ELECTRICAL BONDING - MAINTENANCE PRACTICES

1. General

A. This section describes airplane electrical bonding requirements and procedures. The following procedures and specification MIL-STD-464 - Electromagnetic Environmental Effects Requirements for Systems, govern installation and testing of electrical bonds and ground returns.

B. Some electrical bonding requirements for static discharge wicks are shown in Figure 214 in this section. Refer to Chapter 23, Static Discharging - Maintenance Practices for more required static discharging procedures.

C. Poor electrical bonding can cause or contribute to a variety of operational problems in electrical, avionics, and communication systems, such as complete failure, reduced performance, or electromagnetic interference (EMI), or radio frequency interference (RFI) with navigation and communication systems.

D. Maintenance personnel must follow recommended practices for establishing, remaking, testing, and protecting electrical bonds, particularly during routine maintenance activities.

NOTE: If a component is moved or the bond of an installed component is otherwise broken, the resistance of the connection must be verified again after installation.

(1) Removal and installation of avionics and electrical equipment and mounting trays.

(2) Assembly and reassembly of supporting structure for avionics or electrical equipment.

(3) Reinstallation of control surfaces and removable fairings (including radome and stinger).

2. Definitions

A. In this section, the applicable definitions are as follows:

(1) Method A (nonconductive) bonding is the usual method to seal the surfaces. This is done by cleaning a surface area that is larger than the connector that will be installed. A fillet seal of nonconductive sealant is then applied on and around the connector and the metal bonding surface. To make sure that the finish is nonconductive, it is necessary that you use a micro-ohmmeter to do an electrical bonding test.

(a) The cleaned area must be between 0.063 inch (1.59 mm) and 0.250 inch (6.35 mm) more than the connector.

(b) The sealant must not be applied on screws, rivets, or other mounting hardware.

(2) Method B (conductive) bonding is a different method to seal the surfaces. This is done by cleaning a surface area that is smaller than the connector that will be installed. A fay seal of conductive sealant is then applied between the connector and the metal bonding surface.

(a) The cleaned area must not be more than, and not less than, the diameter of the contact area.

(b) The sealant must be applied between the connector and the bonding surface.

(c) The sealant on and around the bonding must then be removed (cleaned).

(3) Bond (Electrical) - A fixed union existing between two objects that provides good electrical conductivity due to a low-resistance path between the objects.

(4) Bonding (Electrical) - The process of making the necessary connections to provide good electrical conductivity between units or between unit and airplane ground.

(5) Ground - The common connection of the electrical circuits of a system or subsystem to a conductive medium (airplane primary structure) that becomes a common reference plane for all voltage potentials in the airplane.

(6) Grounding - The process of making the necessary connection(s) to provide a ground for an electrical, electronic, or radio frequency circuit.

(7) Primary structure - Load carrying members of the airframe, such as bulkheads, ribs, webs, and stringers, extending through two or more bulkheads or ribs. All primary structure is considered to be airplane ground.

(8) Secondary structure - Sheet metal or extruded metal parts attached to primary structure (or to secondary structure that is ultimately attached to primary structure) in at least two places by structural fasteners or by three or more rivets on each location.

3. Hardware and Material Usage

A. The hardware and materials that are recommended to be used and those that are not to be used for electrical bonding are shown in the tables that follow:

Table 201. Cleaning Material

Aluminum Wool
Sandpaper
Stainless Steel Wool
Aluminum Oxide Cloth, High Purity
Bonding Rotary Brush
P-D-680 Solvent

Table 202. Bolts, Nuts, and Screws

Cadmium Plated Steel	Recommended for all areas other than engine compartment and fuel system.
Corrosion Resistant Steel	Recommended for engine compartment and fuel system.
Aluminum	Recommended for all areas other than engine compartment.
Self-Tapping Screws	Not to be used for bonding application.
Zinc Plated Screws	Not to be used for bonding application.
Spring, Self-Locking, Clip-in Instrument Mounting Nut	Not to be used for bonding application.
Wing Nuts	Not to be used for bonding application.

Table 203. Washers

Anodized	Not to be used for bonding application.
Zinc Plated	Not to be used for bonding application.
Unplated	Not to be used for bonding application.
NAS1149, MS35337, MS35339	Recommended for bonding in all areas.
Tooth Lock Washer	Not to be used for bonding application.

Table 204. Bonding Jumpers

MS25083	Recommended for bonding in all areas, other than fuel tanks.
On Aluminum Alloys	Use aluminum or MS25083 tinned copper jumpers.
On Steel Alloys	Use MS25083 copper, brass or bronze tinned coated jumpers only.
In Fuel System	Use S2876 aluminum only.

Table 205. Clamps

AN735	Recommended for bonding in all areas.
Cushion Clamps	Not to be used for bonding applications.
AN742	Not to be used for bonding applications.

Table 206. Nutplates

Cadmium and Silver Plated (Floating or Nonfloating)	Recommended for direct bonding applications.
Nonmetallic Insert, Dry Film Lube-Type	Not to be used for direct bonding applications.

Table 207. Low-Resistance Test Set (Bonding Meter)

Keithley Model 580 Micro-Ohmmeter (or Equivalent)	Keithley Instruments, Inc. Instrument Division 28775 Aurora Road Cleveland, OH 44139
Megohmmeter Model 2850 (or Equivalent)	Associated Research, Inc. 3773 West Belmont Ave. Chicago, IL 60618

Table 208. Permanent Ground Studs

VNS1924CA3-1-8	Recommended for permanent ground bonding in all areas.

Table 209. Permanent Ground Stud Pulling Head Adapter

VST1116-10 VST1116-8	Voi-Shan 8463 Higuera Street Culver City, CA 90232-0512

4. Bonding Surface Cleaning

NOTE: If you can bond through the fasteners, it is recommended that you use Method B to install static wicks. If you cannot bond through the fasteners, it is necessary that you use Method B to install static wicks.

NOTE: Bonds between two metal surfaces and bonding jumper attachment points must be free of insulating material, such as paint, primer, grease, oil, and materials that prevent corrosion. A clean area is needed to make sure there is an adequate bond and to help get resistance measurements. The cleaned surface must be a clean and smooth finish that has not had too much material removed under the protective finish.

A. Method A (nonconductive) Surface Cleaning

(1) Clean the bonding surface area that is larger than the connector to be installed.

(a) Make sure that the cleaned area is between 0.063 inch (1.59 mm) and 0.250 inch (6.35 mm) more than the connector.

B. Method B (Conductive) Surface Cleaning

(1) Clean the bonding surface area that is smaller than the connector to be installed.

(2) A fay seal of conductive Type XV, Class B sealant is then applied between the metal surfaces.

C. Method A Steel and Aluminum Surface Cleaning

(1) Use medium Roloc surface condition disc pads (Scotchbrite) or medium EXL wheel 6A (Scotchbrite) that is no more than 0.50 inch (12.7 mm) larger than the diameter of the bonding surface of the connector.

NOTE: You are permitted to use 400 through 600 grit emery paper or cloth, or an equivalent fine sandpaper and/or aluminum oxide paper or cloth, stainless steel wool, or a stainless steel or monel bonding brush.

NOTE: You can use aluminum wool only on aluminum.

(2) Use IPA, MPK, or equivalent to clean the bonding surfaces.

(3) To clean aluminum that is not for a bonding jumper, make sure that the bonding surface is between 0.50 inch (12.7 mm) and 0.250 inch (6.35 mm) more than the connector.

NOTE: If the cleaned area is more than 0.50 inch (12.7 mm) more than the connector, you must apply primer, let it dry, then clean it again.

(4) To attach a bonding jumper, clean the bonding surface area to 150 percent of the diameter of the bonding jumper terminal.

(5) For bare aluminum, before an electrical bond is made, apply a chemical film treatment to the bonding surface.

NOTE: This will give the bond electrical and some corrosion protection.

D. Method B Steel and Aluminum Surface Cleaning

(1) Use medium Roloc surface condition disc pads (Scotchbrite) or medium EXL wheel 6A (Scotchbrite) that is no larger than the diameter of the bonding surface of the connector.

NOTE: You are permitted to use 400 through 600 grit emery paper or cloth, or an equivalent fine sandpaper and/or aluminum oxide paper or cloth, stainless steel wool, or a stainless steel or monel bonding brush.

NOTE: You can use aluminum wool only on aluminum.

(2) Use IPA, MPK, or equivalent to clean the bonding surfaces.

(3) To clean aluminum that is not for a bonding jumper, make sure that the bonding surface is no larger than the diameter, but no smaller than 50 percent of the bonding surface of the connector.

NOTE: If the cleaned area is larger than the diameter of the bonding surface, the surface must be primed, dried, then cleaned again.

(4) For bare aluminum, before an electrical bond is made, apply a chemical film treatment to the bonding surface.

NOTE: This will give the bond electrical and some corrosion protection.

E. Method A Magnesium Surface Cleaning

CAUTION: Do not use steel wool, stainless steel wool, or aluminum wool to clean magnesium alloys.

(1) Use medium Roloc surface condition disc pads (Scotchbrite) or medium EXL wheel 6A (Scotchbrite) that is no larger and no smaller than the diameter of the bonding surface of the connector.

NOTE: You are permitted to use 400 through 600 grit emery paper or cloth, or an equivalent fine sandpaper.

(2) Use IPA, MPK, or equivalent to clean the bonding surfaces.

F. Method B Magnesium Surface Cleaning

CAUTION: Do not use steel wool, stainless steel wool, or aluminum wool to clean magnesium alloys.

(1) Use medium Roloc surface condition disc pads (Scotchbrite) or medium EXL wheel 6A (Scotchbrite) that is no larger and no smaller than the diameter of the bonding surface of the connector.

NOTE: You are permitted to use 400 through 600 grit emery paper or cloth, or an equivalent fine sandpaper.

(2) Use IPA, MPK, or equivalent to clean the bonding surfaces.

5. Protective Coating Sealing

NOTE: Although you must apply a corrosion inhibitor to seal the perimeter of some electrical bonds after they are assembled, some electrical bonds must have a finish applied before you can apply the corrosion inhibitor.

NOTE: Method A (nonconductive) Sealing is done after the electrical bond is assembled. To make sure that the finish is nonconductive, it is necessary that you use a micro-ohmmeter to do an electrical bonding test.

NOTE: Method B (conductive) Sealing is done during the electrical bond assembly.

A. All bonded surfaces requiring protective coating must be refinished per the original finish or color chemical film treated within as short a time as possible. Refinishing within a 24-hour period is highly recommended.

B. Sealant as Protective Coatings

(1) Do not use sealants as a protective coating on bulkhead electrical connectors in the pressure vessel (unless required for pressure seal).

(2) Do not apply sealants to equipment racks and equipment mounting surfaces.

(3) Do not apply sealants to stud-type ground blocks.

(4) Do not use sealants as a protective coating to feed-thru plates (unless required for the pressure seal).

NOTE: In areas where the surface already has chemical film applied, such as feed-thru plates on pressure bulkheads, it is not required to remove this finish and reapply chemical film to achieve bonding unless the bonding requirements cannot be met.

NOTE: A cleaned area must not be refinished until the electrical bond connection has been inspected and approved.

NOTE: Bonding jumpers do not need painting.

C. Method A (Nonconductive) Sealing

WARNING: Do not use conductive sealant in fuel tanks. Use only nonconductive sealants that are approved for use in fuel tanks. The metal material in the conductive sealant can create a spark (arcing) in the fuel tank.

NOTE: For Method A sealing, it is recommended that you use corrosion-inhibitive polysulfide-based sealant.

NOTE: If you can bond through the fasteners, it is recommended that you use Method B to install static wicks. If you cannot bond through the fasteners, it is necessary that you use Method B to install static wicks.

(1) Method A sealing is applicable to use in the areas that follow:

- Feed-thru connectors out of the pressure vessels
- All electrical bonding in the fuel tanks
- Surface-mounted ground blocks where the fayed surface must be removed for electrical bonding
- Ground studs out of the pressurized area
- Bonding jumpers and straps out of the pressurized area

(2) For Method A sealing, you can use one of the sealants that follow:

- Type X, Class B sealant (for all but in fuel tank areas)
- Type I, Class B sealant (Polysulfide based fuel, weather, and pressure sealant)
- Type V, Class A sealant (RTV silicone sealant)
- Type V, Class B sealant (RTV silicone sealant)

(3) Apply a fillet seal on and around the connector and the metal bonding surface.

(a) To make sure that the finish is nonconductive, it is necessary that you use a micro-ohmmeter to do an electrical bonding test.

(b) Do not apply sealant on screws, rivets, or other mounting hardware.

(c) Make sure that the sealant is applied between 0.063 and 0.125 inch (1.6 and 3.2 mm) larger than the cleaned area.

D. Method B (Conductive) Sealing

WARNING: Do not use conductive sealant in fuel tanks. Use only nonconductive sealants that are approved for use in fuel tanks. The metal material in the conductive sealant can create a spark (arcing) in the fuel tank.

NOTE: For Method B sealing, you must use corrosion-inhibitive polysulfide-based sealant.

NOTE: If you can bond through the fasteners, it is recommended that you use Method B to install static wicks. If you cannot bond through the fasteners, it is necessary that you use Method B to install static wicks.

(1) Method B sealing is applicable to use in the areas that follow:

- Feed-thru connectors out of the pressure vessels
- Surface-mounted ground blocks where the fayed surface must be removed for electrical bonding
- Ground studs out of the pressurized area
- Bonding jumpers and straps out of the pressurized area

(2) Use Type XV, Class B conductive sealant to apply a fillet seal on and around the bonding surface and the connector.

(a) Do not use this sealant in fuel tank areas.

(b) Make sure that the area of the sealant is no larger than the bonding surface of the connector.

(c) Clean all sealant off of the area that is more than permitted.

6. Electrical Bonding Test

A. Electrical Bonding Criteria

(1) Bonding to primary structure (grounding) - Do this type of bonding only after the resistance between the bonded object and primary structure has been measured with a low-resistance test set (bonding meter) and found to be no more than the maximum allowable resistance for that application. For typical resistance values, refer to Table 210.

NOTE: In many cases the object to be grounded is mounted on or attached to secondary structure, or otherwise separated from direct contact with primary structure. Grounding depends on both the satisfactory bonding of the mounting tray to secondary structure, and of the secondary structure to primary structure. The electrical bonding test is then done to measure resistance across each bond to identify the source(s) of poor grounding.

(2) Bonding one object to another - This type of bonding must be considered satisfactory only after the resistance between the objects has been measured with a bonding meter and found to be no more than the maximum allowable resistance for that application.

B. Using a Low-Resistance Test Set (Bonding Meter)

(1) Follow manufacturers instructions included with test set for setup, operation, and reading of test set display.

(2) Place or connect the probes on bare metal surfaces.

(3) The probes should be placed as close as possible to the bonding area, preferably within six inches along surface of the object or structural member.

(4) If it is necessary to remove paint or primer from a surface in order to provide good probe contact, apply the original (or equivalent) finish after an electrical bonding test.

NOTE: To make sure that the finish is nonconductive, it is necessary that you use a micro-ohmmeter to do an electrical bonding test.

C. Electrical Bonding Test of Composite Panels

(1) Leave out or remove one screw per 4 lineal feet of panel edge.

(2) Make sure that countersink is free of paint or other insulating material.

(3) Do the electrical bonding test between countersink(s) and primary structure.

7. Electrical Bond Type (Class)

A. Electrical Bond Classes

NOTE: The classes of electrical bonds are given in accordance to the type of material that is bonded together and the method used to bond the materials.

(1) Type I usually applies to metallic components bonded together with direct metal to metal contact. Some examples are riveted skin bonds, equipment racks, and bulkhead connectors. These components will have a requirement of less than 0.0025 ohm maximum.

(2) Type II usually applies to aluminum or steel components (i.e., landing gear, doors, and/or airplane structure) bonded together electrically by bonding jumpers, but can also be used when applied to bonds with multiple metal to metal contacts, such as, radome diverter strips to airplane structure or antennas mounted on metal fairings to the airplane structure with a requirement of less than 0.005 ohms.

(3) Type III usually applies to adhesively bonded aluminum components bonded together electrically by bonding jumpers with a requirement of less than 0.005 ohms.

(4) Type IV usually applies to connections between expanded aluminum mesh (or similar material) and the airframe through bonding jumpers and clips with a requirement of less than 0.005 ohms.

(5) Type V usually applies to connections between conductive composite structure, such as, Carbon Fiber Composite (Graphite), and its metallic attachment hardware with a requirement of less than 0.005 ohms.

(6) Type VI usually applies to connections for P-static protection between composite materials and metallic airplane structure with a requirement of less than 100,000 ohms.

(7) Type VI-A usually applies to connections for P-static protection between P-static paint and a high-resistive, low-conductive gasket used in nonconductive fuel doors and the airplane structure with a requirement of less than 10,000,000 ohms

(8) Type VII usually applies to connections for P-static protection between nonconductive materials used in radomes or electrically-heated windshields and their metallic attachment hardware and/or airplane structure with a requirement of 1,000,000 ohms, but not more than 100,000,000 ohms.

(9) Type VIII usually applies to connections for low conductive gaskets and metallic airplane structure with a requirement of 1,000,000 ohms or greater.

(10) Type IX usually applies to connections for hydraulic and fuel lines and tubes, metallic tubing, seat frames

(nonelectrical components) and electrical switches, circuit breakers, and ducts bonded to the airplane structure by different means, such as, clamps or attachment screws. Because this type includes many different installations, the maximum permitted resistance value can be different from one installation to another. These differences are specified in Table 210.

(11) Type X usually applies to connections for different fuel system hardware, such as, fuel filler nozzle, fuel vents, and fuel gages. Because this type includes many different installations, the maximum permitted resistance value can be different from one installation to another. These differences are specified in Table 210.

(12) Type XI usually applies to connections for flaps, slats, piano hinged surfaces, and roller bearing surfaces. This type includes several different installations. The maximum permitted resistance will be different from one installation to another. These differences are specified in Table 210.

(13) Type XII usually applies to return-path grounds. This is for ground studs installed in metal airplane structures. Refer to Table 210.

Table 210. Typical Resistance Values

OBJECT TO BE BONDED	METHOD OF BONDING	MAXIMUM ALLOWABLE RESISTANCE VALUE (Ohms)	BOND TYPE (CLASS)
All electrical and electronic equipment ground return bonds to basic structure	Direct metal case to structure	0.0025	I
		0.005	II
Antenna base	Metal base to metal fuselage through fasteners	0.0025	I
	Metal base to metal screen or expanded metal	0.05	IV
	Metal base to composite fairing through fasteners	0.5	V
Battery box to basic structure	Direct metal case to structure	0.0025	I
Bulkhead feed-thru connectors	Metal to metal	0.0025	I
Cable bundle shields	Direct attachment to connector backshell	0.0025	I
Electric trim (actuator assembly)	Direct metal to metal	0.0025	I
Electrical devices to enclosure	Direct attachment through attachment hardware or bonding jumper	0.0025	I
Electrical motors to adjacent structure	Direct metal to metal	0.0025	I
Engine to nacelle structure bond	Direct attachment by fasteners (metal nacelle)	0.0025	I
Honeycomb panel assemblies	Direct metal to metal attachment by fasteners	0.0025	I
Instrument panels to stationary panel	Direct metal to metal attachment by fasteners	0.0025	I
Instruments	Direct metal to metal	0.0025	I
Radio racks, shelves and brackets to adjacent primary structure	Direct metal to metal	0.0025	I
Radome external diverter strips	Attachment to radome frame	0.0025	I

RFI noise filters (across joint)	Direct metal to metal	0.0025	I
Rivet skin joints and breaks (across joint) or structural joints or breaks (across joint)	Direct metal to metal	0.0025	I
Servos amplifier, gaging equipment instruments, etc.	Direct metal to metal	0.0025	I
Side console and electrical equipment panels to basic structure	Direct metal to metal by fasteners	0.0025	I
Starters, generator and alternator grounds (case to engine frame)	Direct metal case to structure	0.0025	I
Static wicks (metal surface)	Direct metal to metal attachment by fasteners	0.0025	I
Stationary instrument panels to primary structure	Direct metal to metal by fasteners	0.0025	I
Structural joints or breaks (across joint)	Direct metal to metal	0.0025	I
Wing tie down and ground point	Attachment through fasteners	0.0025	I
Wing to fuselage	Direct metal to metal or attachment bolts	0.0025	I
Wire Bundle Shields	Direct attachment to backshell	0.0025	I
		0.005	II
All electrical and electronic equipment ground return bonds to basic structure	Bonding jumper to structure	0.005	II
Baggage/Avionics compartment door	Bonding jumper across hinge	0.005	II
Battery box cover	Fastener to battery box	0.005	II
Bearings (roller and ball) Piano hinged surfaces	Bonding jumper	0.005	II
Cable bundle shields	Bonding jumper	0.005	II
Composite aileron	Bonding jumper across hinge or graphite structure or embedded metal screen/mesh to airplane structure	0.005	II
		0.5	V
		0.05	IV
Composite elevator	Bonding jumper across hinge or graphite structure or embedded metal screen/mesh to airplane structure	0.005	II
		0.5	V
		0.05	IV
Composite flap	Bonding jumper across actuator or roller/track (loaded configuration)	0.005	II
		0.5	XI
		0.5	V
Composite rudder	Bonding jumper across hinge or graphite structure or embedded metal screen/mesh to airplane structure	0.005	II
		0.5	V
		0.05	IV

Doors and Inspection plates	Fastener to airplane structure	0.005	II
Electric trim (actuator assembly)	Direct metal to metal or bonding jumper	0.0025	I
		0.005	II
Electrical devices to enclosure	Bonding jumper	0.005	II
Electrical motors to adjacent structure	Bonding jumper	0.0025	I
		0.005	II
Engine	Bonding jumper across mount	0.005	II
Honeycomb panel assemblies	Direct metal to metal attachment by fasteners or by bonding agent	0.0025	I
		0.005	II
Instruments	Bonding jumper	0.005	II
Landing gear	Bonding jumper	0.005	II
Landing gear doors	Bonding jumper across hinge	0.005	II
Metal aileron	Bonding jumper across hinge	0.005	II
Metal cowls - removable	Fastener to engine frame	0.005	II
Metal elevator	Bonding jumper across hinge	0.005	II
Metal flap	Bonding jumper across actuator or roller/track (loaded configuration)	0.005	II
		0.5	XI
Metal nacelle	Fastener to engine frame	0.005	II
Metal rudder	Bonding jumper across hinge	0.005	II
Nose wheel doors	Bonding jumper across hinge	0.005	II
Panel feed-thru plates	Direct metal to adhesively bonded honeycomb or bonding jumper	0.03	III
		0.005	II
Radome external diverter strips	Attachment to radome frame	0.005	II
Radome	Diverter strips through radome frame to airplane by attachment hardware	0.010	II (NOTE: This measurement involves multiple bond paths. Therefore, the allowable resistance value is twice standard Type II)

Servos amplifier, gaging equipment instruments, etc.	Bonding jumper	0.005	II
Spoiler	Bonding jumper across hinge or directly through hinge	0.005	II
Trim tab	Bonding jumper across hinge	0.005	II
Wire Bundle Shields	Bonding jumper to structure	0.005	II
Panel feed-thru plates	Direct metal to adhesively bonded honeycomb	0.03	III
Composite aileron	Embedded metal screen/mesh to airplane structure	0.05	IV
Composite elevator	Embedded metal screen/mesh to airplane structure	0.05	IV
Composite rudder	Embedded metal screen/mesh to airplane structure	0.05	IV
Antenna base	Metal base to composite fairing through fasteners	0.05	V
Composite aileron	Graphite composite to airplane structure	0.5	V
Composite cowls - removable	Fastener to engine frame	0.5	V
Composite elevator	Graphite composite to airplane structure	0.5	V
Composite flap	Graphite composite to airplane structure	0.5	V
Composite nacelle	Fastener to engine frame	0.5	V
Composite rudder	Graphite composite to airplane structure	0.5	V
Engine to nacelle structure bond	Direct attachment by fasteners (composite nacelle)	0.5	V
Static wicks (composite surface)	Direct metal to composite surface and attachment by fasteners	0.5	V
Control cables and rods to movable surfaces equipment	Bonding through attachment hardware	0.01	IX
Electrical switches, circuit breakers and potentiometer in circuits exceeding 50 volts	Direct attachment through hardware	0.10	IX
Hydraulic cylinders	Direct metal to metal or bonding jumper	0.01	IX
Metal ducts	Direct metal to metal and attachment anchors	0.005	IX

	Metal ducts (nonelectrical: rigid and flexible)	Bonding through clamp and attachment hardware	1.0	IX
	Metallic tubing	Cable runs which terminate in a direct metal to metal contact	1.0	IX
	Metallic tubing	Direct metal to metal	0.0025	I
	Metallic tube wiggins fittings	Feed-thru hardware and attachment anchors	0.1	IX
	Oil and Anti-Ice tank	Attachment through fasteners	0.1	IX
	Oxygen cylinders	Direct metal to metal or bonding jumper	0.01	IX
	Radiators and heat exchangers	Bonding through attachment hardware	0.01	IX
	Seat frame	Attachment through fasteners	0.01	IX
	Shock mounts	Direct metal to metal through attachment hardware	0.01	IX
	Fuel filler nozzle	Attachment through fasteners	0.005	X
	Fuel nozzle jumper ground receptacle	Attachment through fasteners	0.003	X
	Fuel vents scoops	Attachment through fasteners	0.005	X
	Bearings (roller and ball) Piano hinged surfaces	Metal to metal through bearing or hinge	0.01	XI
	Composite flap	Roller/track (loaded configuration)	0.5	XI
	Metal flap	Roller/track (loaded configuration)	0.5	XI
	Slats	Roller/track (loaded configuration)	0.5	XI
	Hoods and canopies	Not applicable	Not required	Not required
	Ground Studs	Base of the ground stud to the aircraft structure	0.0005	XII

8. Bonding Requirements

A. Current Path Return Bonds

(1) Current return bonds are those required to complete the ground return path to the battery and/or the power generator source for all electrical and avionics equipment. This type of bond is accomplished with a standard hook-up wire. The location of the ground bond connection should be to primary structure. In some cases where the equipment is internally case grounded, current return may be accomplished by direct bonding of the surfaces and through the mounting hardware.

(2) If the bonding surface resistance permitted in Table 210 cannot be met by direct surface bonding, then the equipment or component in question must be bonded by a bolted bonding jumper.

B. Radio Frequency and Static Bonds

(1) All electrical and electronic equipment and/or components should be installed in a manner to provide a continuous

low-impedance path from the equipment enclosure to airplane primary structure.

(2) All metallic pipes, tubes and hoses carrying fluids in motion should be bonded to basic structure.

(3) Table 210 includes equipment and areas of radio frequency and static bonds.

(4) All control surfaces should have a bonding jumper between the airframe and the control surface. Where necessary, additional jumpers should be used between the control surface and structure to achieve the resistance level. A piano-type hinge may be considered as self- bonded, provided the resistance across the hinge halves is satisfactory.

(5) All conducting items, such as metal lines and/or tubing carrying fluids or air in motion having a linear dimension of 24 inches or more and installed within one foot of unshielded transmitting antenna lead-ins should have a bond to structure. Refer to bonding of pipes and tubing.

C. Shock Hazard and Lightning Protection Bonds

(1) If the requirements of current path return bonds and radio frequency and static bonds have been successfully accomplished, then shock hazard and lightning protection bonds have been partially fulfilled.

(2) Shock hazard pertaining to exposed conducting frames or surfaces (such as elevators, flaps, trim tabs) or parts of electrical or electronic equipment must have a low- resistance bond to primary structure.

(3) Lightning protection is the bonding of cover assemblies, such as fuel fillers, fuel vents, pitot tubes, radome, plastic and fiberglass surfaces and control surfaces.

(4) Typical resistance values are shown in Table 210.

D. Bonding in Hazard Areas

(1) To eliminate any possible source of ignition in areas prone to explosion or fire hazards, do not add any new bonding installations in hazard areas.

NOTE: Current return grounds must be avoided in fuel vapor areas.

E. Bonding Verification

(1) For Type I through Type V, a small area of the protective finish must be removed or omitted to allow each probe to make electrical contact with the metallic or conductive composite surface. These test areas should be in close proximity to each other on adjacent sections of the airplane. On large panels it is recommended to do several tests approximately 4 feet (1.22 m) apart.

(2) Electrical bonding test for composite panels is to be performed at clean screw countersink to metallic structure.

NOTE: To make sure that the finish is nonconductive, it is necessary that you use a micro-ohmmeter to do an electrical bonding test.

NOTE: Upon completion of the electrical bonding test, the metallic surface must be refinished to protect from corrosion.

(3) For Type VI thru VIII the bond between antistatic paint and metallic attachment hardware is measured using a megohmmeter. A piece of metallic tape is placed directly on the antistatic paint approximately 1.0 inch (25.4 mm) away from attachment hardware. The measurement is accomplished by attaching one probe to the metallic tape and the other probe to the metallic hardware. The measurement should be made with the megohmmeter placed on the 500 volt setting.

F. Bonding Connection

(1) Bonding connections must be installed so vibration, expansion, contraction or relative movement, incident to normal service use, will not break or loosen the connection to the extent that resistance will vary during the movement.

(a) Bonding connections must be located in a protected area and whenever possible near an inspection door or an accessible location to permit inspection or replacement.

(b) Parts must be bonded directly to the primary structure, rather than through other bonded parts, such as plumbing, conduits, etc.

(c) All parts must be bonded to the primary structure with as short a lead as possible.

(d) Bonding jumpers must be installed so that movable components are not impeded in their operation by the jumper.

(e) Bonding connections must not be made by compression fastened through nonmetallic materials.

(f) All bonding surfaces must be cleaned prior to installation of bond joint.

(g) All nuts used in bonding must be of the all metal self-locking type (no nonmetallic inserts).

(h) Radio frequency current returns must not be made through magnesium alloys.

(i) Solder joints alone must not be used for bonding parts that are subject to movement and/or vibration.

(j) All electrical bonding must be accomplished without affecting the structural integrity of the airframe.

(k) Nonmetallic inserts or dry film lube nutplates must not be used for bonding application, such as antenna installation.

(l) All AC ground returns must be connected separate from DC ground returns.

(m) Shielded wire grounds must be attached directly to the primary structure unless otherwise noted.

(n) Where possible, multiple bonding jumpers or dual system grounds (left system and right system) must not be connected to the same ground point on the primary structure.

(o) Electrical bonding procedure must not reduce corrosion protection of bonded objects.

NOTE: Apply sealant or corrosion resistant primer to bare metal for corrosion protection.

9. Bonding Methods

A. The following bonding methods are provided to accomplish satisfactory bonds on the airplane. In most cases, a single method will satisfy the requirements, while in others it may be necessary to use more than one method.

(1) Typical Bolted Bonding Jumper Installation

(a) All bolted type jumpers should be as shown in Figure 201 and Figure 202. All jumper connections are made with number eight screws. Number six screws are used where edge distance will not permit the use of number eight screws.

(2) Bonding by Riveted and/or Bolted Skin Construction

(a) Close riveted and/or bolted skin construction is considered an adequate bond, provided the resistance value between bonding surfaces is 0.0025 ohm or less for current path return areas and 0.005 ohm for other areas.

(b) When bonding by riveted and/or bolted skin construction only is not possible, bonding as shown in Figure 203 and Figure 204 should be done.

(3) Bonding by Riveted and/or Bolted Bracket and Angle Construction

(a) Close riveted and/or bolted bracket and angle construction is considered to be an adequate bond provided the resistance value across bonding surfaces is 0.005 ohm or less.

(b) If the bracket and angle construction is used for current return path, then the resistance value across bonding surfaces and to primary structure must be 0.0025 ohm or less.

(c) Areas not meeting the requirements noted above must be bonded in accordance with Figure 205 or by adding a bonding jumper across each joint to the primary structure.

(4) Bonding of Pipes and Tubing

(a) Metallic pipes and tubes supported with clean metal clamps to a metal structure member is thought to be a sufficient bond if the resistance value between the pipe or tube and primary structure is 0.1 ohm or less, except for inline Wiggins couplings, which are 1.0 ohm or less. Lines not meeting this requirement must be bonded as shown in Figure 206 and Figure 207.

(b) Metallic tubing routed from a valve through the airplane structure is a sufficient bond if the resistance value between the tubing and the airplane structure is 1.0 ohm or less. The resistance value between the bulkhead fitting or the valve to the airplane structure must be 0.0025 ohm or less. Refer to Figure 213.

(5) Typical Access Panel or Door

(a) Fastening hardware such as screws, latches, and hinges are considered sufficient bonding for access panels and doors if the resistance value to the structure is 0.005 ohm or less. Refer to Figure 208.

(6) Typical Antenna Bonding Installation

(a) Fastening hardware, such as screws, nuts and nutplates, are considered adequate bonding for radio antennas, such as ADF loop, marker beacon, NAV, COM, etc., provided the fasteners have a direct contact with the metal base of the antenna and the fasteners are used in conjunction with nutplates or attachment hardware which are riveted into the structure of the airplane.

(b) It is critical that all finishes which are nonconducting are removed from the interfacing contact area of the

countersink and fastening hardware; however, it is usually not required to remove the finishes from the antenna mounting flange or bearing surface, providing the antenna meets the resistance value to structure as defined in Table 210.

NOTE: To make sure that the finish is nonconductive, it is necessary that you use a micro-ohmmeter to do an electrical bonding test.

(c) If the bonding requirement cannot be met by the above procedure, it may be required to remove the finishes from both the antenna flange and the airplane mounting surface.

(d) If an antenna is mounted on a composite fairing, it may be required to remove the finishes from the antenna flange and clean the composite surface down to the outer layer.

NOTE: The outer layer will usually be the lightning protection material and care must be taken not to sand through the layer and conductive sealant used in conduction with the fasteners to achieve the bond.

(e) On antennas not meeting the requirements noted above, refer to Figure 209 and, if necessary, do the bonding as follows:

1 The bearing surface between the mounting screw head and antenna metal insert must be clean, free of paint and all insulating material. This must be done on at least 25 percent of the total mounting screws used for the installation of the antenna.

2 Screw head, nut and/or nutplate structure bearing surface must be clean and bonded by riveted and/or bolted skin construction. If required, the antenna mounting doubler must be bonded to basic structure by the same method.

(7) Ground Studs

NOTE: If ground stud is positioned where it will be exposed to moisture, such as in wheel well, RTV 108 sealant must be used to seal ground stud.

(a) It is recommended to attach single ground wires to permanently installed ground studs rather than attach them to primary structure with removable screws. The stud must be correctly bonded to the primary structure and sealed for a permanent installation. The ground wires can then be attached to and removed from the stud with no effect to the bond. Refer to Figure 210, Figure 211, and Figure 212.

(8) Static Wicks

NOTE: If you can bond through the fasteners, it is recommended that you use Method B to install static wicks. If you cannot bond through the fasteners, it is necessary that you use Method B to install static wicks.

(a) Some electrical bonding requirements for bonding static wicks are shown in Figure 214. Refer to Chapter 23, Static Discharging - Maintenance Practices for more required static discharging procedures.

10. Bonding Protection

A. Bonding protection preserves the integrity of the electrical bond by preventing the entry of water, dirt, grease, oil, and corrosion between the bonded surfaces. It also prevents corrosion damage to structure.

B. Finish

(1) All bonded surfaces requiring protective coating must be brushed chem film and refinished per the original finish within as short a time as possible.

(2) Refinishing within a 24-hour period is highly recommended. The surface should be brought back to original condition.

(3) Sealants are not recommended in the areas that follow:

(a) Bulkhead connectors within the pressure vessel (unless required for pressure seal).

(b) Equipment racks and equipment mounting surfaces.

(c) Stud-type grounding blocks.

(d) Feed-thru plates (unless required for pressure seal).

(4) In areas where the surface already has chem film applied (i.e., feed-thru plates on aft and mid pressure bulkheads, etc.), it is not required to remove this finish and reapply chem film to achieve the bonding unless the bonding requirement cannot be met.

(5) The cleaned area must not be refinished until the electrical bond connection has been inspected and approved.

(6) Bonding jumpers do not need to be painted.

C. Sealing

(1) Fillet seal the perimeter of all electrical bonding areas with Type I, or Type V, Class C sealant. (Refer to Fuel, Weather, Pressure, and High Temperature Sealing - Maintenance Practices.)

(2) Some areas, but not necessarily all, where it is applicable to seal, are as follows:

(a) Feed-thru connectors which are exposed to wide temperature changes, such as temperature changes outside the pressure vessel.

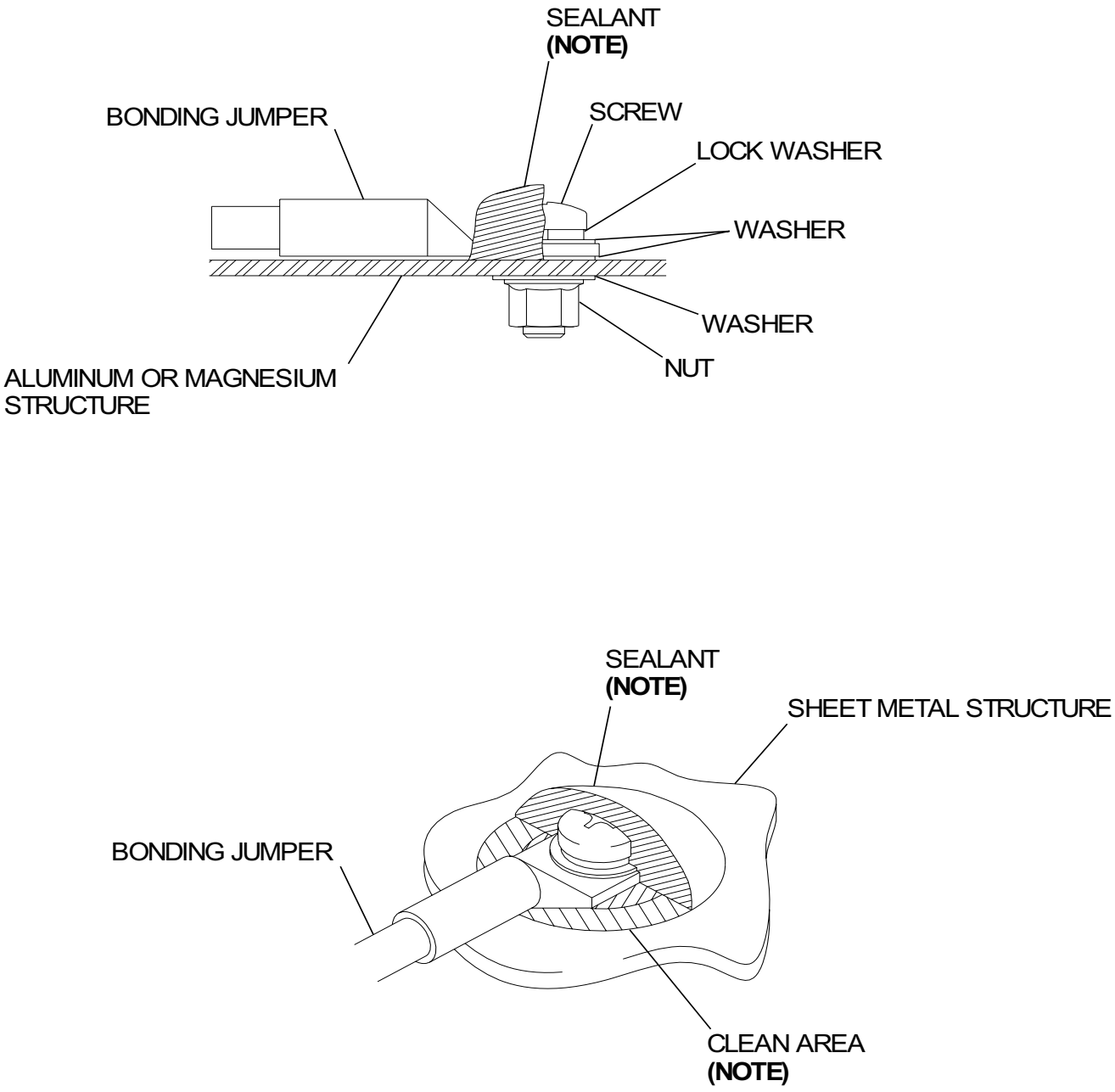
(b) Any bonding surface required within the fuel cells.

(c) Grounding blocks which require a large amount of the surface to be removed to achieve the electrical bond.

(3) Apply the same type (or equivalent) of protective coating that was initially applied to bare areas remaining around the bonding area.

Figure 201 : Sheet 1 : Electrical Bonding - Typical Bonding Jumper Installation for Aluminum and Magnesium Alloys

A2877



NOTE: USE METHOD A OR METHOD B CLEANING AND SEALING PROCEDURES.

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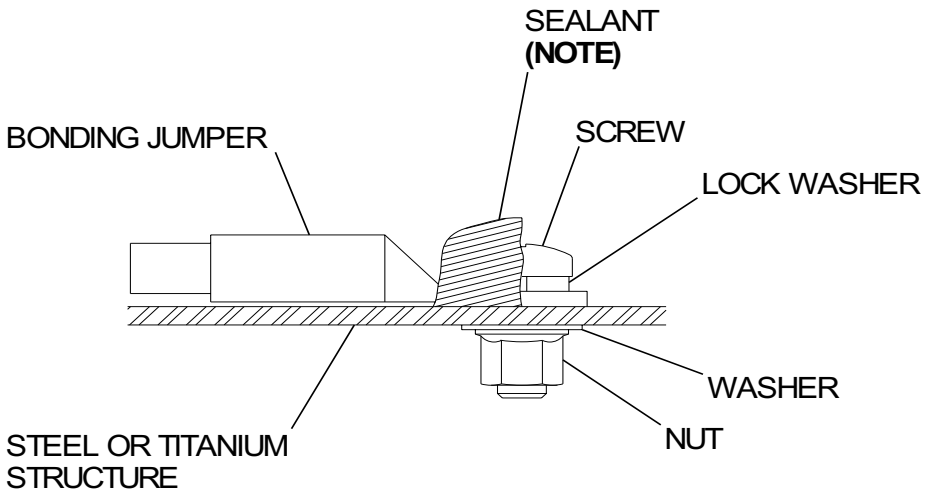
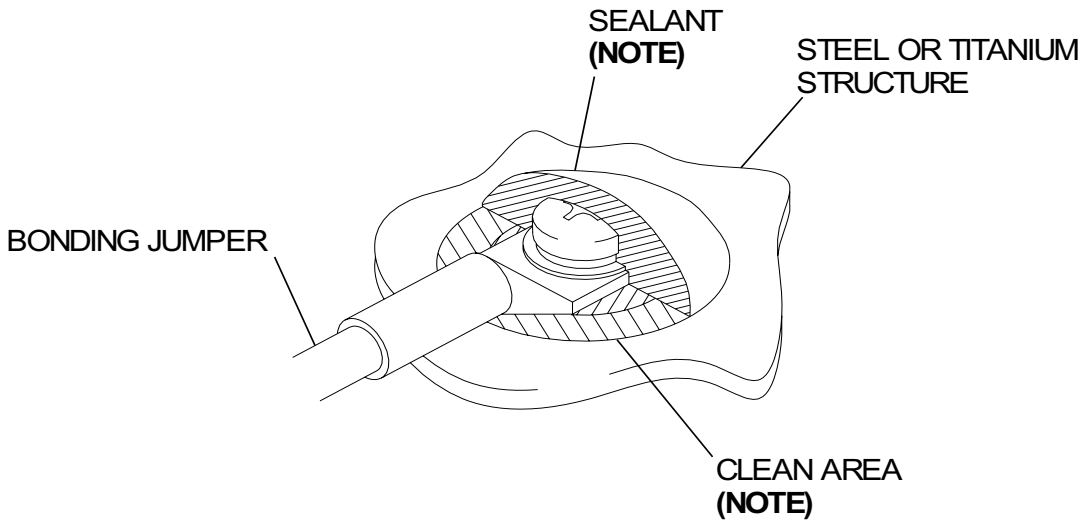
Figure 202 : Sheet 1 : Electrical Bonding - Typical Bonding Jumper Installation for Steel and Titanium Alloys

A2967





NOTE: USE METHOD A OR METHOD B CLEANING AND SEALING PROCEDURES.

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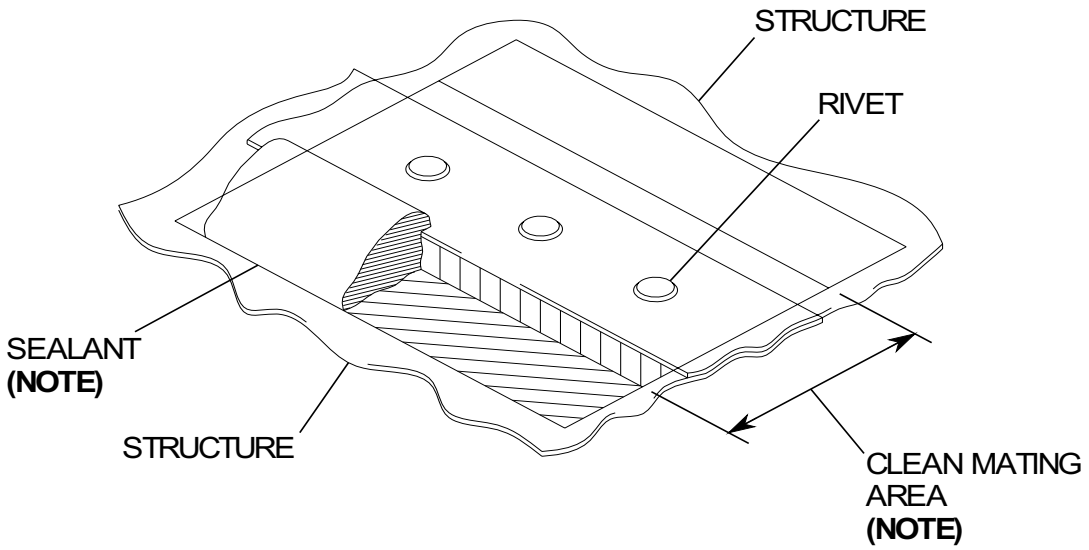
Figure 203 : Sheet 1 : Electrical Bonding - Typical Bonding Joint Installation for Riveted Sheet Metal Construction

A2883



NOTE: USE METHOD A OR METHOD B CLEANING AND SEALING PROCEDURES.

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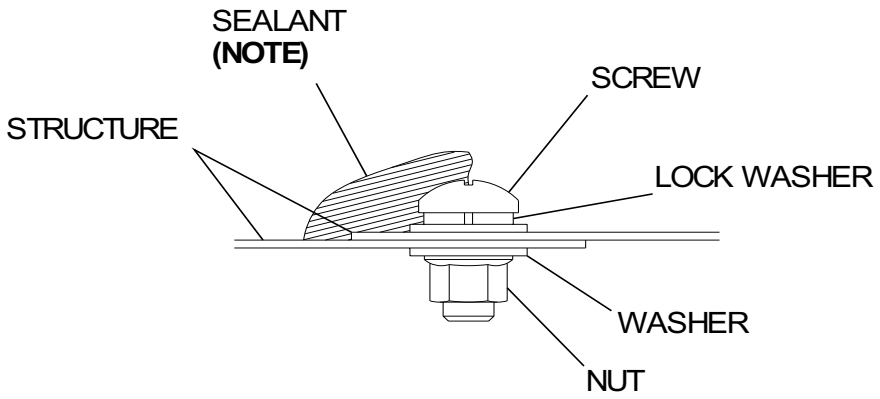
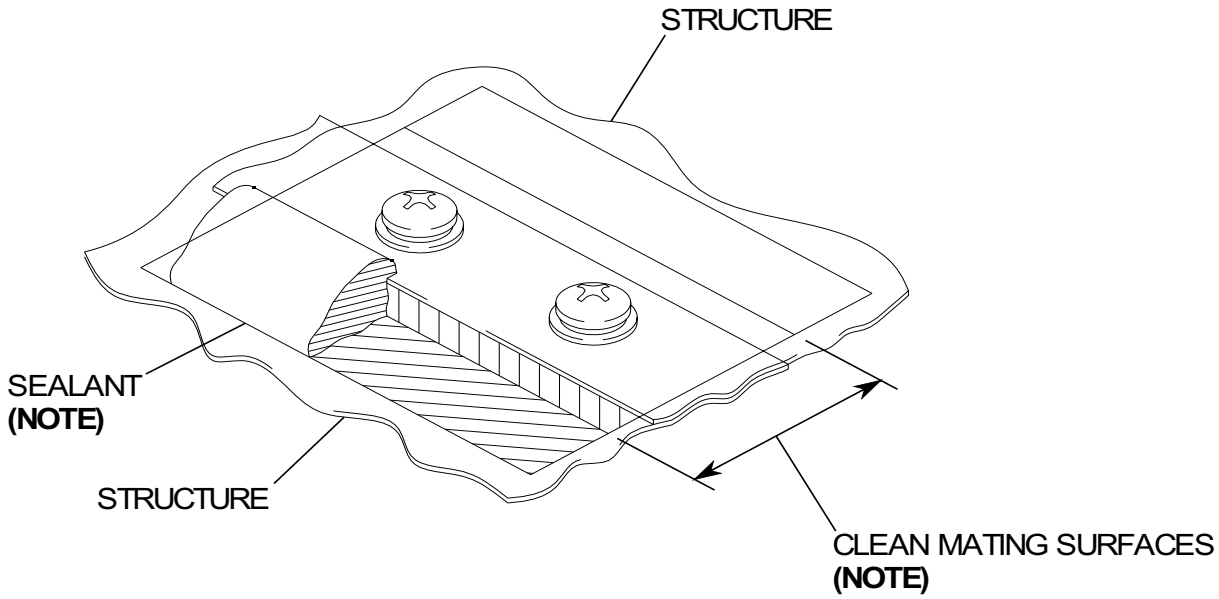
Figure 204 : Sheet 1 : Electrical Bonding - Typical Bonding Joint Installation Using Sheet Metal Screws

A2887





NOTE: USE METHOD A OR METHOD B CLEANING AND SEALING PROCEDURES.

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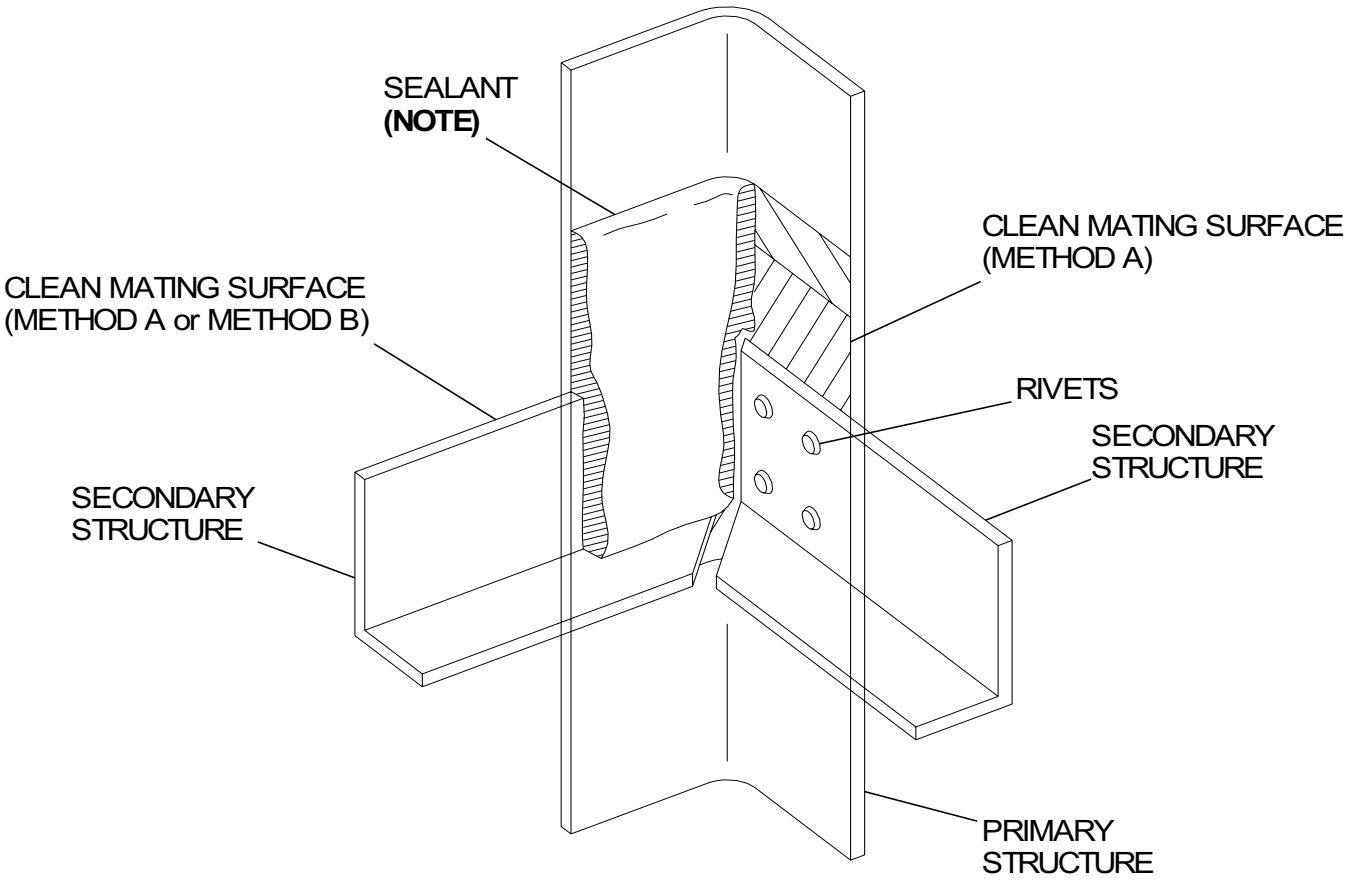
Figure 205 : Sheet 1 : Electrical Bonding - Typical Bonding Installation on Bracket and/or Angle Construction

A2892



NOTE: USE METHOD A OR METHOD B CLEANING AND SEALING PROCEDURES.

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Figure 206 : Sheet 1 : Electrical Bonding - Typical Bonding Jumper Installation of Plumbing to Structure

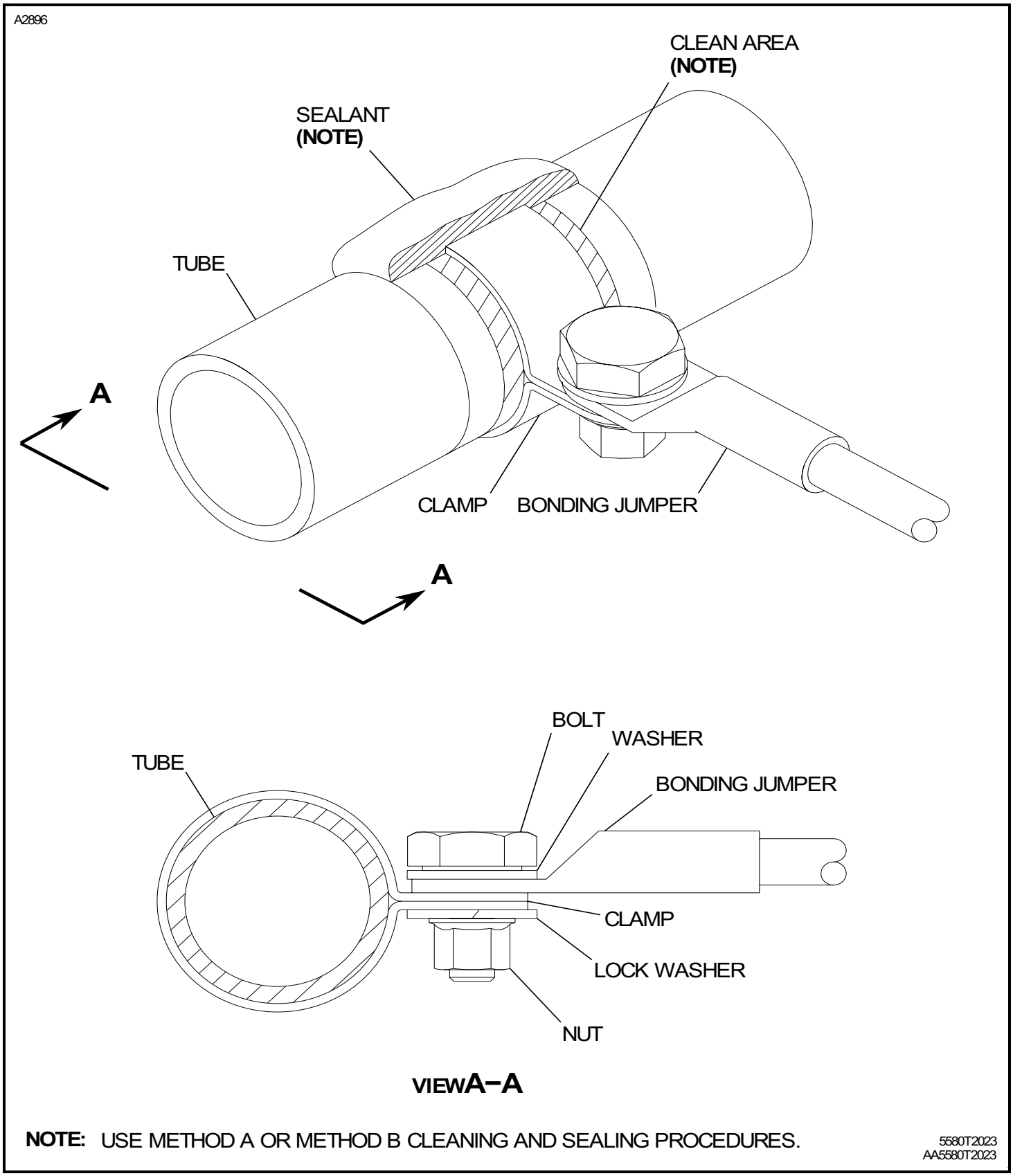


Figure 207 : Sheet 1 : Electrical Bonding - Typical Bonding Jumper Installation for Continuity of Plumbing

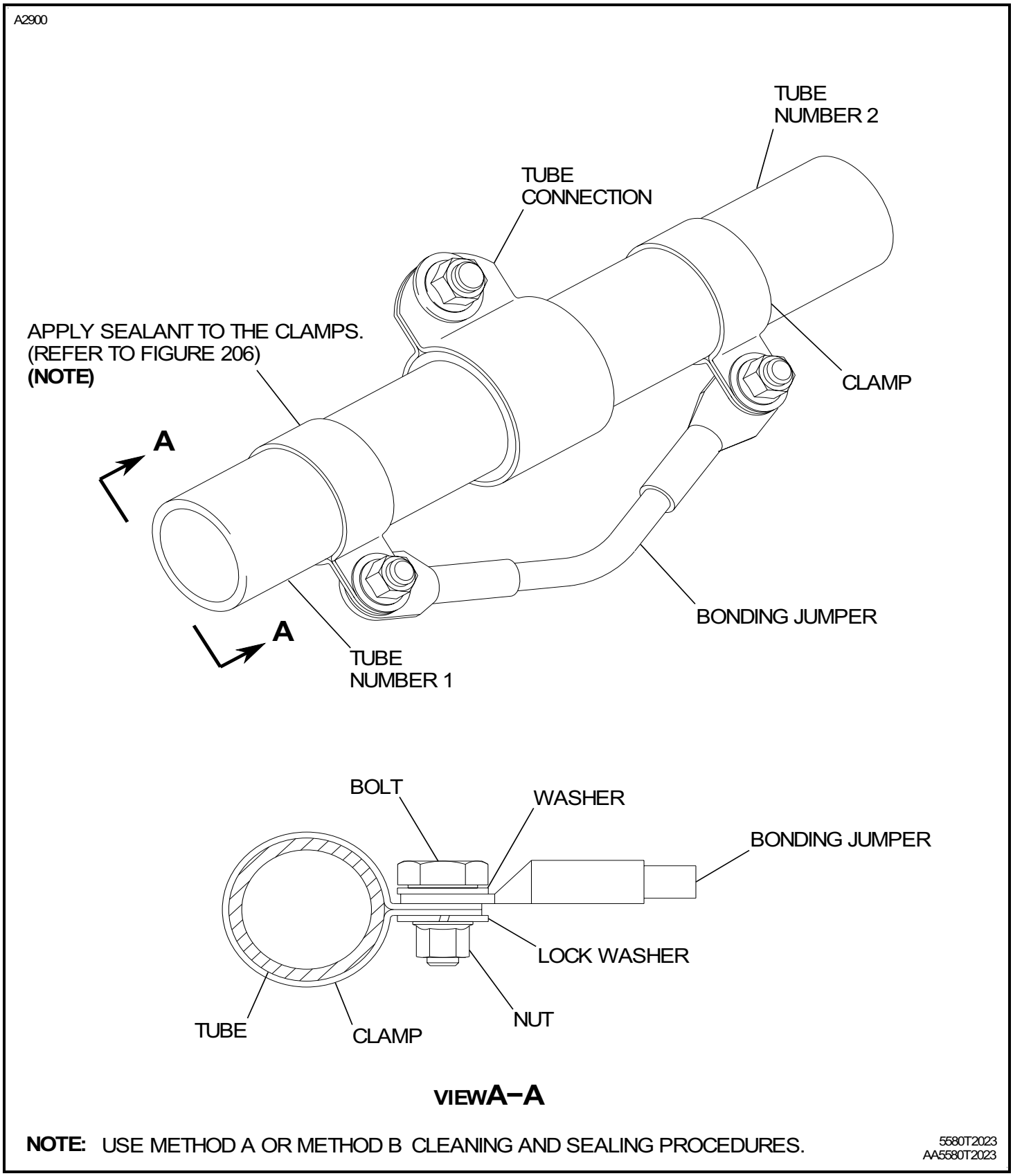


Figure 208 : Sheet 1 : Electrical Bonding - Typical Inspection Plate Bonding

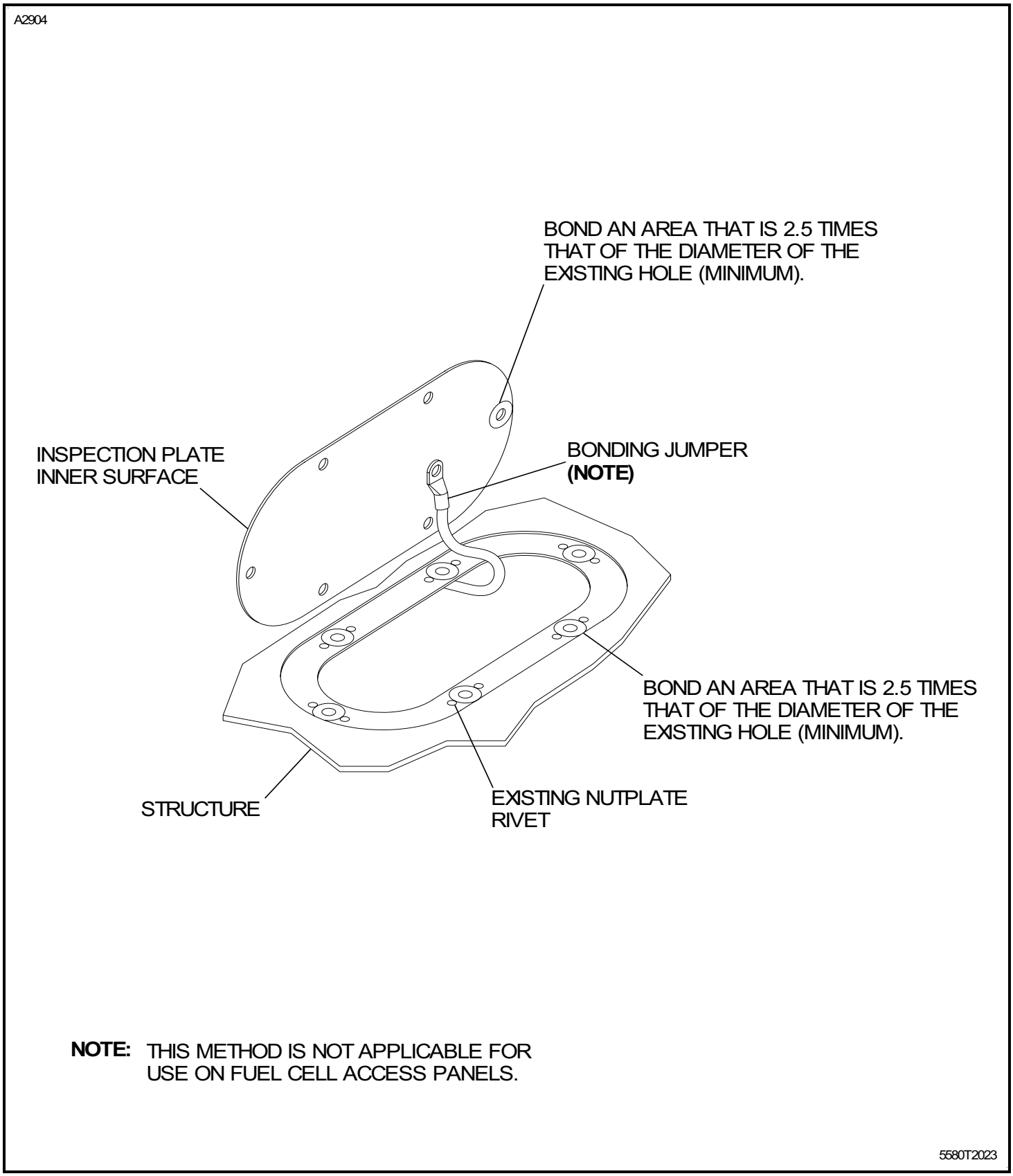


Figure 209 : Sheet 1 : Electrical Bonding - Typical Antenna Bonding

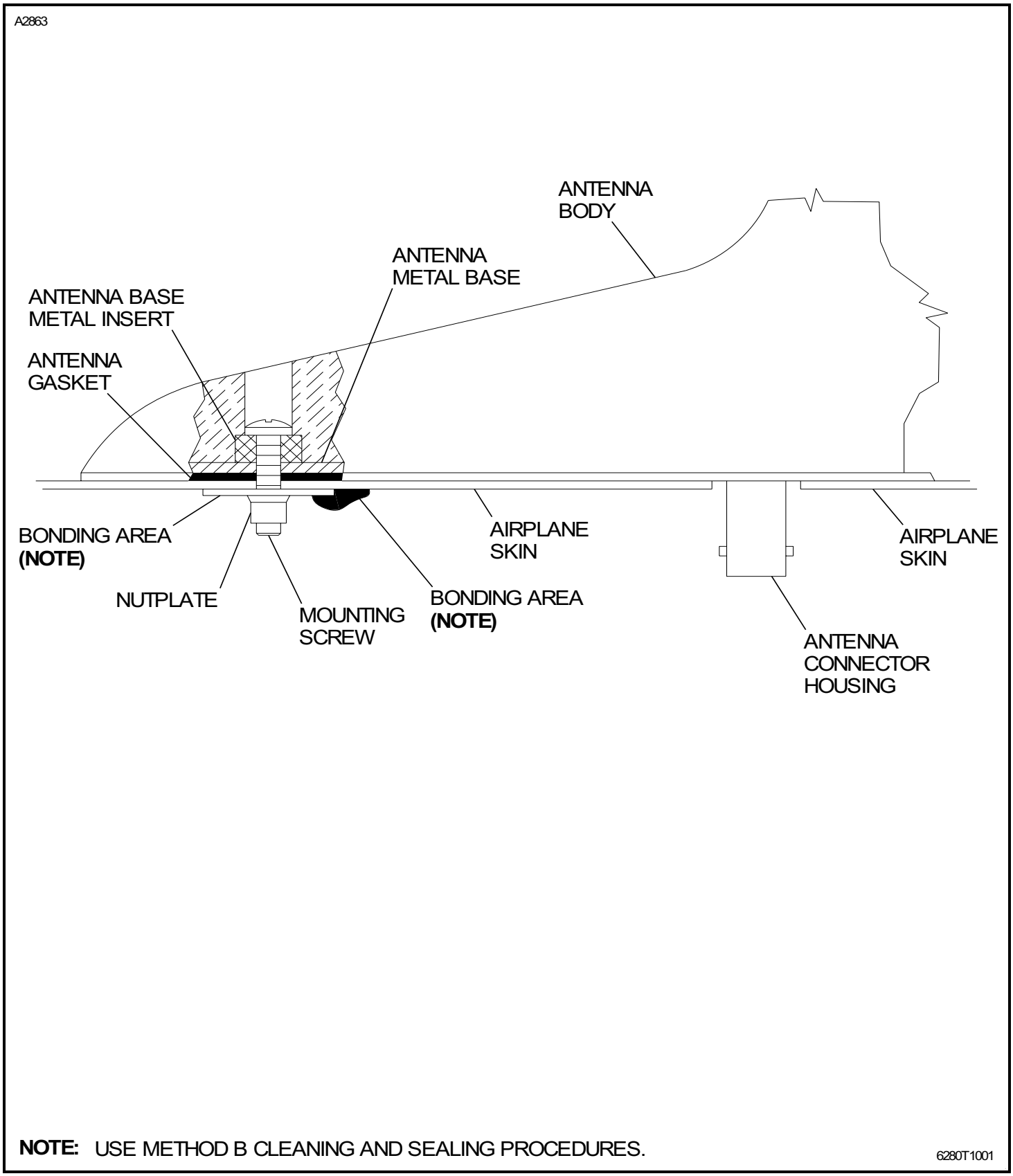
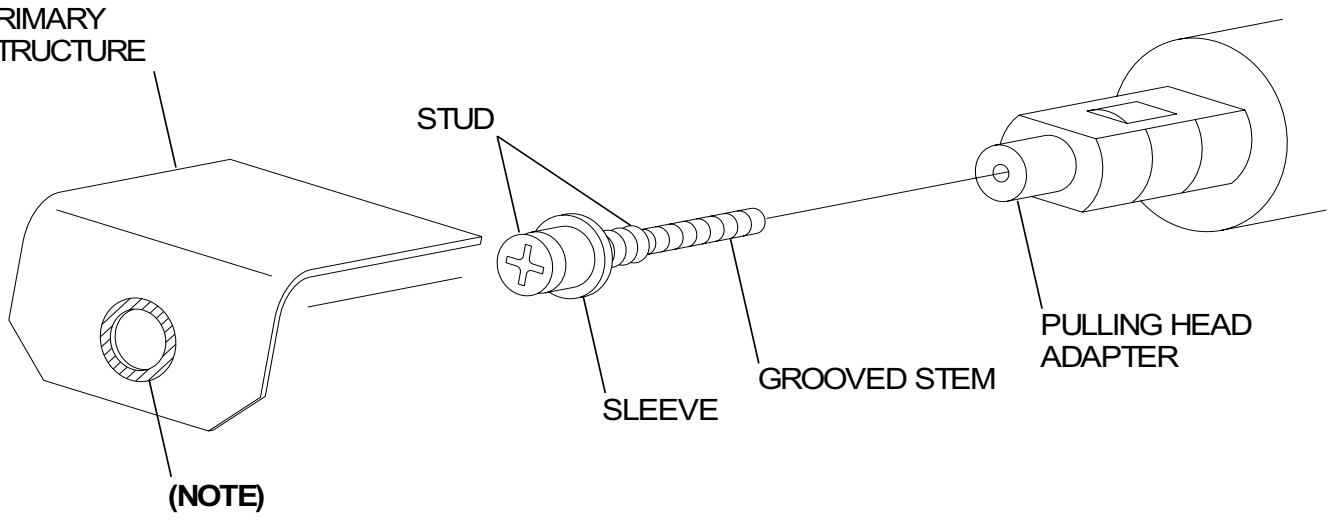


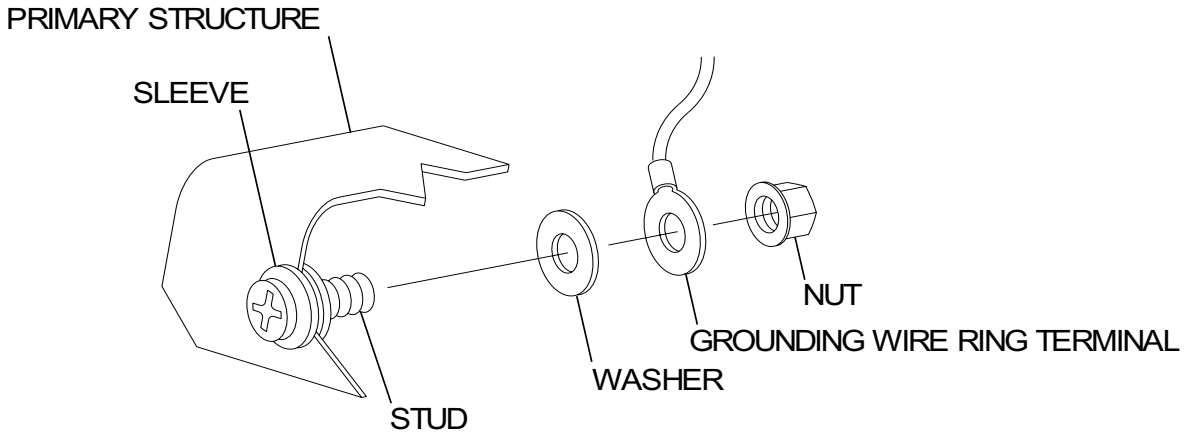
Figure 210 : Sheet 1 : Electrical Bonding - Typical Permanent Ground Stud Installation

A2891



GROUNDING STUD INSTALLATION

NOTE: REMOVE THE PRIMER SEALANT FROM THIS AREA.



GROUNDING WIRE INSTALLATION

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Figure 211 : Sheet 1 : Electrical Bonding - Cockpit Voice Recorder Removable Ground Stud Installation

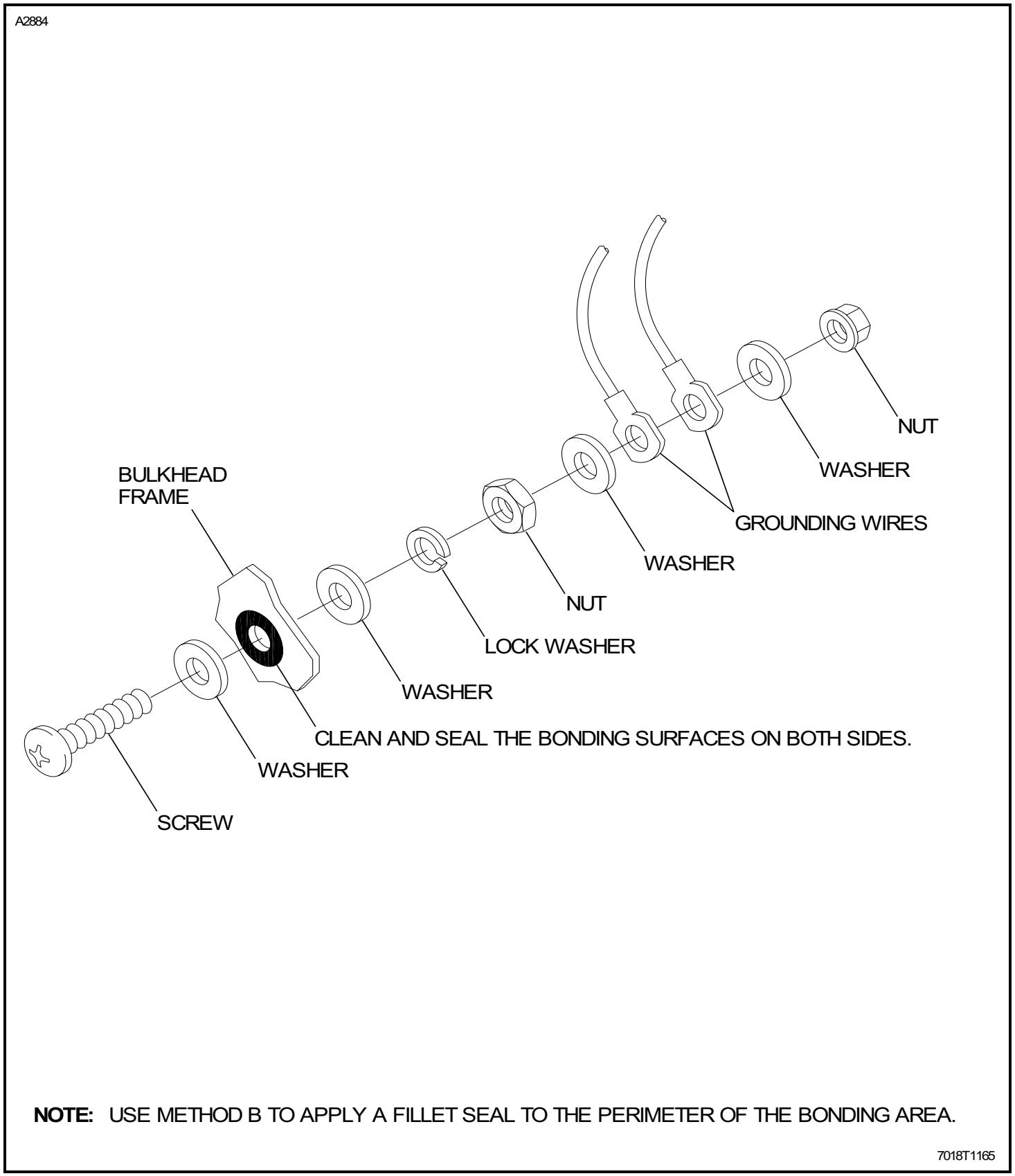


Figure 212 : Sheet 1 : Electrical Bonding - Electrical and Avionic Ground Stud Installation

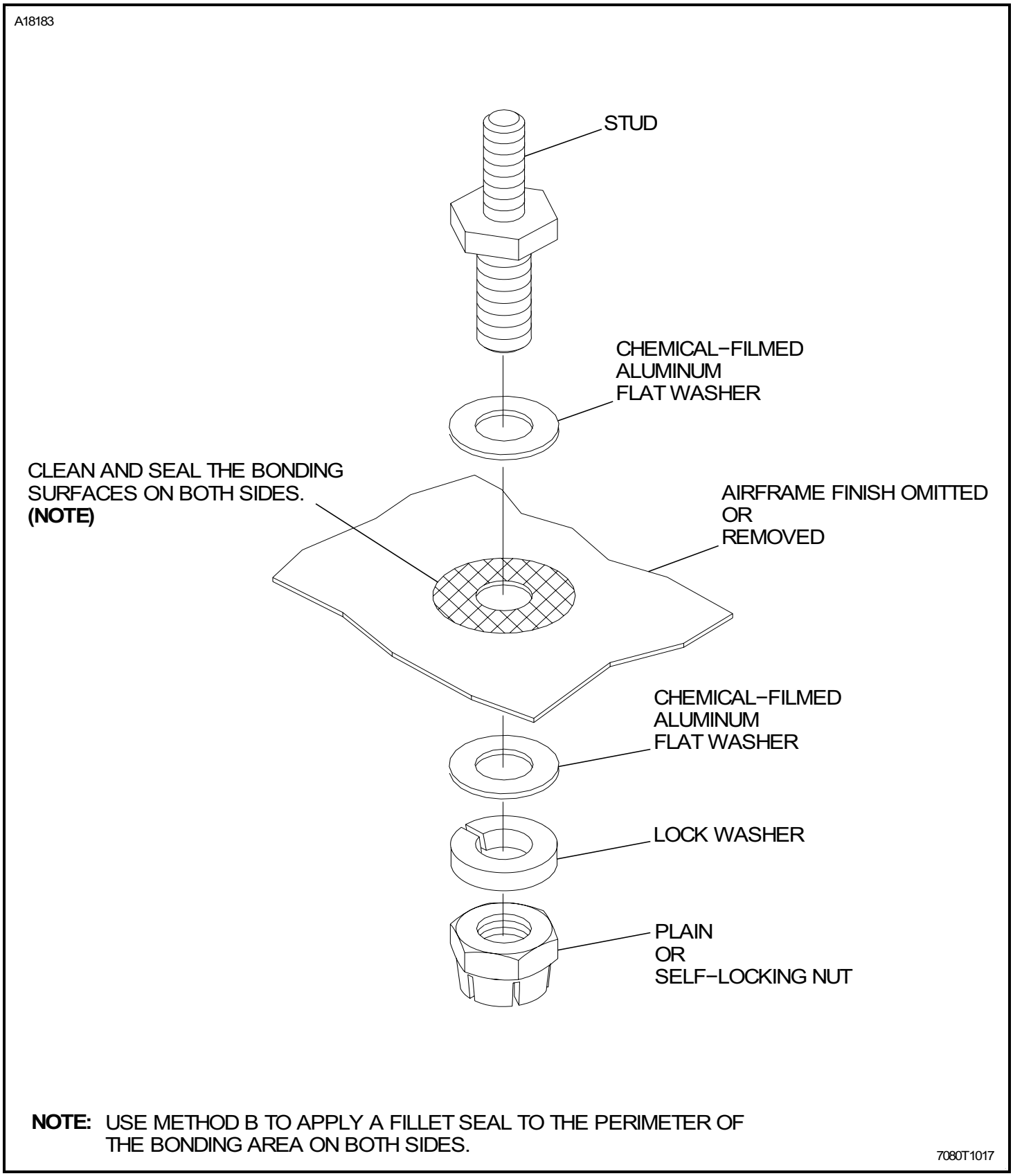


Figure 213 : Sheet 1 : Electrical Bonding - Typical Metallic Tubing Route with a Bulkhead Fitting and a Valve

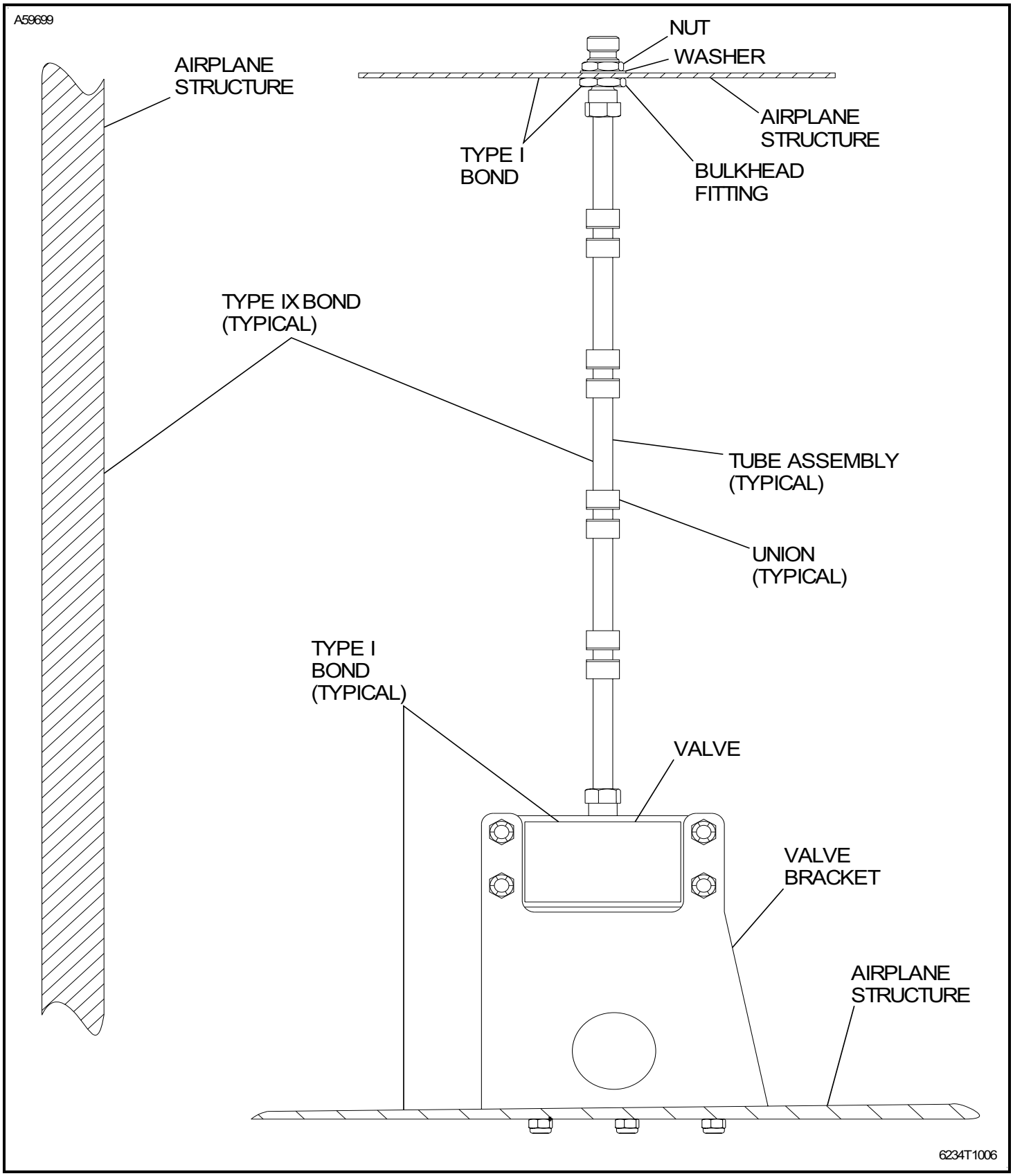
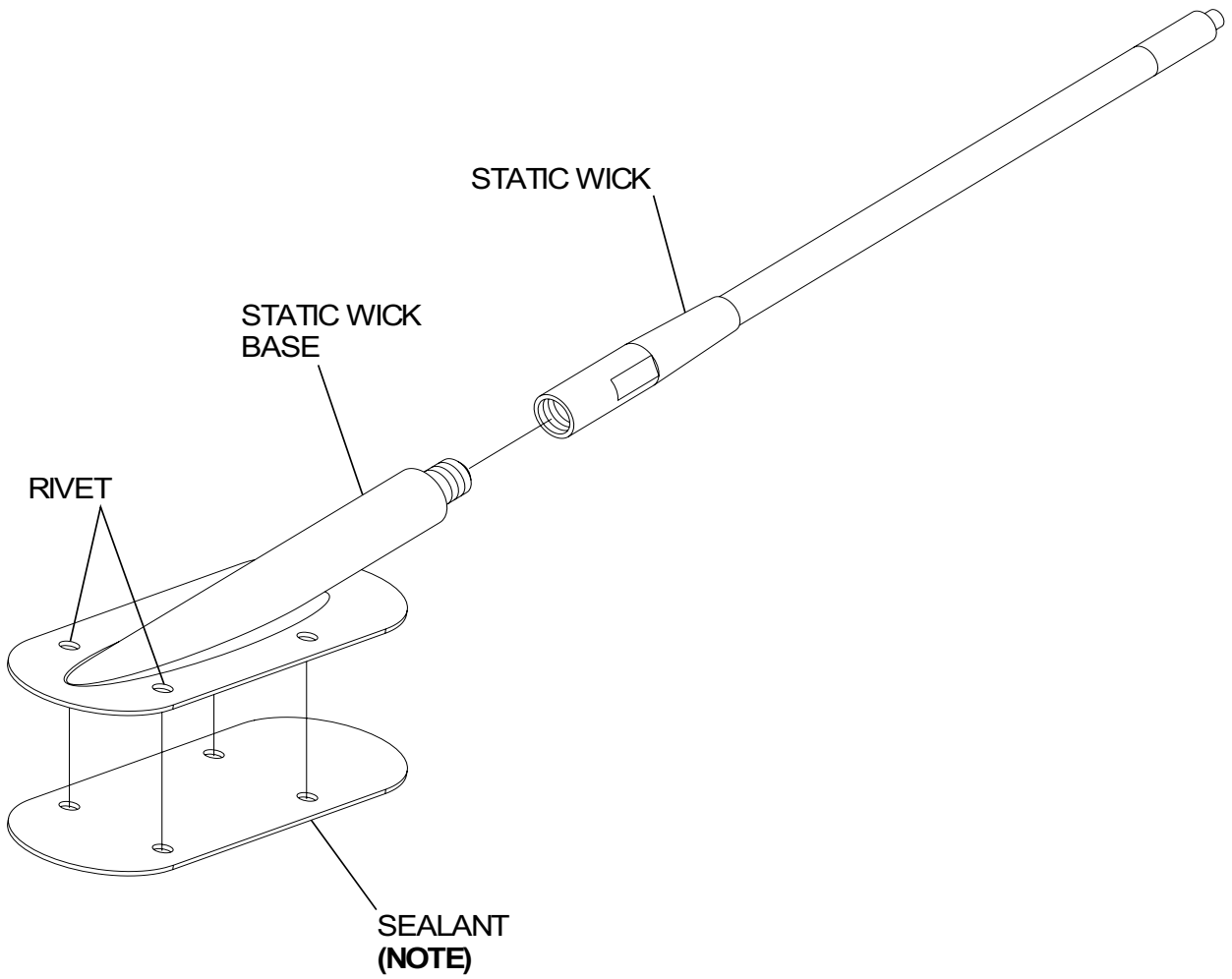


Figure 214 : Sheet 1 : Electrical Bonding - Typical Static Wick Installation

A72775



NOTE: METHOD B CLEANING AND SEALING PROCEDURES ARE RECOMMENDED FOR ALL APPLICATIONS.

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