

**RECOMMENDATIONS FOR
THE DESIGN OF METAL
ARTICLES THAT ARE
TO BE COATED**

BS 4479 : 1969

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BRITISH STANDARDS INSTITUTION

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BRITISH STANDARDS INSTITUTION

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THESE RECOMMENDATIONS, having been approved by the Surface Coatings (other than Paints) Industry Standards Committee, were published under the authority of the Executive Board on 14 August, 1969.

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The Institution desires to call attention to the fact that these recommendations do 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 9,000, fully indexed and with a note of the contents of each, will be found in the BSI Catalogue which may be purchased from BSI Sales Department. The Catalogue may be consulted in many public libraries and similar institutions.

These recommendations make reference to the following British Standards:

- BS 729. Zinc coatings on iron and steel articles.
Part 1. Hot-dip galvanized coatings.
- BS 1615. Anodic oxidation coatings on aluminium.
- BS 2451. Chilled iron shot and grit.
- BS 2569. Sprayed metal coatings.
- BS 3189. Phosphate treatment of iron and steel for protection against corrosion.
- BS 3382. Electroplated coatings on threaded components.
- CP 2008. Protection of iron and steel structures from corrosion.

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 these recommendations:

Committee reference SRE/10

Draft for comment 67/13974

CONTENTS

Co-operating organizations	4
Foreword	5

RECOMMENDATIONS

1. GENERAL

1.1 Scope	6
1.2 General considerations	6

2. ELECTROPLATED COATINGS

2.1 Process	8
2.2 Design considerations	10

3. ANODIC OXIDATION COATINGS

3.1 Process	18
3.2 Design considerations	20

4. CONVERSION COATINGS

4.1 Process	27
4.2 Design considerations	28

5. HOT-DIPPED COATINGS

5.1 Process	33
5.2 Design considerations	34

6. SPRAYED METAL COATINGS

6.1 Process	41
6.2 Design considerations	43

APPENDIX

A. BSI publications relating to processes covered by these recommendations	49
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BS 4479 : 1969

CO-OPERATING ORGANIZATIONS

The Surface Coatings (other than Paints) Industry Standards Committee, under whose supervision these recommendations were 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 Cycle and Motor Cycle Industries Association Limited
- *British Electrical and Allied Manufacturers' Association
- British Jewellers' Association
- British Non-ferrous Metals Research Association
- *British Steel Industry
- Chemical Industries Association
- Electricity Council, the 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 these recommendations:

Welding Institute

RECOMMENDATIONS FOR THE DESIGN OF METAL ARTICLES THAT ARE TO BE COATED

FOREWORD

Time and money are often wasted because the design of articles is unsuitable for the coating process required. Design that takes into account not only the function of the article and its method of manufacture but also the requirements of the finishing process results in a more serviceable and usually a less costly product. The purpose of these recommendations is to give those responsible for designing articles to be finished with a protective coating, guidance on particular design features which will assist in the achievement of these results. Examples are also given of design features that should be avoided although, provided time and cost are no object, almost any article can be satisfactorily coated.

Brief descriptions of the important features of the various coating processes referred to in these recommendations have been given since details of design must frequently be considered in relation to the particular coating process to be employed. It is clearly impossible to cover every conceivable design detail and every type of article and service condition. Adherence to the general principles described will, however, greatly assist in the achievement of the desired results. In any case of doubt or difficulty a specialist in the particular process being considered should be consulted.

Only five of the many coating processes are included in these recommendations but it is likely that others will be added in future revisions.

BS 4479 : 1969

RECOMMENDATIONS

1. GENERAL

1.1 SCOPE

These recommendations apply to the design of metal articles that are to be coated, for protective and decorative purposes, by one or other of the following processes:

- (1) Electroplating.
- (2) Anodic oxidation.
- (3) Chemical conversion.
- (4) Hot dipping.
- (5) Metal spraying.

They do not cover the use of the above processes to provide coatings for engineering applications, such as heavy deposition, hard anodizing or building-up by metal spraying.

It is emphasized that this publication is not a 'specification' and it should not be used as such; the recommendations contained herein are not mandatory but are intended to give guidance towards good practice.

1.2 GENERAL CONSIDERATIONS

There is a great need to take process requirements into consideration at the drawing-board stage and to regard finishing as an essential part of the production process instead of as something to be added as an incidental necessity after production. A design that considers essential features of the finishing process can greatly reduce the time and trouble and hence the cost of producing a good finish. Finishing processes often have a higher labour content than has work at other stages of production; consequently, savings in material and fabrication costs may well be dissipated by an increase in the cost of finishing.

By early consideration of the coating process requirements and reference to the appropriate department or to the outside company undertaking the finishing, designers should be able to ensure that their products can be attractively finished with serviceable coatings without any sacrifice of their main objectives. The need for consultation and co-operation with those expert in the particular coating process is strongly emphasized. It should be appreciated that even when a finish is applied for 'decoration' it should also be 'protective'.

Recommendations concerning each type of coating process are dealt with separately but there are certain features that are relevant to all processes, although their importance can vary according to the particular process. These are:

- (1) Good quality basis metal and sound construction of the article should be used; the coating should not be relied upon to cover up flaws.

(2) Sharp edges and corners, deep recesses and blind holes should be avoided.

(3) Dissimilar metals requiring different methods of treatment should be avoided as parts of an article to be finished after assembly.

(4) Creviced components or assemblies should be avoided wherever possible in order to minimize the seepage of plating or pre-treatment solutions from rolled, riveted, spot welded or similar joints such as the mating faces of bolted or screwed assemblies, which can cause subsequent corrosion problems in storage or service.

(5) An inherent cleanness of design should be adopted so that a uniform coating is obtained and corrosive agents do not readily accumulate.

BS 4479 : 1969

2. ELECTROPLATED COATINGS

2.1 PROCESS

The work to be plated is immersed in a solution consisting mainly of a chemical compound of the metal to be deposited. Low-voltage direct current is passed through the solution between the work, which acts as the cathode, and an anode which is either an insoluble metal or more usually the metal to be deposited (see Fig. 1). Metal is deposited from the solution onto the work.

To obtain proper adhesion between the deposit and the basis metal, the work has to be free from dirt, grease, oxide films or any other contaminating material. The work is usually put through a sequence of cleaning operations, but their nature and order vary according to the basis metal and its condition. The article is thoroughly rinsed and drained as it passes from one operation to another.

Articles to be plated are ordinarily suspended on wires or jigs in tanks (vat-plating). If, however, they are too small for individual treatment, they may be rotated in barrels. (See 2.2.1(2) and 2.2.6 for special requirements.)

Basis metals vary considerably in the readiness with which they can be plated, in their suitability for certain types of plating, and in the thickness of coating necessary to provide adequate protection. Aluminium requires special methods of preparation for plating. Soft solder exposed at joints is difficult to plate satisfactorily.

Good quality electroplate is most readily and cheaply produced on basis metals that are free from surface defects since such faults can rarely be concealed. The saving by using poor quality material can be more than dissipated by resulting increases in finishing costs.

An electrodeposited coating is generally not distributed uniformly over the surface of an article but is likely to be thicker at prominences and corners where the current tends to concentrate, and thinner in depressions. (See Fig. 2.) The deposit is also likely to be thinner at points of electrical contact between the support and the article. When plated parts have to be fitted together, due allowance should be made for the thickness and distribution of the coating, e.g. on screw threads*.

As deposited from simple solutions of the type mentioned, metals are dull. Should a bright finish be required there are two methods by which it may be obtained. If a simple solution is being used, both the basis metal and the plated metal have to be polished. Alternatively certain additives to the solution can make the coating bright as deposited but, while the overall cost is reduced, the need for polishing the basis metal is not always eliminated. Some additives help to smooth the coating by filling-in scratch marks in the basis metal, but there has to be a certain minimum thickness of the plated coating before this 'levelling'

* See BS 3382, 'Electroplated coatings on threaded components'.

action is effective. The brittle nature of some bright deposits should be borne in mind when application is considered for articles that might undergo some flexing action in service.

Polishing being a common operation in the plating process, it should be noted that articles are polished either by being pressed against a rapidly rotating wheel loaded with an abrasive powder or a polishing composition or, if the articles are too small to be handled individually, by tumbling in a barrel with a polishing medium. Polishing wheels are commonly 150–300 mm in diameter and 25–50 mm wide. Barrel polishing is cheaper and is acceptable for many purposes, although it does not produce as good a finish as does wheel polishing.

Automatic or semi-automatic equipment can be used to reduce cost if:

- (1) the shape and size of the article are suitable;
- (2) many similar parts are being polished.

Even so, for the best results, final polishing may have to be done by hand.

Sheet and strip metal can be polished before being formed. The advantages are:

- a. no awkward recesses need to be polished;
- b. surfaces can be polished more uniformly;
- c. simple cost-reducing automatic polishing machines can be used.

A bright finish of a somewhat different type can be obtained on the surface of a limited range of metals and alloys (notably on aluminium, brass and stainless steel) by chemical or by electrochemical means. These processes of chemical brightening and electrobrightening do not in general produce a surface of the same texture and appearance as that given by mechanical polishing. High quality, including fineness and uniformity of grain, in the basis metal is important for the best results, especially on large unbroken surfaces. When producing a bright finish electrochemically, in which the article is made the anode, current densities are usually greater than those for electroplating and good provision for suspension and electrical contact is essential. Sometimes a limited amount of mechanical polishing is required before chemical brightening and electrobrightening. Chemical processes may remove 25–75 μm of the basis metal. The processes have considerable and increasing applications, including the finishing of intricately shaped parts and the production of contrasts and novelty effects. They add therefore to the range of finishes available to the designer but, in view of their special features, they should not ordinarily be specified without reference to someone experienced in their use. Design considerations are similar to those for electroplating and will not be discussed separately.

Whilst bright finishes and especially those produced by mechanical polishing are always likely to be in demand because of their intrinsic attraction, there are a number of alternatives. So-called 'satin' finishes can be obtained either by mechanical treatments such as 'abrasive blasting' applied to the basis metal

or by certain plating processes in which the bath contains additives for this purpose.

The effect of certain plating processes on the mechanical properties of some basis metals and hence on the serviceability of the coated article should be noted. High strength steels (normally above 100 hbar*) are particularly susceptible to embrittlement by the hydrogen evolved during plating or the pre-treatment processes. Such embrittlement can be relieved by suitable heat treatment and in this respect particular references to the appropriate clauses of the related plating specification should be made. Again, the fatigue strength of basis metals in general is reduced by certain plating processes, especially chromium. In all cases where these considerations arise, expert advice should be sought if there is any doubt as to their importance.

2.2 DESIGN CONSIDERATIONS

In order that the reasons for making the following recommendations may be appreciated, they have been listed under the relevant features of the process.

2.2.1 Articles are vat-plated or barrel-plated

(1) Consider whether vat-plating or barrel-plating is likely to be the more suitable, in view of the size and shape of the articles. Design accordingly, taking into account the appropriate parts of the following text.

(2) When plated in barrels, articles are not as readily coated to the same degree of thickness as would be achieved by vat-plating. If, therefore, particular thicknesses are essential to meet the conditions of use of the articles, attention should be drawn to this requirement.

2.2.2 The work is suspended in a solution

(1) Consider which way up the article will be held in the plating solution and either design so that liquid will not be trapped in or around hollows, seams, rivets, spot welds, rolled edges, etc., or provide drain holes where pockets of solution would otherwise be retained. (See Figs. 3 and 4.)

(2) Avoid shapes that could entrap air and prevent contact between surfaces to be plated and the cleaning and plating solutions; if necessary, provide air holes of a size that will permit sinkage of the article within a reasonable time.

(3) Any insoluble particles in the solution may settle on the uppermost surfaces of the article, so causing roughness and possibly lower corrosion resistance on those surfaces. The designer should consider whether this is important and if so arrange either for non-significant surfaces, or for areas of the significant surface that will be less prominently in view during use of the article, to be uppermost when the article is suspended in the plating solution.

* 1 hbar = 10^7 N/m² $\approx$ 0.65 tonf/in².

(4) The cost of plating a given area on an article will be greater if the space occupied by the article in the vat is large. It is sometimes more economical to make the article in sections and assemble them after plating.

2.2.3 Plating is an electrolytic process

(1) Electrical contact will normally be made through the wires or jigs on which the articles are suspended in the solution. Since, at the point of contact, little plating will occur, some holding point or points have to be available in a position that will not show in the final assembly, that will enable the article to be held in the correct position relative to the anode and that will comply with requirements under 2.2.2.

(2) Holding points that permit a firm contact are to be preferred to those which do no more than allow the article to hang loosely under its own weight. Holding points should be of a size that is adequate to achieve good electrical contact and to carry the current required by the particular plating process used.

(3) Protuberances, sharp corners, edges, fins and ribs will draw current preferentially and should be rounded with a radius of at least 1 mm to avoid build-up of metal on them. (See Figs. 5-9.) Edges of holes can with advantage often be countersunk and studs chamfered.

On the other hand, the base of any cavity or depression is likely to be starved of plate. Recesses of all kinds and their edges should, therefore, be smoothed out as far as possible. The minimum radius at the edge and base of an indentation should be one quarter of the depth of indentation. (See Fig. 10.)

(4) Because of the geometry of screw threads there is a tendency for the deposit distribution to be non-uniform and on internal threads the thickness will be less towards the middle due to the screening effect. Such effects should be borne in mind when considering fit-up of threaded parts.

Small threaded parts are usually barrel-plated and they will not all be plated to the same thickness. It is usual to specify the minimum batch average thickness that will ensure adequate protection and the maximum batch average thickness which limits the interference between mating threaded components.

For further guidance on the electroplating of screw threads, see BS 3382*.

(5) Concave surfaces can usually be plated fairly uniformly if the radius is at least 12.5 mm. (See Fig. 11.)

(6) Circular or elliptical holes are more easily plated than straight-edged holes. The space between adjacent holes should preferably be at least twice the diameter of the hole. Similarly, sharp edges and corners should be eliminated from slots. (See Fig. 12.) Blind holes are better avoided, but if essential to the design they should have a depth not exceeding one third of their diameter. (See Fig. 13.)

* BS 3382, 'Electroplated coatings on threaded components'.

NOTE. If points (3), (4), (5) and (6) under 2.2.3 are not taken into account, the plater may have to use special methods to ensure sufficiently uniform plating of the work or at the least will have to build up an unnecessarily thick coating at prominent areas in order to obtain the minimum required in recesses. In either case, the cost of plating will be increased.

2.2.4 Methods of cleaning and of plating are different for different metals

(1) Since methods of preparing different metals for plating may differ even for the same plating operation, it is preferable to design articles for assembly after plating rather than before plating. If, however, there are special advantages in assembling an article made of different metals before it is plated, then it is advisable to make certain that the mixed assembly can be effectively prepared for plating and that any additional cost in dealing with the assembly does not offset the advantages obtained by prior assembly. The choice of pre-assembly plating or plating the complete article can usually only be decided by experience.

(2) Welded and especially soft-soldered joints may become conspicuous after plating and should preferably be positioned where they will not show in the assembled article. If this is unavoidable, it is desirable to specify that the area of exposed soft solder shall be kept to a minimum.

(3) Zinc alloy die castings and articles made of aluminium or its alloys are attacked by the usual nickel plating solutions. Zinc and to a lesser extent aluminium dissolved in the plating solution will ultimately prevent good plating. Articles made of zinc or aluminium are commonly protected from the action of the nickel solution by being first plated with copper. The article should be designed so that all parts of its surface can be covered with copper, not just the area to be plated with nickel.

2.2.5 Bright finishes call for polishing and/or special solutions

(1) If a bright finish is required, consider how far polishing of the basis metal will be necessary and whether by designing the article as a zinc alloy die casting or of brass or of high quality sheet steel as the case may be (all of which will require less polishing than will steel of ordinary quality) polishing of the basis metal can be reduced or eliminated (with a resulting reduction in cost), especially if a plating process with good levelling power is available for the purpose.

(2) If polishing cannot be entirely eliminated, design the article so that all areas to be polished are readily accessible to wheels of normal diameter, avoid large smooth flat areas needing uniform reflectivity (this is costly to achieve and difficult to protect from scratching during later handling, so preferably break with a design motif), avoid design with intricate pattern or ornamentation close to entirely plain surfaces, and (as for plating) avoid sharp edges and corners, abrupt changes in contour, prominent protuberances and ornamentation in sharp relief.

Polishing is most economically performed using automatic or semi-automatic equipment for which it is particularly necessary to avoid intricate patterns and abrupt changes in contour as outlined above.

(3) When polishing is required, give also some thought to the way in which the work will be held by the polishing machine or the operator. Consider any small modification in design that will make possible the use of a holding jig for ease and speed of polishing when many similar articles are to be polished by automatic or semi-automatic equipment.

(4) When the article can be made of sheet metal, consider whether pre-polished stock can be used to simplify polishing and reduce costs.

2.2.6 In barrel processing there are special additional considerations

(1) In order that they may be polished and/or plated in barrels, components have to be strong enough to withstand the vigorous tumbling action to which they will be subjected, especially during barrel polishing in which polishing media are incorporated with the load of work. The barrelling conditions can be modified to a certain degree to accommodate for delicate articles but the basic recommendations remain.

(2) Articles that would interlock are not suitable for finishing in a barrel, since one part would shield another from the action of the polishing media or from being plated.

(3) Small flat articles may stick together during a barrelling process. Consider introducing a dimple or raised edge to prevent this.

2.2.7 Required thickness of coating depends on basis metal and service conditions

(1) Where there is a British Standard for the type of plating required, it should be specified. In many cases it is not sufficient to quote simply the number of the British Standard: the classification number, corresponding to the type of basis metal and conditions of use, should be given whenever the standard covers different classes of coating.

(2) The areas to which the specification is to apply with respect to both finish and thickness should be clearly indicated on the drawing supplied to the plater.

(3) Consider whether any corrosion on a non-significant surface could ultimately cause disfigurement of the significant surface, and if so ensure that there is adequate protection.

BS 4479 : 1969

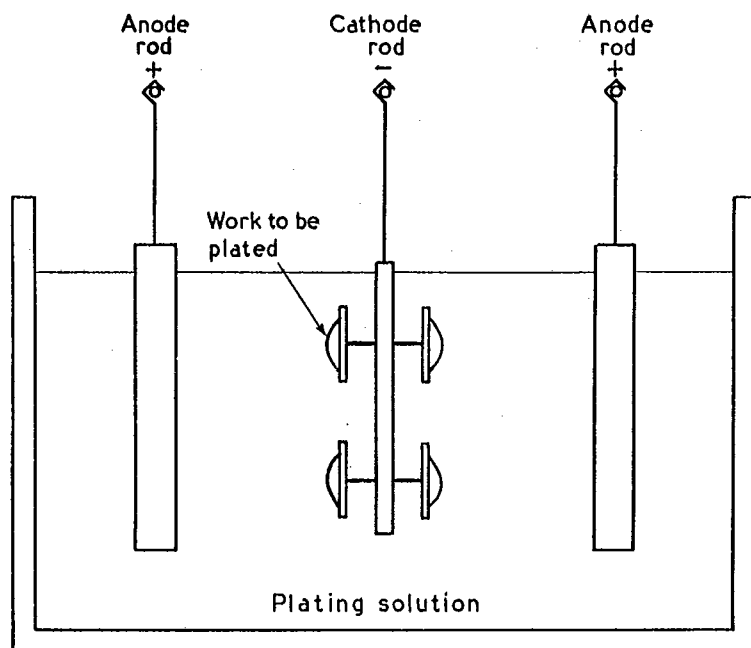


Fig. 1. Diagram of plating bath

**Figs. 1-13, Diagrams relating to
Section 2, Electroplated coatings**

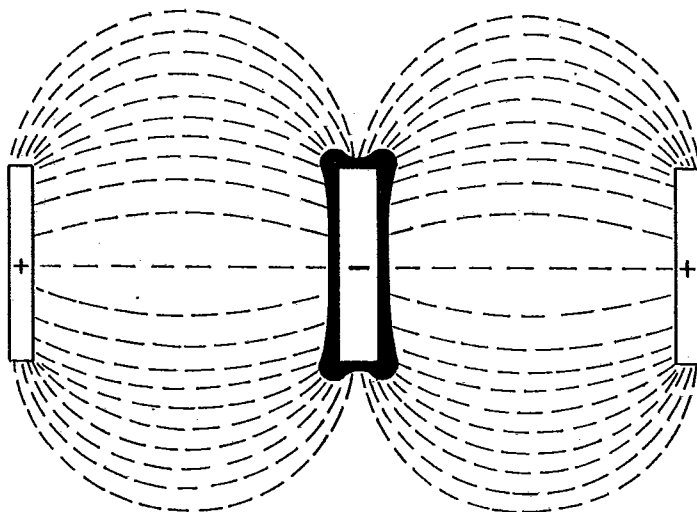


Fig. 2. Plan view showing distribution of current and electrodeposit on a cathode of rectangular cross-section

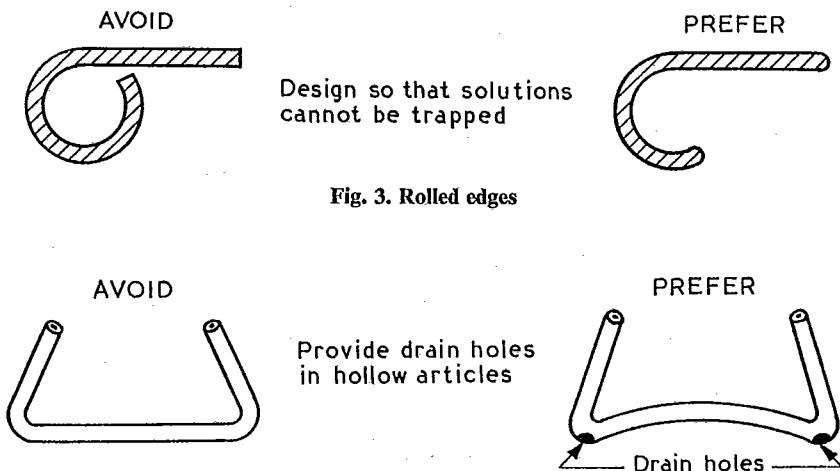


Fig. 3. Rolled edges

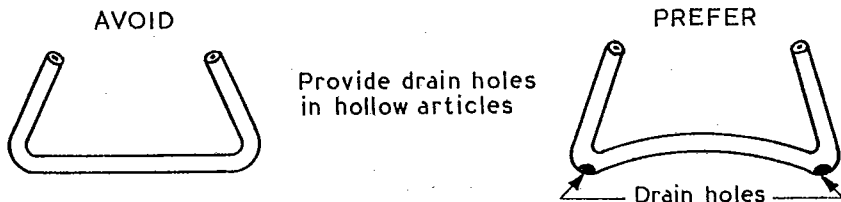


Fig. 4. Hollow articles

Figs. 1–13. Diagrams relating to
Section 2, Electroplated coatings (*continued*)