British Standard

BRITISH STANDARD

BS 3382: Parts 1 & 2: 1961

Incorporating Amendments No. 1, 2 and 3

Specification for

Electroplated coatings on threaded components —

Part 1: Cadmium on Steel Components —

Part 2: Zinc on Steel Components

UDC 621.793:621.882:669.738:669.587

Co-operating organizations

The Mechanical Engineering Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

Admiralty*
Air Ministry*
Associated Offices' Technical Committee
Association of Consulting Engineers (Incorporated)
British Chemical Plant Manufacturers' Association
British Compressed Air Society
British Electrical and Allied Manufacturers' Association*
British Engineers' Association*
British Gear Manufacturers' Association
British Internal Combustion Engine Manufacturers' Association
British Iron and Steel Federation
British Railways, The British Transport Commission*
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Engineering Equipment Users' Association*
Gas Council
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Institute of Marine Engineers
Institute of Petroleum
Institution of Civil Engineers
Institution of Gas Engineers
Institution of Heating and Ventilating Engineers
Institution of Mechanical Engineers*
Institution of Mechanical Engineers (Automobile Division)
Institution of Production Engineers*
Locomotive and Allied Manufacturers' Association of Great Britain*
Machine Tool Trades Association
Ministry of Labour (Factory Inspectorate)
Ministry of Power
Ministry of Transport
Ministry of Works
National Coal Board
National Physical Laboratory (D.S.I.R.)*
Radio Industry Council*
War Office*

The Government departments 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 standard:

Agricultural Engineers Association
British Bolt, Nut, Screw and Rivet Federation
British Non-ferrous Metals Research Association
Council of British Manufacturers of Petroleum Equipment
Electronic Engineering Association
Gauge and Tool Makers' Association
Institute of Metal Finishing
Ministry of Aviation
National Association of Marine Enginebuilders
Radio and Electronic Component Manufacturers Federation
Scientific Instrument Manufacturers' Association
Screw Thread Tool Manufacturers' Association
Society of British Aircraft Constructors
Society of Motor Manufacturers and Traders Ltd.
Telecommunication Engineering and Manufacturing Association
Individual Manufacturers

This British Standard, having been approved by the Mechanical Engineering Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 12 May 1961

The following BSI references relate to the work on this standard:
Committee reference MEE/1 and MEE/1/19
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Contents

Foreword

This standards makes reference to the following British Standards:

BS 57, *B.A. screws, bolts, nuts and plain washers.*

BS 84, *Parallel screw threads of Whitworth form.*

BS 93, *British Association (B.A.) screw threads with tolerances for sizes 0 B.A. to 16 B.A.*

BS 450, *Machine screws and machine screw nuts (B.S.W. and B.S.F. threads).*

BS 811, *Cycle threads.*

BS 919, *Screw gauge limits and tolerances.*

BS 1083, *Precision hexagon bolts, screws, nuts and plain washers.*

BS 1210, *Wood screws.*

BS 1580, *Unified screw threads.*

BS 1706, *Electroplated coatings of cadmium and zinc on iron and steel.*

BS 1768, *Unified precision hexagon bolts, screws, nuts (UNC and UNF threads) and plain washers — normal series.*

BS 1981, *Unified machine screws and machine screw nuts.*

BS 2011, *Basic climatic and durability tests for components for radio and allied electronic equipment.*

BS 2779, *Fastening threads of BSP sizes.*

BS 3155, *American machine screws and nuts in sizes below $^1/_4$ inch diameter.*

This British Standard has been prepared under the authority of the Mechanical Engineering Industry Standards Committee. It deals with the plating of small threaded components such as bolts, screws and nuts in various materials, plated with the commoner protective finishes.

The completed standard will refer to:

— *Part 1: Cadmium on steel components;*

— *Part 2: Zinc on steel components;*

— *Part 3: Nickel and nickel/chromium on steel components;*

— *Part 4: Nickel and nickel/chromium on brass components;*

— *Part 5: Tin on copper and copper alloys (including brass) components;*

— *Part 6: Silver on copper and copper alloys (including brass) components;*

— *Part 7: Thicker platings on threaded components (which will deal with those special cases where greater protection than that provided by Parts 1 and 2 is required).*

Parts 1 and 2 deal with thicknesses of plating which, without preventing the assembly of threaded components, will ensure the best possible protection against corrosion on threads conforming to tolerances and allowances laid down in relevant screw thread standards. These will be adequate for most purposes. Greater thicknesses cannot be accommodated on standard threads without undue risk of interference. In each of Parts 1 and 2 guidance is given as to the degree of protection which will be afforded by each coating.

Under severe conditions or for particular duties for which a threaded component is required, greater protection than that provided in Parts 1 and 2 may be needed. In such cases reference should be made to Part 7 of this standard.

The zinc and cadmium electroplating of ISO metric fasteners is specified in BS 7371-3:1993.

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 to iv, pages 1 to 17 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.

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Introductory notes

The electroplating of threaded components presents a number of peculiar problems which necessitate special care in the specification, application and inspection of electrodeposits. Four main considerations must be borne in mind:

i) The majority of small plated components (nuts, screws, bolts and similar threaded parts) are processed in bulk.

ii) Because of the geometry of screw threads, the increase in simple effective diameter of external threads is several times the deposit thickness (the actual factor depends on flank angles) and the increase in the virtual effective diameter will generally be even greater because of the tendency for the deposit distribution over the screw thread to be non-uniform.

iii) Because there is a screening effect on internal screw threads (the bulk of the deposit is concentrated on the first thread at each end) the thickness will fall off towards the middle.

iv) Because of the shape and size of the majority of threaded components and the distribution of the deposit over them, it is not possible to obtain reliable local measurements of deposit thickness by normal workshop inspection methods.

These factors necessitate the application of special procedures for:

a) Thickness specification.

b) Inspection sampling.

c) Thickness determination.

a) *Thickness specification*. Because of the nature of the plating process when carried out in barrels, there are random variations in the thickness of metal deposited on the various components of a production batch (see Figure 1). Some items have a deposit thickness greater than the average for the production batch while others have a thickness less than the average.

Figure 1 illustrates the degree of scatter likely to be encountered in a typical batch having an average thickness of 0.000 22 inches. It also indicates the percentage of the whole batch falling within the three thickness ranges shown. While this is indicative of the probable scatter which will be encountered, greater or less scatter than that shown may occur in individual batches. Because of this scatter, the method of specifying the deposit in terms of minimum thickness is not so convenient as the method now adopted in this specification of requiring that the *average* thickness of a production batch shall comply with the values laid down. The minimum batch average thickness ensures adequate protection while the maximum batch average thickness reduces the risk of interference between mating threaded components.

b) *Inspection sampling*. Provided a batch is statistically homogeneous (e.g. a plating barrel load of identical components) the accuracy of estimation of the average thickness of the batch depends solely on the variability of the batch and the actual size of the sample taken. It is not related to the size of the batch itself. If a barrel load contains more than one type of component, the group of components of each type must be regarded as a separate production batch for sampling purposes.

The sampling and inspection procedures laid down in this specification have been drawn up to give reasonable accuracy in estimation of thickness for batches of work which are statistically homogeneous. In order to ensure comparable accuracy in thickness estimation for work plated in vats, whether by individual suspension, or in baskets, which do not constitute statistically homogeneous batches, it would be necessary to adopt a far greater density of sampling. For practical and economic reasons this is not normally desirable, and it is recommended that the inspection procedure laid down in Clause **4** be adopted also for vat-plated work.

c) *Thickness determination*. Since, in general, accurate measurements of a deposit thickness at isolated points are difficult on a threaded component, it is generally necessary to determine the average thickness of deposit over its whole surface. This is most easily calculated from the total weight of deposit on the component and its total surface area.

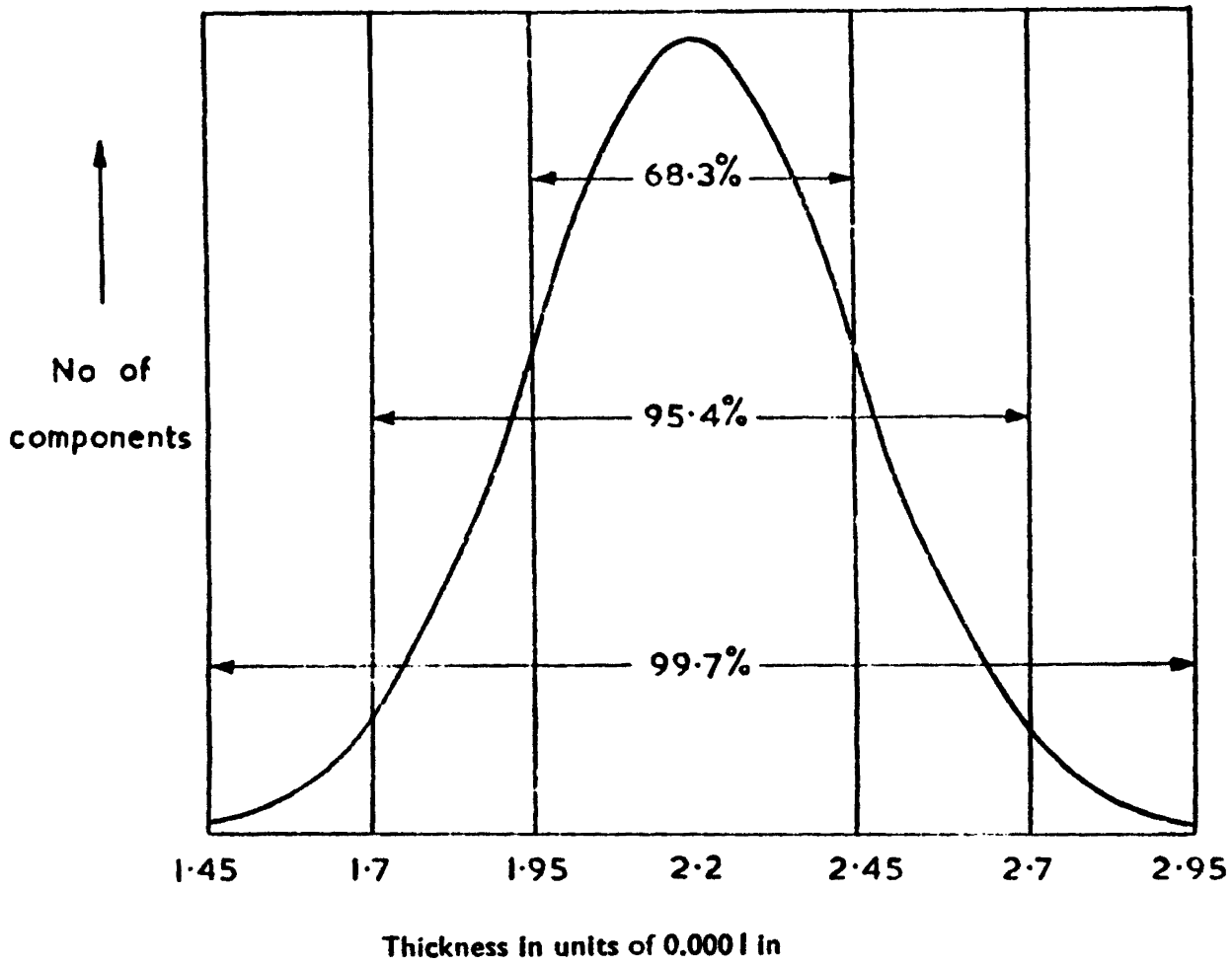

Figure 1 — Probable frequency distribution of thickness in a barrel load

Surface areas of threaded components whose dimensions are on their upper limits are, of course, greater than those of components whose dimensions are on their lower limits. Strictly therefore, the surface area which should be used for calculation of plating thicknesses from the weight of deposited coating should be the sum of the actual surface areas of all the group components. Such a course is, however, neither practicable (because of the numerous calculations involved), nor necessary (since in general tolerances involved are small enough to occasion only very small errors in calculated plating thicknesses). The surface areas specified in Appendix D are "reference surface areas" which, when used in the formula of Appendix B for the components specified in the scope clause (and for the tolerances specified for them in other standards), give approximate values for plating thicknesses. These approximate values are, however, sufficiently close for all practical purposes as is apparent from an examination of the calculations contained in Appendix E. Appendix E contains more exact and exemplary calculations of plating thicknesses based on actual surface areas of components whose dimensions are on their extreme limits. It should be emphasized that the examples chosen represent extreme cases. In practice it is extremely unlikely that any group will have all components with dimensions on "one limit" and, therefore, in practice the errors in group average thicknesses calculated from the use of the reference surface areas will be considerably less than those contained in Appendix E. The examples quoted in Appendix E refer to a unit (1 in) length of threaded shank and if to the thread surface values are added the head and unthreaded-shank areas (as would be necessary, for example, for bolts) to form the denominator of the appropriate formula in Appendix B, resulting errors of calculated plating thickness will be still further reduced.

1 Scope

This British Standard specifies cadmium and zinc plating thicknesses, sampling and other inspection procedures, and methods of thickness determination for components having threads of basic major diameters from 0.060 in to $^{3}/_{4}$ in, inclusive, specified in the following standards:

BS 84, *Parallel screw threads of Whitworth form*.

BS 93, *British Association (B.A.) screw threads (sizes 0 B.A. to 16 B.A.).*

BS 811, *Cycle threads*.

BS 1580, *Unified screw threads*.

BS 2779, *Fastening threads of BSP sizes*.

This standard does not specify plating thickness, sampling and other inspection procedures and methods of thickness determination for components such as self-tapping screws and wood screws (e.g. BS 1210).

The standard refers in particular to the threaded components specified in the following standards. It does not apply to components for aircraft.

a) *Bolts and screws — general purpose*.

BS 57, BS 450, BS 1083, BS 1768, BS 1981, BS 3155.

b) *Nuts — general purpose*.

BS 57, BS 450, BS 1083, BS 1768, BS 1981, BS 3155.

NOTE Surface areas of these components may be calculated from Table 2 to Table 10. Surface areas of other components should be agreed between manufacturer and purchaser.

2 Definitions

For the purposes of this British Standard the following definitions apply:

production batch

a quantity of identical components, plated together at one time in a particular barrel

delivery batch

a consignment of identical components received by the purchaser under cover of one delivery note, and comprising some or all of the constituents of any number of production batches

batch average thickness (applicable to production and delivery batches)

the average thickness of the coating on all the components of a batch. The average thickness of a delivery batch is dependent upon the average thicknesses and the sizes of all relevant production batches

group

ten or more items selected at random from a production batch or from each fifty-six pounds or any remainder of a delivery batch

batch sample

a representative number of components of a batch composed either of one group or of any number of groups

3 Inspection

a) *Inspection by plater*. The plater shall carry out sampling and testing sufficient to ensure that all production batches comply with the plating requirements of this standard.

b) *Sampling*.

i) *Sample Type* 1. If a delivery batch of similar components can be identified as a production batch, one group shall constitute its representative sample.

ii) *Sample Type* 2. If a delivery batch of similar components which weighs 56 lb or less cannot be identified as a production batch, one group shall constitute its representative sample.

iii) *Sample Type* 3. If a delivery batch of similar components which weighs more than 56 lb cannot be identified as a production batch, its representative sample shall be constituted by a group taken from each 56 lb and a group from any remainder.

NOTE 1 For determining the plating thicknesses of very small components by weighing, groups consisting of more than ten items may be found more convenient since effects of weighing errors can thereby be reduced.

NOTE 2 A production or delivery batch complies with the requirements of this standard if the sample representing it conforms to all requirements of appropriate clauses.

4 Screw thread dimensions

a) Thread dimensions of components supplied for plating shall comply with the relevant screw thread standards. Gauging procedure to ensure compliance with requirements is specified in appropriate clauses of Appendix C of BS 919, Part 1, entitled *"A recommended system of gauges for coated screw threads"*.

b) After plating, thread dimensions of components shall be such that the requirements of the appropriate clauses of Appendix C of BS 919, Part 1 are fulfilled.

NOTE NO GO gauging after plating is not recommended.

Part 1: Cadmium (Bright or dull) on steel components

5 Resistance to corrosion

Tests have shown that components plated in accordance with the requirements of this section have a protective coating which satisfactorily withstands exposure to the following conditioning atmospheres defined in BS 2011, "*Basic climatic and durability tests for components for radio and allied electronic equipment*".

Long term damp heat	H 1
Salt mist	Severity 2

NOTE Cadmium is subject to corrosion by vapours which may be released by wood, plastics, paint and other organic substances.[1)]

6 Purity

The plating shall contain not less than 98.5 per cent of cadmium, and shall not contain mercury. Total impurities other than zinc and nickel shall not exceed 0.5 per cent.

7 Adhesion

The plating shall adhere firmly to the underlying metal.

8 Porosity

Plated coatings shall be free from gross porosity on significant surfaces, i.e. those other than internal threads, screw-driver slots and sockets. Gross porosity can be detected by the following test, which is more suitable for parts of which the major diameter of the screw thread is greater than 0.127 in than for parts with a major diameter less than 0.127 in.

If a plated component after being thoroughly cleaned and free from grease is immersed in one per cent volume solution of concentrated hydrochloric acid (sp. gr. 1.16) at room temperature for five minutes, active evolution of hydrogen provides an indication of gross porosity; occasional bubbling should be ignored.

9 Reduction of hydrogen embrittlement

a) The purchaser of cadmium plated threaded steel components shall advise the plater if the tensile strength of the steel exceeds 65 tons/sq in.

b) *Stress-relieving before plating*. Prior to cleaning (other than non-electrolytic degreasing) before electroplating, parts made from steel of minimum specified tensile strength of 65 tons per square inch or greater (or of comparable surface hardness) which have been ground or subjected to severe machining after final tempering should be stress relieved. This may be done by heating either to 130 – 210 °C (270 – 410 °F) for not less than one hour, or to just below the tempering temperature for 15 to 30 minutes.

[1)] DEF DG-3, "Defence guide for the prevention of corrosion of cadmium and zinc plating", is concerned with this problem. For a general statement, see V.E. Rance and H.G. Cole, *Corrosion of metals by vapours from organic materials*, H.M.S.O. (1958). Also P.T.Gilbert and S.E.Hadden, "Corrosion of cadmium and zinc coatings in electrical equipment", *Journal of the Electro-Depositors' Technical Society*, (1950), **25**, 41–49.

c) *Heat treatment after plating*. Parts in steel of minimum tensile strength in the range of 65 to 90 tons per square inch shall be maintained in the temperature range of 130 – 210 °C for not less than 6 hours, after plating.

NOTE Part 1 of this standard does not apply to parts of steel with a minimum specified tensile strength greater than 90 tons per square inch, for which special precautions are required.

10 Finish and appearance of plated surfaces

Plated components shall be free from visible defects such as unplated areas, blisters and nodules.

11 Plating thickness

The plating thickness of a batch of components after any passivation complies with the requirements of the standard if the thickness of Type 1 or Type 2 sample, determined by the method described in Appendix B, [2)]fulfils condition a) below, or if the thickness of Type 3 sample, determined by the method described in Appendix B, fulfils conditions a) and b) below.

a) Group average thicknesses of representative samples, Types 1 and 2, shall be within the limit specified in Table 1. However, if the maximum batch average thickness exceeds that specified in Table 1, parts comply with this standard if they are accepted by an appropriate GO gauge.

b) Notwithstanding the requirements a) above, no group average thickness of a representative sample, Type 3, shall differ from the relevant overall sample average thickness by more than 20 per cent.

Table 1 — Plating Thickness

(Inch dimensions)

Basic major diameter of screw thread		Batch average thickness	
Over	Up to and including	Minimum	Maximum
in	in	in	in
0.060	0.126	0.000 15	0.000 20
0.126	0.250	0.000 20	0.000 25
0.250	0.500	0.000 25	0.000 30
0.500	0.750	0.000 30	0.000 35

Table 1A — Plating Thickness

(Millimetre dimensions)

Basic major diameter of screw thread		Batch average thickness	
Over	Up to and including	Minimum	Maximum
mm	mm	mm	mm
1.52	3.20	0.0038	0.0051
3.20	6.35	0.0051	0.0064
6.35	12.70	0.0064	0.0076
12.70	19.05	0.0076	0.0089

NOTE It is recommended that components with threads of basic major diameters greater than $^3/_4$ in be plated to the requirements of BS 1706, "*Electroplated coating of cadmium and zinc on iron and steel*".

[2)] Appendix C sets out the details of the "Clarke" Time of Gassing Test (which is identical with that specified in BS 1706), and which is suitable for a workshop control or quick acceptance test. Appendix B specifies a referee test for use in case of dispute.

12 Passivation

Passivation of cadmium plating adds considerably to its protective value. Unless otherwise agreed between the purchaser and the manufacturer (or electroplater) cadmium plated components, after any post-plating heat treatment [see Clause **9** c)], shall be passivated by either of the methods detailed in Appendix A or by any other agreed method shown to be equally or more effective. Unless this passivation is done, plated components may not fulfil the conditions specified in Clause **5**. The two methods detailed in Appendix A will provide a coloured, Method (i), or an (almost) uncoloured film, Method (ii). An uncoloured film shall be applied unless the purchaser specifies otherwise. Bleaching of passivated cadmium is not recommended.

Part 2: Zinc (Bright or dull) no steel components

13 Resistance to corrosion

Tests have shown that components plated in accordance with the requirements of this section have a protective coating which satisfactorily withstands exposure to the following conditioning atmosphere defined in BS 2011, "*Basic climatic and durability tests for components for radio and allied electronic equipment*".

Long term damp heat	Twice the duration of H1.
Salt mist	Severity 2.

NOTE Zinc is subject to corrosion by vapour which may be released by wood, plastics, paint and other organic substances, though not as sensitive as cadmium (see also footnote to Clause **5**).

14 Purity

The plating shall contain not less than 98.5 per cent of zinc, and shall not contain mercury. Total impurities other than tin and cadmium shall not exceed 0.5 per cent.

15 Reduction of hydrogen embrittlement

a) The purchaser of zinc plated threaded steel components shall advise the plater if the tensile strength of the steel exceeds 65 tons/sq in.

b) *Stress-relieving before plating*. Prior to cleaning (other than degreasing) before electroplating, parts made from steel of minimum specified tensile strength of 65 tons per square inch or greater (or of comparable surface hardness), which have been ground or subjected to severe machining after final tempering should be stress relieved. This may be done by heating either to 130 – 210 °C (270 – 410 °F) for not less than one hour, or to just below the tempering temperature for 15 to 30 minutes.

c) *Heat treatment after plating*. Parts in steel of minimum specified tensile strength in the range 65 – 90 tons per square inch shall be maintained in the temperature range of 130 – 210 °C for not less than 6 hours, after plating.

NOTE Part 2 of this standard does not apply to parts of steel with a minimum tensile strength greater than 90 tons/sq in for which special precautions are required.

16 Finish and appearance of plated surfaces

Plated components shall be free from visible defects such as unplated areas, blisters and nodules.

17 Plating thickness

The plating thickness of a batch of components after any passivation complies with the requirements of the standard if the thickness of Type 1 or Type 2 sample determined by the method described in Appendix B,[3)] fulfils condition a), below, or if the thickness of Type 3 sample, determined by the method described in Appendix B fulfils conditions a) and b), below.

a) Group average thicknesses of representative samples, Types 1 and 2, shall be within the limits specified in Table 1. However, if the maximum batch average thickness exceeds that specified in Table 1, parts comply with this standard if they are accepted by an appropriate GO gauge.

[3)] See Clause **11**.

b) Notwithstanding the requirement of a) above, no group average thickness of a representative sample, Type 3, shall differ from the relevant overall sample average thickness by more than 20 per cent.

Table 1 — Plating Thickness

(Inch dimensions)

Basic major diameter of screw thread		Batch average thickness	
Over	Up to and including	Minimum	Maximum
in	in	in	in
0.060	0.126	0.000 15	0.000 20
0.126	0.250	0.000 20	0.000 25
0.250	0.500	0.000 25	0.000 30
0.500	0.750	0.000 30	0.000 35

Table 1A — Plating Thickness

(Millimetre dimensions)

Basic major diameter of screw thread		Batch average thickness	
Over	Up to and including	Minimum	Maximum
mm	mm	mm	mm
1.52	3.20	0.0038	0.0051
3.20	6.35	0.0051	0.0064
6.35	12.70	0.0064	0.0076
12.70	19.05	0.0076	0.0089

NOTE It is recommended that components with threads of basic major diameters greater than $^3/_4$ in be plated to the requirements of BS 1706, "*Electroplated coating of cadmium and zinc on iron and steel*".

19 Passivation

Passivation of zinc plating adds considerably to its protective value. Unless otherwise agreed between the purchaser and the manufacturer (or electroplater) zinc plated components, after any post-plating heat treatment [see Clause **15** c)], shall be passivated as detailed in Appendix A , Method (i), or by any other agreed method shown to be equally or more effective. The coloured passivation film produced by the method detailed should then be bleached as described in Appendix A , unless the purchaser specifies a coloured film.

Appendix A Passivation treatment

A.1 Preparation of surface

i) Cleaning may not be necessary with freshly plated parts. It is essential, however, that parts shall be free from alkaline electrolyte.

ii) Degrease parts which are noticeably oily or greasy with a suitable organic solvent. Immerse all parts other than those freshly plated in a boiling solution containing 6 oz of trisodium phosphate per gallon for from 5 to 15 minutes without current.

iii) Wash all parts thoroughly in cold running water to remove traces of plating or cleaning solution. Remove excess water by draining.

iv) As a further precaution against unduly rapid changes in the acidity of the passivating solution defined under "Chromate treatment" below, parts may be rinsed for not more than 10 seconds in a 1 ml/litre solution of nitric or sulphuric acid immediately before immersion.

A.2 Chromate treatment

Treat the components immediately after the preparation of surface, as in Paragraph **A.1** above, by one of the following methods:

Method (i) for cadmium or zinc plated components. Components shall be immersed for from 5 – 10 seconds in the following solution at room temperature:

Ingredients	Recommended strength		Permissible limits	
	For each litre of water	Per litre total volume	For each litre of water	Per litre total volume
Sodium dichromate crystals ($Na_2Cr_2O_7.2H_2O$)	200 g	182 g	150/200 g	136/182 g
Sulphuric acid (sp. gr. 1.84)	6.6 ml	6 ml	5.5/10.0 ml	5/9 ml

Transfer rapidly into:

i) a tank of cold running water for a few seconds,

ii) a second tank of cold running water for one minute approximately.

NOTE 1 The above method of passivation gives a golden colour on cadmium and an iridescent greenish-khaki colour on zinc which should be free from bare patches, and on rubbing components against white paper no appreciable brown stain due to non-adherent chromate film should appear.

NOTE 2 Passivation adds considerably to the protective value of the plating but bleaching while restoring the natural zinc appearance partially reduces its value. Bleach zinc plated components if required by immersing in a mild alkaline solution of 2 oz/gal of sodium carbonate for five to ten seconds at room temperature with fairly vigorous agitation.

Dry in circulating air at a temperature not exceeding 65 °C, without prior insertion into boiling water.

Method (ii) for cadmium plated components. Immerse components for from 5 – 10 seconds in the following solution at room temperature:

Ingredients	Recommended strength		Permissible limits	
	For each litre of water	Per litre total volume	For each litre of water	Per litre total volume
Sodium sulphate (anhydrous)	27.5 g	25 g	24.5/30.0 g	22.5/27.5 g
Chromic acid	220 g	200 g	194/246 g	175/225 g

Transfer rapidly into:

i) a tank of cold running water for a few seconds;

ii) a second tank of cold running water for one minute approximately.

Dry in circulating air at a temperature not exceeding 65 °C, without prior insertion into boiling water.

NOTE The above method gives an almost colourless film.

Appendix B "Strip and weigh" method for the determination of group and sample average plating thicknesses

B.1 Thoroughly clean and free each group of items from grease.

B.2 Thoroughly dry each group of items.

B.3 Weigh each group of items together or in such small groups as are appropriate to the maximum capacity of the balance to an accuracy of 1 mg on each weighing.

B.4 Totally immerse each group of items in the following stripping solution and turn each item over in the solution to permit free access of the liquid to all surfaces.

a) *Stripping solution for cadmium plating:*

A 30 per cent solution of ammonium nitrate.

b) *Stripping solution for zinc plating:*

5 g	ammonium persulphate
10 ml	ammonia (sp. gr. 0.880)
90 ml	water

B.5 Remove items from the stripping solution immediately the coating is completely dissolved; wash, wipe and immerse in clean acetone to remove any trapped water. Dry each item and re-weigh each group exactly as before.

B.6 Deduce the weight of plating for each group by subtraction of the results of the weighings, or evaluate it from the stripping solution by a normal method of chemical estimation.

B.7 Calculate the areas of coatings of the ten or more items in the group from the data given in Table 2 – Table 10.

B.8 Calculate the group average thickness from:

a) For cadmium plating (assuming relative density of 8.6):

$$\text{Group average thickness} = \frac{\text{weight of coating (grammes)}}{\text{area of coating}\,(\text{in}^2)\times 141}\ \text{in} = \frac{\text{weight of coating(grammes)}}{\text{area of coating}\ (\text{cm}^2)\times 8.6}\ \text{cm}$$

b) For zinc plating (assuming relative density of 7.1):

$$\text{Group average thickness} = \frac{\text{weight of coating (grammes)}}{\text{area of coating}\ (\text{in}^2)\times 116}\ \text{in} = \frac{\text{weight of coating (grammes)}}{\text{area of coating}\ (\text{cm}^2)\times 7.1}\ \text{cm}$$

B.9 Calculate the sample average thickness (for sample, Type 3) from the following formula:

$$\text{Sample average thickness} = \frac{\text{sum of all relevant group average thicknesses}}{\text{the number of groups}}$$

NOTE For sample, Types 1 and 2, the sample average thickness equals the group average thickness.

Appendix C Determination of the thickness of cadmium plating by the clarke "time of gassing test"

Reagents. Make up the solution required by dissolving 10 g of nickel sulphate crystal ($NiSO_4.6H_2O$) in 100 ml of concentrated hydrochloric acid (sp. gr. 1.16).

Method. Clean the ten (or more) items and free them from grease. Immerse each item in the reagent and observe accurately the time for which copious gas evolution occurs by means of a stop watch or clock with a seconds hand. (The time to be recorded is that from the moment the gassing starts until there is a marked decrease in rate of gassing.) Take the temperature of the reagent solution and determine the thickness either a) by reference to the curve (see Note 2 below) or b) dividing the time in seconds by 3.9, which gives the thickness in units of 0.0001 in.

NOTE Method a) should be used whenever the time is less than ten seconds because of inaccuracy due to the non-linear relation in this region.

Temperature. The temperature should be maintained between 15 °C and 25 °C during testing. No correction is necessary at a testing temperature of 20 °C but for other temperatures add a correction of 2 per cent of the apparent thickness for each degree above 20 °C or subtract 2 per cent for each degree below 20 °C.

NOTE 1 The testing reagent may be re-used to a limited extent but not beyond the stage where more than 1 gramme of cadmium has been dissolved in 100 ml, i.e. the equivalent of 25 sq in of surface of a 0.0003 in deposit.
NOTE 2 This method is identical with that specified in BS 1706, "*Electroplated coatings of cadmium and zinc on iron and steel*", and Figure 4, "Curve of determination of average thickness of cadmium coatings" from that standard, is reproduced here as Figure 2.

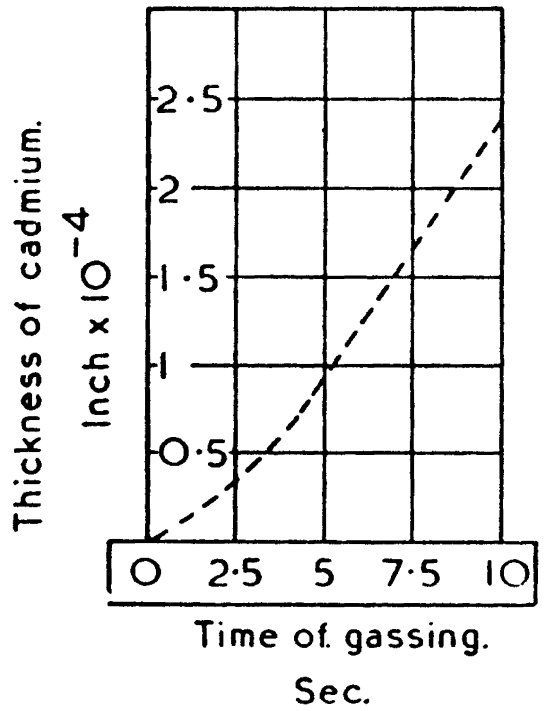

Figure 2 — Curve of determination of average thickness of cadmium coatings

NOTE 3 A.R. hydrochloric acid has now normally a specific gravity of 1.18 and should be diluted to the value specified.
NOTE 4 A suitable workshop control or quick acceptance test for zinc plated components has not yet been developed, but research to that end is proceeding.

Appendix D Notes on surface areas of screws, bolts and nuts

D.1 General

Tables of surface areas of standard screws, bolts and nuts are given in Table 2 – Table 9 as a guide to electroplaters so that they may estimate the conditions of current and plating time necessary to obtain the required deposit thickness and also to assist in the estimation of average thickness on plated components. The tables enable the electroplater to find the surface area of screws and bolts by a simple calculation from values obtained from the tables and the surface area of nuts directly from the tables. The tables cover a range of screws, bolts and nuts having a basic major thread diameter of from 0.06 in to 0.75 in.

D.2 Screws and bolts

Table 2 – Table 6 give values for the calculation of surface areas of general purpose screws and bolts. To obtain the total surface area of a screw or bolt the following values which are given in the tables are necessary:

The surface area *a* of an inch length of the threaded shank of the screw or bolt (see Figure 3).

The surface area *b* of an inch length of the unthreaded shank of the screw or bolt (see Figure 3).

NOTE If the thread is cut, the unthreaded shank will be approximately equal to the basic major diameter. If the thread is rolled, the unthreaded shank will be approximately equal to either the thread effective diameter (rolling diameter) or the basic major diameter. Surface area values for both basic major diameter and rolling diameter are, where appropriate, given in the tables.

The surface area *c* of the head to which has been added the surface area of the end of the shank (see Figure 3).

The total surface area of a screw or bolt may be calculated from the following formula:

Total area = (length of threaded shank × *a*) + (length of unthreaded shank × *b*) + *c*.

The values for area of head of all other screws and bolts given in the tables except hexagon heads, are in respect of slotted and recessed heads.

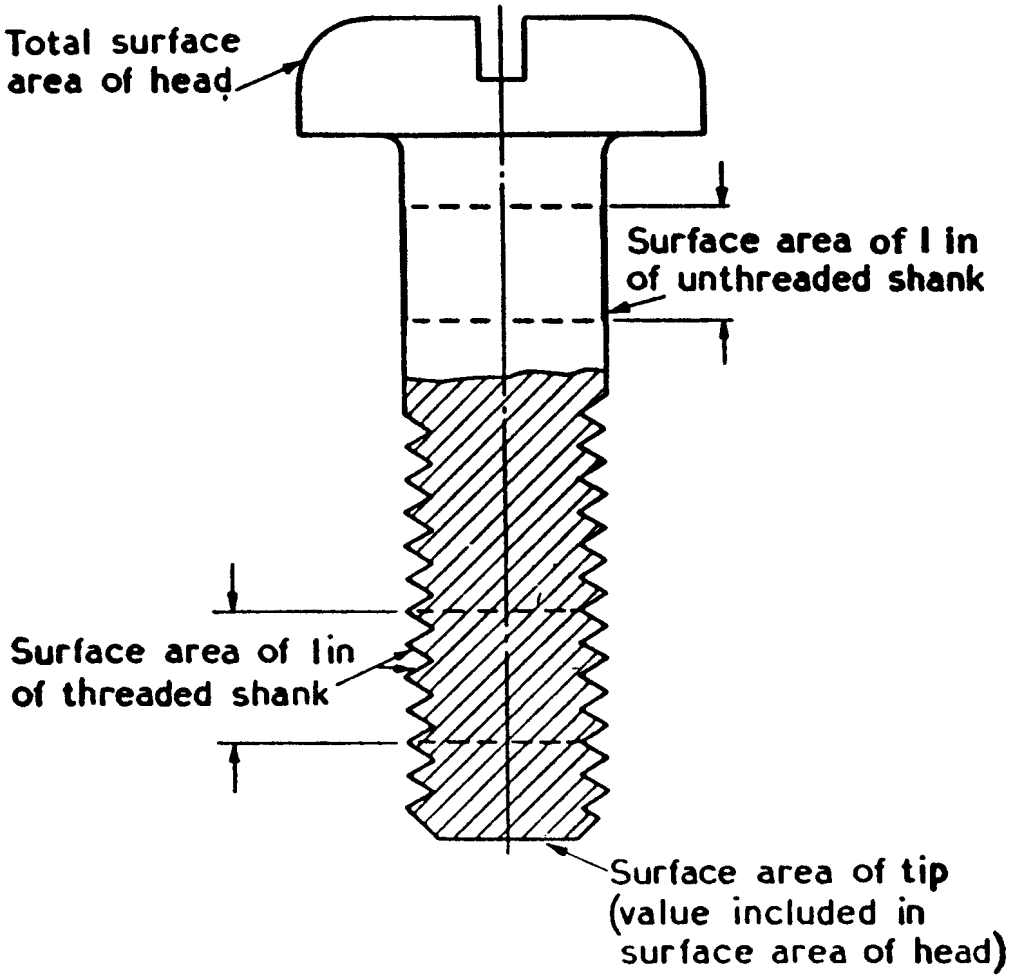

Figure 3 — Constituent surface areas of a screw or bolt (see **D.2**)

D.3 Nuts

Table 7 – Table 9 give the surface areas of general purpose nuts.

The effective surface area of a nut for the purposes of electroplating is normally less than its actual geometrical area because of the difficulty in obtaining a uniform distribution of plating deposit over the interior threads, the majority of the deposit on the threads being on the first thread at each end.

For the purposes of this standard, therefore, the calculation of the surface area of a nut has been based on a solid of the shape of the nut but neither drilled nor tapped.

Appendix E Examples of calculations of deposit thicknesses on plated threaded shanks

E.1 10–32 UNF, 1 in of thread.

Deposit cadmium, plating thickness range 0.000 20 – 0.000 25 in

a) Maximum surface area (as given in Table 3) = 0.903 sq in

b) Minimum surface area = 0.871 sq in

EXAMPLE 1

Suppose weight of deposit on 10 pieces is 0.2545 g.

Taking *a*

$$\text{Group average thickness} = \frac{0.025\ 45}{0.903 \times 141} = 0.000\ 20 \text{ in}$$

Taking *b*

$$\text{Group average thickness} = \frac{0.025\ 45}{0.871 \times 141} = 0.000\ 207 \text{ in}$$

EXAMPLE 2

Suppose weight of deposit on 10 pieces is 0.3180 g.

Taking *a*

$$\text{Group average thickness} = \frac{0.0318}{0.903 \times 141} = 0.000\ 250 \text{ in}$$

Taking *b*

$$\text{Group average thickness} = \frac{0.0318}{0.871 \times 141} = 0.000\ 259 \text{ in}$$

E.2 $^1/_2$ in UNC, 1 in length of thread.

Deposit cadmium, plating thickness range 0.000 25 – 0.000 30 in

a) Maximum surface area (as given in Table 3) = 2.401 sq in

b) Minimum surface area = 2.342 sq in

EXAMPLE 1

Suppose weight of deposit on 10 pieces is 0.8470 g.

Taking *a*

$$\text{Group average thickness} = \frac{0.0847}{2.401 \times 141} = 0.000\ 250 \text{ in}$$

Taking *b*

$$\text{Group average thickness} = \frac{0.0847}{2.342 \times 141} = 0.000\ 256 \text{ in}$$

EXAMPLE 2

Suppose weight of deposit on 10 pieces is 1.0150 g.

Taking *a*

$$\text{Group average thickness} = \frac{0.1015}{2.401 \times 141} = 0.000\ 300 \text{ in}$$

Taking *b*

$$\text{Group average thickness} = \frac{0.1015}{2.342 \times 141} = 0.000\ 307 \text{ in}$$

Tables for calculation of surface areas of screws, bolts and nuts — General purpose

Table 2 — Screws and Bolts — B.S.W. and B.S.F. Threads

Nominal size	Area per inch length of shank (sq in)					Area of head (sq in)							
	Threaded shank		Unthreaded shank			Counter-sunk head	Raised-Counter-sunk head	Round head	Pan head	Cheese head	Raised-cheese head	Mushroom head	Hexagon head
			Nominal dia.	Rolling dia.									
B.S.W. or B.S.F.	B.S.W.	B.S.F.	B.S.W. or B.S.F.	B.S.W.	B.S.F.	BS 450	BS 450	BS 450	BS 450	BS 450	BS 450	BS 450	BS 450 (below 1/4 in) and BS 1083
in													
1/8	0.579	—	0.390	0.339	—	0.099	0.108	0.118	0.151	0.117	0.144	0.166	0.138
5/32	0.725	—	0.487	0.425	—	0.155	0.169	0.184	0.238	0.183	0.237	—	0.183
3/16	0.857	0.894	0.584	0.502	0.523	0.224	0.242	0.265	0.351	0.265	0.339	0.390	0.301
7/32	—	1.046	0.682	—	0.612	0.306	0.331	0.362	0.451	0.362	0.452	—	0.472
1/4	1.164	1.205	0.782	0.682	0.705	0.402	0.436	0.474	0.605	0.473	0.599	0.646	0.625
5/16	1.480	1.516	0.977	0.867	0.887	0.629	0.698	0.741	0.949	0.742	0.924	0.960	0.863
3/8	1.792	1.835	1.175	1.049	1.074	0.905	0.989	1.067	1.348	1.067	1.343	1.332	1.166
7/16	2.096	2.151	1.370	1.228	1.259	1.235	—	1.455	1.851	1.456	1.431	—	1.659
1/2	2.391	2.463	1.565	1.400	1.442	1.614	—	1.901	2.414	1.905	1.922	—	2.211
9/16	2.726	2.798	1.762	1.596	1.638	2.043	—	2.406	2.703	2.414	—	—	2.828
5/8	3.035	3.103	1.957	1.778	1.817	2.522	—	2.970	3.239	2.982	—	—	3.433
3/4	3.675	3.732	2.350	2.152	2.185	3.634	—	4.276	4.113	4.295	—	—	4.922

Table 3 — Screws and Bolts — UNC and UNF Threads

Nominal size	Area per inch length of shank (sq in)					Area of head (sq in)				
	Threaded shank		Unthreaded shank			Counter-sunk (flat) head	Raised Counter-sunk (oval) head	Pan head	Raised-cheese (fillister) head	Hexagon head
			Nominal dia.	Rolling dia.						
UNC or UNF	UNC	UNF	UNC or UNF	UNC	UNF	BS 1981 BS 3155[a]	BS 1981 BS 3155[a]	BS 1981 BS 3155[a]	BS 1981 BS 3155[a]	BS 3155[a] BS 1768
[a]0	—	0.275	0.187	—	0.163	0.025	0.028	0.035	0.031	—
[a]1	0.333	0.339	0.227	0.198	0.201	0.038	0.044	0.052	0.046	—
[a]2	0.395	0.403	0.268	0.234	0.238	0.054	0.059	0.070	0.063	0.047
[a]3	0.454	0.464	0.309	0.269	0.275	0.073	0.081	0.093	0.084	0.093
[a]4	0.508	0.523	0.349	0.298	0.309	0.096	0.104	0.121	0.108	0.097
[a]5	0.578	0.586	0.390	0.342	0.346	0.119	0.129	0.152	0.136	0.103
[a]6	0.626	0.647	0.430	0.367	0.383	0.147	0.160	0.184	0.166	0.184
[a]8	0.764	0.777	0.512	0.448	0.459	0.209	0.227	0.261	0.236	0.199
[a]10	0.867	0.903	0.594	0.509	0.530	0.281	0.305	0.349	0.318	0.293
[a]12	1.006	1.027	0.675	0.593	0.606	0.368	0.386	0.450	0.414	0.330
in										
1/4	1.158	1.209	0.782	0.680	0.709	0.489	0.531	0.605	0.558	0.563
5/16	1.473	1.522	0.977	0.865	0.893	0.772	0.841	0.952	0.875	0.783
3/8	1.783	1.856	1.175	1.047	1.090	1.113	1.215	1.355	1.265	0.999
7/16	2.086	2.161	1.370	1.226	1.269	1.236	—	1.855	1.333	1.284
1/2	2.401	2.495	1.565	1.411	1.466	1.409	—	2.423	1.816	1.778
9/16	2.712	2.810	1.762	1.594	1.651	1.851	—	—	2.182	2.152
5/8	3.020	3.144	1.957	1.775	1.847	2.383	—	3.252	2.583	2.780
3/4	3.657	3.789	2.350	2.149	2.226	3.629	—	4.132	3.428	4.005

[a] BS 3155, "*American machine screws and nuts in sizes below 1/4 in diameter*".

Table 4 — Screws and Bolts — B.A. Threads

Nominal size, B.A	Area per inch length of shank (sq in)			Area of head (sq in)				
	Threaded shank	Unthreaded shank		Cheese head	Round head	Counter-sunk head	Raised Counter-sunk head	Hexagon head
		Nominal diameter	Rolling diameter	BS 57	BS 57	BS 57	BS 57	BS 57
0	1.114	0.738	0.665	0.534	0.423	0.339	0.367	0.539
1	0.981	0.650	0.586	0.418	0.332	0.268	0.288	0.420
2	0.868	0.578	0.518	0.318	0.253	0.205	0.220	0.331
3	0.754	0.503	0.450	0.248	0.197	0.163	0.181	0.251
4	0.659	0.443	0.393	0.197	0.157	0.131	0.139	0.193
5	0.585	0.393	0.349	0.150	0.120	0.101	0.110	0.152
6	0.509	0.342	0.303	0.116	0.093	0.078	0.085	0.117
7	0.453	0.305	0.270	0.092	0.073	0.063	0.070	0.093
8	0.397	0.267	0.237	0.075	0.060	0.051	0.056	0.072
9	0.340	0.232	0.203	0.050	0.040	0.034	0.037	0.053
10	0.303	0.207	0.181	0.038	0.031	0.026	0.029	0.042

Table 5 — Screws and Bolts — B.S.C. and B.S.P. Threads

Nominal size	Area per inch length of shank (sq in)					
	B.S.C. threads to BS 811			B.S.P. fastening threads to BS 2779		
	Threaded shank	Unthreaded shank		Threaded shank	Unthreaded shank	
		Nominal diameter	Rolling diameter		Nominal diameter	Rolling diameter
in						
1/8	0.537	0.390	0.348	1.929	1.197	1.128
5/32	0.672	0.487	0.436	—	—	—
3/16	0.824	0.584	0.534	—	—	—
7/32	0.957	0.682	0.620	—	—	—
1/4	1.108	0.782	0.718	2.596	1.621	1.518
9/32	1.260	0.880	0.816	—	—	—
5/16	1.411	0.977	0.914	—	—	—
3/8	1.714	1.175	1.111	3.337	2.055	1.952
7/16	2.017	1.370	1.307	—	—	—
1/2	2.320	1.565	1.503	—	—	—
9/16	2.623	1.762	1.700	—	—	—
5/8	2.926	1.957	1.896	—	—	—
11/16	3.229	2.152	2.092	—	—	—
3/4	3.533	2.350	2.289	—	—	—

Table 6 — *Table deleted*

Table 7 — Nuts — B.S.W. and B.S.F. Threads

Nominal size B.S.W. or B.S.F.	Area of nut (sq in)			
	Ordinary	Thin	Slotted	Castle
	BS 450 (below 1/4 in) and BS 1083	BS 450 (below 1/4 in) and BS 1083	BS 1083	BS 1083
in				
1/8	0.17	0.14	—	—
5/32	0.21	0.18	—	—
3/16	0.36	0.31	—	—
7/32	0.56	0.47	—	—
1/4	0.64	0.53	0.80	0.81
5/16	0.92	0.76	1.05	1.12
3/8	1.26	1.03	1.34	1.49
7/16	1.78	1.45	1.91	2.19
1/2	2.38	1.94	2.56	2.89
9/16	3.03	2.46	3.25	3.76
5/8	3.69	3.00	3.95	4.51
3/4	5.29	4.29	5.65	6.48

Table 8 — Nuts — B.A. Threads

Nominal size, B.A.	Area of nut (sq in)	
	Ordinary	Thin
	BS 57	BS 57
0	0.59	0.51
1	0.46	0.40
2	0.36	0.31
3	0.28	0.24
4	0.22	0.18
5	0.17	0.14
6	0.13	0.11
7	0.10	—
8	0.08	0.07
9	0.06	—
10	0.05	—

Table 9 — Nuts — UNC and UNF Threads

Nominal size UNC or UNF	Area of nut (sq in)					
	Ordinary (Precision)	Thin	Slotted	Thick slotted	Hexagon machine screw nut (pressed)	Square machine screw nut (pressed)
	BS 1768	BS 1768	BS 1768	BS 1768	BS 1981 and BS 3155[a]	BS 1981 and BS 3155[a]
[a]0	—	—	—	—	0.07	0.08
[a]1	—	—	—	—	0.07	0.08
[a]2	—	—	—	—	0.10	0.12
[a]3	—	—	—	—	0.10	0.12
[a]4	—	—	—	—	0.19	0.22
[a]5	—	—	—	—	0.29	0.34
[a]6	—	—	—	—	0.29	0.34
[a]8	—	—	—	—	0.36	0.42
[a]10	—	—	—	—	0.41	0.48
[a]12	—	—	—	—	0.58	0.66
in						
1/4	0.66	0.56	0.72	0.81	0.62	0.72
5/16	0.89	0.74	0.95	1.05	0.99	1.14
3/8	1.18	0.95	1.24	1.39	1.25	1.42
7/16	1.71	1.40	1.82	2.01	—	—
1/2	2.10	1.76	2.21	2.55	—	—
9/16	2.78	2.33	2.96	3.35	—	—
5/8	3.27	2.69	3.45	4.04	—	—
3/4	4.72	3.81	4.97	5.59	—	—

[a] BS 3155, "*American machine screws and nuts in sizes below 1/4 in diameter*".

Table 10 — *Table deleted*

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