



4S 100 : 1975

(Superseding British Standard 3S 100)

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British Standard : Aerospace Series

Procedure for

Inspection and testing of wrought steels (other than sheet, strip and tubes)

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Section one

Foreword

This British Standard, which covers the inspection and testing requirements for wrought steels, other than sheet, strip and tubes, supersedes British Standard 3S 100 : 1963.

The procedure defined herein is primarily for use in conjunction with related material specifications in the 'S' series of British Standards and the Ministry of Defence (Procurement Executive) D.T.D. series. It may also be used with other material specifications by agreement between the purchaser and the supplier.

NOTE. The corresponding requirements for sheet and strip and for tubes are covered by British Standard S 500 and British Standard T 100, respectively.

In this revision, in which all values are given in SI units only, the definitions have been expanded and account has been taken of narrow end-up ingots, vacuum arc and electroslag melting. The requirements for fracture testing have been revised and new requirements for elevated temperature and hardenability tests, for grain size determination and for optional checks on the overheating of rolled bar material have been introduced. The section which covered billets

and bars for forging now covers such materials for all types of subsequent working, the sections relating to parts finally heat treated after machining (other than carburizing steels) and to case-hardened parts (carburizing steels) have been combined, and the section relating to wire for the manufacture of forged bolts and nuts now covers bar for the same purpose.

In addition, the appendices containing information on ruling section, tables of standard sizes and tolerances for bright bars and details of preferred sizes of bars of rectangular section have been deleted, the appendix covering ultrasonic examination has been expanded, and new appendices relating to the detection and avoidance of coarse grain and to standards of cleanness have been added.

NOTE. Arising from these and other editorial changes, the section and clause numbers in this standard are not in all cases the same as those in the previous edition so that, where such numbers are given in current material specifications, they may not now be appropriate. The progressive revision of the material specifications will rectify this matter.

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Section one

1. Scope

This British Standard specifies the requirements for the inspection and testing of steel billets, bars and forgings, of parts made from such forms and subsequently heat treated and of spring steel rod, wire and springs, to be used for aerospace purposes and other critical applications.

2. General

2.1 In this standard, whenever agreement between the manufacturer and the purchaser is required the onus is on the purchaser to obtain the concurrence of the parent design firm. If such concurrence is mandatory the word 'purchaser' is marked with an asterisk.

2.2 The 'Quality Assurance Authority' referred to throughout this standard shall be as stated in the contract or the accredited representative of the authority stated.

3. References

This standard makes reference to the following British Standards.

A4	Test pieces and test methods for aircraft metallic materials
BS 1837	Methods for the sampling of iron, steel, permanent magnet alloys and ferro-alloys
BS 3683	Glossary of terms used in non-destructive testing Part 4 Ultrasonic flaw detection
BS 4114	Dimensional and quality tolerances for steel drop and press forgings and for upset forgings made on horizontal forging machines
BS 4331	Methods for assessing the performance characteristics of ultrasonic flaw detection equipment Part 1 Overall performance
BS 4437	Method for the end quench hardenability test for steel (Jominy test)
BS 4490	Methods for the determination of the austenitic grain size of steel
BS 4545	Methods for the mechanical testing of steel wire
BS 5046	Method for the estimation of equivalent diameter in the heat treatment of steel
BS 5216	Patented cold drawn carbon steel wire for mechanical springs

The latest editions of these standards shall be used.

4. Definitions

For the purposes of this British Standard and associated material specifications the following definitions apply.

4.1 **bar (rod)**. A length of wrought material which may be solid or hollow, of uniformly round, square, rectangular or regular polygonal section. The term does not include forged bar (see 4.8).

4.2 **billet**. A length of wrought material which may be solid or hollow and which is intended for hot working.

4.3 **air or oxygen melted cast**. A melt of known chemical composition melted and cast in air or a portion of that melt intended for release to this standard.

4.4 **vacuum induction melted cast**. A melt of known chemical composition melted and cast under vacuum or a portion of that melt intended for release to this standard.

4.5 **parent cast**. A melt of known chemical composition or a portion of that melt used to produce consumable electrodes.

4.6 **vacuum arc remelted cast**. An ingot produced by arc remelting a consumable electrode under vacuum.

4.7 **electroslag (electroflux) remelted cast**. An ingot produced by remelting one or more consumable electrode(s) under a protective slag (flux) layer heated by electrical resistance methods.

4.8 **forging**. A product obtained by hot working under a hammer or press. The term includes drop forgings, open die forgings, stampings, pressings, hot rolled rings, forgings made from tubular material and forged bars not intended for further hot working.

4.9 **forging stock**. Cast or wrought steel intended for the production of forgings.

4.10 **oxygen steelmaking process**. A steelmaking process using commercially pure oxygen (99 % purity) excluding air or mixed air/oxygen blowing processes.

4.11 **precipitation hardening steel**. Steel that is solution treated and then subjected to a precipitation or maraging treatment.

4.12 **ruling section**. The equivalent diameter of that portion of the object at the time of heat treatment that is most important in relation to mechanical properties.

4.13 **limiting ruling section**. The largest diameter, for any given composition of steel, in which certain specified mechanical properties can be expected after a specified heat treatment.

4.14 **equivalent diameter** (of an object or part of an object). The diameter at the time of heat treatment of a hypothetical very long bar (effectively of infinite length) of uniform circular cross section, which, if subjected to the same cooling conditions as the object, i.e. same initial and final temperatures and same cooling medium, would have a cooling rate at its axis equivalent to that at the slowest-cooling position in the object or relevant part.

NOTE. For further information see BS 5046.

4.15 **wire**. A round, square or regular polygonal solid section produced by drawing and supplied in coil form.

5. Chemical composition

5.1 The chemical composition of the steel shall comply with the requirements of the relevant material specification. The values stipulated in that specification shall be applied to the satisfaction of the Quality Assurance Authority. Except as required by 5.2, an analysis of every cast shall be made for the specified elements and a certificate of analysis shall be supplied to the purchaser.



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5.2 Each vacuum arc remelted or electroslag remelted cast shall be analysed. The position(s) of the sample(s) and the elements to be determined per cast shall be as required by the material specification or as agreed between the manufacturer, the purchaser* and the Quality Assurance Authority.

5.3 Analytical samples shall be selected and prepared in accordance with the relevant requirements of BS 1837.

5.4 Elements not quoted in the material specification shall not be intentionally added to the steel without the agreement of the purchaser*, except for the purpose of finishing the heat; reasonable precautions shall be taken to prevent their inclusion during manufacture. For special applications, the purchaser*, in agreement with the manufacturer, may set a limit to the amount of one or more such elements and may require the amount of such elements to be stated in the certificate of analysis.

5.5 The deliberate addition of lead is permitted in certain low strength steels if it is explicitly mentioned in the individual material specification. Lead shall not be added to other steels.

5.6 The specified ranges of chemical composition are based on cast analyses. Any subsequent analytical checks shall take into consideration the heterogeneity normal to the steel.

6. Manufacture

6.1 The steel shall be made by the melting process required by the material specification, unless the manufacturer and the purchaser* agree beforehand to the use of a different process. If a specification permits alternative processes, the manufacturer shall decide which of them shall be used, unless the purchaser* specifies a particular process on his order. In all instances the process by which the steel was made shall be stated on the release note.

If vacuum degassing is carried out by the manufacturer and this treatment is not a requirement of the order or material specification, the release note shall state that vacuum degassing has been employed.

If billets are produced by continuous casting, the details of the inspection and testing procedure shall be agreed between the manufacturer and the Quality Assurance Authority.

6.2 Except as provided in 6.3, for both vacuum and electroslag remelted casts, at no time during remelting shall material of any other composition or type be introduced into the melting chamber, i.e. starter material and electrode stub ends shall be to the same specification as the steel being remelted. Not more than one parent cast shall be used to produce a single consumable electrode or remelted ingot. If considered necessary the method of manufacture of the steel for the electrodes shall be agreed between the steelmaker and the purchaser* and shall be stated on the order and the release note.

6.3 For electroslag remelted casts, the electrode stub ends may be of different material to the steel being remelted provided that the remelted steel is not contaminated with material from the stub ends, i.e. the electrode is not all remelted.

*See 2.1.

6.4 The size, shape and method of production of the ingots shall be so selected as to minimize segregation and axial unsoundness. If required, details concerning the production of the ingots shall be agreed between the manufacturer and the purchaser and stated on the order, and shall not be modified significantly except by prior agreement. (See sections five and six.)

6.5 The ingots, unless charged hot into the mill or forge reheating furnace, shall be cooled in a manner that will ensure freedom from any internal or external cracks.

6.6 Reheating for hot working and cooling after hot working shall be controlled to avoid deleterious effects.

6.7 At some stage or stages in the manufacture of billets, bars, forging stock and forgings, adequate discard shall be removed from the portions corresponding to the top and the bottom of each ingot.

7. Temporary identification up to the cast approval stage

Ingots from each cast shall be identified serially, the products shall be identifiable with the particular ingots from which they were made and the portions corresponding to the tops and bottoms of the ingots shall be suitably marked. These markings shall be maintained until it has been proved to the satisfaction of the steelmaker's Approved Metallurgist that the cast complies with the requirements of 10.2, 10.3 (if appropriate) and 10.4.

NOTE. The identification of ingots within a cluster is arbitrary.

8. Surface dressing

8.1 Overall dressing. If overall dressing is required by the material specification or the order, the material shall be machined, ground or scarfed all over at a suitable stage. Sufficient material shall be taken off to remove surface imperfections which might produce harmful defects in products made from the material.

8.2 Local dressing. If local dressing is required by the material specification surface defects shall be removed by local machining, chipping, grinding or scarfing.

9. Preparation for surface inspection

9.1 Unless otherwise agreed between the manufacturer and the purchaser, forgings and black bars for machining shall be descaled to enable the surface to be inspected to the satisfaction of the Quality Assurance Authority.

9.2 Unless otherwise stated on the order, black bars for the subsequent production of bright bars shall be supplied without descaling.

9.3 Acid pickling shall be used if required by the order.

10. Freedom from defects

10.1 General

10.1.1 All material shall be free from harmful defects.

10.1.2 Notwithstanding the previous acceptance of material as complying with the requirements of this British Standard, any material that is found at a later stage to contain harmful defects may be rejected.

10.2 Sulphur printing or deep etching tests

10.2.1 Sulphur printing or deep etching tests shall be carried out, at a suitable stage during manufacture, on full section samples corresponding to the tops of ingots and, if required by the material specification or order, to the bottoms of ingots selected from each cast as required by 10.2.2. Additionally, for narrow end-up ingots, samples corresponding to the middle portions of the ingots shall be selected from each cast as required by 10.2.2. The tests shall reveal no harmful defects.

10.2.2 Unless the material specification stipulates the taking of one sample from each ingot, samples shall be selected as follows.

- (a) For ingots cast individually up to 5000 kg each, the minimum number of samples to be selected shall be as follows:

Number of ingots in cast	Number of ingots to be selected
Up to 5	1
6 to 10	2
11 to 25	3
26 to 40	4
Over 40	5

The selected ingots shall be as widely separated in order of casting as is practicable.

- (b) For ingots cast individually over 5000 kg each, one sample shall be taken from each ingot.

- (c) For ingots cast in clusters, one sample shall be taken from one ingot in each cluster.

10.3 Lead segregation. If lead is added to the steel (see 5.5) the billet adjacent to the bottom discard of each ingot shall be tested for freedom from lead segregation to the satisfaction of the steelmaker's Approved Metallurgist.

10.4 Inclusions. The steelmaker's Approved Metallurgist shall satisfy himself, by examination for cleanliness, that the cast is free from harmful inclusions. Unless a standard of acceptance has been agreed between the steelmaker and the parent design firm, the material shall comply with the requirements of appendix A.

10.5 Surface defects. The steelmaker or steel supplier shall verify by examination that the billets, bars, forging stock, forgings and wire are free from harmful surface defects.

10.6 Ultrasonic examination

10.6.1 *Products of narrow end-up ingots.* The products of narrow end-up ingots shall be subjected to ultrasonic examination at the billet stage in accordance with appendix B and shall comply with the requirements of that appendix.

10.6.2 Other products

10.6.2.1 If required by the material specification, drawing or order, ultrasonic examination of billets that are not the products of narrow end-up ingots, and of bars for machining and reworking up to and including 150 mm in diameter or minor sectional dimension, shall be carried out in accordance with appendix B. Unless a standard of acceptance has been agreed between the steelmaker and the parent design firm, the material shall comply with the requirements of appendix B.

10.6.2.2 In the case of bars exceeding 150 mm in diameter or minor sectional dimension, and of forgings, the method of examination, where required, and the standard of acceptance shall be agreed between the manufacturer and the purchaser.

11. Heat treatment temperatures

If a temperature with a tolerance is stated in a material specification, order or drawing, that temperature shall be mandatory. If a temperature range is stated, a suitable temperature within that range shall be selected to give the required properties.

12. Mechanical properties

12.1 In the related material specifications all the specified mechanical properties refer to tests taken in the longitudinal direction unless transverse properties are specified. The specified properties relate to test pieces machined from defined positions and they will not necessarily be realized when tests are carried out on test pieces selected from other positions in the material. Attention is directed to 4.12, 4.13 and 4.14.

12.2 If transverse property requirements are not specified in the material specification but are required by the purchaser, the requirements shall be agreed between the manufacturer and the purchaser* and shall be stated on the order.

13. Selection and preparation of test samples

13.1 Test samples shall be selected and prepared in accordance with the requirements of the relevant section of this British Standard.

13.2 At the option of the manufacturer or if transverse properties are stated in the material specification, test samples from billets and bars of not less than 75 mm in diameter or major sectional dimension shall consist of transverse slices cut from the billets or bars. If taken in the transverse direction the fact shall be recorded on the release note.

13.3 Except for precipitation hardening steels, test samples for steels for which the specified minimum tensile strength is 1300 MPa or more may be machined to test piece size, plus a grinding allowance if required, and heat treated in that size.

13.4 Test samples for precipitation hardening steels for which the specified minimum tensile strength is 1300 MPa or more may be machined to test piece size, plus a grinding allowance if required, after solution treatment and precipitation hardened in that size.

13.5 If any test sample or test piece fails to comply with the requirements of a test as a result of incorrect test procedure or faulty equipment, the test results shall be discarded and a further test sample(s) shall be selected and tested in accordance with the relevant requirements.

14. Location of test pieces for mechanical tests

14.1 Longitudinal test pieces

14.1.1 For materials and test samples up to and including 30 mm in diameter or minor sectional dimension, the test piece shall be machined coaxially with the test sample.

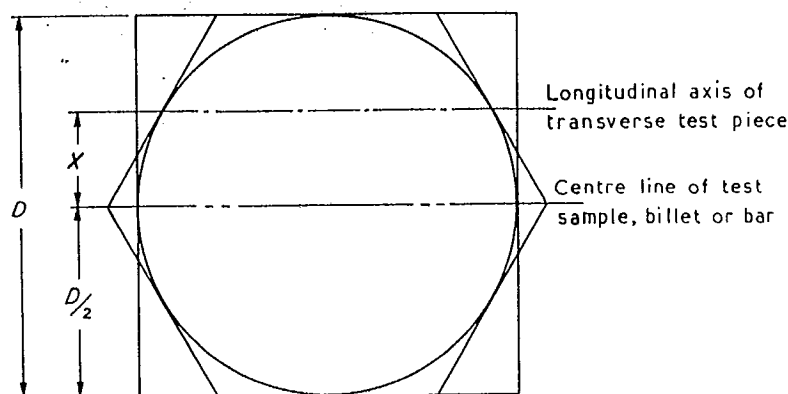
14.1.2 For materials and test samples over 30 mm in diameter or minor sectional dimension, the longitudinal axis of the test piece shall be 12.5 mm from the surface of the material or test sample, unless otherwise agreed.

NOTE. For test samples forming prolongations of forgings or which are cut from forgings see section six.

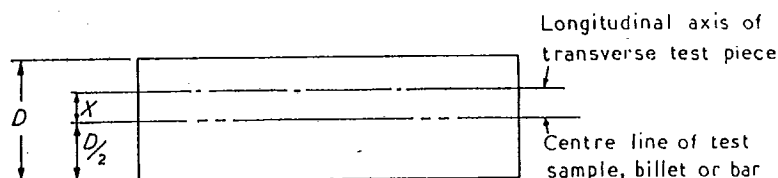


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(a) Round, square or hexagonal section



(b) Rectangular section

Dimension x shall not exceed $D/4$.

Figure 1. Location of transverse test pieces

14.2 Transverse test pieces. The test pieces shall be located as shown in figure 1 or, if required by the material specification, the longitudinal axis of the test piece shall intersect the longitudinal axis of the material or test sample.

15. Tensile test at room temperature

15.1 Except as provided in 15.2, the test piece shall be prepared from the test sample (see clauses 13 and 14) in accordance with the requirements of A4 : Part 1 : Section One. The standard test piece shall be the 11.28 mm diameter proportional round test piece shown in table 1 of A4 : Part 1 : Section One.

15.2 Alternatively to 15.1, at the option of the manufacturer, samples of bars, sections and wire not exceeding 16 mm in diameter or major sectional dimension shall be tested in full section. For these test pieces, the elongation shall be measured on a gauge length equal to five times the original diameter of the test piece or, for material of other than circular section, on a gauge length of 50 mm.

15.3 Unless otherwise stipulated elsewhere in this British Standard, the test pieces shall be tested in accordance with the requirements of A4 : Part 1 : Section One.

15.4 If a value for the proof stress is given in the material specification, on at least one test piece from each cast, the proof stress shall be obtained from accurately determined load-extension data. For all remaining test pieces, either the proof stress shall be

determined as above or compliance with the specified requirements shall be verified by one of the alternative methods given in A4.

15.5 The fracture faces shall be free from defects.

16. Tensile test at elevated temperature

16.1 The test piece shall be prepared from the test sample (see clauses 13 and 14) in accordance with the requirements of A4 : Part 1 : Section Two. The standard test piece shall be the 5.64 mm diameter proportional round test piece shown in table 1 of A4 : Part 1 : Section Two.

16.2 The test pieces shall be tested in accordance with the requirements of A4 : Part 1 : Section Two.

16.3 If a value for the proof stress is given in the material specification, this shall be obtained from accurately determined load-extension or stress-strain data.

16.4 The fracture faces shall be free from defects.

16.5 The results of each test shall be reported in accordance with the requirements of A4 : Part 1 : Section Two.

17. Creep and rupture test

17.1 The test piece shall be prepared from the test sample (see clauses 13 and 14) to the dimensions of one of the test pieces given in A4 : Part 1 : Section Three.

17.2 The test piece shall be tested in accordance with the requirements of A4 : Part 1 : Section Three.

17.3 The duration of the test shall be not less than the minimum required by the material specification.

17.4 A stress higher than that required by the material specification may be used provided that the minimum specified life is attained. Unless otherwise agreed, the stress shall not be increased after the test has been commenced. The actual stress used shall be stated in the release note.

17.5 The fracture faces shall be free from defects.

17.6 The results of each test shall be reported in accordance with the requirements of A4 : Part 1 : Section Three.

18. Impact test

18.1 The test piece shall be prepared from the test sample (see clauses 13 and 14) to the dimensions of one of the test pieces given in A4 : Part 2. If the dimensions of the material are such that none can be made, the nicked fracture test (see clause 20) shall be substituted for the impact test.

18.2 Except as provided in 18.3, the test shall comprise a minimum of three notches. If the Izod test is employed, the three notch test piece shall be prepared, unless the test sample is of insufficient length, in which case three single notch test pieces shall be prepared.

18.3 Exceptionally, as for the selection of samples from actual forgings (see section six, procedure D) and if agreed between the manufacturer and the purchaser*, a test may comprise less than three notches.

18.4 If the test sample is machined to test piece size prior to heat treatment (see clause 13), the notches shall be machined after heat treatment or partly machined before heat treatment in such a manner that at least 0.2 mm of material is removed from the radius at the root of each notch after heat treatment.

18.5 The test piece shall be tested in accordance with the requirements of A4 : Part 2.

18.6 The fracture faces shall be free from defects.

18.7 The results of each test shall be recorded.

19. Hardness test

19.1 The hardness test shall be carried out in accordance with one of the methods in A4 : Part 5, as required by the material specification.

19.2 The tests on the billets, bars, forgings, etc. comprising a batch, and, if applicable, on the test sample or samples representing that batch, shall be made by the same method and under the same conditions of loading.

20. Fracture test

NOTE. The method and direction of fracture testing will vary according to the product and the purpose of the test. For the causes and control of overheating and coarse grain see appendix C and appendix D, respectively.

20.1 General

20.1.1 Except as provided in 20.1.2, the fracture test sample shall be appropriately identified with the material that it represents, cut off, prepared (see 20.2) and fractured separately.

20.1.2 If the material is in the finally heat treated condition, the test sample may be fractured directly from the product.

20.2 Preparation of test sample. The test sample shall be heat treated (unless the material is already in the finally heat treated condition) in accordance with the requirements of the material specification and shall be prepared by one of the following methods, as stipulated in the relevant section of this British Standard.

(a) The full section of the test sample shall be nicked transversely so that the area of the portion to be fractured shall be more than half of the original section (see figure 2(a)).

(b) The full section of the test sample shall be cut and nicked transversely so that the portion to be fractured extends across the full section or width, is not less than 15 mm thick and includes the axis (see figure 2(b)).

(c) The full section of the test sample shall be nicked transversely so that the depth of the portion to be fractured is not less than 15 mm (see figure 2(c)).

(d) Two or more test pieces, each having a minimum fracture area of 150 mm², shall be machined from a suitable length (approximately 50 mm) cut from the full section of the sample (see figure 2(d)). (This method is for use in the case of large sections where methods (a), (b) and (c) are not practicable.)

(e) A transverse slice, not less than 15 mm thick, shall be cut and a nick not more than 5 mm deep shall be made across one face of the slice so that the fracture will extend across the axis (see figure 2(e)).

20.3 Fracturing

20.3.1 Unless otherwise agreed or stipulated in the material specification or order, fracture tests shall be carried out at room temperature.

20.3.2 Preferably, fracturing shall be carried out by the application of steady pressure. Uneven fractures with pronounced shear lips shall be avoided.

20.4 Examination. The fracture shall be examined at a magnification of not less than $\times 10$ and shall be to the required standard.

20.5 Assessment of results. The assessment of fractures shall be the responsibility of the Approved Metallurgist. Where doubt exists about acceptance, the facts shall be reported to the Quality Assurance Authority and, if appropriate, to the purchaser and/or the parent design firm.

*See 2.1

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21. Special tests

21.1 Grain size test. If required by the material specification, the austenitic grain size shall be determined, in accordance with the appropriate method described in BS 4490, on one sample from each cast. Unless otherwise agreed between the manufacturer and the purchaser, the sample shall be selected at the billet stage.

21.2 Hardenability (Jominy) test. If required by the material specification, an end quench hardenability test shall be carried out, in accordance with one of the methods described in BS 4437, on one sample selected from each cast.

22. Maintenance of identity

22.1 The material shall be kept identifiable as to its cast and, if appropriate, its ingot, position in the ingot and heat treatment test batch, to enable final identification marking to be made in accordance with clause 23.

22.2

With the exception of forgings and parts, each piece of steel shall be checked for its class of composition e.g. nickel steel, nickel-chrome steel, etc., immediately before despatch. The method of testing, which shall be agreed with the Quality Assurance Authority, may be by means of a spark test, a spectroscope, an electromagnetic sorting appliance or by any other suitable method. Hardness testing alone may suffice in some instances.

22.3 Test samples shall be kept identifiable with the material that they represent.

23. Final marking

23.1 Each bar over 20 mm in diameter or major sectional dimension and each billet, passed by the inspector, shall be stamped with the mark of the inspector and such other marking as shall ensure adequate identification of the material. The stamp marks shall be near to or on one end of the billet or bar.

23.2 Bar not exceeding 20 mm in diameter or major sectional dimension, rod and wire for springs and bar for forged bolts, passed by the inspector, shall be marked as required by 23.1 or, at the option of the manufacturer, bar, rod and wire from the same batch shall be wired in bundles, each of which shall bear a durable label stamped with the mark of the inspector and such other marking as shall ensure adequate identification of the material.

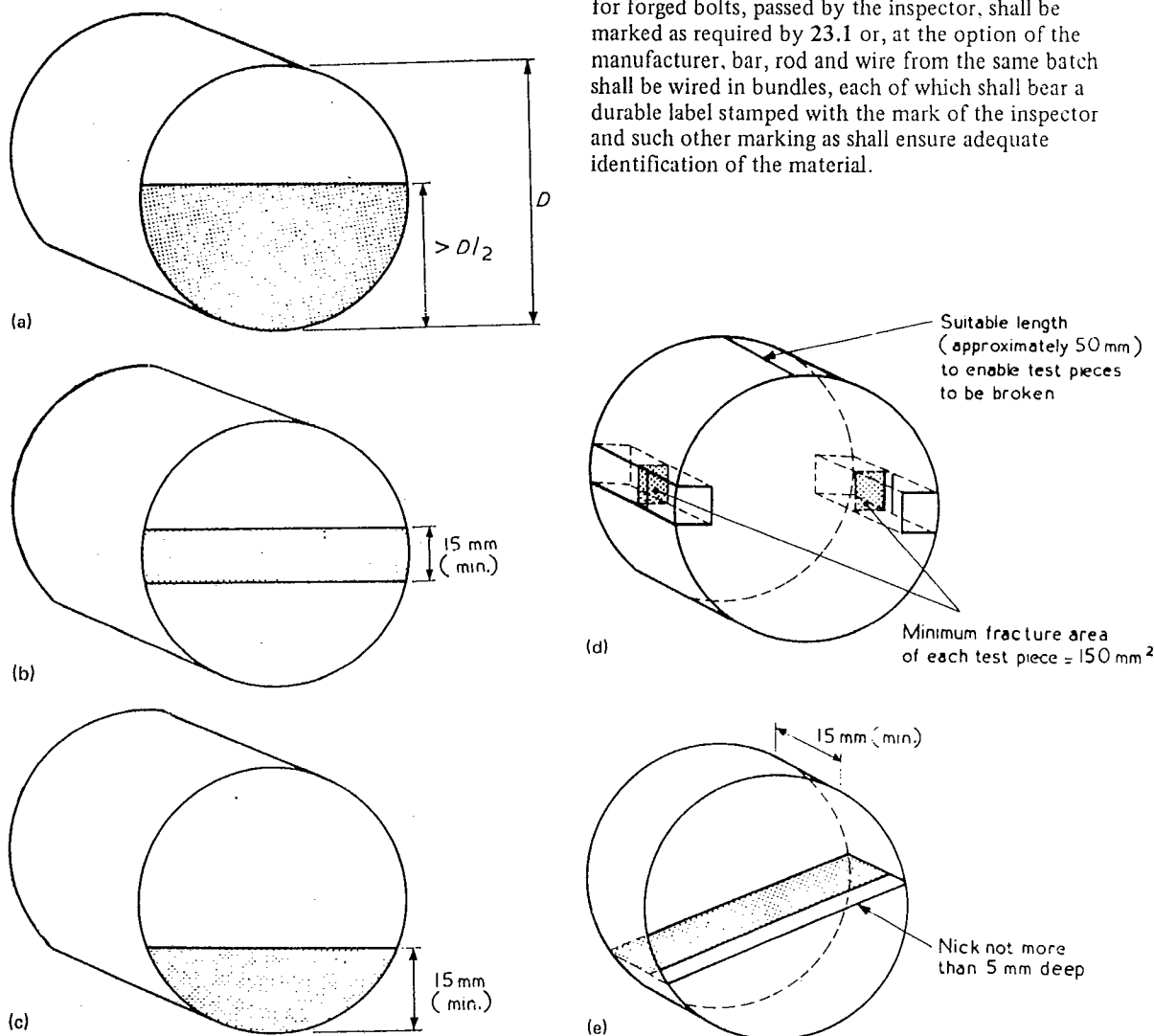


Figure 2. Details of preparation of fracture test samples

23.3 Each forging of 5 kg and over, passed by the inspector, shall be stamped with the mark of the inspector and such other marking as shall ensure adequate identification of the material. The stamp marks shall be placed where shown on forging drawings, or, if no position is shown, where least liable to be detrimental to the forging.

23.4 Forgings of less than 5 kg, passed by the inspector, shall be either individually marked as required by 23.3 or, at the option of the manufacturer, made into bundles, each of which shall bear a durable label stamped with the mark of the inspector and such other marking as shall ensure adequate identification of the material.

23.5 Each parcel of springs, passed by the inspector, shall bear a durable label stamped with the mark of the inspector and such other marking as shall ensure adequate identification of the material.

23.6 Material containing lead shall be identified by a distinguishing mark, 'L' or 'Leaded', and the release note shall be appropriately annotated.

24. Test certificate

24.1 A copy of the test certificate shall be supplied by the manufacturer to the purchaser in respect of all deliveries.

24.2 The certificate shall state the heat treatment temperatures and methods of cooling employed, the ruling section of the test samples at the time of heat treatment and the results of all the tests required by the material specification. If a retest procedure has been invoked, the test certificate shall be annotated accordingly.

Section two. Bars for machining delivered in other than the finally heat treated condition (for parts to be heat treated after machining)

25. Condition

The bars shall be supplied in the condition required by the material specification or order.

26. Dimensional tolerances

26.1 Dimensional tolerances, if required, shall be stated on the order.

26.2 Tolerances on the straightness, if required, shall be stated on the order.

26.3 Where black bars are ordered for subsequent machining, the size ordered shall include a machining allowance of not less than 4 % above the finished machined size.

27. Heat treatment

If required by the material specification, the bars shall be softened, normalized, solution treated or solution treated and primary hardened, as appropriate.

28. Selection and preparation of mechanical test samples

28.1 Steels other than carburizing, nitriding and precipitation hardening steels

28.1.1 The inspector shall select at least one test sample from each cast.

28.1.2 Except as provided in 28.1.3 and in 13.2 or 13.3, the test sample shall be machined to the limiting ruling section stated in the material specification and shall be finally heat treated in that size.

*See 2.1.

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28.1.3 Alternatively to 28.1.2 and except as provided in 13.2 or 13.3, the test sample shall be finally heat treated either in full section or after being machined to the ruling section stated on the order.

NOTE. The ruling section to be stated on the order should be that of the material at the time of heat treatment (see 4.12).

28.1.4 For the purposes of subsequent orders, the test sample, selected and prepared in accordance with 28.1.1 to 28.1.3, shall be accepted as representing all bars from the same cast provided that the ruling sections stated on such orders do not exceed that of the test sample already tested.

28.2 Carburizing steels

28.2.1 The inspector shall select one test sample of full section from a bar in each cast. If the diameter or minor sectional dimension of the test sample is 20 mm or over, the test sample shall be accepted as representing the whole cast; if it is less than 20 mm, the test sample shall be accepted as representing the bars in the cast of a diameter or minor sectional dimension not exceeding that of the selected test sample.

28.2.2 Except as provided in 13.2 or 13.3, the test samples shall be prepared as follows.

- (a) Test samples from bars over 20 mm in diameter or minor sectional dimension shall be forged or machined to 20 mm diameter or square and shall be heat treated in that size.
- (b) Test samples from bars up to and including 20 mm in diameter or major sectional dimension shall be heat treated in full size.
- (c) Test samples from bars up to and including 20 mm minor and over 20 mm major sectional dimension shall have the major sectional dimension reduced to 20 mm and shall be heat treated in that size.

28.2.3 The test samples shall be heat treated in accordance with the requirements of the material specification except that, if agreed between the manufacturer and the purchaser* and stated on the order, carburizing or blank carburizing treatment may be omitted.

28.3 Nitriding steels

28.3.1 The inspector shall select at least one test sample from one bar in each cast. The test sample shall be of sufficient length to allow for an additional impact test.

28.3.2 Except as provided in 28.3.3 and in 13.2 or 13.3, the test sample shall be machined to the limiting ruling section stated in the material specification and shall be finally heat treated in that size.

28.3.3 Alternatively to 28.3.2 and except as provided in 13.2 or 13.3, the test sample shall be finally heat treated either in full section or after being machined to the ruling section stated on the order.

NOTE. The ruling section to be stated on the order should be that of the part at the time of heat treatment (see 4.12).

28.3.4 That portion of the test sample to be used for the additional impact test shall be prepared in accordance with 28.3.2 or 28.3.3 and shall then be blank nitrided in accordance with the requirements of the material specification.

28.3.5 For the purposes of subsequent orders, the test sample, selected and prepared in accordance with 28.3.1 to 28.3.4, shall be accepted as representing all bars from the same cast provided that the ruling sections stated on such orders do not exceed that of the sample already tested.

28.4 Precipitation hardening steels

28.4.1 For bars supplied in the softened condition, the inspector shall select one test sample from one bar in each cast.

28.4.2 For bars supplied in the solution treated or primary hardened condition, the inspector shall select one test sample from each batch of bars of the same nominal dimensions, made from the same cast, processed in a similar manner and solution treated or primary hardened together.

28.4.3 Except as provided in 13.4, the test samples selected in accordance with 28.4.1 or 28.4.2 shall be finally heat treated in accordance with the requirements of the material specification.

29. Mechanical tests

29.1 Initial tests. The mechanical properties obtained from the test pieces, machined from the test samples selected and prepared in accordance with clause 28, shall comply with the requirements of the material specification.

29.2.1 Retest. Except as provided in 29.2.2, if any test piece fails to comply with the requirements of a specified mechanical test, the inspector shall select for test from the same cast or same batch, as appropriate, two further samples, one of which shall be taken from the bar from which the original test sample was taken, unless that bar has

29.2.2 If failure to comply with the specified requirements is attributed to incorrect choice of heat treatment temperature for the test piece, the results shall be discarded and the same bar shall be resampled. The mechanical properties obtained from the test piece prepared from this sample shall comply with the requirements of the material specification.



*See 2.1.

been withdrawn by the manufacturer. The mechanical properties obtained from the test pieces prepared from both these further test samples shall comply with the requirements of the material specification.

30. Hardness test

30.1 Initial tests

30.1.1 If the material specification states a maximum hardness for softened, solution treated or primary hardened material, not less than 10 % of the bars from the same cast and heat treated together shall be hardness tested. The test shall be made near one end of the bar.

30.1.2 The hardness shall comply with the requirements of the material specification.

30.2 Retests. If any bar fails to comply with the requirements of the material specification, the inspector shall adopt one or both of the following procedures, as requested by the manufacturer.

(a) Allow all the bars in the batch not previously tested to be hardness tested. Those with hardness complying with the requirements of the material specification shall be accepted. The remaining bars shall be re-heat treated, as appropriate, and retested in accordance with clauses 29 and 30.1.

(b) Allow all the bars in the batch to be re-heat treated, as appropriate, and retested in accordance with clauses 29 and 30.1.

31. Fracture test

31.1 General. If specified in the order or material specification, and subject to agreement between the manufacturer and the purchaser, fracture tests shall be carried out on bars over 5 mm in diameter or equivalent cross-sectional area, in accordance with the general requirements of clause 20 and the specific requirements of 31.2 or 31.3, as appropriate.

31.2 Test for overheating

31.2.1 Test samples shall be selected as follows.

(a) Bars in straight lengths: from one end of each bar.

(b) Bars in coil form: from both ends of each coil

31.2.2 The test samples shall be prepared in accordance with one of the methods described in 20.2 as follows.

Diameter or equivalent
cross-sectional area of bar

mm

Method

Up to and including 100

(a) or (b)

Over 100

(c) or (d)

31.2.3 The fracture surface shall reveal no evidence of overheating.

31.3 Test for coarse grain. The rate of sampling, test procedure, any heat treatment required, method of fracturing and standards of acceptance shall be agreed between the manufacturer and the purchaser* to the satisfaction of the Quality Assurance Authority.

*See 2.1.

Section three. Bars for machining delivered in the finally heat treated condition

NOTE. This section relates only to bars up to and including the limiting ruling section stated in the relevant material specification. Bars of larger ruling section should be ordered to comply with the requirements of section two, unless alternative mechanical properties have been agreed (see 4.12).

32. Condition

The bars shall be supplied in the condition required by the material specification or order.

33. Dimensional tolerances

33.1 Dimensional tolerances, if required, shall be stated on the order.

33.2 Tolerances on the straightness, if required, shall be stated on the order.

33.3 Where black bars are ordered for subsequent machining, the size ordered shall include a machining allowance of not less than 4 % above the finished machined size.

34. Heat treatment

34.1 The bars shall be heat treated in accordance with the requirements of the material specification.

34.2 No bar shall be subjected to the specified hardening normalizing, softening, solution, primary hardening or precipitation treatment more than three times.

34.3 Any heat treatment applied after cold drawing or other bright finishing may result in the surface of bars being slightly dulled but it shall not form a scale of measurable thickness.

35. Selection and preparation of mechanical test samples

35.1 Normalized, hardened and tempered, and austenitic steels

35.1.1 Bars of the same nominal sectional dimensions, made from the same cast and heat treated together shall be grouped in batches.

35.1.2 The inspector shall select from each batch either one test sample from each 50 bars or part thereof or, at the option of the manufacturer, one test sample from each 1000 kg or part thereof.

35.1.3 Except as provided in 13.3, the test samples shall be selected from the bars after all heat treatment, cold working, straightening and stress relieving processes have been completed and shall not be further heat treated or mechanically worked before testing.

35.2 Nitriding steels

35.2.1 Bars of the same nominal sectional dimensions, made from the same cast and heat treated together shall be grouped in batches.

35.2.2 The inspector shall select from each batch either one test sample from each 50 bars or part thereof or, at the option of the manufacturer, one test sample from each 1000 kg or part thereof. The test sample shall be of sufficient length to provide an additional impact test piece.

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35.2.3 Except as provided in 35.2.4 and 13.3, the test samples shall be selected from the bars after all heat treatment, cold working, straightening and stress relieving processes have been completed and shall not be further heat treated or mechanically worked before testing.

35.2.4 That portion of the test sample to be used for the additional impact test piece shall be blank nitrided in accordance with the requirements of the material specification.

35.3 Precipitation hardening steels

35.3.1 Bars of the same nominal sectional dimensions, made from the same cast, processed in a similar manner and heat treated together shall be grouped in batches.

35.3.2 The inspector shall select from each batch either one test sample from each 50 bars or part thereof or, at the option of the manufacturer, one test sample from each 1000 kg or part thereof, whichever is the lesser.

35.3.3 Except as provided in 13.4, the test samples shall be selected from the bars after all heat treatment, cold working, straightening and stress relieving processes have been completed and shall not be further heat treated or mechanically worked before testing.

36. Mechanical tests

36.1 Initial tests. The mechanical properties obtained from the test pieces, machined from the test samples selected and prepared in accordance with clause 35, shall comply with the requirements of the material specification.

36.2 Retests. If any test piece fails to comply with the requirements of a specified mechanical test, the inspector shall adopt one or both of the following procedures, as requested by the manufacturer.

(a) Select for test from the same batch twice the number of samples originally selected, one of which shall be from the bar represented by the failed test sample, unless that bar has been withdrawn by the manufacturer. The mechanical properties obtained from the test pieces prepared from all these further test samples shall comply with the requirements of the material specification.

(b) Allow the batch to be re-tempered, re-precipitation hardened or re-heat treated and retested in accordance with clauses 35, 36.1, 37 and 38.

37. Hardness test

37.1 Initial tests

37.1.1 If the material specification states a hardness requirement, the bars shall be hardness tested as follows.

(a) *Bars heat treated in straight lengths.* Every bar shall be tested. To ensure uniformity of treatment with regard to the location of bars in the furnace, one third of the bars shall be tested at one end, one third in the middle and one third at the other end.

(b) *Bars heat treated in coil form.* 10 % of the bars produced from each coil shall be tested. The bars shall be selected in such a manner as to be representative of the full length of the coil.

37.1.2 The inspector, at his discretion, may require additional hardness tests to be made.

37.1.3 Every tensile test sample shall also be hardness tested.

37.1.4 The hardness shall comply with the requirements of the material specification.

37.2 Retests

37.2.1 *Bars heat treated in straight lengths.* If any bar in a batch fails to comply with the requirements of the material specification, the inspector shall adopt one or more of the following procedures, as requested by the manufacturer.

(a) For bars with hardness below the minimum value specified:

- (1) allow the softest bar to be submitted to the tensile and impact tests; if this bar complies with the specified tensile and impact requirements, all the bars shall be accepted;
- (2) allow precipitation hardening steel bars to be re-precipitation hardened and retested in accordance with clauses 35, 36, 37.1 and 38;
- (3) allow the bars of incorrect hardness to be re-heat treated and retested in accordance with clauses 35, 36, 37.1 and 38.

(b) For bars with hardness above the maximum value specified:

- (1) allow the hardest bar to be submitted to the tensile and impact tests; if this bar complies with the specified tensile and impact requirements, all the bars shall be accepted;
- (2) allow hardened and tempered bars to be re-tempered and retested in accordance with clauses 35, 36, 37.1 and 38;
- (3) allow the bars of incorrect hardness to be re-heat treated and retested in accordance with clauses 35, 36, 37.1 and 38.

37.2.2 *Bars heat treated in coil form.* If any bar in a batch fails to comply with the requirements of the material specification, all the bars in the batch not previously hardness tested shall be tested and the retest provisions of 37.2.1 shall be applied.

38. Fracture test

38.1 Initial tests

38.1.1 Fracture tests shall be carried out on bars over 5 mm in diameter or equivalent cross-sectional area in other than austenitic heat resisting steels, in accordance with the general requirements of clause 20 and the specific requirements of 38.1.2 to 38.1.5.

38.1.2 Test samples shall be selected as follows.

- (a) Bars heat treated in straight lengths: from one end of each bar.
- (b) Bars heat treated in coil form: from both ends of each coil.

38.1.3 The test samples shall be prepared in accordance with one of the methods described in 20.2 as follows.

Diameter or equivalent cross-sectional area of bar	Method
mm	
Up to and including 100	(a) or (b)
Over 100	(c) or (d)

38.1.4 The fracture surfaces shall reveal no defects or evidence of unsatisfactory condition.

38.1.5 Where specified in the material specification or order, standards of acceptance for grain size shall be agreed between the manufacturer and the purchaser.

38.2 Retests

38.2.1 If any sample reveals a defect, further samples shall be selected for test from both ends of the bar represented by that sample, unless that bar has been withdrawn by the manufacturer. Both these further samples shall comply with the requirements of 38.1.4.

38.2.2 If any test sample reveals evidence of overheating, and subject to the approval of the purchaser, further samples shall be selected for test from both ends of the bar represented by that test sample, unless that bar has been withdrawn by the manufacturer. Both these further samples shall comply with the requirements of 38.1.4.

38.2.3 If any test sample reveals evidence of unsatisfactory heat treatment, the inspector shall adopt one or both of the following procedures, as requested by the manufacturer.

(a) Allow the bar represented to be submitted to the impact test. The impact property obtained shall comply with the requirements of the material specification.

(b) Allow the bar represented to be re-heat treated and retested in accordance with clauses 35, 36, 37 and 38.1.

38.2.4 If any test sample reveals coarse grain, and subject to the approval of the purchaser, the bar represented by that test sample shall be re-heat treated and retested in accordance with clauses 35, 36, 37 and 38.1.

Section four. Carbon steel bars for machining, not subject to hardening and tempering

NOTE. This section relates to bars for machining other than those covered by sections two and three.

39. Condition

The bars shall be supplied in the condition required by the material specification or order.

40. Dimensional tolerances

40.1 Dimensional tolerance, if required, shall be stated on the order.

40.2 Tolerances on the straightness, if required, shall be stated on the order.

40.3 Where black bars are ordered for subsequent machining, the size ordered shall include a machining allowance of not less than 4 % above the finished machined size.

41. Heat treatment

41.1 The bars shall be heat treated in accordance with the requirements of the material specification.

41.2 Any heat treatment applied after cold drawing or other bright finishing may result in the surface of bars being slightly dulled but it shall not form a scale of measurable thickness.

42. Selection and preparation of mechanical test samples

42.1 Bars manufactured in straight lengths

42.1.1 Bars of the same nominal cross-sectional dimensions, made from the same cast and, if heat treated, heat treated together shall be grouped in batches as follows.

Diameter or minor sectional dimension of bar	Maximum mass of batch
mm	kg
Less than 8	150
8 up to and including 10	200
Over 10 up to and including 25	500
Over 25	1000

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42.1.2 The inspector shall select at least one test sample from each batch.

42.2 Bars manufactured in coil form

42.2.1 Except as provided in 42.2.2, the inspector shall select at least one test sample from one end of each coil.

42.2.2 Alternatively to 42.2.1 and at the option of the manufacturer, small coils of bar of the same nominal cross-sectional dimensions, made from the same cast and, if heat treated, heat treated together shall be grouped in batches as follows.

Diameter or minor sectional dimension of bar	Maximum mass of batch
mm	kg
Less than 8	150
8 up to and including 10	200
Over 10	500

The inspector shall select at least one test sample from one end of one coil in each batch.

42.3 Preparation. The test samples shall not be heat treated or mechanically worked, except for any necessary straightening, before testing.

43. Mechanical tests

43.1 Initial tests. The mechanical properties obtained from the test pieces, machined from the test samples selected and prepared in accordance with clause 42, shall comply with the requirements of the material specification.

43.2 Retests. If any test piece fails to comply with the requirements of a specified mechanical test, the inspector shall adopt one or both of the following procedures, as requested by the manufacturer.

- (a) Select for test further samples as follows.
 - (1) *Bars in straight lengths.* Two samples from the same batch of bars, one of which shall be taken from the bar from which the original test sample was taken, unless that bar has been withdrawn by the manufacturer.
 - (2) *Coils tested individually.* One sample from each end of the coil.
 - (3) *Coils grouped in batches.* Two samples from the same batch of coils, one of which shall be taken from the coil from which the original test sample was taken, unless that coil has been withdrawn by the manufacturer.

The mechanical properties obtained from the test pieces prepared from both these further test samples shall comply with the requirements of the material specification.

- (b) If permitted by the material specification, allow the batch or coil to be heat treated or re-heat treated and retested in accordance with clause 42 and 43.1.

Section five. Forging stock and billets and bars for subsequent working

44. Condition

The material shall be supplied in the condition required by the material specification or order.

45. Dimensional tolerances

Dimensional tolerances, if required, shall be stated on the order.

46. Heat treatment

46.1 If required by the material specification or order, the material shall be softened.

46.2 If agreed between the manufacturer and the purchaser* and stated on the order, precipitation hardening steel for subsequent cold forging shall be supplied solution treated or primary hardened, as appropriate.

47. Selection and preparation of mechanical test samples

47.1 Steels other than carburizing, nitriding and precipitation hardening steels

47.1.1 The inspector shall select at least one test sample from each cast.

47.1.2 Except as provided in 13.2 or 13.3, the test sample shall be finally heat treated in full section or after being forged or machined to either the limiting ruling section stated in the material specification or the ruling section stated on the order.

NOTE. The ruling section to be stated on the order should be that of the material at the time of heat treatment (see 4.12).

47.1.3 For the purposes of subsequent orders, the test samples, selected and prepared in accordance with 47.1.1 and 47.1.2, shall be accepted as representing all material from the same cast provided that the ruling sections stated on such orders do not exceed that of the test sample already tested.

47.2 Carburizing steels

47.2.1 The inspector shall select one test sample from each cast. If the diameter or minor sectional dimension of the test sample is 20 mm or over, the test sample shall be accepted as representing the whole cast; if it is less than 20 mm, the test sample shall be accepted as representing the material in the cast of a diameter or minor sectional dimension not exceeding that of the selected test sample.

47.2.2 Except as provided in 13.2 or 13.3, the test samples shall be prepared as follows.

- (a) Test samples from material over 20 mm in diameter or minor sectional dimension shall be forged or machined to 20 mm diameter or square and shall be heat treated in that size.
- (b) Test samples from material up to and including 20 mm in diameter or major sectional dimension shall be heat treated in full size.



*See 2.1.