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Superseding AIR4567

Military Composite Electrical Connectors

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FOREWORD

This SAE Aerospace Information Report (AIR) provides information and guidelines on cylindrical and rectangular connectors and accessories with components manufactured from composite materials.

Military electrical connectors and their associated accessories traditionally utilized aluminum alloy as the standard material for component parts such as shells and coupling nuts. This document provides information on connectors and accessories that utilize composite materials to replace the standard aluminum alloy components.

Composite connectors offer the user advantages over connectors constructed with aluminum components such as weight savings and corrosion protection.

This document addresses factors that military connector specifications, configured for aluminum components, may not clearly define and establishes guidelines for test requirements for specific applications.

General use connectors are designed to operate in severe environments typically associated with military defense electronics and weapon systems and commercial aerospace applications. Qualification test requirements from these environments have evolved and are defined in MIL-STD-1344. These assure the user that qualified connectors will meet those demanding performance parameters. Evaluating connectors containing composite components using testing evolved from experience with aluminum components may not identify stress factors associated with composite materials. The testing designed to find flaws in aluminum components may also inadvertently over stress composite materials.

Composite connectors offer the designer an alternative material to connectors having their shell components manufactured entirely from aluminum alloy for applications where weight saving and corrosion protection are desired. Composite connectors are intended to replace aluminum connectors and be capable of meeting their established performance parameters. See Section 4.

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FOREWORD (Continued)

Composite connectors discussed in this document are connectors with shell components wholly or partly manufactured from high temperature resins in lieu of aluminum alloys. The composite material is generally defined as thermoplastic or thermoset resin mixed with a blend of strengthening fibers to achieve mechanical strength which is then metalized to achieve electrical performance similar to plated aluminum alloy. The composite connector or accessory shell may include a metal insert. The composite materials selected should be comparable to aluminum within the temperature realms specified in general use applications, such as -55 to +150 °C, -65 to +175 °C, -65 to +200 °C, and -65 to +260 °C. The design and construction of composite connectors is subject to the requirements of the connector specification. This document recommends designs that utilize high temperature thermoplastic or thermoset resins, compatible to metalization processes.

The effects of the following types of stress are known when applied to plated aluminum shell connectors, additional testing should be considered for composite connectors:

a. Exposure to ultraviolet light
b. Weatherability
c. Flammability
d. Resistance to hydrolysis
e. Hygroscopicity
f. Outgassing properties in a vacuum environment
g. Fluid resistance
h. Resistance to atomic oxygen
i. Exposure to ozone
j. Vacuum stability
k. Shell electrical conductivity
l. Resistance to EMI/RFI/EMP
m. Resistance to indirect lightning strike
n. Toxicity and odor in a high temperature vacuum environment
o. Thread and bending strength at operating temperature

The purpose of this document is to provide information and guidelines that may not be clearly defined in the military connector specifications and define terms and technologies associated with composite materials as they relate to electrical connectors and accessories.

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1. SCOPE:

1.1 Scope:

This SAE Aerospace Information Report (AIR) establishes guidelines for evaluating composite electrical connectors and accessories.

1.2 Product Classification:

Composite connectors and accessories covered by this document shall be of the following types, grades, and classes.

1.2.1 Types:

a. Type I: Circular
b. Type II: Rectangular

1.2.2 Grades:

a. Grade A: Molded, Conductive
b. Grade B: Molded, Nonconductive
c. Grade C: Molded, Conductive, Encapsulated Metal Insert
d. Grade D: Molded, Nonconductive, Encapsulated Metal Insert

1.2.3 Classes:

a. Class 1: General duty, -55 to +150 °C
b. Class 2: General duty, -65 to +175 °C
c. Class 3: General duty, -65 to +200 °C
d. Class 4: High temperature, -65 to +260 °C
e. Class 5: Space grade, -65 to +200 °C

1.3 Field of Application:

Composite connectors and accessories are intended for general use, where weight reduction and improved corrosion protection are desired.

2. APPLICABLE DOCUMENTS:

The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

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2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR1557	High and Extended Vibration Environment
AE4L-87-3	Protection of Aircraft Electrical/Electronic Systems Against the Effects of Lightning

2.2 U.S. Government Publications:

Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-C-29600	Connectors, Electrical, Circular, Miniature, Composite, High Density, Quick Coupling, Environment Resistant, Removable Crimp Contacts, Associated Hardware, General Specification for
MIL-C-38999	Connectors, Electrical, Circular, Miniature, High Density, Quick Disconnect (Bayonet, Threaded, and Breech Coupling), Environment Resistant, Removable Crimp and Hermetic Solder Contacts, General Specification for
MIL-C-85049	Connector Accessories, Electrical, General Specification for
MIL-DTL-26074F	Coatings, Electroless Nickel, Requirements for
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MIL-STD-1344	Test Methods for Electrical Connectors

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2.3 ASTM Publications:

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM A 342	Standard Test Methods for Permeability of Feebly Magnetic Materials
ASTM B 553-79	Thermal Cycling Test for Evaluation of Electroplated Plastics, Rec. Practice for
ASTM D 350-84	Flexible Treated Sleeving Used for Electrical Insulation, Testing
ASTM D 570-81	Standard Test Method for Water Absorption of Plastics
ASTM D 756-78	Weight and Shape Change of Plastics Under Accelerated Service Conditions Practice for Determination of
ASTM D 2990-77	Standard Test Methods for Tensile, Compressive, and Flexural Creep and Creep-Rupture of Plastics
ASTM E 595-84	Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment, Test for
ASTM G 53-88	Light and Water Exposure Apparatus (Fluorescent UV-Condensation Type) for Exposure of Nonmetallic Materials, Rec. Practices for Operating

2.4 FAA Publications:

Available from FAA, 800 Independence Avenue, SW, Washington, DC 20591.

AC 20-136 Protection of Aircraft Electrical/Electronic Systems Against the Effects of Lightning

2.5 Other Publications:

George C. Marshall Space Flight Center

a. MSFC-SPEC-522 Design Criteria for Controlling Stress Corrosion Cracking

National Aeronautics and Space Administration

a. NASA Publication 1124 Outgassing Data for Selecting Materials

b. NHB 8060.1 Flammability, Odor and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion

Lyndon B. Johnson Space Center

a. SP-R-0022 General Specification Vacuum Stability Requirement of Polymeric Material for Spacecraft Applications

Electronic Industries Association

a. RS364 Test Methods for Electrical Connectors

1. TP72 Hydrolytic Stability Test Procedure for Electrical Connectors
2. TP74 Corona Inception Test Procedure for Composite Electrical Connectors
3. TP75 Lightning Strike Test Procedure for Electrical Connectors
4. TP76 Toxic Products Emission Test Procedure for Composite Electrical Connectors
5. TP80 Low Frequency Shielding Effectiveness Test Procedure for Electrical Connectors

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2.6 Symbols and Abbreviations:

The following are polymeric acronyms associated with composite materials listed in this document.

LCP	Liquid Crystal Polymer
PAI	Polyamide-imide
PAS	Polyarylsulfone
PBT	Polybutylene terephthalate
PEI	Polyetherimide
PEK	Polyetherketone
PEEK	Polyetheretherketone
PES	Polyethersulfone
PPA	Polyphthalamide
PPS	Polyphenylene Sulfide

3. DISCUSSION:

3.1 General:

This document provides information and guidelines that may not be clearly defined in the military connector specifications and defines terms and technologies associated with composite materials as they relate to electrical connectors and accessories.

3.1.1 Application: Composite connectors and accessories offer the user advantages over components constructed with aluminum alloy, such as:

a. Weight savings
b. Corrosion protection

Evaluation of these advantages should take several factors into consideration before making a final part selection, which will determine the product classification. Some of these are:

a. Temperature realm
b. Class
c. Shell conductivity
d. Shell construction

3.1.2 Classification: Composite connectors and accessories may be constructed from different materials with disparate properties, therefore, it is essential for the user to determine the application requirements and select the connector type, grade, and class which best meets their needs. Example: MIL-C-29600 and MIL-C-38999, composite connector class is Type 1, Grade A, Class 2. See 1.2, 3.1.5, 3.1.6, and 3.1.7.

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3.1.3 Weight Savings: Composite materials discussed in this document have the potential of reducing the connector and accessory weight, depending on the percentage of aluminum alloy being replaced (see Table 1).

TABLE 1 - Composite Materials - Weight Savings
Aluminum Versus Composite

Specific gravity	2.70	1.50
Pounds per cubic inch	0.0975	0.0546

3.1.4 Corrosion Resistance: Composite materials discussed in this document have varying degrees of corrosion resistance. This is dependent on product classification and material used. Compared to plated aluminum connectors, all classifications will provide the user with significantly improved corrosion protection. For example, see Table 2.

TABLE 2 - Composite Materials - Corrosion Resistance
Aluminum Versus Composite
(W Class Finish)

Salt Spray (per Method 1001 of MIL-STD-1344)	500 h	2000 h

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3.1.5 Temperature Realm: Composite materials discussed in this document have different thermal properties. Temperature is a factor when considering composite material selection and is the reason for having classifications. See 1.2.

3.1.5.1 Temperature: Temperature effects should be evaluated by continuous temperature testing in the product environment in lieu of short-term temperature excursions. Short-term excursions in this document is defined as minutes or less than 1 h. continuous temperature is defined as life cycle or several hundred hours. Connectors manufactured from composite materials offer the user performance equal to aluminum, within the operating temperature class.

3.1.6 Class: Composite connectors described in this document are classified into three basic groups:

a. General duty: Class 1, 2, and 3
b. High temperature: Class 4
c. Space grade: Class 5

Composite materials discussed in this document offer the user advantages over aluminum within the above classes. Product classes 3, 4, and 5 must be evaluated carefully, temperatures of 200 °C and above can affect aluminum and composite material strength.

3.1.6.1 General Duty: General duty connectors are designed to operate in severe environments typically associated with military defense electronic and weapon systems and commercial aerospace applications.

3.1.6.2 High Temperature: The same as general duty, continuous operating temperature of 200 to 260 °C and vibration associated with jet engine applications. See AIR1557.

3.1.6.3 Space Grade: Same as general duty, materials must meet the following requirements:

a. Permeability: MIL-I-17214
b. Vacuum stability: SP-R-0022
   ASTM E 595-84
c. Flammability, odor, and outgassing: NASA Publication 1124
   NHB 8060.1
d. Stress corrosion: MSFC-SPEC-522 (Grade C only)

3.1.7 Shell Conductivity: Composite materials discussed in this document are composed of primarily nonconductive thermoplastic or thermoset resins with glass and/or mineral reinforcement fibers. Composite materials may include additional metal and/or metalized carbon fiber to enhance thermal conductivity and electrical properties. Composite materials that are intended to replace conductive aluminum connectors and accessories must incorporate a metalization process that meets the specified shell conductivity for RFI and EMI applications.

Composite connectors discussed in this document are listed as conductive and nonconductive to give the user and manufacturer the advantage of selecting materials to meet the application requirements and offer the most cost effective solution to the requirement.

3.1.7.1 Conductive: Conductive class connectors are used to provide a low electrical resistance path for DC (direct current) grounding and low resistance/impedance (transfer impedance) electrical bonding for EMI, RFI, EMP, HIRF shielding, and indirect lightning strike grounding.

Conductive composite connectors and accessories rely primarily upon external metalization processes or internal metal inserts to provide shell conductivity to meet connector specification requirements.

3.1.7.2 Nonconductive: Nonconductive class connectors are used to provide an electrically insulated surface that isolates the normally conductive shell material and eliminates magnetically permeable materials. Composite materials are normally nonconductive unless compounded to have conductive elements. Users and manufacturers are provided a wide range of materials to meet the product class requirements.

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3.2 Design:

Part design is a key factor in determining the product performance with composite materials. Traditional metal connectors discussed in this document are high density, miniature designs that experience severe physical stresses during use. Qualification testing is configured to verify the connector's ability to meet performance requirements. both design and testing criteria evolved around linear stress associated with metal construction. Composite parts discussed in this document are manufactured from injection molded thermoplastic or thermoset polymers which require design disciplines that consider nonlinear or plastic stress.

3.2.1 Shell Construction: Circular connector shells discussed in this document have thin wall construction of approximately 0.062 in average thickness with sharp corner grooves and extra fine pitch unified threads. Part thickness is not always uniform and may have thin to thick wall thickness transition areas such as receptacle flange to barrel configuration and thin wall areas such as barrel diameter under the accessory threads and retaining ring grooves. These examples create nonlinear stress zones that need design evaluation for molded composite connectors.

3.2.1.1 Transition Thickness: Thin to thick wall transitions for composite materials should not exceed a ratio of 2:1. Transition zones should incorporate a radii equal to the thick wall. Example: 0.062 wall to 0.125 wall = 0.125 R or no less than the thin wall = 0.062 R. Transitions greater than 2:1 and wall thicknesses less than 0.025 or greater than 0.200 should be avoided for composite materials.

3.2.1.2 Sharp Corners: Sharp corners create both linear and nonlinear stress and should be avoided. However, connectors and accessories discussed in this document traditionally manufactured from aluminum have fine pitch threads and retaining ring grooves that can require sharp corners. Composite materials are suspect to notched Izod stress that require a radius transition to prevent stress failure. Incorporating controlled root radii threads such as class UNJ form and 0.015 minimum groove root radii will improve performance.

3.3 Materials:

Composite materials described in this document are molded grades of high temperature thermoplastic and thermoset reinfoced resins, with or without conductive metalization, that have a history of established successful production processing technology and manufacturing support.

Resin type and morphology is dependent on the classification. Materials discussed in this document are shown for reference only and may change without notice due to ongoing materials development and availability. See 3.1.7.

3.3.1 Material Recommendations: Composite connectors may be manufactured from the following group in Table 3 of materials listed by class as described in 1.2.3.

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TABLE 3 - Materials

Resin	Morphology	Type	Product Grade	Class
LCP	Semi-crystalline	II	All	4
PAI	Amorphous	All	B, C, and D	3
PAS	Amorphous	All	All	2
PBT	Semi-crystalline	All	All	1
PEI	Amorphous	All	All	2, 5 (175 °C)
PEEK	Semi-crystalline	All	All	3, 4, 5
PEK	Semi-crystalline	All	B, C, and D	3, 4
PES	Amorphous	All	All	2
PPA	Semi-crystalline	All	All	3
PPS	Semi-crystalline	II	B, C, and D	3

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3.3.1.1 Resin Morphology: The two types of morphology listed in this document have some unique but very predictable characteristics.

Amorphous composites have good dimensional stability, with loss of strength at temperatures above their Tg (glass transition) and start to soften. Amorphous composites have lower resistance to some chemicals, compared to semi-crystalline resins.

Semi-crystalline composites dimensional stability is sensitive to part and mold design. Semi-crystalline composites accept reinforcement fibers more favorably than amorphous resins, improving their strength. Semi-crystalline composites retain their useful strength well beyond the Tg and almost up to the melting temperature.

3.3.2 Metalization: Conductive composite class connectors and accessories may rely on metalization processes to meet shell conductivity requirements. See 3.1.7.

3.3.2.1 Plating: Traditional metal plating technology can be applied to composite materials such as electroless deposited nickel (MIL-C-26074) after preplating with electroless deposited copper and/or nickel. Plating adhesion test techniques on composites differ from metal and should follow fluid and temperature stress. ASTM B 553-70 is recommended for production validation test. See 3.2.