AEROSPACE INFORMATION REPORT

AIR4567 **REV. B**

Issued 1994-02
Revised 2009-09
Reaffirmed 2014-10

Superseding AIR4567A

(R) Composite Electrical Connectors

RATIONALE

AIR4567B has been reaffirmed to comply with the SAE five-year review policy.

FOREWORD

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

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 EIA 364. 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.

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 connector specifications and define terms and technologies associated with composite materials as they relate to electrical connectors and accessories.

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. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publicationsn shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AIR1557 High and Extended Vibration Environment

AE4L-87-3 Protection of Aircraft Electrical/Electronic Systems Against the Effects of Lightning

AS85049 Connector Accessories, Electrical, General Specification for

AS29600 Connectors, Electrical, Circular, Miniature, Composite, High Density, Quick Coupling, Environment Resistant, Removable Crimp Contacts, Associated Hardware, General Specification for

2.1.2 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

MIL-DTL--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-STD-202 Test Methods for Electronic and Electrical Component Parts

2.1.3 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM A 342 Standard Test Methods for Permeability of Feebly Magnetic Materials

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

2.1.4 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

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

2.1.5 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 (EIA) Publications

a. EIA364 Test Methods for Electrical Connectors

1. EIA-364-10 Fluid Immersion Test Procedure for Electrical Connectors and Sockets
2. EIA-364-14 Ozone Exposure Test Procedure for Electrical Connectors
3. EIA-364-26 Salt Spray Test Procedure for Electrical Connectors, Contacts and Sockets
4. EIA-364-32 Thermal Shock (Temperature Cycling) for Electrical Connectors
5. EIA-364-66 EMI Shielding Effectiveness Test Procedure for Electrical Connectors
6. EIA-364-72 Hydrolytic Stability Test Procedure for Electrical Connectors
7. EIA-364-74 Corona Inception Test Procedure for Composite Electrical Connectors
8. EIA-364-75 Lightning Strike Test Procedure for Electrical Connectors
9. EIA-364-76 Toxic Products Emission Test Procedure for Composite Electrical Connectors
10. EIA-364-80 Low Frequency Shielding Effectiveness Test Procedure for Electrical Connectors
11. EIA-364-83Shell-to-Shell and Shell-to-Bulkhead Resistance Test Procedure for Electrical Connectors

2.2 Symbols and Abbreviations

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

LCP Liquid Crystal Polymer

PAI Polyamide-imide

PEI Polyetherimide

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 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: AS29600 and MIL-DTL-38999, composite connector class is Type 1, Grade A, Class 2. See 1.2, 3.1.5, 3.1.6, and 3.1.7.

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

	Aluminum	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)

	Aluminum	Composite
Salt Spray per EIA-364-26	500 h	2000 h

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 hr. 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: ASTM A 342.

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. Caution should be taken when utilizing composite components with three (3) threads or less, such as jam nuts on receptacles. For proper electrical bonding, 4 hole flange receptacles are recommended.

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 in most cases, indirect lightning strike grounding. For lightning applications refer to EIA-364-75 and MIL-DTL-38999, 3.51 for guidance.

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.

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 reinforced resins, with or without conductive metalization, that have a history of established successful production processing technology and manufacturing support.

Resin type and morphology are 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.

TABLE 3 - MATERIALS

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

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.

3.3.1.2 Regrind

Grinding of sprues and runners or any by-product of the molding process and combining with any percentage of virgin material. Due to the complex configuration of composite parts discussed in this document, regrind material is not to be used..