Conformal Coating Specifications

Understanding NASA, IPC & NADCAP Requirements

By: Sean Horn

Diamond-MT, Inc.

213 Chestnut Street

Johnstown, Pa 15906

+1 (814) 535 3505 phone

+1 (814) 535 2080 fax

www.paryleneconformalcoating.com

shorn@diamond-mt.com

Electrically nonconductive, insulating and protective, conformal coatings correspond to the surface configurations of the printed circuit assemblies (PCAs) board or other similar electrical components. Properly applied, conformal coatings generate environmental protection for substrate surfaces, limiting degradation of PCA performance that might be caused by external contamination, debris, handling or humidity.

Primary conformal coating types consist of liquid-application acrylic, epoxy, polyurethane and silicone. In addition, parylene, applied through a chemical vapor deposition (CVD) process, offers a versatile coating substance. Conformal coatings have many purposes for many different industries, and their application requires performance and auditing standards to deliver acceptable levels of quality assurance (QA). These techniques are covered by NASA-STD 8739.1, and other industry standards created by the Association Connecting Electronics Industries (IPC classifications), and the National Aerospace and Defense Contractors Accreditation Program (Nadcap).

NASA Inspection Criteria for Conformal Coating

The Workmanship Standards developed by the National Aeronautics and Space Agency (NASA) are essential to assuring reliable performance of the aeronautic, defense and space equipment it uses and monitors.

Conformal coatings have many applications for these purposes, particularly to provide protection for PCAs commonly found in computers or specialized electronic equipment which control their operations. Consisting of microchips and similar electronic components mounted on assembly panels, PCAs need conformal protection to generate insulation and environmental protection; the objective is to minimize degradation of their critical performance factors, maintaining long-term functionality. Major conformal coating materials are acrylic, epoxy, silicone, urethane and parylene.

Origin and Purpose of NASA 8739.1

NASA-STD 8739.1 is the Workmanship Standard for Polymeric Application on Electrical Assemblies, covering conformal coatings for PCAs used for defense and aerospace purposes. Originally released in August of 1999, NASA 8739.1 provides manufacture and performance standards for conformal coatings used in products that must function optimally under continual high-stress conditions, potentially hazardous to human life and mission success. Commitment to using appropriately designated and inspected designs, materials, processes, and personnel assures quality performance, streamlines failure-cause analyses and stimulates ongoing product/process evolution. Among conformally-coated products subjected to NASA inspection criteria during manufacture and use are:

- assemblies and devices used for the aerospace industry, subjected to frequently exceptional atmospheric pressures and temperature conditions during aircraft/spacecraft flight, and
- embedded systems for aeronautic military/battlefield uses requiring dependable functionality through extreme conditions for an often extended duration.

Because these are operating environments where excessive moisture or dryness, extreme temperatures, high levels of vibration, wind, or lack of atmosphere are the rule, NASA standards for conformal coatings are designed to provide suitable quality assurance, with guidelines that:

- minimize product/process defects,
- demand best-practice product design and manufacture,
- designate standards for progressive inspection procedures featuring detailed and specific acceptance/rejection standards to
- stimulate process/product improvement on an ongoing basis, and
- document necessary changes in product design and performance.

NASA 8739.1: Standards of Performance

NASA's numerous outer space exploration projects include

- lunar spacecraft landings, as well as those on Mars, and Saturn,
- manned and unmanned exploration,
- such as the International Space Station, SkyLab, and the Space Shuttle program.

These aerospace missions require functional solutions far exceeding those acceptable for terrestrial use. Communications between earth command and spacecraft, radar/detection equipment, satellite electronics, and a variety of specialized treatments for interstellar functionality stipulate reliable and exceptional performance. Assuring conformal coatings provide the expected protection of assemblies and components is essential to safe project implementation, maintenance and mission completion.

Comprehensive inspection for meticulous component functionality is fundamental to assuring conformally-coated equipment is ready for use for NASA aerospace systems. Particularly important are mission-hardware and related mission-critical ground support technology.

Conformal Protection for NASA Systems

The basic conformal coating materials are acrylic, epoxy, silicone, urethane and parylene. Of these types, the first four are applied by liquid methods – brushing, dipping or spraying the material onto the substrate. Only parylene employs a chemical vapor deposition (CVD) process, wherein the gaseous parylene penetrates deep into the substrate surface in a vaporous form, rather than simply attaching to the surface, as with liquid methods. Because of the different compositional result, liquid methods generally require thicker coating films than parylene.

Whatever application process is used, each conformal coating material requires a specific thickness to function according to standard. As stipulated by NASA-STD 8739.1, these measures of conformal film are mandated for covering the designated circuit or component, (quantified in millimeters [inches]):

- Parylene -- 0.013 – 0.051 [0.0005 to 0.002].
- Silicone -- 0.051 – 0.203 [0.002 to 0.008].
- Acrylic, urethane, epoxy -- 0.025 – 0.127 [0.001 to 0.005].

These levels of coating assure reliable, safe performance of circuits and components under often-extreme conditions.

Change 2

Like all NASA Workmanship Standards, 8739.1 is revised and updated as necessary, to reflect the evolution of aerospace systems and the requirements of conformal coatings protecting their PCAs and related components. The most recent revision is designated NASA-STD 8739.1A with Change 2, approved 2008; it stipulates that, prior to application, PCAs to be coated must be:

- Cleansed and demoisturized no more than 8 hours prior to application of the designated conformal coating.
- Oven-bake or vacuum-bake processes, at the prescribed temperature and time duration, as specified by the assembly's engineering document, are mandated for demoisturizing procedures under 8739.1A.

These processes assure the component will be sufficiently dry, to safely accept application of conformal coating. Further revisions of 8739.1 are developed as necessary to reflect evolution of industry requirements.

Additional Inspection Criteria for Conformal Coatings

Visual inspection of coating coverage employs an ultraviolet (UV) lamp sufficiently equipped to effectively compare fluorescent areas to uncoated portions. The objective is to determine if all the surfaces and electrical parts are adequately and conformally coated. Several factors generate reliable interpretation of conformal coating efficiency under UV light:

- Uniform surface coating is indicated by an even blue glow; nonuniform covering appears as blemishes and discolorations within the blue glow.
- Glowing rings with dark centers indicate bubbles.
- Voids and dry spots are identified by dark spots along the observed surface under UV light; minute dark spots signify debris or surface pinholes.
- A large dark area shows absence of coating.
- Intensely glowing areas denote bulges in the surface.
- Larger, elongated surface sections exhibiting intense glowing indicate runs within the coating.
- Straight dark lines indicate bristles or debris, especially in a brush coating.
- If necessary, higher magnification is suggested to identify and inspect bubbles or surface contaminants.

Inspection of operator workmanship includes use of the proper tools and techniques (UV light, appropriate instrument calibration, etc.). In addition, proper environmental conditions, such as facility cleanliness, product/process handling, and proper material storage/shelf life.

Summary

With the rise of digital technology, conformal coatings are currently being applied to a widely evolving range of advanced PCAs. NASA's Workmanship Standards manage the design and production of equipment and technology intended for space flight and exploration. The Standards designate each component's technical, procedural and documentation requirements, to provide complete and dependable production and performance guidelines. Although NASA

8739.1 is effective, inspection criteria for conformal coatings will require monitoring and improvement as these many uses proliferate.

For instance, liquid coating-materials use spraying, brushing, or dipping methods, alone or in a combination appropriate to assure dependable film adherence to the designated aerospace substrate. Even when applied in multiple layers, sometimes using overlapping techniques – for instance, spraying the coating onto the substrate following dipping processes – crevices, edges and points on the substrate surface may remain inappropriately coated, jeopardizing the component's function (and potentially mission success).

In contrast, parylene's CVD procedures are more expensive, but encompass surface inconsistencies far more comprehensively, resulting in a pinhole- and bubble-free film, completely covering crevices, without surface inconsistencies. Unlike liquid coatings, parylene is less susceptible to excessive filtering and material-runs (dripping or oozing). It also has a far lower incidence of surface scratches or other imperfections in the coating surface; these are acceptable ONLY when they do not expose a component's conductive areas. Parylene's properties are generally more amenable to NASA-STD 8739.1A requirements, suggesting its advantages in comparison to liquid conformal coatings, in most cases.

Conformal Coating Specifications:

Guidelines for Design, Selection and Application of Conformal Coatings

Understanding the characteristics of various conformal coating types, and their interactions with the extreme range of products and materials to which they are applied, ensures optimal function, performance reliability and product-life. Designers and users of conformal coatings should be aware of the properties of various types of conformal coatings and their interactions with the parts/materials they cover, to protect the products in their respective end-use environments for the expected design-life of each component.

In this context, different specifications for conformal coating have been devised to identify and account for differences in operational and material conditions. End-users providing conformal covering are confronted by problems with coating selection or application that can generate difficulties including mismatched coefficients of thermal expansion (CTEs), trapped moisture, outgassing, corrosion, abrasion or future rework/repair. For example, someone who manufactures printed circuit assemblies (PCAs) for standard commercial usage, will be best

served using the IPC-610 standard for their conformal coating. However, NASA standards are far more applicable to aerospace projects.

IPC, the Association Connecting Electronics Industries

Headquartered in Bannockburn, IL (USA), with offices throughout the United States and the world, IPC is a recognized and respected standards-development organization accredited by the American National Standards Institute (ANSI). Its objective is standardizing assembly and production requirements of electronic components, including those for interconnecting and packaging electronic circuits and assemblies. Diamond MT has been a member of the IPC since January 2012.

IPC Classifications Pertinent to Conformal Coating

Particularly important is IPC's Class 3 Standard for Coating Requirements; its guidelines ensure conformally coated surfaces maintain exemplary performance under challenging operational conditions.

IPC-A-610: Additionally titled "Acceptability of Electronic Assemblies," this standard provides visual quality-acceptability requirements for manufacture of electronic assemblies, delineating appropriate PCA/component characteristics that exceed minimal end-item performance criteria.

Requirements for coating thickness are also set by IPC-A-610, according to the coating material and the function of components being covered.

Table 1

Conformal Coating Application Thicknesses

Coating type	Application thickness, mm. (in.)
Acrylic (AR), Epoxy (ER), Urethane (UR)	0.03-0.13 mm. (0.00118-0.00512 in.)
Silicone (SR)	0.05-0.21 mm. (0. 00199-0.00827 in.)
Parylene (XY)	0.01-0.05 mm. (0.000394-0.00197 in.)

IPC-A-610 also classifies products according to their function. Class 1 is the least stringent of these categories, proceeding through Class 2, with Class 3 being most rigorous. More explicitly:

- *CLASS 1* applies to the *General Electronic Products*' category, including products whose primary requirement is efficient function of the completed assembly.
- *CLASS 2* encompasses *Dedicated Service Electronic Products*. This category emphasizes the product's ongoing performance and extended life, under operating conditions where (1) uninterrupted service is preferred but not critical, and (2) the end-use environment would not stimulate failures.
- *CLASS 3* is for *High Performance/Harsh Environment Electronic Products* – those that necessitate performance-on-demand and absence of equipment downtime in end-use environments that may be uncommonly harsh. Although *CLASS 3* is sometimes known as the 'aerospace class' of IPC-A-610, this is not strictly true. While *CLASS 3*/IPC-A-610 has many aerospace functions, it also

applies to any end-use environment where the equipment must function on-demand, such as life-support, fire-control. or similar critical systems.

It is essential in most cases that aircraft flight controls require *CLASS 3* certification. An aircraft's fly-by-wire controls must function without fail every time, while being subjected to temperature/vibration extremes at high altitude. However, *CLASS 1/2* assemblies may be more than adequate for such aircraft-internal functions as its entertainment system or communication among flight stewards. *CLASS 3* is mandated in aerospace, military or other end-use environments where the highest quality performance reliance/capacity is required; *CLASS 3* is also costly, and is not recommended where other classifications will serve.

IPC-7711/7721: Rework and Repair – This standard delineates acceptable procedures for conformal coating and component removal and replacement; modification/repair of laminate material, conductors, solder, and plated through-holes are also stipulated.

IPC CLASS 3: This document provides the Standard for Coating Requirements of the *Class 3* High Performance Electronic Products described for IPC-A-610, those components and systems requiring performance-on-demand, frequently for extended durations of operation, including aerospace, life-support, and military applications, as described above.

IPC J-STD-001 End Item Standards: Like the MIL-S-45743 it replaced, IPC-J-STD-001 establishes procedures and requirements for achieving optimal levels of performance quality and reliability, for uninterrupted operation in the harshest of end-use environments. These are minimal end-product acceptable requirements for soldered electrical and electronic assemblies; evaluation methods, testing-frequency, and process control requirements are also described.

IPC-CC-830: Qualification and conformance requirements for conformal coatings are the subject of IPC-CC-830. Devised as a replacement for MIL-I-46058, a military-grade standard, in 1998, it delineates criteria for optimal confidence for coating materials, with the added benefit of minimum test redundancy

Table 2

IPC-CC-830 Conformal Coating Guidelines for Substrate Type and Quantity

Test	Test Vehicle	Average Success Rate
1) Dielectric Withstanding Voltage (DWV)	IPC-B-25A test boards (with the D-pattern wired)	90 – 100%
2) Moisture and Insulation Resistance (MIR)	IPC-B-25A test boards (with the D-pattern wired)	80%
3) Thermal Shock	IPC-B-25A test boards (with the D-pattern wired)	90 – 100%
4) Temperature/Humidity Aging (Hydrolytic Stability)	"Y" shape test assembly 9 (with resistors, (1 color coded, 1 with numbers/alphabets, soldered)	90 – 100%

IPC-CC-830 standards encompass three categories, testing:

- 1) Qualification of the processes/materials for the coating purpose at hand, with testing required on each product batch;
- 2) Retention of the qualification over a determined performance duration, with testing required every two years; and
- 3) Overall quality conformance of the coating under these conditions, testing required every year.

Military-grade systems and ruggedized products benefit from adhering to IPC-CC-830 standards.

Summary

IPC Standards present achievable, easily recognized benchmarks for the assembly and production requirements of electronic circuits, components and equipment. For conformal coating, the two most important are:

- IPC A 610 Acceptability of Electronic Assemblies Standard, currently the most widely used IPC-standard for consumer and high reliability printed wiring assemblies. It contains valuable, but limited, criteria for conformal coating applications.
- IPC-CC-830B Qualification and Performance of Electrical Insulating Compound for Printed Wiring Assemblies is more applicable to use of conformal coatings, qualifying the definition, use and conformance of all conformal coatings types. It has been designed and constructed with the intent of obtaining maximum confidence in the materials with minimum test redundancy.

Those using conformal coatings need to recognize the properties of various coating-types to select the kind most applicable to the product and its purposes, for extended design-life. Diamond MT focuses on the importance of aligning coating types and processes according to the IPC Standard specifications required to meet clients' material and operational functions.

Nadcap Specifications for Conformal Coatings

The National Aerospace and Defense Contractors Accreditation Program

The National Aerospace and Defense Contractors Accreditation Program (Nadcap) provides cooperative global accreditation covering all aspects of product-manufacture in the aerospace, defense, and engineering industrial sectors, as well as for related industries. Product/process conformity assessment is the key to Nadcap's industry-managed accreditation criteria, generating standards derived from compliance to workmanship-focused checklists for component manufacture; adherence to prescribed standards also relies upon the consistency of blind processes.

Need for Nadcap

Established in 1990, Nadcap is administered by the Performance Review Institute (PRI), located in Warrendale, Pennsylvania (724-772-1616), with additional offices in Europe

(England) and Asia (China, Japan). From the beginning, the Institute's objective has been to develop and maintain reliable, standardized approaches to quality assurance (QA) in the industries it serves, stemming from stringent industry consensus standards that satisfy the requirements of all participants.

Prior to Nadcap's creation, aerospace, defense and related firms verified process-compliance through audits of their own suppliers. Often extreme similarity resulted from their own process analyses for verifying compliance, because these processes paralleled those provided by the suppliers. The consequent redundancy of process assessments created a high incidence of comparable audit results. Despite greater cost in money and time conducting audits, little value was added for firms within these industries. PRI's administration of the Nadcap program has eliminated many of these conditions, generating greater levels of QA and overall product/process consistency for aerospace and other industries.

Nadcap Standards

Consistent Nadcap Standards are developed from contributions by industry-specific, technical experts selected from both government and industry sources. These personnel devise and monitor accreditation requirements, defining operational program standards. Nadcap accreditation is an industry-driven program.

In the case of the aeronautics, the industry-directed program is the outcome of participation from highly qualified individuals with sufficient experience in the aerospace industry to conduct the actual process audits, using criteria specific to each designated manufacturing process; audits are enacted at the company level. In addition to company-level accreditation for such industrial/manufacturing procedures as chemical processing, conventional

machining, heat-treating, product testing and welding, Nadcap offers standards for coatings (CT).

Nadcap for Conformal Coating

The role of conformal coatings as protective insulators of circuit card assemblies is well known, so it is surprising that there is no official NADCAP audit for conformal coatings. One Nadcap Standard particularly relevant to conformal coating is the AC7120.

AC7120 Rev A - Nadcap Audit Criteria for Circuit Card Assemblies: This Nadcap Standard provides a set of test guidelines and performance criteria for conformal coating use in PCAs and other circuit card conditions. Most pertinent is Section 14, Coating and Encapsulation, which specifically covers auditing standards for conformal coating. Unfortunately, most conformal coating applicators do not build or assemble CCA's, making them ineligible to receive this certification. However, as long as the end customer who is certifying the end product is NADCAP certified, we have had no issues with our customers claiming the conformal coating is indeed NADCAP approved.

Summary

Nadcap is the leading worldwide cooperative program encompassing the participation of major companies; it is designed to manage a cost-effective consensus approach to industry-specific manufacturing processes and products.

In this context, Nadcap oversight generates industry-standard manufacturing and testing specifications, designed to stimulate ongoing QA and product improvement within the aerospace industry. Standard AC7109 provides audit criteria for conformal coatings. AC7109/2, covering

Audit Criteria for Vapor Deposited Coatings Physical Vapor Deposition (PVD) and Chemical Vapor Deposition (CVD) processes, such as those used with parylene, is particularly pertinent, but the entire Standard has considerable import for aerospace assemblies. AC7120 Rev A - Nadcap Audit Criteria for Circuit Card Assemblies - is also relevant to providing company-level accreditation based on specific processes used by aerospace suppliers.

NASA Certified and Similarly Rated Conformal Coating Companies

NASA certification is essential to aerospace conformal coating applications, and thus is sought after by many firms in the industry. In addition to 8739.1, other NASA standards, such as ASTM E595 – a test developed by NASA to determine levels of coatings' volatile content,

appropriately screening low outgassing materials for use in space – are inspection and performance parameters applicable to aerospace uses.

The AS9100/9120 and ISO9001 qualification are international aerospace standards for quality assurance, development, production, installation, and servicing also relevant to quality workmanship for aerospace products and the firms that manufacture them; equally relevant are IPC-CC-830 and IPC--A-610 classifications, from the Association Connecting Electronics Industries, often considered equivalent to NASA 8739.1 for aerospace conformal coatings. Nadcap's AC7120 Rev A - Nadcap Audit Criteria for Circuit Card Assemblies is also applicable.

Essential aerospace applications for conformal coatings include: PCAs and related circuit card assemblies, sensors of all types, microelectricalmechanical systems (MEMS), motor components, power supplies. elastomeric components and backplanes.

NASA Certified Conformal Coating Companies:

Diamond-MT, Inc., located at 213 Chestnut Street, Johnstown, Pa 15906 (Phone: 814-535-3505/Fax: 814-535-2080, www.diamond-mt.com), is NASA certified. Other NASA or similarly certified conformal coating companies include:

Advanced Coating: 10723 Edison Ct, Rancho Cucamonga, CA 91730

Astro Manufacturing & Design: 34459 Curtis Blvd., Eastlake, Ohio 44095

DfR Solutions: 5110 Roanoke Place, Suite 101, College Park, Maryland 20740

Electronic Coating Technologies: 1 Mustang Drive, Cohoes, NY 12047

FastSMT.com/Electronic Source Company: 16032 Arminta Street, Van Nuys, CA 91406

Filter Research Corporation, Inc. (FRC Group): 1270 Clearmont Street NE, Palm Bay, FL 32905

Imagineering Finishing Technologies (IFT): 1302 W. Sample St., South Bend, IN 46619

Specialized Coating Services (SpecCoat): 42680 Christy St., Fremont, CA 94538

Specialty Coatings Systems (SCS): 7645 Woodland Drive, Indianapolis, Indiana, 46278

Spectrum Advanced Technologies Manufacturing, Inc.: 3855 Interpark Drive, Colorado Springs, CO 80907

STI Electronics, Inc.: 261 Palmer Rd., Madison, AL 35758

Wildwood Electronics, Inc. (WEI): 29700 Indian Springs Rd., Madison, Al 35756

NASA's 8739 Standards describe uniform engineering and technical requirements for processes, practices, and methods that have been endorsed as standard for NASA programs and

projects, including requirements for selection, application, and design criteria for conformal coating and related encapsulation techniques; these are applied primarily to the manufacture and use of PCAs and electronic assemblies used in space flight components, but have uses for MEMS, sensor and other systems as well. The AS9100 and ISO9001 Standards also provide criteria for coatings similarly essential to their reliable performance during operation.

Diamond MT is committed to providing clients superior conformal coating specifications and standards, generating highest performance products for aerospace and all other applications. For a further list and description of Diamond's commitment to manufacturing standards and specifications, please see: http://www.paryleneconformalcoating.com/standards-specifications.

About Diamond MT

Diamond MT was founded in 2001 as a firm specializing in contract applications of conformal coatings for Department of Defense and Commercial Electronic Systems. Since our beginning, Diamond MT has established a reputation for providing the highest quality services in the industry. Our commitment to quality, integrity, and customer satisfaction combined with an unmatched expertise in applications and processes has provided every one of our customers with superior results.

Diamond MT operates out of a freestanding 12,000 square foot building in Johnstown, Pennsylvania, which is located 60 miles southeast of Pittsburgh. Diamond MT is located near three major interstates and is supported by the Cambria County Airport, which serves as a primary freight terminal for south central Pennsylvania. Diamond MT maintains a strict program per NSI ANSI Standard 20.20 for ESD protection. All work areas are safeguarded with the latest in protection devices including wrist straps, garments, and workstations.

Quality Assurance: Diamond MT's quality manual ensures every employee is focused on continuous improvement and service excellence. Our ESD safe facilities stretch over 12,000 square feet dedicated to your conformal coating requirements. We are continually researching and updating our equipment to make sure we are providing the best ESD protection available.

All employees have been trained in proper ESD procedures. We operate at a class 3 level to ensure the job is done right the first time and to the highest quality standards set forth in accordance with the MIL-STDs, IPC, J-STDs as well as having our biomedical and ITAR certification. Furthermore, all assemblies are tracked through every step of the process with documentation/serialization spreadsheets as well as each assembly going through a 100% visual inspection.

Diamond MT has a strong organization consisting of highly motivated personnel, modern facilities, and diverse capabilities. Diamond MT represents one of the most modern, well-equipped facilities in the region. Diamond MT offers a highly skilled workforce, rapid turnaround manufacturing and high reliability through an established quality program, along with experience of commercial manufacturing requirements, competitive pricing and on-time delivery.

Rapid Turnaround: Diamond MT understands that oftentimes conformal coating is overlooked because it's the last step in the process. We are committed to serving the industry with rapid turn times for parylene, (normally 10 business days) with expedited service in as little as 2-5 business days depending upon the complexity and quantity.

For liquid coatings, our normal turnaround time is five business days; again with expedited service in as little as 2-3 business day turns. We understand that there are times you'll need a project completed FASTER. We will accommodate your needs in a budget friendly manner. This service is offered on a FIFO basis.

To learn more about Diamond MT, please contact us today!

Diamond MT
213 Chestnut Street
Johnstown, PA 15906
Phone: (814) 535-3505
Fax: (814) 535-2080