BRITISH STANDARD A.101:1969+A3:2012

AEROSPACE SERIES

METRIC AND INCH UNITS

GENERAL REQUIREMENTS FOR TITANIUM BOLTS

BRITISH STANDARDS INSTITUTION

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BRITISH STANDARD : AEROSPACE SERIES

SPECIFICATION FOR

GENERAL REQUIREMENTS FOR TITANIUM BOLTS

FOREWORD

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 June 1969. Amendment No.3 came into effect on 30 September 2012. It was prepared by Technical Committee ACE/12, *Aerospace fastners and fastenings.* A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

BS A 101:1969+A3:2012 supersedes BS A 101:1969, incorporating Amendments Nos. 1 and 2, which is withdrawn.

Information about this document

The start and finish of text introduced or altered by Amendment No.3:2012 is indicated in the text by tags ⟨A3⟩ and ⟨A3⟩. Minor editorial changes are not tagged. Changes from Amendments Nos.1 and 2 are not shown.

This British Standard is intended for use in conjunction with those 'A' series British Standard Aerospace specifications in which conformity to this standard is a specific requirement.

It may also be applicable to other aerospace threaded fasteners if required by the relevant specification, drawing, contract or order, and is a companion to British Standard A.100, 'General requirements for bolts and nuts of tensile strength not exceeding 125 hbar (180 000 lbf/in^2)'.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

The standard makes reference to the following specifications:

British Standard:

British Standard A.4. Test pieces and test methods for metallic materials for aircraft.

British Standard TA.28. Titanium-aluminium-vanadium forging stock.

⟨A3⟩ BS 350. Conversion factors for units ⟨A3⟩.

BS 1134. Centre-line-average height method for the assessment of surface texture.

⟨A3⟩ BS 6001-1. Sampling procedures for inspection by attributes – Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection.

Quality management systems - Requirements for aviation, space and defense organizations.

BS EN ISO 3452-4. Non-destructive testing – Penetrant testing – Part 4: Equipment.

BS EN ISO 7083. Technical drawings – Symbols for geometrical tolerancing – Proportions and dimensions.

BS ISO 80000-1. Quantities and units – Part 1: General ⟨A3⟩.

BS ISO 80000-1: BS EN ISO 9000:2005. Quality management systems - Fundamentals and vocabulary.

⟨A3⟩ *References deleted.* ⟨A3⟩

⟨A3⟩ *Footnotes deleted.* ⟨A3⟩

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SPECIFICATION

1. GENERAL

1.1 SCOPE

This British Standard specifies the general requirements for metric and inch aerospace bolts manufactured from titanium alloys.

The requirements related to nominal size are presented in individual tables for use as appropriate to the relevant bolt specification. The values tabulated for metric and inch bolts have a proportional relationship and are not direct conversions.

NOTE. Information concerning SI (metric) units is given in BS 350, and [A3] BS ISO 80000-1 [A3].

1.2 MATERIAL

1.2.1 The bolts shall be manufactured from the material specified in the relevant bolt specification.

1.2.2 Bolts may be rejected at any time for faults in or revealed by manufacture although they have been made from material which previously complied with the relevant material specification.

1.3 MANUFACTURE

1.3.1 The heads of bolts shall be formed by hot forging before heat treatment. Driving recesses and the lightening hole of the double hexagon design may be machined or forged.

1.3.1.1 The heating equipment for hot forging shall be approved by the Inspecting Authority and shall be of a type which ensures a consistent temperature throughout the batch of that part of the material being worked. This temperature shall be automatically controlled.

1.3.2 The forged blanks shall be heat-treated in accordance with the material specification to produce the properties required by the relevant bolt specification and this specification (2.7). No blank shall be subjected to the specified heat treatment more than three times.

1.3.3 The headed and heat-treated blanks shall have the shank and bearing surface of the head wet ground. The amount of metal removed shall be as little as is practicable, consistent with the production of a clean smooth surface, the maintenance of optimum grain flow around the underhead radii as specified in 2.6.2.1 and the removal of surface contamination as specified in 2.6.2.4.

1.3.4 Threads shall be formed by a single rolling process after final heat treatment.

1.3.5 For sizes No. 10 and above, and M5 and above, the head to shank fillet shall be rolled after final heat treatment. The fillet radius, after rolling, shall conform to that specified in the relevant bolt specification. The fillet area may be distorted as shown in Appendix F. There shall be no machining of the fillet radius after rolling.

1.3.6 All processes of manufacture shall be to the satisfaction of the Inspecting Authority.

1.4 DIMENSIONS

All bolts shall conform to the dimensions and tolerances specified in this standard and the relevant bolt specification. The dimensions shall be controlled in accordance with 2.3.

1.5 RUN-OUT OF SCREW THREADS

The bolts shall have a thread run-out conforming to the requirements given in Appendix G.

1.6 SURFACE TREATMENT

The bolts shall be surface treated in accordance with the relevant bolt specification.

1.7 IDENTIFICATION MARKING

1.7.1 Bolts shall have the manufacturer's identification applied to the upper face of the head.

1.7.2 Bolts of No. 10 or M5 and larger shall have the complete part number (e.g. A000-3-D) applied to the upper face of the head.

1.7.3 Each individual package of bolts shall have the complete part number, batch identification and inspection stamp clearly shown on the label.

1.7.4 The method of marking shall be by raised or depressed characters. The depressed characters shall be not greater than 0.25 mm (0.010 in) in depth and shall be of rounded root form.

1.8 PACKAGING

The bolts shall be packed so as to prevent damage during handling, transportation and storage. Bolts of one batch and part number shall be packed in unit packages. An assortment of unit packages may be in larger packages.

2. INSPECTION PROCEDURE

2.1 GENERAL

[A3] **2.1.1 Quality assurance authority.** The quality assurance system selected shall satisfy the requirements of the quality assurance authority.

NOTE 1. The appropriate quality assurance system for the manufacture of aerospace products is given in BS EN ISO 9000:2005 with BS EN 9100.

NOTE 2. Manufacturers and users are advised that in respect of Civil Aviation Authority (CAA) certification, this is no longer appropriate for the manufacture of standard parts (fasteners).

Manufacturers and users should therefore check with their local CAA office for eligibility. [A3]

2.1.2 Inspection. Inspection shall satisfy the requirements of the appropriate authority by use of the sample procedures specified in 2.2.2 on the finished products, except that by agreement with the local Inspecting Authority properly controlled and recorded interstage inspection may be substituted.

2.1.3 Materials and surface treatments. The manufacturer shall provide evidence to the Inspecting Authority that all materials and surface treatments comply with the relevant specifications, and shall also show that the identity of all materials has been maintained throughout all stages of bolt manufacture.

2.1.4 Records. The manufacturer shall establish a batch record chart (or card) to the satisfaction of the Inspecting Authority. The record shall show the batch quantity and the serial numbers of certificates covering approval of all materials. The results of all inspections and tests made in

accordance with this standard shall be recorded and correlated with the batch numbers, and the batch record chart (or card) shall show the serial numbers of those records to the satisfaction of the Inspecting Authority.

2.2 ACCEPTANCE OF PRODUCTION BATCHES

2.2.1 Definition of batch. A batch shall consist of finished bolts which are of the same type and diameter, fabricated by the same process from material of the same cast, heat-treated as one lot and processed and produced as one continuous run, free from any interruptions or changes such as, in the opinion of the Inspecting Authority, might be expected to result in a significant variation in the quality of the finished product.

2.2.2 Sampling. Except where 100% inspection is specified, random samples shall be taken from each batch in accordance with 2.2.3 for dimensional and non-destructive inspection, and with Appendices A and D for destructive inspection.

2.2.3 Samples for dimensional and non-destructive inspection. Samples for dimensional and non-destructive inspection shall be taken from each batch in accordance with ⟨A3⟩ BS 6001-1 ⟨A3⟩, at inspection levels shown in Table 1. The acceptance or rejection shall depend upon the acceptable quality levels (AQL's) applied to the characteristics given in Table 1.

TABLE 1. INSPECTION LEVELS

AQL	Inspection level II	Inspection level S-I
0.065	Penetrant flaw detection	
1.0	Shank diameter Thread size	Plain shank length Underhead radius Squareness Driving geometry Thread run-out
2.5	Protrusion (countersunk heads) Surface texture (visual) Burrs and plating (visual) Identification (visual)	Straightness of shank Concentricity
4.0	Overall length Thread chamfer Other dimensional characteristics	Head height (protruding heads)

2.3 CONTROL OF DIMENSIONS

2.3.1 All dimensions shall be controlled by a system of gauging approved by the Inspecting Authority. The type and quality of all gauges, projection apparatus (including diagrams) and inspecting techniques shall also be to the satisfaction of the Inspecting Authority. In case of dispute fixed limit gauges or optical projection (as appropriate) shall be used for checking dimensions of screw threads.

2.3.2 Each gauge and projection diagram shall be marked with its reference number (serial number) and, in the case of non-adjustable gauges, the gauging dimensions.

Each gauge shall further be certified initially, and thereafter the standard of accuracy of each gauge shall be maintained by regular certification either at an approved gauge test house or, if agreed with the Inspecting Authority, at the manufacturer's own test room. The accuracy of each projection diagram shall be to the satisfaction of the Inspecting Authority.

2.3.3 A record card shall be prepared and maintained, to the satisfaction of the Inspecting Authority, for each gauge, showing the initial dimensions of each gauging element, the frequency of the maintenance checks and the gauge dimensions resulting therefrom.

2.4 SURFACE TEXTURE

The surface texture, determined visually, shall be as specified in Table 2. In cases of dispute measurement shall be made in accordance with BS 1134.

TABLE 2. SURFACE TEXTURE

Feature	Roughness height rating maximum (CLA to BS 1134)	
	µin	µm
Head to shank fillet, thread root, thread sides, and thread run out	16	0.4
Shank and bearing surface of head	32	0.8
Others	125	3.2

2.5 GEOMETRIC TOLERANCES

The tolerances of the bolt's geometric features shall comply with Fig. 1.

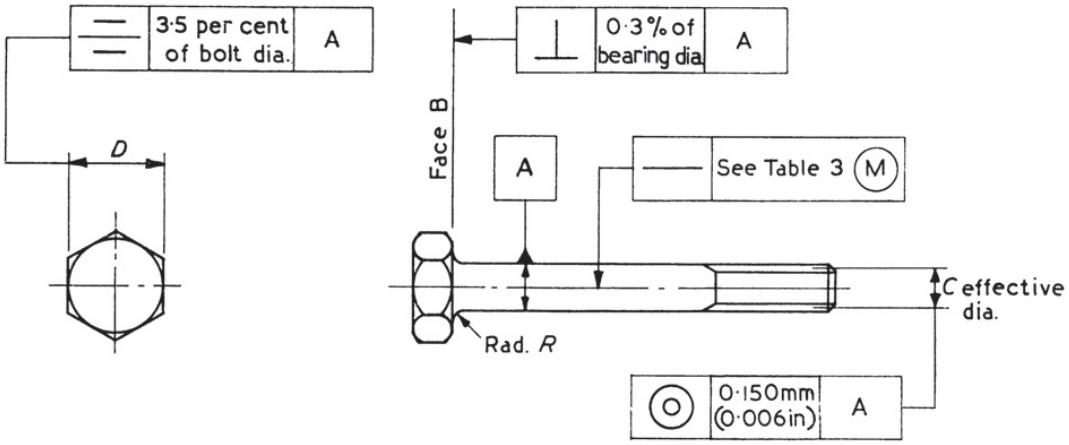

Fig. 1*a*. Hexagonal head

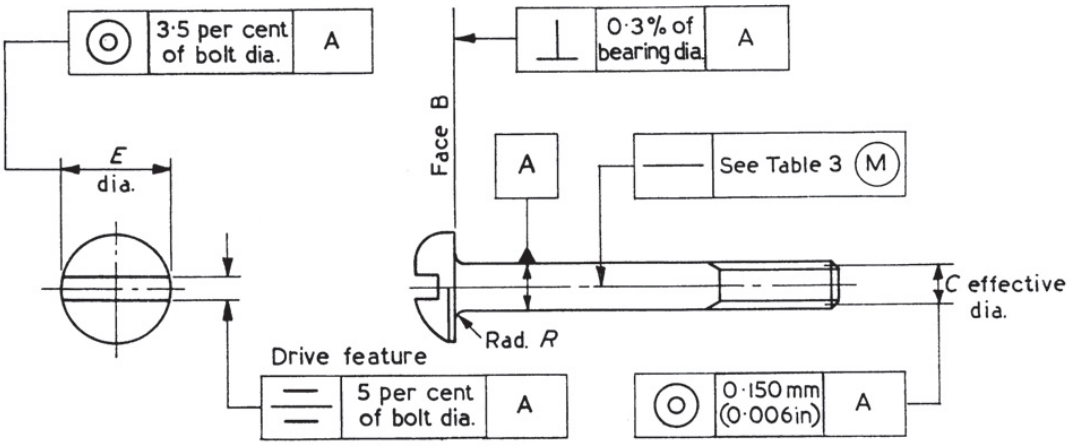

Fig. 1*b*. Pan head and mushroom head

NOTE 1. Fillet rad. *R* to blend smoothly with face and shank, subject to the requirements of Appendix F.

NOTE 2. Geometrical tolerances are presented in accordance with A3 BS EN ISO 7083 A3.

NOTE 3. Third angle projection.

Fig. 1 Geometrical tolerances

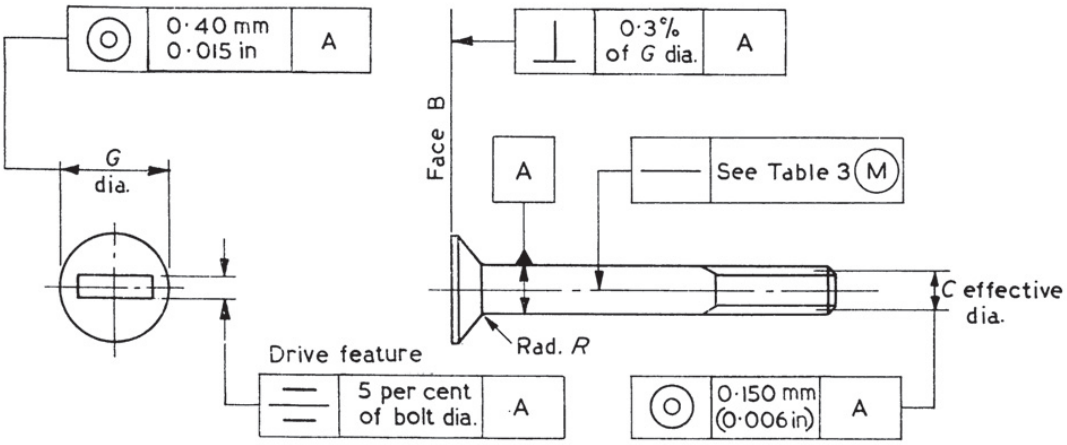

Fig. 1*c*. Countersunk head

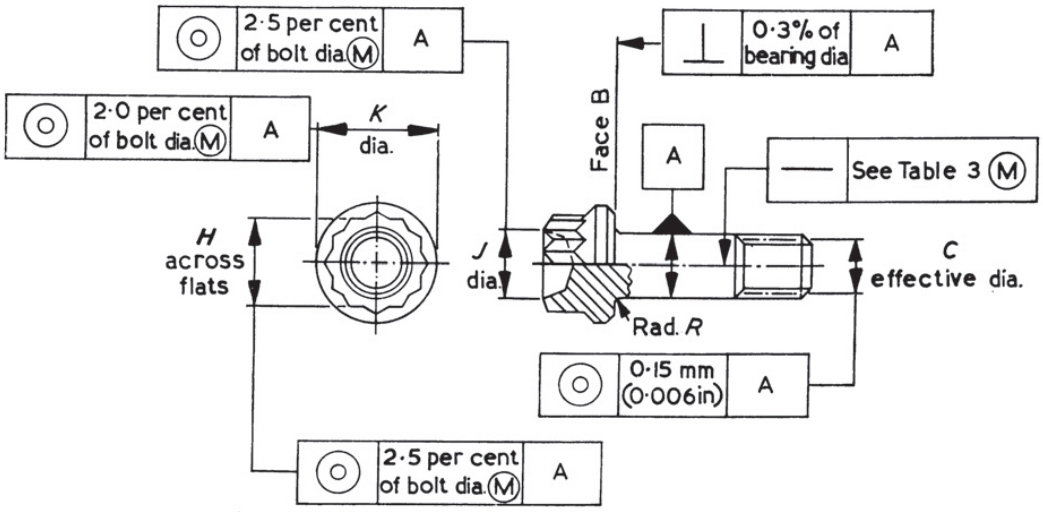

Fig. 1*d*. Double hexagon head

NOTE 1. Fillet rad. *R* to blend smoothly with face and shank, subject to the requirements of Appendix F.

NOTE 2. Geometrical tolerances are presented in accordance with A3 BS EN ISO 7083 A3.

NOTE 3. Third angle projection.

Fig. 1 Geometrical tolerances (cont'd)

TABLE 3. GEOMETRICAL STRAIGHTNESS TOLERANCES FOR BOLT SHANKS

TABLE 3A. INCH BOLTS

Bolt nominal size	Straightness tolerance
in No. 10	in 0.15 % of bolt length plus a constant of 0.001
0.25	0.12 % of bolt length plus a constant of 0.001
0.3125 0.375	0.10 % of bolt length plus a constant of 0.001
0.4375	0.07 % of bolt length plus a constant of 0.001
0.500 and larger	0.05 % of bolt length plus a constant of 0.001

TABLE 3B. METRIC BOLTS

Bolt nominal size	Straightness tolerance
mm M3 M4 M5	mm 0.15 % of bolt length plus a constant of 0.025
M6 M8	0.12 % of bolt length plus a constant of 0.025
M10	0.10 % of bolt length plus a constant of 0.025
M12	0.07 % of bolt length plus a constant of 0.025
M14 M16 M18 M20	0.05 % of bolt length plus a constant of 0.025

2.6 FREEDOM FROM MATERIAL DEFECTS

2.6.1 Non-destructive testing. Samples selected in accordance with *2.2.2* shall be subjected to fluorescent penetrant flaw detection in accordance with 〈A3〉 BS EN ISO 3452-4 〈A3〉. No cracks are permitted in any location. Other discontinuities are only permitted as in 2.6.2.3.

2.6.2 Destructive testing. Unless otherwise specified, samples shall be selected in accordance with 2.2.2. Test pieces prepared in accordance with Appendix E.1 shall be inspected as follows:

2.6.2.1 *Grain flow at transition from head to shank*. Macro specimens shall show continuous grain flow when examined at ×10 magnification (see Appendix E.4).

2.6.2.2 *Grain flow at threads*. Micro specimens shall show continuous grain flow following the general thread contour when examined at ×50 magnification (see Appendix E.2).

2.6.2.3 *Internal defects*. Macro- and micro- examination shall be used to reveal any discontinuities or cracks. No cracks or bursts are permitted in any location. Other discontinuities are only permitted as described in Table 4 and Appendix E.

2.6.2.4 *Surface contamination*. Micro-examination, at ×500 magnification, shall not show contamination greater than the limits specified in Table 4.

2.6.2.5 *Hydrogen content*. The heads of finished bolts shall not have a hydrogen content exceeding 0.0175 %.

The hydrogen content shall be determined for all inspection batches from material removed from the head of the finished bolt. One part per inspection batch shall be checked; if the hydrogen content is below the maximum limit, the batch shall be accepted, but if the hydrogen content is above the maximum limit, a second sample of 2 for batches of under 500 or 5 for batches of 500 and over shall be taken. When none of the analyses in the second sample exceeds the maximum limit, the batch shall be accepted; if any of the analyses in the second sample exceed the maximum limit, the batch shall be deemed not to comply with this standard.

2.6.2.6 *Microstructure*. The microstructure shall be free from gross alloy segregation and from overheating. (In the case of British Standard TA. 28 alloy, an overheated structure is considered to be one consisting of outlines of equiaxed prior β grains with no primary α.) The material shall be free from indications that it has been heated to a temperature above the β transus without subsequently receiving significant mechanical reduction in the α-β temperature range. Slight overheating adjacent to the top of the head is permissible provided measurement normal to the top surface of the head to the greatest depth of overheating does not exceed the limits shown in Table 4.

2.6.2.7 *Microstructural shearing*. A section through the thread profile shall be examined for indications of incipient microstructural shearing (shear banding) at a magnification of not less than ×100. Parts showing microstructural shearing below the pitch diameter shall be deemed not to comply with this standard. Where doubt exists, further samples shall be submitted to a tensile endurance test of 1190 MN/m^2* constant load for 5 h. During this test no sample shall develop cracks. Confirmation shall be obtained by microscopic examination of the section samples at a magnification of not less than ×100 (see Appendix E.5).

*Related to the cross section at thread minor diameter.

TABLE 4. DISCONTINUITIES AND SURFACE CONTAMINATION

TABLE 4A. INCH BOLTS

All dimensions are in inches

Location	Permissible condition	Max. depth normal to surface					
		Bolt nominal size					
		No. 10	0.250	0.3125	0.375	0.4375	0.500 to 1.000
Head to shank fillet	No discontinuities	—	—	—	—	—	—
Root of bolt threads Shank diameter Bearing surface of head	No surface contamination	—	—	—	—	—	—
Bolt thread locations (see Fig. 6)	Laps and surface irregularities	0.005	0.005	0.005	0.006	0.007	0.008
	No surface contamination	—	—	—	—	—	—
Non-bearing surface of head	Laps, seams, nicks or gouges	0.010	0.010	0.010	0.012	0.014	0.016
	Surface contamination	0.003	0.003	0.003	0.003	0.003	0.003
Recess	Surface contamination	0.002	0.002	0.002	0.002	0.002	0.002
Protruding head	Overheating per microstructure requirements	0.080	0.080	0.115	0.140	0.160	0.185
Countersunk head	Overheating per microstructure requirements	0.050	0.050	0.080	0.110	0.130	0.150

TABLE 4B. METRIC BOLTS

All dimensions are in millimetres

Location	Permissible condition	Max. depth normal to surface					
		Bolt nominal size					
		M3, M4 and M5	M6	M8	M10	M12	M14 to M20
Head to shank fillet	No discontinuities	—	—	—	—	—	—
Root of bolt threads Shank diameter Bearing surface of head	No surface contamination	—	—	—	—	—	—
Bolt thread locations (see Fig. 6)	Laps and surface irregularities	0.13	0.13	0.13	0.15	0.18	0.20
	No surface contamination	—	—	—	—	—	—
Non-bearing surface of head	Laps, seams, nicks or gouges	0.25	0.25	0.25	0.30	0.35	0.40
	Surface contamination	0.075	0.075	0.075	0.075	0.075	0.075
Recess	Surface contamination	0.05	0.05	0.05	0.05	0.05	0.05
Protruding head	Overheating per microstructure requirements	2.00	2.3	2.9	3.5	4.0	4.75
Countersunk head	Overheating per microstructure requirements	1.25	1.65	2.0	2.8	3.3	3.8

2.7 TESTS TO DETERMINE MECHANICAL PROPERTIES

2.7.1 Performance tests. Tension, shear and tension-tension-fatigue tests shall be made on bolts selected in accordance with the requirements of 2.2.2, except as specified below:

(1) Tensile tests on threaded bolts having a nominal grip less than ¾ of the nominal diameter.

(2) Shear tests on protruding head bolts having a nominal grip less than twice the nominal diameter and countersunk head bolts having a nominal grip less than 2½ times the nominal diameter.

(3) Tension-tension-fatigue testing on threaded bolts having a grip length less than twice the nominal diameter, or of a size smaller than No. 10 and M5. or bolts with drilled shanks.'

2.7.2 Testing procedure. The performance tests shall be conducted under the following conditions:

2.7.2.1 Tensile tests shall be made in a jig similar to that shown in Fig. 2 of Appendix C. The tensile strengths of the bolts shall conform with the requirements of Appendix A.

2.7.2.2 Shear tests shall be made in a jig similar to that shown in Fig. 3 of Appendix C. The shear strengths of the bolts shall conform with the requirements of Appendix A.

2.7.2.3 Tension-tension-fatigue tests shall be made in a jig similar to that shown in Fig. 2 of Appendix C. The tests on the bolts shall conform with the requirements of Appendix B.

2.7.3 Heat treatment control tests.

2.7.3.1 *Initial test*. A minimum of one test sample shall be heat treated with each batch of bolt blanks. The test sample(s) shall be selected from material of the same nominal diameter and cast used to manufacture the bolt blanks. Tensile test piece(s) shall be prepared from the test sample(s) in accordance with British Standard A.4, Part 1, Section One, and shall not be further heat-treated or worked before testing.

The tensile properties obtained from the test piece(s), tested in accordance with British Standard A.4, Part 1, Section One, shall meet the requirements of the relevant bolt specification.

2.7.3.2 *Retest*. If any test piece fails to meet the specified tensile requirements the inspector shall allow one or both of the following procedures to be adopted by the manufacturer:

(1) Select from the same batch twice the number of test samples previously selected. The tensile properties obtained from the test pieces prepared from these further samples shall meet the requirements of 2.7.3.

(2) Allow the batch, unless the blanks have been machined, to be re-heat-treated and tested in accordance with 2.7.3. If the test piece(s) fail to meet the specified tensile requirements the batch shall be rejected.

APPENDIX A

SAMPLING AND ACCEPTANCE REQUIREMENTS FOR TENSILE, SHEAR AND TENSION-TENSION-FATIGUE TESTS

A.1 Tension and shear tests. Each sample, selected in accordance with Table 5, shall be evaluated for tension and shear as follows:

(1) First sample. Accept if $\bar{X}_1 - K_a S_1 \geqslant M$, reject if $\bar{X}_1 - K_r S_1 < M$.

Take a second sample if the batch is not accepted or rejected.

(2) Second sample. Accept if $\bar{X}_t - K_t S_t \geqslant M$, reject if $\bar{X}_t - K_t S_t < M$.

Where M = Minimum tensile or shear values per Appendix H,
X_1 = individual value in first sample,
$\bar{X}_1$ = average of X_1 values,
X_t = individual value in combined samples,
$\bar{X}_t$ = average of X_t values,

$$S_1 = \sqrt{\frac{N_1 \sum X_1^2 - (\sum X_1)^2}{N_1 (N_1 - 1)}},$$

$$S_t = \sqrt{\frac{N_t \sum X_t^2 - (\sum X_t)^2}{N_t (N_t - 1)}}.$$

where N_1 = number of parts in first sample,
N_t = number of parts in combined sample.

K_a, K_r and K_t are coefficients of S (best estimate of the standard deviation) and are used to determine acceptance or rejection of batches represented by the sample.

A.2 Tension-tension-fatigue tests. Each sample, selected in accordance with Table 5, shall be evaluated for fatigue as follows:

(1) First sample. Accept if the geometric mean life is > 30 000 cycles, and if the minimum individual life is > 20 000 cycles.

Reject if the geometric mean life is ⩽ 30 000 cycles or if 2 or more have lives of ⩽ 15 000 cycles.

Take a second sample if the batch is not accepted or rejected.

(2) Second sample. Accept if the geometric mean life of the combined samples is > 30 000 cycles, and if the minimum individual life in the second sample is > 15 000 cycles.

Reject if the geometric mean life of the combined samples is ⩽ 30 000 cycles, or if the minimum individual life in the second sample is ⩽ 15 000 cycles.

The sample geometric mean life shall be calculated from the actual cycle at failure or 60 000 cycles, whichever is the least.

A.2.1 Fatigue tests to destruction shall be conducted, to establish the statistical distribution curve. The tests may be discontinued before destruction as noted in Appendix B.1. The sampling plan may be revised with the agreement of the Inspecting Authority when distribution curve is well established.

TABLE 5. VARIABLES PLAN FOR TENSION AND SHEAR, AND ATTRIBUTES PLAN FOR TENSION-TENSION-FATIGUE

Batch size	Sample No.	Sample size	Total	First sample		Combined samples
				K_a	K_r	K_t
Under 201	First	5	5	2.21	0.89	—
	Second	10	15	—	—	1.74
201 to 500	First	6	6	2.22	0.94	—
	Second	12	18	—	—	1.70
501 to 1300	First	7	7	2.32	1.10	—
	Second	14	21	—	—	1.78
1301 to 3200	First	8	8	2.48	0.99	—
	Second	16	24	—	—	1.81
3201 to 8000	First	10	10	2.34	1.31	—
	Second	20	30	—	—	1.80
8001 and over	First	15	15	2.20	1.42	—
	Second	30	45	—	—	1.83

NOTE. Coefficients K_a, K_r and K_t have been obtained from 'Sampling inspection by variables' by BOWKER and GOODS (published by McGraw-Hill Book Co., Inc.). The fatique testing attribute plan is an adaptation of the 1 % AQL tables from the same source.

APPENDIX B

TENSION-TENSION-FATIGUE TESTING REQUIREMENTS

B.1 Tension-tension fatigue tests. Tension-tension-fatigue tests on individual bolts shall be applied at a cycling rate within the range 500 to 10 000 cycles per minute and at the load range stated in Table 6, which shall be continued for 60 000 cycles, or to failure, whichever occurs first.

Bolts which have survived the fatigue test shall be destroyed, as they are no longer suitable for aircraft use.

B.2 Fatigue testing machine. The fatigue testing machine shall maintain constant tensile loads within $\pm$ 2 % or $\pm$ 130 N (30 lbf), whichever is the greater, throughout the entire range of load levels encompassed by the test.

B.3 Tandem testing. The tension-tension-fatigue testing of two or more bolts in tandem is permissible.

TABLE 6. FATIGUE TESTING LOADS (110 hbar (1100 MN/m^2) TENSILE STRENGTH MATERIAL)

TABLE 6A. INCH BOLTS

Bolt nominal size	Protruding head		100 ° Countersunk head	
	*High load	†Low load	*High load	†Low load
in	lbf	lbf	lbf	lbf
No. 10	1 350	340	1 050	265
0.250	2 500	625	1 950	490
0.3125	4 040	1 010	3 140	785
0.375	6 200	1 550	4 850	1 210
0.4375	8 400	2 100	6 540	1 640
0.500	11 400	2 850	8 900	2 220
0.5625	14 500	3 620	11 300	2 820
0.625	18 500	4 600	14 400	3 600
0.750	27 000	6 750	21 000	5 250
0.875	37 000	9 250	28 800	7 200
1.000–12	48 200	12 000	37 600	9 400
1.000–14	49 800	12 400	38 800	9 700

TABLE 6B. METRIC BOLTS

Bolt nominal size	Protruding head		100 ° Countersunk head	
	*High load	†Low load	*High load	†Low load
mm	kN	kN	kN	kN
M5	6.85	1.71	5.34	1.33
M6	9.66	2.41	7.51	1.88
M8	17.70	4.42	13.80	3.65
M10	28.20	7.05	22.00	5.50
M12	43.80	10.95	34.00	8.50
M14	56.50	14.12	44.00	11.00
M16	78.00	19.50	60.50	15.12
M18	94.50	23.62	73.50	18.37
M20	122.00	30.50	94.50	23.62

*Based upon the area at the basic minor diameter of the thread, the high load specified will produce a stress of 530 MN/m^2 (77 000 lbf/in^2) in hexagonal (or protruding) head bolts and 410 MN/m^2 (60 000 lbf/in^2) in 100° countersunk head bolts.

†The low load specified is 25 % of the high load.

APPENDIX C

TEST JIGS

C.1 Static tension and tension-tension-fatigue test jig. A typical jig is illustrated in Fig. 2.

C.1.1 The jig shall be so constructed that the tests are conducted with a nut, threaded adaptor or threads in the lower part of the jig, provided that the components have sufficient length to develop the full strength of the bolt without stripping the sample bolt thread.

C.1.2 The jig shall ensure that the test bolts have at least two bolt threads adjacent to the grip not engaged with the internal threads of the nut, adaptor or jig, as permitted in C.1.1.

C.2 Shear strength jig. A typical compression type jig is illustrated in Fig. 3. An alternative tension type of jig having similar features may be employed. In either case the essential dimensions shall be as given in Table 7.

C.3 Jig materials. The test jigs in C.1 and C.2 shall be designed to suit the test machine being employed, and shall be constructed from alloy steel having a minimum tensile strength of 1250 MN/m^2 (125 hbar) (180 000 lbf/in^2).

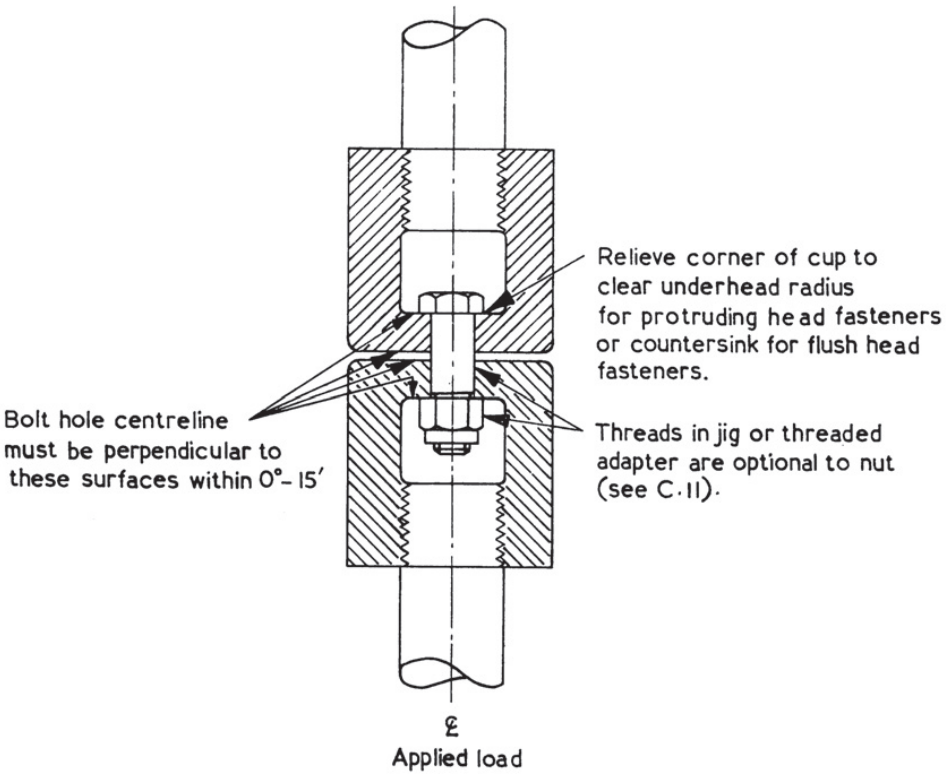

Fig. 2. Typical static tension and tension-tension-fatigue test jig

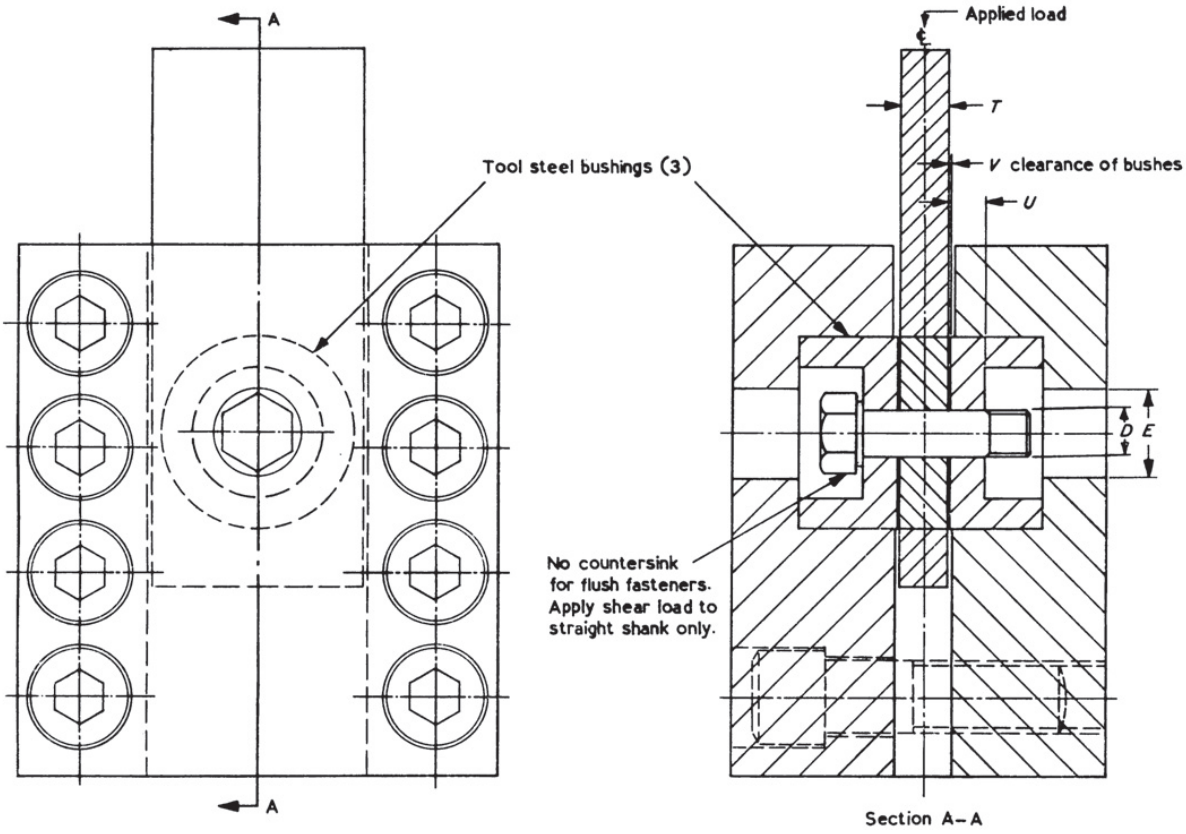

Fig. 3. Typical compression type shear strength test jig

TABLE 7. DIMENSIONS FOR SHEAR STRENGTH TEST JIG

TABLE 7A. INCH BOLTS

Bolt nominal size	*D*		*E*	*T*	*U*	*V*
	Max.	Min.	Min.	± .001	± .001	Max.
in	in	in	in	in	in	in
No. 10	0·1910	0.1903	0.46	0.190	0.095	0.001
0.250	0.2510	0.2503	0.54	0.250	0.125	
0·3125	0·3135	0.3128	0.61	0.312	0.156	
0.375	0.3760	0.3753	0.68	0.375	0.188	
0.4375	0.4385	0.4378	0.83	0.438	0.219	
0.500	0.5010	0.5003	0.90	0.500	0.250	
0.5625	0.5630	0.5623	1.12	0.562	0.281	
0·625	0.6255	0.6248	1.25	0.625	0.312	
0·750	0.7505	0.7498	1.38	0.750	0.375	
0.875	0.8755	0.8748	1.56	0.875	0.438	
1.000	1.0005	0.9998	1.81	1.000	0.500	

TABLE 7B. METRIC BOLTS

Bolt nominal size	*D**		*E*	*T*	*U*	*V*
	Max.	Min.	Min.	±0.025	±0.025	Max.
mm	mm	mm	mm	mm	mm	mm
M3	3.03	3.01	7.2	3.00	1.50	0.025
M4	4.03	4.01	8.9	4.00	2.00	
M5	5.03	5.01	10.0	5.00	2.50	
M6	6.03	6.01	12.3	6.00	3.00	
M8	8.03	8.01	15.8	8.00	4.00	
M10	10.03	10.01	20.4	10.00	5.00	
M12	12.02	12.00	22.7	12.00	6.00	
M14	14.02	14.00	26.2	14.00	7.00	
M16	16.02	16.00	28.5	16.00	8.00	
M20	20.02	20.00	35.4	20.00	10.00	

* These dimensions are based upon bolt diameters given in current French standards, and are subject to International agreement for tolerances on bolt diameters.

APPENDIX D

SAMPLING AND ACCEPTANCE REQUIREMENTS FOR METALLURGICAL PROPERTIES

D.1 Discontinuities

D.1.1 When there are no penetrant indications, (see 2.6.1) examine a random sample selected in accordance with Table 8.

Accept or reject the batch in accordance with Table 8.

NOTE. This sample may also be used for the examination of surface contamination micro structure, grain growth or grain flow as given in D.2 below.

D.1.2 When penetrant indications are present, increase the number of samples selected to a level sufficient to determine whether penetrant indications reveal discontinuities exceeding the level in Table 4. If excessive discontinuities in any bolt are found, the entire batch may be rejected, or the samples may be subjected to penetrant screening and all parts with similar penetrant indications rejected.

NOTE. Bolts used for metallurgical examination of discontinuities may be used as part or all of the sample for the examination of other metallurgical characteristics noted in D.2.

D.2 Surface contamination, microstructure, microstructural shearing, grain growth and grain flow. Metallurgically examine a sample selected in accordance with Table 8.

Accept or reject the entire batch in accordance with Table 8.

NOTE. The sample may be random, or may consist entirely, or in part, of bolts previously examined for discontinuities in accordance with D.1.

TABLE 8. ATTRIBUTE PLAN FOR METALLURGICAL PROPERTIES

Batch size	Sample size	Acceptance No.	Rejection No.
Under 181	*2	0	1
181 to 500	*3	0	1
501 to 800	5	0	1
801 to 1300	7	0	1
1301 to 3200	10	0	1
3201 to 8000	15	0	1
8001 and over	25	0	1

*For microstructural shearing the minimum size is 5.

APPENDIX E

METALLURGICAL EXAMINATION

E.1 Preparation of metallurgical specimens. Specimens shall be cut from sample bolts in the manner indicated by the arrows in Fig. 4, and shall be etched in an aqueous solution of 1% hydrofluoric acid and 2% nitric acid.

E.2 Grain flow at threads. Fig. 5 demonstrates the acceptable grain flow in the thread.

E.3 Laps and surface irregularities in threads. Typical irregularities are demonstrated in Fig. 6.

E.4 Grain flow at transition of shank to head. Typical macro specimens of the grain flow are demonstrated in Figs. 7*a*, 7*b* and 7*c*.

E.5 Microstructural shearing. This defect generally manifests itself as a V or U shape of rippled grain structure immediately below the thread root, but may also occur as chevrons within the thread crest. Typical irregularities are shown in Fig. 7*d*.

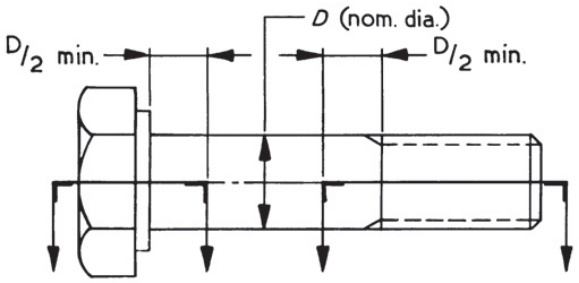

Fig. 4. Detail of metallurgical specimen

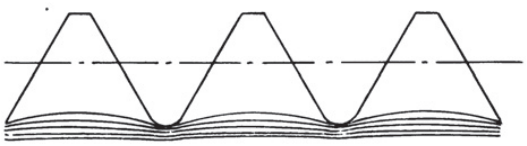

Fig. 5. Grain flow in threads

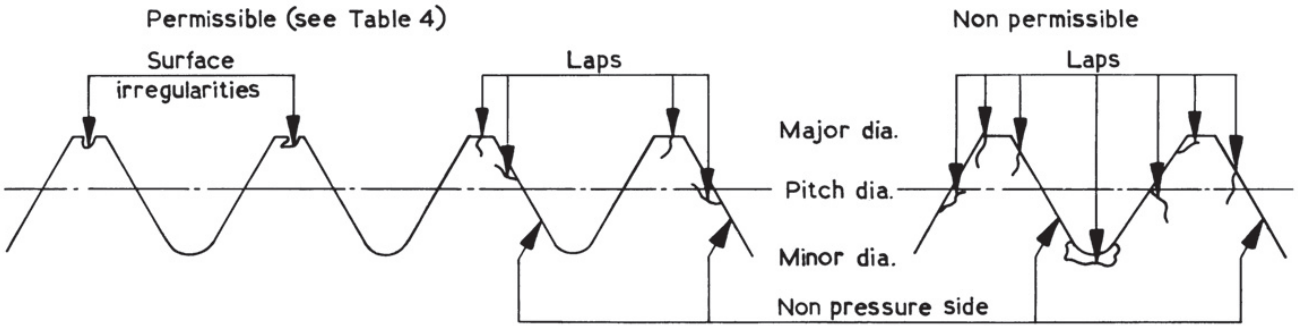

Fig. 6. Typical laps and surface irregularities in threads

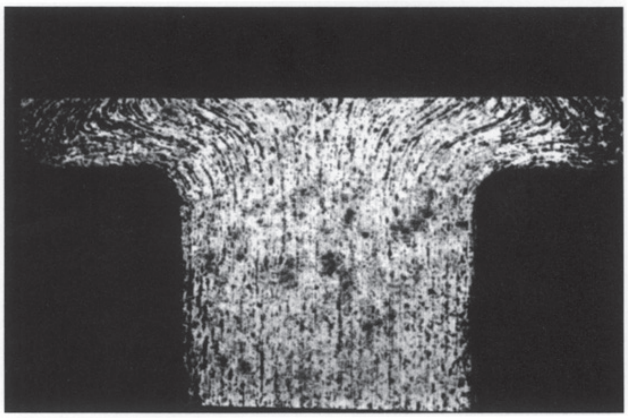

Fig. 7*a*. Satisfactory grain flow (after machining if applicable)

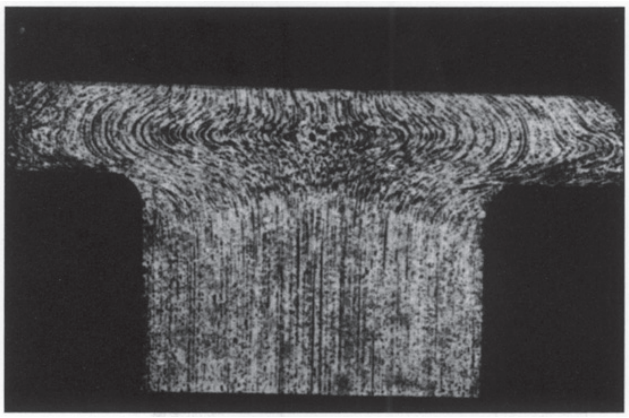

Fig. 7*b*. Minimum acceptable standard of grain flow (after machining if applicable)

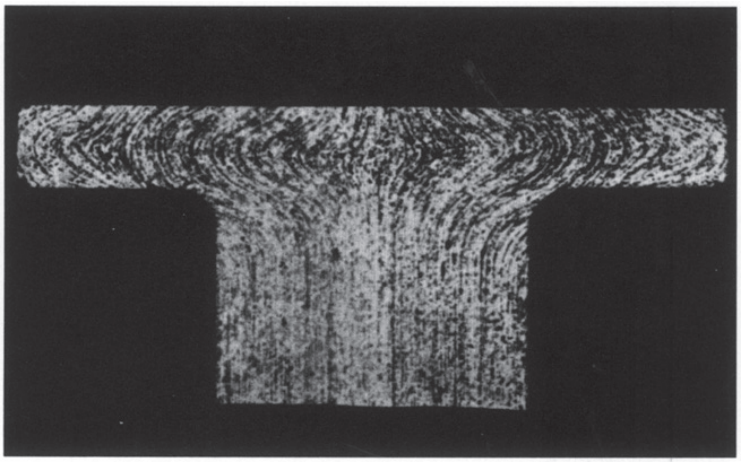

Fig. 7*c*. Unacceptable grain flow (after machining if applicable)

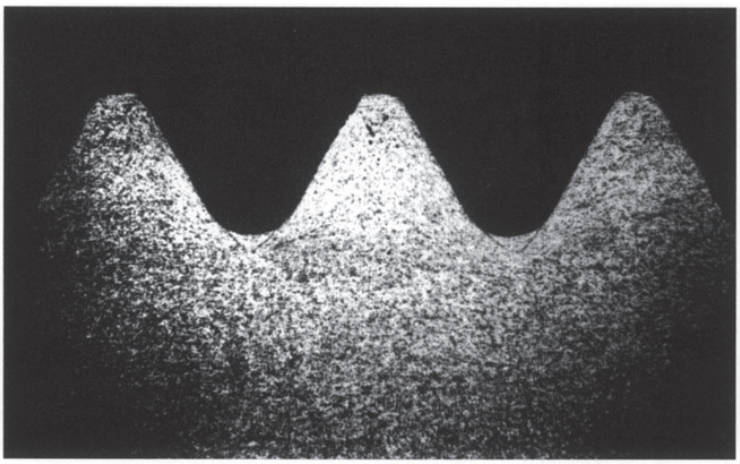

Fig. 7*d*. Microstructural shearing: typical irregularities

APPENDIX F

HEAD TO SHANK FILLET ROLLING—PERMISSIBLE DISTORTION

F.1 Distortion of the head to shank fillet due to cold working shall not exceed 0.05 mm (0.002 in) above or below the points indicated at *A* and *B* in Fig. 8.

F.2 The distorted area shall not extend beyond the dimension *C* indicated in Fig. 8 and listed in Table 9.

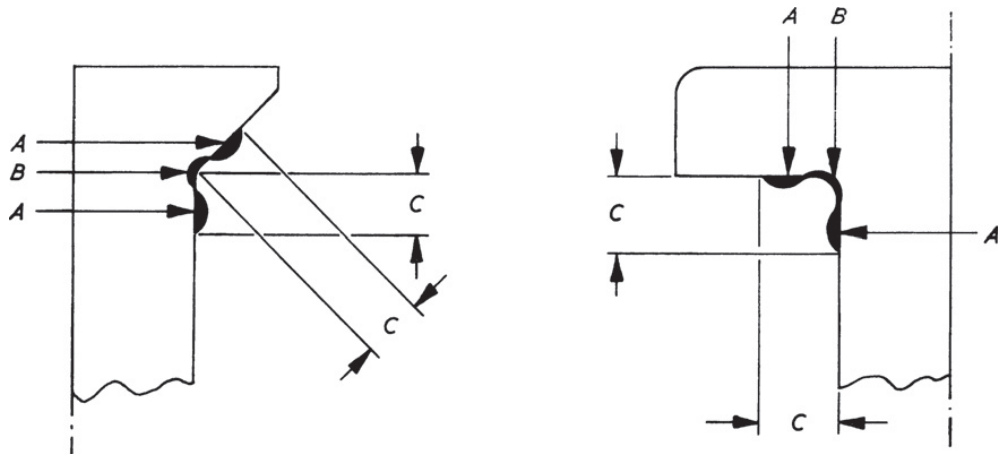

Fig. 8. Permissible distortion of head to shank fillet

TABLE 9. DIMENSIONS OF PERMISSIBLE DISTORTION

TABLE 9A. INCH BOLTS

Bolt nominal size	Dimension *C* (max.)
in	in
No. 10	0.062
0.250	0.062
0.3125	0.094
0.375	0.094
0.4375	0.125
0.5000	0.125
0.5625	0.125
0.625	0.125
0.750	0.156
0.875	0.156
1.000	0.156

TABLE 9B. METRIC BOLTS

Bolt nominal size	Dimension *C* (max.)
mm	mm
M5	1.7
M6	2.0
M8	2.4
M10	3.0
M12	3.3
M14	3.6
M16	3.8
M18	3.9
M20	4.0

APPENDIX G

THREAD RUN-OUT

G.1 Definitions

G.1.1 *Thread run-out* is that portion of the bolt between the end of the full thread and the beginning of the true shank or, if there is no true shank, the underhead or fillet radius.

For full shank bolts it will comprise incomplete threads and also a portion of the blank diameter from which the thread is rolled (see G.2.1.2).

For relieved shank bolts it will comprise incomplete threads only.

G.1.2 *The end of the full thread* is that point on the root of the thread nearest to the bolt shank or head up to which the thread conforms to the requirements of the relevant British Standard.

G.2 Manufacturing and inspection requirements

G.2.1 *Full shank bolts*

G.2.1.1 Unless otherwise specified on the drawing, the run-out shall be not more than two thread pitches nor less than one thread pitch.

G.2.1.2 The transition between the blank diameter and the full shank diameter shall consist of a radius and either a taper or a shoulder as shown in Figs. 9 and 10. The radius *A* shall not be less than that tabulated in Table 10.

G.2.2 *Relieved shank bolts*. Unless otherwise specified on the drawing, the run-out shall be not more than two thread pitches nor less than five-eighths thread pitch as shown in Fig. 11.

G.2.3 *Threaded to head bolts*. Unless otherwise specified on the drawing the dimension *X* between the end of the full thread and the face of the bolt head shall be determined as shown in Figs. 12 and 13, where $X = (1\frac{1}{2}$ thread pitches $+ B$ max.) suitably rounded to the number of decimal places and tolerances given below:

	Inch bolts	Metric bolts
Rounded to: decimal places	3	2
Tolerance:	in	mm
plus	0.020	0.50
minus	0.000	0.00

The run-out shall be as specified in G.2.1 or G.2.2, as appropriate, but shall not encroach on the underhead or fillet radius *B*.

G.2.4 *Incomplete thread*

G.2.4.1 The root radius of the incomplete thread shall not be less than the minimum root radius specified for the full thread.

G.2.4.2 The incomplete thread shall gradually decrease in depth within the specified length and shall blend smoothly with the shank diameter or the blank diameters as appropriate.

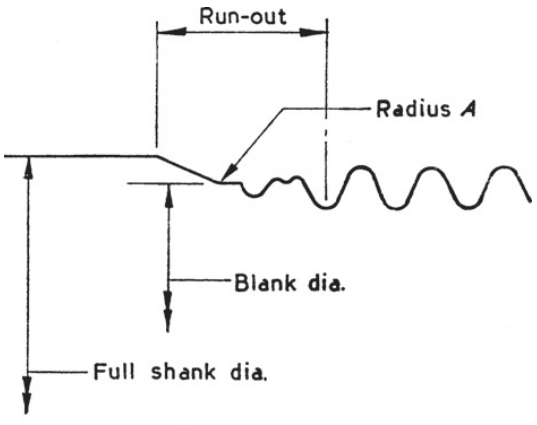

Fig. 9. Thread to shank run-out, tapered

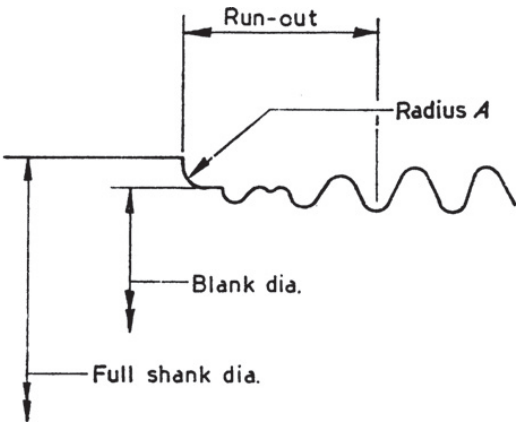

Fig. 10. Thread to shank run-out, shouldered

TABLE 10. DIMENSIONS FOR RADIUS *A*

TABLE 10A. INCH BOLTS

Threads per inch	Radius *A*
	in
over 28	0.005
28 to 13	0.010
12 to 10	0.015
9 and 8	0.020

TABLE 10B. METRIC BOLTS

Pitch	Radius *A*
mm	mm
0.35 to 0.80	0.12
1.00 to 1.75	0.25
2.00 to 2.50	0.38

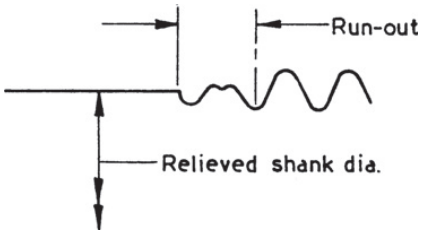

Fig. 11. Thread to shank run-out, relieved

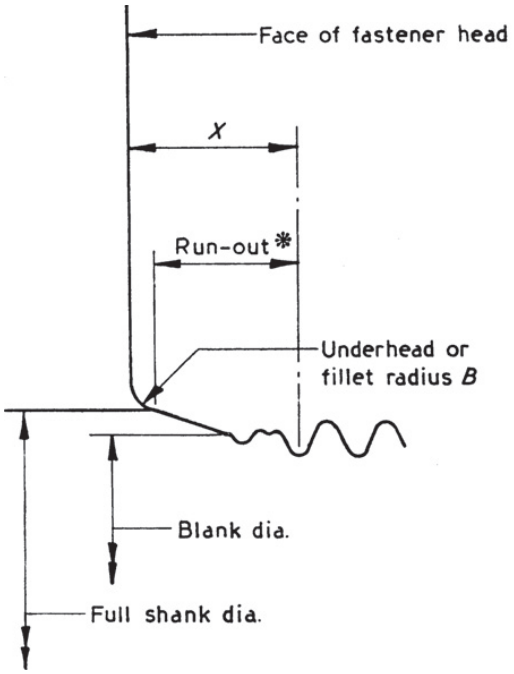

Fig. 12. Thread to head run-out, tapered

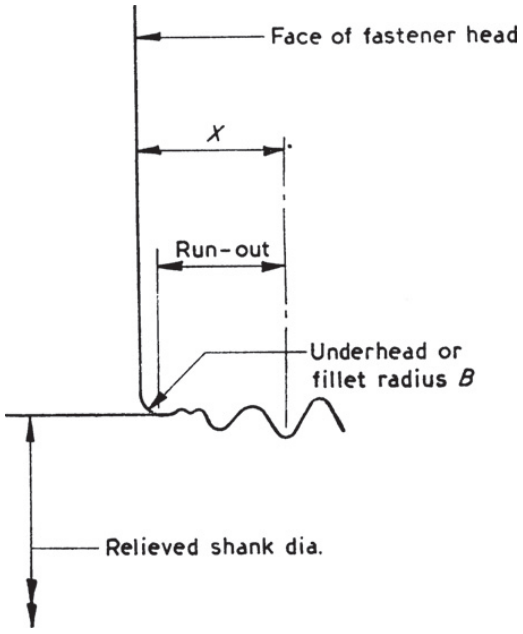

Fig. 13. Thread to head run-out, relieved

*Alternatively as shown in Fig. 10.

APPENDIX H

BOLT STRENGTH LEVELS

H.1 Test conditions. Shear and tensile tests on individual bolts shall be applied at a loading rate not greater than those stated in Tables 11 and 12.

H.2. Test results. The ultimate strength levels of the bolts shall not be less than the figures stated in Tables 11 and 12.

TABLE 11. SHEAR STRENGTH OF BOLTS (110 HBAR (1100 MN/m^2) TENSILE STRENGTH MATERIAL)

TABLE 11A. INCH BOLTS

Bolt nominal size	Ultimate* double shear (min.)	Load rate per minute (max.)
in	lbf	lbf
No. 10	5 380	2 800
0.250	9 300	4 900
0.3125	14 600	7 700
0.375	21 000	11 000
0.4375	28 600	15 000
0.500	37 300	20 000
0.5625	47 200	25 000
0.625	58 300	31 000
0.750	83 900	44 000
0.875	114 200	60 000
1.000	149 200	85 000

TABLE 11B. METRIC BOLTS

Bolt nominal size	Ultimate* double shear (min.)	Load rate per minute (max.)
mm	kN	kN
M3	9.2	5.0
M4	16.4	9.0
M5	25.7	13.5
M6	37.0	20.0
M8	65.8	35.0
M10	102.9	54.5
M12	148.7	78.5
M14	201.6	108.0
M16	263.4	140.0
M18	333.4	177.0
M20	411.6	216.0

* The figures for ultimate double shear breaking load are based upon the formula $L_s = 2F_{sur}A$

where F_{su} = ultimate shear stress (for TA.28 material = 65 hbar = 95 000 lbf/in^2 = 650 MN/m^2.).

A = cross-sectional area of nominal bolt diameter.

TABLE 12. TENSILE STRENGTH OF BOLTS (110 HBAR (1100 MN/m^2) TENSILE STRENGTH MATERIAL)

TABLE 12A. INCH BOLTS

Bolt nominal size	Ultimate tensile breaking load (min.)	Load rate per minute (max.)
in	lbf	lbf
No. 10	3 180	1 000
0.250	5 820	1 800
0.3125	9 200	2 900
0.375	14 000	4 300
0.4375	18 900	6 000
0.500	25 600	8 000
0.5625	32 400	10 000
0.625	41 000	12 700
0.750	59 500	18 500
0.875	81 500	25 200
1.000-12	106 000	32 800
1.000-14	108 200	33 600

TABLE 12B. METRIC BOLTS

Bolt nominal size	Ultimate tensile breaking load (min.)	Load rate per minute (max.)
mm	kN	kN
M3	5.4	1.8
M4	9.4	3.0
M5	15.25	5.0
M6	21.7	7.0
M8	39.6	12.5
M10	62.8	19.5
M12	96.6	30.0
M14	136.7	43.0
M16	183.8	57.0
M18	237.6	73.0
M20	302.5	95.0

This British Standard, having been approved by the Aerospace Industry Standards Committee, was published under the authority of the Executive Board of the Institution on 30 June, 1969.

The following BSI references relate to the work on this standard:
Committee reference ACE/12 Drafts for comment 67/31267, 12/30254180 DC

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