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George C. Marshall Space Flight Center

Marshall Space Flight Center, Alabama 35812

ES42

MSFC TECHNICAL STANDARD

PROCESS SPECIFICATION FOR ELECTRICAL BONDING

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DOCUMENT HISTORY LOG

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1.0 INTRODUCTION

1.1 Scope

This document establishes criteria for the processes involved in electrical bonding of semi-permanent, metal-to-metal joints (joints held together by bolts, rivets, clamps, etc.) and indirect bonds for equipment and elements manufactured at the Marshall Space Flight Center (MSFC).

There are two types of electrical bonds: direct and indirect. Direct bonds are metal-to-metal joints provided by welding, riveting or bolting. Indirect bonds are connected through a strap or jumper. Joints formed by welding, brazing or sweating are inherently bonded provided that proper procedures are followed to ensure no impurities or imperfections are incorporated in the joint.

1.2 Purpose

This document has two purposes:

1. To provide a minimum set of process control requirements to be used in implementing electrical bonds.
2. To provide a specification for callout on mechanical drawings.

1.3 Applicability

This document applies to in-house and contract activities and should be cited in program and contract documents as a technical requirement. All prime contractors and subcontractors performing activities to the requirements of this document shall be on-site audited and approved by NASA as to their quality management system and process controls as specified herein. Individual provisions of this document may be tailored based on application specific experience and sufficient technical rationale. This document may be cited by other NASA centers or Industry.

This document is applicable to all new, used, or repaired flight hardware that is within its scope.

2.0 APPLICABLE DOCUMENTS

The following documents are called out as an extension of the requirements given in this specification:

DOCUMENT NO.	TITLE
NASA-STD-4003	Electrical Bonding for NASA Launch Vehicles, Spacecraft, Payloads, and Flight Equipment

NASA-STD-6016	Standard Materials and Processes Requirements for Spacecraft
MIL-C-81302	Cleaning Compound, Solvent, Trichlorotrifluoroethane
MWI 3410.1	Personnel Certification Program

2.1 Reference Documents

The following documents are cited as references to guide the user in the application of this specification.

DOCUMENT NO.	TITLE
EPA SNAP list	U.S. EPA's Significant New Alternatives Policy (SNAP) Program
SAE-AMS-S-8802	Sealing Compound, Temperature Resistant, Integral Fuel Tanks and Fuel Cell Cavities, High Adhesion
SAE-AMS3276	Sealing Compound, Integral Fuel Tanks and General Purpose, Intermittent Use to 360 Deg. F (182 Deg. C)
SAE-AMS3277	Sealing Compound, Polythioether Rubber, Fast Curing Integral Fuel Tanks and General Purpose, Intermittent Use to 400 Mdf (204Mdc)
MIL-S-81733	Sealing and Coating Compound, Corrosion Inhibitive
MSFC-SPEC-164	Cleanliness of Components for Use in Oxygen, Fuel, and Pneumatic Systems, Specification for
MIL-PRF-16173	Performance Specification Corrosion Preventive Compound, Solvent Cutback, Cold-Application

3.0 REQUIREMENTS

3.1 Manufacturing Facility

The manufacturing facility should include as a minimum the following resources:

a. Adequate lighting and a temperature/humidity controlled ventilation system.
b. Adequate space for safe operation of cleaning and corrosion control equipment.
c. Operating instructions for each piece of equipment.
d. All hazardous Material Safety Data Sheets (MSDS) for materials used.
e. Safety equipment and protective personal equipment as required by local, state, and federal ordinances.

f. Personnel trained in the recognition of corrosion.
g. Personnel trained in the safe and proper operation of support equipment.
h. Quality assurance inspectors trained in the operational characteristics and restrictions of each piece of support equipment.

3.2 Materials and Equipment

Materials used in the electrical bonding process shall meet the requirements of NASA-STD-6016. In some cases, special consideration may be required to resolve situations where material selection criteria conflicts with electrical bonding requirements. Deviations from the requirements in NASA-STD-6016 associated with electrical bonding shall be approved by the NASA program/project authority with technical inputs from the responsible Materials and Processes (M&P) and Electromagnetic Environmental Effects (E3) organizations. Specific/special tools, equipment, and materials shall be documented in the detailed process instructions for implementing this process specification.

3.3 Process Flow

The electrical bonding process is not unique, but imposes constraints on processes that are already in place to prepare metallic surfaces for assembly such as material selection, cleaning, and finishing. Figure 1 is a flow diagram of the processes and procedures to achieve an electrical bond.

Pre-process Conditions:

A. Unless otherwise specified, all fabrication operations, including cutting, bending, welding, thermal treatments and cleaning, have been completed prior to application of any surface treatment, metallic coating, and/or non–metallic coating.
B. Engineering drawings are available that identify:

1. Direct bonds:
    a) Areas to be bonded
    b) Class of bond
    c) Type of materials
    d) Type of sealant, if required
    e) Fastener type, number, and torque
2. Indirect bonds:
    a) Strap type and dimensions
    b) Location of strap
    c) Fastener type, number, and torque

3.4 Surface Preparation

Both direct and indirect bonding connections require metal-to-metal contact of bare surfaces or surfaces with a qualified conductive finish. Bonding surfaces shall be masked off to prevent contamination prior to applying a nonconductive protective finish to nearby areas. Alternatively, the nonconductive finish shall be removed from the bonding area to provide a satisfactory bond. Removal of conductive coatings or finishes is not required. The area cleaned for bonding should be slightly larger than the area to be bonded. Ridges of paint around the periphery of the bonding area can prevent good metal-to-metal contact. Washers or fittings shall fit inside the cleaned area. Immediately prior to bonding, all chips, paint, grease, or other non-conductive matter shall be removed with a proper cleaning solution. The final selection of protective surface treatments (conductive coatings, plating, paints, sealants, cleaning agents, etc.) should be reviewed by the M&P and E3 organizations for concurrence.

3.4.1 Cleaning

Unless otherwise specified on the engineering drawing, the minimum cleanliness levels for electrical bonding faying surfaces shall be Class V, visually clean/no silting, per MSFC-SPEC-164. Bare, clean, metal-to-metal contact will ensure a low-impedance connection between mating surfaces. Most, if not all, faying surfaces will have undergone pre-cleaning and precision cleaning as part of the fabrication process. Faying surfaces shall be inspected and cleaned as necessary prior to final assembly. Cleaning processes chosen by the user shall be approved by the NASA procuring activity prior to cleaning and handling. If the service is NASA-to-NASA then approval of the cleaning and handling process shall be obtained from the hardware owner or the owner's organization. All cleaning processes used in preparation of electrical bonding faying surfaces shall be documented at a level of detail that ensures the process is repeatable.

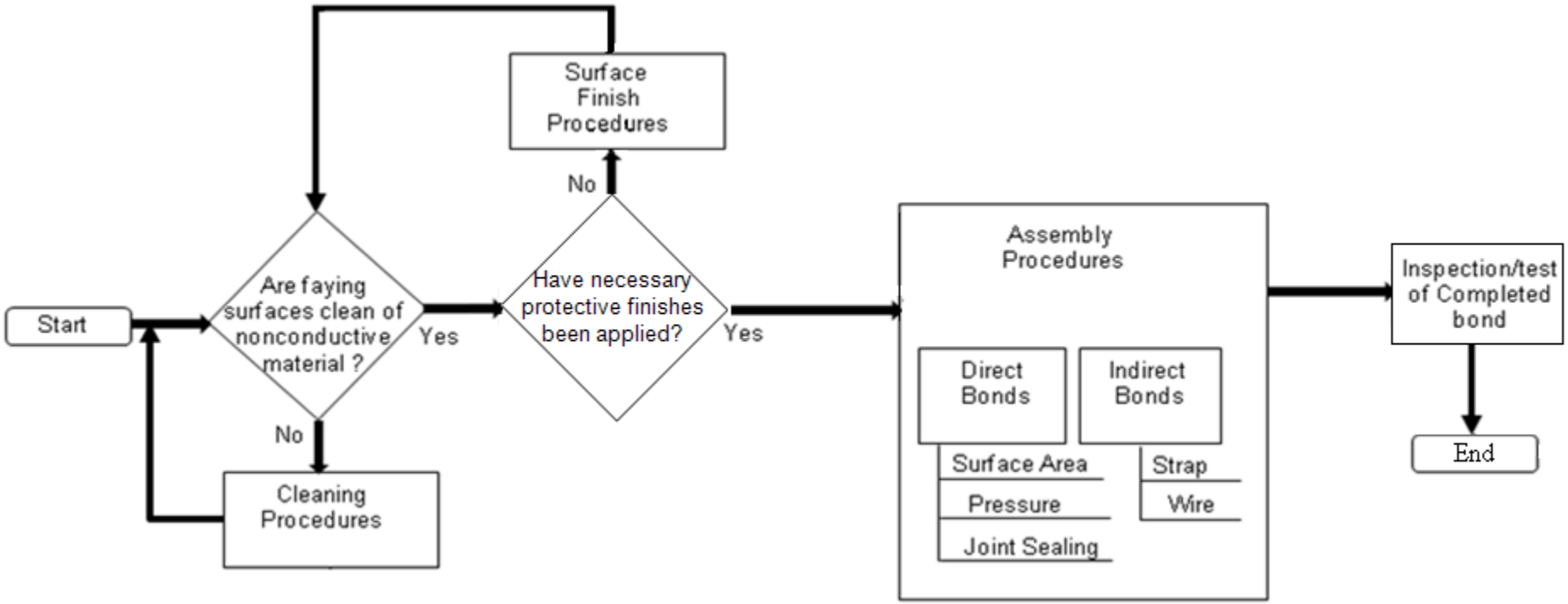

FIGURE 1. Electrical Bonding Process Flow

3.4.1.1 Cleaning Method Selection Criteria

Cleaning materials are chosen on the basis of the effectiveness of contaminant removal, inertness to substrate material, and environmental compatibility. Cleaning methods or solutions used shall not adversely affect the functioning of the part or attack the bond joint materials. The mildest cleaning method that will accomplish the task should be selected. The Environmental Protection Agency Significant New Alternatives Policy (EPA SNAP) list should be consulted for a list of environmentally acceptable cleaning materials.

Note: NASA-STD-6016 prohibits the use of chlorinated solvents to clean titanium.

3.4.2 Protective Finishes

Many metals are plated or coated with other metals or are treated to produce surface films to achieve improved wearability or provide corrosion resistance. Metal platings such as gold, silver, nickel, and tin, shall have all foreign solid materials removed by brushing or scraping and all organic materials removed with an appropriate solvent. Since such platings are usually very thin, acids and other strong etchants should not be used. Once the foreign substances are removed, the bond surfaces should be burnished to a bright, shiny condition with an appropriate abrasive for the finish. Care should be exercised to ensure that excessive metal is not removed and the finish is not contaminated. Finally, the surfaces should be wiped with a cloth dampened in a denatured alcohol or dry cleaning solvent and allowed to dry before completing the bond. Coatings that offer low resistance as well as provide corrosion protection should not be removed. Coatings or finishes that are insulative shall ~~either~~ not be applied to the bonding area or shall be removed from the bonding area prior to assembly.

3.4.3 Refinishing

Sometimes nonconductive finishes are removed incidentally to prepare a bonding surface. Prior to refinishing the surface with the same nonconductive finish that was removed, the area shall be inspected. Surfaces shall be refinished within 24 hours after they are inspected. In no case shall inspection be delayed more than 6 days after removal of the finish. Excessively thinned paint should be avoided; otherwise, the paint may seep under the edges of the bonded components and impair the quality of the connection. Gold, nickel, chromium, rhodium, tin-lead alloys or sufficiently thick platings of these metals are satisfactory without additional protection or treatment other than buffing or cleaning.

3.5 Bond Jumpers or Straps

Bonding jumpers should be made as short as practicable. The jumper should not interfere with equipment operation, and conversely, equipment operation should not result in damage to the bonding jumper. Basically, the interface between the lug on the bonding jumper or strap and the

mating surface shall meet the same requirements as for direct bonding interfaces. It is preferable to not use a washer under the fastener head for securing the lug of the bonding jumper or strap. When a washer must be used in order to have a good mechanical joint, the material of the washer shall be chosen to prevent galvanic corrosion to the greatest extent possible. When a galvanic couple still exists, the entire joint should be sealed against the entrance of moisture as defined in Section 3.6.

3.6 Completion of the Bond

After cleaning of the mating surfaces, the bond members should be assembled or attached within 30 minutes if possible. If delays beyond 2 hours are necessary between cleaning and assembly in a corrosive environment, a temporary protective coating, such as MIL-PRF-16173, grade 4 or other approved sealant, shall be applied. This coating shall be removed before completing the bond. Cleaned and treated surfaces should not be handled by the bare hand. The bond surfaces shall be kept dry before assembly and, when called for on the engineering drawings, the completed bond shall be sealed against the entrance of moisture into the mating region. Various conductive compounds and paints may serve as acceptable sealants, such as those conforming to SAE-AMS-S-8802, SAE-AMS3276, SAE-AMS3277, or MIL-S-81733. Nothing in this specification should be interpreted as preventing implementation of advancing technology or use of state-of-the-art materials.

4.0 VERIFICATION

4.1 Process Qualification

Electrical bonding procedures shall be qualified prior to acceptance of bond installations on production parts. Qualification shall consist of documented evidence that the procedures are capable of meeting all the requirements of this specification and NASA-STD-4003.

4.2 Product Acceptance

Acceptance of electrical bond installations shall be based upon evidence of compliance with the procedures used for qualification and with requirements of the Engineering Drawing.

4.3 Inspection

An in-progress inspection shall be conducted at each step in the process to check installation procedures, methods, and materials to determine compliance with requirements. After the completion of each bond, a final inspection shall be made. This inspection shall be in accordance with approved procedures to determine that all requirements of this specification and NASA-

STD-4003 have been met. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspections, prior to delivery. For MSFC contracts, the supplier may utilize his own facilities or any other commercial laboratory acceptable to MSFC. The MSFC reserves the right to perform any of the inspections deemed necessary to assure supplies and services conform to prescribed requirements.

4.4 Tests

A limited number of resistance measurements, made as partial proof of satisfactory bonding, shall be conducted on at least two bonds of each type. Spot checks shall be made to verify the process and workmanship are still acceptable. Testing of every bond is neither required nor desirable unless specifically noted by the procuring agency. The electrical bond measurements shall be performed using a four-terminal micro-ohm resistance meter. Bonding measurements often require the protective finish to be penetrated with the ohmmeter's electrical probes in order to obtain good electrical contact. Care should be taken so that a corrosion problem is not introduced by surface scars created during the measurement.

Caution: Do not perform electrical bond checks in a hazardous atmosphere. Meter probes can produce sparks.

4.5 Records, Reports, and Forms

Standard manufacturing records, reports and forms shall be used. Records shall be maintained to provide evidence that all production and inspection/verification operations have been completed as planned, or as otherwise documented and authorized.

4.6 Personnel Training and Certification

Personnel performing electrical bonding shall be qualified through training or experience and certified, as required by MWI 3410.1, to perform the task or operation required to conduct the process.

5.0 PACKAGING

The requirements of Section 5 are not applicable to this specification.

6.0 NOTES

6.1 Implementation

When using this document as a technical requirement, engineering drawings shall identify the surfaces to be bonded, the Class of bond, and the allowed dc resistance per NASA-STD-4003.

The following are examples of electrical bonding notes on engineering drawings:

THE RESISTANCE ACROSS THIS JOINT SHALL BE LESS THAN XX OHMS TO MEET THE ELECTRICAL BOND REQUIREMENTS OF NASA-STD-4003, CLASS X.

THE BOND RESISTANCE BETWEEN FN XX AND FN YY SHALL BE LESS THAN ZZ MILLIOHMS TO MEET THE BOND REQUIREMENTS OF NASA-STD-4003, CLASS X.

This process specification shall be called out using the following drawing note:

PERFORM SURFACE PREPARATION AND JOINING IN ACCORDANCE WITH MSFC-SPEC-3659.

6.2 Safety Precautions and Warning Notes

Appropriate safety precautions shall be documented in the detailed process instructions for implementing this process specification.

APPENDIX A

DEFINITIONS AND ACRONYMS

DEFINITIONS

Aqueous - Made from, with, or by water.

Bond Classifications per NASA-STD-4003:

CLASS "C" – for intentional current return through structure
CLASS "H" – for fault current return and protection against fire and shock hazards
CLASS "L" – for protection against lightning effects
CLASS "R" – for protection against and to prevent radio frequency emissions
CLASS "S" – for dissipation of electrostatic charge

Electrical Bonding - Electrical bonding is the process for joining two or more pieces of material together in order to create a path exhibiting low electrical impedance.

Cleaned Surface - A surface from which all materials, oxides, films, oils and greases, that could cause corrosion or electrical resistance greater than specified limits, have been removed.

Faying Surface - The surface of a material that is or will be joined with another.

Impedance - The total opposition that a circuit offers to the flow of time varying current at a particular frequency. For electrical bonding, the primary concern is with minimizing impedance in the form of resistance and inductance in the bond path.

ACRONYMS

dc	Direct Current
E3	Electromagnetic Environmental Effects
EPA	Environmental Protection Agency
M&P	Materials and Processes
MIL	Military
MSDS	Material Safety Data Sheets
MSFC	Marshall Space Flight Center
S&MA	Safety and Mission Assurance
SAE	Society of Automotive Engineers
SNAP	Significant New Alternatives Policy
SPEC	Specification
STD	Standard