International Standard 6158

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Metallic coatings — Electroplated coatings of chromium for engineering purposes

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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council.

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It has been approved by the member bodies of the following countries:

Australia	Ireland	Spain
Czechoslovakia	Italy	Sweden
Egypt, Arab Rep. of	Japan	Switzerland
France	Netherlands	United Kingdom
Germany, F. R.	Poland	USA
Hungary	Romania	USSR
India	South Africa, Rep. of	

No member body expressed disapproval of the document.

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Metallic coatings — Electroplated coatings of chromium for engineering purposes

0 Introduction

Electroplated coatings of chromium used for engineering purposes are much thicker than those used for decorative purposes. They are often called "heavy chromium" or "hard chromium" coatings.

Chromium coatings are used for engineering purposes in industry mainly to take advantage of one or more of the following properties :

a) low coefficient of friction;

b) anti-stick properties;

c) wear resistance;

d) corrosion resistance;

e) load-bearing properties.

ISO 1456 and ISO 1457 specify requirements for coatings intended primarily for decorative purposes.

It should be recognized that whilst electrodeposited chromium is hard, it is also brittle. This means that coatings will not permit significant deformation without cracking or spalling and therefore the following precautions should be observed :

a) the basis metal should be such that it will resist all applied stresses in depth;

b) under conditions of deformation or shock loading, the thickness of the coating should be kept to a minimum.

Close liaison between designers, manufacturers, electroplaters and purchasers is desirable in order to obtain satisfactory electroplating and to avoid any adverse effects on the mechanical properties of the article. The introduction of compressive stresses into the surface of components is generally beneficial for both sustained load and fatigue properties of unplated components and on subsequently electroplated components, and partially offsets loss of fatigue strength by delaying crack propagation from the coating into the basis metal.

The thickness of chromium to be applied will depend upon the properties required and the particular application. In view of the wide variety of industrial uses of chromium coatings, it is not possible to specify thicknesses but the following is intended to indicate typical practice.

a) **Coatings normally used in the as-plated condition or finished by polishing or honing only :**

1) Coatings up to 12 µm thick.

Examples of use :

i) plastics moulds, where chromium provides a surface that resists corrosion and allows easy release of the product;

ii) cutting tools, taps, dies, drills, etc., where the chromium coating prevents metal removed by machining from adhering behind the cutting edge.

2) Coatings 12 to 50 µm thick.

Examples of use :

i) rams for use in hydraulic equipment;

ii) cylinder liners for internal combustion engines.

3) Coatings over 50 µm thick.

Examples of use :

Prevention of corrosion and/or wear on articles where finish and close limits are not of importance.

b) **Coatings finished to size by grinding**

The hardness of chromium is such that the only practicable method of finishing to size is by grinding or by a similar procedure.

Examples of use :

1) on new articles : the thickness of chromium remaining after grinding should be specified by the purchaser. The recommended finished thickness is 50 to 250 µm.

2) for reclamation of worn or over-machined articles (see annex B) : the thickness required will be that needed to replace lost metal. If heavy coatings are necessary, it is possible to deposit sufficient thickness of an undercoat metal, for example nickel, such that, after grinding, the final chromium coating will be 100 to 250 µm thick. If using chromium alone, the maximum thickness to be applied will be limited by technical and economic requirements.

c) **Use of undercoats**

Nickel undercoats are recommended for protection against severe corrosion, and tests for the corrosion resistance of the nickel alone may be desirable. Nickel undercoats should be in accordance with ISO 4526. For special requirements, other metals may be used as undercoats.

1 Scope and field of application

This International Standard specifies requirements for electroplated coatings of chromium, with or without undercoats, on ferrous and non-ferrous metals for engineering purposes.

2 References

ISO 468, *Surface roughness — Parameters, their values and general rules for specifying surfaces.*

ISO 1456, *Metallic coatings — Electroplated coatings of nickel plus chromium.*

ISO 1457, *Metallic coatings — Electroplated coatings of copper plus nickel plus chromium on iron or steel.*

ISO 1463, *Metallic and oxide coatings — Measurement of coating thickness — Microscopical method.*

ISO 2177, *Metallic coatings — Measurement of coating thickness — Coulometric method by anodic dissolution.*[1)]

ISO 2178, *Non-magnetic coatings on magnetic substrates — Measurement of coating thickness — Magnetic method.*

ISO 2819, *Metallic coatings on metallic substrates — Electrodeposited and chemically deposited coatings — Review of methods available for testing adhesion.*

ISO 4516, *Metallic and related coatings — Vickers and Knoop microhardness tests.*

ISO 4518, *Metallic coatings — Measurement of coating thickness — Profilometric method.*

ISO 4519, *Electrodeposited metallic coatings and related finishes — Sampling procedures for inspection by attributes.*

ISO 4526, *Metallic coatings — Electroplated coatings of nickel for engineering purposes.*

3 Definition

For the purpose of this International Standard, the following definition applies.

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.

4 Sampling

If required, select a random sample of the size required by ISO 4519 from the inspection lot. Inspect the articles in this sample for conformity with the requirements of this International Standard and classify the lot as conforming or not conforming to each requirement according to the criteria of the sampling plans in ISO 4519.

5 Information to be supplied to the electroplater

The electroplater shall be supplied with the following information :

a) the number of this International Standard, i.e. ISO 6158;

b) the nominal composition, or specification, and metallurgical condition of the basis metal;[2)]

c) the necessity for any stress-relieving treatment before electroplating;

d) the necessity for any treatment to induce compressive stress, for example peening before electroplating;

e) the details of significant surfaces and of any surfaces that are not to be electroplated, and of any areas on to which the chromium coating may be allowed to extend. These details can be indicated, for example, by drawings or by the provision of suitably marked samples;

f) any special requirements for, or restrictions on, pretreatment, for example vapour blasting instead of acid pretreatment;

g) the minimum thickness of chromium to be deposited and, if undercoats are applied, the total electroplated thickness. A maximum thickness may be quoted if desired, especially for the building-up of worn or over-machined parts. These dimensions shall be those of the finished surface after any grinding of the electroplated part (see 7.1.3);

h) the type of chromium coating required, i.e. porous, crack-free, micro-cracked, duplex or regular (see 7.2);

j) the final surface finish of the chromium coating, for example as-plated, ground or honed (see 7.1.2);

k) the type, size, extent and location of surface defects that can be tolerated (see 7.1.1 and 7.2);

1) At present at the stage of draft. (Revision of ISO 2177-1972.)

2) In the case of reclaimed articles, it may not be possible to supply this information and it may, therefore, be difficult, if not impossible, to guarantee the quality of the coating.

m) requirements for any heat treatment after electroplating;

n) any other special requirements.

6 Treatment of basis metal before electroplating

6.1 General

The significant surface shall be examined by the electroplater for visible surface defects, such as porosity, cracks and undesirable coatings or any other defects detrimental to the final finish. Any defects shall be brought to the attention of the purchaser prior to any processing.

6.2 Stress relief

Before being electroplated, parts shall, if specified, be stress relieved. The conditions set out in table 1 shall normally be used, but different conditions, that is, suitable combinations of a shorter time at appropriate higher temperatures may be used if they have been shown to be effective. The heat treatment shall be carried out before the commencement of any preparation or cleaning treatment using aqueous solutions.

Table 1 — Stress relief conditions before electroplating

Maximum specified tensile strength of steel, R_m (MPa)	Heat treatment
$R_m \leqslant 1\,050$	None required
$1\,050 < R_m \leqslant 1\,450$	1 h minimum at between 190 and 220 °C
$1\,450 < R_m \leqslant 1\,800$	18 h minimum at between 190 and 220 °C
$R_m > 1\,800$	24 h minimum at between 190 and 220 °C

If stress relief is performed after peening or other cold working processes, the temperature shall not exceed 220 °C. Parts with surface-hardened areas shall be stress relieved at 130 to 150 °C for not less than 5 h, but shorter times at higher temperatures may be used if the resulting loss of surface hardness of the substrate is acceptable.

Stress-relieving heat treatment is not normally required for non-ferrous metals.

6.3 Peening

6.3.1 Steels

If peening is necessary to improve the fatigue strength, the peening intensity, unless otherwise specified, shall be such that, when measured by the method described in annex A, the arc height is at least

— 0,3 mm for steels of tensile strength less than 1 100 MPa;

— 0,4 mm for steels of tensile strength 1 100 MPa or greater.

NOTE — Lower intensities may be necessary on thin sections to avoid distortion, but may not be fully effective in avoiding loss in fatigue strength.

Unless otherwise specified, the peening shall be performed so that the area concerned is completely covered, i.e. the ball marks completely overlap each other.

6.3.2 Non-ferrous metals

For non-ferrous metals, the peening intensity shall be specified by the purchaser.

7 Coating requirements

7.1 Appearance of regular chromium

7.1.1 The significant surface shall be bright or lustrous and, when inspected by the naked eye, shall be free from pits, blisters and exfoliation or any other defects detrimental to the final finish. Nodular growths elsewhere than at the extreme edges of coatings are not permitted on articles used in the as-plated condition or on the surface of ground articles.

Any electroplated articles shall be free from cracks visible to the naked eye. Coatings thicker than 50 µm shall be free from cracks extending to the basis metal.

Blisters or cracks produced by heat treatment or grinding procedures, if carried out by the electroplater, and that are visible to the naked eye, shall be cause for rejection.

7.1.2 Surface finish

If a specified final surface roughness is required, the method of measurement shall be as specified in ISO 468.

NOTE — As a guide, for ground finishes 0,4 µm R_a may be regarded as a "commercial finish" and 0,2 µm R_a as a "good commercial finish".

7.1.3 Thickness

The finished minimum thickness of chromium on the significant surface, and of any undercoat(s), shall be as specified by the purchaser [see clause 5, item g)].

7.1.4 Hardness

The hardness of the coating, unless otherwise specified, shall be not lower than 750 HV when measured by the method specified in ISO 4516.

NOTE — Some softening of the coating may occur during heat treatment.

7.1.5 Adhesion

No universally satisfactory test for the adhesion of chromium coatings to the basis metal is known. However, a bend test on

a representative sample, electroplated with 25 µm of chromium, can be applied as a test of the effectiveness of the process. A review of methods of testing adhesion is given in ISO 2819, which includes a thermal shock test that has been found applicable in certain cases.

7.2 Other types of chromium

For special applications, coatings other than regular chromium may be required.

Examples of these are as follows.

a) "Crack-free" chromium, which is less hard and, being less brittle and essentially free from cracks, offers greater corrosion resistance than regular chromium. Such deposits should not normally exceed 25 µm in thickness and shall not be finished by grinding or used on highly-loaded areas. The heat treatment described in clause 8 may adversely affect the corrosion protection afforded by this type of coating.

b) Porous chromium, which is produced either by mechanical, chemical or electrochemical treatment to obtain an oil-retaining surface. The method for the determination of the degree or type of porosity (for example channel or point) and criteria of acceptance shall be specified, but the method specified in 9.3 is recommended.

c) Cracked chromium, formed with an intentional crack pattern. Micro-cracked chromium has a crack pattern which is invisible to the naked eye, having more than 250 cracks per centimetre in any direction over the whole of the significant surface. Macro-cracked chromium has fewer than 250 cracks per centimetre, and usually a much smaller number.

Cracked chromium coatings are usually equivalent in hardness to regular chromium coatings and, due to their structure, retain oil more readily. Micro-cracked chromium coatings confer increased corrosion protection when compared to macro-cracked chromium, if applied over an undercoat of nickel.

d) Duplex chromium, which usually comprises a layer of regular chromium applied over an undercoat of crack-free chromium. Its hardness is, therefore, similar to that of regular chromium but it confers greater corrosion protection.

With these coatings the appearance, and also other properties such as hardness, may vary considerably from the requirements of regular chromium coatings. Nevertheless, such coatings shall be smooth, dense, uniform and free from plating defects which may affect their proper functioning or protective value. If appropriate, the requirements of 7.1 shall apply to these other types of chromium.

8 Heat treatment after electroplating

8.1 General

If required by the purchaser, heat treatment after electroplating shall be performed as described in 8.2 and 8.3. The heat treatment shall be performed as soon as possible and not later than 4 h after electroplating and before any grinding or other mechanical finishing operation.

8.2 Heat treatment of steels for reduction of hydrogen embrittlement

The heat treatment of electroplated steel articles for the reduction of hydrogen embrittlement shall be in accordance with the requirements given in table 2, but heat treatment at 400 to 480 °C is applicable only to parts that are liable to fatigue failure in service.

Articles shall not be heat treated above their tempering temperature.

Unpeened parts may be heated for shorter periods at a higher temperature if the conditions have been shown to be effective (see clause 6 and the note to table 2).

If nickel undercoats are used, heat treatment shall be carried out in accordance with ISO 4526 after nickel electroplating. For nickel undercoats thinner than 25 µm, a second heat treatment shall be carried out in accordance with table 2 after chromium electroplating.

Parts having surface-hardened areas shall be heated at 130 to 150 °C for not less than 5 h or at a higher temperature if the resultant loss of hardness of the substrate is acceptable.

Table 2 — Treatment of steels after electroplating

Maximum specified tensile strength of steel, R_m (MPa)	Heat treatment for reduction of hydrogen embrittlement a) of unpeened parts not subject to fatigue; b) for all peened parts	Heat treatment for reduction of hydrogen embrittlement and restoration of fatigue strength of unpeened parts only[1)]
$R_m \leqslant 1\,050$	None required	1 h minimum at between 400 and 480 °C
$1\,050 < R_m \leqslant 1\,450$	2 h minimum at between 190 and 220 °C	1 h minimum at between 400 and 480 °C
$1\,450 < R_m \leqslant 1\,800$	6 h minimum at between 190 and 220 °C	1 h minimum at between 400 and 480 °C
$R_m > 1\,800$	18 h minimum at between 190 and 220 °C	1 h minimum at between 400 and 480 °C

1) Treatment at 400 to 480 °C will reduce the hardness of the chromium coating and may also reduce the hardness of the steel.

8.3 Heat treatment of aluminium and aluminium alloys to improve adhesion

It should be noted that the mechanical properties of some aluminium alloys may be adversely affected by heating. If heat treatment can be carried out and is required to give the desired adhesion on aluminium or aluminium alloys, the electroplated articles shall be heated in air to give a temperature rise of 2 to 3 K/min until a temperature of 130 to 140 °C is attained. This temperature shall then be maintained for a period of not less than 2 h and not more than 3 h.

9 Test methods

9.1 Determination of coating thickness

Measure the thickness at any place on the significant surface designated by the purchaser. Use a method capable of giving a measurement uncertainty of less than 10 %.

9.1.1 Direct measurement

Provided that there is a reference point, measurement before and after electroplating provides a direct reading of thickness. For this purpose, normal engineering instruments, for example micrometers, depth gauges etc., can be used. Measurement of the increase in diameter of cylindrical parts does not provide a true reading of thickness unless the distribution of the deposit is even. Such distribution can be checked, for example, by rotating between centres and using a dial indicator or by the use of indirect methods of measurement.

9.1.2 Magnetic method

Use the method specified in ISO 2178 for measuring the thickness on magnetic basis metals.

9.1.3 Metallographic sectioning and microscopical method

Use the method specified in ISO 1463.

9.1.4 Coulometric method

Use the method specified in ISO 2177.

This method becomes decreasingly reliable for thicknesses over 50 µm. The test conditions and electrolyte are dependent on the test equipment used and the relevant information should be obtained from the manufacturer's instructions.

9.1.5 Profilometric method

Use the method specified in ISO 4518.

9.2 Visual examination for cracks (not applicable to regular chromium)

Examine the surface for cracks in reflected light under an optical microscope at a magnification of X 100. For very fine crack patterns and accurate counting, a higher magnification may be desirable. Use a micrometer eyepiece or similar device for indicating the distance over which cracks are counted.

According to the magnification used, take a measured length such that at least 40 cracks are counted.

9.3 Copper deposition for determination of cracks or pores

9.3.1 Principle

Electrodeposition of copper from an acidic sulfate solution at low current density or low voltage; deposition of copper occurs only on the underlying metal which is exposed through cracks, pores and other discontinuities.

This method provides a rapid means of visual inspection for uniformity of cracks or pores but, if counting of cracks or pores is required, a microscope should be employed as described in 9.2.

9.3.2 Procedure

Best results are obtained if the test is performed immediately on completion of electroplating. If there is any delay, thoroughly degrease the specimen, avoiding the use of any electrolytic treatment. Ultrasonic cleaning or rubbing with an aqueous paste of levigated magnesia are examples of suitable methods.

Deposit copper for approximately 1 min at room temperature from a bath containing approximately 200 g of copper(II) sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) and 20 g of sulfuric acid per litre, at an average current density of 30 A/m^2.

NOTE — The test specimen and the anode should be connected to the current supply before immersion.

In cases when the test is applied several days after chromium deposition, immerse the specimen in a solution containing 10 to 20 g of nitric acid per litre for 4 min at approximately 95 °C before deposition of copper, to help reveal the cracks or pores.

Annex A
Method for establishing peening conditions

Use a test specimen from carbon steel sheet[1], of hardness range 400 HV 30 to 500 HV 30 and of thickness 1,6 mm, which has been cut to a size of 75 mm × (20 ± 0,2) mm and ground to a thickness of 1,3 ± 0,02 mm.

The deviation from flatness shall not exceed an arc height of 38 µm when measured as described below. With the specimen rigidly held in the fixture shown in the figure, peen it on the exposed side for the same period and under the same conditions as the part to be electroplated.

After peening, remove the specimen from the fixture and measure the curvature of the unpeened surface with a depth gauge, the specimen being supported on four 5 mm diameter balls, forming a rectangle 32 mm × 16 mm. Align the gauge symmetrically on the specimen with its centre stylus at the centre of the specimen. Measure the arc height at the centre of the specimen over the gauge length of 32 mm, measuring to the nearest 25 µm. Then adjust the peening conditions if necessary, to give the required arc height.

Dimensions in millimetres

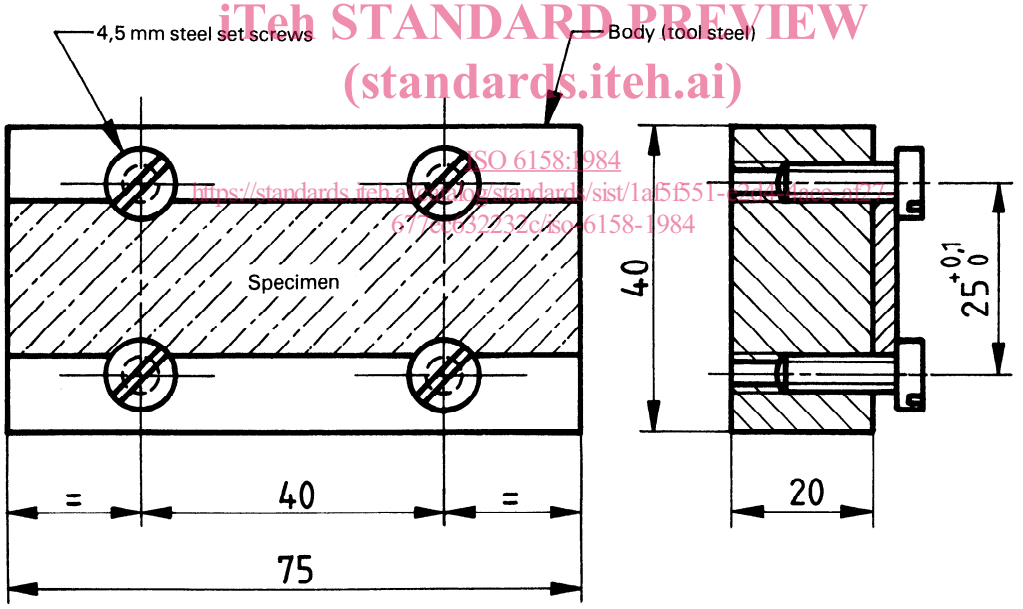

Figure — Fixture for peening test specimens

1) Carbon steel sheet will form the subject of a future International Standard.

Annex B

Reclamation of worn chromium electroplated articles and of articles electroplated with insufficient chromium

Before reclamation, consideration should be given to the need for crack detection of parts. Complete removal of the chromium from worn chromium electroplated parts and from parts electroplated with insufficient chromium is recommended before electroplating in accordance with this International Standard.

Nevertheless, with special pre-treatment, worn or undersized sound chromium coatings may be built up without stripping. This should be carried out after cleaning and anodically etching in the electroplating bath at normal electroplating current density for 10 to 20 s. The direction of the current flow shall then be immediately reversed and normal deposition commenced. This method should not be used if the basis metal or undercoat is exposed or is likely to become exposed during anodic treatment in the electroplating bath.