer cartridge. After passage through the cartridge, the resistivity of the solution shall be greater than 6×10^6 ohm-cm (conductivity less than 0.166 micromhos/cm).
2. Clean a funnel, a wash bottle, and a container with a portion of this test solution. Measure out 1.55 ml for each square centimeter (10 ml for each square inch) of PWA area on both sides of the PWA.
3. Slowly, direct the test solution in a fine stream onto both sides of the PWA until all the measured solution is used.
4. The resistivity of the solvent extract shall be determined by using a resistivity meter.

7.6 Sodium Chloride Salt Equivalent Ionic Contamination Test

Sodium chloride salt equivalent ionic contamination shall be measured as follows (also, see Table 7-1):

1. The sodium chloride salt equivalent ionic contamination test must use a solution of 75 percent isopropyl alcohol and 25 percent deionized water. This solution must be verified for correct composition upon initial use and every 4 hours during a shift. The time limit may be extended when the results of data provide definite indications that such actions will not adversely affect the results of the test.

2. The equipment must be calibrated using a known amount of sodium chloride standard on the same schedule as the percentage composition verification.
3. The starting or reference purity of the solution must be greater than 20×10^6 ohm-centimeters (0.05 micromhos/centimeter) before each sample is tested.
4. Commercial equipment is available that can perform this test automatically. Such equipment is recommended to control continuous solvent cleaning operations. The equipment gives a direct readout in micrograms of NaCl per square centimeter or inch, but requires careful calibration to the flux system used for accurate results.

CAUTION: ***VAPOR DEGREASING MAY BE DETRIMENTAL TO SOME STAKING COMPOUNDS.***

TABLE 7-1. Cleanliness Test Values

Test Method	Starting Resistivity	Ending Values
Resistivity of Solvent Extract	6×10^6 ohm-cm	Shall be greater than 2×10^6 ohm-cm
Sodium Chloride Salt Equivalent Ionic contamination	20×10^6 ohm-cm	Shall be less than 1.55 Micrograms/square centimeter (10.0 micrograms/square inch)

CHAPTER 8 - PREPARATION FOR STAKING AND CONFORMAL COATING

8.1 Surface Preparation

Surface preparation varies with the type of material and substrate. For materials, substrates, or combinations not specifically addressed in this Standard, special instructions shall be generated in accordance with paragraph 1.4.

8.2 Masking

1. **Material.** Areas to be kept free of conformal coating material shall be masked with approved tape, covers, or other suitable masking material or devices. Masking material shall be compatible with the PWA being coated. Do not use anti-static masking tapes containing conductive adhesive on PWB conductor patterns.

CAUTION: *TAPES MAY CONTAIN METALLIC OR METALLIZED POLYMERIC MATERIAL THAT CAN CAUSE ELECTRICAL SHORTS OR CORROSION.*

NOTE: *PRECAUTIONS MUST BE TAKEN TO ASSURE THAT NO RESIDUES ARE LEFT WHEN THE MASKING MATERIAL IS REMOVED.*

2. **Masking Methods.** The method of conformal coating application may dictate completeness of masking. For instance, dip conformal coating application requires more thorough masking than brush conformal coating application, which in turn requires better masking than spray conformal coating application.
3. **Masking for Paraxylene Conformal Coating.** Unsealed parts and areas not to be coated shall be properly masked to prevent paraxylene vapors from penetrating minute openings. Masking materials must be compatible with the vacuum deposition system.

8.3 Priming

1. **Conformal Coatings Requiring Primer.** Silicone and paraxylene conformal coatings usually require a primer, whereas most other conformal coatings may not. When a primer is used, it shall be of a material recommended by the same manufacturer that produced the conformal coating material and shall be applied and cured in accordance with the manufacturer's instruction.
2. **Silicone and Paraxylene Conformal Coating Requirements.** For those silicone and paraxylene conformal coatings requiring priming, the primer shall be applied in accordance with the manufacturer's instructions. Any excess buildup must be removed.
3. **Repriming Requirements.** Most primers are effective only for a specified period of time with well-protected storage. If, after priming, subsequent conformal coating has not been applied within the manufacturer's recommended elapsed time, repriming is mandatory.

NOTE: ***SOME SURFACE PRIMERS WILL DAMAGE CERTAIN TYPES OF MATERIALS. REFER TO MANUFACTURERS' SPECIFICATIONS FOR THE SPECIFIC TYPE OF SURFACE PRIMER RECOMMENDED FOR USE.***

8.4 Material Preparation

Staking and conformal coating material shall be mixed and prepared according to the manufacturer's instructions or the appropriate process document. It must be verified, prior to usage, that materials have not exceeded their shelf life. General information and requirements on materials follows:

1. **Single-Component Materials.** Materials that are supplied as a single part may require stirring because of settling of fillers or other ingredients in the system.
2. **Multicomponent Materials.** Multicomponent materials shall be thoroughly mixed until the mixture is smooth and homogeneous and shall be used within the working life limit. Frozen premixes do not need mixing, but will have working life limits after being thawed.
3. **Premixing of Fillers.** If filler is to be added, it shall be premixed into the less moisture-sensitive part before final mixing. Highly absorbent fillers shall not be used.
4. **Moisture Removal.** Fillers are normally hygroscopic and should be oven baked to remove absorbed moisture before being added to resins.
5. **Order of Mixing.** When used, accelerators (or catalysts) shall be mixed in last to extend working life as much as possible. Mixing shall be carefully conducted to minimize entrapped air. High-solid materials or high-viscosity materials may be deaerated to remove trapped air. Be aware of the possibility of losing the volatile ingredients, if any, in the deaeration process.
6. **Mix Record.** A record of each mix batch date and procedure shall be maintained
7. **Spray Applications.** In spray application, viscosity of conformal coatings shall be closely observed and controlled by adding solvents as necessary to preserve the best sprayable viscosity. Solvent addition shall not be used to extend the working life of the material.
8. **Containers.** In all mixing operations, nonabsorbent plastic, glass, or metal containers and stirrers shall be used. Containers with seams and crevices that will trap unmixed materials shall not be used. Metal stirrers shall not be used when materials are mixed in plastic containers.
9. **Material Condition.** Materials shall not be used that exhibit any evidence of excessive crystallization, surface skinning, or gelling.
10. **Silicones.** All silicone operations shall be segregated from other material operations.

11. **Working Life.** The working life (pot life) of the material shall begin immediately after mixing.

8.5 Witness Sample

A witness sample shall be maintained for each mixed batch. The witness sample shall be processed at the same time and under the same conditions as the PWA. Witness samples shall be maintained for 5 years, or as specified by the contract. Acceptance of the witness sample shall be indicated on the mix record. The witness sample shall be identified and stored under controlled conditions of temperature and humidity.

8.6 Preparation For Conformal Coating Control Specimens

A control board specimen, preferably a scrapped PWB, shall be coated concurrently with the regular PWA conformal coating operation whenever a new lot of material or a newly mixed batch of material is prepared. The control PWB specimens shall be used for tests and analyses to avoid damage or destruction of the production boards. The control assemblies shall be marked as so and stored separately from the process assemblies.

CHAPTER 9 - STAKING

9.1 Purpose

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

9.2 Staking

1. **Application.** Spatulas and syringes, with or without pressure-control pneumatic dispensers, may be used to apply the material. Staking material shall be applied to the parts and areas specified by the approved engineering documentation. This material shall adhere to all surfaces to be joined. Some typical staking methods are shown in Figures 9-1 through 9-9. Staking material shall not be allowed to bridge between the bottom of ceramic-bodied DIP's or surface mounted parts and the PWB.
2. **Flexible Materials.** Flexible staking material with a high thermal expansion coefficient shall not be applied where excessive stress may be damaging.
3. **Staking Concerns.** Caution must be taken to assure that:
 - a. The staking compound does not negate stress relief of parts and enclose joints, part leads, or mechanically compromise the reliability of the hardware.
 - b. Staking material shall be free from contamination.
 - c. Glass-bodied parts shall be covered with resilient material prior to staking with rigid material.
4. **Mandatory Staking.** Some parts must be staked (e.g. solid tantalum capacitors). Jumper wires shall be staked every 2.54 cm (1 inch), at a minimum, and at every change of direction outside of the radius of curvature.
5. **Curing.** Staking material shall be cured in accordance with the manufacturer's recommended cure schedule. Staking material shall be tack-free when cured. Ovens used for curing silicones shall not be used for curing other materials.
6. **Hardness Testing.** Following cure, the staking material shall be tested for hardness in accordance with paragraph 11.7-3. Material shall meet the manufacturer's recommended hardness. Hardness testing is performed on the witness sample.

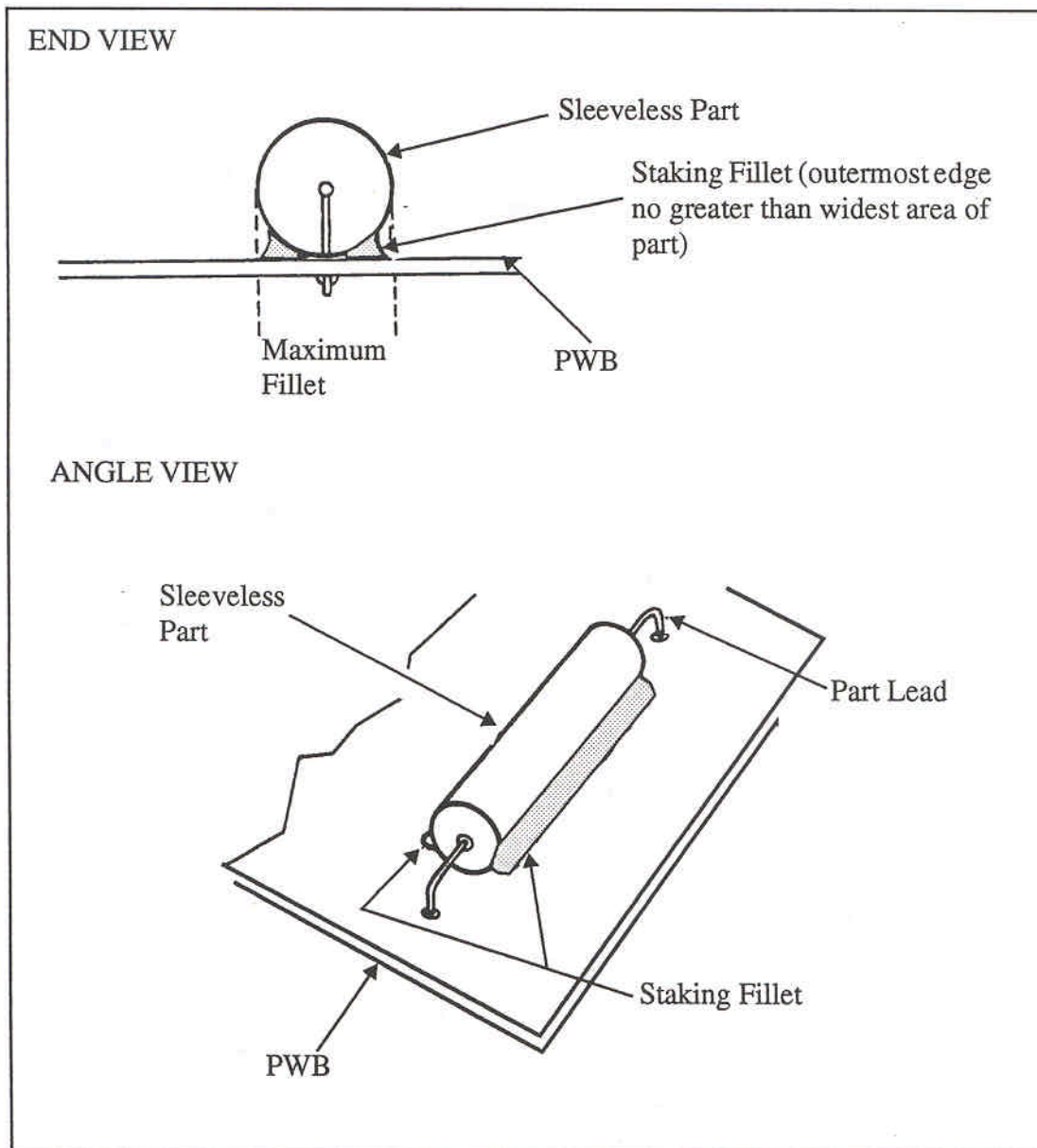


FIGURE 9-1. Typical Staking for Horizontally Mounted Sleeveless Cylindrical Parts

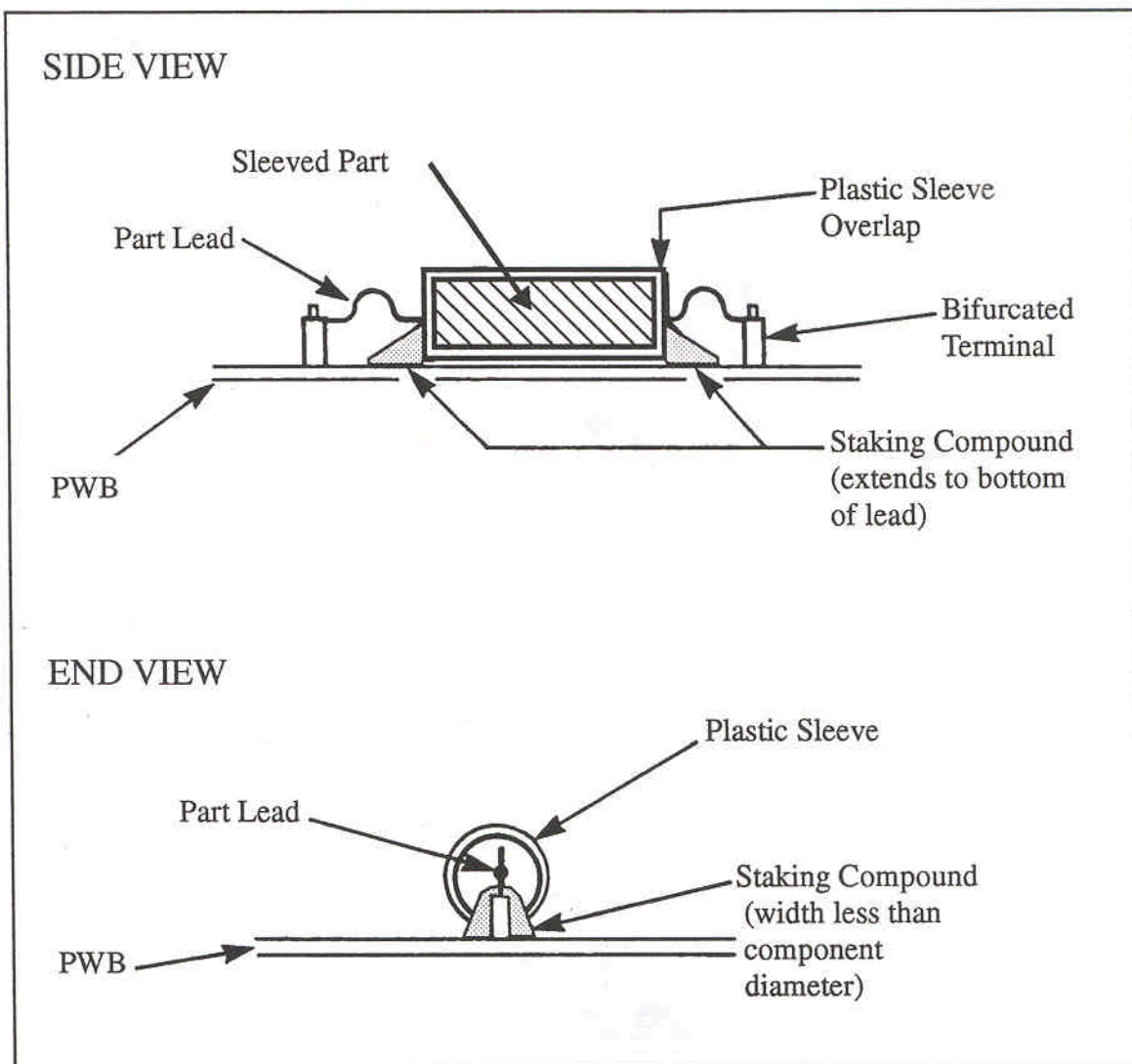


FIGURE 9-2. Typical Staking for Horizontally Mounted Sleeved Cylindrical Parts

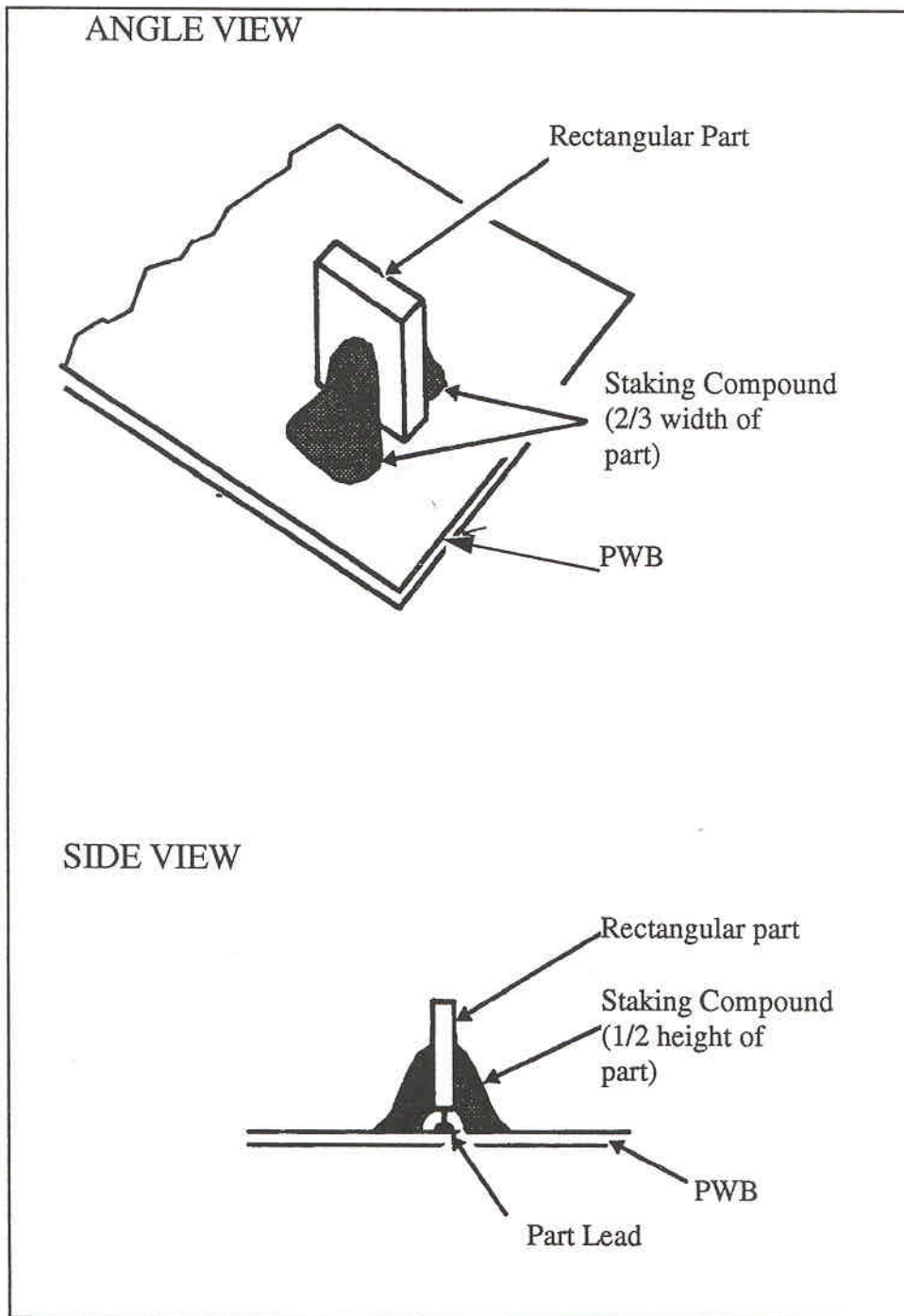


Figure 9-3. Typical Staking of a Single Vertically Mounted Rectangular Part

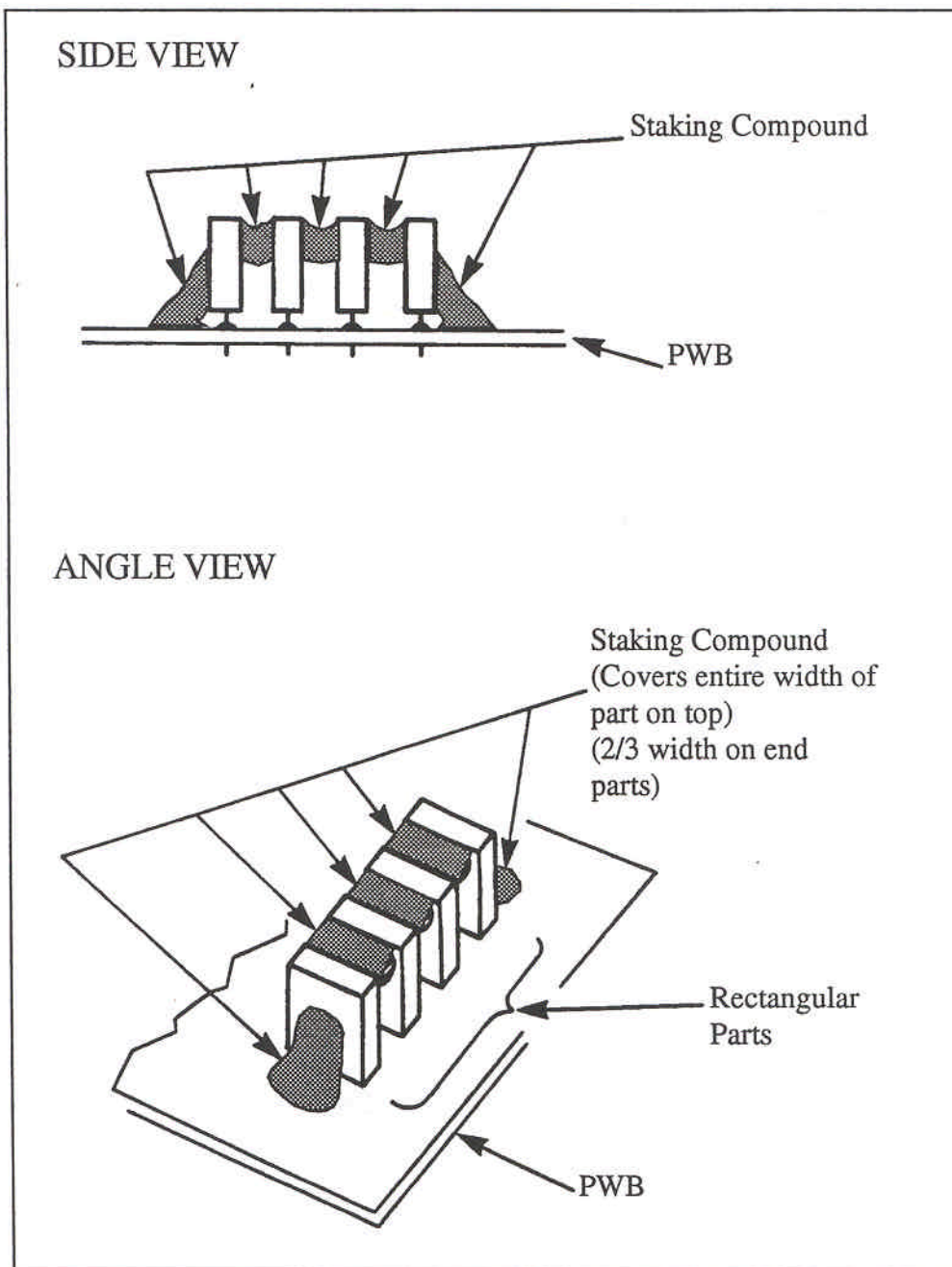
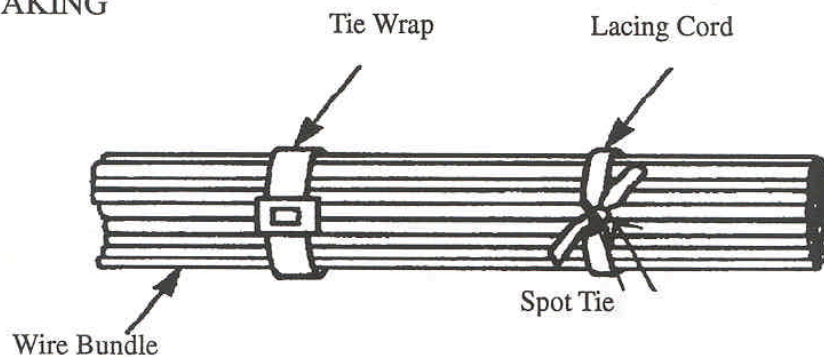
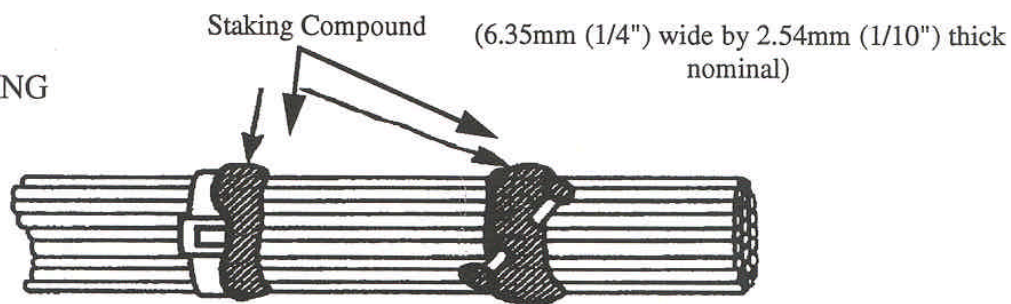


FIGURE 9-4. Typical Staking for an Array of Vertically Mounted Rectangular Parts

PRE-STAKING



POST-STAKING



CROSS-SECTIONAL VIEW

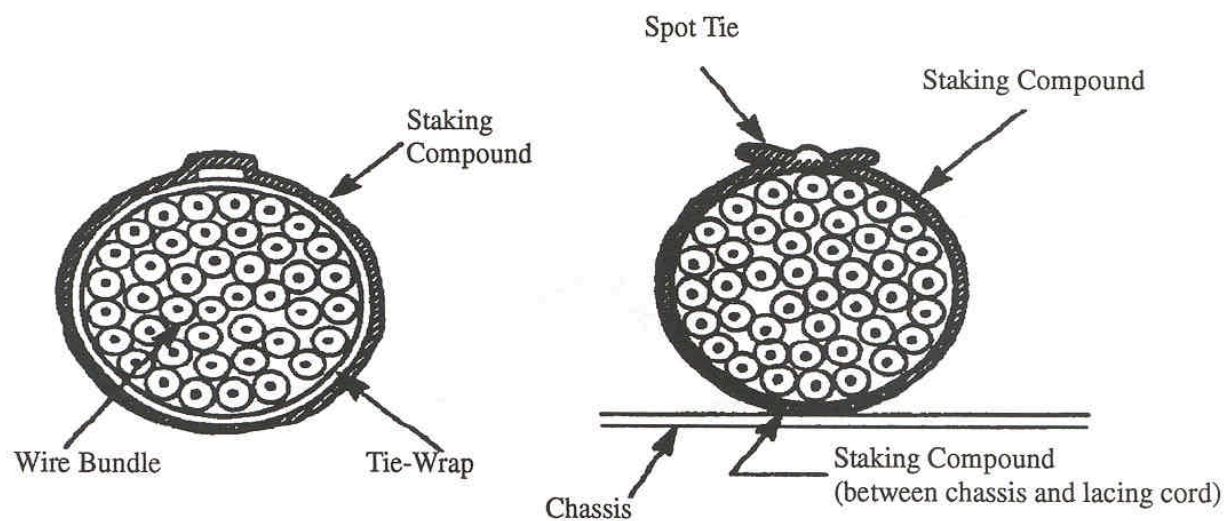


FIGURE 9-5. Typical Wire Bundle Staking

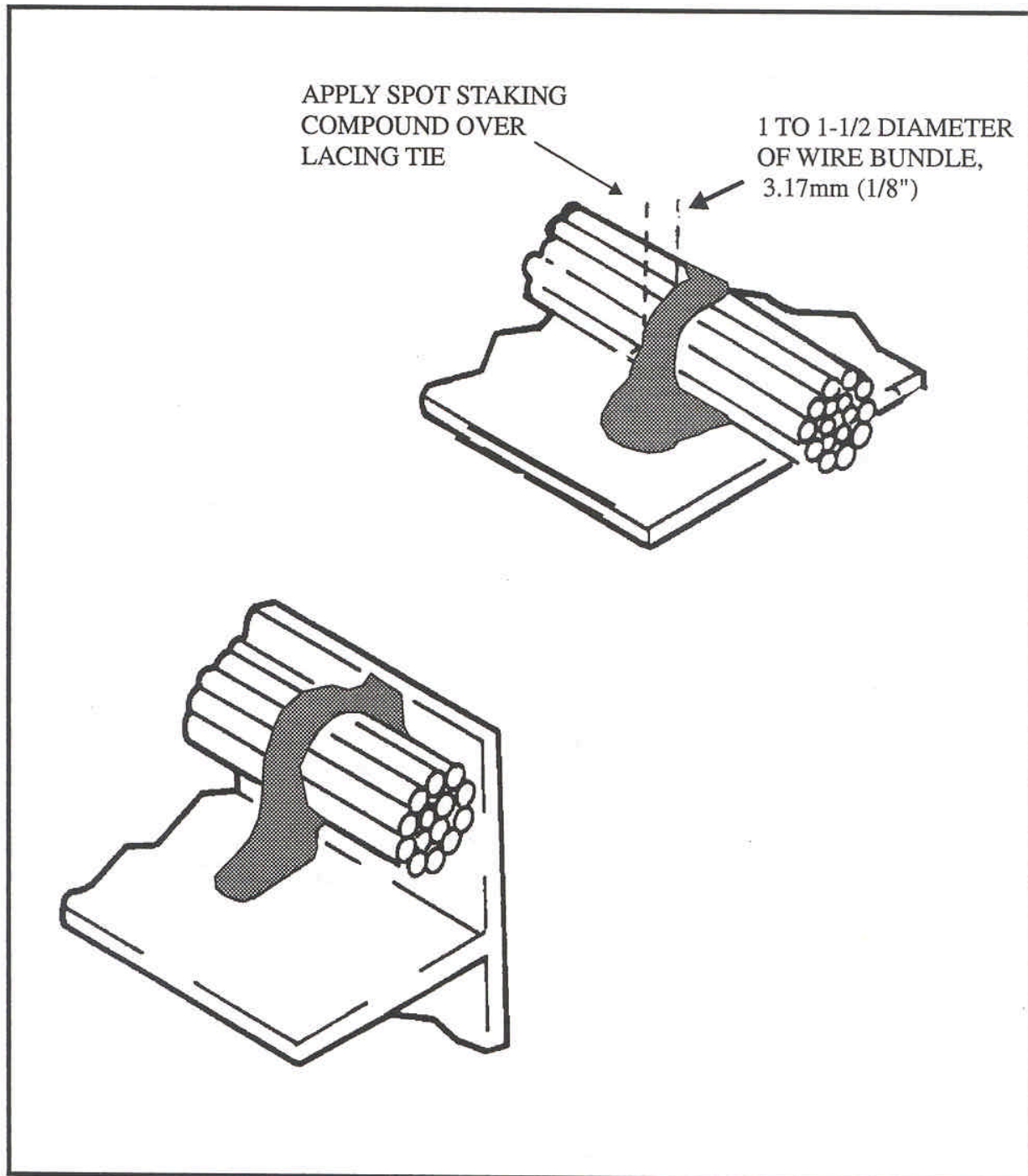


FIGURE 9-6. Typical Wire Bundle Staking

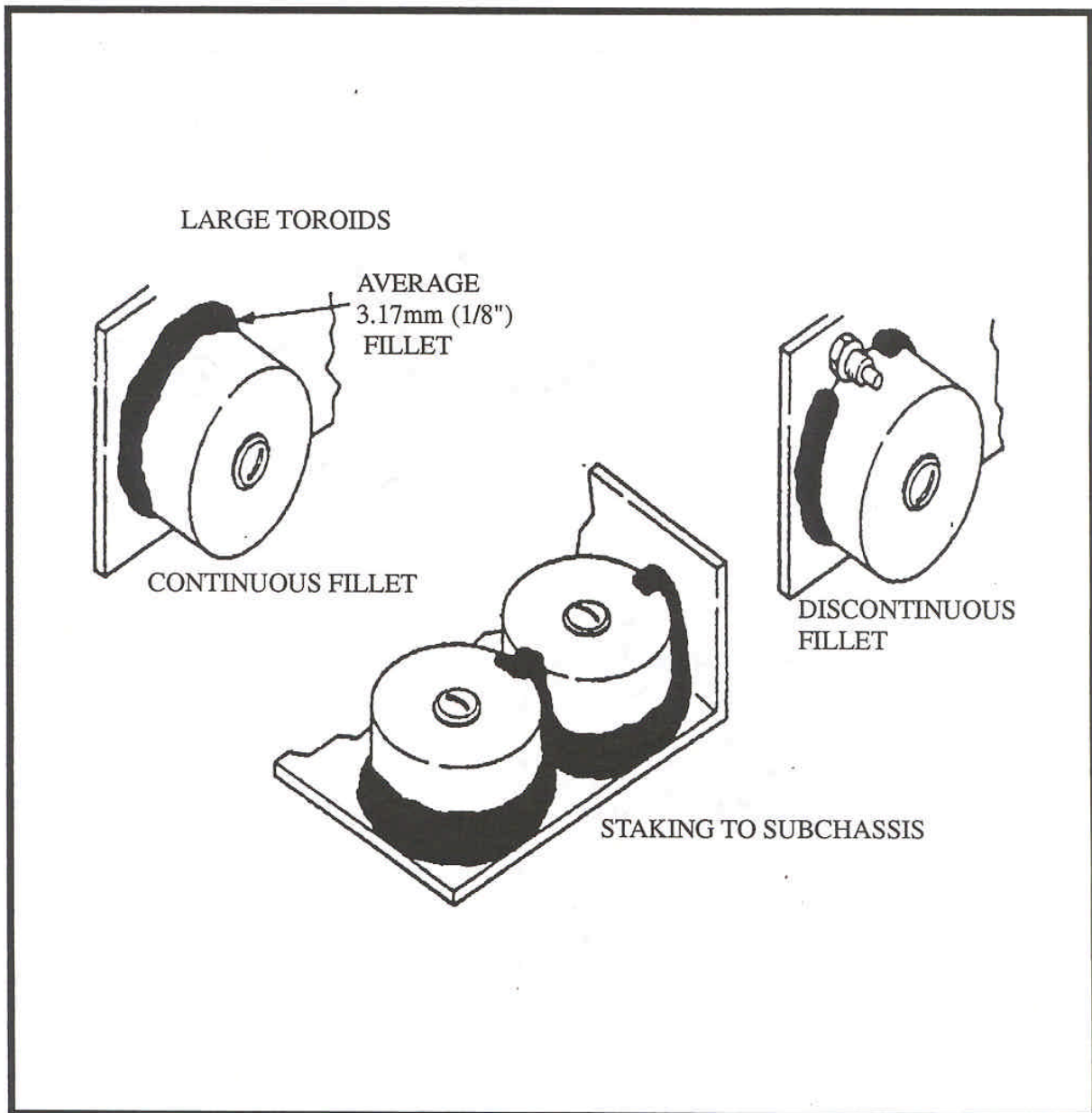


FIGURE 9-7. Typical Toroid Staking

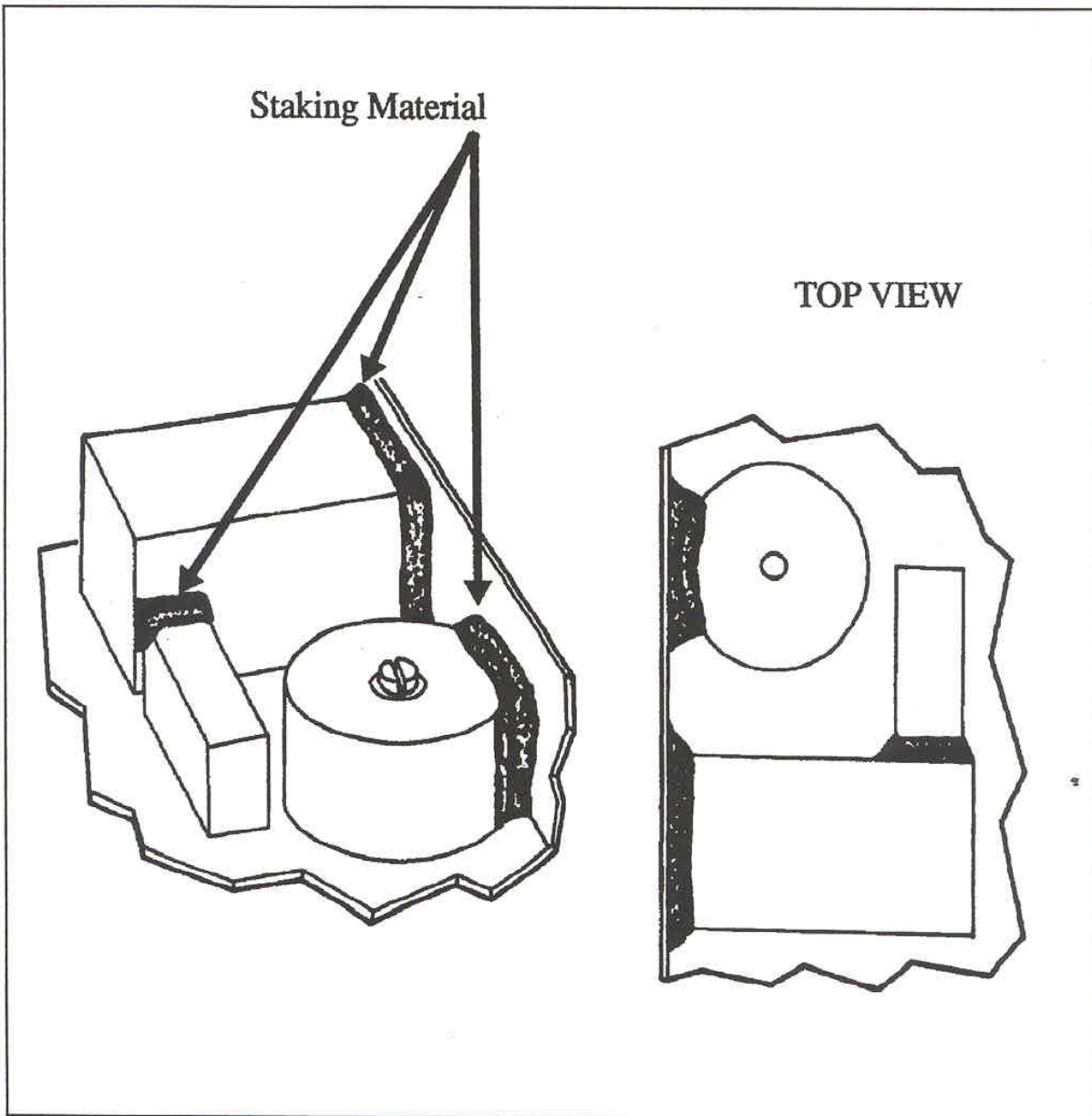


FIGURE 9-8. Typical Vibration Isolation Staking

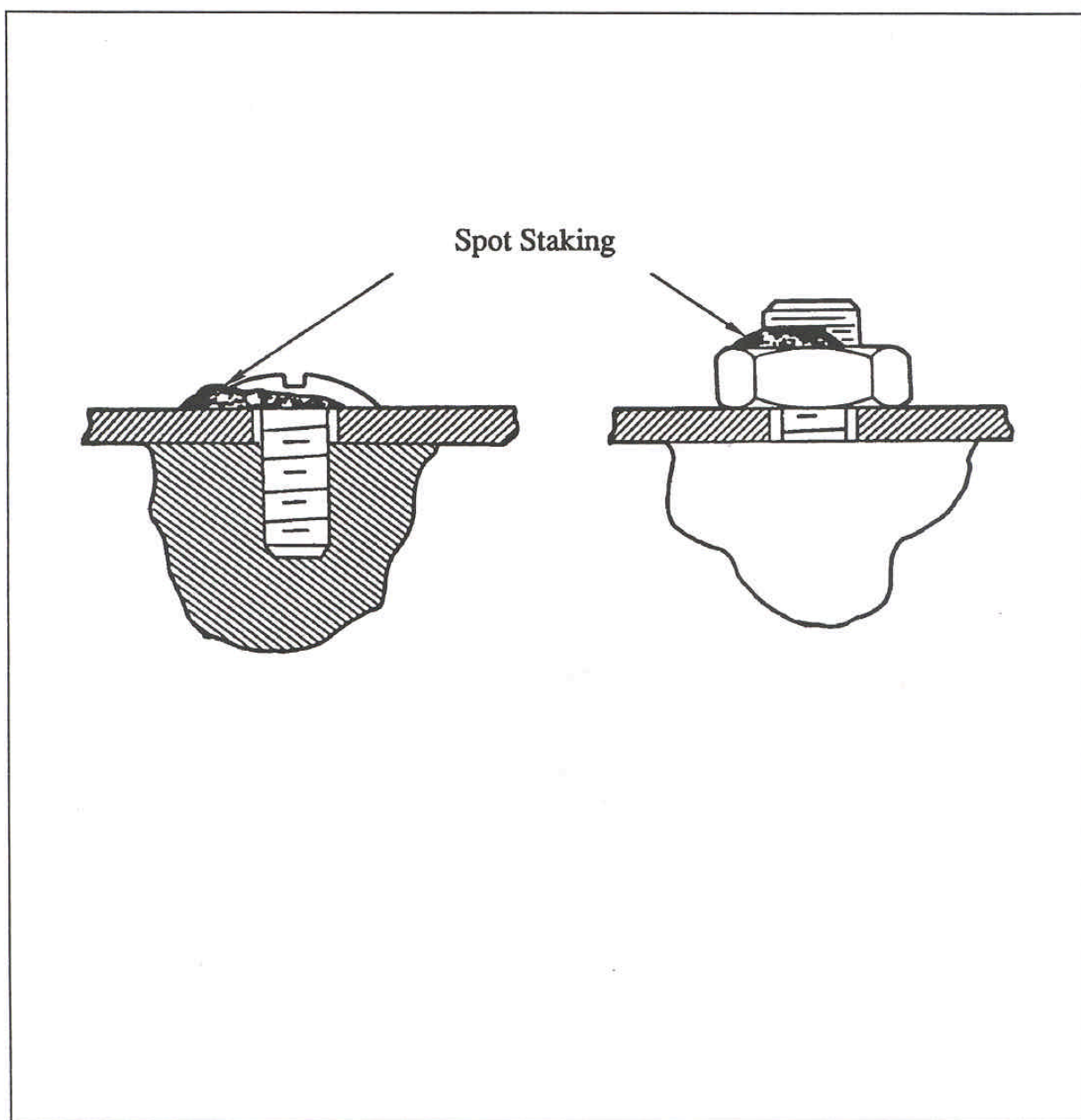


FIGURE 9-9. Fastener Spot Staking

CHAPTER 10 - CONFORMAL COATING

10.1 Purpose

Conformal coatings are intended to provide electrical insulation and environmental protection thus minimizing the performance degradation to electronic PWA's by humidity, handling, debris, and contamination. Conformal coating materials may include solvents (diluent), fillers, and catalysts and/or accelerators, in addition to the basic resin. Some conformal coating materials come in a one-part form. Vacuum deposition material, including paraxylene, requires a special conformal coating chamber. Staking shall be performed prior to conformal coating unless it is specifically stated otherwise on the engineering documentation.

10.2 Conformal Coating Application

1. The PWA's shall be cleaned and demohumidized within 8 hours before conformal coating. Demohumidizing shall be defined on the engineering documentation. Demohumidizing may be accomplished by an oven bake at $93^{\circ}\text{C} \pm 5.5^{\circ}\text{C}$ ($200^{\circ}\text{F} \pm 10^{\circ}\text{F}$) for a minimum of 4 hours for a PWA or 2 hours for a PWB, or by a vacuum bake at a lower temperature. The time in and out of the oven or chamber and the temperature shall be recorded.
2. Conformal coating shall be applied using a method that will yield complete coverage without excessive filleting or runs. Common coating application methods include spraying, brushing, dipping, or a combination thereof. Chemical Vapor Deposition (CVD) is the process used for paraxylene.
 - a. **Spraying.** The conformal coatings shall be sprayed onto the PWA using clean dry gas at a pressure sufficient to provide proper atomization. One pass shall be sprayed across the entire surface of the PWA holding the spray gun at an angle of approximately 45° to the PWA. The PWA shall be rotated 90° after each pass, and spraying repeated, so that all four directions are sprayed. See Figure 10-1.
 - b. **Brushing.** The material shall be evenly applied without forming excessive fillets and thick areas. Particular attention shall be paid to undersides of parts and lead wires. The brush selected shall be made from natural bristles and provide adequate control for appropriate coverage, be cleaned in a non-reactive solvent, and thoroughly dried before use.
 - c. **Dipping.** The entire PWA shall be dipped. The extraction rate shall be such as to obtain uniform thickness. The conformal coated PWA shall be allowed to drain until the conformal coating stops running and minimum part filleting is achieved.

- d. **Vacuum Deposition.** Paraxylene conformal coating shall be applied using a special vacuum deposition chamber. The conformal coating shall be thin, uniform, and fillet free.

CAUTION: *CONTAMINATION CAN BE FORCED INTO PARTS DURING CHAMBER BACKFILLING; THEREFORE, CLEAN, DRY GAS SHOULD BE USED.*

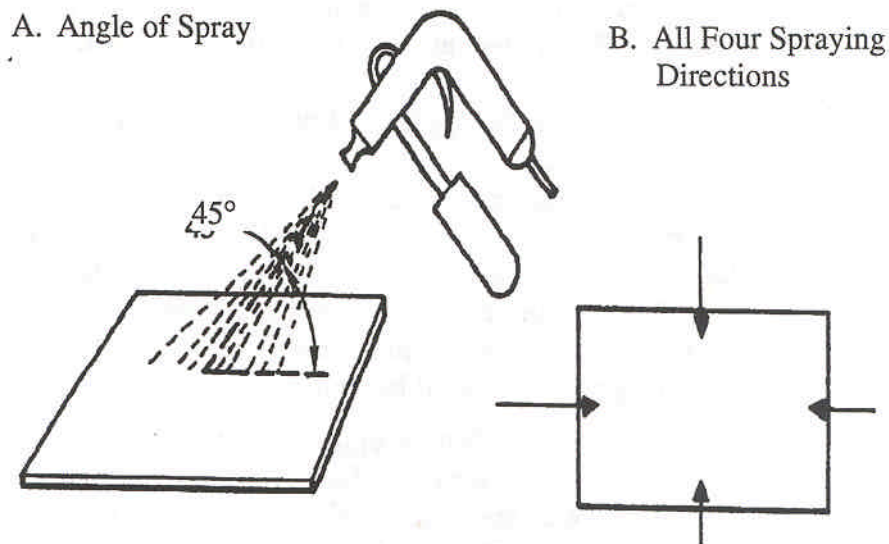


Figure 10-1. Spray Application

3. **Thickness Measurements.** Thickness measurements shall be made on coupons processed at the same time and under the same conditions as the PWA. The coupon substrate may be any compatible rigid material with a smooth flat surface. Thickness measurements shall be made with a wet film thickness gauge or equivalent tool. See Table 10-1.
- a. **Excessive Coating Removal.** Excessive coating shall be removed prior to cure.

TABLE 10-1. Conformal Coating Thickness

Type of Coating	Cured Coating (MIL)
ACRYLIC	0.001 to 0.005
URETHANE	0.001 to 0.005
EPOXY	0.001 to 0.005
SILICONE	0.002 to 0.008
PARAXYLENE	0.0005 to 0.002

4. **Pre-Cure Examination.** Immediately after material application, the uncured conformal coating shall be examined for:
 - a. **Bubbles and Air Entrapments.** These defects shall be broken by vacuum, with a sharp probe, or other appropriate tools.
 - b. **Bridging.** Conformal coating material shall not be allowed to bridge between the bottom of ceramic-bodied DIP's or surface mounted parts and the PWB, or between the part lead and the PWB, thereby negating stress relief.
5. **Post Cure Examination.** After the cure cycle, the conformally coated PWB or PWA shall be examined to assure that the following conditions are met. See Figure 10-2 through Figure 10-5 for additional requirements.
 - a. Conformal coating is uniform in color, thickness, and texture, tack-free, and shows proper adhesion to all coated surfaces.
 - b. Conformal coating shall cover all areas as specified on the engineering documentation, have a smooth continuous surface, and follow the contours of the PWA. Minor pull back from sharp points and edges is permissible unless otherwise specified on engineering documentation.
 - c. Conformal coating is free from contamination.
 - d. Terminals shall be conformal coating encapsulated, including the insulation gap of the wire, unless it is a solder ball type connection (as in a high voltage connection). This is normally applied with a brush after the initial conformal coating application.
 - e. Conformal coating may bridge between adjacent part leads providing stress reliefs are not negated.
 - f. Conformal coating shall not exhibit discoloration (due to such things as excessive curing oven temperature, contamination, etc.).

10.3 Curing

1. **Cure Schedule.** The conformal coating material shall be cured in accordance with a specified cure schedule that is compatible with the thermal limitations of the hardware. The conformal coating shall be tack-free when cured.
2. **Multiple Conformal Coatings.** When multiple conformal coatings of the same material are employed, each layer may be partially cured before the next layer is applied.
3. **Curing Silicones.** Ovens used for curing silicones shall not be used for curing other materials.

4. **Humidity Requirements.** While high humidity may retard the completion of curing, some materials specifically require a higher-than-ambient relative humidity to cure properly. Where necessary, an enhanced humidity environment shall be provided as defined by the engineering documentation.
5. **Handling and Storage.** After application of the polymeric material, particularly when the material is still wet and tacky (during curing cycle), hardware shall be handled and stored in a manner that minimizes exposure to contamination or handling damage.

10.4 Cleanup

Conformally coated PWA's shall be cleaned to remove any maskant, loose debris, or material that may damage or degrade its performance.

10.5 Touchup/Rework

Conformally coated assemblies shall be touched up to correct coating coverage deficiencies. Touched up areas will normally not meet the thickness requirement of Table 10-1. Removal and replacement of conformal coating is considered rework and the procedures shall be documented.

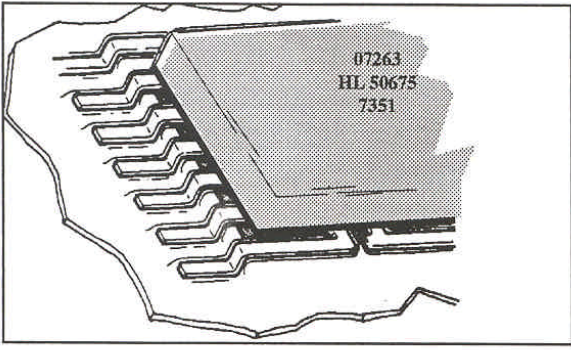
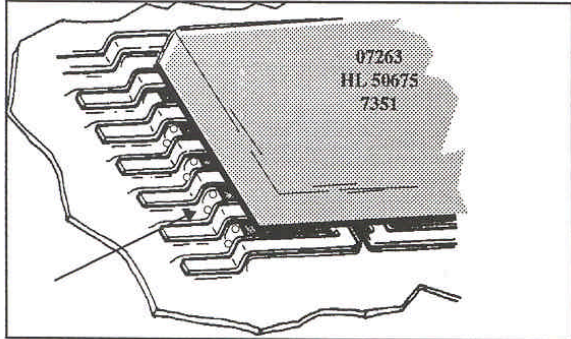
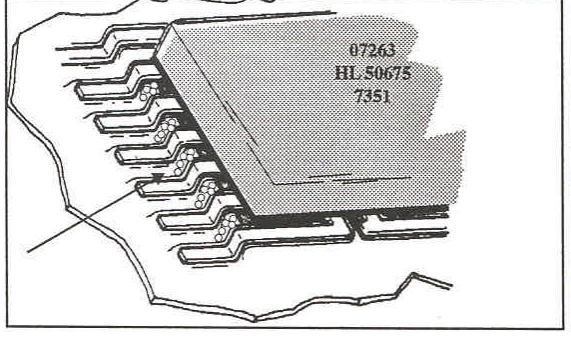
	PREFERRED Completed uniform coverage with no visual bubbles.
	ACCEPTABLE Small bubbles, but they do not bridge between uncommon conductors, expose a bare conductor surface, or exceed 0.76mm (0.03 inch) in any dimension.
	UNACCEPTABLE Excessive bubbling.

FIGURE 10-2. Conformal Coating – Bubbles

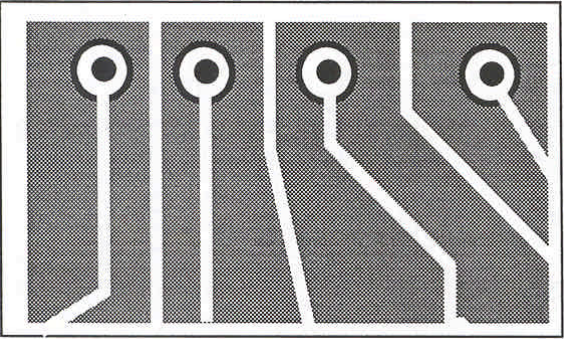
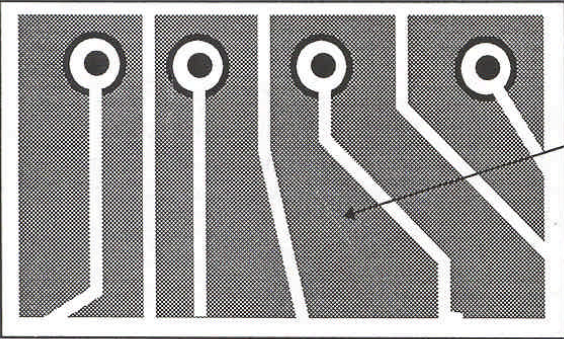
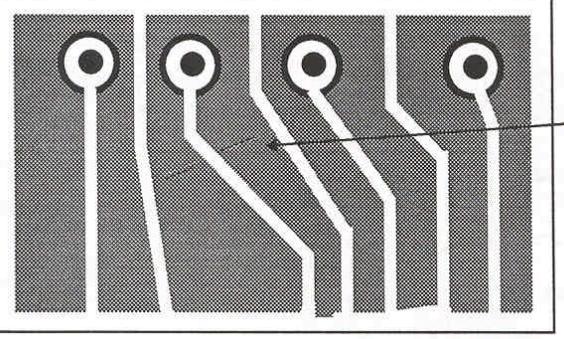
	PREFERRED No defects.
	ACCEPTABLE Scratch does not expose any conductive area.
	UNACCEPTABLE Scratch exposes conductive areas.

FIGURE 10-3. Conformal Coating – Scratches

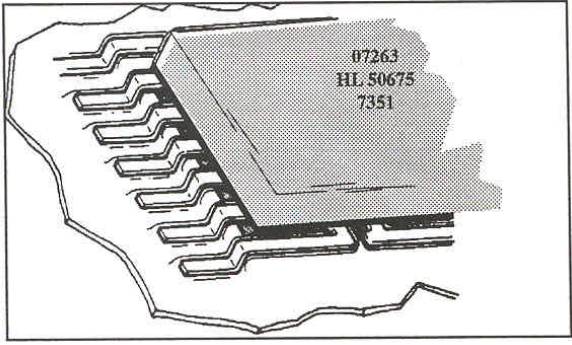
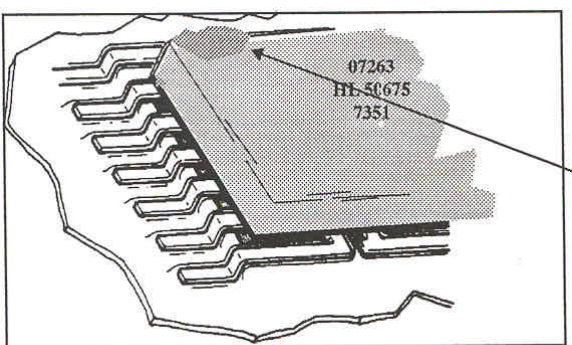
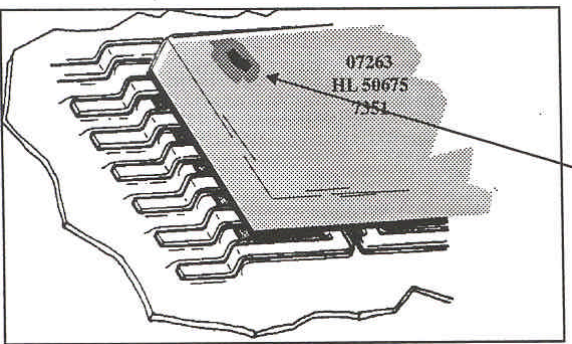
	PREFERRED Uniform color, texture, and thickness with apparent good adhesion on parts and board surface. The coating should show uniform fluorescence under a UV light.
	ACCEPTABLE Some evidence of variation in coating thickness. Minor lifting on nonconductive areas.
	UNACCEPTABLE Excessive lifting and peeling indicating improper surface cleaning or excessive thickness. Any lifting on conductive areas is nonconforming.

FIGURE 10-4. Conformal Coating - Lifting and Peeling

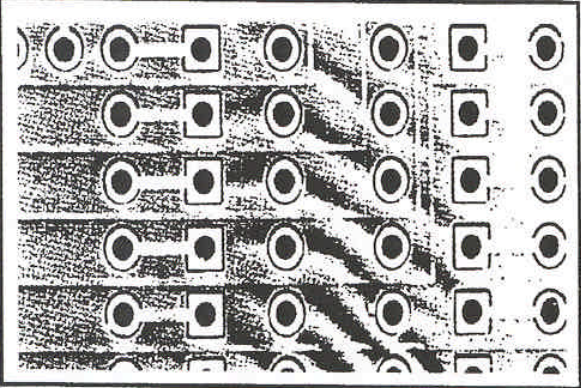
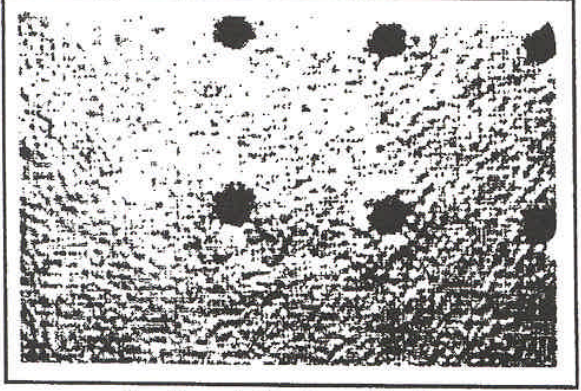
 Conformal Coating - Runs	ACCEPTABLE Not to exceed 5% of PWB surface area.
 Conformal Coating - Fish Eyes	ACCEPTABLE Not to exceed 5% of PWB surface area.
 Conformal Coating - Peeling	UNACCEPTABLE Loss of adhesion.

FIGURE 10-5. Conformal Coating - Coverage Defects

CHAPTER 11 - QUALITY ASSURANCE

11.1 General

1. **Workmanship.** Workmanship shall be of a level of quality adequate to assure that the processed products meet the performance requirements of the engineering documentation and criteria delineated herein.
2. **Inspection.** Inspection for acceptability shall be performed on all staked or conformally coated PWA's to the requirements specified in this Standard. Parts and conductors shall not be physically disturbed to aid inspection.
3. **Quality Assurance.** The following functions shall be performed:
 - a. Verify that all tests, inspections, and measurements specified by this Standard have been performed.
 - b. Verify that all personnel who stake, coat, or inspect hardware in accordance with this document have been trained and certified as specified in Chapter 5.
 - c. Conduct in-process surveillance of all assembly operations to verify that all processes and procedures implementing the requirements of this document are current, approved, adequate, and being accurately utilized.
 - d. Verify that no damage exists on parts and PWB's prior to their being staked or conformally coated.
 - e. Verify that the facility cleanliness, environmental conditions, and lighting requirements of Chapter 6 are being met.

11.2 Magnification Aids

Inspection optics shall conform to the requirements of paragraph 6.8. Visual inspection shall be aided by magnification between 4X and 10X. Additional magnification shall be used as necessary to resolve suspected anomalies or defects.

11.3 Documentation Verification

Quality assurance personnel shall verify that all required documentation is current and approved. The documentation shall include:

1. **Records**
 - a. Results of the visual examination as per paragraph 5.2-1.
 - b. Evidence of operator and inspector certification as per paragraph 5.5.
 - c. Material purchase data as per paragraphs 6.7-3a and b.

- d. Mix record as per paragraph 8.4-6.
- e. Witness sample as per paragraph 8.5.
- f. Demoisturizing as per paragraph 10.2.

2. **Procedures**

- a. Staking or conformal coating program as per paragraphs 4.2 and 5.1.
- b. Training and certification program as per paragraph 5.4-3b.
- c. Tooling and equipment operating procedures as per paragraph 6.5-1e.
- d. Calibration system as per paragraph 6.5-2.
- e. In-process storage and handling procedures as per paragraph 6.9.
- f. Cleaning procedures as per paragraph 7.1.

11.4 Documentation Authorization

Quality assurance personnel shall verify that the following documentation has been approved by the procuring NASA Center prior to implementation:

- 1. Special engineering requirements as per paragraph 1.4.
- 2. Special processes, materials, or parts as per paragraph 4.1-3.
- 3. Special documents as per paragraph 4.1-3.
- 4. Departures from requirements as per paragraph 1.5.
- 5. Repairs as per paragraph 4.3.
- 6. Process documentation for special tools as per paragraph 6.5-3.
- 7. Staking and coating materials as per paragraph 6.6.
- 8. Special cleanliness test methods as per paragraph 7.2-2.

11.5 Verification of Tools, Equipment, and Materials

- 1. **Tools and equipment.** Tools and equipment shall be verified for conformance to the applicable requirements found in paragraph 6.5.
- 2. **Materials.** Materials shall conform to the requirements of paragraph 6.6. Controls shall be implemented to assure that only approved and conforming materials are used.

Materials not conforming or not required for the operations involved shall be removed from the work areas or tagged non-usable.

11.6 Acceptance/Rejection Criteria for Staking

1. **Documentation.** All acceptance and rejection criteria for staking shall be clearly defined in the application processing document(s). Reference Figure 9-1 through Figure 9-9 for typical, acceptable staking requirements.
2. **Acceptance Criteria.** Staked PWA's shall exhibit, as a minimum, the following workmanship characteristics in order to be judged acceptable:
 - a. The staking material shall adhere to the intended surfaces as per paragraph 9.2-1.
 - b. The staking material shall be free from contamination as per paragraph 9.2-3b.
 - c. Jumper wires shall be staked a minimum of every 2.54 cm (1 inch) and every change of direction, outside of the radius of curvature as per paragraph 9.2-4.
 - d. All axial lead solid slug tantalum capacitors shall be staked as per paragraph 9.2-4.
 - e. The staking material shall be tack-free when cured as per paragraph 9.2-5.
 - f. Staking material meets the hardness requirements as per paragraph 9.2-6.
3. **Rejection Criteria.** The following are some characteristics of unsatisfactory conditions, any of which is cause for rejection.
 - a. Staking material used after shelf life expiration as per paragraph 6.7-1b.
 - b. Staking material bridges between the PWB and the bottom of the DIP's or flatpacks as per paragraph 9.2-1.
 - c. Staking material fills the stress relief areas as per paragraph 9.2-3a.
 - d. Staking material encloses the part lead as per paragraph 9.2-3a.
 - e. Rigid staking has been applied directly to glass bodied parts as per paragraph 9.2-3c.

11.7 Inspection Methods for Staking

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

3. **Hardness.** When applicable, hardness shall be measured in accordance with ASTM-D-2240.

11.8 Acceptance/Rejection Criteria for Conformal Coating

1. **Documentation.** All acceptance and rejection criteria for conformal coating shall be clearly defined in the application processing document(s). Reference Figure 10-2 through Figure 10-5 for conformal coating acceptance and rejection criteria.
2. **Acceptance Criteria.** Conformally coated PWA's shall exhibit, as a minimum, the following workmanship characteristics to be acceptable:
 - a. Unless otherwise specified by the approved engineering documentation, the conformal coating, when measured in flat unencumbered areas of the board, or preferably on the witness coupon, shall have a thickness appropriate for the conformal coating material being used as per paragraph 10.2-3.
 - b. Conformal coating shall be uniform in color and texture as per paragraph 10.2-5a.
 - c. Conformal coating shall be tack-free when cured as per paragraph 10.2-5a.
 - d. Conformal coating shall adhere to all coated surfaces as per paragraph 10.2-5a.
 - e. Conformal coating shall have a smooth continuous surface and follow the contours of the PWA as per paragraph 10.2-5b.
 - f. Conformal coating shall be uniform in thickness as specified in Table 10-1 or on engineering documentation except in touched-up areas as per paragraph 10.5.
 - g. Conformal coating shall cover all areas as specified on the engineering documentation. Pull back from sharp points and edges shall be permitted unless otherwise specified as per paragraph 10.2-5b.
 - h. Conformal coating shall be free of contamination as per paragraph 10.2-5c.
 - i. Each terminal without a solder ball shall be conformal coating encapsulated to include the insulation gap of the wire as per paragraph 10.2-5d.
 - j. Conformal coating material that bridges between adjacent part leads is acceptable as per paragraph 10.2-5e.
3. **Rejection Criteria.** The following are some characteristics of unsatisfactory conditions, any of which is cause for rejection:
 - a. Conformal coating material used after shelf life expiration as per paragraph 6.7-1b.

- b. Conformal coating bridges stress relief areas thereby negating stress relief as per paragraph 10.2-4b.
- c. Conformal coating bridges between the PWB and the bottom of DIP's and flatpacks as per paragraph 10.2-4b.
- d. Conformal coating exhibits tackiness or soft spots as per paragraph 10.2-5a.
- e. Pinholes, blistering, scratches, whitish spots (measling), wrinkling, or cracking as per paragraph 10.2-5a and paragraph 10.2-5b.
- f. Any signs of contamination (e.g., flux, loose particles, or foreign material) as per paragraph 10.2-5c.
- g. Discolored conformal coating as per paragraph 10.2-5f.
- h. Bubbles or bare spots bridging two electrically conductive elements as per Figure 10-2.
- i. Bubbles larger than 0.76 mm (0.03 inch) in any dimension as per Figure 10-2.
- j. Conformal coating exhibits lifting or peeling as per Figure 10-4.
- k. Conformal coating exhibits excess runs, fish eyes, or peeling as per Figure 10-5.

11.9 Inspection Methods for Conformal Coating

1. **Visual Inspection of Workmanship and Adhesion 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 verify suspected anomalies or defects.
2. **UV-Light Inspection.** When fluorescent conformal coating materials are used, coverage and location shall be determined by UV-light examination.
3. **Conformal Coating Thickness Inspection.** Conformal coating thickness shall be determined using a wet film thickness gauge, micrometer, or other tool on flat surfaces of the PWB, PWA, or preferably, the coupon required by paragraph 10.2-3.
4. **Tackiness and Soft Spots.** Gentle finger pressure shall be used to inspect for tackiness and soft spots. For this purpose, lint-free gloves or finger cots shall be worn.

APPENDIX A

CONFORMAL COATING PROBLEMS

The following are the major problems encountered in the conformal coating process:

1. **Conformal Coating Thickness.** Conformal coating thickness can be critical to the proper function of a PWA. If a coating is too thin, proper coverage is impossible; if a coating is too thick, it may create excessive stresses on solder joints and components (particularly glass-bodied components). Controlling coating thickness is of special importance with rigid coating materials (e.g., epoxies and some of the urethanes) because the residual stresses associated with an excessively thick application of these materials are much greater than with flexible coating materials (such as silicones and some urethanes).

The thickness of a conformal coating can best be controlled by controlling the material viscosity during application. Where permitted, diluent solvents can be used to control viscosity. A multiple-coating process can also be used to attain more uniform thickness. Excessive filleting of adjacent components, caused by surface tension, may necessitate use of a brush to remove the excess.

2. **Coverage -- Points and Edges.** Liquid coatings, because of gravity and their surface energy, tend to pull away from sharp points and edges which are often formed in conductors needing the most coverage. Inadequately protected conductors exposed to atmospheric humidity or condensing moisture can easily develop circuitry malfunctions.

This problem can be alleviated by using a multiple-coat process with some drying between coat applications or by using an initial coat with a filler that will reduce the tendency of the coating to pull away from points and edges better. Vacuum deposition of paraxylylene is the best method for covering points and edges.

3. **Bubbles.** Bubbles normally originate from air trapped underneath components and at solder joints. When bubbles bridge uncommon conductors, entrapped moisture or other contaminants may reduce insulation resistance or cause shorts and possible arcing.

Bubbling may be controlled by various means. The angle at which an assembly is dried, cured, or dipped is important in preventing bubble formation. The best angle for spraying conformal coating is usually 45° to the PWA. The drying and cure schedule can also affect bubble formation. Sometimes air cure is needed to permit solvent evaporation; sometimes immediate thermal cure is more desirable because of lower material viscosity caused by higher temperature. Spray coating, being more thinly applied, is not as susceptible to bubbling caused by solvent and air entrapment as are dip coating and brush coating. For thicker coating applications, degassing in a vacuum chamber will remove entrapped air.

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(SEE INSTRUCTION - REVERSE SIDE)

1. DOCUMENT NUMBER		2. DOCUMENT TITLE	
3. NAME OF SUBMITTING ORGANIZATION			
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a. Paragraph Number and Wording			
b. Recommended Wording:			
c. Rational for Recommendation:			
6. REMARKS			
7. NAME OF SUBMITTER	8. TELEPHONE NO.		9. DATE

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