

Please be aware that this PDF has been created from the original hardcopy document, which might not be in good condition and so the PDF might reflect this.

BRITISH STANDARD 970 : Part 3 : 1971

IMPERIAL UNITS

SPECIFICATION FOR
**WROUGHT
STEELS**

(BLOOMS, BILLETS, BARS AND FORGINGS)

Part 3. Steels for case hardening

BRITISH STANDARDS INSTITUTION

Gr 8

SPECIFICATION FOR
WROUGHT STEELS
IN THE FORM OF BLOOMS, BILLETS, BARS
AND FORGINGS

Part 3. Steels for case hardening

BS 970 : Part 3 : 1971

*Incorporating amendments issued May, 1973 (AMD 1166)
and April, 1974 (AMD 1418)*

BRITISH STANDARDS INSTITUTION

Incorporated by Royal Charter

PARK STREET, LONDON W1A 2BS

Telex: 266933

Telephone: 01-629 9000

UDC 669.14-13-4:669,14.018.298.2

THIS BRITISH STANDARD, having been approved by the Iron and Steel Industry Standards Committee, was published under the authority of the Executive Board on 30 July, 1971.

© British Standards Institution, 1971.

First published July, 1941.

First revision, October, 1942.

Second revision, March, 1947.

Third revision, January, 1955.

Fourth Revision, (Part 3) July, 1971.

SBN: 580 06983 4

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

This standard makes reference to the following British Standards:

- BS 18. Methods for tensile testing of metals Part 2. Steel (general).
- BS 131. Methods for notched bar tests. Part 1. The Izod impact test on metals.
- BS 240. Method for Brinell hardness test.
- BS 427. Method for Vickers hardness test.
- BS 891. Method for Rockwell hardness test.
- BS 1837. Methods for the sampling of iron, steel, permanent magnet alloys and ferro-alloys.
- BS 4114. Dimensional and quantity tolerances for steel drop and press forgings and for upset forgings made on horizontal forging machines.
- 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.
- Handbook No. 19. Methods for the sampling and analysis of iron and steel and other ferrous metals.

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following BSI references relate to the work on this standard: Committee references ISE/31, ISE/31/2, ISE/31/2/2 Draft for comment 69/9339.

CONTENTS

	Page
Co-operating organizations	6
Foreword	7

SPECIFICATION

1. GENERAL REQUIREMENTS

1.1 Scope	8
1.2 General	9
1.3 Information to be supplied by the purchaser	10
1.4 Steelmaking process	10
1.5 Chemical composition	11
1.6 Product analysis and permitted variations	12
1.7 Freedom from defects	13
1.8 Standard sizes and tolerances	14
1.9 Condition of material on delivery	15
1.10 Provision of material for mechanical testing	15
1.11 Location of tensile and Izod test pieces	16
1.12 Frequency of other tests	16
1.13 Test methods	16
1.14 Retests	17
1.15 Inspection	18
1.16 Test facilities	18
1.17 Manufacturer's statement	18
1.18 Identification	18
1.19 Symbols	18

**2. SPECIFIC REQUIREMENTS FOR ALLOY STEELS
FOR CASE HARDENING SUPPLIED TO CLOSE
LIMITS OF CHEMICAL COMPOSITION**

2.1 Chemical composition	22
2.2 Condition of supply	22

**3. SPECIFIC REQUIREMENTS FOR ALLOY STEELS
FOR CASE HARDENING SUPPLIED TO HARDENABILITY
REQUIREMENTS**

(For detailed list of steels contained in this section refer to
Table 3)

3.1 The purchase of steels to hardenability requirements	25
---	----

	Page
4. SPECIFIC REQUIREMENTS FOR ALLOY STEELS FOR CASE HARDENING SUPPLIED WITH SPECIFIED MECHANICAL PROPERTIES	45

(For detailed list of steels contained in this section refer to Table 4)

APPENDICES

A. Weights per foot and tolerance for billet for forging; standard sizes and tolerances for round, square, hexagonal and flat hot rolled bar; and standard sizes and tolerances for round, square and hexagonal bright bar—imperial units	65
B. Summary tables	73
C. Mechanical properties and heat treatments previously specified for alloy steels for double quenched $1\frac{1}{8}$ in diameter test bars	76
D. Comparison between elongation values obtained on gauge lengths of $5.65\sqrt{S_0}$ and $4\sqrt{S_0}$	77

TABLES

1. Permitted variations on product analysis from specified range	13
2. Numerical list of steels contained in Sections 2, 3 and 4 showing page references and the En steels replaced	19
3. Table of page references for steels supplied to hardenability requirements	24
4. Table of page references and the En steels replaced for steels supplied with specified mechanical properties	46
5. Billets for forging. Standard weights per foot and tolerances—inch and pound units	65
6. Standard sizes for hot rolled, round, square, hexagonal and flat bar	66
7A. Tolerances for general and special applications for hot rolled round, square and hexagonal bar under 3 in diameter or width across flats	67

TABLES—*continued*

7B.	Tolerances for hot rolled round and square bar between 3 in and 10 in diameter or width across flats	67
7C.	Tolerances for hot rolled hexagonal bar between 3 in and $4\frac{1}{8}$ in width across flats	68
7D.	Tolerances for general and special applications for hot rolled flat bar—inch units	68
8.	Tolerance on length for hot rolled round, square, hexagonal and flat bar up to and including 3 in—inch units	69
9A.	Standard sizes for round and square bright steel bar—inch units	70
9B.	Standard sizes for hexagonal bright steel bar—inch units	71
10.	Tolerances for round, square and hexagonal bright steel bar—inch units	72
11.	Alloy steels supplied to comply with the requirements of Section 3 (hardenability requirements)—chemical composition	73
12.	Alloy steels supplied to comply with the requirements of Section 4 (mechanical properties)—chemical composition	74
13.	Alloy steels supplied to comply with the requirements of Section 4—mechanical properties for $\frac{3}{4}$ in diameter test bars in the single quenched condition	75

FIGURE

1.	Examples illustrating alternate ways of specifying hardenability requirements	27
----	---	----

CO-OPERATING ORGANIZATIONS

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

- British Cast Iron Research Association
- British Constructional Steelwork Association
- British Electrical and Allied Manufacturers' Association
- British Ironfounders' Association
- British Mechanical Engineering Confederation
- *British Steel Industry
 - Council of Iron Producers
 - Council of Ironfoundry Associations
 - Crown Agents for Oversea Governments and Administrations
 - Department of Employment and Productivity
 - Department of Trade and Industry (Marine Division)
 - Engineering Equipment Users' Association
 - Federation of Civil Engineering Contractors
 - Institute of British Foundrymen
 - Institute of Iron and Steel Wire Manufacturers
- *Institute of Marine Engineers
- Institution of Civil Engineers
- Institution of Mechanical Engineers (Automobile Division)
- Institution of Production Engineers
- Institution of Structural Engineers
- Lloyd's Register of Shipping
- Ministry of Defence
- *Ministry of Defence, Army Department
- *National Association of Drop Forgers and Stampers
- National Physical Laboratory (Department of Trade and Industry)
- Oil Companies Materials Association
- Royal Institute of British Architects
- Shipbuilders' and Repairers' National Federation
- Society of British Aerospace Companies
- *Society of Motor Manufacturers and Traders Ltd.
- *Stainless Steel Development Association
- Steel Castings Research and Trade Association
- Tank and Industrial Plant Association
- Tin Research Institute
- Water-tube Boilermakers' Association

The Government department and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this British Standard:

- Association of British Railway Carriage and Wagon Manufacturers
- British Bolt, Nut, Screw and Rivet Federation
- British Internal Combustion Engine Manufacturers and Traders
- British Railways Board
- Ministry of Aviation Supply
- Ministry of Defence (Navy Dept.)
- National Coal Board
- Spring Research Association
- Stainless Steels Fabricators' Association of Great Britain
- Individual companies

BRITISH STANDARD SPECIFICATION FOR

WROUGHT STEELS

IN THE FORM OF BLOOMS, BILLETS, BARS

AND FORGINGS

Part 3. Steels for case hardening

FOREWORD

This British Standard has been prepared under the authority of the Iron and Steel Industry Standards Committee and forms Part 3 of the five Part revision of BS 970. It covers requirements for alloy steels for case hardening only. Requirements for carbon and carbon manganese steels for case hardening are specified in Supplement No. 1 to this, Part 3 of BS 970. The complete revision of BS 970 is comprised as follows:

Part 1. Carbon and carbon manganese steels, including free cutting steels
 Part 2. Direct hardening alloy steels, including alloy steels capable of surface hardening by nitriding

Part 3. Steels for case hardening

Supplement No. 1 to Part 3. Requirements for carbon and carbon manganese steels for case hardening, including free cutting steels

Part 4. Stainless, heat resisting and valve steels

Part 5. Carbon and alloy spring steels for the manufacture of hot formed springs.

In addition, Part 6. SI metric values (for use with BS 970: Parts 1 to 5) has also been published.

Presentation of this Part of the standard is in 4 sections, Section 1, 'General requirements', Section 2, 'Specific requirements for steels supplied to close limits of chemical composition', Section 3, 'Specific requirements for steels supplied to hardenability requirements' and Section 4, 'Specific requirements for steels supplied with specified mechanical properties'.

With regard to Section 3, 'Hardenability requirements', it should be noted that this is the first time that this method for purchasing steel has been included in a British Standard and reference should be made to 1.2.3 and also to the clauses on the purchase of steel to hardenability requirements included at the beginning of Section 3.

In preparing this revision it has been found necessary to abandon the 'En' designation system used in previous editions of BS 970 since it did not possess

*As altered
May, 1973*

*As added
April, 1974*

sufficient flexibility to permit the inclusion of the new steels proposed for the revised standard, nor did it permit the separation of the revised standard into parts.

A new six digit designation system, for which further information regarding carbon steels is given in PD 6423 and for alloy steels in PD 6431, has therefore been introduced. For the carbon and carbon manganese steels which will be included in this Part of the standard and also for those which will be specified in Parts 1 and 5 of the revision the series 000-249 has been allocated. The plain carbon and carbon manganese steels are within the range 000 to 199, where these digits represent 100 times the mean manganese content. The free cutting steels are, at present, within the range 200 to 240 where the second and third digits bear an approximate relationship to 100 times the minimum or mean sulphur content. For the alloy steels specified in this part of the standard and also those specified in Part 2 and later to be specified in Part 5 of the revision, the series 500 to 999 has been allocated in groups of 10 or multiples of groups of 10 according to alloy type for the first 3 digits.

In all cases the letter A, M or H has been introduced at the 4th digit to indicate if the steel is supplied to analysis, mechanical properties, or hardenability requirements. The 5th and 6th digits represent 100 times the mean carbon content.

The opportunity has been taken to align the compositions of the steels more closely with those demanded in practice, to introduce steels not covered by the previous edition of BS 970 and also to introduce permissible variations on product analysis. In the case of Section 4, 'Mechanical properties', the properties quoted are those obtained on the $\frac{3}{4}$ in diameter test bars in the single or direct quenched condition. In the previous edition of BS 970 properties quoted were those obtained on $1\frac{1}{2}$ in diameter test pieces in the double quenched condition.

In addition to the previously included tables of tolerances and sizes for bright bar, similar tables have been included for hot rolled material. The inclusion of these latter tables in inch units is considered justified at this time as they are representative of already established practice in industry.

This standard is written in terms of imperial units but it is intended that a metric version of the standard, which will take account of relevant ISO and European work, will be published as soon as possible. In the meantime, as an interim measure, provisions have been published in BS 970 : Part 6 to enable the steels in this and the other Parts 1, 2, 4 and 5 of BS 970 to be purchased to SI metric values for limiting ruling section and size (excluding standard bar sizes and tolerances) stress and hardenability requirements.

SPECIFICATION

1. GENERAL REQUIREMENTS

1.1 SCOPE

This Part of BS 970 applies to wrought alloy steels for case hardening to give minimum core strengths, in the heat treated conditions, up to 85 tonf/in², for use

*As amended
Sept., 1969*

*As altered
May, 1973*

in the form of blooms, billets, bars and forgings. For alloy steels for case hardening the specified mechanical properties relate to those obtained on a standard size of test bar, see 1.2.3.

Requirements for wrought carbon and carbon manganese steels for case hardening are specified in Supplement No. 1 to BS 970 : Part 3.

NOTE. The titles of British Standards referred to in this standard are listed on page 2.

1.2 GENERAL

1.2.1 Alternative methods of supply. The steel shall be supplied in accordance with the general requirements specified in this section and the specific requirements given in Sections 2, 3 or 4. The specific requirements given in Section 2, 3 and 4 cover alternative methods of supply as follows:

When it is required that steel shall be supplied to SI metric values the steel shall also be supplied to the appropriate requirements of BS 970 : Part 6.

*As added
April, 1974*

Section 2. Close limits of chemical composition where no mechanical properties are specified, or

Section 3. A combination of hardenability and chemical composition, or

Section 4. A combination of mechanical properties and chemical composition.

NOTE. If ordered to Sections 3 or 4 above, the hardenability or mechanical properties specified should be the governing criteria for acceptance. In such cases the cast composition may deviate slightly from the figures shown in the specification.

1.2.2 Controlled grain size. If required these steels can be supplied fine grain size controlled, i.e. having a McQuaid Ehn grain size of 5-8 (see BS 4490).

Hardenability steels are normally supplied fine grained, and if coarse grain steel is specifically required, then the hardenability shall be subject to negotiation.

1.2.3 Ruling section and hardenability. The mechanical properties developed in the steel are dependent on the shape and size, that is the 'ruling section', at the time of heat treatment. This limitation on the ability of a grade of steel to harden effectively is due to the inherent 'hardenability' of the steel.

Test methods are available to determine the hardenability of a steel and the Jominy end quench test has been accepted as a reliable test procedure for obtaining data for the plotting of hardenability bands. Bands for a number of alloy steels based on Method 1 of BS 4437 are included in Section 3 and methods for ordering are also recommended in this section.

These hardenability bands may be used as a guide to estimating the tensile strength of a ruling section at the time of heat treatment and for the ordering of the steel as detailed in Section 3 of this Part of BS 970.

For steels for case hardening, whilst the effect of ruling section (expressed in terms of the diameter of an equivalent round bar) is applicable, it is customary to test and release steel to specified mechanical property levels on a standard

size of test bar. For alloy steels for case hardening the test bar size, which was previously $1\frac{1}{8}$ in diameter, has now been changed to $\frac{3}{4}$ in diameter as the latter size is more representative of the ruling section of the majority of parts at the time of heat treatment.

1.3 INFORMATION TO BE SUPPLIED BY THE PURCHASER

The following information shall be stated on the enquiry and order; a drawing of the part to be made may be useful in appropriate cases:

*As amended
April, 1974*

- (1) *a.* Whether the steel is required to be supplied to the SI metric values specified in BS 970 : Part 6 and, if so, the information required by Clause 3 of Part 6.
- b.* The material specification in Section 2, 3 or 4 in this Part of the standard.
- (2) *a.* The sulphur and phosphorus contents required if different from the limits shown in 1.5.2.1.
- b.* If electric quality steel is required (see 1.4 (Note)).
- c.* If a lead bearing steel is required (see 1.5.4).
- (3) If a grain controlled steel is required (see 1.2.2).
- (4) The application of the billets or bars required, e.g. for forging, cold drawing, re-rolling, etc. (see 1.7).
- (5) *a.* The condition in which the material is to be supplied if different from the normal condition of delivery as shown in 1.9.
- b.* If a maximum hardness, as specified in Section 4, is required (see also 1.9.4).
- (6) If ordered to comply with the requirements of Section 3, the hardness values at the required distance(s).
- (7) If a statement giving the cast analysis and/or results of mechanical or other tests is required (see 1.17).
- (8) If any other special quality criteria (e.g. vacuum degassing, ultrasonic testing, cleanness check, etc.) are required.
- (9) If special identification of the steel is required (see 1.18).
- (10) If a representative will be sent to witness manufacture and/or testing (see 1.15).

1.4 STEELMAKING PROCESS

The steelmaking process shall be at the option of the manufacturer unless otherwise specified in the order. The air or mixed air oxygen bottom blown basic converter process is not permitted. The steel shall be killed.

NOTE. *Electric quality steel* is steel melted in an induction furnace or in a basic lined electric arc furnace. When produced in the arc furnace the conventional double slag process is used. The steel is characterized by a high standard of cleanness and by low sulphur and phosphorus contents.

Electrically melted steel is steel made in an electric furnace under conditions not necessarily conforming with the above requirements, and which complies with standards similar to those required of open hearth steel.

1.5 CHEMICAL COMPOSITION

1.5.1 Composition ranges. The specific ranges of chemical composition are based on cast analysis which shall comply with the relevant specifications. The determination of lead shall be on the product (see 1.5.4).

1.5.2 Sulphur and phosphorus contents

1.5.2.1 The maximum content of sulphur and phosphorus, unless otherwise agreed, shall be as follows:

	S %	P %
Acid processes	0.050	0.040
Basic open hearth or electrically melted or oxygen processes	0.040	0.040
Electric quality	0.025	0.025

NOTE. Electric quality steel is recommended for tensile strength minima of 80 tonf/in² and over.

1.5.2.2 The sulphur and phosphorus contents may be ordered to other maxima by agreement between the purchaser and the supplier. The preferred figures on which such agreement should be reached and which shall be stated on the order, are:

S %	P %
0.035	0.035
0.030	0.030
0.020	0.020

1.5.2.3 Low residual sulphur can have an adverse effect on the machinability of the steel. To minimize this effect, steels can be supplied to a controlled sulphur range by agreement between the purchaser and the supplier. The preferred ranges, which shall be stated on the order, are:

	S %	P %
Open hearth, electrically melted or oxygen process	0.025/0.050	0.040 max.
Electric quality	0.015/0.040	0.025 max.

1.5.3 Residual elements. Elements not quoted in the relevant specification shall not be added to the steel without the agreement of the purchaser other than for the purpose of finishing the heat. All reasonable precautions shall be taken to prevent the addition of such elements during manufacture.

Percentages of elements up to the following limits shall be considered as incidental.

Nickel	0.40 %
Chromium	0.30 %
Molybdenum	0.15 %

For special applications the purchaser may specify by agreement with the supplier a different limit to the amount of one or more of these, or other residual elements, or combinations of them in the steel, and may require the amount of such elements to be stated.

1.5.4 Lead bearing steels. Lead bearing steels may be supplied by agreement between the purchaser and the supplier. The lead content, unless otherwise agreed, shall be not less than 0.12 % on the product analysis.

The supplier shall endorse the invoice or delivery document that lead has been added to the minimum requirement, and the steel shall be identifiable by a distinguishing mark agreed between the purchaser and the supplier (see 1.3 (2) c).

1.6 PRODUCT ANALYSIS AND PERMITTED VARIATIONS

1.6.1 Analysis of the semi-finished product may vary from the cast analysis due to heterogeneity arising during the casting and solidification of the ingot. Table 1 shows the variations permitted in product analysis in relation to cross sections not greater than 100 in².

The variations may occur either above or below the individual element ranges but shall not be applied both above and below the range for any one element in any cast of steel.

1.6.2 Any billet, bar or forging which on chemical analysis falls outside the limits of permissible variation from the specified composition range for a significant element shall be deemed not to comply with this British Standard.

1.6.3 In the event of a single sample falling outside the permitted variations on the product analysis further samples shall be selected for check analysis from the remainder of the consignment, as follows:

At least two samples from the same cast for delivered weights up to 5 tons, at least five samples from the same cast for delivered weights up to 20 tons, and at least eight samples from the same cast for delivered weights over 20 tons.

These samples shall fall within the permitted variations. If any of these further samples are proved to be outside the permitted variations for any significant element the consignment shall be deemed not to comply with this British Standard.

1.6.4 Samples for product analysis shall be taken in accordance with BS 1837 and, in the event of dispute, analysed in accordance with the appropriate methods of British Standard Handbook No. 19.

1.7 FREEDOM FROM DEFECTS

1.7.1 Internal soundness. The steel shall be free from piping, harmful segregation and other internal defects.

TABLE 1. PERMITTED VARIATIONS ON PRODUCT ANALYSIS FROM SPECIFIED RANGE

Element	Range in which maximum of specified element falls, %	Variation on specified range for alloy steels	
		Over maximum, %	Under minimum, %
Carbon	Up to and including 0.25	0.01	0.01
	Over 0.25	0.02	0.02
Silicon	0.10 up to and including 0.35	0.03	0.03
Manganese	Up to 0.70	0.03	0.03
	Over 0.70 up to and including 1.0	0.04	0.04
Nickel	Up to and including 1.0	0.03	0.03
	Over 1.0 up to and including 3.0	0.05	0.05
	Over 3.0 up to and including 5.0	0.07	0.07
Chromium	Up to and including 0.60	0.03	0.03
	Over 0.60 up to and including 1.25	0.04	0.04
	Over 1.25 up to and including 2.50	0.05	0.05
Molybdenum	Up to and including 0.50	0.02	0.02
Sulphur	Up to and including 0.030	0.003	
	Over 0.030 up to and including 0.040	0.004	
	Over 0.040 up to and including 0.050	0.005	
	<i>When range is specified</i>		
	0.015 to 0.040	0.004	0.003
	0.025 to 0.050	0.005	0.003
Phosphorus	Up to and including 0.030	0.003	
	Over 0.030 up to and including 0.040	0.004	

1.7.2 Surface defects

1.7.2.1 Blooms, billets, slabs and black bars intended for applications such as hot forging and for the production of bright drawn bars which are not required for subsequent machining (see 1.7.2.2) shall have a high standard of surface quality, and the surface conditioning shall be such as to remove defects detrimental to the end products.

Applications such as upset forging, cold heading, cold forging or cold extrusion may require a higher degree of freedom from surface imperfection which shall be agreed between the purchaser and the supplier.

1.7.2.2 Blooms, billets, slabs, black bars and bright drawn bars which are intended for subsequent overall machining may not have the same freedom from surface defects as specified in 1.7.2.1. Surface conditioning need only be such as to remove harmful defects having regard to the machining allowance.

The machining allowance shall be not less than 4 % on minimum permissible diameter of rounds or 4 % across the minimum permissible dimensions of flats and other solid sections.

1.7.2.3 Blooms, billets and slabs for re-rolling, black bars and bright drawn bars for applications other than specified in 1.7.2.1 and 1.7.2.2 shall be free from defects harmful to their intended end uses. Material supplied to these conditions may not be suitable for the applications specified in 1.7.2.1 and 1.7.2.2.

1.7.2.4 Forgings and drop forgings shall be finished in a workmanlike manner and shall be free from flaws and harmful defects.

1.7.3 Special testing and inspection arrangements may, if required, be agreed between the purchaser and the supplier.

1.8 STANDARD SIZES AND TOLERANCES

1.8.1 Billets for forging shall be supplied in accordance with Appendix A, Table 5.

1.8.2 Black bars shall be supplied in accordance with Appendix A, Tables 6 to 8.

1.8.3 Bright bars shall be supplied in accordance with Appendix A, Tables 9 and 10.

1.8.4 Drop and press forgings and upset forgings made on horizontal forging machines shall conform to the requirements of BS 4114 unless otherwise agreed between the purchaser and the supplier.

1.8.5 Bars for machining shall be commercially straight.

1.9 CONDITION OF MATERIAL ON DELIVERY

1.9.1 Blooms, billets, slabs and black bars shall be delivered as rolled or as forged unless the order states otherwise.

NOTE. With certain steels precautions after hot working are necessary and in such cases the supplier shall ensure that the condition in which the steel is supplied is satisfactory.

1.9.2 Forgings and drop forgings shall be delivered in the condition stated on the order.

1.9.3 Bright bars shall be delivered in the condition stated on the order.

1.9.4 When a maximum hardness in the condition of delivery is specified on the order the hardness shall be that shown in Section 4 for the appropriate M steel and the values shall also apply to the corresponding A and H steels.

1.10 PROVISION OF MATERIAL FOR MECHANICAL TESTING

1.10.1 Definitions. For the purposes of this Part of this British Standard the following definitions apply:

- (1) *Test sample.* That portion of the material selected for testing.
- (2) *Test bar.* The test sample after preparation for heat treatment.
- (3) *Test piece.* The test sample or test bar as finally prepared for testing.

1.10.2 Size of test bar. The standard size of test bar shall be $\frac{3}{4}$ in diameter except for steels to be heat treated to 85 tonf/in² minimum tensile strength, when the test bar shall be machined to test piece size, plus a grinding allowance if required, before heat treatment.

1.10.3 Selection of test samples and preparation of test bars for tensile and Izod tests

1.10.3.1 Selection of test samples. One test sample shall be selected to represent each cast. If the size of the test sample is greater than the test bar size of $\frac{3}{4}$ in, test bars shall be prepared by forging and/or machining to that size; but for smaller sizes the test bar shall be heat treated in the full section of the sample. When the test sample is smaller than the standard test bar diameter, the mechanical properties may differ from those stated in the individual specification to an extent which may be determined by comparative tests on the test sample and on a standard test bar from the same cast. Agreement between the purchaser and the supplier will be required for an appropriate level of mechanical properties.

1.10.3.2 Heat treatment of test bars. The test bars shall be carburized or blank carburized for at least one hour at a temperature between 880°C and 930°C.

After cooling to room temperature they shall be reheated to the single quenching temperature, as stated in the individual specification, and quenched in oil.

NOTE. The 1955 edition of BS 970 specified a double quenching heat treatment for test bars. The test bar size, heat treatment and mechanical properties then specified are shown in Appendix C for information.

Direct quenching from the carburizing temperature or after cooling back from the carburizing temperature may also be used when the mechanical properties as those specified in Section 4 will normally be obtained.

1.11 LOCATION OF TENSILE AND IZOD TEST PIECES

The test piece shall be machined parallel to the longitudinal direction of the rolling or forging of the test sample.

1.12 FREQUENCY OF OTHER TESTS

1.12.1 Number of hardness tests. The manufacturer shall carry out sufficient tests in accordance with the relevant clauses of this standard in order to ensure that the material complies with the specified hardness.

1.12.2 Number of hardenability tests for steels supplied to Section 3. Unless otherwise agreed one test sample selected to represent each cast shall be reduced by forging or rolling to a size not greater than $1\frac{1}{2}$ in diameter, which shall represent the full cross section of the material. This test bar shall also be of sufficient size to ensure the complete removal of decarburization in machining to the standard test piece of 1 in diameter.

1.12.3 Number of grain size tests. When a grain controlled steel is required, and unless otherwise agreed, one test sample for the determination of austenitic grain size shall be selected to represent each cast (see 1.3 (3)).

1.13 TEST METHODS

1.13.1 Tensile test

1.13.1.1 The tensile test shall be carried out in accordance with the requirements of BS 18.

1.13.1.2 Except as provided in 1.13.1.3, tensile test pieces shall be machined from the test bar to the dimensions of the 0.564 in (14 mm) diameter test piece or, if the test bar is too small, to the dimensions of the largest recommended round test piece that can be obtained having a gauge length equal to 5.65 times the square root of the area of the cross section.

1.13.1.3 When agreed between the purchaser and the supplier, or for material not greater than $\frac{1}{2}$ in diameter or width across flats, unmachined test pieces having a gauge length equal to 5.65 times the square root of the area of the cross section may be used.

1.13.2 Izod impact test. The Izod impact test carried out on a 3-notch test piece shall be in accordance with the requirements of BS 131, Part 1.

1.13.3 Hardness test. The Brinell hardness test shall be carried out in accordance with BS 240 by the application where possible of 3000 kgf to a 10 mm diameter ball. Alternatively, Vickers and Rockwell methods of hardness testing in accordance with BS 427 and BS 891 respectively may be used. Considerable caution should be exercised when converting from one hardness scale to another and in cases of dispute the Brinell hardness test shall be used.

1.13.4 Hardenability test. Hardenability tests shall be carried out in accordance with Method 1 of BS 4437.

1.13.5 Grain size test. Grain size tests shall be carried out in accordance with the requirements of BS 4490.

1.14 RETESTS

1.14.1 Tensile and Izod tests

1.14.1.1 Should any of the original test pieces fail to meet the specified requirements, twice the original number of test samples shall be selected for retesting, one of which shall be taken from the bar, billet, forging or drop forging from which the original test sample was taken, unless that item has been withdrawn by the manufacturer.

1.14.1.2 The mechanical properties obtained from the test pieces prepared from the further test samples shall comply with the specified requirements. Should any of the retests fail, the material represented shall be deemed not to comply with this British Standard.

1.14.1.3 In the case of material supplied in the heat treated condition the manufacturer shall have the right to re-heat treat the material and re-submit it for inspection and testing.

1.14.2 Hardness test

1.14.2.1 If any item (bloom, billet, slab, bar, forging, drop forging or machined part) does not meet the specified requirements, one or both of the following procedures shall be adopted at the discretion of the manufacturer.

1.14.2.2 All the items in the batch shall be hardness tested and only those items which comply with the specified hardness requirement shall be regarded as acceptable.

1.14.2.3 Items of incorrect hardness or the complete batch shall be re-heat treated and re-submitted for testing.

1.14.3 Hardenability and grain size tests. Should the results of either of these tests fail to meet the specified requirements and this is confirmed on retesting, acceptance of the material shall be subject to negotiation between the purchaser and the supplier.

1.15 INSPECTION

The purchaser or his representative shall have access at all reasonable times to those parts of the manufacturer's works engaged on the order. He shall be at liberty to inspect the manufacture at any stage and to witness the required tests. When the material is to be inspected and tested in the presence of the purchaser's representative, it shall be so stated on the enquiry and order (see 1.3 (10)).

1.16 TEST FACILITIES

The manufacturer shall supply the material required for testing and shall furnish and prepare the necessary test pieces and supply labour and appliances for such testing as may be carried out on his premises and in accordance with this British Standard. Failing facilities at his own works for making the prescribed tests, the manufacturer shall arrange for the tests to be carried out elsewhere.

1.17 MANUFACTURER'S STATEMENT

If required by the order, the manufacturer shall supply the ladle analysis of the material or the results of the mechanical or other tests or combination of these (see 1.3 (7)).

1.18 IDENTIFICATION

If the purchaser requires special identification to be applied to the material then the manner of identification shall be the subject of negotiation between the purchaser and the supplier and that this identification is required shall be stated on the enquiry or order (see 1.3 (9)).

1.19 SYMBOLS FOR MECHANICAL PROPERTIES

The symbols for mechanical properties used in this standard are those described in BS 18. These are as follows:

R_m denotes tensile strength.

A denotes percentage elongation.

S_0 denotes original cross-sectional area.

TABLE 2. NUMERICAL LIST OF STEELS CONTAINED IN SECTIONS 2, 3 AND 4 SHOWING PAGE REFERENCES AND THE EN STEELS REPLACED

Steel	Page reference	En steel replaced	Type
523A14	22	206	} ½ % chromium
523M15	47	—	
527A19	22	207	} ¾ % chromium
527M20	48	—	
635A14	22	—	} ¾ % nickel chromium
635H15	28	—	
635M15	49	351	
637A16	22	—	} 1 % nickel chromium
637H17	29	—	
637M17	50	352	
655A12	22	—	} 3¼ % nickel chromium
655H13	30	—	
655M13	51	36A	
659A15	22	—	} 4 % nickel chromium
659H15	31	—	
659M15	52	39A	
665A17	22	—	} 1¼ % nickel molybdenum
665H17	32	—	
665M17	53	34	
665A19	22	—	
665H20	33	—	
665M20	54	—	
665A22	22	35A	
665H23	34	—	
665M23	55	35	
665A24	22	35B	

TABLE 2.—*continued*

Steel	Page reference	En steel replaced	Type
805A15	22	—	} ½ % nickel chromium molybdenum
805A17	22	—	
805H17	35	—	
805M17	56	361	
805A20	22	—	
805H20	36	—	
805M20	57	362	
805A22	22	—	
805H22	37	—	
805M22	58	—	
805A24	22	—	
805H25	38	—	
805M25	59	363	
815A16	22	—	} 1½ % nickel chromium molybdenum
815H17	39	—	
815M17	60	353	
820A16	22	—	} 1¾ % nickel chromium molybdenum
820H17	40	—	
820M17	61	354	
822A17	22	—	} 2 % nickel chromium molybdenum
822H17	41	—	
822M17	62	355	
832H13	42	—	} 3½ % nickel chromium molybdenum
832M13	63	36C	
835A15	22	—	} 4 % nickel chromium molybdenum
835H15	43	—	
835M15	64	39B	

TABLE 2.—continued

Steel	Page reference	En steel replaced	Type
805A15	22	—	} ½ % nickel chromium molybdenum
805A17	22	—	
805H17	35	—	
805M17	56	361	
805A20	22	—	
805H20	36	—	
805M20	57	362	
805A22	22	—	
805H22	37	—	
805M22	58	—	
805A24	22	—	
805H25	38	—	
805M25	59	363	
815A16	22	—	} 1½ % nickel chromium molybdenum
815H17	39	—	
815M17	60	353	
820A16	22	—	} 1¾ % nickel chromium molybdenum
820H17	40	—	
820M17	61	354	
822A17	22	—	} 2 % nickel chromium molybdenum
822H17	41	—	
822M17	62	355	
832H13	42	—	} 3½ % nickel chromium molybdenum
832M13	63	36C	
835A15	22	—	} 4 % nickel chromium molybdenum
835H15	43	—	
835M15	64	39B	

**2. SPECIFIC REQUIREMENTS FOR ALLOY STEELS FOR
CASE HARDENING SUPPLIED TO CLOSE LIMITS OF
CHEMICAL COMPOSITION**

2.1 CHEMICAL COMPOSITION

The steels shall contain the following*:

Steel	Carbon		Manganese		Nickel		Chromium		Molybdenum	
	% min.	% max.	% min.	% max.	% min.	% max.	% min.	% max.	% min.	% max.
523A14	0.12	0.17	0.30	0.50	$\frac{1}{2}$ % Cr steel		0.30	0.50	—	—
527A19	0.17	0.22	0.70	0.90	$\frac{3}{4}$ % Cr steel		0.70	0.90	—	—
635A14	0.12	0.17	0.70	0.90	$\frac{3}{4}$ % Ni	Cr steel	0.50	0.75	—	0.10
637A16	0.14	0.19	0.70	0.90	1 % Ni	Cr steel	0.70	1.00	—	0.10
655A12	0.10	0.15	0.40	0.60	$3\frac{1}{4}$ % Ni	Cr steel	0.75	1.00	—	—
659A15	0.13	0.18	0.30	0.50	4 % Ni	Cr steel	1.00	1.30	—	—
665A17	0.15	0.20	0.45	0.65	$1\frac{3}{4}$ % Ni	Mo steels	—	0.25	0.20	0.30
665A19	0.17	0.22	0.45	0.65	1.60	2.00	—	0.25	0.20	0.30
665A22	0.20	0.25	0.45	0.65	1.60	2.00	—	0.25	0.20	0.30
665A24	0.22	0.27	0.45	0.65	1.60	2.00	—	0.25	0.20	0.30
805A15	0.13	0.18	0.70	0.90	$\frac{1}{2}$ % Ni	Cr Mo steels	0.40	0.60	0.15	0.25
805A17	0.15	0.20	0.70	0.90	0.40	0.70	0.40	0.60	0.15	0.25
805A20	0.18	0.23	0.70	0.90	0.40	0.70	0.40	0.60	0.15	0.25
805A22	0.20	0.25	0.70	0.90	0.40	0.70	0.40	0.60	0.15	0.25
805A24	0.22	0.27	0.70	0.90	0.40	0.70	0.40	0.60	0.15	0.25
815A16	0.14	0.19	0.70	0.90	$1\frac{1}{2}$ % Ni	Cr Mo steel	0.90	1.20	0.10	0.20
820A16	0.14	0.19	0.70	0.90	$1\frac{3}{4}$ % Ni	Cr Mo steel	0.90	1.20	0.10	0.20
822A17	0.15	0.20	0.50	0.70	2 % Ni	Cr Mo steel	1.40	1.70	0.15	0.25
835A15	0.13	0.18	0.30	0.50	4 % Ni	Cr Mo steel	1.00	1.30	0.15	0.25

*Silicon content. The silicon content of all steels shall be within the range 0.10 % to 0.35 %.

2.2 Condition of supply. See 1.9.

3. SPECIFIC REQUIREMENTS FOR ALLOY STEELS FOR CASE HARDENING SUPPLIED TO HARDENABILITY REQUIREMENTS