AEROSPACE MATERIAL SPECIFICATION

AMS03-19

Issued 2015-05

Electro-Deposition of Cadmium

RATIONALE

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LICENSING AGREEMENT

FOREWORD

REVISION NOTE

This Defence Standard was raised to Issue 4 to update its content and incorporate the latest MoD/DStan policy in place at the time.

HISTORICAL RECORD

This standard supersedes the following:

Def Stan 03-19 Issue 1 dated 3 July 1981

Def Stan 03-19 Issue 2 dated 31 March 1994

Def Stan 03-19 Issue 3 dated 14 October 2005

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INTRODUCTION

This SAE Standard specifies the requirement for the electro-deposition of cadmium.

Cadmium has been employed as a coating for many years and is particularly useful due to its combination of inherent resistance to atmospheric and bi-metallic corrosion along with its good anti-galling and electrical conductivity.

However toxicity problems are a cause for concern and its use is being restricted by International, National and Departmental legislation. These concerns apply to potential in-service and disposal problems as well as initial processing problems.

In view of this increasing legislation against the use of cadmium the user is advised to consider possible alternative coatings – see Def Stan 03-36 – before defining the use of cadmium.

TABLE OF CONTENTS

1. SCOPE

This SAE Standard specifies the requirements for the electro-deposition of cadmium on non-corrosion resisting steel items for protection against corrosion, and on copper based alloy items and corrosion resisting steel items for the reduction of contact corrosion of less noble metallic materials.

2. WARNING

This section which appeared in DEF STAN 03-19 Issue 4 has been deliberately deleted.

3. NORMATIVE REFERENCES

3.1 The publications shown below are referred to in the text of this standard. Publications are grouped and listed in alpha-numeric order.

BS EN ISO 1463	Metallic and Oxide Coatings. Measurement of Coating Thickness. Micoscopic Means
BS EN ISO 2177	Metallic Coatings. Measurement of Coating Thickness. Coulometric Method by Anodic Dissolution
BS EN ISO 2178	Non-Magnetic Coatings on Magnetic Substrates. Measurement of Coating Thickness. Magnetic Method.
BS EN ISO 3497	Metallic Coatings. Measurement of Coating Thickness. X-ray Spectrometric Method
BS EN ISO 3543	Metallic and Non-Metallic Coatings. Measurement of Thickness. Beta Backscatter Method
BS EN ISO 4516	Metallic and other Inorganic Coatings. Vickers and Knoop Microhardness Tests.
BS EN ISO 6507-1	Metallic Materials. Vickers Hardness Test. Test Method.
BS 2868	Specification for Cadmium Anodes and Cadmium Oxide for Electroplating
BS 6338	Specification for Chromate Conversion Coatings on Electroplated Zinc and Cadmium Coatings
Def Stan 03-2	Cleaning and Preparation of Metal Surfaces
AMS03-2	Cleaning and Preparation of Metal Surfaces
Def Stan 03-4	The Pre-Treatment and Protection of Steel Items of Specified Maximum Tensile Strength Exceeding 1450 MPa
AMS03-4	The Pre-Treatment and Protection of Steel Items of Specified Maximum Tensile Strength Exceeding 1450 MPa
Def Stan 03-14	Electrodeposition of Chromium for Engineering Purposes
AMS03-14	Electrodeposition of Chromium for Engineering Purposes
Def Stan 03-21	Mechanical Methods for the Inducement of Compressive Surface Residual Stresses
Def Stan 03-36	Guidance to the Use of Cadmium Alternatives in the Protective Coating of Defence Equipment

3.2 This section which appeared in DEF STAN 03-19 Issue 4 has been deliberately deleted.

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4. DEFINITIONS

4.1 For the purposes of this standard the following definitions apply.

4.2 PROCESS CONTROL SCHEDULE

The document which specifies/defines:

a. The sequence of Manufacturing operations and processes.

b. The control parameters, and their tolerances, for each individual process within the total sequence.

4.3 SIGNIFICANT SURFACE

That area of the item, covered or to be covered by the coating, and for which the coating is essential for serviceability and/or appearance.

4.4 TENSILE STRENGTH OF STEELS

4.4.1 TENSILE STRENGTH

Throughout this standard the tensile strength figures refer to specified maximum tensile strength. Steels shall be categorized according to specified maximum tensile strength in accordance with Table 1. Where the steel specification specifies only the minimum tensile strength, the equivalent maximum tensile strength category shall be determined from Table 1.

4.4.2 TENSILE STRENGTH/HARDNESS RELATIONSHIP

If no maximum or minimum tensile strength is specified for the steel, hardness values of 310HV, 340HV, 435HV, 450HV and 545HV (as measured in accordance with BS EN ISO 6057-1 shall be regarded as equivalent to 1000, 1100, 1400,145, and 1850 MPa respectively. Steels which have been wholly or partly surface hardened shall be considered as being in the category appropriate to the hardness of the surface hardened layer.

Table 1 - Tensile strength of steels

Specified Minimum Tensile Strength MPa	Specified Maximum Tensile Strength MPa
up to 1000	up to 1100
over 1000 up to 1400	over 1100 up to 1450
over 1400 up to 1800	over 1450 up to 1800
over 1800	over 1800

5. INFORMATION TO BE SUPPLIED TO THE PROCESSOR

The following information shall be given on the drawing, contract or order:

a. The number of this AMS Material Specification or its superseded Defence Standard.

b. The specification and metallurgical condition of the basis metal.

c. The significant surface. This may be indicated on the drawing or by marked example.

d. The process to be used.

e. The details of any pre and post-deposition heat treatment.

f. The thickness of the coating required.

g. The details of any necessary undercoat to be applied.

h. The details of any finishing treatment required.

I. The details of any special requirements (e.g., masking).

6. PROCESS CONTROL

6.1 A Process Control Schedule suitable of achieving the requirements of this Standard shall be prepared by the processing contractor(s) prior to the commencement of production.

6.2 Details of the coating process, including all preparatory treatments, post coating treatments, processing, significant surfaces, tests and all other processes and treatments shall be included in the Process Control Schedule.

6.3 All stages in the complete schedule shall follow each other without delay.

7. PRE-TREATMENT AND PREPARATION

All items to be coated shall be prepared and treated in accordance with AMS03-2/Def Stan 03-2 or AMS03-4/Def Stan 03-4 as appropriate.

8. HEAT TREATMENT

If required, steel items shall be stress relieved prior to the electro-deposition of cadmium in accordance with AMS03-2/Def Stan 03-2 or AMS03-4/Def Stan 03-4 as appropriate.

9. SURFACE PREPARATION

All surfaces shall be free from solids such as soap, drawing compounds, oil, grease, machine fluid, polishing compounds, etc., discoloration, oxide scale, or other foreign matter. All items shall be degreased prior to the commencement of a cleaning sequence which shall be in accordance with AMS03-2/Def Stan 03-2 or AMS03-4/Def Stan 03-4 as appropriate, to produce a chemically clean surface. Drying by means of chlorinated solvents is not permitted. Any shot peening of the basis metal shall be carried out before the application of the coating and shall be in accordance with Def Stan 03-21.

10. CADMIUM PLATING

10.1 Electrolyte

10.1.1 Cadmium is normally electro-deposited from a cyanide complex electrolyte, but any other process meeting the requirements of this standard may be used subject to the limitations of AMS03-4/Def Stan 03-4 (see also Section 6).

10.1.2 Addition agents such as are included for the purpose of brightening the deposit can accentuate hydrogen absorption, and shall not be used in electrolytes for plating steels with a specified maximum tensile strength greater than 1100 MPa.

10.1.3 Examples of suitable cyanide electrolytes for vat or barrel plating, with guidance in making up and operation are given in Annex A. The supplier or user of the materials employed for making up and maintaining the electrolyte shall certify them as free from mercury when tested by the method given in Annex B or by any other method agreed with the responsible Technical or Supervising Authority. Care shall be taken to avoid accidental contamination of the electrolyte with mercury.

NOTE: Cadmium plating electrolytes (particularly bright high speed solutions) should be pumped to circulate the electrolyte to avoid a concentration profile in the solution.

10.2 Anodes

Cadmium anodes shall conform to the requirements of BS 2868, in addition they shall be certified by the supplier as free from mercury when tested by the method described in Annex B or by any other method agreed with the responsible Technical or Supervising Authority.

10.3 Material other than Steel

Items made from materials other than steel may, at the discretion of the responsible Technical or Supervising Authority, be plated with a suitable undercoat to an agreed thickness before cadmium plating.

10.4 Locally Chromium Plated Items

Where items are to have local areas hard chromium plated, that operation and any subsequent heat treatment in the range 400 to 480 °C (see AMS03-14/Def Stan 03-14) shall be carried out prior to cadmium plating.

10.5 Thickness Requirements

The electro-deposited coating shall be smooth and adherent, and shall conform to the minimum thickness requirement detailed in Table 2. In certain cases where it is necessary to conform to the tolerance requirements of mating items or where interchangeability considerations apply, it may be necessary to impose additional limitations on the thickness of the coating. In such instances the requirement shall be stated on the drawing, contract or order.

Table 2 - Thickness requirements

Application	Minimum Local Thickness µm	Minimum Average Thickness µm (see Note 1)
1. Normal requirements		
Steels (noncorrosion resisting)	10	14
Copper-base materials and corrosion resisting steels	8	12
2. Threaded items not exceeding 20 mm dia. (see Notes 2 & 3), screws, bolts and nuts of nominal major thread diameter		
Up to 3 mm	-	4
Over 3 mm up to 5 mm	-	4
Over 5 mm up to 13 mm	-	6.5
Over 13 mm up to 20 mm	-	7.5
3. Washers	-	5
4. Rivets, taper pins and split cotters	-	8

NOTE 1 For barrel plated items average thickness is normally based on the whole sample, but if used for vat plated items it is normally based on individual item.

NOTE 2 Thickness requirements for copper based materials are inclusive of nickel undercoating.

NOTE 3 The coating thickness requirements for threaded items are dictated by dimensional tolerance limits. The thicknesses specified will not necessarily provide adequate protection against corrosion in all applications.

11. WASHING

The electroplated items shall be washed in clean running water to remove the electrolyte, then dried.

12. PASSIVATION

12.1 Items shall be chromate passivated to the requirements of BS 6338, unless otherwise specified.

12.2 Items shall be passivated immediately after plating and washing unless requiring relief from hydrogen embrittlement in which case heat treatment shall take place before passivation.

NOTE: Process control of chromate passivation is required to prevent excessive conversion of the cadmium coating.

13. HEAT TREATMENT RELIEF OF HYDROGEN EMBRITTLEMENT

13.1 Plated steel items shall be heat treated in accordance with Table 3 as soon as practicable but within four hours of plating.

Table 3 - Heat treatment requirements

Specified Maximum Tensile Strength MPa	Specified Minimum Tensile Strength MPa	Temperature °C	Time (Minimum) Hours
Up to 1100	Up to 1000	Not Applicable	
Over 1100 up to 1450	Over 1000 up to 1400	190 to 230	8
Over 1450	Over 1400	See AMS03-4/Def Stan 03-4	

13.2 Plated steel items having surface hardened areas, e.g., carburized, and through hardened or bearing steels which would suffer an unacceptable reduction in hardness by treatment in accordance with Table 3 shall be heat treated at a lower temperature but not less than 130 °C for a minimum of 6 hours.

14. INSPECTION

All plated items shall be subject to visual inspection and representative samples as specified below are to be subsequently tested in the following order for adhesion, thickness and freedom from mercury.

15. SELECTION OF TEST SAMPLES

15.1 A sample comprising 1% of each vat or barrel load, but not less than 8 items or more than 48 shall be selected for tests, the number of items selected to be such that significant weighing errors are avoided.

15.2 Where a continuous form of vat plating is in operation, representative samples shall selected at intervals of not more than one hour.

15.3 The sample shall be divided into equal parts, one part for thickness tests and one part for adhesion tests.

15.4 In exceptional circumstances, e.g., the vat plating of a single large item or the barrel plating of a small number of items, the sampling procedure specified in 15.1, 15.2, and 15.3 may be modified. Coupon samples plated together with the items may be used, due consideration being given to their shape, size, material, and if applicable, position in the vat. The treatment of the coupon samples shall be representative of that applied to the items being plated.

15.5 If any part of a sample fails a test, a further sample shall be selected and the test repeated. If this sample fails, the vat or barrel load represented by this test shall be rejected.

16. VISUAL INSPECTION

At the conclusion of all processing all items shall be inspected to ensure that the coating is smooth, continuous, uniform in appearance, is free from stains, burns, blisters, exfoliation, pits, nodules, cracks, porosity, uncoated areas, excessive edge build up or other defects and show no indication of improper use of equipment. Items shall be clean and free from damage. Unavoidable contact marks may be allowed with prior agreement of the responsible Technical or Supervising Authority.

17. ADHESION

When tested in accordance with either of the methods described in Annex C, there shall be no indication of the deposit becoming blistered or otherwise detached from the base metal.

18. THICKNESS OF COATING

18.1 General

Local thickness tests shall be made except that, with prior agreement of the responsible Technical or Supervising Authority, an average thickness test may be substituted on items, such as small barrel plated items, which are considered unsuitable for local thickness determination.

18.2 Local Thickness

The local thickness of the coating shall be determined by one or more of the following methods:

a. Micro-sectioning (BS EN ISO 1463)

b. Coulometric (BS EN ISO 2177)

c. Electromagnetic (BS EN ISO 2178) (ferrous substrates)

d. Beta backscatter (BS EN ISO 3543)

e. X-ray spectrometic (BS EN ISO 3497)

The referee method is the micro-section method (BS EN ISO 1463).

18.3 Average Thickness

18.3.1 The average thickness of the cadmium coating and where applicable, the nickel undercoat, shall be determined by the weight loss methods described in Annex D.

18.3.2 For barrel plated items the average thickness shall be based on the whole sample, but if used for vat plated items it shall be carried out on the individual items comprising the sample.

19. FREEDOM FROM MERCURY

Evidence of freedom from mercury in coatings shall be proven by periodic testing in accordance with the method given in Annex B or any other method defined in the Process Control Schedule.

20. RE-TREATMENT OF ITEMS REJECTED ON INSPECTION

20.1 If for any reason items are required to be stripped of their coating and recoated the procedure shall be in accordance with a Process Control Schedule agreed by the responsible Technical or Supervising Authority.

20.2 Steel items shall be reprocessed immediately after stripping.

20.3 Steel items with specified maximum tensile strengths over 1450 MPa shall not be reprocessed without the prior written agreement of the responsible Technical or Supervising Authority.

21. NOTES

21.1 A change bar (l) 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.

UNDER THE JURISDICTION OF AMS COMMITTEE "B"

ANNEX A - COMPOSITION AND PREPARATION OF SUITABLE ELECTROLYTES

A.1 COMPOSITION

A.1.1 For Vats

Cadmium	14 to 17 g/l
Total cyanide (as NaCN)	46 to 63 g/l
Sodium hydroxide	11 to 14 g/l
Suitable addition agents may be included in the electrolyte if desired	
Temperature	15 to 35 °C
Current density	50 to 100 A/m^2

A.1.2 For Barrels

Cadmium	23 to 27 g/l
Total cyanide (as NaCN)	94 to 100 g/l
Sodium hydroxide	19 to 38 g/l
Suitable addition agents may be included in the electrolyte if desired	
Temperature	15 to 35 °C
Current density (approx)	50 A/m^2

A.1.3 For Vats and Barrels ("High Speed" Bright Plating Electrolyte)

Cadmium	10 to 25 g/l
Total cyanide (as NaCN)	94 to 137 g/l
Sodium hydroxide	19 to 38 g/l
It is essential that this electrolyte shall be used with a suitable addition agent	
Temperature	15 to 35 °C
Current density (approx)	300 A/m^2

A.2 PREPARATION

Electrolytes, having approximately the composition of those given above, may be prepared using cadmium cyanide or cadmium oxide to provide the metal content, from the following formulae:

A.2.1 For A.1.1 (Vats)

Cadmium cyanide	25	g/l
Sodium cyanide	43	g/l
Sodium hydroxide	12	g/l
or		
Cadmium oxide	19	g/l
Sodium cyanide	58	g/l

A.2.2 For A.1.2 (Barrels)

Cadmium cyanide	38	g/l
Sodium cyanide	75	g/l
Sodium hydroxide	19	g/l
or		
Cadmium oxide	29	g/l
Sodium cyanide	97	g/l

A.2.3 For A.1.3 (Vats and Barrels, "High Speed" Electrolyte)

Cadmium cyanide	32	g/l
Sodium cyanide	106	g/l
Sodium hydroxide	31	g/l
or		
Cadmium oxide	25	g/l
Sodium cyanide	125	g/l
Sodium hydroxide	16	g/l