BRITISH STANDARD

BS 729:1971

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Specification for

Hot dip galvanized coatings on iron and steel articles

UDC 669.586.5

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:

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Assay Offices Committee of Great Britain
Association of Metal Sprayers
British Bolt, Nut, Screw and Rivet Federation
British Electrical and Allied Manufacturers' Association
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Department of the Environment
Electric Cable Makers' Confederation
Galvanizers' Association
Institution of Corrosion Technology
Institute of Engineering Inspection
Institute of Iron and Steel Wire Manufacturers
Post Office
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Contents

Foreword

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.

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This standard makes reference to the following British Standards:

BS 4360, *Weldable structural steels.*

BS 4479, *Recommendations for the design of metal articles that are to be coated.*

BS 4652, *Metallic zinc-rich priming paint.*

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 7 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.

Foreword

BS 729:1961, was entitled "Zinc coatings on iron and steel articles", and it was divided into two parts, namely Part 1, "Hot-dip galvanized coatings" and Part 2 "Sherardized coatings". This edition, which is a revision of BS 729-1, applies solely to galvanized coatings and in consequence its title has been changed to "Hot dip galvanized coatings on iron and steel articles". Sherardized coatings will still be covered by BS 729-2, for the time being, but this standard is currently undergoing revision and will be re-issued with a new number and the new title of "Sherardized coatings on iron and steel articles".

This revision takes cognizance of the provisions of the three recommendations of the International Organization for Standardization (ISO) which relate to hot dip galvanized coatings, namely ISO Recommendation R1459[1)] ISO Recommendation R1460[2)] and ISO Recommendation R1461[3)] A minimum coating weight requirement for any individual test area has been introduced, but the specified values are greater than those recommended in ISO Recommendation R1461[3)].

Introduction

(1) *Basis metal.* Mild and low alloy steel and cast iron are particularly suitable for hot dip galvanizing. The purchaser should provide the galvanizer with as much information as possible about the nature of the material to be processed. In case of doubt, it is advisable to submit samples for testing.

The surface should be free from contamination which will not be removed by pickling, e.g. paint, oil, grease, welding slag, etc. Water soluble paints may be used for identification during fabrication; permanent identification marks should be deeply punched or embossed.

Surface unevenness such as laps, seams and rolled-in impurities will affect the galvanizing process and give a visible effect on the surface of the coating. A rough surface will increase the coating weight.

The effect of surface roughness on coating weight can be turned to advantage if, as described in Clause **8**, it is desired to produce heavier coating weights in particular defined cases. A similar effect can be produced by the use of fully-killed silicon steels.

(2) *Design.* Attention should be paid to the requirements of the galvanizer at the design stage. Provision for filling, venting and draining is essential for fabricated tubular assemblies and closed vessels to avoid the danger of an explosion during galvanizing and to ensure a good finish. Guidance on design is given in BS 4479[4)]

(3) *Coating appearance.* The specification calls for the coating to be continuous, smooth and free from flux stains. "Smoothness" is a relative term and the smoothness of the coating on articles galvanized after fabrication should not be judged for smoothness in comparison with mechanically wiped products such as galvanized sheet and wire.

In some cases, particularly with steels with a significant silicon content, the galvanized coating may have the dark grey appearance of the zinc-iron alloys showing at the surface. Provided that such a coating has adequate adhesion (Clause **7**) the dark grey finish is not detrimental to corrosion resistance.

The standard requires the coating to be inspected and tested for compliance prior to shipment from the galvanizer's works. Care should be taken to avoid defects arising from poor transport and storage conditions. Some guidance on the avoidance and treatment of such defects is given in Appendix C.

(4) *Coating weight determination.* The coating weight is determined by one of of the three methods specified in Clause **10**. The stripping test, as described in Appendix A, gives the true value for the weight of coating, since the zinc-iron alloy layers, which have a corrosion resistance similar to the zinc, are removed in the hydrochloric acid. The simple weighing test specified in Clause **10** will give a slightly lower value. The magnetic and electronic thickness measuring devices measure the thickness non-destructively and can give useful guidance. In cases of dispute, the stripping test should be the referee test.

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1) ISO/R 1459, "Guiding principles for protection against corrosion by hot dip galvanizing".

2) ISO/R 1460, "Determination of the weight per unit area of hot dip galvanized coatings on ferrous materials by chemical dissolution of the coating — gravimetric method".

3) ISO/R 1461, "Requirements for hot dip galvanized coatings on fabricated ferrous products".

4) BS 4479, "Recommendations for the design of metal articles that are to be coated".

(5) *Uniformity of coating.* The copper sulphate (Preece) test for uniformity of the coating (see Appendix B) has been retained as an optional test since, although it is often abused, it does have some merit as a test of quality on certain classes of small articles where it is difficult to calculate surface area. It should be emphasized that the test is concerned only with the coating uniformity and should not be used as a measure of coating thickness.

(6) *Distortion and embrittlement.* Distortion may arise on some articles due to the relief of fabricating or welding stresses during galvanizing. When it occurs it is generally due to factors which are outside the control of the galvanizer but can often be eliminated or minimized by consultation at the design stage.

In very rare cases a galvanized article can be brittle after galvanizing and this, again, is due to factors outside the control of the galvanizer. Some comments on this phenomenon are given in Appendix E.

(7) *Renovation of damaged areas.* Some recommendations for the renovation of small areas damaged by welding, cutting or excessively rough treatment during transit and erection are given in Appendix D. Such treatments should be used only to renovate areas which have been adequately coated; they should not be used to remedy defects due to faulty processing. The sacrificial nature of the protection given by a galvanized coating will prevent damage from spreading underneath the sound coating.

(8) *Threaded work.* Oversize tapping or re-tapping of nuts or female threads is required when the bolt or male thread is hot dip galvanized. Although this procedure results in an uncoated female thread, this will be protected by the coating on the male thread when the fastener is assembled.

1 Scope

This British Standard specifies requirements for hot dip galvanized coatings on steel articles galvanized after fabrication and on grey and malleable iron castings. The standard does not apply to semi-finished products such as galvanized wire, tube or sheet which are suitable for subsequent fabrication.

Where particular galvanized articles are covered by other standards, reference should be made to these standards for any special qualification, which should take preference over BS 729.

2 Definition

For the purposes of this British Standard, the following definition applies:

hot dip galvanized coating

a coating of zinc, and zinc-iron alloy layers, obtained by dipping prepared iron or steel articles in molten zinc. Under some circumstances the whole coating may consist of zinc-iron alloy layers

3 Information to be supplied by the purchaser to the galvanizer

The following information, when appropriate, shall be supplied by the purchaser to the galvanizer:

1) the number of this British Standard, i.e. BS 729;

2) the nature of the material to be galvanized;

3) the method of sampling to be adopted;

4) if a post-treatment is required, the type of treatment, e.g. chromating or phosphating;

5) any special requirements, e.g. heavier coating weight (see Clause **8**).

4 Basis metal

Where it is necessary to drill holes for filling, venting or draining, this shall be done by the purchaser in consultation with the galvanizer unless the purchaser gives written consent for the galvanizer to carry out the work.

The galvanizer shall not be responsible for changes in the mechanical properties of the basis metal as a result of hot dip galvanizing, except where these changes can be shown to be due to faulty processing.

5 Galvanizing bath

The molten metal in the galvanizing bath shall contain not less than 98·5 % by weight of zinc.

6 Appearance of the coating

The coating shall be smooth, continuous and free from flux stains.

7 Adhesion of the coating

The coating shall be sufficiently adherent to withstand normal handling conditions without peeling or flaking. Any tests for adhesion shall be agreed between the purchaser and the galvanizer.

8 Coating weight

The coating weight shall comply with the minimum values quoted in Table 1. Higher or lower weights can be agreed between the purchaser and the galvanizer in particular defined cases. For example, heavier coatings may be obtained by grit-blasting before galvanizing or by using fully-killed silicon steels. In some instances it may be necessary to grit-blast before galvanizing in order to achieve the coating weights specified in Table 1.

Table 1 — Coating Weight[a]

Category		Minimum average coating weight for any individual test area[b]
		g/m^2
Steel articles which are not centrifuged[c]	5 mm thick and over	610
	Under 5 mm but not less than 2 mm	460
	Under 2 mm but not less than 1 mm	335
Grey and malleable iron castings		610
Threaded work and other articles which are centrifuged[d]		305

[a] The coating weight per unit area of the surface is given in terms of g/m^2 of surface. If the coating thickness is required, the following conversion factor should be used, which assumes the density of the coating to be 7 g/cm^3:
1 g/m^2 = 0·14 µm (305 g/m^2 = 1 oz/ft^2 = 43 µm = 0·0017 in).

[b] For small articles the test area shall consist of the whole surface or agreed parts thereof. For large articles, e.g. structural steel sections, the minimum coating weight referred to in Table 1 shall be the average of determinations over a test area of 600 to 1 200 mm^2.

[c] Where the threads of bolts unsuitable for centrifuging are brushed after galvanizing, the coating weights on the brushed areas shall be exempt from the requirements of Table 1.

[d] Bolts are galvanized after screwing unless otherwise specified. Bolts which are to be fitted with nuts are screwed to the tolerance laid down in the appropriate specification without allowance being made for galvanizing. The nuts are tapped up to 0·4 mm oversize after galvanizing and the threads are oiled.

9 Sampling

The method of sampling shall be agreed between the purchaser and the galvanizer.

10 Determination of coating weight

The weight of coating shall be determined by one or more of the following methods.

1) The stripping test as described in Appendix A.

2) By weighing the articles before and after galvanizing and dividing the difference by the surface area. The weight before galvanizing shall be determined after pickling and drying, the weight after galvanizing when the article has cooled to ambient temperature.

3) By means of magnetic or electronic measuring devices.

In cases of dispute the stripping test, where practicable, shall be the referee test.

11 Uniformity of coating

Where agreed between the purchaser and the galvanizer, the copper sulphate (Preece) test (described in Appendix B) for uniformity of coating shall be applied to suitable articles. The coating shall withstand four one-minute dips in the standard copper sulphate solution without the formation of an adherent red spot of metallic copper upon the basis metal. The following areas are exempt from the requirements of this clause:

less than 25 mm from any cut edge,

less than 13 mm from threads of over 10 mm diameter cut or brushed after galvanizing,

less than 6 mm from such threads up to 10 mm diameter.

12 Post-treatments

Most galvanized products do not require any post-treatment. Where required by the purchaser, treatments such as chromating or phosphating may be applied to reduce the risk of wet storage staining or to assist subsequent painting.

13 Distortion and cracking of materials

The galvanizer shall not be responsible for distortion resulting from the effect of heating during galvanizing or for the cracking of basis materials caused by thermal expansion and contraction during the process, except where such defects are due to faulty processing.

14 Testing

Unless agreed in writing between the purchaser and the galvanizer, inspection and testing for compliance with this standard shall take place at the galvanizer's works prior to despatch.

If any test area fails to comply with the standard, two further areas shall be tested. If either of these fails to meet the requirement, the consignment shall be deemed not to comly with the standard. In this case the consignment may be re-galvanized and again submitted for testing and inspection.

Appendix A Stripping test for weight of coating

A.1 Stripping solution. 3·2 g of antimony trichloride ($SbCl_3$) or 2 g of antimony trioxide (Sb_2O_3) are dissolved in 500 ml of concentrated hydrochloric acid (d = 1·14). The solution is then diluted to 1 litre with distilled water.

A.2 Preparation of samples. The samples are degreased with a suitable organic solvent, e.g. trichlorethylene, and wiped dry with a clean soft cloth.

A.3 Procedure. Each sample shall be weighed to an accuracy of better than 1 % of the presumed coating weight. The sample shall be completely immersed in the stripping solution at room temperature until the coating has completely dissolved, i.e. until the vigorous chemical action has ceased. The sample shall then be rinsed in running water and, if necessary, brushed to remove any loose substances, dipped in alcohol, dried and re-weighed. The surface area of the sample is then determined.

A.4 Interpretation. The weight of zinc coating per unit surface area is obtained by dividing the difference in weight by the surface area.

Appendix B Copper sulphate (preece) dip test for uniformity of coating

B.1 Reagent. The reagent used is copper sulphate solution, made by dissolving approximately 36 g of crystalline copper sulphate ($CuSO_4.5H_2O$) in each 100 ml of distilled water. The water may be heated to facilitate solution of the crystals, but if it is heated the solution must be allowed to cool before neutralizing.

For neutralization, the solution shall be shaken with an excess of copper carbonate or copper hydroxide (about 1 g/l of solution), allowed to stand (preferably for at least 24 h), and shall then be filtered or decanted from the sediment.

The relative density of the test solution shall be 1·18 at 18 °C. Adjustment may be made by adding distilled water or solution of higher relative density, as appropriate.

The volume of the solution in millilitres shall be numerically at least eight times the approximate surface area in square centimetres of the immersed portion of the articles being tested. The solution shall be discarded when these have been tested.

B.2 Apparatus. The container used for the test shall be made of a material inert to copper sulphate solution. Its internal dimensions shall be such as to allow a clearance of at least 25 mm between the container and any article immersed in the solution.

B.3 Preparation of samples. Before testing, the samples shall be degreased with a suitable solvent and/or synthetic detergent, wiped dry with a clean, soft cloth, dipped in a 2 % solution of sulphuric acid (prepared by diluting 2 ml sulphuric acid (d = 1·84) with 98 ml distilled water) for 15 s, and then thoroughly rinsed in clean running water. Finally, they shall be wiped dry with a clean soft cloth.

B.4 Temperature. At the commencement and during the progress of the test, the temperature of the samples and of the solution shall not vary outside the limits of 18 ± 2 °C.

B.5 Procedure. The samples shall be subjected to four successive dips in the solution, each lasting 1 minute.

If possible they shall be completely immersed, but they shall not touch each other. While they are immersed, neither they nor the solution shall be agitated.

After each dip the samples shall be withdrawn, rinsed immediately in clean running water, and any black deposit removed with a fibre brush, care being taken to clean out all holes and pockets. The samples shall then be wiped dry with a clean, soft cloth and, except after the final dip, returned immediately to the solution.

B.6 Supplementary false end point test. If, after the procedure described above, a red deposit of metallic copper appears on the sample, such a deposit may be tested for adherence either by peeling, light rubbing or by immersion in a 10 % solution of hydrochloric acid (prepared by diluting 10 ml hydrochloric acid (d = 1·14) with 90 ml of distilled water) for 15 s, followed by immediate rinsing in clean running water with vigorous scrubbing. If the copper has been removed and zinc appears underneath, the sample does not fail the test.

Appendix C Transport and storage of galvanized articles

The purchaser should pay particular attention to the conditions of transport, shipment and storage to avoid the possibility of wet storage staining. This condition, sometimes known as "white rust", can occur on freshly galvanized articles which are transported or stored under damp, badly ventilated conditions.

The susceptibility to wet storage staining can be reduced by applying a post-treatment (see Clause **12**). Galvanized articles should never be stored on clinkers or ashes.

A galvanized coating has excellent resistance to rough treatment. Nevertheless, some damage may occur in the course of transit and erection; small areas damaged in this way may be renovated by the procedures described in Appendix D.

Appendix D Renovation of damaged areas

Small areas of galvanized coating damaged by welding, cutting or by excessively rough treatment during transit and erection may be renovated either by the use of low melting point zinc alloy repair rods or powders made specifically for this purpose, or by the use of at least two coats of good quality zinc-rich paint[5]. Sufficient material should be applied to provide a zinc coating at least equal in thickness to the galvanized layer.

The maximum size of the areas for which such repairs are acceptable will depend, to some extent, on the article and the application but for general guidance an area of 40 mm^2 is suggested as being suitable. For large structures it may well be acceptable to renovate larger areas.

Appendix E Embrittlement

E.1 Embrittlement of steel. For steel to be in an embrittled condition after galvanizing is rare, and its occurrence depends on a combination of factors. Under certain conditions, some steels can lose their ductile properties and become embrittled. There are several different types of embrittlement which can occur and one only, strain age-hardening, can be aggravated by the hot dip galvanizing process. The following information is given as guidance in critical applications.

E.1.1 Factors which may cause embrittlement of galvanized steel. The following factors may contribute to the embrittlement of galvanized steel.

E.1.1.1 *A steel which is susceptible to strain age-hardening.* Strain age-hardening is principally caused by the nitrogen content of the steel which in turn is largely dependent on the steel-making process. As a general guide the open hearth, electric or oxygen processes are preferable to the Bessemer process in this respect and the aluminium-killed steels are the least susceptible to strain age-hardening. BS 4360[6] permits the customer to specify the steel-making process and proscribes the use of air, and mixed air-oxygen, bottom-blown basic converter processes.

E.1.1.2 *A severe degree of cold working.* The degree of strain introduced into a fabrication will depend on the cold forming operations carried out and on the thickness of the steel. Cold working operations carried out before galvanizing which may give rise to embrittlement of susceptible steels include the punching of holes, severe bending and shearing. No steels are likely to be severely affected in thicknesses less than 3 mm.

E.1.1.3 *The galvanizing process.* The hot dip galvanizing process involves immersion in a bath of molten zinc for up to 5 minutes at a temperature of about 450 °C and this heat treatment can accelerate the onset of strain-age embrittlement in susceptible steels which have been severely cold worked. No other aspect of the galvanizing process is significant.

E.1.2 Recommendations for avoiding the risk of embrittlement. The following recommendations should be followed to avoid risk of embrittlement.

1) Use a steel which is not susceptible to strain age-hardening whenever possible

2) If a susceptible steel must be used, avoid severe cold work, e.g. punched holes or bending over a radius less than three times the thickness of the material. Punched holes are generally satisfactory in steels other than Bessemer steels up to a thickness of 18 mm. Holes in susceptible steels over 6 mm should be reamed after punching or be drilled. If severe working is unavoidable it is better, from a galvanizing point of view, if the fabrication is hot worked.

3) If severe cold work on a susceptible steel cannot be avoided, stress relieve at a minimum of 600 °C before galvanizing.

[5] BS 4652, "Metallic zinc-rich priming paint".

[6] BS 4360, "Weldable structural steels".

E.2 Embrittlement of malleable and spheroidal graphite iron. When malleable or nodular cast irons are galvanized, embrittlement may occur and this is related to the chemical composition of the material. A low phosphorus content will avoid embrittlement: alternatively, the casting can be heated to 650 °C and quenched in water before galvanizing.

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London
W4 4AL