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**Metallic and other inorganic coatings —  
Electrodeposited coatings of nickel,  
nickel plus chromium, copper plus nickel  
and of copper plus nickel plus chromium**

*Revêtements métalliques et autres revêtements inorganiques — Dépôts électrolytiques de nickel, de nickel plus chrome, de cuivre plus nickel et de cuivre plus nickel plus chrome*



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ISO copyright office  
Case postale 56 • CH-1211 Geneva 20  
Tel. + 41 22 749 01 11  
Fax + 41 22 749 09 47  
E-mail [copyright@iso.org](mailto:copyright@iso.org)  
Web [www.iso.org](http://www.iso.org)

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 1456 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*, Subcommittee SC 3, *Electrodeposited coatings and related finishes*.

This fourth edition cancels and replaces the third edition (ISO 1456:2003), which has been technically and editorially revised. This edition also cancels and replaces ISO 1458:2002.

## Introduction

This International Standard is a revised version of ISO 1456:2003: *Metallic coatings — Electrodeposited coatings of nickel plus chromium and of copper plus nickel plus chromium* incorporating ISO 1458:2002: *Metallic coatings — Electrodeposited coatings of nickel*.

Decorative, electrodeposited nickel coatings, with and without copper undercoats and without chromium topcoats, are suitable for applications in which tarnishing could be prevented by avoiding rubbing or handling in service or by the use of topcoats other than chromium. They are also suitable for those applications where tarnishing is of no importance. Corrosion resistance depends on the type and thickness of the coatings.

Decorative, electrodeposited nickel plus chromium and copper plus nickel plus chromium coatings are applied to manufactured articles to enhance their appearance and corrosion resistance. Corrosion resistance depends on the type and thickness of the coatings. In general, multilayer nickel coatings provide better corrosion resistance than single-layer nickel coatings of equal thickness, and micro-discontinuous chromium coatings provide better protection than conventional chromium.



# Metallic and other inorganic coatings — Electrodeposited coatings of nickel, nickel plus chromium, copper plus nickel and of copper plus nickel plus chromium

**WARNING** — This International Standard may not be compliant with some countries' health and safety legislations and calls for the use of substances and/or procedures that may be injurious to health if adequate safety measures are not taken. This International Standard does not address any health hazards, safety or environmental matters and legislations associated with its use. It is the responsibility of the user of this International Standard to establish appropriate health, safety and environmentally acceptable practices and take suitable actions to comply with any national and international regulations. Compliance with this International Standard does not in itself confer immunity from legal obligations.

## 1 Scope

This International Standard specifies requirements for decorative nickel, nickel plus chromium, copper plus nickel and copper plus nickel plus chromium coatings that are applied to iron, steel, zinc alloys, copper and copper alloys, and to aluminium and aluminium alloys, to provide an attractive appearance and enhanced corrosion resistance. Coating designations are specified that differ in thickness and type, and guidance is given on selecting the coating designation appropriate for the service conditions to which the coated product will be exposed.

This International Standard does not specify the surface condition required by the basis metal prior to the coating process, and is not applicable to coatings on sheet, strip or wire in the non-fabricated form nor to threaded fasteners or coil springs.

Requirements for decorative, electroplated copper plus nickel plus chromium coatings on plastic materials are specified in ISO 4525. ISO 4526 and ISO 6158 specify requirements for coatings of nickel and chromium, respectively, for engineering purposes.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 2064, *Metallic and other inorganic coatings — Definitions and conventions concerning the measurement of thickness*

ISO 2080, *Metallic and other inorganic coatings — Surface treatment, metallic and other inorganic coatings — Vocabulary*

ISO 2177, *Metallic coatings — Measurement of coating thickness — Coulometric method by anodic dissolution*

## ISO 1456:2009(E)

ISO 2361, *Electrodeposited nickel coatings on magnetic and non-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 3497, *Metallic coatings — Measurement of coating thickness — X-ray spectrometric methods*

ISO 3543, *Metallic and non-metallic coatings — Measurement of thickness — Beta backscatter method*

ISO 3882, *Metallic and other inorganic coatings — Review of methods of measurement of thickness*

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

ISO 4541:1978, *Metallic and other non-organic coatings — Corrodokote corrosion test (CORR test)*

ISO 9220, *Metallic coatings — Measurement of coating thickness — Scanning electron microscope method*

ISO 9587, *Metallic and other inorganic coatings — Pretreatment of iron or steel to reduce the risk of hydrogen embrittlement*

ISO 9588, *Metallic and other inorganic coatings — Post-coating treatments of iron or steel to reduce the risk of hydrogen embrittlement*

ISO 10289, *Methods for corrosion testing of metallic and other inorganic coatings on metallic substrates — Rating of test specimens and manufactured articles subjected to corrosion tests*

ISO 10587, *Metallic and other inorganic coatings — Test for residual embrittlement in both metallic-coated and uncoated externally-threaded articles and rods — Inclined wedge method*

ISO 15724, *Metallic and other inorganic coatings — Electrochemical measurement of diffusible hydrogen in steels — Barnacle electrode method*

ISO 16348, *Metallic and other inorganic coatings — Definitions and conventions concerning appearance*

ISO 27831-2, *Metallic and other inorganic coatings — Cleaning and preparation of metal surfaces — Part 2: Non-ferrous metals and alloys*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2064, ISO 2080, ISO 9587, ISO 9588 and ISO 16348 apply.



## 4 Information to be supplied by the purchaser to the processor

### 4.1 Essential information

When ordering articles to be electroplated in accordance with this International Standard, the purchaser shall provide the following information in writing, in, for example, the contract or purchase order, or on engineering drawings:

- a) a reference to this International Standard, ISO 1456, and the designation (see Clause 5);
- b) the significant surfaces, to be indicated on drawings of the parts or by providing suitably marked specimens;
- c) the appearance required, e.g. bright, dull or satin, or high- or low-sulfur-containing bright, semi-bright or dull (see 5.5 and 6.1); alternatively, samples showing the required finish or range of finishes may also be supplied and approved by the purchaser, and used for comparison purposes (see 6.1);
- d) the type of nickel coating, e.g. decorative, sulfur-containing bright, semi-bright, or satin containing a lamellar structure; or high-sulfur-containing bright, semi-bright or dull containing a lamellar structure without mechanical polishing; or dull or semi-bright with mechanical polishing; or sulfur-free dull or semi-bright with a columnar structure without mechanical polishing; or double- or triple-layer coating (see 5.5 and 6.3);
- e) the type of chromium coating, e.g. regular, black, micro-cracked or micro-porous (see 5.6);
- f) the type of corrosion test to be used (see 6.5 and Table 6);
- g) the type of adhesion test and minimum local thickness to be used (see 6.4 and 6.2);
- h) the extent to which defects shall be tolerated on non-significant surfaces (see 6.1);
- i) positions on the significant surface for rack or contact marks, where such marks are unavoidable (see 6.1);
- j) the tensile strength of the steel and any requirement for stress relief for pre- or post-coating embrittlement-relief treatments of iron or steel to reduce the risk of hydrogen embrittlement, as well as hydrogen-embrittlement test methods (see 6.8 and 6.9);
- k) sampling methods and acceptance levels (see 6.10).

### 4.2 Additional information

The following additional information shall also be provided by the purchaser, when appropriate:

- a) any requirements for STEP testing and the type of test method (see 6.6);
- b) thickness requirements on those areas that cannot be touched by a ball 20 mm in diameter (see 6.2);
- c) whether or not a copper undercoat is required (see 5.2 and 5.4).

## 5 Designation

### 5.1 General

The designation shall appear on engineering drawings, in the purchase order, in the contract or in the detailed product specification.

The designation specifies, in the following order, the basis metal, the specific alloy (optional), stress-relief requirements, the type and thickness of undercoats (when present), the thickness and composition of the nickel or nickel-alloy coating or coatings (when double or multilayer coatings are specified), and supplementary treatments, such as heat treatment to reduce susceptibility to hydrogen embrittlement (for designation, see the Bibliography).

### 5.2 Designation specifications

The coating designation specifies the basis metal and the types and thickness of coatings appropriate for each service-condition number (see Tables 1 to 4 for various substrates and coatings) and comprises the following:

- a) the term, "Electroplated coating", the number of this International Standard, ISO 1456, followed by a hyphen;
- b) the chemical symbol for the basis metal (or for the principal metal if an alloy) followed by a solidus (/) as follows:
  - 1) Fe/ for iron or steel;
  - 2) Zn/ for zinc or zinc alloys;
  - 3) Cu/ for copper and copper alloys;
  - 4) Al/ for aluminium or aluminium alloys;
- c) the chemical symbol for copper (Cu), if copper, or brass containing greater than 50 % copper, is used as an undercoat;
- d) a number indicating the minimum local thickness, in micrometres, of the copper coating, where applicable;
- e) a letter indicating the type of copper coating (see 5.4), where applicable;
- f) the chemical symbol for nickel (Ni);
- g) a number indicating the minimum local thickness, in micrometres, of the nickel coating;
- h) a letter designating the type of nickel coating (see 5.5);
- i) if a topcoat is to be applied over the nickel, its chemical symbol and a number indicating its minimum local thickness; if the topcoat is an electrodeposited alloy, the chemical symbols of the principal alloy constituents; for example, the chemical symbol for chromium (Cr) if chromium is the top coat;
- j) for a chromium topcoat, a letter or letters designating the type of chromium and its minimum local thickness (see 5.6);
- k) the heat treatment requirements in brackets and designated as follows: the letters SR for stress-relief heat treatment prior to electroplating, and/or the letters ER for hydrogen-embrittlement-relief heat treatment after electroplating; in parentheses, the minimum temperature, in degrees Celsius (°C); the duration of the heat treatment in hours (h).

Solidi (/) shall be used to separate data fields in the designation corresponding to the different sequential processing steps. Double separators or solidi indicate that a step in the process is either not required or has been omitted (see the Bibliography).

It is recommended that the specific alloy be identified by its standard designation following the chemical symbol of the basis metal; for example, its UNS number, or the national or regional equivalent may be placed between the symbols < >. For example, Fe<G43400> is the UNS designation for one high-strength steel. (See Bibliography.)

#### EXAMPLE

A coating on steel comprising 20 µm (minimum) ductile, levelling copper plus 30 µm (minimum) bright nickel plus 0,3 µm micro-cracked chromium is designated as follows:

#### **Electroplated coating ISO 1456 – Fe/Cu20a/Ni30b/Crmc**

A coating on steel, when stress-relief heat treatment prior to application of any coating is applied at 200 °C for 3 h and embrittlement-relief heat treatment after coating is applied at 210 °C for 8 h, is designated as follows:

#### **Electrodeposited coating ISO 1456 – Fe/SR(200)3/Ni30b/ER(210)8/Crmc**

For ordering purposes, the detailed product specification shall include not only the designation, but also clear written statements of other requirements that are essential for the serviceability of a particular product (see Clause 4).

### **5.3 Service-condition number**

The service-condition number is used by the purchaser to specify the degree of protection required, as related to the severity of the conditions to which a product is to be subjected, in accordance with the following scale:

- |   |                      |   |
|---|----------------------|---|
| 1 | Mild                 | Service indoors in warm dry atmospheres, e.g. offices.  |
| 2 | Moderate             | Service indoors where condensation may occur, e.g. bathroom, kitchens.  |
| 3 | Severe               | Service outdoors where occasional or frequent wetting by rain or dew may occur, e.g. outdoor furniture: bicycles, hospital goods.   |
| 4 | Very severe          | Service outdoors in very severe conditions, e.g. components of automobiles, boat fittings.  |
| 5 | Exceptionally severe | Service outdoors in exceptionally severe conditions where long-time protection, such as longer than about 10 years, of the substrate is required, e.g. vehicle components: bumpers, wheels. |

**Table 1 — Coatings on ferrous materials**

Ni	Cu + Ni	Ni + Cr	Cu + Ni + Cr
<b>Partial designation in Service condition 1</b>			
Fe/Ni10p	Fe/Cu10a/Ni5p	Fe/Ni10p/Crr Fe/Ni10p/Crmc Fe/Ni10p/Crmp Fe/Ni10p/Crb	Fe/Cu10a/Ni5p/Crr Fe/Cu10a/Ni5p/Crmc Fe/Cu10a/Ni5p/Crmp Fe/Cu10a/Ni5p/Crb
Fe/Ni10s	Fe/Cu10a/Ni5s	Fe/Ni10s/Crr Fe/Ni10s/Crmc Fe/Ni10s/Crmp Fe/Ni10s/Crb	Fe/Cu10a/Ni5s/Crr Fe/Cu10a/Ni5s/Crmc Fe/Cu10a/Ni5s/Crmp Fe/Cu10a/Ni5s/Crb
Fe/Ni10b	Fe/Cu10a/Ni5b	Fe/Ni10b/Crr Fe/Ni10b/Crmc Fe/Ni10b/Crmp Fe/Ni10b/Crb	Fe/Cu10a/Ni5b/Crr Fe/Cu10a/Ni5b/Crmc Fe/Cu10a/Ni5b/Crmp Fe/Cu10a/Ni5b/Crb
<b>Partial designation in Service condition 2</b>			
Fe/Ni20p	Fe/Cu15a/Ni15p	Fe/Ni20p/Crr Fe/Ni15p/Crmc Fe/Ni15p/Crmp Fe/Ni15p/Crb	Fe/Cu15a/Ni15p/Crr Fe/Cu15a/Ni10p/Crmc Fe/Cu15a/Ni10p/Crmp Fe/Cu15a/Ni10p/Crb
Fe/Ni20s	Fe/Cu15a/Ni15s	Fe/Ni20s/Crr Fe/Ni15s/Crmc Fe/Ni15s/Crmp Fe/Ni15s/Crb	Fe/Cu15a/Ni15s/Crr Fe/Cu15a/Ni10s/Crmc Fe/Cu15a/Ni10s/Crmp Fe/Cu15a/Ni10s/Crb
Fe/Ni20b	Fe/Cu15a/Ni15b	Fe/Ni20b/Crr Fe/Ni15b/Crmc Fe/Ni15b/Crmp Fe/Ni15b/Crb	Fe/Cu15a/Ni15b/Crr Fe/Cu15a/Ni10b/Crmc Fe/Cu15a/Ni10b/Crmp Fe/Cu15a/Ni10b/Crb
Fe/Ni20d	Fe/Cu15a/Ni15d	Fe/Ni20d/Crr Fe/Ni15d/Crmc Fe/Ni15d/Crmp Fe/Ni15d/Crb	Fe/Cu15a/Ni15d/Crr Fe/Cu15a/Ni10d/Crmc Fe/Cu15a/Ni10d/Crmp Fe/Cu15a/Ni10d/Crb

Table 1 (continued)

Ni	Cu + Ni	Ni + Cr	Cu + Ni + Cr
<b>Partial designation in Service condition 3</b>			
Fe/Ni35p	Fe/Cu15a/Ni25p	Fe/Ni35p/Crr Fe/Ni30p/Crmmc Fe/Ni30p/Crmp Fe/Ni30p/Crb	Fe/Cu15a/Ni30p/Crr Fe/Cu15a/Ni25p/Crmmc Fe/Cu15a/Ni25p/Crmp Fe/Cu15a/Ni25p/Crb
Fe/Ni35s	Fe/Cu15a/Ni25s	Fe/Ni35s/Crr Fe/Ni30s/Crmmc Fe/Ni30s/Crmp Fe/Ni30s/Crb	Fe/Cu15a/Ni30s/Crr Fe/Cu15a/Ni25s/Crmp Fe/Cu15a/Ni25s/Crmp Fe/Cu15a/Ni25s/Crb
Fe/Ni35b	Fe/Cu15a/Ni25b	Fe/Ni35b/Crr Fe/Ni30b/Crmmc Fe/Ni30b/Crmp Fe/Ni30b/Crb	Fe/Cu15a/Ni30b/Crr Fe/Cu15a/Ni25b/Crmmc Fe/Cu15a/Ni25b/Crmp FeCu15a/Ni25b/Crb
Fe/Ni30d	Fe/Cu15a/Ni20d	Fe/Ni30d/Crr Fe/Ni25d/Crmmc Fe/Ni25d/Crmp Fe/Ni25d/Crb	Fe/Cu15a/Ni25d/Crr Fe/Cu15a/Ni20d/Crmmc Fe/Cu15a/Ni20d/Crmp Fe/Cu15a/Ni20d/Crb
<b>Partial designation in Service condition 4</b>			
		Fe/Ni40p/Crr Fe/Ni30p/Crmmc Fe/Ni30p/Crmp Fe/Ni30p/Crb	Fe/Cu20a/Ni35p/Crr Fe/Cu20a/Ni25p/Crmmc Fe/Cu20a/Ni25p/Crmp Fe/Cu20a/Ni25p/Crb
		Fe/Ni40s/Crr Fe/Ni30s/Crmmc Fe/Ni30s/Crmp Fe/Ni30s/Crb	Fe/Cu20a/Ni35s/Crr Fe/Cu20a/Ni25s/Crmmc Fe/Cu20a/Ni25s/Crmp Fe/Cu20a/Ni25s/Crb
		Fe/Ni40b/Crr Fe/Ni30b/Crmmc Fe/Ni30b/Crmp Fe/Ni30b/Crb	Fe/Cu20a/Ni35b/Crr Fe/Cu20a/Ni25b/Crmmc Fe/Cu20a/Ni25b/Crmp Fe/Cu20a/Ni25b/Crb
		Fe/Ni35d/Crr Fe/Ni25d/Crmmc Fe/Ni25d/Crmp Fe/Ni25d/Crb	Fe/Cu20a/Ni30d/Crr Fe/Cu20a/Ni20d/Crmmc Fe/Cu20a/Ni20d/Crmp Fe/Cu20a/Ni20d/Crb
<b>Partial designation in Service condition 5</b>			
		Fe/Ni45d/Crmmc Fe/Ni45d/Crmp	Fe/Cu25a/Ni35d/Crmmc Fe/Cu25a/Ni35d/Crmp

Table 2 — Coatings on zinc alloys

Ni	Cu + Ni	Ni + Cr	Cu + Ni + Cr
<b>Partial designation in Service condition 1</b>			
Zn/Ni10p	Zn/Cu10a/Ni10p	Zn/Ni10p/Crr Zn/Ni10p/Crmc Zn/Ni10p/Crmp Zn/Ni10p/Crb	Zn/Cu8a/Ni10p/Crr Zn/Cu8a/Ni10p/Crmc Zn/Cu8a/Ni10p/Crmp Zn/Cu8a/Ni10p/Crb
Zn/Ni10s	Zn/Cu10a/Ni10s	Zn/Ni10s/Crr Zn/Ni10s/Crmc Zn/Ni10s/Crmp Zn/Ni10s/Crb	Zn/Cu8a/Ni10s/Crr Zn/Cu8a/Ni10s/Crmc Zn/Cu8a/Ni10s/Crmp Zn/Cu8a/Ni10s/Crb
Zn/Ni10b	Zn/Cu10a/Ni10b	Zn/Ni10b/Crr Zn/Ni10b/Crmc Zn/Ni10b/Crmp Zn/Ni10b/Crb	Zn/Cu8a/Ni10b/Crr Zn/Cu8a/Ni10b/Crmc Zn/Cu8a/Ni10b/Crmp Zn/Cu8a/Ni10b/Crb
		Zn/Ni10d/Crr Zn/Ni10dCrmc Zn/Ni10d/Crmp Zn/Ni10d/Crb	Zn/Cu8a/Ni10d/Crr Zn/Cu8a/Ni10d/Crmc Zn/Cu8a/Ni10d/Crmp Zn/Cu8a/Ni10d/Crb
<b>Partial designation in Service condition 2</b>			
Zn/Ni20p	Zn/Cu15a/Ni15p	Zn/Ni20p/Crr Zn/Ni15p/Crmc Zn/Ni15p/Crmp Zn/Ni15p/Crb	Zn/Cu15a/Ni15p/Crr Zn/Cu15a/Ni10p/Crmc Zn/Cu15a/Ni10p/Crmp Zn/Cu15a/Ni10p/Crb
Zn/Ni20b	Zn/Cu15a/Ni15b	Zn/Ni20b/Crr Zn/Ni15b/Crmc Zn/Ni15b/Crmp Zn/Ni15b/Crb	Zn/Cu15a/Ni15/Crr Zn/Cu15a/Ni10b/Crmc Zn/Cu15a/Ni10b/Crmp Zn/Cu15a/Ni10b/Crb
Zn/Ni20s	Zn/Cu15a/Ni15s	Zn/Ni20s/Crr Zn/Ni15s/Crmc Zn/Ni15s/Crmp Zn/Ni15s/Crb	Zn/Cu15a/Ni15s/Crr Zn/Cu15a/Ni10s/Crmc Zn/Cu15a/Ni10s/Crmp Zn/Cu15a/Ni10s/Crb
Zn/Ni15d	Zn/Cu15a/Ni10d	Zn/Ni20d/Crr Zn/Ni15d/Crmc Zn/Ni15d/Crmp Zn/Ni15d/Crb	Zn/Cu15a/Ni15d/Crr Zn/Cu15a/Ni10d/Crmc Zn/Cu15a/Ni10d/Crmp Zn/Cu15a/Ni10d/Crb

Table 2 (continued)

Ni	Cu + Ni	Ni + Cr	Cu + Ni + Cr
<b>Partial designation in Service condition 3</b>			
Zn/Ni40p	Zn/Cu20a/Ni30p	Zn/Ni35p/Crr Zn/Ni30p/Crmc Zn/Ni30p/Crmp Zn/Ni30p/Crb	Zn/Cu20a/Ni30p/Crr Zn/Cu20a/Ni25p/Crmc Zn/Cu20a/Ni25p/Crmp Zn/Cu20a/Ni25p/Crb
Zn/Ni40s	Zn/Cu20a/Ni30s	Zn/Ni35s/Crr Zn/Ni30s/Crmc Zn/Ni30s/Crmp Zn/Ni30s/Crb	Zn/Cu20s/Ni30s/Crr Zn/Cu20a/Ni25s/Crmc Zn/Cu20a/Ni25s/Crmp Zn/Cu20a/Ni25s/Crb
Zn/Ni40b	Zn/Cu20a/Ni30b	Zn/Ni35b/Crr Zn/Ni30b/Crmc Zn/Ni30b/Crmp Zn/Ni30b/Crb	Zn/Cu20a/Ni30b/Crr Zn/Cu20a/Ni25b/Crmc Zn/Cu20a/Ni25b/Crmp Zn/Cu20a/Ni25b/Crb
Zn/Ni30d	Zn/Cu20a/Ni25d	Zn/Ni30d/Crr Zn/Ni25d/Crmc Zn/Ni25d/Crmp Zn/Ni25d/Crb	Zn/Cu20a/Ni25d/Crr Zn/Cu20a/Ni20d/Crmc Zn/Cu20a/Ni20d/Crmp Zn/Cu20a/Ni20d/Crb
<b>Partial designation in Service condition 4</b>			
		Zn/Ni40p/Crr Zn/Ni35p/Crmc Zn/Ni35p/Crmp Zn/Ni35p/Crb	Zn/Cu20a/Ni35p/Crr Zn/Cu20a/Ni30p/Crmc Zn/Cu20a/Ni30p/Crmp Zn/Cu20a/Ni30p/Crb
		Zn/Ni40s/Crr Zn/Ni35s/Crmc Zn/Ni35s/Crmp Zn/Ni35s/Crb	Zn/Cu20a/Ni35s/Crr Zn/Cu20a/Ni30s/Crmc Zn/Cu20a/Ni30s/Crmp Zn/Cu20a/Ni30s/Crb
		Zn/Ni40b/Crr Zn/Ni35b/Crmc Zn/Ni35b/Crmp Zn/Ni35b/Crb	Zn/Cu20a/Ni35b/Crr Zn/Cu20a/Ni30b/Crmc Zn/Cu20a/Ni30b/Crmp Zn/Cu20a/Ni30b/Crb
		Zn/Ni35d/Crr Zn/Ni30d/Crmc Zn/Ni30d/Crmp Zn/Ni30d/Crb	Zn/Cu20a/Ni30d/Crr Zn/Cu20a/Ni25d/Crmc Zn/Cu20a/Ni25d/Crmp Zn/Cu20a/Ni25d/Crb
<b>Partial designation in Service condition 5</b>			
		Zn/Ni45d/Crmc Zn/Ni45d/Crmp	Zn/Cu25a/Ni35d/Crmc Zn/Cu25a/Ni35d/Crmp

Table 3 — Coatings on copper and copper alloys

Ni	Cu + Ni	Ni + Cr	Cu + Ni + Cr
<b>Partial designation in Service condition 1</b>			
Cu/Ni8s		Cu/Ni8s/Crr Cu/Ni8s/Crb	
Cu/Ni8b		Cu/Ni8b/Crr Cu/Ni8b/Crb	
<b>Partial designation in Service condition 2</b>			
Cu/Ni15p		Cu/Ni12p/Crr Cu/Ni10p/Crmc Cu/Ni10p/Crmp Cu/Ni10p/Crb	
Cu/Ni15s		Cu/Ni12s/Crr Cu/Ni10s/Crmc Cu/Ni10s/Crmp Cu/Ni10s/Crb	
Cu/Ni15b		Cu/Ni12b/Crr Cu/Ni10b/Crmc Cu/Ni10b/Crmp Cu/Ni10b/Crb	
<b>Partial designation in Service condition 3</b>			
Cu/Ni25p		Cu/Ni20p/Crr Cu/Ni15p/Crmc Cu/Ni15p/Crmp Cu/Ni15p/Crb	
Cu/Ni25s		Cu/Ni20s/Crr Cu/Ni15s/Crmc Cu/Ni15s/Crmp Cu/Ni15s/Crb	
Cu/Ni25b		Cu/Ni20b/Crr Cu/Ni15b/Crmc Cu//Ni15b/Crmp Cu/Ni15b/Crb	
Cu/Ni20d		Cu/Ni15d/Crr Cu/Ni12d/Crmc Cu/Ni12d/Crmp Cu/Ni12d/Crb	



Table 3 (continued)

Ni	Cu + Ni	Ni + Cr	Cu + Ni + Cr
<b>Partial designation in Service condition 4</b>			
		Cu/Ni30p/Crr Cu/Ni25p/Crmc Cu/Ni25p/Crmp Cu/Ni25p/Crb	
		Cu/Ni30s/Crr Cu/Ni25s/Crmc Cu/Ni25s/Crmp Cu/Ni25s/Crb	
		Cu/Ni30b/Crr Cu/Ni25b/Crmc Cu/Ni25b/Crmp Cu/Ni25b/Crb	
		Cu/Ni25d/Crr Cu/Ni20d/Crmc Cu/Ni20d/Crmp Cu/Ni20d/Crb	
<b>Partial designation in Service condition 5</b>			
		Cu/Ni45d/Crmc Cu/Ni45d/Crmp	

Table 4 — Coatings on aluminium and aluminium alloys

Ni	Cu	Ni + Cr	Cu + Ni + Cr
<b>Partial designation in Service condition 1</b>			
Al/Ni10b		Al/Ni10b/Crr	
<b>Partial designation in Service condition 2</b>			
Al/Ni25p		Al/Ni25p/Crr Al/Ni20p/Crmc Al/Ni20p/Crmp	
Al/Ni25s		Al/Ni25s/Crr Al/Ni20s/Crmc Al/Ni20s/Crmp	
Al/Ni25b		Al/Ni25b/Crr Al/Ni20b/Crmc Al/Ni20b/Crmp	
Al/Ni20d		Al/Ni20d/Crr Al/Ni15d/Crmc Al/Ni15d/Crmp	
<b>Partial designation in Service condition 3</b>			
Al/Ni35p		Al/Ni35p/Crr Al/Ni30p/Crmc Al/Ni30p/Crmp	
Al/Ni35s			
Al/Ni35b		Al/Ni35b/Crr Al/Ni30b/Crmc Al/Ni30b/Crmp	
Al/Ni30d		Al/Ni30d/Crr Al/Ni25d/Crmc Al/Ni25d/Crmp	
<b>Partial designation in Service condition 4</b>			
		Al/Ni45d/Crr	
		Al/Ni35d/Crmc	
		Al/Ni35d/Crmp	
<b>Partial designation in Service condition 5</b>			
		Al/Ni50d/Crmc	
		Al/Ni50d/Crmp	

#### 5.4 Type of copper coating

The type of copper is designated by the symbol “a” for ductile, levelling copper electrodeposited from acid-type solutions [see 4.2 c)].

An initial copper coating, 5  $\mu\text{m}$  to 10  $\mu\text{m}$  thick, is normally applied to iron and steel from a copper cyanide solution before electroplating with ductile acid copper to prevent immersion deposition and poorly adherent deposits. The initial copper coating (copper strike) may not be substituted for any portion of the ductile acid copper specified in Table 1.

Zinc alloys are first electroplated with copper to ensure adhesion of the subsequent nickel coatings. The initial layer of copper is usually electrodeposited from a copper cyanide solution but cyanide-free alkaline copper solutions may also be used. The minimum thickness of the initial copper layer is 8  $\mu\text{m}$  to 10  $\mu\text{m}$ . For articles of complex shape, the minimum copper thickness may need to be increased to about 15  $\mu\text{m}$  to ensure adequate coverage on low-current density areas outside the significant surfaces. Ductile, levelling copper electrodeposited from acid solutions is usually applied over the initial cyanide copper deposit when the specified copper thickness is greater than 10  $\mu\text{m}$ .

For aluminium and aluminium alloys, suitable immersion deposits of zinc or tin, electrodeposited copper or other undercoats are necessary as part of the preparation for electroplating to ensure adhesion (see ISO 27831-2) prior to application of the designated nickel coatings given in Table 4.

#### 5.5 Types of nickel coating

The types of nickel coating shall be designated by the following symbols:

- b, for decorative, sulfur-containing bright, semi-bright, or satin nickel with a lamellar structure;
- i, for high-sulfur-containing bright, semi-bright or dull nickel with a lamellar structure that has not been mechanically polished;
- p, for dull or semi-bright nickel which has been mechanically polished;
- s, for sulfur-free dull or semi-bright nickel with a columnar structure that has not been mechanically polished;
- d, for double- or triple-layer nickel, the requirements for which are given in Table 5.

If sulfur-containing or sulfur-free bright, semi-bright or dull nickel, with or without mechanical polishing is required, it shall be specified by the purchaser [see 4.1 d)].

The sulfur contents are specified to indicate the type of nickel plating solution that is to be used. No simple method exists for determining the sulfur content of a nickel deposit on a coated article. However, an accurate determination is possible on a specially prepared test specimen using the methods specified in Annex D. It will usually be possible to identify the type and to determine the ratios of nickel layers by microscopical examination of a polished and etched section of an article prepared in accordance with ISO 1463, or by means of the STEP test. The test method for determination of specific elongation (or ductility) is specified in Annex C.

**Table 5 — Requirements for double- and triple-layer nickel coatings**

Layer (type of nickel)	Specific elongation %	Potential difference mV		Sulfur mass fraction %	Thickness as a percentage of total nickel thickness	
		Double nickel	Triple nickel		Double layer	Triple layer
Bottom (s)	> 8	80 to 150	≥ 120	< 0,005	30 to 60	≥ 50
Middle (i-type)	—			> 0,15	—	10
Top (b)	—		≥ 25	> 0,04 to < 0,15	40 to 70	≤ 40

**5.6 Types and thicknesses of chromium**

The type and thickness of the chromium shall be designated by the following symbols placed after the chemical symbol, Cr, as follows:

- b, black chromium thicknesses in the range 0,5 µm to 2 µm;
- r, for regular (i.e. conventional) chromium having a minimum local thickness of 0,3 µm;
- mc, for micro-cracked chromium having more than 200 cracks per centimetre in any direction, forming a closed network over the whole of the significant surface when determined by one of the methods specified in Annex A and having a minimum local thickness of 0,5 µm; with some processes, a substantially greater thickness (0,8 µm or above) of chromium may be required to achieve the necessary crack pattern, in which case the minimum local thickness shall be included in the coating designation as follows: Crmc (0,8);
- mp, for micro-porous chromium, containing a minimum of 10 000 pores per square centimetre when determined by one of the methods specified in Annex A and having a minimum local thickness of 0,3 µm; the pores shall be invisible to the unaided eye or corrected vision.

Micro-porous chromium is achieved by depositing the chromium over a special thin nickel layer which contains inert non-conducting particles, the special nickel layer being applied on top of b, s or d nickel (see 5.5). The thickness of this special nickel layer is not taken into account for the required total thickness of nickel.

There may be some loss of lustre after a period of service in the case of mp or mc chromium deposits, which may be unacceptable in some applications. This tendency can be reduced by increasing the minimum chromium coating thickness to 0,5 µm in cases where micro-porous or micro-cracked chromium is specified in Tables 1 to 4.

**6 Requirements**

**6.1 Appearance**

Over the significant surface, there shall be no plating defects such as blisters, pits, roughness, cracks, non-plated areas, stains or discolorations. The extent to which defects may occur on non-significant surfaces shall be specified by the purchaser [see 4.1 h)]. Where rack marks on the significant surface are unavoidable, their position shall be specified by the purchaser [see 4.1 i)]. The appearance shall be uniform and of an agreed colour and approved samples of artefacts shall be used for comparison purposes [see 4.1 c)].

## 6.2 Coating thickness

The thickness of the coating specified in the designation shall be the minimum local thickness. The minimum local thickness of an electrodeposited coating shall be measured at any point on the significant surface that can be touched by a ball 20 mm in diameter, unless otherwise specified by the purchaser [see 4.1 g) and 4.2 b)].

The thickness of the electrodeposited coating shall be measured by one of the methods described in Annex B.

## 6.3 Double- and triple-layer nickel coatings

The requirements for double- and triple-layer nickel coatings are summarized in Table 5.

## 6.4 Adhesion

The coating shall be sufficiently adherent to the basis metal, and the separate layers of a multilayer nickel coating shall be sufficiently adherent to each other, to pass either the file test or the thermal shock test specified in ISO 2819 [see 4.1 g)]. There shall not be any detachment of the coating from the substrate, or any separation between layers of the coating.

It is the responsibility of the electroplater to determine that the method for surface preparation, prior to electroplating, results in a surface that is capable of meeting the requirements of this subclause.

## 6.5 Corrosion resistance in CASS, Corrodkote and salt spray tests

Coated articles shall be subjected to one of the corrosion tests shown in Table 6 for the stated time that is appropriate for the particular service-condition number. The particular test to be used in any instance shall be specified by the purchaser [see 4.1 f)]. The accelerated corrosion tests are described in ISO 4541 and in the Bibliography and provide a means of controlling the continuity and quality of the coating and are not corrosion tests on metals. However, the duration and results of these tests may bear little relationship to the service life of the finished article and, therefore, the results obtained are not to be regarded as a direct guide to the corrosion resistance of the tested coatings in all environments where these coatings may be used. After the articles have been subjected to the appropriate corrosion test, they shall be examined and rated in accordance with ISO 10289. The minimum rating after corrosion testing shall be 9.

**Table 6 — Corrosion tests appropriate for each service-condition number**

Basis metal	Service-condition number	Duration of corrosion test h		
		CASS test (see the Bibliography)	Corrodkote test (ISO 4541)	Salt spray test (see the Bibliography)
Steel, copper or copper alloys, zinc or zinc alloys, aluminium or aluminium alloys	1	No test requirement	No test requirement	8
	2	8	8	48
	3	16	16	96
	4	24	2 × 16	144
	5	64	No test requirement	No test requirement

## 6.6 STEP test requirements

When specified by the purchaser, the electrochemical potential differences between individual nickel layers shall be measured for multilayer coatings by means of the STEP test [see 4.2 a)]. See Annex E and the Bibliography for STEP test methods.

## 6.7 Ductility

The specific elongation or ductility of the semi-bright nickel layer in multilayer nickel coatings, as well as for copper undercoats, shall be that specified in Table 5 when tested in accordance with the method specified in Annex C.

## 6.8 Stress-relief heat treatments before coating

Steel parts that have an ultimate tensile strength equal to or greater than 1 000 MPa (31 HRC) and that contain tensile stresses caused by machining, grinding, straightening or cold-forming operations shall be given a stress-relief heat treatment prior to cleaning and metal deposition, in accordance with the procedures and classes in ISO 9587 [see 4.1 j)], unless otherwise specified by the purchaser.

Steels with oxide or scale shall be cleaned before application of the coatings. For high-strength steels, non-electrolytic alkaline and anodic alkaline cleaners, as well as mechanical cleaning procedures, are preferred to avoid the risk of producing hydrogen embrittlement during cleaning operations.

## 6.9 Hydrogen-embrittlement-relief treatment

Steel parts having an ultimate tensile strength equal to or greater than 1 000 MPa (31 HRC), as well as surface-hardened parts, shall receive hydrogen-embrittlement-relief heat treatment in accordance with the procedures and classes in ISO 9588, unless otherwise specified by the purchaser [see 4.1 j)].

The effectiveness of the hydrogen-embrittlement-relief treatment shall be determined in accordance with ISO 10587 for testing threaded articles for residual hydrogen-relief heat treatment, and with ISO 15724 for measuring relative, diffusible hydrogen concentration in steels, unless otherwise specified by the purchaser.

Electroplated springs or other parts subject to flexure shall not be flexed before hydrogen-embrittlement-relief heat treatment.

The coatings described in this International Standard are rarely, if ever, applied to steel parts having a tensile strength greater than 1 000 MPa, and rarely, if ever, heat treated. If they are applied to steels that are susceptible to hydrogen embrittlement and heating after electroplating is required, the purchaser must be aware that heating may discolour and embrittle nickel coatings that contain sulfur.

## 6.10 Sampling

The method of sampling shall be selected from the procedures specified in ISO 4519. The acceptance levels shall be specified by the purchaser.

## **Annex A** (informative)

### **Determination of cracks and pores in chromium coatings**

#### **A.1 General**

Micro-cracking can usually be detected by direct microscopical examination without pretreatment. However, the copper deposition method is recommended as a means of revealing cracks (see A.3) in case of dispute, and is necessary to reveal micro-pores.

Both micro-cracked or micro-porous coatings are expected to exhibit a certain number of cracks or pores to assure specified corrosion resistance.

#### **A.2 Microscopical examination for cracks without pretreatment**

Examine the surface for cracks in reflected light under an optical microscope at a suitable magnification. Use a micrometer eyepiece or a similar device for indicating the distance over which cracks are counted. Carry out the determination over a measured length so that at least 40 cracks are counted.

#### **A.3 Copper deposition method by copper sulfate test for cracks and pores**

##### **A.3.1 Principle**

Electrodeposition of copper from an acid sulfate solution at low current density or low voltage occurs only on the underlying nickel that is exposed through discontinuities in the chromium. For counting discontinuities, the use of a microscope is essential.

Both tests are best applied immediately on completion of the electroplating process. If there is any delay, degrease the test specimen thoroughly prior to testing, avoiding any electrolytic treatment.

##### **A.3.2 Test method**

###### **A.3.2.1 Galvanostatic (Dubpernell) test**

In this method, the current density at a single crack or pore varies depending on the total number of cracks or pores in the test specimen.

This method, using constant current, may be used as a rapid means of visually assessing the uniformity of cracks or pores or for counting them. In the latter case, a microscope is to be used.

## ISO 1456:2009(E)

Mask the edges not covered by a chromium coating and all wires in contact with the electrodes using non-conductive material. Using the test specimen as the cathode, immerse in the following solution:

- copper(II) sulfate pentahydrate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) 200 g/l;
- sulfuric acid ( $\text{H}_2\text{SO}_4$ , 1,84 g/l) 20 g/l;
- current density (cathodic) 3 A/dm<sup>2</sup>;
- temperature (20 ± 5) °C;
- time (approximately) 1 min.

Rinse in cold and hot water and dry in air (see ISO 27831-2).

It is essential that the test specimen and the anodes be connected to the current supply before immersing them in the bath.

In case of delay, degrease and clean in accordance with ISO 27831-2 or using one of the methods given below:

For a short delay, degrease in a hot alkaline solvent below 65 °C and clean in sulfuric acid of 5 % to 10 % by volume ( $\text{H}_2\text{SO}_4$ , 1,84 g/l) with appropriate rinsing (see ISO 27831-2) and without drying before immersion in the above solution.

In cases where the test is applied several days after chromium deposition, immerse the test specimen in a solution containing 10 g/l to 20 g/l of nitric acid ( $\text{HNO}_3$ , 1,42 g/cm<sup>3</sup>) for 4 min at approximately 65 °C before the copper deposition stage to help reveal cracks or pores.

Carry out the determination by counting the copper nodules over a measured length until at least 40 cracks or 200 pores are counted using metallurgical microscopes with calibrated reticules or using micrographs covering representative fields of the test specimens.

### A.3.2.2 Potentiostatic method (Fuhrmann) test

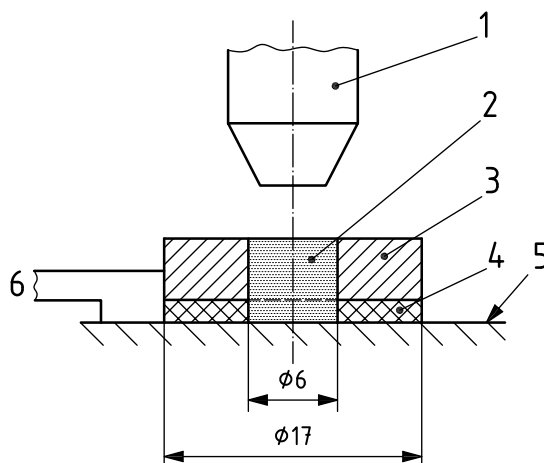
In this method, current densities at all cracks or pores are identical, independent of the total number of cracks or pores on the test specimen. This method, using constant voltage, provides more precise and reproducible results in counting pores.

#### A.3.2.2.1 Apparatus

The apparatus, as shown in Figure A.1, consists of a copper anode disc of diameter 17 mm, 4 mm thick with a cavity of diameter 6 mm.



Dimensions in millimetres

**Key**

- 1 microscope
- 2 copper sulfate electrolyte
- 3 copper disc anode
- 4 inert insulating disc
- 5 test specimen
- 6 constant current source

**Figure A.1 — Schematic drawing of apparatus for potentiostatic measurement**

**A.3.2.2.2 Procedure**

Using the test specimen as the cathode, immerse in the following solution:

- copper(II) sulfate pentahydrate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ )      33,00 g/l;
- sulfuric acid ( $\text{H}_2\text{SO}_4$ , 1,84 g/l)                              16,00 g/l;
- potassium chloride (KCl)    2,25 g/l;
- voltage    0,4 V (constant voltage);
- temperature     $(20 \pm 5) ^\circ\text{C}$ ;
- time    0,5 min to 1,0 min.

Fill up the cavity of the cell with copper electrolyte, place the equipment underneath a microscope for measurement and connect to the power supply. On wet surfaces, repeat the filling-up process twice to obtain a plain or slightly convex electrolyte surface.

Determine the number of pores by counting the copper nodules deposited within a known area using  $50 \times$  to  $200 \times$  magnification. The result is indicated as pores per square centimetre.

## **Annex B** (normative)

### **Methods of test for the determination of thickness**

#### **B.1 General**

ISO 3882 reviews methods for measuring the thickness of metallic and other inorganic coatings. The following methods are widely used.

#### **B.2 Destructive methods**

##### **B.2.1 Microscopical method**

Use the method specified in ISO 1463 with, if required, the nitric acid/glacial acetic acid etchant specified therein or, for coatings of copper plus nickel, a solution of 1 part by volume of nitric acid (density = 1,40 g/ml) to 5 parts by volume of glacial acetic acid.

NOTE The use of these etchants enables the thickness of the different layers in double- and triple-layer coatings to be distinguished and hence measured.

##### **B.2.2 Coulometric method**

The coulometric method specified in ISO 2177 may be used to measure the thickness of the chromium coating, the total thickness of the nickel, the thickness of the copper and the thickness of a copper alloy layer, if its composition is known, at any point on the significant surface than can be touched by a ball of 20 mm in diameter.

In case of dispute, the coulometric method shall be used for measuring the thickness of the chromium coating and for nickel coatings of thickness less than 10 µm. The microscopical method shall be used for measuring the thickness of nickel coatings and undercoats 10 µm and above.

##### **B.2.3 Scanning electron microscope method**

The scanning electron microscope method specified in ISO 9220 may be used to measure the thickness of the individual layers in multilayer coatings.

##### **B.2.4 STEP test**

The thickness of the individual nickel layers in double- and triple-layer coatings can be measured by one of the STEP test methods (see Annex E and the Bibliography).

#### **B.3 Non-destructive methods**

##### **B.3.1 Magnetic method (applicable to nickel coatings only)**

Use the method specified in ISO 2361.

NOTE This method is sensitive to variations in the permeability of coatings.

**B.3.2 Beta backscatter method (applicable only in the absence of copper undercoats)**

Use the method specified in ISO 3543.

This method determines the total coating thickness, including that of a copper undercoat, if present. The thickness of this undercoat can, however, be distinguished from that of the outer coating by using this method in conjunction with that specified in ISO 2177 for nickel and chromium coatings, or in conjunction with that specified in ISO 2361 for nickel coatings.

**B.3.3 X-ray spectrometry**

Use the method specified in ISO 3497.

## Annex C (normative)

### Ductility test

#### C.1 Scope

This annex specifies a method for determining the specific elongation of nickel electrodeposited onto a test piece and provides a means of assessing the ductility of the coating.

The test is used to check that the type of nickel deposit complies with the coating requirements specified in Table 5 and may be used in assessing the ductility of copper and other coatings.

#### C.2 Principle

The test is based on bending a test piece that has been electroplated with nickel, around a mandrel of specified diameter, to produce a minimum elongation of the coatings of 8 %, followed by examining the coatings visually for signs of cracking.

#### C.3 Apparatus

**C.3.1 Mandrel**, diameter 11,5 mm  $\pm$  0,1 mm.

#### C.4 Preparation of test piece

Prepare a coated test piece 150 mm long, 100 mm wide and 1 mm  $\pm$  0,1 mm thick as follows.

Polish a sheet of the appropriate base metal, similar to that of the articles being coated, except that the sheet may be of soft brass if the basis metal is zinc alloy. Use a sheet that is sufficiently large to allow the test strip to be cut from it after trimming off a border at least 25 mm wide all round.

Electroplate the polished side of the sheet with nickel to a thickness of 25  $\mu$ m under the same conditions and in the same bath as used with the corresponding articles.

Cut the test piece from the coated sheet with a guillotine or flat shear. Round or chamfer the longer edges of the test strip, at least on the plated side, by careful filing or grinding.

#### C.5 Procedure

Bend the test piece with the coated side in tension, by steadily applied pressure, through 180° over the mandrel until the two ends of the test piece are parallel. Ensure that contact between the test piece and the mandrel is maintained during bending. Visually examine the convex side of the bent test piece for cracks.

#### C.6 Expression of results

The coating is deemed to comply with the minimum requirement of an elongation of 8 % provided that, after testing, there are no cracks passing completely across the convex surface.

## **Annex D** **(normative)**

### **Determination of the sulfur content of electrodeposited nickel**

#### **D.1 Determination by combustion and iodate titrimetry**

The sulfur content of electrodeposited nickel shall be determined, when required, by combustion of a test portion of the nickel in a stream of oxygen in an induction furnace. The sulfur dioxide that is evolved is absorbed in an acidified potassium iodide/starch solution. The solution is then titrated with potassium iodate solution that has been freshly standardized against steels of known sulfur content, in order to compensate for day-to-day variations in sulfur dioxide recovery. Compensation is made for the blank to allow for the effects of crucibles and accelerators.

This method is applicable to electrodeposited nickel having a sulfur mass fraction in the range of 0,005 % to 0,5 %

**NOTE** Commercial instruments are available that utilize infrared and thermal conductivity detection methods to measure the sulfur dioxide produced by combustion, and that have computer facilities that permit direct read-out of the sulfur content.

#### **D.2 Determination by sulfide formation and iodate titrimetry**

Alternatively, the sulfur content of electrodeposited nickel shall be determined by converting the sulfur in the nickel to hydrogen sulfide by treatment with hydrochloric acid containing dissolved hexachloroplatinic acid, as an accelerator for dissolution. The hydrogen sulfide that is evolved is reacted with ammoniacal zinc sulfate. The zinc sulfide that is formed is titrated with standard volumetric potassium iodate solution. The results are based on potassium iodate as the primary standard.

## Annex E (informative)

### Step test method

#### E.1 General

When specified by the purchaser [see 4.2 a)], use one of the two methods described in References [10] and [18] in the Bibliography.

#### E.2 Test methods

##### E.2.1 Potential difference in multilayer deposit

In triple-layer nickel coatings, the STEP potential difference between the special high-activity nickel layer and the bright nickel layer is within the range of 15 mV to 35 mV, and the high-activity layer is always more active (anodic) than the bright nickel layer.

The STEP potential difference between the thin nickel layer immediately below the chromium (applied, for example, to induce micro-porosity or micro-cracking) and the bright nickel layer is within 0 mV to 30 mV, and the bright nickel layer is always more active (anodic) than the thin nickel layer applied prior to chromium.

Although universally accepted, STEP values have not been established and some agreement exists for required ranges. For example, the STEP potential difference between the semi-bright and bright nickel layer is within the range of 15 mV to 200 mV, and the semi-bright nickel layer is always more noble (cathodic) than the bright nickel layer.

The STEP test is a modification of the coulometric method of thickness testing by anodic dissolution described in ISO 2177, the essential difference being the incorporation of a standard reference electrode within the coulometric cell. Changes in potential are recorded as a function of time as the multilayer nickel coating is dissolved anodically at a constant current in a standard solution of, for nickel, nickel chloride ( $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ ; 300 g/l), sodium chloride (NaCl; 50 g/l) and boric acid ( $\text{H}_3\text{BO}_3$ ; 25 g/l), at pH 3,0 and at ambient temperature. The graph of potential versus time that results from the measurement is then analysed to determine the potential differences between individual layers, the thickness of each layer and the total coating thickness (see Bibliography, Reference [10]).

##### E.2.2 Potential determination of individual layers of deposits

This test is also a modification of the coulometric method of thickness testing by anodic dissolution described in ISO 2177, the essential difference being the incorporation of a standard reference electrode within the coulometric cell and measurements of potential differences between individual nickel layers in multilayer nickel deposits. According to this method, the STEP potential difference is between 80 mV and 150 mV for double nickel layers with the semi-bright nickel layer being more noble than the bright nickel layer, and 20 mV and 60 mV for the bright nickel layer with bright nickel being less noble than the nickel layer applied prior to, for example, the micro-porous chromium coating.

Changes in potentials between individual layers are recorded by dissolving anodically in a similar solution as described in E.2.1, i.e. nickel chloride ( $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$ ; 300 g/l), sodium chloride (NaCl; 50 g/l) and boric acid ( $\text{H}_3\text{BO}_3$ ; 25 g/l), at pH 3,0 and at ambient temperature. The graphs of potential variations are analysed. With most commercially available instruments, the thicknesses are automatically calculated from the dissolution time and potential differences are measured as a function of layer thicknesses (in micrometres) (see Bibliography, Reference [18]).

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