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APPROVED TO BRITISH STANDARD

BRITISH STANDARD 1224 : 1970

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SPECIFICATION FOR

ELECTROPLATED COATINGS OF NICKEL & CHROMIUM

BRITISH STANDARDS INSTITUTION

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TABLES

CO-OPERATING ORGANIZATIONS

The Surface Coatings (other than Paints) Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Assay Offices Committee of Great Britain
Association of Metal Sprayers
British Bolt, Nut, Screw and Rivet Federation
British Electrical and Allied Manufacturers' Association
British Jewellers' Association
*British Non-ferrous Metals Research Association
*British Steel Industry
*Chemical Industries Association
*Cycle & Motor Cycle Industries Association Limited
Electricity Council, the Central Electricity Generating Board and the Area Boards in England and Wales
*Electronic Engineering Association
Engineering Equipment Users' Association
Greater London Council
*Institute of Metal Finishing
Institute of Sheet Metal Engineers
Institute of Vitreous Enamellers
*Metal Finishing Association
*Ministry of Defence, Army Department
Ministry of Defence, Navy Department
Ministry of Technology
*Society of Motor Manufacturers and Traders Limited
Tin Research Institute
Vitreous Enamel Development Council
*Zinc Development Association

The Government department and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

Association of Builders' Hardware Manufacturers
British Lock and Latch Manufacturers' Association
British Plastics Federation
British Railways Board
Institution of Chemical Engineers
Institution of Corrosion Technology
Institution of Engineering Inspection
Lighting Industry Federation Limited
Lloyds Register of Shipping
National Brassfoundry Association
Post Office
Scientific Instrument Manufacturers' Association
Spring Research Association
Zinc Alloy Die Casters' Association
Individual firms

This British Standard, having been approved by the Surface Coatings (other than Paints) Industry Standards Committee, was published under the authority of the Executive Board on 13 January, 1970.

First published, July, 1945
First revision, October, 1953
Second revision, November, 1959
Third revision, March, 1965
Fourth revision, January, 1970

SBN: 580 05964 2

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 6000, fully indexed and with a note of the contents of each, will be found in the British Standards Yearbook, which may be purchased from BSI Sales Department. It may also be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

BS 576. Acetic acid.
BS 872. Abrasive papers and cloths (technical products).
BS 998. Vacuum salt for butter and cheese making.
BS 2870. Rolled copper and copper alloys. Sheet, strip and foil.
BS 3745. Method for the evaluation of results of accelerated corrosion tests on metallic coatings.

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following BSI references relate to the work on this standard;
Committee reference SRE/2 Draft for comment 69/12352

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BRITISH STANDARD SPECIFICATION FOR

ELECTROPLATED COATINGS OF NICKEL AND CHROMIUM

FOREWORD

This revision of BS 1224, prepared under the authority of the Surface Coatings (other than Paints) Industry Standards Committee, incorporates the provisions of the three draft Recommendations* of the International Organization for Standardization (ISO) which relate to electroplated coatings of nickel and chromium. As a result, the following fundamental changes to the designation of coatings complying with this standard have been made:

(1) The service condition numbers (previously service grade numbers) are now in the reverse order so that the highest number relates to the most severe conditions.

(2) The service condition numbers do not incorporate a letter designating the basis metal, as did the service grade numbers in the previous edition of the standard: the basis metal must be stated separately.

(3) The classification number uses chemical symbols for the basis metal and coating metals.

(4) Although not yet included in the draft ISO Recommendations, the use of micro-porous chromium coatings is now covered by this standard which thus recognizes four different types of chromium coating.

In this standard no account is taken of the condition of the basis metal before plating and agreement should be reached between the plater and the purchaser regarding the acceptable degree of roughness of the basis metal.

For a nickel plus chromium coating the purchaser should specify the basis metal and the service condition number denoting the severity of the conditions which the coating is required to withstand. It is not necessary to state the classification number of the coating, defined in terms of the nature, thickness and properties of the deposits it comprises, but the purchaser may include this if he wishes. The classification number should always be specified for nickel coatings without a chromium topcoat. **Merely to ask for plating to be carried out to BS 1224 without the above additional information is insufficient.**

For both nickel and chromium deposits, the minimum thickness requirements apply only to those portions of the significant surface that can be touched by a ball 20 mm in diameter.

*At present:
ISO/DR 1456, ' Electroplated coatings of nickel plus chromium '.
ISO/DR 1457, ' Electroplated coatings of copper plus nickel plus chromium on steel '.
ISO/DR 1458, ' Electroplated coatings of nickel '.

Of the laboratory corrosion tests included in this standard for nickel plus chromium coatings only the acetic acid salt spray test is appropriate for all such coatings (with the exception of the thinnest coatings on copper or copper alloy), the duration of the test being varied according to the service condition number. For the highest quality coatings the shorter term CASS test may be used instead or, except on coated copper or copper alloy, the Corrodkote test.

Acceptance or rejection of an article subjected to corrosion tests is governed by the extent of basis metal corrosion. Surface deterioration of the coating itself will occur on some types of coating, and it is recommended that the extent to which this can be tolerated should be subject to agreement between the supplier and the purchaser.

NOTE. Attention is drawn to certification facilities offered by BSI; see the back cover of this standard.

SPECIFICATION

1. SCOPE

This British Standard specifies requirements for electroplated coatings of nickel* plus chromium and nickel* alone on steel (or iron), zinc alloy, copper or copper alloys, and aluminium or aluminium alloys, except for the following:

Coatings applied to machine screw threads.

Coatings applied to sheet, strip, wire in the unfabricated form, or coil springs.

Coatings applied for engineering purposes.

2. SIGNIFICANT SURFACE

For the purposes of this British Standard, the significant surface is defined as the part of the surface which is essential to the appearance or serviceability of the article and which is to be covered by the coating.

When necessary, the significant surface shall be the subject of agreement, and shall be indicated on drawings, or by the provision of suitably marked samples.

3. APPEARANCE

Over the significant surface, the plated article shall be free from clearly visible plating defects such as blisters, pits, roughness, cracks or unplated areas, and

*With a copper undercoat in some cases.

shall not be stained or discoloured. The extent to which blistering can be tolerated on non-significant surfaces shall be the subject of agreement between the supplier and the purchaser. On articles where a contact mark is inevitable, its position shall be the subject of agreement between the supplier and the purchaser.

The plated article shall be clean and free from damage. The purchaser shall state the appearance required, e.g. bright, dull, or satin. Alternatively, a sample showing the required finish shall be supplied or approved by the purchaser.

4. HEAT TREATMENT FOR STEEL

When required by the purchaser, heat treatment as described below shall be performed on certain steels to reduce the risk of damage by hydrogen embrittlement.

4.1 Stress relief before plating

4.1.1 ***Severely cold-worked steel parts.*** Severely cold-worked steel parts, or parts made from steel of tensile strength of about 100 hbar* or greater which have been ground or subjected to severe machining after tempering, shall normally be stress relieved. As a guide, the parts may be maintained for 30 minutes, preferably at the highest temperature which can be applied without adversely affecting their strengths, e.g. for heat treated steels, at temperatures not exceeding the tempering temperature. For parts made from certain types of steel a temperature of 190–210 °C for not less than 1 hour may be adequate.

4.1.2 ***Heat-treated steels.*** Some steels which have been carburized, flame-hardened or induction hardened and subsequently ground would be impaired by the treatment given as guidance in 4.1.1, and shall instead be stress relieved at a lower temperature; for example at 130–150 °C for not less than 1 hour.

4.2 Hydrogen embrittlement relief after plating

4.2.1 ***Components subject to stress or made from higher tensile steels.*** Components subject to fatigue or sustained loading stresses in service and made from severely cold-worked steels or from steels of tensile strength of about 100 hbar* or greater shall be heat-treated after plating. A temperature of 190–210 °C for not less than 5 hours may be taken as a guide.

4.2.2 ***Surface-hardened components.*** Where the proposed temperature of heat treatment would be harmful, as for some surface-hardened parts, a lower temperature for a longer time may be required, e.g. 170 °C for not less than 15 hours.

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*1 hbar = 10^7 N/m^2 $\simeq$ 0·65 tonf/in^2.

5. REQUIREMENTS FOR COATINGS OF NICKEL PLUS CHROMIUM

5.1 Manner of specifying requirements. When ordering articles to be plated with nickel plus chromium in accordance with this standard, the purchaser shall state, in addition to the number of the standard, BS 1224, the basis metal and the service condition number denoting the severity of the conditions the coating is required to withstand (see 5.2). He need not, but he may if he wishes, also state the classification number of the particular coating required (see 5.3). If the service condition number is quoted and not the classification number, the supplier shall be free to supply any of the classes of coating corresponding to the service condition number, but he shall inform the purchaser of the classification number of the coating supplied.

5.2 Grading of service conditions. The service condition number* indicates the severity of the service conditions in accordance with the following scale:

4: exceptionally severe
3: severe
2: moderate
1: mild

Typical service conditions for which the various service condition numbers are appropriate are listed in Appendix A.

5.3 Classification of coatings. The classification number comprises:

the chemical symbol for the basis metal (or for the principal metal if an alloy), followed by an oblique stroke;

when appropriate, the chemical symbol for copper, Cu;

when appropriate, a number indicating the minimum thickness (in μm)† of the copper coating;

the chemical symbol for nickel, Ni;

a number indicating the minimum thickness (in μm) of the nickel coating;

a letter designating the type of nickel deposit;

the chemical symbol for chromium, Cr;

a letter designating the type of chromium deposit and its minimum thickness.

5.3.1 ***Basis metal.*** The following chemical symbols shall be used:

Fe for steel (or iron)
Zn for zinc alloy
Cu for copper or copper alloy
Al for aluminium or aluminium alloy

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*See the first paragraph of the Foreword.
† 1 μm (micrometre) = 0·001 mm $\simeq$ 0·00004 in.

5.3.2 ***Copper deposit on steel.*** The number following the chemical symbol Cu indicates, in micrometres, the minimum thickness of the copper deposit, measured by the method given in Appendix B, at any point on the significant surface that can be touched by a ball 20 mm in diameter.

5.3.3 ***Nickel deposit.*** The number following the chemical symbol Ni indicates, in micrometres, the minimum thickness of the nickel deposit, measured by the method given in Appendix B, at any point on the significant surface that can be touched by a ball 20 mm in diameter.

5.3.3.1 *Type of nickel.* The type of nickel* shall be designated by the following symbols:

b: for nickel deposited in the fully bright condition

p: for dull or semi-bright nickel requiring polishing to give full brightness, containing less than 0·005 % sulphur† and having an elongation greater than 8 % when tested by the method given in Appendix C.

d: for a double-layer or triple-layer nickel coating, of which the bottom layer contains less than 0·005 % sulphur† and has an elongation greater than 8 % when tested by the method given in Appendix C and the top layer contains more than 0·04 % sulphur†; the thickness of the bottom layer in double-layer coatings shall be not less than 60 % of the total nickel thickness and in triple layer-coatings shall be not less than 50 % of the total nickel thickness, the thickness of the top layer in either case being not less than 20 % of the total nickel thickness. If there are three layers, the intermediate layer shall contain more sulphur than the top layer and shall not exceed 10 % of the total nickel thickness.

5.3.4 ***Chromium deposit.*** The thickness of the chromium deposit shall be measured by the method given in Appendix D at any point on the significant surface that can be touched by a ball 20 mm in diameter.

The type of chromium shall be designated by the following symbols placed after the chemical symbol Cr:

r: for regular (i.e. conventional) chromium, having a minimum thickness of 0·3 μm;

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* It will usually be possible to identify the type of nickel by microscopical examination of a polished and etched section of an article prepared according to Appendix B.

† The sulphur 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 sulphur content of a nickel deposit on a coated article. An accurate determination is possible on a specially prepared test specimen.

f: for chromium free from cracks, when checked by the method given in Appendix E.2 (except for cracks extending from the edges of the component to 25 % of the width of the component or 10 mm whichever is the less), and having a minimum thickness of 0·8 μm.

mc: for micro-cracked chromium, having more than 250 cracks per 10 mm in any direction forming a closed network over the whole of the significant surface, when determined by one of the methods given in Appendix E, and having a minimum thickness of 0·3 μm*. (With many processes a substantially greater thickness, approximately 0·8 μm, will be required to achieve the necessary crack pattern.)

As amended May 1972

mp: for micro-porous chromium†, containing a minimum of 10 000 pores per 100 mm^2 when determined by the method given in Appendix E.2 and having a minimum thickness of 0·3 μm. The pores shall be invisible to the unaided eye.

There may be some loss of lustre after a period of service in the case of mc and mp chromium deposits of 0·3 μm thickness which could be unacceptable in some applications. This tendency can be reduced by increasing the chromium deposit thickness to 0·5 μm in which case the modified designations to be used shall be as follows:

Cr mc (0·5)

Cr mp (0·5)

5.3.5 ***Example of complete classification number.*** A coating on steel comprising 40 μm (minimum) bright nickel plus 0·3 μm (minimum) regular chromium has the classification number Fe/Ni40b Cr r.

5.4 Coatings appropriate to each service condition number. Tables 1–5 show, for the various basis metals, the coating classification numbers appropriate for each service condition number.

The nickel plus chromium coatings in Table 3 shall be applied over an undercoat of copper having a minimum thickness of 8 μm, but for articles of complex shape the minimum thickness on the significant surface may need to be increased to 10 μm or 12 μm in order to achieve adequate coverage. The method for determining the thickness of the undercoat is given in Appendix B.

5.5 Adhesion. Adhesion of the coating shall be tested by one of the methods given in Appendices F and G. The coating shall continue to adhere to the basis metal when subjected to the test selected.

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*The specified crack pattern at a minimum chromium thickness of 0·3 μm can be achieved by depositing chromium over a tensile stressed nickel layer.

† This is commonly achieved by depositing chromium over a nickel layer which contains inert non-conducting particles.

TABLE 1. NICKEL PLUS CHROMIUM COATINGS ON STEEL (OR IRON)

Service condition number*	Classification number
4	Fe/Ni40p Cr r
	Fe/Ni30p Cr mc
	Fe/Ni30p Cr mp
	Fe/Ni40d Cr r
	Fe/Ni40d Cr f
	Fe/Ni30d Cr mc
	Fe/Ni30d Cr mp
3	Fe/Ni40b Cr r
	Fe/Ni30b Cr mc
	Fe/Ni30b Cr mp
	Fe/Ni30p Cr r
	Fe/Ni25p Cr mc
	Fe/Ni25p Cr mp
	Fe/Ni30d Cr r
	Fe/Ni30d Cr f
	Fe/Ni25d Cr mc
	Fe/Ni25d Cr mp
2	Fe/Ni20b (or p or d) Cr r (or f or mc or mp)
1	Fe/Ni10b (or p or d) Cr r (or f or mc or mp)

NOTE. Modified designations are used for mc and mp chromium coatings in applications where loss of lustre cannot be tolerated and these are given in 5.3.4.

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* See the first paragraph of the Foreword.

TABLE 2. COPPER PLUS NICKEL PLUS CHROMIUM COATINGS ON STEEL (OR IRON)

Service condition number*	Classification number
4	Fe/Cu20 Ni25b Cr mc
	Fe/Cu20 Ni25b Cr mp
	Fe/Cu20 Ni30p Cr r
	Fe/Cu20 Ni25p Cr mc
	Fe/Cu20 Ni25p Cr mp
	Fe/Cu20 Ni30d Cr r
	Fe/Cu20 Ni30d Cr f
	Fe/Cu20 Ni25d Cr mc
	Fe/Cu20 Ni25d Cr mp
3	Fe/Cu20 Ni30b Cr r
	Fe/Cu20 Ni20b Cr mc
	Fe/Cu20 Ni20b Cr mp
	Fe/Cu15 Ni25p Cr r
	Fe/Cu15 Ni20p Cr mc
	Fe/Cu15 Ni20p Cr mp
	Fe/Cu15 Ni25d Cr r
	Fe/Cu15 Ni25d Cr f
	Fe/Cu15 Ni20d Cr mc
	Fe/Cu15 Ni20d Cr mp
2	Fe/Cu20 Ni10b (or p or d) Cr r (or f or mc or mp)
1	Fe/Cu10 Ni5b (or p or d) Cr r (or f or mc or mp)

NOTE. Modified designations are used for mc and mp chromium coatings in applications where loss of lustre cannot be tolerated and these are given in 5.3.4.

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* See the first paragraph of the Foreword.

TABLE 3. NICKEL PLUS CHROMIUM COATINGS ON ZINC ALLOY

(see 5.4)

Service condition number*	Classification number
4	Zn/Cu Ni35b Cr f
	Zn/Cu Ni35b Cr mc
	Zn/Cu Ni35b Cr mp
	Zn/Cu Ni35p Cr r
	Zn/Cu Ni35p Cr f
	Zn/Cu Ni25p Cr mc
	Zn/Cu Ni25p Cr mp
	Zn/Cu Ni35d Cr r
	Zn/Cu Ni35d Cr f
	Zn/Cu Ni25d Cr mc
	Zn/Cn Ni25d Cr mp
3	Zn/Cu Ni35b Cr r
	Zn/Cu Ni25b Cr f
	Zn/Cu Ni25b Cr mc
	Zn/Cu Ni25b Cr mp
	Zn/Cu Ni25p Cr r
	Zn/Cu Ni25p Cr f
	Zn/Cu Ni20p Cr mc
	Zn/Cu Ni20p Cr mp
	Zn/Cu Ni25d Cr r
	Zn/Cu Ni 25d Cr f
	Zn/Cu Ni20d Cr mc
	Zn/Cu Ni20d Cr mp
2	Zn/Cu Ni15b (or p or d) Cr r (or f or mc or mp)
1	Zn/Cu Ni8b (or p or d) Cr r (or f or mc or mp)

NOTE. Modified designations are used for mc and mp chromium coatings in applications where loss of lustre cannot be tolerated and these are given in 5.3.4.

*** See the first paragraph of the Foreword.**

TABLE 4. NICKEL PLUS CHROMIUM COATINGS ON COPPER OR COPPER ALLOY

Service condition number*	Classification number
4	Cu/Ni25b Cr mc
	Cu/Ni25b Cr mp
	Cu/Ni30p Cr r
	Cu/Ni25p Cr mc
	Cu/Ni25p Cr mp
	Cu/Ni30d Cr r
	Cu/Ni30d Cr f
	Cu/Ni25d Cr mc
	Cu/Ni25d Cr mp
3	Cu/Ni20b (or p or d) Cr r (or f or mc or mp)
2	Cu/Ni10b (or p or d) Cr r (or f or mc or mp)
1	Cu/Ni5b (or p or d) Cr r (or f or mc or mp)

NOTE. Modified designations are used for mc and mp chromium coatings in applications where loss of lustre cannot be tolerated and these are given in 5.3.4.

*** See the first paragraph of the Foreword.**

TABLE 5. NICKEL PLUS CHROMIUM COATINGS ON ALUMINIUM OR ALUMINIUM ALLOY

Service condition number*	Classification number
4	Al/Ni40p Cr r Al/Ni30p Cr mc Al/Ni30p Cr mp Al/Ni40d Cr r Al/Ni30d Cr mc Al/Ni30d Cr mp
3	Al/Ni40b Cr r Al/Ni30b Cr mc Al/Ni30b Cr mp Al/Ni30p Cr r Al/Ni25p Cr mc Al/Ni25p Cr mp Al/Ni30d Cr r Al/Ni25d Cr mc Al/Ni25d Cr mp
2	Al/Ni20b (or p or d) Cr r (or mc or mp)
1	Al/Ni10b (or p or d) Cr r (or mc or mp)

NOTE. Modified designations are used for mc and mp chromium coatings in applications where loss of lustre cannot be tolerated and these are given in 5.3.4.

5.6 Corrosion resistance. Coated articles shall be subjected for the stated time to one of the corrosion tests shown in Table 6 to be appropriate for the particular service condition number. The tests are described in detail in Appendices H, J and K.

The corrosion tests given in Table 6 are a means of controlling the continuity and quality of the coatings and the duration of the tests does not necessarily have a fixed relationship with the service life of the finished article.

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* See the first paragraph of the Foreword.

TABLE 6. CORROSION TESTS APPROPRIATE TO EACH SERVICE CONDITION NUMBER

Basis metal	Service condition number*	Corrosion test (duration in hours)		
		CASS (Appendix H)	Corrodkote (Appendix J)	Acetic-salt (Appendix K)
Steel, zinc alloy, aluminium or aluminium alloy	4	24	2 × 16	144
	3	16	16	96
	2	—	—	24
	1	—	—	8
Copper or copper alloy	4	16	—	96
	3	8	—	48
	2	—	—	16
	1	—	—	—

NOTE. It will be noticed that the duration of the tests is less when the basis metal is copper or copper alloy than when it is any other metal. This is necessary since, for the same service condition number, the nickel deposits on copper and copper alloy are thinner than those on the other basis metals. The use of these thinner and less corrosion-resistant coatings is justified by the slower corrosion of copper and copper alloys when the coatings are penetrated. The duration of the corrosion tests is not, therefore, to be understood as a direct indication of overall performance in service.

Employing the procedure described in BS 3745†, a rating shall be assigned to each tested article representing the relative freedom from spots at which the coating is penetrated, with resulting corrosion of the basis metal. This rating shall be at least 8.

This rating shall be assigned to the article after subjecting it to the treatments described in the relevant test method, as given in Appendix H, J or K.

Surface deterioration of the coating itself is expected to occur during the testing of some types of coating. The extent to which surface deterioration will be tolerated shall be subject to agreement between the supplier and the purchaser.

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* See the first paragraph of the Foreword.

† BS 3745 ' Method for the evaluation of results of accelerated corrosion tests on metallic coatings '.

6. REQUIREMENTS FOR COATINGS OF NICKEL WITHOUT CHROMIUM

6.1 General. Nickel coatings without chromium topcoats are suitable for applications in which tarnishing is prevented by rubbing or handling in service or in which loss of lustre is of no importance. In many applications resistance to wear and abrasion is as important as resistance to corrosion, while in other applications resistance to fracture in service is an essential feature. Thus the requirements for hardness and ductility as well as lustre should be borne in mind when selecting the type and thickness of nickel to be used. The range of applications for these coatings is so wide that the corrosion resistance tests given in Appendices H, J and K are not appropriate.

6.2 Manner of specifying requirements. When ordering articles to be plated with nickel without chromium in accordance with this standard, the purchaser shall state, in addition to the number of the standard, BS 1224, the classification number of the particular coating required, using the relevant symbols and numbers defined in 5.3.

6.3 Coatings appropriate to each application grade. Tables 7–10 show, for the various basis metals, the coating classification number appropriate for each application grade.

The nickel coatings in Table 8 shall be applied over an undercoat of copper having a minimum thickness of 8 μm, but for articles of complex shape the minimum thickness on the significant surface may need to be increased to 10 μm to 12 μm in order to achieve adequate coverage. The method for determining the thickness of the undercoat is given in Appendix B.

TABLE 7. NICKEL COATINGS ON STEEL (OR IRON)

Application grade	Classification number
High	Fe/Ni30b (or p or d)
Medium	Fe/Ni20b (or p or d)
Low	Fe/Ni10b (or p or d)

TABLE 8. NICKEL COATINGS ON ZINC ALLOY

Application grade	Classification number
High	Zn/Cu Ni25b (or p or d)
Medium	Zn/Cu Ni15b (or p or d)
Low	Zn/Cu Ni8b (or p or d)

TABLE 9. NICKEL COATINGS ON COPPER OR COPPER ALLOY

Application grade	Classification number
High	Cu/Ni20b (or p or d)
Medium	Cu/Ni10b (or p or d)
Low	Cu/Ni5b (or p or d)

TABLE 10. NICKEL COATINGS ON ALUMINIUM OR ALUMINIUM ALLOY

Application grade	Classification number
High	Al/Ni30b (or p or d)
Medium	Al/Ni20b (or p or d)
Low	Al/Ni10b (or p or d)

6.4 Adhesion. The requirements of 5.5 shall apply.

APPENDIX A

EXAMPLES OF SERVICE CONDITIONS FOR WHICH THE VARIOUS SERVICE CONDITION NUMBERS ARE APPROPRIATE

Examples of service conditions for which the various service condition numbers are appropriate are as follows:

Service condition no. 4. Service outdoors in exceptionally severe corrosive conditions.

Service condition no. 3. Service outdoors in normal conditions.

Service condition no. 2. Service indoors in places where condensation may occur, e.g. kitchens and bathrooms.

Service condition no. 1. Service indoors in warm dry atmospheres, e.g. offices.

APPENDIX B

DETERMINATION OF NICKEL AND COPPER THICKNESS

Section the sample at one or more positions. Mount the section by moulding in a suitable plastics material so that the plated surface is perpendicular to the face which is to be prepared for examination*. Ensure that the section is rigidly held and that there are no voids between the plated surface and the mounting material.

Prepare the section using successively finer abrasives, the last being no coarser than Grade 240 as specified in BS 872†. Final polishing may be carried out on a low-speed wheel using suitable media.

Where necessary, lightly etch the section with a suitable reagent‡ to reveal the boundaries between the different deposits and between the coating and the basis metal.

Measure the thickness of the deposit with a microscope having a magnification sufficient to allow the thickness to be determined to ± 1 μm.

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* A deviation of 10 degrees from the perpendicular introduces an errror of about 2 % in thickness.

† BS 872, ' Abrasive papers and cloths (technical products) '.

‡ Suitable etchants are:

(1) Equal parts by volume of nitric acid ($d = 1\cdot42$) and glacial acetic acid.

(2) Equal parts by volume of solutions of sodium cyanide (100 g/l) and sodium or ammonium persulphate (100 g/l): toxic fumes are evolved when these chemicals are mixed in solution.

APPENDIX C

DUCTILITY TEST*

C.1 Preparation of test piece. Prepare a plated test strip 150 mm long, 10 mm wide and 1 mm thick by the following method:

Polish a sheet of the appropriate basis metal, similar to that of the articles being plated 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. Plate the sheet on one side with nickel to a thickness of 25 μm under the same conditions and in the same bath as the corresponding articles.

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

C.2 Procedure. Bend the test strip with the plated side in tension, by steadily applied pressure, through 180° over a mandrel of diameter 11·5 mm until the two ends of the test strip are parallel. Ensure that contact between the test strip and the mandrel is maintained during bending.

C.3 Assessment. The plating 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. Small cracks at the edges do not signify failure.

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* This test is used to check that the type of nickel deposit complies with the appropriate definition given in 5.3.3.

† See BS 2870, ' Schedule of rolled copper and copper alloys. Sheet, strip and foil '.

APPENDIX D

DETERMINATION OF CHROMIUM THICKNESS—COULOMETRIC METHOD*

D.1 Principle. The method is based on the measurement of the quantity of electricity required to dissolve anodically an electrodeposited coating over a known area.

D.2 Test solution. Dilute 62 ml of orthophosphoric acid ($d = 1{\cdot}75$) to 1 litre.

D.3 Procedure. Clean the area to be tested with a cloth, wetted with an organic solvent for grease removal if necessary.

Press an electrolytic cell, fitted with a flexible sealing ring and incorporating an annular cathode, on to the coating so that a circle of known area is exposed to the test solution. Introduce the test solution into the cell; insert and operate the stirrer if appropriate to the instrument used and the thickness of the deposit.

Make the electrical connections with the specimen anodic. Continue electrolysis until dissolution of the chromium coating is complete, as indicated by a sudden change in anode potential, and record the quantity of electricity consumed.

Examine the specimen and ensure that chromium removal is complete over the area of the cell.

Calculate the thickness of the chromium coating from the following formula assuming 100 % current efficiency:

$$\frac{Q}{A} \times 12{\cdot}6 = \text{thickness in micrometres}$$

where: Q is quantity of electricity consumed (coulombs)

and: A is the area tested (mm^2).

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* Instruments for carrying out this test are commercially available.

APPENDIX E

DETERMINATION OF CRACKS AND PORES IN CHROMIUM COATINGS

E.1 Visual examination for cracks. Examine the surface for cracks in reflected light under an optical microscope at a magnification of 100 x. For very fine patterns and accurate counting, a higher magnification may be desirable. Use a micrometer eyepiece or similar device for indicating the distance over which cracks are counted.

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

E.2 Copper deposition for determination of cracks or pores.

E.2.1 ***Principle.*** Electrodeposition of copper from an acid sulphate solution at low current density or low voltage occurs only on the underlying nickel that is exposed through cracks, pores and other discontinuities.

This method provides a rapid means of visual inspection for uniformity of distribution of cracks or pores, but, if counting of cracks or pores is required, a microscope should be employed as described in E.1.

E.2.2 ***Procedure.*** The test is best applied immediately on completion of the plating process. If there is any delay, degrease the specimen thoroughly by chemical means, avoiding the use of any electrolytic treatment.

Deposit copper for approximately 1 minute at room temperature from a bath containing approximately 200 g/l of crystalline copper sulphate and 20 g/l of sulphuric acid at an average current density of 30 A/m^2.

NOTE. Specimen and anode should be connected to the current supply before immersion.

In cases when the test is applied several days after chromium deposition, immerse the specimen in 10–20 g/l nitric acid solution for 4 minutes at approximately 95 °C before the copper deposition stage, to help reveal the cracks or pores.

APPENDIX F

FILE TEST FOR ADHESION

The File Test shall be carried out as follows:

Saw a piece off a plated article, hold it in a vice and apply a coarse file to the cut edge in such a manner as to raise the deposit. File in the direction from the basis metal to the coating at an angle of approximately 45 ° to the coated surface.

APPENDIX G

QUENCHING TEST FOR ADHESION

The Quenching Test shall be carried out as follows:

Heat a plated article for 1 hour in an oven at a temperature appropriate to the basis metal as given below, with a tolerance of ± 10 degC.

Articles of:

Steel	300 °C
Zinc alloy	150 °C
Copper or copper alloy	250 °C
Aluminium or aluminium alloy	250 °C

Then quench the article in water at room temperature.

Caution: This test may have an adverse effect on the mechanical properties of the articles tested.

APPENDIX H

CASS TEST

(Copper accelerated acetic acid salt spray test)

H.1 Spraying liquid. Dissolve 50 ± 5 g of sodium chloride* (NaCl) and 0·26 ± 0·02 g of cupric chloride ($CuCl_2$) in water containing less than 100 p.p.m. of total solids or having a conductivity of less than 0·002 S/m and dilute to 1 litre.

Add glacial acetic acid† (CH_3COOH) to adjust the pH to 3·2 ± 0·1.

H.2 Test conditions. The test is carried out in a suitable cabinet (see H.4).

Operating temperature inside cabinet: 50 ± 1 °C.

Spray collection rate: 1·5 ± 0·5 ml/h over 8000 mm^2 horizontal area averaged over at least 8 hours.

Collected spray: solution containing 50 ± 10 g of sodium chloride per litre and having a pH of 3·2 ± 0·1.

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* BS 998. ' Vacuum salt for butter and cheese making '.

† BS 576. ' Acetic acid '.

H.3 Procedure. Immediately before testing clean the specimens with a slurry of light magnesium oxide on a swab; rinse the specimens in clean running water so that they are free from water breaks.

Place the specimens in the heated cabinet so that as far as possible their significant surfaces are at an angle of 15° to 30° to the vertical. Do not allow test solution from one specimen to drip on to any other. Place at least two collector vessels in the zone where the specimens are located, but take care that only fog, and no liquid falling from specimens or parts of the cabinet and its fittings, is collected.

Restore the cabinet and saturator tower to the required temperature and commence the test. Do not recirculate the spraying liquid.

After the test is completed, rinse the specimens in clean, running water to remove any deposits of salt, and dry. For each specimen make an assessment of the frequency of corrosion spots, based on the number of spots showing evidence of basis metal corrosion.

To examine any deterioration in appearance, swab the surface using a mild abrasive to remove all corrosion products, rinse in clean water, and dry.

H.4 Suggested apparatus. A fog cabinet or room should be made or lined with a material resistant to the corrosive medium employed in this test (glass, rubber or certain plastics materials are suitable), and should be provided with specimen supports meeting the same requirements.

Provision should be made for a supply of clean air of controlled pressure and humidity, one or more spray nozzles, and means for heating the apparatus and maintaining the test temperature.

Baffles inside the cabinet should prevent direct impingement of the spray on the specimens. The use of adjustable baffles will be found of assistance in obtaining a uniform collection rate throughout the cabinet.

The air used to provide the spray should first be humidified by passing it through a saturator tower containing water* thermostatically maintained at the correct temperature. The termperature of the water in this tower will need to be several degrees higher than the test temperature, but should be adjusted according to the pressure used and the type of nozzle, so that both the collection rate and the concentration of collected fog are kept within the specified limits. It is desirable to maintain the level of the water in the saturator tower at a set height, and this is most conveniently done by an automatic level control.

It is also important to maintain a constant head between the nozzle or nozzles and the test solution in the supply tank. If this cannot be done manually throughout the cycle, an automatic level control should be fitted.

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* The water used should contain less than 100 p.p.m. of solids, or have a conductivity of less than 0·002 S/m.

APPENDIX J

CORRODKOTE TEST

J.1 Preparation of reagents. Make up the following solutions in distilled or deionized water.

Cupric nitrate. Dissolve 2·50 g of cupric nitrate ($Cu(NO_3)_2.3H_2O$) in water and dilute to 500 ml.

Ferric chloride. Dissolve 2·50 g of ferric chloride ($FeCl_3.6H_2O$) in water and dilute to 500 ml. (This reagent should not be kept for more than 2 weeks.)

Ammonium chloride. Dissolve 50·0 g of ammonium chloride (NH_4Cl) in water and dilute to 500 ml.

J.2 Preparation of slurry. Mix 7·0 ml of cupric nitrate solution, 33·0 ml of ferric chloride solution and 10·0 ml of ammonium chloride solution.

Add 30 g of kaolin and stir with a glass rod until a homogeneous slurry is obtained.

Make up the slurry fresh as required.

J.3 Procedure. Brush the slurry on to the specimens to be tested with circular movements, then smooth in one direction. The wet film thickness should be approximately 0·05 mm. Allow the coating to dry for 1 hour.

Place the specimens for the period specified in a humidity cabinet at 38 ± 1 °C and 94 ± 4 % relative humidity without condensation.

When two cycles of testing are required, clean off the paste with running water and a sponge after the first test period, then apply fresh slurry as before and test for the second period.

For plated *steel* specimens, dry and inspect. Make an assessment of the frequency of corrosion spots on the basis of the number of rust spots visible in the paste.

To examine any deterioration in appearance, clean off the paste with running water and a sponge (mild abrasive may be used), dry and inspect.

For plated *zinc alloy* or *aluminium alloy* specimens, clean off the paste with running water and a sponge (mild abrasive may be used), dry and inspect.

Make an assessment of the frequency of corrosion spots on the basis of the number of spots showing evidence of basis metal corrosion, and examine for any deterioration in appearance.

J.4 Suggested apparatus. It is necessary to maintain the temperature and relative humidity within the specified limits, while ensuring that no condensation occurs on the articles under test. A suitable controlled-humidity cabinet for this purpose is one in which the air is continuously circulated via an outer chamber where it is humidified by a hygrostatically controlled water spray.

APPENDIX K

ACETIC SALT TEST

(Acetic acid salt spray test)

K.1 Spraying liquid. Dissolve 50 ± 5 g of sodium chloride* ($NaCl$) in water containing less than 100 p.p.m. of total solids or having a conductivity of less than 0·002 S/m and dilute to 1 litre.

Add glacial acetic acid† (CH_3COOH) to adjust the pH to 3·2 ± 0·1.

K.2 Test conditions. The test is carried out in a suitable cabinet (see K.4). Operating temperature inside cabinet : 35 ± 2 °C.

Spray collection rate : 1·5 ± 0·5 ml/h over 8000 mm^2 horizontal area averaged over at least 8 hours.

Collected spray: solution containing 50 ± 10 g of sodium chloride per litre and having a pH of 3·2 ± 0·1.

K.3 Procedure. Immediately before testing, clean the specimens with a slurry of light magnesium oxide on a swab; rinse the specimens in clean running water so that they are free from water breaks.

Place the specimens in the heated cabinet so that as far as possible their significant surfaces are at an angle of 15° to 30° to the vertical. Do not allow test solution from one specimen to drip on to any other. Place at least two collector vessels in the zone where the specimens are located, but take care that only fog, and no liquid falling from specimens or parts of the cabinet and its fittings, is collected.

Restore the cabinet to the required temperature and commence the test. Do not re-circulate the spraying liquid.

Operate the test continuously for the specified period except for the short interruptions necessary to inspect or replace test specimens and to replenish the solution in the reservoir.

After the test is completed, rinse the specimens in clean, running water to remove any deposits of salt, and dry. For each specimen, make an assessment of the frequency of corrosion spots, based on the number of spots showing evidence of basis metal corrosion.

To examine any deterioration in appearance, swab the surface using a mild abrasive to remove all corrosion products, rinse in clean water, and dry.

K.4 Suggested apparatus. A fog cabinet or room should be made or lined with a material resistant to the corrosive medium employed in this test (glass, rubber

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* BS 998, 'Vacuum salt for butter and cheese making'.

† BS 576, 'Acetic acid'.

or certain plastics materials are suitable), and should be provided with specimen supports meeting the same requirements.

Provision should be made for a supply of clean air of controlled pressure and humidity, one or more spray nozzles, and means for heating the apparatus and maintaining the test temperature.

Baffles inside the cabinet should prevent direct impingement of the spray on the specimens. The use of adjustable baffles will be found of assistance in obtaining a uniform collection rate throughout the cabinet.

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