BRITISH STANDARD

BS 1706:1990

*Incorporating Amendment No. 1*

## Method for specifying

# Electroplated coatings of zinc and cadmium on iron and steel

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# Committees responsible for this British Standard

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British Constructional Steelwork Association Ltd.
British Industrial Fasteners Federation
British Lock Manufacturers' Association
British Malleable Tube Fittings Association
British Metal Finishing Suppliers' Association
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# Foreword

This British Standard has been prepared under the direction of the Surface Coatings (other than Paints) Standards Policy Committee. It is based on the international standards ISO 2081:1986 "Metallic coatings – electroplated coatings of zinc on iron or steel", and ISO 2082:1986 "Metallic coatings – electroplated coatings of cadmium on iron or steel" which were prepared with the active participation of the United Kingdom by Subcommittee 3, Electrodeposited coatings and related finishes, of Technical committee 107, Metallic and other non-organic coatings, of the International Organization for Standardization (ISO). It describes a method for specifying zinc and cadmium coatings for the protection of iron and steel under various corrosive conditions. It revises and supersedes BS 1706:1960 which is withdrawn.

BS 1706 was first published in 1951 and last revised in 1960. This revision of the standard brings the technical content up to date and in line with that of ISO 2081 and ISO 2082. **It differs from the previous edition of BS 1706 in that it has been drafted as a method for specifying and not as a specification. For this reason it is no longer appropriate for a claim to be made that a coating complies with BS 1706:1988.**

The other main changes in the content of the standard are the different choice of coating thicknesses and the revised heat treatment conditions for minimizing the risk of hydrogen embrittlement failures of articles made from high strength steel.

CAUTION. Cadmium vapour is toxic by inhalation. During heat treatment, therefore, all precautions should be taken to ensure that no person is exposed to it.

Because of its toxicity, it is essential that cadmium is not employed as a coating for any object likely to come into contact with food or beverages. Attention is also drawn to the danger arising from welding, soldering or heating as its vapour is toxic.

The surface condition of the basis material is not specified in this standard.

Chromate conversion coatings on top of electroplated coatings of cadmium or zinc give additional protection against corrosion and should normally be specified. Zinc or cadmium electroplated articles to be painted may require alternative treatment such as phosphating to promote good adhesion.

CAUTION. Chromates can cause dermatitis so skin contact with chromated components should be avoided as much as possible.

Zinc and cadmium electroplated articles are subject to attack by certain organic materials, e.g. cardboard, wood or certain electrical insulating materials which emit reactive vapours. Cognizance of this should be taken when articles are packed, stored or transported.

Attention is drawn to the fact that electroplated cadmium is more readily soldered than electroplated zinc.

It is essential that the purchaser specifies all his requirements and provides at least all the essential information (see **3.1**) to the electroplater; merely to ask for electroplating to be carried out in accordance with BS 1706 without this information is insufficient.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

**Compliance with a British Standard does not of itself confer immunity from legal obligations.**

**Summary of pages**

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 6, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

## 1 Scope

This British Standard describes a method for specifying electroplated coatings of cadmium or zinc on iron or steel for protection against corrosion. It does not apply to coatings applied to sheet, strip or wire in the unfabricated form.

It gives information to be supplied by the purchaser to the electroplater and information on coating thicknesses and chromate treatments. It also includes requirements for heat treatment both before and after electroplating.

NOTE 1 The coating thickness that can be applied to threaded components may be limited by dimensional requirements, including class or fit. Attention is drawn to BS 3382 which includes tables specifying the maximum thicknesses that can be applied to standard threads.

NOTE 2 The titles of the publications referred to in this standard are listed on the inside back cover.

## 2 Definitions

For the purpose of this British Standard the following definitions, as given in BS 5411-1, apply.

**2.1**
**significant surface**

the part of the article covered or to be covered by the coating and for which the coating is essential for serviceability and/or appearance

**2.2**
**local thickness**

the mean of the thickness measurements, of which a specified number is made within a reference area

**2.3**
**minimum local thickness**

the lowest value of the local thicknesses found on the significant surface of a single article
(see also **7.3.1**)

**2.4**
**reference area**

the area within which a specified number of single measurements is required to be made

## 3 Information to be supplied by the purchaser to the electroplater

NOTE A summary of clause references pertaining to this information is given in Table 1.

**Table 1 — Summary of information required**

| Information required | Relevant clauses | | Other related clauses |
|---|---|---|---|
| | Essential information | Additional information required | |
| Reference (i.e. the number of this British Standard) | **3.1 a)** | | |
| Coating classification code | **3.1** b) | | **5.2** |
| Significant surface | **3.1** c) | **3.2** b) | **7.1**, **7.2**, **7.3**, **8.1** |
| Basis material | **3.1** d) | | Clause **4** |
| Appearance | **3.1** e) | | **7.2** |
| Heat treatment | **3.1** f) | | **7.6**, appendix A |
| Chromate or other conversion coatings | **3.1** g) | | **7.5** |
| Corrosion resistance | **3.1** h) | | **8.2** |
| Sampling | **3.1** i) | | Clause **6** |
| Area for thickness determination on small articles of complex shape | **3.1** j) | | **8.1**, appendix B |
| Contact marks | | **3.2** a) | **7.2** |
| Additional significant surfaces | | **3.2** b) | **7.1** |

### 3.1 Essential information

The information listed in a) to i) shall be supplied by the purchaser to the electroplater, if necessary in consultation with the electroplater.

a) The number of this British Standard, i.e. BS 1706.

b) The classification code (see clause **5**).

c) The significant surface indicated, for example, by drawings or by the provision of suitably marked samples (see **7.1**).

d) The nature and surface condition of the basis material (see clause **4**).

e) The surface appearance of the coating (see **7.2**).

f) Any requirements for heat treatment before or after electroplating and, for steels, a statement of the maximum tensile strength (see **7.6** and appendix A).

g) A statement as to whether or not chromate coating is to be omitted and, if omitted, as to whether or not another type of conversion coating is to be applied (see **7.5**).

h) Whether or not the chromate coating, if applied, is to be subjected to a corrosion test (see **8.2**).

i) The sampling procedure to be used, any special inspection requirements and details of the sampling and acceptance levels (AQL) required (see clause **6**).

j) If appropriate, the area to be used for the determination of local thickness on small articles of complex shape and the method of measuring such an area (see **8.1** and appendix B).

### 3.2 Additional information

The additional information listed in a) and b), as applicable, shall be supplied by the purchaser, if necessary in consultation with the electroplater.

a) The location of areas of surface that can be used for connecting parts to jigs or racks and where contact marks are acceptable (see **7.2**).

b) An indication of those parts of the surface of the article that cannot be touched by a ball of diameter 20 mm but which are to be included in the significant surface (see **7.1**).

## 4 Basis material

The nature of the basis material shall be specified by the purchaser to the electroplater (see **3.1** d)).

NOTE This British Standard does not specify requirements for the surface condition of the basis material before electroplating with zinc or cadmium but agreement should preferably be reached between the interested parties that the surface finish of the basis material is not too rough to prevent the appearance and/or the serviceability of the coating from being satisfactory.

## 5 Service conditions and classification code

**5.1** The purchaser shall supply the following information to the electroplater by quoting the appropriate classification code described in **5.2** (see also **3.1** b) and **3.1** g)

a) the chemical identity of the basis material;

b) the chemical identity of the coating;

c) the minimum local thickness of the coating;

d) the identity of the chromate conversion coating or other type of conversion coating required, unless this is to be omitted.

NOTE The thickness of the coating required depends on the severity of the service conditions and on the service life required. Classes Fe/Cd 5 and Fe/Zn 5 (see **5.2**) are recommended only for dry, indoor conditions. As the service conditions become more severe
and/or the life required increases, coatings with greater thickness should be specified.

**5.2** The classification code consists of the following parts, the first two of which are separated by an oblique stroke:

*a*/*b* *c* *d*

where

*a* indicates the chemical symbol, i.e. Fe, for the basis material (iron or steel);

*b* indicates the chemical symbol for cadmium, Cd, or for zinc, Zn, as appropriate;

*c* indicates the minimum local thickness (in micrometres) of the cadmium or zinc coating;

*d* indicates the chromate conversion coating required. This is indicated by a lower case c followed by the class and designation of the coating (see Table 3). It is omitted if a chromate conversion coating is not required. Details of other types of conversion coating are given separately.

**5.3** A typical example of a complete classification code is

Fe/Zn 8 c 1A

i.e. a coating on steel of zinc of minimum local thickness 8 $\mu$m with a class 1A chromate conversion coating.

**5.4** Table 2 shows the coating classification code and the corresponding minimum local thickness (see **7.3**) of coatings prior to chromate treatment, if carried out, and an indication of their relationship to service conditions and to service life. It should be noted however that equal thicknesses of cadmium and zinc do not normally give the same service life under identical service conditions.

## 6 Sampling

Unless otherwise specified, the sampling procedure shall be selected from BS 6001 or BS 6041. The sampling and acceptance levels (AQL) required shall be agreed between the purchaser and the electroplater.

## 7 Coatings

### 7.1 Significant surface

Unless otherwise specified by the purchaser those parts of the surface of an article which cannot be touched by a ball of diameter 20 mm shall not be considered part of the significant surface (see **3.2** b)).

**Table 2 — Typical coating classification codes, thickness, service condition and service life**

| Service condition or service life | Classification code, cadmium[a] | Classification code, zinc[a] | Minimum local thickness |
|---|---|---|---|
| | | | $\mu$m |
| Increasing severity of | Fe/Cd 5 | Fe/Zn 5 | 5 |
| service | Fe/Cd 8 | Fe/Zn 8 | 8 |
| condition or life | Fe/Cd 12 | Fe/Zn 12 | 12 |
| required | Fe/Cd 25 | Fe/Zn 25 | 25 |

[a] Followed by the appropriate symbol (see **7.5**) for the chromate conversion coating, when present. Details of other conversion coatings shall be given separately.

NOTE 1 In any particular environment, the protective value of a zinc coating is directly proportional to its thickness. Therefore a zinc coating of 40 $\mu$m thickness may also be used for special purposes.

NOTE 2 When a very long service life is required, as for example on structural steel components, the thicker zinc coatings required are usually applied by hot-dip galvanizing (see BS 729), by zinc spraying (see BS 2569) or by sherardizing (see BS 4921).

### 7.2 Appearance

Over the significant surface, the electroplated article shall be free from clearly visible plating defects such as blisters, pits, roughness, cracks or unplated areas. On articles where a contact mark is unavoidable, its position shall, if appropriate, be specified by the purchaser, preferably by the provision of a suitably marked sample (see **3.2** a)).

The articles shall be clean and free from damage. Unless specified otherwise by the purchaser (see **3.1** e)), the coatings shall be bright.

NOTE Heat treatment may cause a slight dullness in the coating appearance.

### 7.3 Thickness of coatings

#### 7.3.1 *Minimum local thickness*

The minimum local thickness requirement of the coating, as indicated by the classification code (see **5.2**), applies to any part of the significant surface (see **7.1**).

#### 7.3.2 *Thickness of coatings on small articles*

In the case of articles having a significant surface area less than 100 mm$^2$ the minimum local thickness is deemed to be the minimum value of the average thickness determined by the method specified in **8.1**.

### 7.4 Adhesion

The coating shall continue to adhere to the basis metal when subjected to the test described in **B.2**.

### 7.5 Application of conversion coatings

Conversion coatings, particularly chromate coatings, enhance the corrosion resistance of the electrodeposited cadmium and zinc coatings, and chromate coatings shall only be omitted, or replaced by other conversion coatings, if specified by the purchaser (see **3.1** g)). The types of chromate coating which can be produced on electrodeposited cadmium and zinc coatings are summarized in Table 3 and described more fully in BS 6338. (See also **5.4**).

### 7.6 Heat treatment

If the purchaser specifies that stress relief or hydrogen embrittlement relief is required (see **3.1** f)), the necessary heat treatment shall be carried out in accordance with appendix A. The purchaser shall also indicate the maximum tensile strength of steels if they form the basis material.

NOTE Attention is drawn to the note to appendix A.

**Table 3 — Classification of chromate coatings**

| Class | Designation | Type | Typical appearance |
|---|---|---|---|
| 1 | A | Clear | Transparent clear, sometimes with a bluish tinge |
| | B | Bleached | Transparent with slight iridescence |
| 2 | C | Iridescent | Yellow iridescent |
| | D | Opaque | Olive green, shading to brown or bronze |

NOTE 1 Finishes may be characterized by class alone or by class and type designation (see BS 6338).

NOTE 2 In addition, black coatings can be produced by several methods. Such coatings may have different degrees of corrosion protection.

# 8 Tests

## 8.1 Measurement of local thickness

The local thickness of the coating shall be determined by one of the methods described in BS 5411-4, BS 5411-5, BS 5411-7, and BS 5411-11. In the case of dispute, the method described in BS 5411-4 shall be used except for articles having a significant surface less than 100 $mm^2$ when the method described in **B.1** shall be used.

NOTE 1 If the coatings are rough or matt, the microscopical (BS 5411-5) and profilometric (BS 5411-7) methods may give unreliable results, and magnetic methods may give measurements which are somewhat greater than those of smooth coatings of the same mass.

NOTE 2 Prior to the use of the method specified in BS 5411-4, it is necessary to remove the chromate or other conversion coating using a very mild abrasive, e.g. a paste of levigated alumina. In the case of heavy conversion coatings, the results will, therefore, be slightly low.

## 8.2 Corrosion resistance of the chromate film

If specified by the purchaser (see **3.1** h)), parts shall be subjected to the corrosion test specified in BS 5466-1. in such cases the time taken for formation of white corrosion products on chromated zinc or cadmium coatings shall be not less than the values given in Table 4. The chromate coatings shall be allowed 24 hours to harden before testing is carried out.

NOTE The edges of the test specimens should be excluded from the test area.

**Table 4 — Requirements for corrosion resistance of chromate coatings**

| Designation (see Table 3) | Possible classifications | Minimum time to formation of white corrosion products |
|---|---|---|
| | | h |
| A | 1, 1A | 6 |
| B | 1B | 24 |
| C | 2, 2C | 72 |
| D | 2D | 96 |

# Appendix A. Heat treatment

NOTE Work is at present being undertaken that may further refine the contents of this appendix.

## A.1 General

In all cases, the duration of heat treatment shall commence from the time at which the whole of each part attains the specified temperature.

NOTE Parts made from steels with maximum tensile strengths greater than 1050 MPa (corresponding hardness values approximately 34 HRC, 340 HV or 320 HB) and surface-hardened parts will require heat treatment. Preparation involving cathodic treatments in alkaline or acid solutions should be avoided. Additionally, the selection of electroplating solutions with high cathodic efficiencies is recommended for steel components with tensile strengths greater than 1450 MPa (corresponding hardness values approximately 45 HRC, 440 HV or 415 HB).

## A.2 Categorization of steels

**A.2.1** With the exception of surface-hardened parts (see **A.3.2** and **A.4.2**), the heat treatment conditions are selected on the basis of the specified maximum tensile strength. Steels are categorized according to specified maximum tensile strength according to Table 5. If the steel is specified only in terms of minimum tensile strength, the corresponding maximum tensile strengths shall be determined from Table 5.

**A.2.2** If neither maximum nor minimum strength is specified for the steel, Vickers hardness values of 320 HV, 440 HV and 560 HV shall be regarded as equivalent to maximum tensile strengths of 1050 MPa, 1450 MPa and 1800 MPa, respectively, and the heat treatment conditions shall be selected accordingly.

## A.3 Heat treatment before electroplating

### A.3.1 *Non-surface hardened parts*

The conditions given in Table 6 are recommended if the purchaser requires the parts to be stress relieved before electroplating. Different conditions from those given in Table 6, i.e suitable combinations of shorter times at appropriate higher temperatures may be used if they have been shown to be effective. The treatment shall be carried out before the commencement of any preparation or cleaning treatment using aqueous solutions.

**Table 5 — Categories of steels and maximum tensile strengths corresponding to specified minimum tensile strengths**

| Specified minimum tensile strength | Corresponding maximum tensile strength |
|---|---|
| MPa | MPa |
| Up to 900 | Up to 1 050 |
| More than 1 000, up to and including 1 400 | More than 1 050, up to and including 1 450 |
| More than 1 400, up to and including 1 750 | More than 1 450, up to and including 1 800 |
| More than 1 750 | More than 1 800 |

### A.3.2 *Surface-hardened parts*

Surface-hardened parts shall be heat treated at 190 °C to 220 °C for not less than 2 h.

#### A.3.3 *Cold worked parts*

If stress relief is given after shot peening or other cold working processes, the temperature shall not exceed 220 °C.

### A.4 Heat treatment after electroplating

**A.4.1** Heat treatment conditions after electroplating shall be in accordance with Table 7, and heat treatment shall be carried out not later than 4 h after electroplating and before any chromate treatment.

**A.4.2** Surface-hardened parts shall be heat treated at 190 °C to 220 °C for not less than 2 h.

**A.4.3** Other temperatures and durations may be specified by the purchaser and used if they have been shown to be effective for the particular coated part, but parts shall not be heat treated above a temperature 50 °C below their tempering temperature.

## Annex B Test methods

### B.1 Measurement of thickness on small articles

#### B.1.1 *Procedure*

Take a sufficient number of articles to give a mass of coating of not less than 100 mg. If the article is of a complex shape, an area and method of measuring the area shall be agreed between the interested parties. Weigh the articles to the nearest milligram, and strip off the coating at room temperature using one of the solutions in **B.1.2**. When testing for referee purposes, use either solutions a) or b) for zinc and solution d) for cadmium.

**Table 6 — Recommendations for heat treatment for stress relief before electroplating**

| Specified maximum tensile strength | Heat treatment |
|---|---|
| MPa | |
| Up to 1 050 | None required |
| More than 1 050, up to and including 1 450 | 1 h minimum at between 190 °C and 220 °C |
| More than 1 450, up to and including 1 800 | 18 h minimum at between 190 °C and 220 °C |
| More than 1 800 | 24 h minimum at between 190 °C and 220 °C |

**Table 7 — Recommendations for heat treatment for hydrogen embrittlement relief after electroplating**

| Specified maximum tensile strength | Heat treatment |
|---|---|
| MPa | |
| Up to 1 050 | None required |
| More than 1 050, up to and including 1 450 | 8 h minimum at between 190 °C and 220 °C |
| More than 1 450, up to and including 1 800 | 18 h minimum at between 190 °C and 220 °C |
| More than 1 800 | 24 h minimum at between 190 °C and 220 °C |

WARNING. The stripping solutions have hazards associated with them and the precautions given in **B.1.2** should be carefully observed.

Rinse the articles in running water, if necessary brushing to remove any loose dark deposit (of antimony when using solutions a) or b)) from the surface, dry carefully, and reweigh to the nearest milligram, noting the loss in mass. Calculate the thickness $d$, in micrometres, of the coating from the formula:

$$d = \frac{m \times 10^3}{A\rho}$$

where

$m$ is the loss in mass (in mg);

$A$ is the area of the surface under examination (in $mm^2$);

$\rho$ is the density of the zinc or cadmium coating (in $g/cm^3$), as follows:

$\rho = 7.1$ for zinc

$\rho = 8.6$ for cadmium

#### B.1.2 *Examples of suitable stripping solutions and precautions to be taken*

WARNING. Antimony trioxide ($Sb_2O_3$) dissolved in hydrochloric acid solution and antimony trichloride ($SbCl_3$) are poisonous. Avoid contact with the skin. Stibine ($SbH_3$), which is a very poisonous gas, may be released during the stripping process when using either solution a) or b) and stringent precautions should be taken to avoid breathing it. Carry out the stripping process in a fume cupboard.

Formaldehyde solution is toxic, irritant and causes burns. Avoid breathing the vapour. Avoid contact with the skin and eyes.

The following solutions may be used for stripping.

| | | |
|---|---|---|
| a) | antimony trioxide ($Sb_2O_3$) in hydrochloric acid solution | 20 g |
| | $\rho$ > 1.16 g/mL | 800 mL |
| | water | 200 mL |
| b) | antimony trichloride ($SbCl_3$) in hydrochloric acid solution | 32 g |
| | $\rho$ > 1.16 g/mL | 800 mL |
| | water | 200 mL |

Stripping solutions a) and b) are satisfactory provided that the articles are removed from the solution as soon as the coating has been completely dissolved i.e. once the vigorous chemical action has ceased. However, they may attack the basis iron or steel if the articles are left in the solution for any considerable time after the stripping has been completed.

| | | |
|---|---|---|
| c) | formaldehyde (30 % *m/m* solution) in hydrochloric acid solution | 10 mL |
| | $\rho$ > 1.16 g/mL | 500 mL |
| | water | 500 mL |
| d) | (for cadmium only) | |
| | ammonium nitrate ($NH_4NO_3$) with water to make 1 litre | 300 g |

**B.2 Burnishing test for adhesion**

Rub an area of not more than 6 $cm^2$ of the electroplated surface rapidly and firmly with a smooth metal implement for 15 s.

The pressure shall be sufficient to burnish the coating at every stroke, but not so great as to cut the coating. Poor adhesion will be shown by the appearance of a loose blister which grows as rubbing is continued. If, in addition, the quality of the coating is poor, the blister may crack and the coating will peel away from the basis metal.

More than one area may be tested if desired.

# Publications referred to

BS 729, *Specification for hot dip galvanized coatings on iron and steel articles.*

BS 2569, *Specification for sprayed metal coatings.*

BS 3382, *Specification for electroplated coatings on threaded components.*

*BS 3382-1, Cadmium on steel components.*

*BS 3382-2, Zinc on steel components.*

*BS 3382-7, Thicker platings for threaded components.*

BS 4921, *Specification for sherardized coatings on iron and steel articles.*

BS 5411, *Methods of test for metallic and related coatings.*

BS 5411-*1, Definitions and conventions concerning the measurement of thickness.*

BS 5411-*4, Coulometric method for the measurement of coating thickness.*

BS 5411-*5, Measurement of local thickness of metal and oxide coatings by the microscopical examination of cross-sections.*

BS 5411-*7, Profilometric method for measurement of coating thickness.*

BS 5411-*11, Measurement of coating thickness of non-magnetic metallic and vitreous or porcelain enamel coatings on magnetic basis metals: magnetic method.*

BS 5466, *Methods for corrosion testing of metallic coatings.*

BS 5466-1*, Neutral salt spray test (NSS test).*

BS 6001, *Sampling procedures for inspection by attributes.*

BS 6041, *Method of sampling electrodeposited coatings and related finishes: procedures for inspection by attributes.*

BS 6338, *Specification for chromate conversion coatings on electrodeposited zinc and cadmium coatings.*

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BSI
389 Chiswick High Road
London
W4 4AL