MINISTRY OF AVIATION

D.T.D. 904C

(Superseding D.T.D. 904B)
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Process Specification
CADMIUM PLATING

NOTE 1. Cadmium plating followed by chromate passivation, with or without the addition of organic protectives as required by the design document, is the preferred method of protecting close-tolerance steel parts against corrosion. It is particularly useful for reducing or avoiding bimetallic corrosion and is suitable for soldering.

NOTE 2. Cadmium plating is liable to rapid attack by vapours emanating from certain woods, varnishes, plastics and other organic materials, particularly in poorly ventilated or humid conditions (see Defence Guide DG-3).

1. Scope

1.1 This specification covers the requirements for cadmium plating of carbon steel and low alloy steel parts for protection against corrosion. Parts made of steel of specified minimum tensile strength exceeding 90 tonf/in² or of equivalent hardness (see Clause 2.3) are subject to the special limitations and requirements of D.T.D. 934. The specification also covers the requirements for cadmium plating of copper-base materials and corrosion-resisting steels for the reduction of contact corrosion of less noble metallic materials.

1.2 Cadmium plating shall not be used on parts which are liable to be subjected to temperatures in excess of 250°C (480°F).

2. General

2.1 The treatments required for steel parts before and after cadmium plating depend partly on: —

(a) the tensile strength (or hardness) of the steel

(*b*) the presence of surface-hardened areas

(*c*) the need or otherwise for stress-relieving heat treatment

(*d*) the type of steel, i.e., carbon, low alloy, or corrosion-resisting.

2.2 The Design Authority or main contractor shall give the plater instructions regarding the treatments to be applied under Clauses 3, 5 and 6 or, alternatively, the information necessary to enable the plater to select appropriate treatments under these clauses.

2.3 If no minimum tensile strength is specified for the steel, the treatments shall be based on the specified minimum hardness. For the purpose of this specification, steels having hardness values of 300 HV or 295 HB and 430 HV or 405 HB shall be regarded as having tensile strengths of 65 and 90 tonf/in² respectively.

3. Pre-treatment

3.1 *Steels, carbon and low alloy.* Stress-relieving heat treatment (if required) and preparation for plating shall be carried out in accordance with D.T.D. 901.

3.2 *Steels, corrosion-resisting.* These shall be cleaned and prepared as described in D.T.D. 901.

3.3 *Steel parts locally chromium plated.* Parts which are to be chromium plated locally and then heated in the range 440—480°C (825—895°F) as described in D.T.D. 916, shall be given these treatments before cadmium plating.

3.4 *Copper-base materials.* These shall be cleaned in accordance with D.T.D. 901 and shall be plated with nickel, preferably to a thickness of 0·00005—0·0001 in before cadmium plating.

4. Plating

4.1 *Electrolyte*

4.1.1 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 Appendix II or by any other method approved by the Inspecting Authority. Care shall be taken to avoid accidental contamination of the electrolyte with mercury.

Note. Cadmium is usually deposited from a cyanide electrolyte. Where freedom from hydrogen embrittlement is a primary consideration the use of other electrolytes, e.g., modified cyanide or fluoborate, may be advantageous. Some of these electrolytes, however, have a lower throwing power than the normal cyanide electrolyte. Addition agents such as are used to improve the properties or appearance of the coating may accentuate hydrogen absorption during plating. Examples of suitable cyanide electrolytes for vat and barrel plating, with guidance in making up and operation, are given in Appendix I for information.

4.2 *Anodes.* Cadmium anodes shall conform to the requirements of B.S. 2868, and in addition shall be certified by the supplier as free from mercury when tested by the method given in Appendix II or by any other method approved by the Inspecting Authority.

5. Treatment after plating

5.1 *Washing procedure.* Parts shall be washed in clean running water immediately after plating and, unless they are to be immediately passivated (see Clause 5.2) without drying, shall then, unless specifically prohibited by the Design Authority, be dipped in a 5 per cent (8 oz per gal) aqueous solution of sodium dichromate or chromic acid free from other acids, maintained at a temperature of not less than 60°C (140°F), for 15 to 30 seconds. They shall then be washed in clean running water, finally in warm water, and dried.

5.2 *Chromate passivation*

5.2.1 Parts shall normally be chromate passivated. The passivation shall conform to DEF-130. Passivation may only be omitted when the parts are to be etch primed or at the specific request of the Design Authority.

5.2.2 Parts not required to be heated for removal of embrittlement (see Clause 6) shall be passivated immediately after plating and washing, without intermediate drying. Parts made of high tensile steel shall be heated for removal of embrittlement before chromate passivation.

Note. In order to avoid staining it may be found desirable in some districts to use demineralised water in washing or chromate dip operations.

6. Removal of embrittlement

6.1. All plated steel parts of minimum specified tensile strength of 65 tonf/in² or greater (or of equivalent hardness) shall be heated as described below as soon as is practicable but not more than 16 hours after plating. This treatment shall also be applied to parts of this tensile strength after any stripping, except that the minimum time of heating of stripped parts may be reduced to not less than half of that specified for plated parts. Parts of minimum specified tensile strength exceeding 90 tonf/in² shall not be replated without the consent of the Design Authority.

6.2 Plated parts, other than those with carburised areas (see Clause 6.3), or certain bolts (see Clause 6.4), made of steel of minimum specified tensile strength of 65 tonf/in² or greater, up to and including 90 tonf/in², shall be heated at a temperature within the range 190°C to 210°C (375°F to 410°F) for not less than 4 hours. Parts of minimum specified tensile strength exceeding 90 tonf/in² shall be heated in accordance with the requirements of D.T.D. 934.

6.3 Plated steel parts having carburised areas which would suffer an unacceptable reduction in hardness by treatment as in Clause 6.2 shall be heated at not less than 130°C (265°F) for not less than 6 hours.

6.4 Plated bolts of less than ½ in nominal diameter made of steel of minimum specified tensile strength of 65 tonf/in² or greater, up to and including 75 tonf/in², which have been thread rolled and rolled under the head after final heat treatment, shall be heated at a temperature within the range 190° to 230°C (375° to 445°F) for not less than 2 hours.

7. Inspection

7.1 *Visual.* Before chromate passivation (Clause 5.2) or chromate dipping (Clause 5.1) the coating shall be smooth and white (matt or bright) and of uniform appearance. The coating shall be free from "burns" or blisters, and shall appear to be adherent and continuous. The part or parts shall not have developed any defect as a result of the plating process.

7.2 *Selection of test samples*

7.2.1 *Parts plated by the vat process.* The Inspector shall select a sample, normally comprising at least two parts, to represent each vat load. Where a continuous form of vat plating is in operation, a representative sample shall be taken at intervals of not more than one hour. Each part in the sample shall be tested for freedom from porosity (where applicable), adhesion and thickness, the tests being carried out in this order. The mean of the local thickness or the average thickness for each part shall not be less than that specified in Table 1. The difference between the coating thickness of the parts (mean local thickness or average thickness as appropriate) shall not exceed 50 per cent of the thickness specified in Table 1.

7.2.2 *Parts plated by the barrel process*

(i) The Inspector shall select a sample, normally comprising ten parts of more, from each group of parts of the same size and shape from each barrel load for freedom from porosity (where applicable), adhesion and thickness tests. The number of parts selected shall be such that significant weighing errors are avoided.

(ii) For each group of not more than one hundred parts of the same size and shape plated together, the Inspector shall select a sample, normally comprising two or more parts, for freedom from porosity (where applicable), adhesion and thickness tests. The number of parts selected shall be such that significant weighing errors are avoided.

7.2.3 *Parts plated in small numbers.* In exceptional circumstances, e.g., the vat plating of single large parts or the barrel plating of small numbers of parts, the sampling procedure specified in Clause 7.2.2 (i) or (ii) may be modified at the discretion of the Inspecting Authority. In suitable instances coupon samples 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 suitably representative of that applied to the parts being plated.

7.3 *Freedom from porosity.* Freedom from porosity shall be determined by the method in Appendix III. Active evolution of hydrogen shall not occur but infrequent bubbling shall not normally lead to rejection. This test is applicable to all steel parts cadmium plated all over, except screws and bolts of major

thread diameter not exceeding 0·126 in (see Table 1) and parts made from corrosion-resisting steels. Internal threads, driver slots and sockets and similar shielded areas are also excepted at the discretion of the Inspector. Large or complex parts plated to the normal requirement of thickness (see Table 1) may be excepted from the porosity test at the discretion of the Design Authority.

7.4 *Thickness of coating*

7.4.1 *General*

(i) The thickness of cadmium coating shall be reasonably uniform and when tested as described in Clause 7.4.2 or 7.4.3 shall comply with the minimum requirement shown in Table 1. Wherever practicable the local thickness test (Clause 7.4.2) shall be used.

(ii) For certain parts, where it is necessary to conform to the tolerance requirements of mating parts or where interchangeability considerations apply, e.g., screw threads, it may be necessary to impose an upper limit on the thickness of deposit. In such instances the maximum thickness requirement shall be stated on the order. Alternatively, the plater shall be supplied with a drawing containing this information.

7.4.2 *Local thickness.* The local thickness of cadmium shall be determined by the B.N.F. Jet Test or other local test method approved by the Inspecting Authority for the parts concerned.

The points selected for test shall be not less than ¼ in from an edge and the tests on any one part shall normally be not less than four in number. Wherever practicable the tests shall be made at points which are widely separated and which would be expected to be comparatively thinly coated, but normally the points selected shall each be capable of being touched by a sphere of 1 in diameter. When the full specification thickness of coating is required on shielded areas, this shall be stated on the drawing or order and the test procedure shall be suitably modified.

The local thickness requirements of Table 1 shall normally apply to parts plated by the vat process except that, at the discretion of the Inspector, an average thickness test may be used for parts unsuitable for local thickness test or which, by virtue of their size, shape or the method of plating (e.g., where auxiliary anodes are used) would be expected to be reasonably uniformly coated.

7.4.3 *Average thickness.* The average thickness shall be determined by the stripping-and-weighing methods described in Appendices IV and V or by any method approved by the Inspecting Authority. The average thickness requirements of Table 1 shall normally apply to parts plated by the barrel process.

7.5 *Adhesion.* When the shape and size of the part permits, a small area of the plated surface, selected at the discretion of the Inspector, shall be rubbed rapidly and firmly with a suitable tool for about 15 seconds and visually inspected when there shall be no indication of the deposit becoming blistered or otherwise detached from the basis metal. The pressure applied shall be sufficient to burnish the coating at each stroke but not to cut the deposit.

Note. A suitable tool is a steel rod of ¼ in diameter with a smooth hemispherical end or a copper disc used edgewise and broadside.

7.6 *Freedom from mercury.* Tests for mercury in the deposit shall be made periodically at the discretion of the Inspector. Mercury shall not be detectable when the deposit is tested by the method given in Appendix II or by any other method approved by the Inspecting Authority.

TABLE 1

Thickness requirements

	Local thickness, in, minimum	Average thickness,* in, minimum
1. Normal requirements		
(i) Steels, carbon and low alloy	0·0004	0·0006
(ii) Copper-base materials and corrosion-resisting steels	0·0003	0·0005
2. Threaded parts not exceeding 0·75 in diameter † ‡		
Screws, bolts and nuts of nominal major thread diameter:—		
(i) up to and including 0·126 in	—	0·00015
(ii) 0·127 in to 0·249 in inclusive	—	0·00020
(iii) 0·250 in to 0·375 in inclusive	—	0·00025
(iv) 0·376 in to 0·75 in inclusive	—	0·00030
3. Washers		
(i) up to and including 0·126 in nominal bore	—	0·00020
(ii) exceeding 0·126 in nominal bore	—	0·00030
4 Rivets, taper pins and split cotters	—	0·00030

*For barrel-plated parts average thickness is normally based on the whole sample, but if used for vat-plated parts is normally based on individual parts.

†Thickness requirements for threaded copper-base materials are inclusive of nickel undercoating.

‡The coating thickness requirements for threaded parts are dictated by dimensional tolerance limits. Such thicknesses will not necessarily provide adequate protection against corrosion.

APPENDIX I

Composition and preparation of suitable electrolytes

1. Composition

(*a*) *For vats*

Cadmium	2·25-2·75 oz/gal (14-17 g/l)
Total cyanide (as NaCN)	9-10 oz/gal (56-63 g/l)
Sodium hydroxide	1·75-2·25 oz/gal (11-14 g/l)

Suitable addition agents may be included in the electrolyte if desired (see Clause 4, Note).

Temperature	15-35°C (59-95°F)
Current density, approx.	7-10 amp/sq ft

(*b*) *For barrels*

Cadmium	3·75-4·25 oz/gal (23-27 g/l)
Total cyanide (as NaCN)	15-16 oz/gal (94-100 g/l)
Sodium hydroxide	2·75-3·25 oz/gal (17-20 g/l)

Suitable addition agents may be included in the electrolyte if desired (See Clause 4, Note).

Temperature	15-35°C (59-95°F)
Current density, approx.	5 amp/sq ft

(*c*) *For vats and barrels ("high-speed" bright plating electrolyte)*

Cadmium	3-4 oz/gal (19-25 g/l)
Total cyanide (as NaCN)	15-22 oz/gal (94-137 g/l)
Sodium hydroxide	3-6 oz/gal (19-38 g/l)

It is essential that this electrolyte shall be used with a suitable addition agent.

Temperature	15-35°C (59-95°F)
Current density, approx.	30 amp/sq ft

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:—

For 1 (*a*) (*Vats*)

Cadmium cyanide	4·0 oz/gal (25 g/l)
Sodium cyanide	6·9 oz/gal (43 g/l)
Sodium hydroxide	1·5 oz/gal (9 g/l)
or	
Cadmium oxide	3·1 oz/gal (19 g/l)
Sodium cyanide	9·3 oz/gal (58 g/l)

For 1 (*b*) (*Barrels*)

Cadmium cyanide	6·0 oz/gal (38 g/l)
Sodium cyanide	12·0 oz/gal (75 g/l)
Sodium hydroxide	3·0 oz/gal (19 g/l)
or	
Cadmium oxide	4·7 oz/gal (29 g/l)
Sodium cyanide	15·5 oz/gal (97 g/l)

For 1 (*c*) (*Vats and barrels, "high-speed" electrolyte*)

Cadmium cyanide	5·1 oz/gal (32 g/l)
Sodium cyanide	17·0 oz/gal (106 g/l)
Sodium hydroxide	5·0 oz/gal (31 g/l)
or	
Cadmium oxide	4·0 oz/gal (25 g/l)
Sodium cyanide	20·0 oz/gal (125 g/l)
Sodium hydroxide	2·5 oz/gal (16 g/l)

APPENDIX II

Detection of mercury

1. Mercury in salts

Make up as required an alkaline stannous chloride solution by dissolving 1·2g of stannous chloride in 20 ml of water, disregarding the precipitate formed by hydrolysis. Pour whilst stirring into 20 ml of 20 per cent sodium hydroxide solution, and continue stirring until the precipitate is dissolved.

Using the salts to be tested, dissolve in water 10g of sodium cyanide, 6g of sodium hydroxide and 10g of cadmium cyanide in the order given, filter and dilute to 100 ml in a Nessler cylinder.

Alternatively, if cadmium oxide is used to make up the bath instead of cadmium cyanide, dissolve 15g of sodium cyanide and 6g of cadmium oxide, filter and dilute.

Add 2 ml of the alkaline stannous chloride and mix. A turbidity indicates the presence of mercury and is visible if 0·0002g or more is present.

2. Mercury in electrolyte

Test 100 ml of solution with alkaline stannous chloride as described in 1 above.

3. Mercury in anodes

Dissolve 5g of the anode in 50 ml of nitric acid (sp. gr. 1·42). Dilute the solution with about 50 ml of water, boil to remove oxides of nitrogen, and cool. Dilute the solution further to 100 ml in a Nessler cylinder. Immerse a 3 in length of clean 16 S.W.G. copper wire in the solution and allow to remain for 15 minutes. A deposit on the copper wire indicates the presence of mercury, and will be seen if 0·004 per cent or more is present in the anode.

4. Mercury in coating

Cut a piece of clean steel sheet 4½ in x 4½ in which has been electro-plated to produce a cadmium coating 0·0002 in thick into pieces 1½ in square and place the pieces in a 250 ml beaker. Pour 25 ml of hot nitric acid (sp. gr. 1·42) over the pieces, completely covering them, and swirl the beaker until effervescence has ceased. Transfer the liquid to another beaker, rinse the specimens with cold distilled water and add the rinsings to the main solution. Boil the solution to remove oxides of nitrogen, cool and dilute to 100 ml in a Nessler cylinder, and test as in 3 above. A deposit will be visible on the copper wire if the test solution contains 0·0002g or more of mercury.

APPENDIX III

Determination of freedom from porosity

Clean the sample carefully in a suitable solvent vapour and totally immerse it in a solution of 1 per cent (vol.) of hydrochloric acid (sp. gr. 1·16) at room temperature for 5 minutes. The treatment is non-destructive of the coatings and samples which pass the test should be washed thoroughly in hot water and dried. The test is not suitable for non-ferrous or corrosion-resisting steel parts.

APPENDIX IV

Determination of average thickness of cadmium coating

Clean the plated sample in a suitable solvent vapour, weigh and then totally immerse in a solution prepared by dissolving 30g of ammonium nitrate in 100 ml of water. Stir the solution occasionally until the plating is dissolved, 10 minutes being usually sufficient. Remove the sample from the solution, wash, dry, and reweigh.

$$\text{Cadmium thickness (in)} = \frac{\text{Loss in weight (g)}}{\text{Area (sq in)} \times 141}$$

APPENDIX V

Determination of average thickness of nickel undercoat on copper-base materials

After the thickness of the cadmium coating has been estimated, immerse the sample in a solution of 70 per cent (vol.) sulphuric acid (sp. gr. 1·84) with a little glycerine added. Treat anodically at 6-12 volts. Immediately solution of the nickel is complete, remove sample, wash rapidly, dry and reweigh.

$$\text{Nickel thickness (in)} = \frac{\text{Loss in weight (g)}}{\text{Area (sq in)} \times 146}$$

Approved for issue,

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Director of Materials Research and Development.

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