

IPC-5262

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Design, Critical Process and Acceptance Requirements for Polymeric Applications

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Developed by 5-24g Polymerics Standard Task Group

Users of this publication are encouraged to participate in the development of future revisions.

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Design, Critical Process and Acceptance Requirements for Polymeric Applications

1 GENERAL REQUIREMENTS

1.1 Scope This document prescribes the minimum design, critical process and acceptance requirements for the application of polymeric materials to electrical/electronic components, modules, printed wiring assemblies and other elements thereof.

IPC-AJ-820, IPC-HDBK-001, IPC-HDBK-830 and IPC-HDBK-850 are companion documents to this specification. They contain valuable explanatory and tutorial information compiled by IPC Technical Committees that is relevant to this specification.

Although the handbooks are not a part of this specification, when there is confusion over the specification verbiage, the reader is encouraged to refer to the handbooks for assistance.

Reference materials listed in this text are recommended reading. The User is encouraged to obtain all relevant referenced materials as this document cannot (nor can any single document) cover every material, process, environment, performance or safety aspect that affects a given design.

1.2 Purpose The intent of this document is to establish a baseline of requirements, procedures, practices and process attributes based on Lessons Learned and Best Practices that have been demonstrated through use and experience, to result in a robust design and high reliability.

This document is intended for use by the design engineer, manufacturing engineer, quality engineer or other individual responsible for implementation and compliance with requirements of this document to the applicable performance class.

- a. **In-Service Criteria.** This document defines design requirements and acceptability criteria for “New/Beginning of Life” hardware. It is not the intent of this document to establish or define “In Service” acceptance criteria to address performance or reliability issues caused by aging or use. However, the acceptability criteria and limits that are currently detailed in this document may be considered to be wide enough to be applicable to the more common hardware degradation caused by aging/use. Use of these criteria for acceptance of “In Service” hardware conditions **shall [N1D2D3]** be as agreed between the Manufacturer and the User.
- b. **Metallic Whisker Control.** It is not the intent of this document to be used as a stand-alone document for the control and mitigation of performance and/or reliability concerns related to metallic whiskers.

Note: Users of this document are encouraged to review GEIA-STD-0005-1, GEIA-STD-0005-2 or IPC-AJ-820 for additional information pertaining to control of metallic whiskers.

- c. **Alternate/Proprietary Documents or Processes.** It is not the intent of this document to exclude any alternate or manufacturer-proprietary documents or processes that meet or exceed the baseline of requirements established by this document. Use of alternate or manufacturer-proprietary documents or processes that tailor (e.g., change, increase, reduce, delete) any of the mandatory requirements of this document **shall [N1D2D3]** require review and prior approval of the User.
- d. For purposes of this document:
 - 1) The Designer is the design agent for the User.
 - 2) The User is the individual, organization, company, contractually designated authority or agency responsible for the procurement or design of electrical/electronic/electromechanical (EEE) hardware and having the authority to define the class of equipment and any variation or restrictions to the requirements of this document (e.g., the originator/custodian of the contract detailing these requirements).
 - 3) The Supplier is considered the individual, organization or company which provides the Manufacturer (Assembler) components (e.g., electrical, electronic, electromechanical, mechanical, printed boards) and/or materials (e.g., solder, flux, cleaning agents).
 - 4) The Manufacturer is considered the entity that provides a service or product to the User.
- e. The acceptability of the use of polymeric with no-clean flux chemistries **shall [N1D2D3]** be as agreed between the Manufacturer and the User.

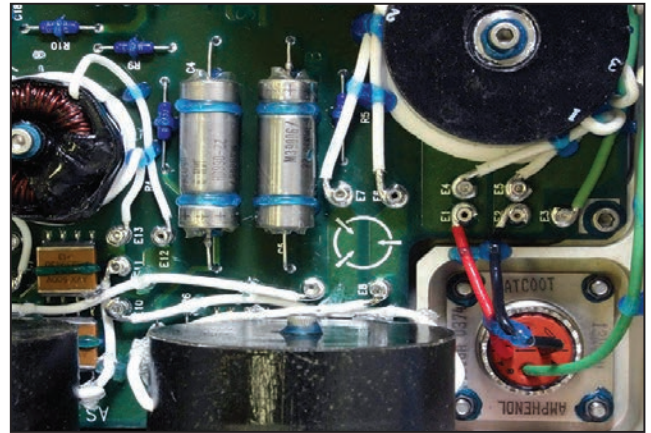


Figure 1-1 Printed wire Assembly With Staking

Image Courtesy: NASA/Johnson Space Center (JSC) Quality & Flight Equipment Division Group

1.3 Applicability This document is applicable to manufacturers involved in the application of polymeric processes (e.g., bonding, staking, conformal coating, encapsulation) to electrical/electronic components, including printed board assemblies, optical and metallic cable and wiring harness assemblies, mechanical items (e.g., tin-plated chassis, brackets, fasteners), and elements thereof, and wherever invoked contractually. The User is responsible for determining whether the use of polymeric materials may be required to ensure performance or reliability of the hardware.

1.4 Performance/Product Classification This document recognizes that electrical and electronic assemblies are subject to classifications by intended end-item use. Three general end-product classes have been established to reflect differences in functional performance requirements, and verification (inspection/test) frequency.

- a. It should be recognized that there may be overlaps of equipment between classes.
- b. The User is responsible for defining the product class.
- c. The contract should specify the performance class required, whether compliance to any of the Appendices is required, and indicate any exceptions to specific parameters where appropriate. If the performance Class is not specified, Class 3 requirements are applicable.

CLASS 1 – General Electronic Products

Includes products suitable for applications where the major requirement is function of the completed assembly.

CLASS 2 – Dedicated Service Electronic Products

Includes products where continued performance and extended life is required, and for which uninterrupted service is desired but not critical. Typically, the end-use environment would not cause failures.

CLASS 3 – High Performance Electronic Products

Includes products where continued high performance or performance-on-demand is critical, equipment downtime cannot be tolerated, end-use environment may be uncommonly harsh, and the equipment must function when required, such as life support or other critical systems.

MILITARY/SPACE

Includes products from Performance Class 3 – High Performance/Harsh Environment Electronic Products, with additional considerations for unique materials requirements and more extreme operational environments, such as vibration and thermal cycling. Space/military classification deviations to IPC-A-5262 requirements are defined and listed in Appendix A.

[M/S] When the [M/S] symbol appears next to a paragraph, it indicates that Appendix A contains requirements to be used in addition to, and in some cases in place of, those published in that paragraph. The criteria in Appendix A are not binding, unless separately and specifically included by the applicable contract, approved drawing(s), or purchase order. Appendices do not apply unless separately invoked per 1.13.

1.5 Definition of Requirements The imperative form of action verbs are used throughout this document to identify acceptance requirements that may require compliance, depending upon the Performance Classification of the hardware.

SHALL/SHALL NOT. The words **shall** or **shall not** are used whenever a requirement is intended to express a provision that is mandatory. Deviation from a **shall** or **shall not** requirement for a particular Performance Class may be considered if sufficient technical rationale/objective evidence (OE) is supplied to the User to justify the exception.

- d. **SHOULD/SHOULD NOT.** The words **should** or **should not** are used whenever a requirement is intended to express a provision that is non-mandatory, and which reflects general industry practice and/or procedure.
- e. **MAY.** The word **may** is intended to express an action or provision that is to be considered non-mandatory, and which is provided as a “recommendation”.

1.5.1 Requirement Format (N/A/D) To assist the User, each requirement is identified by its Performance Classification (x1x2x3) and applicability, where “x” represents:

N = No requirement has been established for this Class

A = Acceptable

D = Defect

Examples:

- [N1N2D3] is Requirement Not Established Class 1 or 2, Defect Class 3
- [N1D2D3] is Requirement Not Established Class 1, Defect Classes 2 and 3
- [N1A2D3] is Requirement Not Established Class 1, Acceptable Class 2, Defect Class 3
- [A1A2D3] is Acceptable Classes 1 and 2, Defect Class 3
- [D1D2D3] is Defect for all Classes.

- a. A defect for a Class 1 product means that the characteristic is also a defect for Class 2 and 3.
- b. A defect for a Class 2 product means that the characteristic is also a defect for a Class 3 product but may not be a defect for a Class 1 product where less demanding criteria may apply.

1.5.1.1 Material and Process Nonconformance Hardware characteristics or conditions that do not conform to the requirements of this specification are classified as either hardware defects or hardware process indicators.

- a. For purposes of this document:
 - A Defect is a condition that may affect the form, fit, or function of the item in its end use environment, or other risk factors as identified by the Manufacturer.
 - Disposition is the determination of how defects are to be treated, and include, but are not limited to, rework, scrap, use as-is, or repair.
- b. It is the responsibility of the User to define additional or unique defect categories applicable to the product.
- c. It is the responsibility of the Manufacturer to identify defects that are unique to the assembly process.
- d. Hardware found to be produced using either materials or processes that do not conform to the requirements of this standard **shall [N1D2D3]** be dispositioned to address the potential effect of the nonconformance on functional capability of the hardware such as reliability and design life (longevity).

***Note:** Material and process nonconformance differs from hardware defects or hardware process indicators in that the material/process nonconformance often does not result in an obvious change in the hardware's appearance but can impact the hardware's performance.*

1.5.2 Requirements Flowdown

- a. This document **shall not [N1D2D3]** be binding, unless separately and specifically included by the applicable contract, approved drawing(s) or purchase order.
- b. When invoked, the applicable requirements of this document **shall [N1D2D3]** be imposed on all applicable subcontracts, assembly drawing(s), documentation and purchase orders.

1.5.2.1 Notes/Italicized Text Information provided in Notes or presented as italicized text is for informational purposes only.

1.5.3 Commercial Off-The-Shelf (COTS) The requirements of this document **shall not [N1D2D3]** apply to suppliers of Commercial-Off-The-Shelf (COTS) or catalog items (e.g., components, assemblies, subassemblies, hardware).

- a. The design and workmanship of COTS items should be evaluated and modified as required to ensure that the COTS items meet contract performance and reliability requirements in the expected worst-case use environment.
- b. Modifications of COTS **shall [N1D2D3]** be documented.
- c. All modifications **shall [N1D2D3]** meet the applicable requirements of this document for the specified Product Class, and be completed, inspected, and tested in accordance with this document, unless otherwise specified by the User.

1.5.4 Existing or Previously Approved Designs The requirements of this document **shall not [N1D2D3]** constitute the sole cause for the redesign of previously approved designs.

- a. When drawings for existing or previously approved designs undergo revision, they should be reviewed and changes made that allow for compliance with the requirements of this document.
- b. If the review results in any material or part changes to a currently qualified design, the revised drawing **shall [N1D2D3]** be subject to User approval.

1.6 Measurement Units and Applications All dimensions and tolerances, as well as other forms of measurement in this standard, are expressed in SI (System International) units, with Imperial English equivalent dimensions provided in [brackets], except as noted.

- a. Linear dimensions and tolerances use centimeters (cm) [inches (in)] as the main form of dimensional expression; millimeters (mm) [inches (in)] or micrometers (μm) [microinches (μin)] are used when the required precision makes the use of centimeters (cm) too cumbersome.
- b. Temperature values are expressed in degrees Celsius (°C) [Fahrenheit (°F)].
- c. Mass is expressed in grams (g) [ounces (oz)].
- d. Wire, wire harness and cable diameters are expressed in the nondimensional unit (d), where a numerical dimension, such as 2d, is solely dependent on a physical attribute of the hardware (e.g., wire gauge, harness diameter).
- e. Time values are expressed in hours, minutes and seconds (hh:mm:ss).



1.6.1 Use of Measurement Units All specified measurement units in this standard are defined as “nominal.”

1.6.2 Verification of Dimensions Actual measurement of specific dimensions and determination of percentages are not required, except for referee purposes or when specified by contract. For determining conformance to the measurement units specified in this Standard, round all observed or calculated values “to the nearest unit” in the last right-hand digit used in expressing the specification limit (e.g., the retained digit), in accordance with ASTM E29 (Rounding Procedure).

1.7 Definition of Terms For purposes of this document, the acronyms, abbreviations, and terms used, but in addition to those listed in IPC-T-50 are listed in Section 9.

1.8 Engineering Documentation The engineering documentation **shall [N1D2D3]** identify the appropriate Product Class and depict all applicable design and acceptance details.

1.9 Order of Precedence The contract **shall [N1D2D3]** take precedence over this document, referenced standards and drawings.

1.10 Conflict

- a. In the event of conflict between the requirements of this document and the approved assembly drawing(s)/documentation, the User-approved assembly drawing(s)/documentation governs.
- b. In the event of a conflict between the text of this document and the applicable documents cited herein, the text of this document takes precedence.
- c. In the event of conflict between the requirements of this document and an assembly drawing(s)/documentation that has not been User approved, this document governs.

1.11 Clause References When a clause in this document is referenced, its subordinate clauses also apply.

1.12 Line Drawings and Illustrations Line drawings and illustrations are depicted herein to assist in the interpretation of the written requirements of this standard. The written requirement always takes precedence over the drawings and illustrations.

1.13 Appendices For the purpose of this document, the Appendices are considered separate and optional documents, which provide additional engineering rationale and technical guidance on polymeric processes.

- a. Appendices are not binding, unless separately and specifically included by the applicable contract, approved drawing(s) or purchase order.
- b. When invoked, the applicable requirements of the appendices **shall [N1D2D3]** be imposed on all applicable subcontracts, assembly drawing(s), documentation and purchase orders.
- c. When not invoked, the Manufacturer may implement the Appendices, individual requirements of the Appendices and/or flowdown of said appendices and/or individual requirements.

1.14 Approval of Departures from Standards and Requirements Special engineering or design requirements may exist which are not covered by, do not comply with or which are in conflict with program-specific documents, and/or program-specified design requirements.

Use of alternate control plans, documents or processes **shall [N1D2D3]** require technical evaluation and approval of the User prior to use.

1.15 Personnel Proficiency All instructors, operators and inspection personnel **shall [N1D2D3]** be proficient in the tasks to be performed.

- a. Objective evidence of that proficiency **shall [N1D2D3]** be maintained and be available for review.
- b. Objective evidence **shall [N1D2D3]** include records of training to the applicable job functions being performed, work experience, testing to the requirements of this standard and/or results of periodic reviews of proficiency.
- M/S** c. Supervised On-the-Job Training (OJT) **shall [N1D2D3]** be acceptable until proficiency is demonstrated.

M/S **1.16 Acceptance Requirements** All products **shall [N1D2D3]** meet the requirements of the assembly drawing(s)/documentation and the applicable requirements for the product class specified herein.

- a. Manufacturers **shall [N1D2D3]** perform 100% inspection unless sampling inspection is defined as part of a documented process control plan.
- b. The User has the responsibility to specify acceptance criteria. If no criteria are specified, required or cited, then best manufacturing practice **shall [N1D2D3]** apply.

1.17 Facilities Work areas/facilities used for the mixing, application, cure and testing of polymeric materials **shall [N1D2D3]** be classified as a Controlled Work Area (CWA).

Controlled Work Area (CWA): For the purpose of this document, a Controlled Work Area (CWA) is defined as an assembly/processing area that is designed, maintained and monitored to achieve shop cleanliness, environmental control and Foreign Object Debris (FOD) mitigation, either by process or procedure, to limit the entry of contamination, and/or environmental conditions that would interfere with the application and complete cure of the polymeric materials, or damage/degrade the hardware.

See Section 4 for additional guidance/requirements.

1.18 Health and Safety The use of some materials referenced in this standard may be hazardous. To provide for personnel safety, follow the applicable local and Federal (National) occupational, safety and health regulations.

***Warning:** Chemicals, materials and solvents used in the application, cure, rework and/or repair of polymeric materials may represent serious human health, safety and environmental concerns. Follow government and the material manufacturer's precautions and guidelines for storing, handling, transporting, staging and disposal of hazardous waste.*

***Caution:** The ingestion of chemicals, materials and/or solvents used in the application, cure, rework and/or repair of polymeric materials through the act of smoking (including the use of tobacco, non-tobacco, vapor products, etc.), eating and/or drinking may be detrimental to human health.*

1.19 Packaging, Handling, Shipping and Transportation (PHS&T)

- a. Hardware **shall [N1D2D3]** be packaged, handled, shipped and transported in accordance with the PHS&T requirements specified in the detail specification and/or contract.
- b. All polymeric materials **shall [N1D2D3]** be fully cured in accordance with a documented procedure or per material specification prior to shipment of the item.

1.20 Documentation Requirements The documentation package **shall [N1D2D3]** be in accordance with ASME Y14.100 (including subset Y14.24, Y14.34, Y14.35, and Y14.44), the User-specified format or an equivalent format agreed upon by the Designer and User. See Section 8 for additional guidance/requirements.

1.21 Intellectual Property (IP) Control Requirements The use, control and disposition of tangible and intangible information related to the design and manufacture of the product, including data, drawings, engineering documentation, trade secrets, etc., should be in accordance with IPC-1791, the User-specified control plan or an equivalent control plan agreed upon by the Designer and User.

1.22 Supply Chain Traceability

- a. When specified by contract, a supply chain traceability program in accordance with IPC-1782, or equivalent, **shall [N1N2D3]** be developed and maintained.
- b. Duration of maintenance of records **shall [N1N2D3]** be as agreed between the Manufacturer and the User.

1.23 Trusted Source When specified by contract, the Design, Manufacturing and/or Supply activities/entities (as applicable) **shall [N1N2D3]** be certified as a "Trusted Source" in compliance with IPC-1791.

1.24 Materials and Substances Declaration When specified by contract, a Materials and Substances Declaration Plan in accordance with IPC-1751, or equivalent, **shall [N1N2D3]** be developed and implemented.

2 APPLICABLE DOCUMENTS

The following documents are applicable to the extent specified herein. Unless otherwise specified, the issue/revision in effect on the date of invitation for bid, or request for proposal, will be applicable.

2.1 IPC¹

IPC-HDBK-001 Handbook and Guide to Supplement J-STD-001

IPC-T-50 Terms and Definitions for Interconnecting and Packaging Electronic Circuits

IPC-WP-113 Guidance for the Development and Implementation of a Red Plague Control Plan (RPCP)

IPC-WP-116 Guidance for the Development and Implementation of a Foreign Object Debris (FOD) Control Plan

IPC-A-610 Acceptability of Electronic Assemblies

IPC/WHMA-A-620 Requirements and Acceptance for Cable and Wire Harness Assemblies

IPC/WHMA-A-620-S Space and Military Applications Electronic Hardware Addendum to IPC/WHMA-A-620

¹ www.ipc.org

IPC-TM-650 IPC Test Methods Manual

2.3.25 Detection and Measurement of Ionizable Surface Contaminations by Resistivity of Solvent Extract (ROSE)

2.6.9.1 Test to Determine Sensitivity of Electronic Assemblies to Ultrasonic Energy

IPC-AJ-820 Assembly and Joining Handbook

IPC-CC-830 Qualification and Performance of Electrical Insulating Compound for Printed Wiring Assemblies

IPC-HDBK-830 Guidelines for Design, Selection and Application of Conformal Coatings

IPC-HDBK-850 Guidelines for Design, Selection and Application of Potting Materials and Encapsulation Processes Used for Electronics Printed Circuit Board Assembly

IPC-1782 Standard for Manufacturing and Supply Chain Traceability of Electronic Products

IPC-1791 Trusted Electronic Designer, Fabricator and Assembler Requirements

IPC-7711/21 Rework, Modification and Repair of Electronic Assemblies

IPC-9505 Guideline Methodology for Assessing Component and Cleaning Materials Compatibility

2.2 Joint Standards²

IPC-J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

IPC-J-STD-001S Space and Military Applications Electronic Hardware Addendum to IPC J-STD-001 Requirements for Soldered Electrical and Electronic Assemblies

IPC J-STD-030 Selection and Application of Board Level Underfill Materials

IPC/JEDEC-J-STD-033 Handling, Packing, Shipping and Use of Moisture, Reflow, and Process Sensitive Devices

2.3 American Society of Mechanical Engineers (ASME)³

ASME Y14.100 Engineering Drawing Practices

ASME Y14.24 Types and Applications of Engineering Drawings

ASME Y14.34 Associated Lists

ASME Y14.35 Revision of Engineering Drawings and Associated Lists

ASME Y14.44 Reference Designations for Electrical and Electronics Parts and Equipment

2.4 ASTM International⁴

ASTM E29 Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

ASTM E595 Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment

ASTM D770 Standard Specification for Isopropyl Alcohol

ASTM D1005 Standard Test Method for Measurement of Dry-Film Thickness of Organic Coatings Using Micrometers

ASTM D2240 Standard Test Method for Rubber Property – Durometer Hardness

2.5 International Electrotechnical Commission (IEC)⁵

IEC 61086-3-1 Coatings for loaded printed wire boards (conformal coatings) – Part 3-1: Specifications for individual materials – Coatings for general purpose (Class 1), high reliability (Class 2) and aerospace (Class 3)

IEC 61340-5-1 Electrostatics – Part 5-1: Protection of Electronic Devices from Electrostatic Phenomena – General Requirements

2.6 EOS/ESD Association, Inc.⁶

ANSI/ESD S20.20 Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

2.7 National Aeronautics and Space Administration (NASA)⁷

NASA-STD-6001 Flammability, Offgassing and Compatibility Requirements and Test Procedures

² www.ipc.org

³ www.asme.org/

⁴ www.astm.org

⁵ www.iec.ch

⁶ www.esda.org

⁷ <https://standards.nasa.gov/>

2.8 National Conference of Standards Laboratories (NCSL)⁸

ANSI/NCSL Z540.3 Requirements for the Calibration of Measuring and Test Equipment

2.9 SAE International⁹

GEIA-STD-0005-1 Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder

2.10 U.S. Office of the Federal Register – Code of Federal Regulations (CFR)¹⁰

27 CFR 21.35 Code of Federal Regulations, Title 27, Alcohol, Tobacco and Firearms, Part 21, Formulas for Denatured Alcohol and Rum, Subpart D, Specially Denatured Spirits Formulas and Authorized Uses, Formula No. 3-A

2.11 United States Department of Defense (US DoD)¹¹

MIL-I-46058, Military Specification: Insulating Compound, Electrical (For Coating Printed Circuit Assemblies)

2.12 Reference Documents Unless otherwise specified, these documents fall in order of precedence behind the contract, approved drawings and any standards imposed on the program. The requirements and recommendations in these documents are not binding and are not to be construed as implied requirements to be imposed on the program. Nor are they to be used if they conflict with any contractual or program-specific requirements.

EV-067 (JSC) Foreign Object Debris (FOD) Control Plan for the Avionic Systems Division

IPC-WP-114 Guidance for the Development and Implementation of a White Plague Control Plan (WPCP)

IEC 60617 Graphical Symbols for Diagrams

IEEE 315 Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Class Designation Letters)

IPC-2611 Generic Requirements for Electronic Product Documentation

IPC-OI-645 Standards for Visual Optical Inspection Aids

IPC-TA-724 Clean Rooms for Printed Circuit Boards

JPR 5335.05 JSC Foreign Object (FOD) Damage Prevention Program

MIL-A-46146 Adhesives-Sealants, Silicone, RTV, Noncorrosive (For Use with Sensitive Metals and Equipment)

MIL-STD-1686 Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

MIL-HDBK-691 Adhesive Bonding

MIL-HDBK-863 Handbook for Wiring Data and System Schematic Diagrams, Preparation of

MSFC-STD-3598 MSFC Technical Standard, Standard for Foreign Object Damage/Foreign Object Debris (FOD) Prevention

NASA RP 1124¹² Outgassing Data for Selecting Spacecraft Materials

NASA-HDBK-6024 Spacecraft Polymers Atomic Oxygen Durability Handbook

NASA-STD-8739.1 Workmanship Standard for Polymeric Application on Electronic Assemblies

NPD 8730.5 NASA Quality Assurance Program Policy

SAE AS12500 Corrosion Prevention and Deterioration Control in Electronic Components and Assemblies

AS9146 Foreign Object Damage (FOD) Prevention Program – Requirements For Aviation, Space, And Defense Organizations

NAS412 Foreign Object Damage (FOD) Prevention Guidance Document

2.13 Guidance on Use of “Inactive for New Design” Documents The term “Inactive for New Design” is used to identify an existing standardization document that is no longer approved for use in new designs because it is no longer maintained or updated by the document custodian. Inactive documents are often used for procurements and sustaining support of existing designs, equipment or legacy programs. Use of “Inactive for New Design” documents for new designs is not recommended without technical rationale.

2.14 Documentation References Documentation references cited are provided as additional sources of supporting information, guidance and technical insight into the design and acceptance requirements for the use of polymeric in electrical/electronic assemblies. Documentation references are not requirements and are not binding unless separately and specifically included by the applicable contract, approved drawing(s) or purchase order.

⁸ www.ncsl.org

⁹ www.sae.org

¹⁰ www.ecfr.gov/

¹¹ www.dla.mil/HQ/InformationOperations/DLMS/ellibrary/manuals/milstds/

¹² <http://outgassing.nasa.gov>

3 GENERAL ASSEMBLY REQUIREMENTS

The electrical and mechanical integrity of components and assemblies **shall [N1D2D3]** be retained after exposure to processes employed during the preparation, application and cure of polymeric materials (e.g., handling, baking, cleaning, masking).

3.1 Materials The polymeric materials and processes used to assemble/manufacture electronic assemblies **shall [N1D2D3]** be selected such that their use, separately or in combination, produce products that:

- Meet the required performance and reliability in the intended worst-case operational environment.
- Meet the acceptance requirements of this document.
- Be in accordance with User-approved engineering documentation (e.g., drawings, parts lists).

3.1.1 Changes in Materials, Processes, or Requirements When major elements of the design, proven processes, or acceptance **[M/S]** requirements are changed, validation of the acceptability of the change(s) **shall [N1N2D3]** be performed and documented.

3.1.2 Nonstandard/Special Processes, Materials or Parts When the Manufacturer intends to use processes, materials or parts not covered by this standard, the Manufacturer, when requested, **shall [N1D2D3]** document the details of fabrication and inspection, including acceptance and rejection criteria, and provide the documentation along with appropriate test data to the User for approval prior to use.

3.1.3 Documentation The Manufacturer **shall [N1D2D3]** document the methods and procedures to be used to incorporate the requirements of this standard into the design, application, cure and inspection of polymeric materials (e.g., bonding, staking, conformal coating, encapsulation) as specified by contract or purchase order.

- Polymeric materials **shall [N1D2D3]** be applied as specified herein, and in the sequence specified, unless exceptions or additions are documented on the approved engineering drawing(s).
- To avoid unnecessary duplication of process development, applicable polymeric documents and/or procedures (or portions thereof) previously approved for use on other hardware builds or contracts should be reviewed and considered for adoption (provided those documents/procedures are not identified by contract as proprietary).

3.2 Rework and Repair

3.2.1 Rework Rework is permissible unless excluded by other provisions of the contract. All rework **shall [N1D2D3]** meet the requirements of this standard and approved engineering documentation.

3.2.2 Repair

- Repairs **shall [N1D2D3]** be made only in compliance with applicable contractual requirements and after authorization for each incident.
- Repairs **shall [N1D2D3]** be accomplished using documented procedures approved by the User.

3.3 Electrostatic Discharge Requirements

- If assemblies contain components or parts sensitive to ESD, the Supplier **shall [N1D2D3]** implement a documented ESD Control Program in accordance with ANSI/ESD S20.20, IEC 61340-5-1 or as agreed between the Manufacturer and the User.
- Documentation necessary for an effective ESD Control Program **shall [N1D2D3]** be available for review.

3.4 Selection Requirements for Polymeric Materials The polymeric material(s) **shall [N1D2D3]** be selected in accordance with the following:

- Workable using the processes described herein such that the intended performance of the polymer is realized in the application. This includes continuous and consistent coverage for conformal coating, material volume control for staking material and bond line control for bonding materials.
- Suitable to the complexity of the assembly and the mission lifetime defined by the project.
- Compatible with, and adheres to, the intended substrates (including the printed board; electrical, electronic and electromechanical (EEE) parts; jumper wires; cable ties; metal brackets; and enclosure surfaces).
- [M/S]** Stable when exposed to worst-case expected operational and storage environmental conditions (as applicable). Environmental conditions include (but may not be limited to): Exposure to moisture (humidity, condensing, incidental contact, immersion), temperature (test, operating and storage), radiation (ultraviolet (UV), thermal) and/or chemicals (corrosives, solvents, vapors, etc.).
- Selected to conform to the project contamination control requirements plan.
- Polymeric material and any outgassing byproducts are noncorrosive to the electronic assembly for which it is selected.

- g. Curable under temperature conditions compatible with the assembly on which it is located.
- h. Selected to enable the finished assembly to meet all mechanical, thermal, electrical and optical requirements associated with test and engineering specification.
- i. Allow repair and rework as needed without damaging the assembly or other elements where applicable.

3.5 Qualification and Acceptance of Polymeric Materials Materials proposed for use in accordance with this standard **shall [N1D2D3]** be validated, approved and accepted using the following as a minimum:

- a. When required by the User, verification tests will be conducted to establish confidence in the reliability of the polymeric material(s).
 - 1) A test plan will be submitted to the User, or its designated representative, for approval.
 - 2) The test plan will detail the test environment, test duration, test assembly design and failure criteria based on life and mission requirements.
- b. The suppliers have established a consistent record of supplying lots which have been verified to meet their datasheet characteristics and are homogeneous on a lot-to-lot basis.
- c. Materials are traceable to a production lot identifier and manufacturing date.
- d. Procurements will be made from the Supplier or their authorized distributors.
- e. A certificate of compliance (CofC) validating that the polymeric material is compliant to the contract or procurement specification, material specification, technical standard, and/or applicable performance/reliability requirement(s).

3.5.1 Special Design Elements for Staking Additional minimum design elements when staking:

- a. Staking material **shall [N1D2D3]** be electrically insulative.
- b. The mechanical support provided by staking **shall [N1D2D3]** extend to the worst-case expected thermal, shock and vibration conditions.
- c. Staking **shall not [N1D2D3]** negate stress relief.
- d. Through-hole solid tantalum capacitors and jumper wires in excess of 25 mm [1 in] **shall [N1D2D3]** be staked.
- e. Jumper wires **shall [N1D2D3]** be staked with staking compound in contact around the full circumference of the wire and in contact with the board and:
 - 1) At a minimum of every 25.4 mm [1 in].
 - 2) At every change of direction beyond the radius of curve for a radius bend that is shorter than 25.4 mm [1 in].

3.5.2 Special Design Elements for Conformal Coating Additional minimum design elements for conformal coating are the following:

- a. The conformal coating process and material **shall [N1D2D3]** be capable of continuous and consistent coverage of the printed board assembly to the desired thickness as measured on either a flat, unpopulated region of the printed board assembly or on the coupon.
- b. To facilitate the examination for coverage and to reduce inspection time, the use of conformal coating materials with a fluorescent indicator (e.g., dye, tracer) or other visual indicators is recommended.

Caution: *UV-sensitive components (e.g., UV-erasable memory) may be adversely affected by using UV sources for inspection of polymeric materials containing a fluorescent dye/tracer.*

- c. The following **shall [N1D2D3]** be identified in the engineering documentation:
 - 1) Areas to be masked (if masking is required) and/or keep-out area(s)
 - 2) Maskant materials
 - 3) Conformal coat material
 - 4) Thinners (if applicable)

3.5.3 Special Design Elements for Bonding The minimum design elements to assure reliable bonding are:

- a. Fixturing or other methods for controlling device placement during bonding and cure may be required.
- b. The following **shall [N1D2D3]** be identified in the engineering documentation:
 - 1) Bonding material

- 2) Locations of the items to be bonded
- 3) Bond line thickness requirements (if applicable)

3.5.4 Special Design Elements for Encapsulation The minimum design elements to assure reliable encapsulation are:

- a. **Shall [N1D2D3]** extend to worst-case expected electrical, thermal and mechanical conditions
- b. **Shall [N1D2D3]** prevent damaging stress during processing
- c. **Shall [N1D2D3]** identify the following in the engineering documentation:
 - 1) The encapsulation material
 - 2) The items to be encapsulated

3.5.5 Special Design Elements for Underfill Underfilling encapsulants were originally developed to improve the reliability of early flip chip assemblies employing alumina (Al_2O_3) substrates. Solder fatigue of the outermost solder bump interconnections caused the failures in these assemblies. Insertion of a curable liquid epoxy resin between the die and substrate dramatically improved assembly reliability by distributing stress due to CTE mismatch over the entire area of the die, instead of just the solder joints.

In addition to imparting thermal cycling reliability, underfills protect chips and interconnections from environmental factors and increase the mechanical strength of the package attachment. When determining the appropriate board level adhesive for product use, material coverage type as well as appropriate material properties should be considered.

3.5.5.1 General Requirements The use of underfill (Figure 3-1), whether for thermal or mechanical purposes, **shall [N1D2D3]** require qualification for the intended application and applied using a documented process.

3.5.5.1.1 Types of Underfill Type of underfill includes, but may not be limited to, the following filled/unfilled polymeric systems:

- Capillary
- Fluxing (no-flow) encapsulant
- Removable/Reworkable
- Corner bond adhesive (dispensed or placed prior to reflow process)
- Corner glue/Corner tack underfills (applied after SMT reflow)

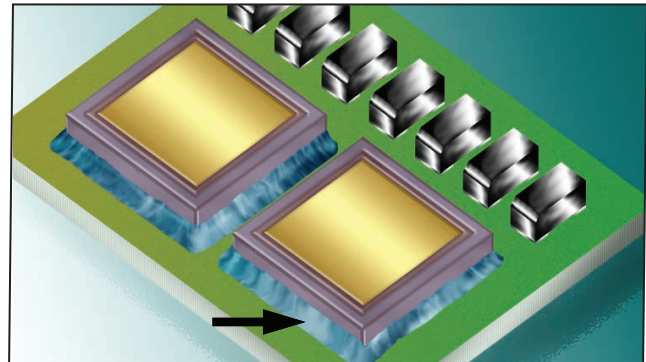


Figure 3-1 Example – Underfill
Image credit: NASA/Johnson Space Center

3.5.5.1.2 Requirements

- a. **Keep-Out Perimeter** – A keep-out perimeter along each edge of the component **shall [N1D2D3]** be established to ensure dispensing needle access during application and to minimize the wicking of underfill material into adjacent areas of the printed board assembly where it is not needed or wanted (e.g., test points, contacting/encapsulating adjacent components).
- b. **Reworkability/Repairability** – Reworkable/Removable underfills should be used when component replacement/repair capability is specified by engineering documentation.

Rationale: Conventional underfills are often not reworkable or removable once cured without destroying the substrate and/or pads, requiring that a malfunctioning assembly be discarded, sometimes at considerable cost.

- c. **Flux Residue Compatibility** – Underfill **shall [N1D2D3]** be compatible with the solder paste or tacky flux residue produced during the soldering process.

Rationale: Compatibility with flux residues is especially critical to “no-clean” or low-residue fluxes that may leave a residue on the board or on the underside of the package. In addition, the more aggressive fluxes used for Pb-free soldering tend to have a greater adverse impact on underfill compatibility.

- d. **Board Surface Compatibility** – Underfill **shall [D1D2D3]** be compatible with the board surface materials and finish (e.g., solder mask, marking inks).

Rationale: In general, adhesives have better adhesion to rough surfaces; therefore, a matte surface, rather than a glossy surface, provides a better surface for mechanical adhesion.

- e. **Component Compatibility** – Underfill **shall [D1D2D3]** be compatible with component surfaces (e.g., component body, leads, solder joints, vias).

Rationale: Good adhesion to these surfaces is critical in order to eliminate delamination or degradation of performance/reliability.

- f. Coefficient of Thermal Expansion (CTE) – Underfill should be selected with a CTE that approximates the CTE of the interconnect system.
- g. Dielectric Properties – The dielectric characteristics of the underfill material **shall [N1D2D3]** be taken into consideration.
- h. Outgassing – Outgassing of underfill **shall not [N1D2D3]** contaminate adjacent areas/components; contaminate, damage or degrade critical surfaces such as contacts and connectors; or result in void formation within the cured volume in excess of specification.
- i. Dispensing Pattern – The dispensing pattern **shall [N1D2D3]** ensure material has flowed completely into and filled all designated areas; material is present at all sides of the device; a full and complete fillet along the periphery of the device is formed; and that air entrapment, voiding and phase separation (e.g., dynamic, filtering, gravitational) are within specification.
- j. Cure – Underfill **shall [N1D2D3]** be cured within time and thermal parameters (e.g., temperature, rate) that ensure the most thermally sensitive components on the printed board assembly are not damaged or degraded.
- k. Secondary Soldering Processes – Underfilled components on subassemblies (e.g., multichip modules, land grid arrays) that are used in subsequent soldering processes **shall [D1D2D3]** be compatible with the additional processing conditions.

4 FACILITIES, TOOLS AND MATERIALS

4.1 Health and Safety The use of some materials referenced in this standard may be hazardous. To provide for personnel safety, follow the applicable local and Federal (National) occupational, safety and health regulations.

4.2 Facility Cleanliness The work area **shall [D1D2D3]** be maintained in a clean and orderly condition.

- a. Smoking (including the use of tobacco, non-tobacco, vapor products, etc.), eating and drinking in areas where the mixing, application, cure, rework and/or repair of polymeric materials is performed and at individual workstations **shall not [D1D2D3]** be permitted.
- b. Nonessential tools and materials **shall not [D1D2D3]** be permitted at the workstation.
- c. Tools **shall [D1D2D3]** be verified as visually clean prior to use.

4.3 Environmental Conditions Areas where the mixing, application, cure and testing of polymeric materials are performed **shall [D1D2D3]** have a controlled environment that limits the entry of contamination, and/or environmental conditions that would interfere with the application and complete cure of the polymeric materials or damage/degrade the hardware.

4.3.1 Temperature Unless otherwise specified in engineering documentation, the temperature in work areas/facilities used for the mixing, application, cure and testing of polymeric materials **shall [N1D2D3]** be monitored and controlled as follows:

- a. Mixing, application and testing: 18 °C to 30 °C [64.4 °F to 86 °F].
- b. As specified by polymer manufacturer's cure schedule and/or engineering specification.

4.3.2 Humidity The range (lower and upper limits) of humidity in the assembly area **shall [N1D2D3]** be monitored and controlled to ensure the application and cure of polymeric materials does not result in the damage or degradation of dielectric, mechanical or thermal properties of the polymer and/or the hardware below minimum specification.

- a. Humidity **shall [N1D2D3]** be controlled to the extent necessary to:
 - 1) Prevent immediate or latent damage to precision-machined and/or corrosion-sensitive surfaces
 - 2) Control buildup of electrical static charges
 - 3) Ensure full and complete wetting of the polymer to the designated surface(s)
 - 4) Ensure full section cure within the specified time limits
- b. For operator comfort, the relative humidity (RH) should not exceed 70%.
- c. For protection of precision-machined or corrosion-sensitive surfaces, the RH should not exceed 50%.
- d. When RH decreases to a level of 30% or lower, the Manufacturer **shall [N1D2D3]** verify that ESD control is adequate.

4.3.3 Special Environmental Requirements Parts, materials or equipment being processed that require more stringent control of environmental conditions than those stated above **shall [N1D2D3]** have these requirements and controls identified and specified on the engineering documentation.

4.3.4 Test Temperature and humidity ranges and limits for performance and/or functional testing **shall [N1D2D3]** be identified and specified on the engineering documentation.

4.3.5 Field Operations In field operations where the required controlled conditions cannot be effectively achieved, special precautions **shall [N1D2D3]** be identified in the appropriate documentation and followed to minimize the effects of the uncontrolled environment on the operation being performed on the hardware.

4.4 Foreign Object Debris (FOD) Control Plan When a FOD prevention program (a.k.a.: FOD control plan) is required, it **shall [N1D2D3]** prevent immediate and latent damage and ensure compliance to the specified cleanliness level.

- a. See IPC-WP-116A for technical guidance and requirements.
- b. See 5.5.8.2.2.e for additional requirements.

4.5 Lighting Requirements Light sources used for visual inspection **shall [D1D2D3]** be selected that are capable of producing shadow-less and reflection-less illumination of the surfaces being inspected to facilitate visual detection of acceptable and defect conditions, including but not limited to, coverage, placement, and surface contours.

Exception: Shadows caused by the item or surfaces being inspected are allowed.

4.5.1 Lighting Requirements – Visible/White Light Unless specified otherwise by engineering documentation, light intensity on the surfaces where polymeric materials are applied or inspected **shall [N1D2D3]** be a minimum of 1,000 lux [~93 foot-candles].

- a. Color: In selecting a light source, color temperature and polarization are important considerations when inspecting surfaces with subtle tints or a high reflectivity index. Light temperature ranges from 3,000 K to 5,000 K enable the identification of various metal and plating features and contaminants with increased clarity.
- b. Supplemental Lighting: Supplemental lighting may be used to achieve the required levels.
- c. Polarized/Directed Light: Polarized and directed (point) light sources reduce the possibility of “ghost imaging” caused by the simultaneous reflection of light off of multiple adjacent surfaces. The use of fixed-intensity (non-adjustable brightness) fluorescent “ring lights” should be avoided when inspecting closely-spaced or highly reflective surfaces.

4.5.2 Lighting Requirements – Short-Wave Black Light/Ultraviolet (UV) Coatings and polymeric materials that possess a UV tracer will fluoresce (glow) under exposure to a short-wave black light/ultra-violet (UV) source, making the inspection for complete coverage and coating thickness a much easier task (than when viewed under white light only).

Source: A low-intensity UV light source (LED or fluorescent) of 3,650 Å to 3,950 Å [365 nm to 395 nm] wavelength, capable of producing a shadow-less illumination may be used in an inspection process.

- a. Lighting Distance: The assembly should be placed anywhere from 50 mm to 152 mm [2.0 in to 6.0 in] from the light source for optimal illumination and visual evaluation.
- b. General Area Lighting: Visible (white) light in the inspection area should be reduced to less than 20 lux [1.86 foot-candles] to accommodate the low light intensity generated by the short-wave black light/ultra-violet (UV) source. A high/ultra-high intensity UV light source should be considered when it is not practical to reduce the visible (white) light intensity to less than 20 lux [1.86 foot-candles].

Safety Warning: *The recommendation of visible (white) light intensity of less than 20 lux [1.86 foot-candles] in the inspection area when using short-wave black light/ultra-violet (UV) illumination for inspection is below the minimum illumination levels recommended by many governmental workplace safety organizations. Care should be exercised to prevent personal injury when working in the darkened area and when returning to the normally lighted area(s).*

4.6 Inspection Optics Visual inspection **shall [N1D2D3]** be performed using magnification aids conforming to the following:

- a. Inspection magnification aids that permit simultaneous viewing with both eyes are preferred, but single-eye viewing devices are acceptable.
- b. Magnification aids **shall [N1D2D3]** be capable of rendering true colors, proportional dimensions and adequate resolution at the chosen magnification to perform the specified inspection.
- c. The light source **shall [N1D2D3]** provide shadowless illumination of the area being viewed except when oblique lighting is required.
- d. Inspection optics **shall [N1D2D3]** be capable of 1X to 10X magnification.
- e. See 6.2 for general inspection requirements.

4.7 Silicone Operations Items exposed to uncured silicone material **shall not [N1D2D3]** be used for processing other material.

Rationale: Silicone processing is segregated from other polymeric applications to prevent silicone contamination/cross-contamination of assemblies, tools, workspaces and equipment.

- a. Exception: An authorized exception is allowed only in cases in which equipment is used for co-curing processes and the Manufacturer has demonstrated through system tests that the material properties of non-silicone polymers have not changed and design requirements are met. Objective evidence **shall [N1D2D3]** be maintained and available for review.

Warning: *Equipment and product can be contaminated when tools and equipment used for silicone processing are not rigorously segregated from those not used for silicone processing.*

4.8 Tool and Equipment Control

- a. Each Manufacturer **shall [N1D2D3]**:
- 1) Select tools to be used in the preparation and application of polymeric materials, and in work preparation areas, appropriate to their intended function
 - 2) Clean and properly maintain all tools and equipment
 - 3) Examine all elements of tools used in polymeric applications for physical damage
 - 4) Prohibit unauthorized, defective or uncalibrated tools in the work area
 - 5) Document detailed operating procedures and maintenance schedules for tools and equipment requiring calibration or set up
 - 6) Maintain records of tool and equipment calibration and functional testing
- b. The Manufacturer **shall [N1D2D3]** have a documented calibration system in accordance with ANSI/NCSL Z540.3, or as required by the supplier's quality management system (QMS).
- c. When specified by contract, the Manufacturer's process documentation for tool control **shall [N1D2D3]** be subject to review and approval by the User.

4.9 Material Storage and Records Retention

4.9.1 Storage

- a. Solvents – All cleaning and diluent solvents **shall [N1D2D3]** be stored in accordance with applicable regulations.
- b. Polymeric Materials – Materials **shall [N1D2D3]** be stored in accordance with the manufacturer's recommendations.

4.9.2 Records

- a. Purchase Data – Records of manufacturing date, lot number, receiving date and manufacturer's certification of compliance of each material shipment **shall [N1D2D3]** be maintained.
- b. Container Markings – Material containers **shall [N1D2D3]** be marked per the engineering documentation requirements, and may include but not be limited to the following:
- 1) Manufacturer's identification
 - 2) Manufacturer's product designation
 - 3) Expiration date of guaranteed product life (e.g., shelf life)
 - 4) Traceability code (e.g., lot, batch)
 - 5) Storage temperature range (if applicable)
 - 6) Safety and environmental information (e.g., Hazardous Materials Identification System (HMIS), safety data sheet (SDS), PPE)
 - 7) Caution notes (e.g., handling)
- c. Mix Records – When specified by contract or project requirements, a mix record **shall [N1D2D3]** be created and maintained for each batch of polymer (see 5.5.5.2).
- d. Test Specimens – When specified by contract or project requirements, test specimens **shall [N1D2D3]** be created and maintained for each batch of polymer (see 5.5.5.3).