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Metallic coatings — Electrodeposited coatings of nickel plus chromium and of copper plus nickel plus chromium

Revêtements métalliques — Dépôts électrolytiques de nickel plus chrome et de cuivre plus nickel plus chrome

Reference number
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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. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 1456 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings.*

This second edition cancels and replaces the first edition (ISO 1456 : 1974) and International Standard ISO 1457 : 1974 of which it constitutes a technical revision.

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

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Metallic coatings — Electrodeposited coatings of nickel plus chromium and of copper plus nickel plus chromium

1 Scope and field of application

1.1 This International Standard specifies requirements for nickel plus chromium and for copper plus nickel plus chromium electrodeposited coatings that are applied to iron, steel, zinc alloys, copper and copper alloys, and aluminium and aluminium alloys to provide an attractive appearance and corrosion resistance. Several classes of coatings are provided that differ in thickness and type and guidance is given in selecting the coating class appropriate to the service conditions to which the coated product will be exposed.

1.2 This International Standard does not specify the surface condition required by the basis metal prior to the coating process.

1.3 This International Standard is not applicable to coatings on sheet, strip or wire in the unfabricated form nor to threaded fasteners or coil springs.

NOTES

1 ISO 4526 and ISO 6158 specify requirements for coatings of nickel and chromium used for engineering purposes.

2 Requirements for similar coatings, except for the absence of a top-coat of chromium, that can be used for appearance and protection are specified in ISO 1458.

2 References

ISO 1458, *Metallic coatings — Electrodeposited coatings of nickel.*

ISO 1462, *Metallic coatings — Coatings other than those anodic to the basis metal — Accelerated corrosion tests — Method for the evaluation of the results.*

ISO 1463, *Metal and oxide coatings — Measurement of thickness by microscopical examination of cross-sections.*

ISO 2064, *Metallic and other non-organic coatings — Definitions and conventions concerning the measurement of the thickness.*

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

ISO 2361, *Electrodeposited nickel coatings on magnetic and non-magnetic substrates — Measurement of coating thickness — Magnetic method.*

ISO 2819-1, *Metallic coatings on metallic substrates — Review of methods available for testing adhesion — Part 1 : Electrodeposited and chemically deposited coatings.*

ISO 2859, *Sampling procedures and tables for inspection by attributes.*

ISO 3497, *Metallic coatings — Measurement of coating thickness — X-ray spectrometric methods.*

ISO 3769, *Metallic coatings — Acetic acid-salt spray test (ASS test).*

ISO 3770, *Metallic coatings — Copper-accelerated acetic acid salt spray test (CASS test).*

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

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

ISO 4541, *Metallic and other non-organic coatings — Corrodkote corrosion test (CORR test).*

ISO 6158, *Metallic coatings — Electroplated coatings of chromium for engineering purposes.*

3 Definitions

For the purposes of this International Standard, the definitions given in ISO 2064 apply.

4 Information to be supplied by the purchaser to the electroplater

4.1 Essential information

When ordering articles to be electroplated in accordance with this International Standard, the purchaser shall provide the following information :

4.1.1 The number of this International Standard.

4.1.2 The basis metal and either the service condition number (see 5.1) denoting the severity of the conditions to be withstood by the coated article or the classification code (see 5.2) of the particular coating required.

If the basis metal and the service condition number are quoted and not the classification code, the electroplater is free to supply any of the classes of coating corresponding to the service condition number, but he shall inform the purchaser of the classification code of the coating which he has selected (see also 7.2).

4.1.3 The finish required, for example, bright, dull, or satin (see 7.2). Alternatively, samples showing the required finish or range of finish shall be supplied or approved by the purchaser.

4.1.4 Significant surfaces, to be indicated on drawings of the parts, or by the provision of suitably marked specimens.

4.1.5 The type of corrosion test to be used (see 7.4).

4.1.6 The type of adhesion test to be used (see 7.3).

4.1.7 The extent to which defects shall be tolerated on non-significant surfaces (see 7.1).

4.1.8 The positions on the significant surface for rack or contact marks, where such marks are unavoidable (see 7.1).

4.1.9 Sampling methods and acceptance levels (see clause 8).

4.2 Additional information

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

4.2.1 The tensile strength of the steel and any requirement for heat treatment either before or after electroplating (see clause 6).

4.2.2 Thickness requirements on those areas that cannot be touched by a ball 20 mm in diameter (see 7.2.1).

4.2.3 Whether or not a copper undercoat is required [see 5.2 b)].

5 Classification

5.1 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 :

4 — Exceptionally severe

3 — Severe

2 — Moderate

1 — Mild

0 — Exceptionally mild

Typical service conditions for which the various service condition numbers are appropriate are listed in annex E.

5.2 Coating classification code

The coating classification code comprises the following :

a) The chemical symbol for the basis metal (or for the principal metal if an alloy) followed by a stroke, as follows :

— Fe/ for iron or steel;

— Zn/ for zinc alloys;

— Cu/ for copper or copper alloys;

— Al/ for aluminium or aluminium alloys.

b) The chemical symbol for copper (Cu), if copper, or brass containing greater than 50 % copper, is used as an undercoat.

c) A number indicating the minimum local thickness, in micrometres, of the copper coating where applicable.

d) The chemical symbol for nickel (Ni).

e) A number indicating the minimum local thickness, in micrometres, of the nickel coating.

f) A letter designating the type of nickel coating (see 7.2.3.2).

g) The chemical symbol for chromium (Cr).

h) A letter or letters designating the type of chromium coating and its minimum thickness (see 7.2.4).

Example of a complete classification code : A coating on steel comprising 20 µm copper (minimum) plus 30 µm bright nickel (minimum) plus 0,3 µm micro-cracked chromium (minimum) has the classification code

Fe/Cu20 Ni30b Cr mc

NOTE — For nickel plus chromium and copper plus nickel plus chromium coatings, the minimum thickness requirements apply only to those portions of the significant surface that can be touched by a ball 20 mm in diameter unless otherwise specified by the purchaser (see 7.2.1).

5.3 Coatings appropriate to each service condition number

Tables 2A to 5 show, for various basis metals, the coating classification codes appropriate for each service condition number.

6 Heat treatment of steel

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

If the purchaser specifies that heat treatment is necessary (see 4.2.1), before and/or after electroplating, it shall be carried out in accordance with the appropriate recommendations given in annex A.

7 Coating requirements

7.1 Appearance

Over the significant surface, there shall be no clearly visible plating defects such as blisters, pits, roughness, cracks, unplated areas, stains or discolorations. The extent to which defects may occur on non-significant surfaces shall be specified by the purchaser. Where rack marks on the significant surface are unavoidable, their position shall be specified by the purchaser.

7.2 Thickness and type of coatings

7.2.1 General

For a specified service condition number, the thickness and type of coatings shall correspond to the classification codes given in tables 2A to 5. The minimum allowable thickness for the metal coatings shall be required on any point on the significant surface that can be touched by a ball 20 mm in diameter and the purchaser may also specify that other points shall meet those thickness requirements. Test methods for determining coating thickness are specified in 9.1.

7.2.2 Thickness of copper coating

For copper plus nickel plus chromium coatings, the minimum thickness for copper is indicated in the classification codes given in tables 2B and 3B. The minimum copper thickness for a system of nickel plus chromium on zinc alloys is 8 µm. (See table 3A.)

NOTE — All the nickel coatings given in table 3A are applied over an undercoat of copper having a thickness of at least 8 µm [see 5.2 b) and 7.2.2]. However, for articles of complex shape, the minimum thickness of copper on the significant surface may need to be increased to 10 µm or 12 µm in order to achieve adequate coverage on low-current areas outside the significant surfaces.

7.2.3 Thickness and type of nickel coatings

7.2.3.1 Thickness of nickel coating

The total minimum thickness of nickel shall be that designated by the classification code (see 5.2).

7.2.3.2 Type of nickel coating

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

b for nickel deposited in the fully bright condition;

p for dull or semi-bright nickel which has been mechanically polished;

s for dull, satin, or semi-bright nickel which shall not have been mechanically polished;

d for double- or triple-layer coatings; the requirements for such coatings are given in table 1.

NOTES

1 The test method for the determination of specific elongation is specified in annex B.

2 The sulfur contents are specified in order 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 either of the methods specified in annex D.

3 It will usually be possible to identify the type and to determine the ratios of thicknesses of nickel layers by microscopical examination of a polished and etched section of an article prepared in accordance with ISO 1463.

7.2.4 Thickness and type of chromium coating

7.2.4.1 Thickness of chromium coating

The thickness of the chromium coatings shall be as follows :

— Regular (conventional) chromium (designated Cr r) — minimum thickness 0,3 µm.

— Micro-cracked chromium (designated Cr mc) — minimum thickness 0,3 µm (see notes 1 and 2).

— Micro-cracked chromium (designated Cr mc 0,5) — minimum thickness 0,5 µm (see note 2 and note in 7.2.4.2).

— Micro-porous chromium (designated Cr mp) — minimum thickness 0,3 µm (see note 2).

— Micro-porous chromium (designated Cr mp 0,5) — minimum thickness 0,5 µm (see note 2).

Table 1 — Requirements for double- or triple-layer nickel coatings

Layer (type of nickel coating)	Specific elongation % (see note 1)	Sulfur content % (*m*/*m*) (see note 2)	Thickness, as a percentage of total nickel thickness (see note 3)	
			Double-layer	Triple-layer
Bottom (s)	> 8	< 0,005	⩾ 60	⩾ 50
Middle (high-sulfur) (b)	—	> 0,15	—	10
Top (b)	—	> 0,04 and < 0,15	< 40	< 40

NOTES

1 With some processes a substantially greater thickness, approximately 0,8 µm, will be required to achieve the necessary crack pattern.

2 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 every case where micro-porous or micro-cracked chromium is specified in tables 2A to 5.

7.2.4.2 Type of chromium coating

The type of chromium coating is designated by placing symbols after the chemical symbol, Cr, as follows :

Cr r for regular chromium;

Cr mc for micro-cracked chromium which, when tested by the method described in annex C, has more than 250 cracks per centimetre in any direction and form a closed network over the whole significant surface;

Cr mp for micro-porous chromium which, when tested by the method specified in annex C, contains at least 10 000 pores per square centimetre (see the note).

NOTE — This type of coating is often achieved by depositing chromium over a special thin nickel layer which contains inert non-conducting particles, the special nickel layer being applied on top of b, s, p or d nickel.

7.3 Adhesion

The coating shall be sufficiently adherent to the basis metal, and the separate layers of a multilayer coating shall be sufficiently adherent to each other, to pass the appropriate test specified in 9.2.

7.4 Corrosion resistance

Coated articles shall be sufficiently corrosion-resistant and pore-free to pass the appropriate test specified in 9.3 for the particular service condition number. The performance rating shall be determined in accordance with ISO 1462. The minimum acceptance rating, after testing in accordance with 9.3, shall be a rating of 9.

8 Sampling

The method of sampling shall be selected from the procedures specified in ISO 2859 or ISO 4519. The acceptance levels shall be specified by the purchaser.

9 Methods of test

9.1 Thickness

The thickness of a coating and of its component layers shall be measured at any part of the significant surface that can be touched by a ball 20 mm in diameter. The coulometric method specified in ISO 2177 may be used to measure the thickness of the chromium, the total thickness of the nickel, the thickness of the copper and the thickness of a copper alloy undercoat, if its composition is known.

The X-ray method specified in ISO 3497 may be used to measure the thickness of the chromium. It may also be used to measure the thickness of an undercoat prior to electroplating with nickel.

The microscopical method specified in ISO 1463 may be used to measure the thickness of each nickel layer, where the minimum thickness is 10 µm, and of a copper or copper alloy undercoat, when present (see 7.2).

NOTE — The thickness of the individual nickel layers in double-layer and triple-layer coatings, as well as the electrochemical relationships between the individual layers, can also be measured by the STEP test[1]. Because this test can be used on production parts, it is being evaluated intensively and being incorporated in company and national standards. The optimum value of the potential difference between bright and semi-bright nickel layers to assure good corrosion performance is still a matter of controversy, but one company has specified that it shall be not less than 125 mV. It is recommended that users of this International Standard become familiar with this test and begin using it, because it has the potential of greatly improving the quality of electroplated production parts.

The magnetic method specified in ISO 2361 may be used to measure the total thickness of b, d, s or p nickel on zinc alloys and copper alloys and on ferrous materials, if an appropriate calibration can be made. Other methods may be used if it can be demonstrated that the uncertainty of the measurement is less than 10 %.

In cases 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, and the microscope method shall be used for measuring the thickness of nickel coatings and undercoats of thickness 10 µm and above.

9.2 Adhesion

Adhesion of the coating shall be tested by either the file test or the thermal shock test specified in ISO 2819-1. There shall not be any detachment of the coating from the substrate, or any separation between layers of the coating.

9.3 Corrosion resistance

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.

The corrosion tests are described in ISO 3769, ISO 3770 and ISO 4541 and provide a means of controlling the continuity and quality of the coating. However, the duration of these tests bears little relationship to the service life of the finished article.

After the articles have been subjected to the appropriate corrosion test, they shall be examined and rated in accordance with ISO 1462 (see 7.4).

9.4 Ductility

The ductility shall be such that the elongation will be not less than specified in 7.2.3.2 for nickel when tested in accordance with the method specified in annex B.

9.5 Discontinuities in the chromium deposit

The density of cracks or pores in micro-cracked or micro-porous chromium deposits shall meet the minimum requirements specified in 7.2.4.2.

A method of measuring the discontinuities is specified in annex C.

10 Bibliography

[1] HARBULAK, E. P., Simultaneous Thickness and Electrochemical Potential Determination of Individual Layers in Multilayer Nickel Deposits, *Plating and Surface Finishing, 67 (February),* **49** (1980).

Table 2A — Nickel plus chromium coatings on iron or steel

Service condition number	Classification code[1)]
4	Fe/Ni40d Cr r Fe/Ni30d Cr mc Fe/Ni30d Cr mp
4	Fe/Ni40p Cr r Fe/Ni30p Cr mc Fe/Ni30p Cr mp
3	Fe/Ni30d Cr r Fe/Ni25d Cr mc Fe/Ni25d Cr mp
3	Fe/Ni30p Cr r Fe/Ni25p Cr mc Fe/Ni25p Cr mp
3	Fe/Ni40b Cr r Fe/Ni30b Cr mc Fe/Ni30b Cr mp
2	Fe/Ni20b Cr r
1	Fe/Ni10b Cr r
0	Fe/Ni5b Cr r

1) s nickel may be substituted for b nickel, and mc or mp chromium may be substituted for r chromium for service conditions 3, 2, 1 and 0. p and d nickel may be substituted for b nickel for service conditions 2 and 1.

Table 2B — Copper plus nickel plus chromium coatings on iron or steel

Service condition number	Classification code[1)]
4	Fe/Cu20 Ni30d Cr r Fe/Cu20 Ni25d Cr mc Fe/Cu20 Ni25d Cr mp
4	Fe/Cu20 Ni30p Cr r Fe/Cu20 Ni25p Cr mc Fe/Cu20 Ni25p Cr mp
4	Fe/Cu20 Ni30b Cr mc Fe/Cu20 Ni30b Cr mp
3	Fe/Cu15 Ni25d Cr r Fe/Cu15 Ni20d Cr mc Fe/Cu15 Ni20d Cr mp
3	Fe/Cu15 Ni25p Cr r Fe/Cu15 Ni20p Cr mc Fe/Cu15 Ni20p Cr mp
3	Fe/Cu20 Ni35b Cr r Fe/Cu20 Ni25b Cr mc Fe/Cu20 Ni25b Cr mp
2	Fe/Cu20 Ni10b Cr r
1	Fe/Cu10 Ni5b Cr r
0	Fe/Cu5 Ni5b Cr r

1) s nickel may be substituted for b nickel, and mc or mp chromium may be substituted for r chromium for service conditions 3, 2, 1 and 0. p and d nickel may be substituted for b nickel for service condition 2.

Table 3A — Nickel plus chromium coatings on zinc alloys

Service condition number	Classification code[1)]
4	Zn/Cu Ni35d Cr r Zn/Cu Ni25d Cr mc Zn/Cu Ni25d Cr mp
4	Zn/Cu Ni35p Cr r Zn/Cu Ni25p Cr mc Zn/Cu Ni25p Cr mp
4	Zn/Cu Ni35b Cr mc Zn/Cu Ni35b Cr mp
3	Zn/Cu Ni25d Cr r Zn/Cu Ni20d Cr mc Zn/Cu Ni20d Cr mp
3	Zn/Cu Ni25p Cr r Zn/Cu Ni20p Cr mc Zn/Cu Ni20p Cr mp
3	Zn/Cu Ni35b Cr r Zn/Cu Ni25b Cr mc Zn/Cu Ni25b Cr mp
2	Zn/Cu Ni15b Cr r
0 and 1	Zn/Cu Ni8b Cr r

1) s nickel may be substituted for b nickel, and mc or mp chromium may be substituted for r chromium for service conditions 3, 2 and 1. p and d nickel may be substituted for b nickel for service condition 2.

Thinner coatings than those given for service condition 1 are not specified for service condition 0.

Table 3B — Copper plus nickel plus chromium coatings on zinc alloys [see 5.2b)]

Service condition number	Classification code[1)]
4	Zn/Cu20 Ni30d Cr r Zn/Cu20 Ni20d Cr mc Zn/Cu20 Ni20d Cr mp
4	Zn/Cu20 Ni30p Cr r Zn/Cu20 Ni20p Cr mc Zn/Cu20 Ni20p Cr mp
4	Zn/Cu20 Ni30b Cr mc Zn/Cu20 Ni30b Cr mp
3	Zn/Cu15 Ni20d Cr r Zn/Cu15 Ni15d Cr mc Zn/Cu15 Ni15d Cr mp
3	Zn/Cu15 Ni20p Cr r Zn/Cu15 Ni15p Cr mc Zn/Cu15 Ni15p Cr mp
3	Zn/Cu20 Ni30b Cr r Zn/Cu20 Ni20b Cr mc Zn/Cu20 Ni20b Cr mp
2	Zn/Cu20 Ni10b Cr r
0 and 1	The coating systems given in table 3A for service condition number 1 shall apply here.

1) s nickel may be substituted for b nickel, and mc or mp chromium may be substituted for r chromium for service conditions 3, 2 and 1. p and d nickel may be substituted for b nickel for service condition 2.

Table 4 — Nickel plus chromium coatings on copper or copper alloys

Service condition number	Classification code[1)]
4	Cu/Ni30d Cr r Cu/Ni25d Cr mc Cu/Ni25d Cr mp Cu/Ni30p Cr r Cu/Ni25p Cr mc Cu/Ni25p Cr mp Cu/Ni30b Cr mc Cu/Ni30b Cr mp
3	Cu/Ni25b Cr r
2	Cu/Ni10b Cr r
1	Cu/Ni5b Cr r
0	Cu/Ni3b Cr r

1) s nickel may be substituted for b nickel, and mc or mp chromium may be substituted for r chromium for service conditions 3, 2, 1 and 0. p and d nickel may be substituted for b nickel for service conditions 3 and 2.

Table 5 — Coatings of nickel plus chromium on aluminium or aluminium alloys

Service condition number	Classification code[1)]
4	Al/Ni50d Cr r Al/Ni35d Cr mc Al/Ni35d Cr mp
3	Al/Ni30d Cr r Al/Ni25d Cr mc Al/Ni25d Cr mp Al/Ni35p Cr r Al/Ni30p Cr mc Al/Ni30p Cr mp
2[2)]	Al/Ni20b Cr r
0 and 1[2)]	Al/Ni10b Cr r

1) A copper undercoat in addition to the specified nickel coatings may be used on certain alloys and for certain applications.

2) p, d or s nickel may be substituted for b nickel, and mc or mp chromium may be substituted for r chromium for service conditions numbers 2 and 1.

Table 6 — Corrosion tests appropriate for each service condition number

Basis metal	Service condition	Duration of corrosion test, h		
		CASS test (ISO 3770)	Corrodkote test (ISO 4541)	Acetic acid salt spray test (ISO 3769)
Steel	4	24	2 × 16	144
	3	16	16	96
	2	8	8	48
	1	—	—	8
Zinc alloy	4	24	2 × 16	144
	3	16	16	96
	2	8	8	48
	1	—	—	8
Copper or copper alloy	4	16	—	96
	3	—	—	24
	2	—	—	8
	1	—	—	—
Aluminium or aluminium alloy	4	24	2 × 16	144
	3	16	16	96
	2	8	8	48
	1	—	—	8

NOTES

1 The duration of tests is less when the basis metal is copper or copper alloy than when it is iron or steel, zinc alloy or aluminium alloy. This is necessary since, for the same service condition number, the nickel deposits on copper and copper alloy are thinner than those on iron or steel, zinc alloy or aluminium alloy. The use of these thinner and less corrosion-resistant coatings is justified by the slower corrosion of copper and copper alloys when the coating are penetrated.

2 Dashes indicate that there is no test requirement.

3 There are no corrosion test requirements for service condition 0.

Annex A

Recommendations for heat treatment of steel

(This annex forms an integral part of the Standard.)

Heat treatment is normally necessary for some steels to reduce the risk of damage by hydrogen embrittlement and can comprise

a) stress relief before electroplating;

b) heat treatment after electroplating.

Recommendations for such treatment are summarized in table 7.

Table 7 — Recommendations for heat treatment of steels

	Before electroplating	After electroplating		
Steel components normally requiring heat treatment	Components that have been severely cold-worked or that are made from steel of tensile strength of 1 000 MPa (or corresponding hardness[1]) or greater, that have been ground or subjected to severe machining after tempering.	Components that are made from severely cold-worked steels or from steels of tensile strength of 1 000 MPa (or corresponding hardness[1]) and that are subject to fatigue or sustained loading stress in service.		
Heat treatment **a) General recommendations**	30 min at the highest temperature within the limit imposed by the tempering temperature **but not higher than 50 °C below the tempering temperature** or 1 h minimum at a temperature of between 190 and 210 °C	**Tensile strength** MPa	**Maximum thickness of component** mm	**Minimum period at 190 to 210 °C** h
		> 1 000 and ⩽ 1 150	< 12	2
			12 to 25	4
			> 25	8
		> 1 150 and ⩽ 1 400	< 12	4
			12 to 25	12
			> 25	24
				NOTE — Heating to commence within 16 h of plating.
b) Restrictions	Steels that have been carburized, flame- or induction-hardened shall be heated at a lower temperature for a longer period, e.g. more than 1 h at a temperature of 170 °C.	If the components have been surface-hardened, they shall be heated at a lower temperature for a longer period, provided that these conditions have been shown to be effective for a particular component and are acceptable to the purchaser.		

1) 30 HRC, 295 HV, 280 HB (approximate values).

Annex B

Ductility test

(This annex forms an integral part of the Standard.)

B.1 Scope and field of application

This annex specifies a method for determining the specific elongation of the coating on an electrocoated test piece and provides a means of assessing the ductility of the coating.

NOTE — The test is used to check that the type of nickel deposit complies with the coating requirements specified in 7.2.3.2 and may be used in assessing the ductility requirements of other types of coating (see 9.4).

B.2 Principle

Bending a nickel coated test piece around a mandrel in order to produce a minimum elongation in the coating of 8 % and visual examination to observe whether or not cracking has taken place in the coating.

B.3 Apparatus

Mandrel, diameter 11,5 ± 0,1 mm.

B.4 Procedure

B.4.1 Preparation of test piece

Prepare a coated test piece 150 mm long, 10 mm wide and 1,0 ± 0,1 mm thick as follows.

Polish a sheet of the appropriate basis 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 if 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 µm 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.

B.4.2 Test

Bend the test piece (B.4.1) with the coated side in tension, by steadily applied pressure, through 180° over the mandrel (B.3) until the two ends of the test piece are parallel. Ensure that contact between the test piece and the mandrel is maintained during bending. Examine the convex side of the bent test piece visually for cracks.

B.5 Expression of results

If there are no cracks in the nickel coating on the test piece which have propagated completely over the convex surface (see note), the coating is deemed to have a specific elongation of 8 % or greater and is deemed to have passed the test.

NOTE — Short cracks in the nickel coating at the edges of the test piece do not indicate failure.