



AEROSPACE INFORMATION REPORT

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Guide for the Design of Threaded Screw or Stud Type Electrical Equipment Terminations

RATIONALE

Revision required to revise Table 1 and refer users to AIR6151 and provide minor editing as needed.

INTRODUCTION

The standardization and use of electrical wire lug terminals are generally well covered in various government and commercial specifications and practices. Design of the terminations on electrical equipment, to which lug terminals are attached, however, is less well covered. Therefore, this guide sets forth design recommendations for equipment terminations that will provide satisfactory connections to lug terminals.

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1. SCOPE

To establish design recommendations that will provide a basis for safe and reliable connections to threaded screw-type or stud-type electrical equipment terminations. These recommendations are directed primarily, but not solely, to the aerospace and ground support equipment industries.

Since individual design criteria may alter the details as outlined, it is therefore important that this SAE Aerospace Information Report (AIR) not be considered mandatory but be used only as a design guidance.

2. 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 publications 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 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR6151	Torque, Threaded Application, Electrical Conductor, Accessory and Terminal Board Installation
AIR6540	Fundamentals in Wire Selection and Sizing for Aerospace Applications
ARP1870	Aerospace Systems Electrical Bonding and Grounding for Electromagnetic Compatibility and Safety
ARP4404	Aircraft Electrical Installations
AS7928	Terminals, Lug: Splices, Conductor: Crimp Style, Copper, General Specification For
AS7928/4	Terminals, Lug and Splices, Conductor, Crimp Style, Copper Terminal, Lug, Insulated, Ring Tongue, Bell-Mouthed, Type II, Class 1 (For 150 °C Total Conductor Temperature)
AS8879	Screw Threads - UNJ Profile, Inch, Controlled Radius Root with Increased Minor Diameter
AS17143	Terminal, Lug, Crimp Style, Copper, Insulated, Rectangular Tongue, Type II, Class 1, for 105 °C Total Conductor Temperature
AS18029	Cover Assembly, Electrical, for MS27212 Terminal Board Assembly
AS20659	Terminal, Lug, Crimp Style, Copper, Uninsulated, Ring Tongue, Type I, Class 1, for 175 °C or 260 °C Total Conductor Temperature
AS21004	Terminal, Lug, Uninsulated, Rectangular Tongue, Crimp Style, Copper, Type I, Class 1, for 150 °C Total Conductor Temperature
AS25036	Terminal, Lug, Crimp Style, Copper, Insulated, Ring Tongue, Bell-Mouthed, Type II, Class 1 (For 105 °C Total Conductor Temperature)
AS25435	Terminal-Lug, Crimp Style, Straight Type, for Aluminum Aircraft Wire, Class 1
AS27212	Terminal Board Assembly, Molded-In-Stud, Electric

- AS50151 Connectors, Electrical, Circular Threaded, AN Type, General Specification for
- AS50881 Wiring Aerospace Vehicle
- AS70991 Terminals: Lug and Splice, Crimp Style, Aluminum, for Aluminum Aircraft Wire

2.2 AIA/NAS Publications

Available from Aerospace Industries Association, 1000 Wilson Boulevard, Suite 1700, Arlington, VA 22209-3928, Tel: 703-358-1000, www.aia-aerospace.org.

- NASM6812 Bolts, Aircraft
- NASM25027 Self-Locking Nuts
- NASM21042 Nut, Self-Locking, 450 °F, Reduced Hexagon, Reduced Height, Ring Base, Non-Corrosion Resistant Steel
- NASM21044 Nut, Self-Locking, Hexagon - Regular Height, 250 °F, 125 ksi FTu and 60 ksi FTu
- NASM21045 Nut, Self-Locking, Hexagon - Regular Height, 450 °F, 125 ksi FTu
- NASM25440 Washers, for Use with Aircraft Aluminum Terminals
- NASM35338 Washer, Lock-Spring, Helical, Regular (medium) Series
- NASM35649 Nut, Plain - Hexagon, Machine Screw, UNC-2B
- NASM35650 Nut, Plain - Hexagon, Machine Screw, UNF-2B

2.3 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

- FED-STD-H28 Federal Standard, Screw Thread Standards for Federal Services
- FF-N-836 Nut, Square, Hexagon Cap, Slotted, Castle, Knurled, Welding and Single Ball Seat
- FF-S-85 Screw, Cap, Slotted and Hexagon Head
- MIL-HDBK-131 Identification Markings for Fasteners (Handbook H-131)
- MIL-HDBK-454 General Guidelines for Electronic Equipment
- MIL-STD-108 Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment
- MIL-STD-889 Galvanic Compatibility Of Electrically Conductive Materials
- MIL-STD-7179 Finishes, Coatings, and Sealants, for the Protection of Aerospace Weapons Systems

3. GENERAL

Solderless crimp-type lug terminals are now widely used and accepted as a means to satisfactorily terminate electrical conductors. A high degree of reliability has been achieved through standardization of sizes, dimensions, materials, crimping techniques, and performance specifications. The overall connection reliability, however, is equally dependent on the integrity of the interface contact between the lug terminal tongue and its mating surface. This critical connection has often been overlooked when threaded fasteners are used, probably due to the apparent simplicity of attachment.

There are many design factors to consider in achieving the same degree of reliability at the tongue contact as in the crimp contact to the conductor. Both mechanical and electrical requirements are to be taken into account, including such factors as selection of screw size, fastening hardware, materials, insulator design, and consideration for both copper and aluminum wire.

3.1 Lug Terminal Selection

Since the equipment termination is an electrical extension of a lug terminal, proper design must include considerations of the style and characteristics of the lug terminals expected to be used. Preferred copper crimp-type lug terminals are those specified in AS7928. Several of the more common straight types are detailed in the following associated SAE Standards, although a variety of other tongue configurations are also standardized:

AS17143	Insulated Rectangular Tongue
AS20659	Uninsulated Ring Tongue
AS21004	Uninsulated Rectangular Tongue
AS25036	Insulated Ring Tongue
AS7928/4	Insulated Ring Tongue

These range in wire size from No. 26 AWG through 0000 AWG with stud holes from No. 2 (0.086 inch) through 0.875 inch diameter. The temperature rating of tin-plated copper lug terminals is 105 to 150 °C for the insulated type and 175 °C for uninsulated. Specialized terminals such as tin whisker resistant types are also available. The MS20659-2XX nickel plated uninsulated ring tongue terminal lug offers the highest temperature rating, of up to 260 °C.

Preferred aluminum crimp-style terminals are those specified in AS70991 for aluminum aircraft wire. AS25435 details a straight, uninsulated tongue with aluminum wire size from No. 8 AWG through 0000 AWG and stud holes from No. 10 (0.190 inch) through 0.500 inch diameter. Uninsulated aluminum terminals are rated for 105 °C conductor temperature.

Recommended military practice is to use Class 1 pre-insulated terminal lugs. Uninsulated terminal lugs are also used to meet the system temperature and performance requirements.

Both AS70991 and AS7928 provide the lug terminal performance requirements which could also be applicable, in part, for the stud contact on equipment terminations.

4. SCREW AND STUD SIZE SELECTION

4.1 Threads

Screws and studs should be of the unified standard form and be selected in accordance with AS8879 so that the maximum usage is of a limited number of sizes for aircraft. Refer to FED-STD-H28 and its related documents (FED-STD-H28/1, /2, and /4 through /23). Recommended sizes are listed in Table 1.

4.2 Size

Screw or stud size is initially established from wire size and current requirements of the equipment.

Table 2 lists minimum recommended termination screw sizes for various current loads with both copper and aluminum wire, when terminated with terminal lugs. These are based on bundled cable wire ratings from AS50881.

Selection of aircraft wiring size is determined by various factors (e.g., wire size, temperature rating, number of wires in a bundle, altitude, ambient temperature, load factor, etc.). AS50881 provides the recommended maximum wire ampacity. Further guidance and examples are provided in AIR6540. When determining the largest probable wire size to be used, consider one stud size larger. This will assure adequate termination conductivity when voltage drop or circuit protection considerations require larger wires than on the basis of wire current rating alone.

4.3 Length

Length should be sufficient to accommodate at least two, but not more than four lug terminals, plus a flat washer, a split lock-washer, and a nut while maintaining a minimum of 1-1/2 screw threads showing after the assembly is complete. Lug terminals are usually positioned back-to-back as illustrated in Figure 2. For aircraft installations, refer to AS50881 for guidance on how and the number of terminals or bus bars to be used on one screw or stud.

4.4 Strength

In addition to meeting the electrical requirements, screws or studs should have sufficient mechanical strength to resist deformation or damage from tension test loads in any direction. The terminal tongue of a straight lug may be bent up to 90 degrees maximum, provided the bend radius is not less than twice the thickness of the lug tongue, and the distance from the tip of the tongue to the beginning of the bend is not less than the diameter across the lug. The size of the screw or stud and retaining means, should meet the equipment physical test requirements and withstand repeated torque loads from attaching terminated wires. Consideration should be given to tensile, shock, vibration, and thermal cycling loads to meet performance testing and service conditions.

Unless equipment design dictates specific strength criteria, Table 1 lists recommended minimum static tensile and torque test values to ensure satisfactory mechanical and electrical performance. Refer to AIR6151 for recommended installation torque values. If the torque values provided by the component manufacturer disagree with the ones in AIR6151 Table 1 and Table 6, then the manufacturers torque takes precedence.

5. TERMINAL CONTACT AREA DESIGN

5.1 Equipment Leads

- 5.1.1 Contact areas of equipment leads should be flat, clean, burr free, and raised above the surface of the surrounding insulator material. The area should preferably be equal to the mating surface of the tongue of the largest wire terminal expected to be used, but never less than required to permit the current density to exceed 1000 amps per square inch (155 amps per square centimeter).
- 5.1.2 It is recommended practice that the lug terminal stud hole be selected to match the stud size for both maximum effective electrical connection and mechanical security. Also, when lug terminals of different tongue sizes are attached to the same stud the largest should be located on the bottom directly against the equipment lead as illustrated in Figure 6.
- 5.1.3 Current carrying stud should be avoided, where possible, to ensure the optimum mechanical strength of the connection. However, when necessary, the contact area should be an integral part of the stud with a shoulder section as illustrated in Figure 3. Separate spacers or washers should not be used between the integral stud shoulder and the lug terminal tongue. This adds another interface in series with the circuit creating additional contact resistance. Refer to AS27212 terminal board application for additional guidance on stud terminations.

5.2 Contact Supporting Materials

The pressure for electrical contact must not be transmitted through, or dependent on, materials that shrink or relax with time or at elevated temperatures. Soft metal plating or interfaces such as soft solder are to be avoided. No insulating material should be in compression when the screw or nut is tightened over the lug terminal tongue. Insulating plastic materials may be used with retaining studs or captive nuts due to repeated torque or tension loads, but must remain contact pressure-free, since most are subject to varying degrees of excessive relaxation. The use of split lock washers ensures consistent pressure is applied for maintaining electrical contact during thermal expansion and contraction (see 7.3, Figure 2, and refer to ARP1870).