SAE Aerospace
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AEROSPACE INFORMATION REPORT

SAE AIR5919 | REV. A

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Superseding AIR5919A

(R) Alternatives to Cadmium Plating

RATIONALE

Revised to include additional information accumulated from independent industry test results on alternative surface treatment finishes. Updated specification references and reformatted the document where applicable.

FORWARD

General use connectors and associated connector accessories design to operate in severe environments traditionaly utilize aluminum alloy as the standard base material and plated with cadimum to protect the base material from corrosion. Due to recent legislation regarding Health and Safety issues, there is an on-going effort to eliminate cadmium from these systems.

INTRODUCTION

The purpose of this document is to provide information and guidelines for evaluating alternate surface treatment finishes, for general use connectors and associated connector accessories, typically associated with military defense electronics, weapon systems and commercial aerospace applications. This Aerospace Information report (AIR) addresses the essential elements for testing and evaluating alternative surface treatment finishes and the resulting performance capabilites they offer when compared to cadimum plating.

Surface treatment finishes discussed in this document have been tested to the same qualification requirements used to determined acceptability of general connectors and associated connector accessories when tested in accordance with the applicable EIA364 test method for electrical performance and suitability in severe environments.

1. SCOPE

1.1 This SAE Aerospace Information Report (AIR) is intended to document and provide access to information obtained by an industry survey. It summarizes and documents data regarding possible alternatives to the use of cadmium plating on general connectors and connector accessories typically used in aerospace and military defense electrical interconnect systems.

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 the 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.

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SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/AIR5919A

2.1 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.

AMS-QQ-P-35 Passivation Treatments for Corrosion Resisting Steel

AMS-QQ-P-416 Plating, Cadmium (Electrodeposited)

AMS-C-26074 Electroless Nickel Coatings

AIR 4789 Aerospace Information Report on Evaluating Corrosion Testing of Electrical Connectors and Accessories for the Purpose of Qualification

AS85049 Connector Accessories, Electrical General Specification For

2.2 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 B 26/26M Aluminum Alloy Sand Castings

ASTM B 85 Aluminum Alloy Die Castings

ASTM B 117 Standard Practice for Operating Salt Spray (Fog) Apparatus

ASTM B 209 Aluminum and Aluminum Alloy Plate and Sheet

ASTM B 211/221 Aluminum and Aluminum Alloy, Bar, Rod, Wire or Shapes, Rolled, Drawn, Extruded or Cold Finished

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

ASTM B 733 Autocatalytic Nickel-Phosphorus Coating on Metal

ASTM B 841 Electrodeposited Coatings for Zinc Nickel Alloy Deposits

ASTM G 85 Modified Salt Spray Testing

ASTM D 1654 Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments

2.3 U.S. Government Publications

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

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

MIL-DTL-24308 Connectors, Electric, Rectangular, Miniature, Polarized Shell, Rack and Panel

MIL-DTL-28840 Connectors, Electrical, Circular, Threaded, High Density, High Shock, Shipboard, Class D, General Specification for.

MIL-DTL-38999 Connectors, Electrical, Circular, Miniature, High Density, Quick Disconnect, Bayonet, Threaded & Breech Coupling, Hermetic Solder

MIL-DTL-83488 Coating, Aluminum, High Purity

MIL-DTL-83513 Connectors, Electrical, Rectangular, Microminiature, Polarized Shell, General Specification for

MIL-DTL-83723 Connectors, Electrical, Circular, Environment Resisting, Receptacles & Plugs, General Specification for

MIL-DTL-26482 Connectors, Electrical, (Circular, Miniature, Quick Disconnect, Environment Resisting), Receptacles and Plugs, General Specification for

2.4 ANSI/ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO 10012-1 Equipment, Quality Assurance Requirements for Measuring -
Part 1: Metrological Confirmation System for Measuring Equipment

ISO 21207 Corrosion Tests in Artificial Atmospheres – Accelerated Corrosion Tests Involving Alternate Exposure to Corrosion-Promiting Gases, Neutral Salt Spray and Drying

ANSI Z540-1 Calibration Laboratories and Measuring and Test Equipment - General Requirements

2.5 EIA Publications

Avaliable from Electronic Industries Alliance (EIA), 2500 Wilson Boulevard, Arlington, VA 22201-3834, Tel: 703-907-7500, www.eia.org

EIA 364 Electrical Connector/Socket Test Procedures Including Environmental Classifications

EIA 364-09 Durability Test Procedure for Electrical Connectors and Contacts

EIA 364-13 Mating & Unmating Force Test Procedure for Electrical Connectors and Sockets

EIA 364-26 Salt Spray Test Procedure for Electrical Connectors, Contacts and Sockets

EIA 364-32 Thermal Shock (Temperature Cycling) Test Procedure for Electrical Connectors and Sockets

EIA 364-83 Shell-to-Shell and Shell-to-Bulkhead Resistance Test Procedure for Electrical Connectors

3. TEST SAMPLE PREPARATION REQUIREMENTS

3.1 The test specimens should be representative of products produced under essentially the same condition and processes used during normal production prior to applying the alternative surface treatment finish to be evaluated.

3.2 All test specimens should be identified as such and traceable to the base material and the alternative surface treatment finish applied. It is recommended a minimum of two (2) test specimens for each base material and alternative surface treatment finish under evaluation be used. Photographs of the test specimens before and after test conditioning is recommended but not required.

3.3 The test specimens shall be tested in accordance with the test group sequence specified in Table 1A or 1B for general connectors and Table 2 for associated connector accessories.

3.4 Testing shall be conducted using the test method specified in either Table 1A, 1B or Table 2. Alternate test methods may be used provided the alternative test method employed does not significantly depart from the preferred test method and is traceable to an approved industry recognized test method standard.

3.5 It is recommended that a controlled sample form a part of the test program for alterntive surface treatment finishes under evaluation. The controlled sample should consist of an appropriate base material, such as aluminum alloy, and plated Cadmium – Olive Drab color over a suitable underplate qualified to withstand 500-hour salt spray exposure.

4. POST TEST EVAULATION

4.1 Post test specimens shall be evaluated using the applicable connector or accessory specification unless otherwise stated herein.

4.2 The duration for each test will very slightly depending on the associated connector or accessory specification requirements applicable to the test specimen(s) submitted for evaluation of the applied surface treatment finish to be tested.

4.3 The results of the evaluation that identifies the performance capabilities for each surface treatment finish tested is shown in the summary evaluation matrix outlined in Table 3. This matrix is a summarized abstract from industry supplied data submitted and in no way replaces the detailed data or otherwise implies being absolute in part or in whole.

5. CONCLUSIONS

5.1 Due to the unique properties of cadmium, there does not appear to be a substitute surface treatment finish material that provides the same advantages and corrosion protection. However, a number of alternative surface treatment finishes are available. Each has its own merits as compared to cadmium.

5.2 Three (3) alternative surface treatment finishes have reported performance characteristics similar to cadmium which have been accepted by the industry for inclusion into the applicable connector and accessory specifications. It must be understood that these alternative surface treatment finish options have limitations and are not a direct replacement for cadmium in all cases. The user must consider their application's specific needs and determine if one of these alternative surface treatment finishes will suit their performance requirements.

5.3 Below is a cross reference matrix listing of the finish code designators assigned to each alternative surface treatment finish that was included in each respective connector or accessory specification listed. The user should refer to the latest release of the cited connector or accessory specifications to ensure continued availability.

Cross Reference Matrix
(Finish Code designators)

Plating Description	Alternative Surface Treatment Finish Code Designators								
	Specification	MIL-DTL-38999	MIL-DTL-28840	MIL-DTL-83723	MIL-DTL-26482	MIL-DTL-24308	MIL-DTL-83513	SAE-AS85049	
	Base Material	Alum	Alum	Alum	Alum	Alum	Alum	Alum	SST	Composite
Nickel Fluorocarbon Polymer. Nickel with fluorocarbon polymer additives over a suitable underplate to withstand 500 hours of dynamic salt spray testing. Color shall be nonreflective.		T	L or M	T	T	T	T	X	XS	XC
Zinc Nickel in accordance with ASTM B 841, Type D (black) over suitable underplate to withstand 500 hours of dynamic salt spray testing. Color shall be nonreflective.		Z	S or U	Z	Z	K	K	Z	ZS	ZC
Pure Dense Electrodeposited Aluminum in accordance with MIL-DTL-83488, Type II, to withstand 500 hours of dynamic salt spray testing. Color shall be nonreflective.		P	N/A *	M	D	A	A	Y	YS	YC

* N/A = Not Applicable

6. NOTES

6.1 A change bar (|) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

TABLE 1A - TEST REQUIREMENT / SEQUENCE – CIRCULAR CONNECTORS

Test Description	Requirement	Test Method	Test Group by Sequence	
			1	2
Examination	Plating is uniform in appearance and non-reflective	Visual, unaided eye	x	x
Shell Conductivity 1/	2.5 Millivolts max	EIA 364-83, mated connectors may be wired or unwired	x	x
Plating Adhesion	No blistering, peeling or separation of the plating or other damage detrimental to the operation of the connector (applicable to composite base material connectors only)	In accordance with MIL-DTL-38999L W/Amendment 1, paragraph 4.5.5.		x
Temperature Cycling 2/	No blistering, peeling or separation of the plating or other damage detrimental to the operation of the connector	EIA 364-32, Method A, Test Condition V, Test Duration A (5-cycles) except steps 2 & 4 shall be 2-minutes maximum duration		x
Coupling Torque	Recorded values shall meet the requirements specified in the applicable connector specification	The coupling torque applied to facilitate full mate / unmate shall be measured and recorded	x	
Shell Conductivity 1/	2.5 Millivolts max	EIA 364-83, mated connectors may be wired or unwired	x	x
Durability	Connectors shall show no defects detrimental to their operation and shall meet subsequent testing	50 mate / unmate cycles prior to salt spray conditioning. Cycle rate not to exceed 300 cycles per hour	x	
Salt Spray (corrosion)	No separation of plating or exposure of base material when examined in accordance with AIR 4789	EIA 364-26, Test Condition C, 452-hrs mated and 48-hrs unmated	x	
Durability 3/	Connectors shall show no defects detrimental to their operation and shall meet subsequent testing	450 mate / unmate cycles after salt spray conditioning. Cycle rate not to exceed 300 cycles per hour	x	
Coupling Torque	Recorded values shall meet the requirements specified in the applicable connector specification	The coupling torque applied to facilitate full mate / unmate shall be measured and recorded	x	
Shell Conductivity	5.0 Millivolts max after conditioning	EIA 364-83, mated connectors may be wired or unwired	x	

1/ Shell conductivity shall be 5.0 Millivolts for M83723 and M26482 connector types.
2/ Temperature cycle testing for step 3; temperature to be 125°C for M26482 connector types.
3/ Durability: Mate / unmate cycles shall be 50 after salt spray conditioning for M28840 connector types

TABLE 1B - TEST REQUIREMENT / SEQUENCE – RECTANGULAR CONNECTORS

Test Description	Requirement	Test Method
Examination	Plating is uniform in appearance and non-reflective	Visual, unaided eye
Plating Adhesion	No blistering, peeling or separation of the plating or other damage detrimental to the operation of the connector (applicable to composite base material connectors only)	In accordance with MIL-DTL-38999L W/Amendment 1, paragraph 4.5.5.
Temperature Cycling	No blistering, peeling or separation of the plating or other damage detrimental to the operation of the connector	EIA 364-32, Method A, Test Condition I, Test Duration A (5-cycles) except steps 3, temperature to be 125°C
Durability 1/	Connectors shall show no defects detrimental to their operation and shall meet subsequent testing	EIA 364-09 except 500 mate / unmate cycles prior to salt spray conditioning. Cycle rate not to exceed 200 cycles per hour
Salt Spray (corrosion)	No separation of plating or exposure of base material when examined in accordance with AIR 4789	EIA 364-26, Test Condition B (48-Hrs)
Durability 2/	Connectors shall show no defects detrimental to their operation and shall meet subsequent testing	500 mate / unmate cycles after salt spray conditioning. Cycle rate not to exceed 200 cycles per hour
Mate / Unmate Force	Recorded values shall meet the requirements specified in the applicable connector specification	EIA 364-13, Method A except the rate shall be 1 to 10 inches per minute. The force applied to facilitate full mate / unmate shall be measured and recorded

1/ Durability testing prior to salt spray conditioning and mate / unmate force testing applies to M24308 connector types only.
2/ Durability testing after salt spray conditioning applies to M83513 connector types only.

TABLE 2 - TEST REQUIREMENT / SEQUENCE – CONNECTOR ACCESSORIES

Test Description	Requirement	Test Method	Test Group by Sequence	
			1	2
Examination	Plating is uniform in appearance and non-reflective	Visual, unaided eye	x	x
Shell Conductivity	2.5 Millivolts max	EIA 364-83, measured from a point on the rear of the accessory to the connector or dummy connector mounting flange	x	x
Plating Adhesion	No blistering, peeling or separation of the plating or any other condition that adversely affects the function of the accessory. (applicable to composite base material accessories only)	In accordance with AS85049B, paragraph 4.6.18		x
Temperature Cycling 2/	No blistering, peeling or separation of the plating or any other condition that adversely affects the function of the accessory.	EIA 364-32, Method A, Test Condition V, Test Duration A (5-cycles) except steps 2 & 4 shall be 2-minutes maximum duration		x
Durability	Accessory shall show no defects detrimental to its function.	50 mate / unmate cycles prior to salt spray conditioning. Cycle rate not to exceed 200 cycles per hour.	x	
Shell Conductivity	2.5 Millivolts max	EIA 364-83, measured from a point on the rear of the accessory to the connector or dummy connector mounting flange	x	x
Salt Spray (corrosion)	No separation of plating or exposure of base material when examined in accordance with AIR 4789	EIA 364-26, Test Condition C (500-hrs)	x	
Shell Conductivity	5.0 Millivolts max after conditioning	EIA 364-83, measured from a point on the rear of the accessory to the connector or dummy storage connector mounting flange	x	
Coupling Thread Strength	Accessory threads shall withstand the torque requirement without damage	Accessory thread torque in accordance with AS85049B, paragraph 4.6.10, Table 3.	x	

TABLE 3 - TEST SUMMARY EVALUATION MATRIX

Surface Treatment (Finish) Basic Description	Base Mat'l	Sample Type & Source #	Examination	Shell Conductivity	Plating Adhesion	Temperature Cycling	Coupling Torque	Shell Conductivity	Durability	Salt Spray	Durability	Coupling Torque	Post Shell Conductivity	Coupling Thd. Strength
Cadmium OD (Control sample)	Alum	Accessory & Connector	P	P	P	P	P	P	P	P	P	P	P	P
Cadmium OD (Control sample)	SST		P	P	P	P	P	P	P	P	P	P	P	P
Cadmium OD (Control sample)	Comp-osite		P	P	P	P	P	P	P	P	P	P	P	P
Nickel Fluorocarbon Polymer (Teflon Ni, type 1)	Alum	Connector: Source 1	P	N	N	N	P	P	P	P	P	P	P	R
Nickel Fluorocarbon Polymer (Teflon Ni, type 2)	Peek		P	N	N	N	P	P	P	P	P	P	P	R
Nickel Fluorocarbon Polymer (Teflon Ni, type 3)	Alum		P	N	N	N	P	P	P	P	P	P	P	R
Zinc Nickel	Alum		P	N	N	N	P	P	P	P	P	F	P	R
Ion-Vapor- Deposited (IVD)	Alum		P	N	N	N	P	P	P	P	F	P	P	R
Ion-Vapor- Deposited (IVD)	Peek		P	N	N	N	P	F	P	F	P	P	F	R
Electrodeposited Aluminum (type 1)	Peek		P	N	N	N	P	P	P	F	P	P	P	R
Electrodeposited Aluminum (type 2)	Peek		P	N	N	N	P	P	P	F	P	P	P	R
Electrodeposited Aluminum	Alum		P	N	N	N	P	P	P	F	F	P	P	R
Nickel Fluorocarbon Polymer (Teflon Ni)	Alum	Connector: Source 2 1/	P	P	N	P	N	N	P	P	P	N	P	R
Nickel Fluorocarbon Polymer (Enslic™)	Alum		P	P	N	P	N	N	P	F	P	N	F	R
Zinc Nickel	Alum		P	P	N	P	N	N	P	P	P	N	F	R
Zinc Cobalt	Alum		P	P	N	P	N	N	P	P	P	N	F	R
Nickel Fluorocarbon Polymer (Teflon Ni)	SST		P	P	N	P	N	N	P	P	P	N	F	R
Nickel Fluorocarbon Polymer (Enslic™)	SST		P	P	N	P	N	N	P	P	P	N	F	R
Zinc Nickel	SST		P	P	N	P	N	N	P	P	P	N	F	R
Zinc Cobalt	SST		P	P	N	P	N	N	P	P	P	N	F	R
Nickel Fluorocarbon Polymer (Teflon Ni)	Alum	Accessory: Source 3	P	N	N	N	R	P	N	P	R	R	N	N
Zinc Nickel	Alum		P	N	N	N	R	P	N	P	R	R	N	N
Electrodeposited Aluminum	Alum		P	N	N	N	R	P	N	P	R	R	N	N
Nickel Fluorocarbon Polymer (Teflon Ni)	Ultem		P	N	N	N	R	P	N	P	R	R	N	N
Zinc Nickel	Ultem		P	N	N	N	R	P	N	P	R	R	N	N
Electrodeposited Aluminum	Ultem		P	N	N	N	R	P	N	P	R	R	N	N
Nickel Fluorocarbon Polymer (Teflon Ni)	Alum	Accessory: Source 4	P	N	N	P	R	P	P	P	R	R	P	N
Zinc Nickel	Alum		P	N	N	P	R	P	P	P	R	R	P	N
Electrodeposited Aluminum	Alum		P	N	N	N	R	P	P	P	R	R	P	N
Zinc Cobalt	Alum		P	N	N	P	R	P	P	F	R	R	F	N
Nickel Fluorocarbon Polymer (Teflon Ni)	SST		P	N	N	P	R	P	P	P	R	R	P	N
Zinc Nickel	SST		P	N	N	P	R	P	P	P	R	R	P	N
Zinc Cobalt	SST		P	N	N	P	R	P	P	P	R	R	P	N

Legend: P = Met requirement F = Failed to meet requirement N = Not tested R = Test not required

1/ Durabiliy testing: 50-cycles before and 50-cycles after salt spray conditioning.

TABLE 3 (CONT'D) - TEST SUMMARY EVALUATION MATRIX

Surface Treatment (Finish) Basic Description	Base Mat'l	Sample Type & Source #	Mated Connector Set							
			Durability (500 cycles)	Shell Conductivity	Salt Spray (1,000 -hrs)	Post Shell Conductivity		Durability (500 cycles)	Shell Conductivity	Salt Spray (SO_2 336-hrs)	Post Shell Conductivity
Zinc Nickel (sample type 1)	Alum	Connector: Source 5 2/ & 3/	N	N	3	P		N	N	3	P
Zinc Nickel (sample type 1) cycled	Alum		P	N	3	F		P	N	3	P
Nickel Fluorocarbon Polymer (Teflon Ni)	Alum		N	N	2	P		N	N	2	P
Nickel Fluorocarbon Polymer (Teflon Ni) cycled	Alum		P	N	3	F		P	N	2	P
Zinc Nickel (sample type 2)	Alum		N	N	3	F		N	N	3	F
Zinc Nickel (sample type 2) cycled	Alum		N	N	N	N		P	N	3	F
Electrodeposited Aluminum, cycled	Alum		P	N	0	F		P	N	0	P
Zinc Nickel (sample type 3)	Alum		N	N	1	P		N	N	2	F
Zinc Nickel (sample type 3) cycled	Alum		P	N	2	F		P	N	2	F
Zinc Cobalt, cycled	Alum		N	N	N	N		P	N	3	F
Cadmium OD (control sample 1)	Alum		N	N	2	F		N	N	2	P
Cadmium OD (control sample 2)	Alum		N	N	1	P		N	N	1	P
Cadmium OD (control sample 3)	Alum		N	N	1	F		N	N	1	F

Legend: P = Met requirement F = Failed to meet requirement N = Not tested R = Test not required

2/ Planned for 1,000 hours , terminated @ 840 hours due to the extent of visible corrosion.

3/ Evaluated per ASTM D 1654 – Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments. A rating system was used to determine the amount of corrosion as follows: 0 = no corrosion, 1 = light corrosion, 3 = heavy corrosion. Based on the utilization of this evaluation method, the results in the matrix are rated in a similar fashion. However, since each connector was evaluated as a separate specimen, the results above were rated on the average for a mated connector set. For example: the connecotr receptacle received a "0" rating put the mated connector plug received a rating of "3"; the mated connector set was rated as a 2.