



AEROSPACE INFORMATION REPORT

AIR7929™

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Qualification of Percon® 24,
a New High-Strength Conductor Alloy to AS29606

RATIONALE

This SAE Aerospace Information Report (AIR) documents evaluation of a new cadmium-free high-strength copper alloy conductor. It provides a basis for testing to establish new copper alloys capable of meeting AS29606 requirements for a high-strength copper alloy conductor.

1. SCOPE

This SAE Aerospace Information Report (AIR) is limited to information about evaluation of a new cadmium-free high-strength copper alloy. The testing described in this AIR was conducted prior to the publication of AS6324 and is intended to provide information regarding evaluation of this new copper alloy. It is recognized that a simple specification such as AS29606 can not cover all possible requirements for performance in every field application. To address this basic issue, the introduction of a new, but similar to already field proven, component requires comparative testing to verify the new component will perform at the same or above level as the already approved component in a broader set of relevant tests.

1.1 Purpose

The purpose of this AIR is to provide information in regards to evaluation and approval of a new copper alloy capable of meeting MIL-W-29606 (superseded by AS29606) requirements for a high-strength copper alloy conductor.

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: 877-606-7373 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AS4373	Test Methods for Insulated Electric Wire
AS22520	Crimping Tools, Wire Termination, General Specification for
AS22759	Wire, Electrical, Fluoropolymer-Insulated, Copper or Copper Alloy
AS22759/33	Wire, Electrical, Fluoropolymer-Insulated, Cross-Linked Modified ETFE, Lightweight, Silver-Coated, High-Strength Copper Alloy, 200 °C, 600 Volt, ROHS

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Documents
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AS22759/44	Wire, Electrical, Fluoropolymer-Insulated, Cross-Linked Modified ETFE, Lightweight, Silver-Coated, Copper, 200 °C, 600 Volt, ROHS
AS22759/82	Wire, Electrical, Polytetrafluoroethylene/Polyimide Insulated, Lightweight, Nickel-Coated, High-Strength or Ultra High-Strength Copper Alloy, 260 °C, 600 Volt, ROHS
AS22759/92	Wire, Electrical, Polytetrafluoroethylene/Polyimide Insulated, Lightweight, Nickel-Coated, Copper Conductor, 260 °C, 600 Volt, ROHS
AS29606	Wire, Electrical, Stranded, Uninsulated Copper, Copper Alloy, or Aluminum, or Thermocouple Extension, General Specification for
AS39029/56	Contacts, Electrical Connector, Socket, Crimp Removeable (for MIL-DTL-38999 Series I, III, and IV Connectors)
AS39029/58	Contacts, Electrical Connector, Pin, Crimp Removeable (for MIL-DTL-38999 Series I, III, and IV, and MIL-DTL-55302/69 and MIL-DTL-83733 Connectors)

2.2 NEMA Publications

Available from National Electrical Manufacturers Association, 1300 North 17th Street, Suite 900, Arlington, VA 22209, Tel: 703-841-3200, www.nema.org.

NEMA WC-67 Uninsulated Conductors - Used in Electrical and Electronic Applications

2.3 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 B470 Standard Specification for Bonded Copper Conductors for Use in Hookup Wire for Electronic Equipment

ASTM B624 Standard Specification for High-Strength, High-Conductivity Copper-Alloy Wire for Electronic Applications

2.4 U.S. Government Publications

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

MIL-DTL-81381 Wire, Electric, Polyimide-Insulated, Copper or Copper Alloy

3. GENERAL

3.1 Background

Mechanical and physical properties of “high-strength alloy” are specified in ASTM B624, AS22759, MIL-DTL-81381, NEMA WC-67, AS29606, etc. Each of these specifications require the material to possess a 60 ksi (minimum) tensile strength, electrical conductivity of 85% IACS (minimum), and a minimum elongation of 6% or 8% depending on the specification.

Although none of these specifications is material specific, qualification of high-strength copper alloy conductors for military or commercial aerospace wire and cable requires rigorous testing to ensure that the conductor material performs equally to currently accepted materials. Copper alloy C18135 (PD135) was the only accepted conductor material for high-strength alloy conductor in military applications.

Qualification or acceptance criteria for new conductor materials for military applications are not well defined, since there are no test procedures to qualify the performance of the conductor itself. There are many performance specifications for insulated wire, but the test procedures focus primarily on the performance of the insulated material and merely assume that it was applied over one of the accepted conductor materials.

Development of high-performance military wire and cable resulted in numerous innovations in insulation materials and systems which have undergone rigorous performance testing before being accepted for military use. The innovation of new conductor materials has been infrequent. Copper, the standard conductor material, was most probably accepted by default. PD135 was accepted as a high-strength copper alloy, but its qualification process and data were not available. Aluminum was also qualified many years ago and its qualification process and data are not readily available. Conductor for a new category, "ultra high-strength copper alloy," was the most recent military qualified material and was approved approximately 10 years prior to testing this new cadmium-free high-strength copper alloy. Documentation of that test program and results is available.

The qualification program for ultra high-strength alloy included tests of voltage drop, break strength, and flex life, before and after conditioning by thermal aging and thermal shock.

Testing was conducted to compare the performance of 24 AWG new copper alloy with 24 AWG PD135 and 22 AWG copper wire. Tests and conditioning environments similar to those used to qualify ultra high-strength conductor were also included in this investigation. A vibration environment to characterize conductor and crimp termination compatibility, a modified AS4373 flex test and a comparison of propensity for Red Plague (silver plated wire) were also performed.

Voltage drop, tensile, and flex tests were performed on wire and terminated specimens in the as received condition, after thermal aging, thermal shock, and exposure to vibration. Some tests were performed on terminated specimens in which the contact was applied to the wire after thermal aging (reterminated specimens). Thermal aging and shock conditioning were performed at the rated operating temperatures of the wires.

Testing performance confirmed that the new copper alloy was comparable to PD135.

The results of this test program were forwarded to Naval Air Systems Command for review and acceptance of new copper alloy as a high-strength conductor alloy for military wire and cable applications.

4. TESTING

4.1 Description of Test Articles

Fisk Alloy Conductors provided conductor samples of:

- 24 AWG silver plated (SP) Percon® 24 - 19/36 unilay
- 24 AWG nickel plated (NP) Percon® 24 - 19/36 unilay

Military QPL suppliers provided conductor samples of:

- 24 AWG SP-PD135 - 19/36 unilay
- 22 AWG SPC (copper) - 19/34 unilay
- 24 AWG NP-PD135 - 19/36 unilay
- 22 AWG NPC (copper) -19/34 unilay

A 6 mil extruded wall of cross-linked ethylene-tetrafluoroethylene copolymer (XL-ETFE) was applied to the 24 AWG silver plated alloy conductors per AS22759/33 and to the 22 AWG silver plated copper per AS22759/44.

A 6 mil thick composite tapewrap insulation was applied to the 24 AWG nickel plated alloy conductors per AS22759/82 and to the 22 AWG nickel plated copper per AS22759/92.

Termination contacts, when required, met the requirements of M39029/56-348 (refer to AS39029/56) for sockets and/or M39029/58-360 (refer to AS39029/58) for pins. All crimp terminations were attached using tools and positioners meeting the AS22520 specification.

4.2 Specimen Conditioning

Wire specimens were subjected to thermal aging, thermal shock, and vibration to simulate environmental conditions that may affect conductor/wire performance. Unconditioned specimens were taken from as received wire.

Specimens that required thermal aging were placed in an air circulating oven for 1000 hours at the wire's specified operating temperature. Silver plated wire was aged at 200 °C and nickel plated wire was aged at 260 °C.

Specimens that required thermal shock were exposed to a total of eight shock cycles. Each shock cycle consisted of soaking the specimens at the specific wire's operating temperature for 1 hour followed immediately by cooling to -55 °C for 1 hour. The soak temperature for silver plated conductor was 200 °C and 260 °C for nickel plated conductor.

Specimens that required exposure to vibration conditioning were fixtured to simulate a functional application of the conductor/crimp termination. Test setup, conditions, monitoring, and reporting conformed to MIL-C-39029 para 3.5.10 and 4.7.11 and Method 2005 of MIL-STD-1344, test condition VI, letter J. A vibration duration of 8 hours in the longitudinal direction and 8 hours in the perpendicular direction was applied. Note that MIL-C-39029 was superseded by AS39029 and the vibration test method has changed since the time of this testing.

4.3 Procedures, Results, and Discussion

4.3.1 Conductor Dimensions and Properties

The conductor construction used for this investigation was 24 AWG - 19/36 lightweight unilay. Conductor diameter, weight, DC resistance, lay length, break, tensile strength, and elongation were measured to confirm that the material and conductor construction conformed to ASTM B624, NEMA WC67, and AS29606 before insulating. Summaries of the conductor test results for the Percon® 24 samples are included in Tables 1 and 2.

All conductor used for this investigation met the requirements of the applicable conductor and material specs.

Table 1 - SP Percon® 24 properties

	Spec Req	SP-Percon® 24
Diameter (inches)	0.0225-0.0244	0.0233
Weight (lb/mft)	1.33 min	1.42
DCR (Ω /mft)	28.4 max	23.87
Lay/Dir (inches)	8-16L	0.333
Break (pounds)	22.4 min	23.05
Tensile (psi)	60000 ⁽¹⁾	61785
Elongation (%) in 10 inches	6 min	9.5

NOTES:

Specification requirements from NEMA WC-67 and AS29606, except as noted.

⁽¹⁾ ASTM B624 requirement.

Table 2 - NP Percon® 24 properties

	Spec Req	NP-Percon® 24
Diameter (inches)	0.0225-0.0254	0.0234
Weight (lb/mft)	1.33 min	1.42
DCR (Ω /mft)	30.1 max	26.3
Lay/Dir (inches)	8-16L	0.333
Break (pounds)	22.4 min	24.92
Tensile (psi)	60000 ⁽¹⁾	66798
Elongation (%) in 10 inches	6 min	8.9

NOTES:

Specification requirements from NEMA WC-67 and AS29606, except as noted.

⁽¹⁾ ASTM B624 requirement.