BRITISH STANDARD

BS 443:1982

Incorporating amendment No. 1

Specification for

Testing zinc coatings on steel wire and for quality requirements

UDC 669.58:669.14-426

Cooperating organizations

The Iron and Steel Standards Committee, under whose direction this British Standard was prepared, consists of representatives from the following:

British Constructional Steelwork Association
British Internal Combustion Engine Manufacturers' Association
British Ironfounders' Association
British Railways Board
British Steel Corporation
British Steel Industry*
British Steel Industry (Wire Section)*
Concrete Society Limited
Council of Ironfoundry Associations
Department of Industry (National Physical Laboratory)
Electricity Supply Industry in England and Wales
Engineering Equipment Users' Association
Federation of Civil Engineering Contractors
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Oil Companies Materials Association
Process Plant Association
Royal Institute of British Architects
Society of Motor Manufacturers and Traders Limited
Steel Casting Research and Trade Association
Water-tube Boilermakers' Association

The organizations marked with an asterisk in the above list, together with the following, were directly represented on the Technical Committee entrusted with the preparation of this British Standard:

British Wire Netting Association
Fencing Contractors' Association
Society of Chain Link Fencing Manufacturers

This British Standard, having been prepared under the direction of the Iron and Steel Standards Committee, was published under the authority of the Board of BSI and comes into effect on 26 February 1982.

First published March 1932
First revision November 1939
Second revision January 1961
Third revision January 1969
Fourth revision February 1982

The following BSI references relate to the work on this standard:
Committee reference ISM/26
Draft for comment 80/71262 DC

ISBN 0 580 12612 9

Amendments issued since publication

Amd. No.	Date of issue	Comments
6158	December 1989	Indicated by a sideline in the margin

Contents

Foreword

This British Standard has been prepared under the direction of the Iron and Steel Standards Committee. This edition has been technically up-dated in detail although the major technical concepts have not been altered significantly. BS 443:1969 is now withdrawn.

With the emphasis on adoption of international standards in national standards, there is the future possibility that some British Standards may not refer to the standard values for coating thickness given in section three of this standard, or may not require the dip test. Ease of cross-reference will, therefore, be improved by separation of test methods and general quality requirements.

The standard coatings specified in section three are intended for a wide variety of wire applications in which medium/long term protection of the steel against corrosion is desired. It is emphasized that the protection afforded by the zinc is sacrificial and the duration of the protection is therefore dependent on the conditions in which the zinc coated wire will be expected to function.

The dip test has been retained as a standard requirement but it is not intended as an indirect measurement of the mass of coat. It is intended only to reveal any serious eccentricity of a coating that could lead to failure over a portion of the circumference, even though the total mass of coat may be in accordance with the standard.

Following international practice which is becoming established, the term “zinc coated” rather than “galvanized” has been adopted in this standard. The terms are synonymous.

Factors for converting coating mass from imperial to metric units and for converting coating mass to coating thickness are included in appendix A.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 8, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This British Standard specifies the methods of testing zinc coated steel wires and products fabricated from them to determine the nominal mass of the zinc coating, its uniformity and its adhesion.

In addition, requirements are specified (see section three) for mass, uniformity and adhesion of coating on steel wires of circular section in diameters from 0.23 mm to 10.0 mm. These requirements are not applicable to articles made from wire which have been coated after fabrication.

NOTE Coatings in accordance with section three are not necessarily available in every combination of wire size and tensile strength grade and reference should be made to the appropriate British Standard for the type of wire.

2 Reference

The title of the standards publication referred to in this standard is given on the inside back cover.

3 Metallurgical quality of coating

The metallurgical quality of the coating is dependent on the quality of the zinc used. Wire shall be coated in a bath using zinc of purity not less than grade Zn 3 of BS 3436.

4 Test pieces

4.1 The number and basis of selection of test pieces shall be that specified in the standard for the product. In the absence of such a standard the degree of sampling shall be agreed between the manufacturer and the purchaser.

4.2 In removing the test pieces care shall be taken to avoid surface damage. Portions of wire which are obviously damaged shall not be used.

4.3 For all the tests a piece of total length of at least 500 mm will usually be needed (see **8.2.2**, **8.3.4**, **9.4** and clause **10**).

5 Test pieces from fabricated wire products

If the test pieces have been taken from a product fabricated from zinc coated wires, then unless otherwise stated in the product standard, the specified minimum coating mass shall be reduced by 5 % and the specified dips shall be reduced by one half-minute dip.

6 Surface condition

The coating on wire shall be continuous and reasonably smooth. It is recognized that thick coatings produced by the final hot dip process may exhibit some surface irregularities, but the coating shall be free from imperfections, such as gross dross contamination, not consistent with good coating practice.

7 Uniformity and adherence

The coating on wire shall be reasonably uniform, as judged by the copper sulphate solution dip test, and shall be adherent to the steel under the conditions of the adhesion wrap test (see clause **10**).

Section 2. Test methods

8 Determination of mass of coating

8.1 General. The mass of coating shall be determined by either a gravimetric or volumetric method. The latter has an acceptable degree of accuracy and has the advantage of rapidity. It is therefore the preferred method for routine testing of all the sizes of wire which can be conveniently accommodated in the measuring apparatus. In any case of dispute, the gravimetric method shall be accepted as the referee method.

NOTE The methods of test contained in this standard do not necessarily detail all precautions necessary to meet the requirements of the Health and Safety at Work etc., Act 1974. Attention should be paid to any appropriate precautions and the methods should be operated only by trained personnel.

8.2 Gravimetric method

8.2.1 *Reagents.* The following reagents are used.

Antimony chloride solution. Dissolve 20 g antimony trioxide or 32 g antimony trichloride in 1 000 ml hydrochloric acid, of relative density of between 1.16 and 1.18.

Stripping solution. Add 5 ml of the antimony chloride solution to every 100 ml hydrochloric acid, of relative density of between 1.16 and 1.18.

8.2.2 *Test piece.* For wires of diameter 3 mm and larger, the length of the test piece should not be less than 100 mm. As a guide to the length for smaller sizes of wire, this should be such that the mass in grams is numerically not less than approximately four times the diameter in millimetres.

After cleaning the test piece in a suitable organic solvent, e.g. methylated spirit, wipe the wire dry with a clean, soft cloth and weigh it to the nearest 0.01 g.

8.2.3 *Stripping the zinc.* Strip the coating from the steel wire by complete immersion of the test piece in any convenient volume of the stripping solution.

NOTE The same solution may be repeatedly used, without further additions of antimony chloride solution, until the time of stripping becomes inconveniently long.

The temperature of the stripping solution should not be allowed to exceed 38 °C and the number of test pieces immersed at any one time shall not exceed 3 per 100 ml of solution.

As soon as the violent chemical action has ceased, remove the wire from the acid, wash it thoroughly in running water and wipe dry. The diameter of the wire shall then be determined to the nearest 0.02 mm by taking the average of two measurements at right angles to each other. Weigh each piece of stripped wire to the nearest 0.01 g.

8.2.4 *Determination.* The mass of zinc coating in g/m^2 of steel surface is given by the formula

$$\frac{(W_{ZS} - W_S)}{W_S} d \times 1962$$

where

W_{zs} is the mass (in g) of the zinc coated steel wire.

W_s is the mass (in g) of the bare steel wire.

d is the diameter (in mm) of the bare steel wire.

NOTE The expression is derived from the relationship between the curved surface area and the volume of a cylinder and the density of steel (7 850 kg/m^3).

8.3 Gas volumetric method

8.3.1 *Principle.* The volumetric method of determining the mass of coating depends on the fact that a metal dissolved in acid always releases a quantity of hydrogen proportional to the amount of metal dissolved, i.e. the chemical equivalent of the metal in question.

1 g of zinc releases 343 ml of hydrogen at a temperature of 0 °C and a pressure of 1 014 mbar[1)].

NOTE With very large wires problems of test piece preparation and damage to the glass burette may be introduced. This method of determination is therefore usually limited to wires of maximum diameter 5 mm.

8.3.2 *Reagent.* The same stripping solution as specified in **8.2.1** is used, subject to the following qualifications. Acid concentration may affect the result in the volumetric method, strong acid giving slightly high results and weak acid giving low results. Assuming a 36 % mass content of HCl in the concentrated acid (relative density 1.18), 70 parts by volume should be mixed with 30 parts by volume of water to give a mass concentration of approximately 25 % HCl (relative density approximately 1.13).

NOTE The stripping solution should be replaced when the acid concentration is reduced to a level where, for example, vigorous evolution of gas lasts longer than about 80 s with a zinc mass of 230 g/m^2.

8.3.3 *Apparatus.* The apparatus consists of a 100 ml glass burette fitted with a stopcock at the top and bottom and connected at the bottom with a rubber tube to a reservoir. The apparatus is shown in Figure 1(a) set up for the commencement of a test.

The 100 ml burette should be graduated to at least 0.5 ml subdivisions.

NOTE Where small sizes of wire, say less than 1.5 mm diameter, are regularly tested, it may be found useful to use a 50 ml burette of about the same length and graduated to at least 0.2 ml subdivisions.

[1)] 1 mbar = 100 N/m^2 = 0.1 kPa.

8.3.4 *Test pieces.* From a straightened and undamaged length of wire, test pieces of the required length are accurately cut (error no more than 1 %). The most suitable length of test piece depends upon the size of burette, diameter of wire and expected mass of coating. The lengths indicated in Table 1 will usually be found convenient.

Table 1 — Length of test piece

Zinc coated wire diameter		Length of test piece	
Over	Up to and including	for a 100 ml burette	for a 50 ml burette
mm	mm	mm	mm
0.45	0.85	—	200
0.85	1.06	200	150
1.06	1.8	100	75
1.8	3.6	75	—
3.6	5.0	50	—

8.3.5 *Procedure.* Pour the acid reagent into the reservoir C until it completely fills the burette leaving a small portion in the reservoir when in the elevated position.

To carry out a test, adjust the height of the reservoir C so that the acid reagent just fills the burette up to the stopcock A with the bottom stopcock B closed. Drop the test piece, cut to the specified length, into the burette and immediately close the stopcock A.

NOTE Where long test pieces are necessary, rapid entry into the burette may be difficult and it may be more convenient to drop two short pieces simultaneously through the stopcock.

The zinc coating rapidly dissolves and liberates hydrogen and the test is continued until evolution of hydrogen, but for a few fine bubbles, has ceased. Then lift the reservoir from its supporting ring and place alongside the burette until the levels of the acid reagent in the burette and the reservoir are the same, as shown in Figure 1(b), then read off the volume of hydrogen on the burette scale.

When the test is concluded open stopcock A and draw all acid reagent from the burette by lowering the reservoir to a position below stopcock B. Then open stopcock B to eject the test piece and close again. The procedure given above may then be repeated for a succeeding test.

The stripped wire shall then be washed, wiped dry and the diameter measured.

8.3.6 *Determination.* The mass of zinc coating is calculated from the formula:

$$\text{Mass of coating/unit area of steel surface} = \frac{V}{dl} \times f$$

where

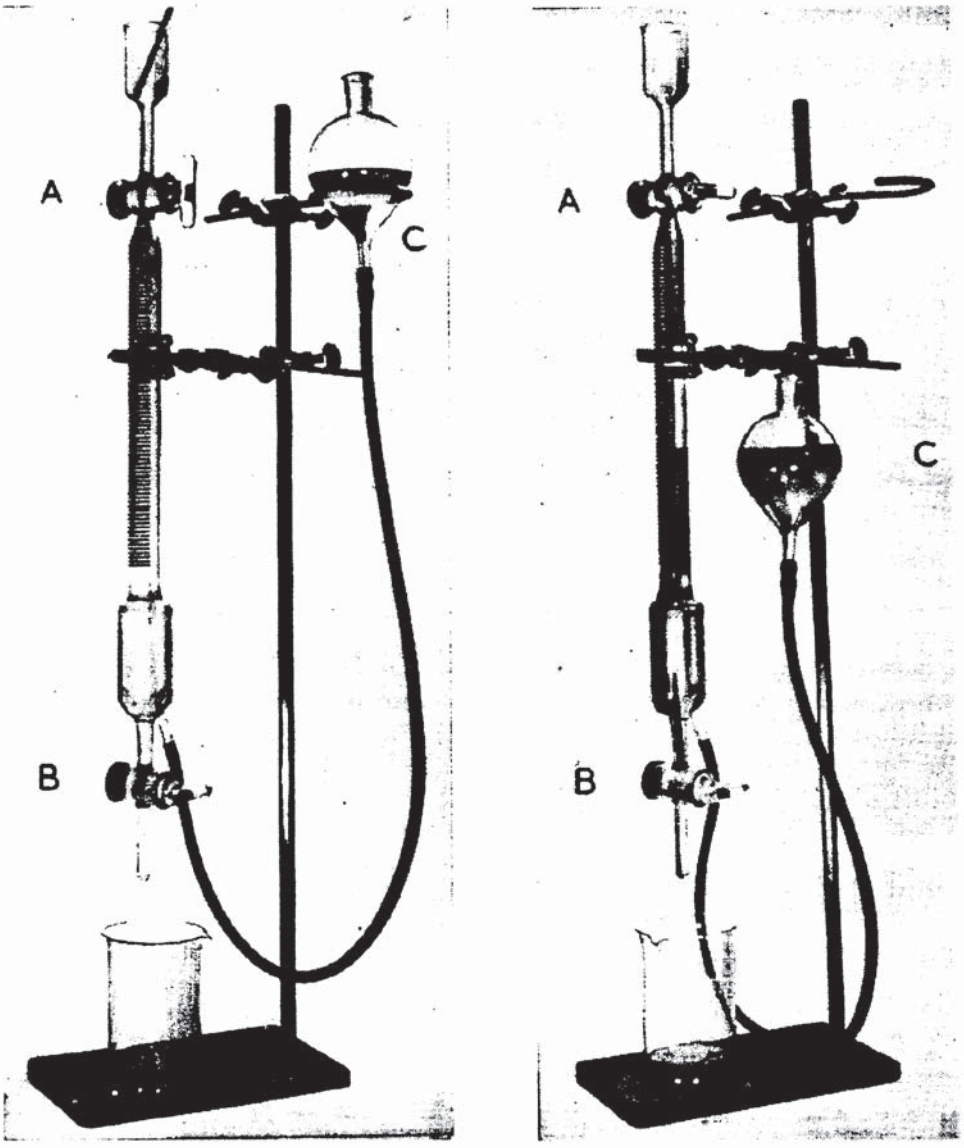
V is the volume of hydrogen evolved in millilitres (ml)

d is the stripped wire diameter

l is the length of test piece

Where length and diameter are in millimetres, $f = 872$, to give a mass of zinc coating in g/m^2.

NOTE In practice the mass of zinc (in g/m^2) is read directly from tables relating mass of zinc to diameter of stripped wire and volume of hydrogen.



(a) Arrangement of apparatus when commencing test

(b) Arrangement of apparatus when measuring volume of hydrogen on completion of test

Figure 1 — Apparatus for determining coating mass by gas-volumetric method

8.3.7 *Correction for temperature and barometric pressure*. The factor (*f*) has been calculated for a temperature of 18 °C and a barometric pressure of 1 014 mbar. If the atmospheric pressure is outside the range 987 mbar to 1 040 mbar or if the temperature is outside the range 16 °C to 20 °C, apply the appropriate correction factor from Table 2. If the combination of pressure and temperature results in a correction factor within ± 0.02 of unity (see outlined zone in Table 2), then the factor need not be applied to the calculated mass of zinc or to that obtained from tables.

NOTE 1 Where the test result is within 5 g/m^2 of the specified minimum value, it is desirable to check the atmospheric pressure and temperature, in case a negative correction is necessary.

Where climate or altitude cause permanent divergence from standard conditions, the formula shall be corrected to suit prevailing conditions. If tables are used these shall be corrected.

NOTE 2 At high altitudes it will be found convenient to have a burette of greater capacity than 50 ml or 100 ml.

9 Test for uniformity of coating (Preece dip method)

9.1 General. The uniformity of the coating shall be tested by the method described below.

9.2 Reagent. The following reagent is used.

Copper sulphate solution. Dissolve approximately 36 g of crystalline copper sulphate ($CuSO_4.5H_2O$) in each 100 ml of distilled or deionized water. The water may be heated to aid solution of the crystals; but if heated, the solution shall be allowed to cool before neutralizing.

For neutralization, shake the solution with an excess of basic cupric carbonate (1 g/l to 2 g/l of solution) and allow it to stand, preferably for at least 24 h, before filtering or decanting the solution from the sediment.

NOTE Analytical reagent quality copper sulphate is not essential. The pH of the solution is initially 3.0 to 2.7 and after "neutralization" with basic cupric carbonate the pH is 3.7 to 3.5, and it appears to be consistent over a period of time. If cupric oxide is used for "neutralization" with a recommended standing time of 48 h, the pH will be in the range 3.6 to 3.3 and may vary with time. For these reasons only the basic cupric carbonate is specified as the neutralizing agent.

The relative density of the test solution shall be 1.186 at 18 °C. Adjustment may be made by adding distilled (or de-ionized) water or solution of higher relative density, as appropriate.

The solution shall be discarded and replaced with fresh solution after six samples have been tested.

9.3 Apparatus. The following apparatus is required.

Glass or plastics container of internal diameter not less than 50 mm for wires of 2.8 mm diameter and smaller or 75 mm for larger wires. It should be filled with copper sulphate solution to a depth of at least 100 mm.

9.4 Test pieces. The test piece should be not less than 150 mm in length and shall be undamaged as far as possible. The test piece may be hand straightened and shall be cleaned with an organic solvent, e.g. methylated spirit, and then wiped dry with a clean soft cloth.

9.5 Temperature. At the commencement, and during the progress of the test, the temperature of the test pieces and of the solution shall not vary outside the limits of 18 ± 2 °C.

9.6 Procedure. It is preferable that not more than three test pieces be immersed in the solution at one time. The test pieces shall not touch one another. During the immersion the test pieces shall not be disturbed, and the solution shall not be agitated.

The test piece or test pieces shall be subjected to successive dips of exactly 1 min. After each dip remove the sample and immediately rinse it in clean running water and wipe dry with a clean soft cloth. If running water is not available, the rinse water shall be changed frequently so that there is no obvious contamination with copper sulphate solution.

Half-minute dips, where specified, shall be given after the completion of all the one-minute dips.

9.7 Examination. After the specified number of dips, the final rinsing and wiping dry, the test piece shall not show any adherent bright deposit of metallic copper on the steel. Any deposit of metallic copper within 25 mm of the cut end shall be disregarded.

Table 2 — Correction factors for temperature and barometric pressure used in calculating mass of coating

Temperature	**Atmospheric pressure**, mbar														
°C	**693**	**720**	**747**	**773**	**800**	**827**	**853**	**880**	**907**	**933**	**960**	**987**	**1 014**	**1 040**	**1 067**
10	0.703	0.730	0.758	0.784	0.811	0.839	0.866	0.892	0.920	0.947	0.974	1.001	1.028	1.055	1.082
12	0.698	0.725	0.752	0.779	0.806	0.833	0.860	0.886	0.914	0.940	0.967	0.994	1.021	1.048	1.075
14	0.694	0.720	0.747	0.774	0.800	0.827	0.854	0.880	0.908	0.934	0.960	0.988	1.014	1.040	1.068
16	0.689	0.715	0.742	0.768	0.795	0.822	0.848	0.874	0.901	0.927	0.954	0.981	1.007	1.033	1.060
18	0.684	0.710	0.737	0.763	0.789	0.816	0.842	0.868	0.895	0.921	0.947	0.974	1.000	1.026	1.053
20	0.679	0.705	0.732	0.758	0.783	0.810	0.836	0.862	0.889	0.915	0.940	0.967	0.993	1.019	1.046
22	0.674	0.700	0.727	0.752	0.778	0.805	0.830	0.856	0.882	0.908	0.934	0.960	0.986	1.012	1.038
24	0.670	0.696	0.722	0.748	0.773	0.800	0.825	0.851	0.877	0.903	0.928	0.955	0.980	1.005	1.032
26	0.666	0.691	0.717	0.742	0.769	0.794	0.819	0.845	0.871	0.896	0.921	0.947	0.973	0.998	1.025
28	0.661	0.687	0.713	0.738	0.763	0.789	0.814	0.839	0.865	0.891	0.916	0.942	0.967	0.992	1.018
30	0.657	0.682	0.708	0.732	0.757	0.783	0.808	0.833	0.859	0.884	0.909	0.935	0.960	0.985	1.011
	520	**540**	**560**	**580**	**600**	**620**	**640**	**660**	**680**	**700**	**720**	**740**	**760**	**780**	**800**
	Height of barometer, mmHg														

10 Adhesion of coating

For wires of 7.5 mm and smaller the adhesion of the zinc shall be tested by wrapping the wire at least six close turns round a cylindrical mandrel. Larger wires shall be bent through an angle of at least 90° round the mandrel. The ratio of mandrel diameter to wire diameter (d) shall be in accordance with Table 3.

Table 3 — Ratio of mandrel diameter to wire diameter

Wire diameter (d)	Mandrel diameter
mm	
Up to and including 3.8	$4d$
Over 3.8	$5d$

The zinc shall remain firmly adherent to the steel and shall not crack or flake to such an extent that any flakes of zinc can be removed by rubbing with bare fingers.

Section 3. Standard coating

11 Thickness and quality

When tested in accordance with clauses **8** and **9**, the zinc coating mass and the number of dips in the copper sulphate solution when testing for uniformity of coating shall comply with the requirements given in Table 4.

The coating shall be adherent in accordance with the adhesion wrap test (see clause **10**).

Table 4 — Minimum mass of coating and number of dips

Nominal diameter of coated wire		Wire of tensile strength less than 540 N/mm^2			Wire of tensile strength 540 N/mm^2 and above		
Over	Up to and including	Minimum mass of coating	Number of dips		Minimum mass of coating	Number of dips	
			Minute	Half minute		Minute	Half minute
mm	mm	g/m^2			g/m^2		
0.23	0.33	45	no test		45	no test	
0.33	0.40	60	no test		60	no test	
0.40	0.46	75	—	1	75	—	1
0.46	0.53	90	1	—	90	1	—
0.53	0.63	105	1	—	105	1	—
0.63	0.75	120	1	—	120	1	—
0.75	0.85	135	1	1	135	1	1
0.85	0.95	150	1	1	140	1	1
0.95	1.06	170	2	—	150	1	1
1.06	1.18	185	2	—	160	2	—
1.18	1.32	200	2	—	170	2	—
1.32	1.55	215	2	—	180	2	—
1.55	1.8	230	2	1	200	2	—
1.8	2.24	240	3	—	215	2	—
2.24	2.72	260	3	—	230	2	1
2.72	3.15	275	3	1	240	3	—
3.15	3.55	275	3	1	250	3	—
3.55	4.25	290	3	1	260	3	—
4.25	5.0	290	3	1	275	3	1
5.0	8.0	290	3	1	290	3	1
8.0	10.0	305	4	—	305	4	—

Appendix A
Conversion factors

From	To	Multiply by
oz/ft^2	g/m^2	305.152

Mass of coat	Average radial thickness of coat
1 oz/ft^2	42.926 µm (micrometres)
1 g/m^2	0.1407 µm (micrometres)

Standards publication referred to

BS 3436, *Ingot zinc*.

BSI — British Standards Institution

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