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Metallic coatings — Review of porosity tests

Revêtements métalliques — Passage en revue des essais de porosité

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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 10308 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*, Subcommittee SC 7, *Corrosion tests*.

This second edition cancels and replaces the first edition (ISO 10308:1995), which has been technically revised.

Metallic coatings — Review of porosity tests

WARNING — This international Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and in no way absolves either the designer, the producer, the supplier or the user from statutory and all other legal obligations relating to health and safety at any stage of manufacture or use.

1 Scope

This International Standard reviews published methods for revealing pores (see ISO 2080) and discontinuities in coatings of aluminium, anodized aluminium, brass, cadmium, chromium, cobalt, copper, gold, indium, lead, nickel, nickel-boron, nickel-cobalt, nickel-iron, nickel-phosphorus, palladium, platinum, vitreous or porcelain enamel, rhodium, silver, tin, tin-lead, tin-nickel, tin-zinc, zinc and chromate or phosphate conversion coatings (including associated organic films) on aluminium, beryllium-copper, brass, copper, iron, NiFeCo alloys, magnesium, nickel, nickel-boron, nickel-phosphorus, phosphor-bronze, silver, steel, tin-nickel and zinc alloy basis metal.

The tests summarized in this International Standard are designed to react with the substrate when exposed, by a discontinuity, in such a way as to form an observable reaction product.

NOTE 1 Pores are usually perpendicular to the coating surface but may be inclined to the coating surface. They are frequently cylindrical in shape but may also assume a twisted shape (see Annex C).

NOTE 2 Porosity may vary in size from the submicroscopic, invisible using a light microscope, to the microscopic, visible from × 10 to × 1 000, to the macroscopic, visible to the naked eye.

NOTE 3 Porosity may be visibly indicated by discolouration of the coated surface.

NOTE 4 Porosity in a coating is not always detrimental. In microdiscontinuous chromium, for example, porosity or microcracking is beneficial and tests are conducted to indicate the pores.

NOTE 5 Results obtained from porosity tests, expressed in terms such as pores per square centimeter, are relative values associated with the specific test method used and the magnification used during examination. Annex B gives typical report criteria.

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 2080:1981, *Electroplating and related processes — Vocabulary*

ISO 10289:1999, *Methods for corrosion testing of metallic and other inorganic coatings on metallic substrates — Rating of test specimens and manufactured articles subjected to corrosion tests*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2080 and the following apply.

3.1
discontinuities
cracks, micro-holes, pits, scratches or any other opening in the coating surface that exposes a different underlying metal

NOTE For further information on discontinuities, see Annex D and reference [1] in the Bibliography.

4 Principle

The results of porosity tests are the end products of a chemical reaction with a metallic substrate. Some occur *in situ,* others on paper or in a gel coating. Observations are made that are consistent with the test method and the items being tested, as specified by the purchaser. These may be visual inspections (naked eye) or at × 10 magnification (microscope). Other methods may involve enlarged photographs or photo-micrographs. See references [1,2, 3, 5 and 6] in the Bibliography (see also Annex A for a tabular summary of the porosity tests and Annex D for a classification of discontinuities).

5 Common features of porosity tests

Porosity tests differ from corrosion tests and, particularly, ageing tests regarding test duration. Porosity tests are primarily short-time tests. A good porosity test process shall clean, depolarize and activate the substrate metal exposed by the pore and attack it to such a degree as to cause the reaction product to fill the pore to the surface of the coating. The corrosive shall not react with the coating. It is essential that the time of reaction be limited, particularly with thin coatings, since the corrosive will attack the substrate in all directions and, in so doing, will undermine the coatings resulting in misleading observations. When the corrosion product is soluble in the reagent, the precipitating indicator is used to form the reaction product. (See Annex E for a classification of methods of porosity testing).

6 Test specimens

Porosity tests are generally destructive in nature and are designed to assess the quality of the coating process of the substrate. Therefore, as a rule, separate test specimens are not used.

7 Specific porosity tests

7.1 Alizarin test

7.1.1 Scope

For coatings of chromium (including Cr/Ni/Cu and Cr/Ni/Ni), cobalt, copper, nickel, nickel-boron, nickel-cobalt, nickel-iron and nickel-phosphorus on aluminium substrate.

7.1.2 Summary of method

The test specimens are treated with sodium hydroxide, sodium alizarin sulfonate and glacial acetic acid under defined conditions. Formation of red markings or spots indicates porosity. Details of the test procedure can be found in references [9, 21 and 25] in the Bibliography.

7.2 Anthraquinone test

7.2.1 Scope

For coatings of chromium (including Cr/Ni/Ni), cobalt, nickel, nickel-boron, nickel-cobalt, nickel-iron and nickel-phosphorus on aluminium, magnesium or zinc alloy substrates.

7.2.2 Summary of method

The test specimens are treated with sodium hydroxide and potassium 1-aminoanthraquinone-2-carboxylic acid under defined conditions. The formation of red markings or spots indicates porosity. Details of the test procedure can be found in reference [13] in the Bibliography.

7.3 Cadmium sulfide test

7.3.1 Scope

For metallic coatings of chromium (including Cr/Ni/Ni), gold, palladium, platinum and rhodium on beryllium-copper, brass, copper, phosphor-bronze and silver substrates.

7.3.2 Summary of method

Filter paper is soaked in cadmium chloride and then treated with sodium sulfide to precipitate cadmium sulfide. The sample is sandwiched between the cadmium sulfide paper (which acts as the anode) and the moistened blotting paper fastened to a high-purity clean aluminium or stainless steel platen (which acts as the cathode). D.C. current is applied for a specific time. Brown stains on the paper indicate pores. Details of the test procedure can be found in ISO 4524-3.

7.4 Copper sulfate (Preece) test

7.4.1 Scope

Variation A. For coatings of cadmium and zinc on iron, steel or iron-based alloy substrates.

Variation B. For thin (< 5 µm) anodic oxide coatings on aluminium and aluminium alloy substrates.

7.4.2 Summary of method

The test specimen is immersed in a solution of copper sulfate; different solution compositions are used for aluminium alloy and iron alloy substrates. Reddish markings or spots, of copper, indicate pores on ferrous substrates; black markings or spots indicate pores on aluminium alloy substrates. Details of the test procedures can be found in ISO 2085. See also reference [26] in the Bibliography.

7.5 Copper sulfate (Dupernell) test

7.5.1 Scope

For coatings of chromium and micro-cracked or microporous chromium on nickel/copper or nickel/nickel on iron, steel, zinc alloys, copper and copper alloys, aluminium and aluminium alloy, plastic substrates.

7.5.2 Summary of method

The test specimen is used as the cathode in an acid copper plating bath. Copper is deposited only where the basis metal or the substrate is exposed, the chromium remaining passive. After the test, examine the surface for cracks using an optical microscope. Details of the test procedure can be found in ISO 1456, ISO 4525 and ISO 6158. See also references [27 and 28] in the Bibliography.

7.6 Corrodkote test (CORR)

7.6.1 Scope

For coatings of chromium and micro-cracked or microporous chromium on nickel/copper or nickel/nickel on aluminium alloy, plastic, steel and iron alloy or zinc alloy substrates.

7.6.2 Summary of method

The test specimen is coated with a slurry of corrosive salts and dried. The coated specimens are exposed to high relative humidity for a specified period of time, then cleaned and treated for redeveloping the points of failure, e.g. in a salt spray cabinet. Porosity is indicated by black markings or red rust on the iron-based substrates or by white markings on the aluminium and zinc substrates (see ISO 10289). Details of the test procedure can be found in ISO 4541. See also reference [38] in the Bibliography.

7.7 Electrographic tests

7.7.1 Scope

Variation A. Acrylamide electrography (See warning in 7.7.2.)

For gold coatings on nickel and silver, or nickel coatings on copper substrates.

Variation B. Gel bulk electrography.

For gold, cobalt, nickel and palladium coatings on copper; gold, copper, cobalt and palladium coatings on nickel; gold on silver substrates.

Variation C. Paper electrography.

For the following combinations of indicator-coatings/substrate that have flat or nearly flat surfaces.

Indicator	Coating/substrate
1. Cadmium sulfide	Chromium, gold, palladium, platinum and rhodium on beryllium-copper, brass, copper, phosphor-bronze and silver substrates
2. Dimethylglyoxime	Gold, palladium, platinum, rhodium and silver on brass, beryllium-copper, copper, phosphor-bronze, nickel, nickel-boron and nickel-phosphorus substrates
3. Dithioxamide	Chromium, gold, palladium, platinum and rhodium on beryllium-copper, brass, copper and phosphor-bronze substrates
4. Nioxime	Gold, palladium, platinum and rhodium on nickel, nickel-boron, nickel-iron, nickel-phosphorus and tin-nickel substrates
5. Potassium ferrocyanide	Chromium, gold, palladium platinum and rhodium on brass, beryllium-copper, copper and phosphor-bronze substrates
6. Potassium ferricyanide	Cadmium, nickel, tin and zinc on brass, silver and steel substrates
7. Magneson	Chromium, cobalt, copper, nickel, nickel-boron, nickel-cobalt, nickel-iron and nickel-phosphorus on magnesium substrates

7.7.2 Summary of methods

Variation A. Acrylamide electrography.

Acrylamide solution containing a hardener and an indicator is poured onto the sample shortly before gelatinizing. The sample is made the anode in a cell with a chloride solution and electrolized. Pores are revealed as coloured marks or spots. Details of the test procedure can be found in reference [7] in the Bibliography.

WARNING — Acrylamide has been identified as a neurotoxin and carcinogen; use with extreme caution.

Variation B. Gel bulk electrography.

A mixture of clear gelatin, conducting salts and an indicator are poured into an electrolytic cell with a gold or platinum cathode and with the specimen as the anode. The composite gel solution is allowed to solidify, following which the cell is electrolized. Pores are revealed as coloured spots or blooms. Details of the test procedure can be found in ISO 15720. See also reference [39] in the Bibliography.

Variation C. Paper electrography.

Test specimens are sandwiched as an anode between electrolyte-soaked paper and indicator paper and clamped with two cathode covers (of non-reactive materials such as gold or stainless steel). A specified current (usually 0,15 mA/cm^2 to 1,55 mA/cm^2) for a specified time (usually 10 s to 30 s) is applied. After exposure, the test paper is wetted with indicator and allowed to dry. Pores are revealed as coloured spots.

A variety of commercially prepared test papers is available. Details of the test procedures can be found in ISO 4524-3. See also references [15, 18, 24 and 29] in the Bibliography.

7.8 Ferrocyanide test

7.8.1 Scope

For coatings of chromium, cobalt, gold, nickel, nickel-boron, nickel-iron, nickel-phosphorus, palladium, platinum and rhodium on copper substrate.

7.8.2 Summary of method

The test specimens are treated with glacial acetic acid and potassium ferrocyanide under defined conditions. Formation of brown markings or spots indicates porosity. Details of the test procedure can be found in references [12 and 37] in the Bibliography.

7.9 Ferron test

7.9.1 Scope

For coatings of aluminium, brass, cadmium, chromium, cobalt, indium, lead, nickel, nickel-boron, nickel-phosphorus, organic films, silver, tin, tin-lead, tin-nickel, tin-zinc and zinc, on iron and steel substrates.

7.9.2 Summary of method

The test specimens are treated with acid and a 0,1 % solution of ferron (8-hydroxyquinoline 7-iodo-5-sulfonic acid), under defined conditions. Formation of red markings or spots indicates porosity. Details of the test procedure can be found in reference [4] in the Bibliography.

7.10 Ferroxyl test

7.10.1 Scope

For metallic coatings, such as brass, chromium, cobalt, copper, gold, indium, lead, nickel, nickel-boron, nickel-phosphorus, organic films, silver, tin, tin-lead and tin-nickel, that are resistant, for the duration of the test period, to ferricyanide and chloride and are also cathodic to their iron or steel alloy substrates.

7.10.2 Summary of method

Electrolyte-wetted, gel-chloride-treated paper strips are placed firmly in contact with test specimen surfaces for a specified time. After the allotted time, the paper strips are wetted adequately with ferricyanide indicator solution. Blue markings or spots indicate pores. Details of the test procedure can be found in ISO 4526 and ISO 10309. See also references [20 and 30] in the Bibliography.

7.11 Flowers-of-sulfur porosity test

7.11.1 Scope

For coatings of gold, nickel, tin, tin-lead, palladium and their alloys on copper, copper alloy or silver substrates. It may be used with other coatings that do not significantly tarnish in a reduced-sulfur atmosphere.

7.11.2 Summary of method

Test specimens are suspended on non-reactive supports in a non-reactive container with controlled humidity and elevated temperature (50 °C) for a specified time in a closed system over the flowers of sulfur. Brown or black tarnish marks or spots indicate porosity. Details of the test procedure can be found in ISO 12687. See also reference [31] in the Bibliography.

7.12 Hot-water test

7.12.1 Scope

For metallic coatings cathodic to a ferrous substrate: for example, brass, copper, gold, indium, nickel, nickel-boron, nickel-phosphorus, tin, tin-lead and tin-nickel on iron, NiFeCo alloys or steel substrates; organic films on steel substrate.

7.12.2 Summary of method

The test specimens are placed in a glass vessel filled with distilled or deionized and aerated water (pH 6,0 to 7,5, conductivity not higher than 0,5 mS/m). Water is heated to 85 °C and the temperature shall be maintained throughout 60 min (test period). After exposure and drying, black markings or spots and red rust indicate porosity. Details of the test procedure can be found in ISO 4526. See also references [25 and 30] in the Bibliography.

7.13 Hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

7.13.1 Scope

Variation A. For coatings of less than 5 µm of gold, palladium or rhodium on beryllium-copper, brass, copper, phosphor-bronze and silver substrates.

Variation B. For coatings of more than 5 µm of gold, palladium, rhodium, tin, tin-lead, or tin-nickel on beryllium-copper, brass, copper, nickel, nickel-boron, nickel-phosphorus, phosphor-bronze or silver substrates.

7.13.2 Summary of method

Variation A. Test specimens are suspended on non-reactive supports in a non-reactive container with a freshly generated hydrogen sulfide atmosphere for a specified time, usually 24 h. Discolouration on the surface indicates porosity. Details of the test procedure can be found in reference [41] in the Bibliography. See also reference [53] in the Bibliography.

Variation B. Test specimens are suspended on non-reactive supports in a non-reactive container with a freshly generated sulfur dioxide atmosphere for a specified time, usually 24 h, followed by freshly generated hydrogen sulfide atmosphere for a specified time, usually 24 h. Discolouration on the surface indicates porosity. Details of the test procedure can be found in reference [17] in the Bibliography.

7.14 Haematoxylin test

7.14.1 Scope

For coatings of brass on aluminium; or silver on brass and copper substrates.

7.14.2 Summary of method

Paper strips treated with haematoxylin are immersed in water and are placed firmly in contact with test specimen surfaces for a specified time. After the allotted time, the paper strips are examined for blue markings or spots which indicate pores. Details of this test can be found in references [8 and 11] in the Bibliography.

7.15 Magneson test

7.15.1 Scope

For coatings of chromium, cobalt, copper, nickel, nickel-boron, nickel-cobalt, nickel-iron and nickel-phosphorus on magnesium substrate.

7.15.2 Summary of method

The test specimens are treated with sodium hydroxide. Dry magneson test paper, prepared by dipping filter paper in a 0,01 % alcohol solution of ρ-nitrobenzene-azo-resorcinol is applied to the treated surface. Formation of blue markings or spots on a red background indicates porosity. Details of the test procedure can be found in reference [15] in the Bibliography.

7.16 Nitric acid vapour test

7.16.1 Scope

For gold coatings on substrates of copper, nickel and their alloys.

7.16.2 Summary of method

A stabilized acid atmosphere is established by placing concentrated nitric acid in a non-reactive container, which is covered and left to stand for 0,5 h at a specified ambience.

Test specimens are suspended in this closed-system atmosphere and exposed for 60 min $\pm$ 5 min. After exposure, the specimens are heated to dry the reaction products. Each reaction-product marking or spot, usually protruding, indicates a pore in the coating. Details of the test procedure can be found in ISO 14647. See also reference [32] in the Bibliography.

7.17 Oxine test

7.17.1 Scope

For coatings of chromium, cobalt, copper, nickel, nickel-boron, nickel-cobalt, nickel-iron and nickel-phosphorus on aluminium, magnesium and zinc substrates.

7.17.2 Summary of method

The test specimens are treated with sodium hydroxide. Dry oxine test paper, prepared by dipping filter paper in a 5 % alcohol solution of 8-hydroxyquinoline, is applied to the treated surface. Formation of coloured markings or spots indicates porosity. Details of the test procedure can be found in references [10 and 14] in the Bibliography.

7.18 Permanganate test

7.18.1 Scope

For coatings of aluminium, cadmium and zinc on iron, steel or iron-based alloy substrates.

7.18.2 Summary of method

The test specimen is immersed in a dilute solution of potassium permanganate. Black markings or spots, of manganese dioxide, indicate pores. Details of this test can be found in reference [8] in the Bibliography.

7.19 Polysulfide test

7.19.1 Scope

For metallic coatings of tin, tin-nickel and tin-zinc on beryllium-copper, brass, copper and phosphor-bronze substrates.

7.19.2 Summary of method

Coated parts are solvent-cleaned and then immersed in a solution of sodium polysulfide. Formation of black markings or spots indicates pores. Details of the test procedure can be found in reference [32] in the Bibliography.

7.20 Porotest test

7.20.1 Scope

For metallic coatings, such as brass, chromium, copper, gold, nickel, nickel-boron, nickel-phosphorus, tin, tin-nickel and their alloys, which are cathodic to their iron, steel or iron-based alloy substrates.

7.20.2 Summary of method

Paper strips, treated with α-nitroso-β-naphthol, are immersed in water — or, to speed up the reaction, 5 % sodium chloride — are placed firmly in contact with test specimen surfaces for a specified time. After the allotted time, the paper strips are examined for green markings or spots which indicate pores. Details of this test can be found in reference [8] in the Bibliography.

7.21 Salt spray tests [neutral (NSS), acetic (AASS) and cuproacetic (CASS)]

7.21.1 Scope

For metallic coatings, such as brass, chromium, cobalt, copper, gold, lead, nickel, nickel-boron, nickel-phosphorus, tin, tin-lead and tin-nickel, that are resistant, for the duration of the test period, to chloride and which are also cathodic to their iron, steel, or iron-based alloy substrates. The test is also suitable for coatings of chromium on nickel/copper and chromium on nickel/nickel on aluminium, magnesium, zinc and plastic substrates.

7.21.2 Summary of method

Specimens are placed in a cabinet and subjected to a fog spray of 5 % sodium chloride solutions. Porosity is indicated by black markings or spots and red rust on substrates of iron, steel or iron-based alloys, or white markings, spots or blisters in the coating on substrates of aluminium, magnesium or zinc alloy (see ISO 10289). Details of the test procedure can be found in ISO 9227. See also references [22, 23, 34 and 35] in the Bibliography.

7.22 Sulfur dioxide test

7.22.1 Scope

Variation A. For coatings of gold on copper, copper alloy and nickel substrates.

Variation B. For coatings of gold on silver substrates.

Variation C. For coatings of tin, tin-lead and tin-nickel on copper, copper alloy and steel substrates.

7.22.2 Summary of method

Test specimens are suspended on non-reactive supports in a non-reactive container with a freshly generated sulfur dioxide atmosphere for a specified time, usually 24 h. The concentrations of sulfur dioxide, generated as the corrosive atmosphere, are selected for the specific variation A, B or C (coating and substrate combination). Colour on the surface indicates porosity. Details of the test procedure can be found in ISO 6988. See also references [19, 22, 36, 37 and 53] in the Bibliography.

7.23 Sulfurous acid/sulfur dioxide vapour test

7.23.1 Scope

For coatings of gold and palladium on substrates of copper, nickel and their alloys.

7.23.2 Summary of method

Test specimens are suspended on non-reactive supports in a non-reactive container with a sulfurous acid/sulfur dioxide atmosphere for a specified time, usually 24 h. Colour on the surface indicates porosity. Details of the test procedure can be found in ISO 15721. See also reference [40] in the Bibliography.

7.24 Thiocyanate test

7.24.1 Scope

For metallic coatings, such as chromium, copper, nickel, nickel-boron, nickel-phosphorus, tin, tin-nickel and their alloys, that are resistant to thiocyanate and chloride during the time period of the test, and which are also cathodic to their iron or steel alloy substrates.

7.24.2 Summary of method

Electrolyte-wetted, gel-chloride-treated paper strips are placed firmly in contact with test specimen surfaces for a specified time. After the allotted time, the paper strips are wetted adequately with thiocyanate indicator solution. Red markings or spots indicate pores. Details of this test procedure can be found in reference [8] in the Bibliography.

7.25 Thioacetamlde test (TAA)

7.25.1 Scope

For gold, nickel, tin and tin-nickel coatings on copper, copper alloys and silver substrates. This test can also be used for organic coatings on brass, copper or silver substrates.

7.25.2 Summary of method

Test specimens are suspended on non-reactive supports in a non-reactive container with a saturated solution of sodium acetate for maintaining the relative humidity of 75 %, and crystals of thioacetamide (at least 50 mg per square decimetre) at 25 °C for a specified time in the closed system. Coloured spots, pits, cracks, blisters, etc. indicate porosity. Details of the test procedure can be found in ISO 4538. See also reference [16] in the Bibliography.

7.26 Watch-case acetic acid test

7.26.1 Scope

For gold coatings on cuprous alloy with or without nickel, and die-cast zinc-based alloy substrates.

7.26.2 Summary of method

Test specimens are suspended on non-reactive supports in a non-reactive vessel and exposed to vapours of acetic acid for 24 h at 23 °C ± 2 °C. Pores are revealed as green markings on cuprous alloy substrates or white markings on die-cast zinc-based alloy substrates. Details of the test procedure can be found in ISO 3160-2.

7.27 Watch-case sodium bisulfite test

7.27.1 Scope

For gold coatings on ferrous alloy substrates.

7.27.2 Summary of method

Test specimens are suspended on non-reactive supports in a non-reactive vessel and exposed to vapours of sodium bisulfite for 24 h at 23 °C ± 2 °C. Every trace of corrosion on the significant surface indicates porosity. Details of the test procedure can be found in ISO 3160-2.

Annex A
(normative)

Tables of porosity tests

Table A.1 — Substrate or underlayer: aluminium alloys, copper alloys, iron alloys

Coating	Substrate or underlayer						
	Aluminium alloys	Copper alloys				Iron alloys	
		Beryllium Copper	Brass	Copper	Phosphor-bronze	Cast iron and steel	NiFeCo
Aluminium						9,18	9
Anodized aluminium	4B						
Brass	14					9,10,12,20,21	9,10,12
Cadmium			7C6			4A,7C6,9,18	4A,9
Chromate conversion	21				11		
Chromium	1,2,5,6,17	3,7C1,7C3, 7C5	3,7C1,7C3, 7C5	3,5,7C1,7C3, 7C5,8	3,7C1,7C3, 7C5	5,6,9,10,12,20, 21,24	5,6,9,10, 12
Chromium on nickel/nickel	1,2,5,6,17,21	3,7C5	3,7C5	3,7C5	3,7C5	5,6,9,10,20,21	5,6,9,10
Chromium on nickel/copper	1,2,5,6,17,21	3,7C5	3,7C5	3,7C5	3,7C5	5,6,9,10,20,21	5,6,9,10
Cobalt	1,2,17			8,7B		9,10,12,21	9,10,12
Copper	1,5,17					10,12,20,21,24	10,12
Gold		3,7C1,7C2, 7C3,7C5,11, 13A,13B,16, 22A,23,25,26	3,7C1,7C2, 7C3,7C5,11, 13A,13B,16, 22A,23,25,26	3,7B,7C1,7C2, 7C3,7C5,8,11, 13A,13B,16, 22A,23,24,25, 26	3,7C1,7C2, 7C3,7C5, 11,13A,13B, 16,22A,23, 25,26	10,12,20,21,27	10,12
Indium						9,10,12	9,10,12
Lead						9,10,12,21,22	9,10,12
Nickel	1,2,17	11,25	7C6,11,25	1,7A,7B,10,11, 25	11,25	1,7C6,9,10,12, 20,21,24	9,10,12
Nickel-boron	1,2,17	11,25	11,25	8,11,25	11,25	9,10,12,20,21, 24	9,10,12
Nickel-cobalt	1,2,17	11	11	11	11		
Nickel-iron	1,2,17	11	11	11	11		
Nickel-phosphorus	1,2,17	11,25	11,25	8,11,25	11,25	9,10,12,20,21, 24	9,10,12
Palladium		3,7C1,7C2, 7C3,7C5, 13A,13B,16,23	3,7A,7C1,7C2, 7C3,7C5,13A, 13B, 16,23	3,7B,7C1,7C2, 7C3,7C5,8,11, 13A,13B, 16,23	3,7C1,7C2, 7C3,7C5, 13A,13B,16, 23		
Phosphate conversion							
Platinum		3,7C1,7C2, 7C3,7C5	3,7C1,7C2, 7C3,7C5	3,7C1,7C2,7C3, 7C5	3,7C1,7C2, 7C3,7C5		
Rhodium		3,7C1,7C2, 7C3,7C5,13A, 13B	3,7C1,7C2, 7C3,7C5,13A, 13B	3,7C1,7C2,7C3, 7C5,8,13A,13B	3,7C1,7C2, 7C3,7C5, 13A,13B		
Silver		7C2	7C2,14	7C2,14	7C2	9,10	9,10
Tin		19,22C,25	7C6,19,22C,25	11,13B,19,22C, 25	19,22C,25	7C6,9,10,12,20, 21,22C,24	9,10,12
Tin-lead		22C	22C	11,13B,22C	22C	9,10,12,21,22C	9,10,12
Tin-nickel		19,22C,25	19,22C,25	13B,19,22C,25	19,22C,25	9,10,12,20,21, 22C,24	9,10,12
Tin-zinc		19	19	19	19	9	9
Zinc			7C6			4A,7C6,9,18	4A,9
Porcelain enamel						9,10,12	9,10,12
Organic films	4	11,25	11,25	11,25	11,25	9,10,12	9,10,12

NOTE Numbers refer to subclauses of Clause 7, and the letters to their variations.

Table A.2 — Substrate or underlayer: magnesium alloys, nickel alloys, silver tin-nickel, zinc alloys

Coating	Substrate or underlayer						
	Magnesium alloys	Nickel alloys			Silver	Tin-nickel	Zinc alloys
		Nickel	Nickel-boron	Nickel-phosphorus			
Aluminium							
Anodized aluminium	—	—	—	—	—	—	—
Brass							
Cadmium					7C6		
Chromate conversion	21						21
Chromium	2,7C7,15, 17,21	5			3,7C1		2,5,6,17, 21
Chromium on nickel/nickel	2,7C7,15, 17,21						2,5,6,17, 21
Chromium on nickel/copper	2,7C7,15, 17,21						2,5,6,17, 21
Cobalt	2,7C7,15, 17,21						2,17,21
Copper	7C7,15,17	7B					17
Gold		1,7A,7B, 7C2,7C4, 13B,16,22A, 23	7C2,7C4,16, 23	7C2,7C4,16,23	1,3,7A,7B, 7C1,11, 13A,13B, 22B,25	7C4,16,23	26
Indium							
Lead							
Nickel	2,7C7,15,17	—	—	—	7C6,11,25		2,17,21
Nickel-boron	2,7C7,15,17	—	—	—	11,25		2,17,21
Nickel-cobalt	2,7C7,15,17	—	—	—			2,17,21
Nickel-iron	2,7C7,15,17	—	—	—	11		2,17,21
Nickel-phosphorus	2,7C7,15,17				11,25		2,17
Palladium		7B,7C2,7C4, 13B, 16, 23	7C2,7C4,13B, 16, 23	7C2,7C4,13B,16, 23	3,7C1,11, 13A,13B	7C4,23	
Phosphate conversion							
Platinum		7C2,7C4	7C2,7C4	7C2,7C4	3,7C1	7C4	
Rhodium		7C2,7C4, 13B	7C2,7C4,13B	7C2,7C4,13B	3,7C1,13A, 13B	7C4	
Silver		7C2	7C2	7C2	—		
Tin					7C6,11, 13B,25		
Tin-lead					11,13B		
Tin-nickel					13B,25	—	
Tin-zinc							
Zinc					7C6		—
Porcelain enamel							
Organic films					25		

NOTE Numbers refer to subclauses of Clause 7, and the letters to their variations.

Annex B
(informative)

Typical report and evaluation of porosity tests

B.1 Report

The results of a porosity test are usually given in terms of one of the following.

B.1.1 Option 1

The number and size of the pores in the significant area. Convert to a pore density in number of defects per 100 mm^2.

B.1.2 Option 2

The percentage of total area covered by the pores.

B.1.3 Option 3

The area, in square millimetres, of the largest marking or spot on the significant surface.

B.2 Evaluation

B.2.1 Scope

Porosity tests offer some indication as to the expected performance of coating(s) when exposed to corrosive environments. When a given coating of a specified thickness is known to be protective when properly deposited, the porosity test(s) serve(s) as a measure of control of the process. When the coating is porous, one or more of the following may be the cause: substrate finish; substrate preparation; plating bath; coating process.

B.2.2 Procedure

In option 1, count individual pores at × 10 magnification in the significant area of the coating, as defined by the specification or drawing of the product. In option 2, compare results with panels shown in ISO 10289 or those supplied as criteria by the purchaser. In option 3, scan for the largest defect.

B.2.3 Criteria (pass-fail)

Pass-fail criteria are properly part of the specification requiring the porosity test. The reasons for this are that the sensitivity of the individual methods vary from one another and with the different metal combinations therefore precluding a single criterion. Further, the wide variety of products to which coatings are applied has, in itself, significantly different acceptance criteria for porosity.

Listed below are examples of the criteria frequently used to constitute failure:

— a pore count greater than 50/100 mm^2 or an area greater than 1 %;

— a marking, spot or crack with a total area greater than 2,5 mm^2.

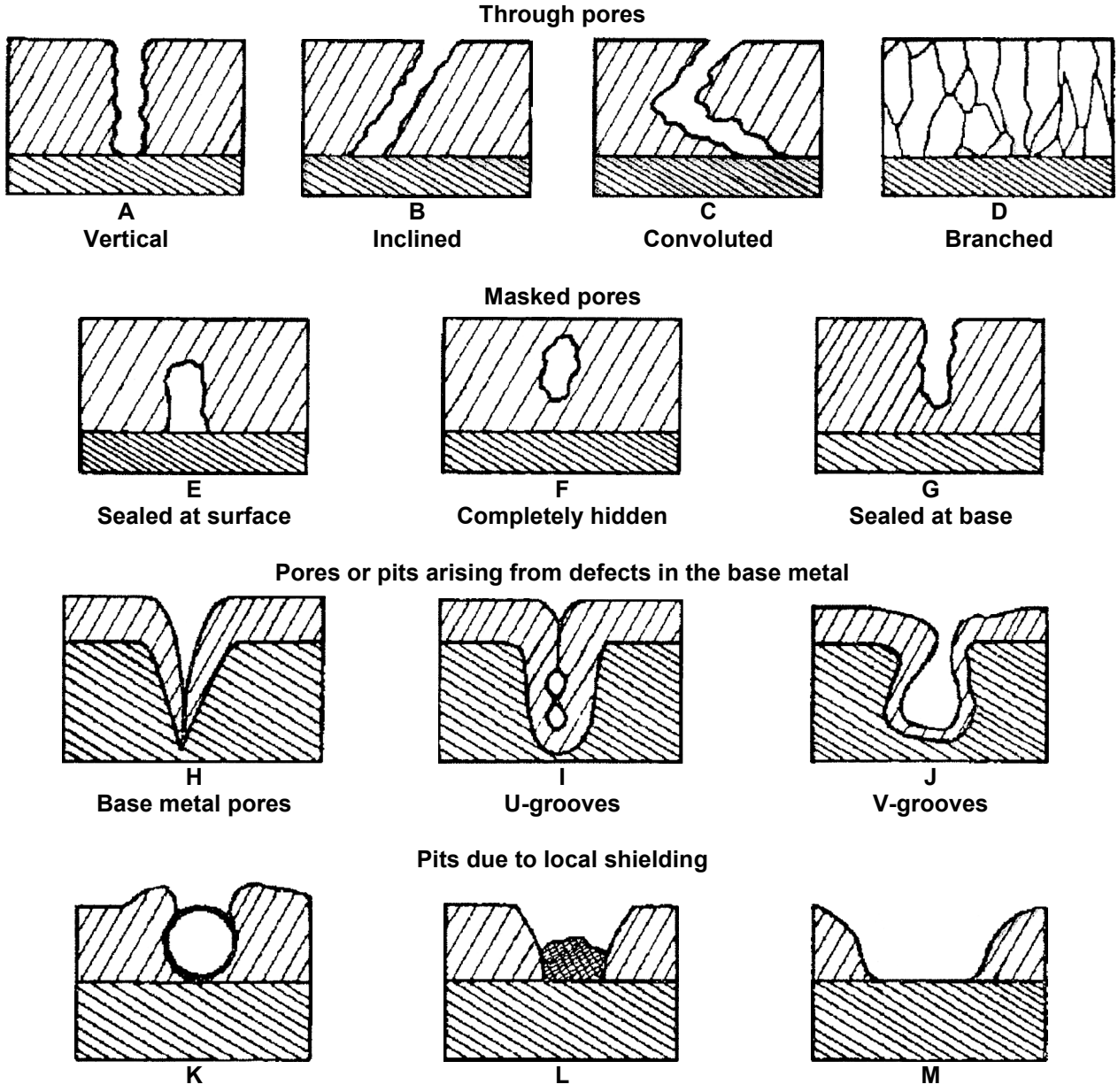
B.3 Uncertainty of measurement

Porosity tests serve to indicate the completeness of protection or cover offered by the coating. The effects of substrate, process, handling and packaging, may all affect the degree of imperfection measured. For this reason, these tests serve only as qualitative guides to keeping the coating, handling and packaging processes under control.

Annex C
(informative)

Schematic representation of types of pore

Various types of pore are shown schematically in Figure C.1. See also reference [8] in the Bibliography



Key

A to D: pores due to inherent coating properties
E to G: pores due to the masking effect
H to J: pores due to the microgeometry of the basis metal
K to M: pores due to occlusion of hydrogen bubbles and foreign particles from the bath, or residual contaminants on the surface of the basis metal

Figure C.1 — Types of pore in electroplated coatings and cause of formation (after Kutzelnigg and Gioria)

Annex D
(informative)

Classification of discontinuities in metallic and other inorganic coatings

Table D.1 — Classification of discontinuities in metallic and other inorganic coatings

Classification of discontinuity	Type of discontinuity	Type of discontinuity according to localization
According to type and localization of the discontinuity	Pores extending from the basis metal to the surface of the coating metal	Pores perpendicular to the coating surface
		Pores inclined with respect to the coating surface
		Twisted pores
	Masked pores	Pores extending from the basis metal surface
		Internal pores reaching neither the basis metal nor the coating surface
	Scratches and cracks	Scratches and cracks extending from the basis metal surface to the coating surface
		Scratches and cracks not reaching the basis metal
According to size of the discontinuity	Macroscopic (visible to the naked eye)	
	Microscopic (using microscope or at a magnification of × 10)	
	Submicroscopic (invisible using a light microscope; their occurrence is connected with the coating structure)	
According to cause of formation of the pores	Effect of deposition conditions (formation of masked pores or pores extending to the basis metal)	
	Effect of microgeometry (surface finish and substrate preparation) of the coated surface	
	Effect of hydrogen bubbles and small solid particles from the bath incorporated into the coating	
	Effect of contaminants (dirt, grease) not removed from the metal surface	

Annex E
(informative)

Classification of methods of testing coating porosity

Table E.1 — Classification of methods of testing coating porosity

Classification of methods	Type of tests	Methods of testing
Chemical methods	Immersion tests	Alizarin
		Antraquinone
		Copper sulfate (Preece)
		Ferrocyanide
		Ferron
		Hot water
		Permanganate
		Polysulfide
	Filter-paper tests	Cadmium sulfide
		Ferroxyl
		Haematoxylin
		Magneson
		Oxine
		Porotest
		Thiocyanate
	Solution-fog tests	Neutral, acetic acid, cuproacetic acid salt spray
		Corrodkote
	Gas atmosphere tests	Flowers of sulfur
		Hydrogen sulfide or sulfur dioxide/hydrogen sulfide
		Nitric acid vapour
		Sulfur dioxide
		Sulfurous acid/sulfur dioxide vapour
		Thioacetamide
		Watch-case acetic acid
		Watch-case sodium bisulfite
Electrochemical methods	Anodic treatment	Copper sulfate (Dupernell)
	Electrographic tests	Acrylamide electrography
		Gel bulk electrography
		Paper electrography
Physical methods	Optical methods	
	Gas permeability methods	
	Ultrasonic methods	
	Autoradiographic and isotope methods	
	High-voltage or high-frequency methods	

Annex F
(informative)

Alphabetical list of tests by substrate and coating

Letters in parentheses indicate variations.

A

aluminium substrate

anodized aluminium
— copper sulfate (Preece) test
brass coating
— haematoxylin test
chromium coating
— anthraquinone test
— oxine test
chromium on nickel/copper coating
— alizarin test
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)
chromium on nickel/nickel coating
— alizarin test
— anthraquinone test
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)
chromium, micro-cracked, on nickel/copper coating
— copper sulfate (Dupornell) test
— Corrodkote test (CORR)
chromium, micro-cracked, on nickel/nickel coating
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
chromium, micro-porous, on nickel/copper coating
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
chromium, micro-porous, on nickel/nickel coating
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
cobalt coating
— alizarin test
— anthraquinone test
— oxine test
copper coating
— alizarin test
— oxine test
— salt spray tests (NSS, AASS, CASS)
nickel coating
— alizarin test
— anthraquinone test
— oxine test
— salt spray tests (NSS,AASS, CASS)
nickel-boron coating
— alizarin test
— anthraquinone test
— oxine test
nickel-cobalt coating
— alizarin test
— anthraquinone test
— oxine test
nickel-iron coating
— alizarin test
— anthraquinone test
— oxine test
nickel-phosphorous coating
— alizarin test
— anthraquinone test
— oxine test
— salt spray tests (NSS, AASS,CASS)

B

beryllium-copper substrate

chromium coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dithiooxamide paper electrography (C 3.)
— potassium ferrocyanide paper electrography (C 5.)
chromium on nickel/nickel coating
— cadmium sulfide test
gold coating
— acetic acid (watch case) test (A)
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— flowers of sulfur test
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nitric acid test
— potassium ferrocyanide paper electrography (C 5.)
— sulfur dioxide test (A)
— sulfurous acid/sulfur dioxide vapour test
— thioacetamide test (TAA)

nickel coating
— flowers of sulfur test
— thioacetamide test (TAA)
nickel-boron coating
— flowers of sulfur test
— thioacetamide test (TAA)
nickel-cobalt coating
— flowers of sulfur test
nickel-iron coating
— flowers of sulfur test
nickel-phosphorus coating
— flowers of sulfur test
— thioacetamide test (TAA)
palladium coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— potassium ferrocyanide paper electrography (C 5.)
— sulfurous acid/sulfur dioxide vapour test
platinum coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— potassium ferrocyanide paper electrography (C 5.)
rhodium coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— potassium ferrocyanide paper electrography (C 5.)
silver coating
— dimethylglyoxime paper electrography (C 2.)
— haematoxylin test
tin coating
— polysulfide test
— sulfur dioxide test (C)
— thioacetamide test (TAA)
tin-lead coating
— sulfur dioxide test (C)
tin-nickel coating
— sulfur dioxide test (C)
— polysulfide test
— thioacetamide test (TAA)
tin-zinc coating
— polysulfide test

brass substrate

cadmium coating
— potassium ferricyanide paper electrography (C 6.)
chromium coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dithiooxamide paper electrography (C 3.)
— potassium ferrocyanide paper electrography (C 5.)
chromium on nickel/nickel coating
— cadmium sulfide test
gold coating
— acetic acid (watch case) test (A)
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— flowers of sulfur test
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nitric acid test
— potassium ferrocyanide paper electrography (C 5.)
— sulfur dioxide test (A)
— sulfurous acid/sulfur dioxide vapour test
— thioacetamide test (TAA)
nickel coating
— flowers of sulfur test
— potassium ferricyanide paper electrography (C 6.)
— thioacetamide test (TAA)
nickel-boron coating
— flowers of sulfur test
— thioacetamide test (TAA)
nickel-cobalt coating
— flowers of sulfur test
nickel-iron coating
— flowers of sulfur test
nickel-phosphorus coating
— flowers of sulfur test
— thioacetamide test(TAA)
organic film coating
— thioacetamide test (TAA)
palladium coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— potassium ferrocyanide paper electrography (C 5.)
— sulfurous acid/sulfur dioxide vapour test
platinum coating

— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— potassium ferrocyanide paper electrography (C 5.)

rhodium coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— potassium ferrocyanide paper electrography (C 5.)

silver coating
— dimethylglyoxime paper electrography (C 2.)
— haematoxylin test

tin coating
— polysulfide test
— potassium ferricyanide paper electrography (C 6.)
— sulfur dioxide test (C)
— thioacetamide test (TAA)

tin-lead coating
— sulfur dioxide test (C)

tin-nickel coating
— polysulfide test
— sulfur dioxide test (C)
— thioacetamide test (TAA)

tin-zinc coating
— polysulfide test

zinc coating
— potassium ferricyanide paper electrography (C 6.)

C

copper substrate

chromium coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— copper sulfate (Dupernell) test
— dithiooxamide paper electrography (C 3.)
— ferrocyanide test
— potassium ferrocyanide paper electrography (C 5.)

chromium on nickel/nickel coating
— cadmium sulfide test

cobalt coating
— ferrocyanide test
— gel bulk electrography (B)

gold coating
— acetic acid (watch case) test (A)
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— ferrocyanide test
— flowers of sulfur test
— gel bulk electrography (B)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nitric acid test
— thioacetamide test (TAA)

nickel coating
— acrylamide electrography (A)
— ferrocyanide test
— flowers of sulfur test
— gel bulk electrography (B)
— thioacetamide test (TAA)

nickel-boron coating
— ferrocyanide test
— flowers of sulfur test
— thioacetamide test (TAA)

nickel-cobalt coating
— flowers of sulfur test

nickel-iron coating
— ferrocyanide test
— flowers of sulfur test

nickel-phosphorus coating
— ferrocyanide test
— flowers of sulfur test
— thioacetamide test (TAA)

organic films coating
— thioacetamide test (TAA)

palladium coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— ferrocyanide test
— flowers of sulfur test
— gel bulk electrography (B)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— potassium ferrocyanide paper electrography (C 5.)
— sulfurous acid/sulfur dioxide vapour test

platinum coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— ferrocyanide test

— potassium ferrocyanide paper electrography (C 5.)

rhodium coating

— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— ferrocyanide test
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— potassium ferrocyanide paper electrography (C 5.)

silver coating

— dimethylglyoxime paper elctrography (C 2.)
— haematoxylin test

tin coating

— flowers of sulfur test
— polysulfide test
— sulfur dioxide test (C)
— thioacetamide test (TAA)

tin-lead coating

— flowers of sulfur test
— sulfur dioxide test (C)

tin-nickel coating

— polysulfide test
— sulfur dioxide test (C)
— thioacetamide test (TAA)

tin-zinc coating

— polysulfide test

I

iron substrate

aluminium coating

— ferron test
— ferroxyl test
— permanganate test

brass coating

— ferron test
— ferroxyl test
— hot water test
— porotest test
— salt spray tests (NSS, AASS, CASS)

cadmium coating

— copper sulfate (Preece) test (A)
— ferron test
— permanganate test

chromium coating

— ferron test
— ferroxyl test
— porotest test
— thiocyanate test

chromium on nickel/copper coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS,AASS, CASS)

chromium on nickel/nickel coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium micro-cracked on nickel/copper coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS AASS, CASS)

chromium microcracked on nickel/nickel coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium micro-porous on nickel/copper coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium micro-porous on nickel/nickel coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

cobalt coating

— ferron test
— ferroxyl test
— salt spray tests (NSS, AASS, CASS)

copper coating

— ferroxyl test
— hot water test
— porotest test
— salt spray tests (NSS, AASS, CASS
— thiocyanate test

gold coating

— bisulfite (watch case) test
— ferroxyl test
— hot water test
— porotest test
— salt spray tests (NSS, AASS, CASS)

indium coating

— ferron test
— ferroxyl test
— hot water test

lead coating

— ferron test
— ferroxyl test
— salt spray tests (NSS, AASS, CASS)

nickel coating
— ferron test
— ferroxyl test
— hot water test
— porotest test
— salt spray tests (NSS, AASS, CASS)
— thiocyanate test
nickel-boron coating
— ferron test
— ferroxyl test
— hot water test
— porotest test
nickel-phosphorus coating
— ferron test
— ferroxyl test
— hot water test
— porotest test
— salt spray tests (NSS, AASS, CASS)
— thiocyanate test
organic films coating
— ferron test
— ferroxyl test
silver coating
— ferron test
— ferroxyl test
tin coating
— ferron test
— ferroxyl test
— hot water test
— porotest test
— salt spray tests (NSS, AASS, CASS)
— thiocyanate test
tin-lead coating
— ferron test
— hot water test
— salt spray tests (NSS, AASS, CASS)
tin-nickel coating
— ferron test
— ferroxyl test
— hot water test
— porotest test
— salt spray tests (NSS, AASS, CASS)
— thiocyanate test
tin-zinc coating
— ferron test
zinc coating
— copper sulfate (Preece) test (A)
— ferron test
— permanganate test

M

magnesium substrate

chromium coating
— anthraquinone test
— magneson paper electrography (C 7.)
— magneson test
— oxine test
chromium on nickel/copper coating
— salt spray tests (NSS, AASS, CASS)
chromium on nickel/nickel coating
— anthraquinone test
— salt spray tests (NSS, AASS, CASS)
chromium micro-cracked on nickel/copper coating
— salt spray tests (NSS, AASS, CASS)
chromium, micro-cracked, on nickel/nickel coating
— salt spray tests (NSS, AASS, CASS)
chromium, micro-porous, on nickel/copper coating
— salt spray tests (NSS, AASS, CASS)
chromium, micro-porous, on nickel/nickel coating
— salt spray tests (NSS, AASS, CASS)
cobalt coating
— anthraquinone test
— magneson paper electrography (C 7.)
— magneson test
— oxine test
copper coating
— magneson paper etectrography (C 7.)
— magneson test
— oxine test
— salt spray tests (NSS, AASS, CASS)
nickel coating
— anthraquinone test
— magneson paper electrography (C 7.)
— magneson test
— oxine test
— salt spray tests (NSS, AASS. CASS)
nickel-boron coating
— anthraquinone test
— magneson paper electrography (C 7.)
— magneson test
— oxine test
— salt spray tests (NSS, AASS, CASS)
nickel-cobalt coating
— anthraquinone test
— magneson paper electrography (C 7.)
— magneson test
— oxine test
nickel-iron coating
— anthraquinone test
— magneson paper electrography (C 7.)

— magneson test
— oxine test

nickel-phosphorus coating

— anthraquinone test
— magneson paper electrography (C 7.)
— magneson test
— oxine test
— salt spray tests (NSS, AASS, CASS)

N

nickel substrate

cobalt coating

— gel bulk electrography (B)

copper coating

— gel bulk electrography (B)

gold coating

— acrylamide electrography (A)
— dimethylglyoxime paper electrography (C 2.)
— gel bulk electrography (B)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nioxime paper electrography (C 4.)
— nitric acid test
— sulfur dioxide test (A)
— sulfurous acid/sulfur dioxide vapour test

palladium coating

— dimethylglyoxime paper electrography (C 2.)
— gel bulk electrography (C 4)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nioxime paper electrography (C 4.)
— sulfurous acid/sulfur dioxide vapour test

platinum coating

— dimethylglyoxime paper electrography (C 2.)
— nioxime paper electrography (C 4.)

rhodium coating

— dimethylglyoxime paper electrography (C 2.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nioxime paper electrography (C 4.)

silver coating

— dimethylglyoxime paper electrography (C 2.)

tin coating

— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

tin-lead coating

— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

tin-nickel coating

— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

nickel-boron substrate

gold coating

— dimethylglyoxime paper electrography (C 2.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nitric acid test
— nioxime paper electrography (C 4.)
— sulfurous acid/sulfur dioxide vapour test

palladium coating

— dimethylglyoxime paper electrography (C 2.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nioxime paper electrography (C 4.)
— sulfurous acid/sulfur dioxide vapour test

platinium coating

— dimethylglyoxime paper electrography (C 2.)
— nioxime paper electrography (C 4.)

rhodium coating

— dimethylglyoxime paper electrography (C 2.)
— hydrogen sulfide or sulfur dioxide/hydrogen test
— nioxime paper electrography (C 4.)

silver coating

— dimethylglyoxime paper electrography (C 2.)

tin coating

— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

tin-lead coating

— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

tin-nickel coating

— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

nickel-iron substrate

gold coating

— nioxime paper electrography (C 4.)

palladium coating

— nioxime paper electrography (C 4.)

platinum coating

— nioxime paper electrography (C 4.)

rhodium coating

— nioxime paper electrography (C 4.)

NiFeCo substrate

brass coating

— hot water test

copper coating

— hot water test

gold coating

— hot water test

indium coating
— hot water test
nickel-boron coating
— hot water test
nickel coating
— hot water test
nickel-phosphorus coating
— hot water test
tin coating
— hot water test
tin-lead coating
— hot water test
tin-nickel coating
— hot water test

nickel-phosphorus substrate

gold coating
— dimethylgloxime paper electrography (C 2.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nioxime paper electrography (C 4.)
— nitric acid test
— sulfurous acid/sulfur dioxide vapour test
palladium coating
— dimethylgloxime paper electrography (C 2.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nioxime paper electrography (C 4.)
— sulfurous acid/sulfur dioxide vapour test
platinum coating
— dimethylglyoxime paper electrography (C 2.)
— nioxime paper electrography (C 4.)
rhodium coating
— dimethylglyoxime paper electrography (C 2.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nioxime paper electrography (C 4.)
silver coating
— dimethylglyoxime paper electrography (C 2.)
tin coating
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
tin-lead coating
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
*tin-nickel coatin*g
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

P

Phosphor-bronze substrate

chromium coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dithiooxamide paper electrography (C 3.)
— potassium ferrocyanide paper electrography (C 5.)
chromium on nickel/nickel coating
— cadmium sulfide test
gold coating
— acetic acid (watch case) test (A)
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— flowers of sulfur test
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— nitric acid test
— potassium ferrocyanide paper electrography (C 5.)
— sulfur dioxide test (A)
— sulfurous acid/sulfur dioxide vapour test
— thioacetamide test (TAA)
nickel coating
— flowers of sulfur test
— thioacetamide test (TAA)
nickel-boron coating
— flowers of sulfur test
— thioacetamide test (TAA**)**
nickel-cobalt coating
— flowers of sulfur test
nickel-iron coating
— flowers of sulfur test
nickel-phosphorus coating
— flowers of sulfur test
— thioacetamide test (TAA)
organic film coating
— thioacetamide test (TAA)
palladium coating
— cadmium sulfide paper electrography (C 1.)
— cadmium sulfide test
— dimethylglyoxime paper electrography (C 2.)
— dithiooxamide paper electrography (C 3.)
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— potassium ferrocyanide paper electrography (C 5.)
— sulfurous acid/sulfur dioxide vapour test

platinum coating
- — cadmium sulfide paper electrography (C 1.)
- — cadmium sulfide test
- — dimethylglyoxime paper electrography (C 2.)
- — dithiooxamide paper electrography (C 3.)
- — potassium ferrocyanide paper electrography (C 5.)

rhodium coating
- — cadmium sulfide paper electrography (C 1.)
- — cadmium sulfide test
- — dimethylglyoxime paper electrography (C 2.)
- — dithiooxamide paper electrography (C 3.)
- — hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
- — potassium ferrocyanide paper electrography (C 5.)

silver coating
- — dimethylglyoxime paper electrography (C 2.)
- — haematoxylin test

tin coating
- — hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
- — polysulfide test
- — sulfur dioxide test (C)
- — thioacetamide test (TAA)

tin-lead coating
- — hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
- — sulfur dioxide test (C)

tin-nickel coating
- — hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
- — polysulfide test
- — sulfur dioxide test (C)
- — thioacetamide test (TAA)

tin-zinc coating
- — polysulfide test

plastic substrate

chromium on nickel/copper coating
- — Corrodkote test (CORR)

chromium on nickel/nickel coating
- — Corrodkote test (CORR)
- — copper sulfate (Dupernell) test
- — salt spray tests (AASS, CASS)

chromium micro-cracked on nickel/copper coating
- — Corrodkote test (CORR)

chromium micro-cracked on nickel/nickel coating
- — Corrodkote test (CORR)

chromium micro-porous on nickel/copper coating
- — Corrodkote test (CORR)

chromium, micro-porous, on nickel/nickel coating
- — Corrodkote test (CORR)

S

silver substrate

cadmium coating
- — potassium ferricyanide paper electrography (C 6.)

chromium coating
- — cadmium sulfide paper electrography (C 1.)

gold coating
- — acrylamide electrography (A)
- — cadmium sulfide paper electrography (C 1)
- — flowers of sulfur test
- — gel bulk electrography (R)
- — hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
- — sulfur dioxide test (B)
- — thioacetamide test (TAA)

nickel coating
- — flowers of sulfur test
- — potassium ferricyanide paper electrography (C 6.)
- — thioacetamide test (TAA)

nickel-boron coating
- — flowers of sulfur test
- — thioacetamide test (TAA)
- — nickel-cobalt coating

nickel-iron coating
- — flowers of sulfur test

nickel-phosphorus coating
- — flowers of sulfur test
- — thioacetamide test (TAA)

organic film coating
- — thioacetamide test (TAA)

palladium coating
- — cadmium sulfide paper electrography (C 1.)
- — flowers of sulfur test
- — hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

platinum coating
- — cadmium sulfide paper electrography (C 1.)

rhodium coating
- — cadmium sulfide paper electrography (C 1.)
- — cadmium sulfide test
- — hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

tin coating
- — hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

— potassium ferricyanide paper electrography (C 6.)
— thioacetamide test (TAA)

tin-lead coating
— flowers of sulfur test
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test

tin-nickel coating
— hydrogen sulfide or sulfur dioxide/hydrogen sulfide test
— thioacetamide test (TAA)

zinc coating
— potassium ferricyanide paper electrography (C 6.)

steel substrate

aluminium coating
— ferron test
— permanganate test

brass coating
— ferron test
— ferroxyl test
— hot water test
— porotest test
— salt spray test (NSS,AASS,CASS)

cadmium coating
— copper sulfate (Preece) test (A)
— ferron test
— permanganate test
— potassium ferricyanide paper electrography (C 6.)

chromium coating
— ferron test
— ferroxyl test
— porotest test
— salt spray test (NSS,AASS,CASS)
— thiocyanate test

chromium on nickel/copper coating
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium on nickel/nickel coating
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium micro-cracked on nickel/copper coating
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium micro-cracked on nickel/nickel coating
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium micro-porous on nickel/copper coating
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium micro-porous on nickel/nickel coating
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

cobalt coating
— ferron test
— ferroxyl test
— salt spray test (NSS,AASS,CASS)

copper coating
— ferron test
— ferroxyl test
— porotest test
— salt spray tests (NSS,AASS,CASS)
— sulfur dioxide test (C)
— thiocyanate

gold coating
— bisulfite (watch case) test
— ferroxyl test
— hot water test
— porotest test
— salt spray test (NSS,AASS,CASS)
— sulfur dioxide test (C)
— thiocyanate test

indium coating
— ferron test
— ferroxyl test
— hot water test

lead coating
— ferron test
— ferroxyl test
— salt spray test (NSS,AASS,CASS)

nickel coating
— ferron test
— ferroxyl test
— hot water test
— porotest test
— potassium ferricyanide paper electrography (C 6.)
— salt spray tests (NSS,AASS,CASS)
— thiocyanate test

nickel-boron coating
— ferron test
— ferroxyl test
— hot water test
— porotest test
— salt spray tests (NSS,AASS,CASS)

— thiocyanate test

nickel-phosphorus coating

— ferron test
— ferroxyl test
— hot water test
— porotest test
— salt spray tests (NSS,AASS,CASS)
— thiocyanate test

organic film coating

— ferron test
— ferroxyl test
— hot water test

silver coating

— ferron test
— ferroxyl test

tin coating

— ferron test
— ferroxyl test
— hot water test
— porotest test
— potassium ferricyanide paper electrography (C 6.)
— salt spray test (NSS,AASS,CASS)
— sulfur dioxide test (C)
— thiocyanate test

tin-lead coating

— ferron test
— ferroxyl test
— hot water test
— porotest test

tin-zinc coating

— ferron test

zinc coating

— copper sulfate (Preece) test (A)
— ferron test
— permanganate test
— potassium ferricyanide paper electrography (C 6.)

T

tin-nickel substrate

gold coating

— nioxime paper electrography (C 4.)
— nitric acid test

palladium coating

— nioxime paper electrography (C 4.)

platinium coating

— nioxime paper electrography (C 4.)

rhodium coating

— nioxime paper electrography (C 4.)

Z

zinc substrate

chromium coating

— anthraquinone test
— oxine test

chromium on nickel/copper coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium on nickel/nickel coating

— anthraquinone test
— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium micro-cracked on nickel/copper coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium micro-cracked on nickel/nickel coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

chromium micro-porous on nickel/copper coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS,AASS,CASS)

chromium, micro-porous, on nickel/nickel coating

— copper sulfate (Dupernell) test
— Corrodkote test (CORR)
— salt spray tests (NSS, AASS, CASS)

cobalt coating

— anthraquinone test
— oxine test

copper coating

— antraquinone test
— oxine test
— potassium ferricyanide paper electrography (C 6.)
— salt spray test (NSS,AASS,CASS)

gold coating

— acetic acid (watch case) test (A)

nickel coating

— anthraquinone test
— oxine test
— salt spray tests (NSS, AASS, CASS)

nickel-boron coating

— anthraquinone test
— oxine test
— salt spray tests (NSS, AASS, CASS)

nickel-cobalt coating
— anthraquinone test
— oxine test
nickel-iron coating
— anthraquinone test
— oxine test

nickel-phosphorus coating
— anthraquinone test
— oxine test
— salt spray tests (NSS, AASS, CASS)

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